EVALUATION OF SPECIES ESTABLISHMENT AND REVEGETATION PRACTICES ALONG ROADSIDES IN TUCSON, AZ

by

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A Thesis Submitted to the Faculty of the

COLLEGE OF ARCHITECTURE, PLANNING, AND LANDSCAPE ARCHITECTURE

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF LANDSCAPE ARCHITECTURE

In the Graduate College

THE UNIVERSITY OF ARIZONA

2004

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ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to those who have aided in the development of this thesis, including the Arizona Game and Fish Department for their financial support. I would like to thank my thesis director, Dr. Margaret Livingston, for her persistent guidance and encouragement. I would also like to thank Dr. Steven Smith and Dr. Mintai Kim for serving on my committee and for their helpful suggestions and assistance.

I would like to give special thanks to Dr. Steven Smith and Dr. Margaret Livingston for their valuable assistance during the data collection and analysis process. I would also like to express my appreciation for the countless hours of assistance provided by Phil Jenkins with the University of Arizona's Herbarium in identifying the plant specimens collected in this study. I wish to also thank the staff at the Pima County and Arizona Departments of Transportation and many of Tucson's landscape architects for their assistance in the selection of the study sites and for providing me with valuable information regarding the process of roadside revegetation in the Tucson area.

Finally, I would like to thank my family and friends for their unwavering support and confidence in me – I couldn't have done it without you. Thank you so much for always being there for me.

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ABSTRACT

This study evaluated the success of recently revegetated roadsides in Tucson, Arizona. The primary objectives of this study were to (1) evaluate a sample of revegetated roadsides by assessing site condition and comparing existing vegetation to the original seed mix; and (2) develop recommendations for appropriate revegetation practices for use in Tucson. Density data were collected at 20 locations using belt transects to derive species information such as origin, vegetative life-form, and invasiveness. Results indicated that the study sites had greater proportions of plant material not specified in the original construction documents than specified plant material. Of the specified species, creosote bush, desert senna, and triangle-leaf bursage had the highest rates of establishment while brittlebush, globemallow, shrubby buckwheat, and fourwing saltbush provided the most vegetative cover. Several non-specified species exhibited successful establishment on many study sites, while some species rarely or never appeared in the study sites despite frequent specification.

Chapter 1

INTRODUCTION

Project Overview

Growth and development of cities in the southwestern United States have resulted in significant disturbance to the health and stability of the region's native plant and animal communities. Reclamation of these disturbed landscapes using traditional practices can be complicated due to the aridity of the Southwest. For example, the process of revegetation has been negatively influenced by the region's climatic extremes, such as periods of intense heat and drought. Furthermore, research on the development of revegetation techniques for arid environments has only recently begun to address many of the ecological issues associated with the revegetation of disturbed sites in urban environments. However, revegetation can play an integral role in restoring and maintaining the overall health of these disturbed ecosystems and is essential in the efforts to establish a balance between successful urban development and a vital, sustainable natural environment.

In order to further the region's knowledge of revegetation in arid environments, this study evaluated the success of recently revegetated roadsides in Tucson, Arizona. As one of the more rapidly growing cities in the Southwest, Tucson is faced with the need to integrate the progress and innovation of a metropolitan community with the scenic grandeur of the surrounding desert. Many of Tucson's suburban roadsides exist at the edge of these two communities, and sensitive development of these roadsides may provide an opportunity to lessen some of the habitat fragmentation typical of

Southwestern urban environments. The purpose of this study was to determine if recent revegetation practices result in a persistent vegetative cover of native species capable of supporting indigenous wildlife communities. This was done through the quantitative analysis of vegetation located along revegetated roadsides in the study area. In addition, this study identifies some of the more effective practices for revegetation and provides recommendations for successful techniques and plant species for use in roadside revegetation projects in Tucson.

Study Objectives

The primary objectives of this study were to (1) evaluate a sample of revegetated roadsides by assessing site condition and comparing existing vegetation to the species specified in the original planting plan; and (2) develop recommendations for appropriate revegetation practices, including recommendations for appropriate native plant species for use in roadside revegetation in Tucson. An ecological site description was conducted by measuring total vegetative cover (including grasses, trees, succulents, etc.), plant density (including recognition of dominant or invasive species), and species richness (Shaw et al., 1998). The existing vegetation on each study site was evaluated against the intended species richness as indicated in the initial revegetation plan. Factors of interest included the presence and origin of non-specified species, herbaceous and woody plant richness, and similarities of the existing species composition to natural communities in the region. Richness, species origin, and cover were used for determining a vegetation suitability index (VSI) for addressing site potential as urban wildlife habitat. Three VSI classes were created based on the VSI values to indicate high, medium, and low quality wildlife habitat. Recommendations relating to effective revegetation techniques were derived from data and interviews with local practitioners involved in roadside revegetation. Species recommendations were supported by the data collected in this study and wildlife habitat considerations.

Chapter 2

LITERATURE REVIEW

Revegetation in the Arid Southwest

The arid Southwest has long been a region of complex interactions between its human inhabitants and the landscape that supports them. The harsh limitations of a true desert environment (i.e., low and unevenly distributed rainfall, low humidity, and variable surface and air temperatures) have often complicated the tasks of inhabitation and cultivation throughout past centuries (Shreve and Wiggins, 1964). In more recent times, advances in technology enabled the rapid growth of cities once supported by limited local hydrologic conditions through the delivery of water from outside sources. By the early 1900's, development in the Southwest had created numerous concerns regarding the surrounding environment, such as variations in climatic conditions, disturbances to historic fire regimes, and the mismanagement of the region's rangelands (Roundy, 1995).

The reduced condition of the rangelands was of particular concern during this time, and numerous studies into the restoration of these lands were conducted in an effort to conserve soil resources and promote the growth of livestock forage (Martinez, 2001). Early revegetation trials focused on the restorative qualities of numerous grass species, palatable shrubs, and cacti but were met with disappointing results due to the drought conditions of the desert environment and the lack of appropriate technology relating to seed distribution (McKell, 1978; Martinez, 2001). Advances in revegetation techniques over several decades, such as improved seed bed preparation and seeding techniques, increased the success of revegetation attempts, though research in the area remains relatively insufficient (Bainbridge and Virginia, 1990; James, 1992; Roundy, 1995).

Despite an influx of information regarding revegetation in other semi-arid portions of the country such as the northern plains, there has historically been little national interest in the restoration of desertscrub landscapes due to the low value placed upon them by society (Jackson et al., 1991). As a consequence, much of the disturbance that has taken place in lowland deserts has been unregulated and has resulted in detrimental conditions to the surrounding environment, such as reduced groundwater infiltration, increased air pollution from blowing dust, decreased wildlife habitat, and increased soil erosion (Clary, 1983; Thacker and Cox, 1990; Jackson et al., 1991). Soil losses in arid climates are particularly damaging to the regional ecosystem due to a characteristically thin layer of productive surface soil that can be quickly lost during erosive events. The natural rejuvenation of only 1 in. of this surface soil may take as many as 1,000 years to develop through the complex physical-chemical process of soil formation (Harris and Dines, 1998). With this in mind, it is important to note that 18 – 24 in. of plant growth medium is required to establish a stable vegetative community – thus, the excessive loss of soil from a particular site may take hundreds of *centuries* to fully recover on its own (Harris and Dines, 1998).

In addition to the loss of a stable substrate for plant growth, soil erosion is one of the leading causes of water pollution due to sediment transport and delivery. Overland flow carries sediments suspended by the erosion process and additional pollutants (e.g., nutrients, metals, and organic compounds) into surrounding aquatic systems (Harris and

Dines, 1998; ADEQ, 2003). Though re-establishing a permanent vegetative cover is widely viewed as the most effective method for controlling erosion on disturbed lands, numerous methods exist that may be used in combination with revegetation on severely erodible sites (Johnson and Fifer, 1979; Gray et al., 1980; Toy and Hadley, 1987). These methods may include erosion control blankets made of straw, wood, or fiber; wood or straw sediment logs; and numerous types of mulch that can stabilize soils until revegetation seedlings take root (Granite Seed, 2003). The temporary seeding of non-persistent fast growing species, known as cover crops, is also a useful and effective measure of soil stabilization prior to final revegetation (Harris and Dines, 1998; Granite Seed, 2003).

Despite the difficulties associated with the revegetation of disturbed landscapes in arid climates due to low amounts of precipitation and high temperatures, the process of establishing a permanent vegetative cover is essential to the efforts of soil and site conservation (Cook et al., 1974). If left to revegetate naturally, disturbed sites in this region may take as many as 60 years for growth to reach pre-disturbance biomass and as many as 180 years for the recovery of usual species diversity (Webb et al., 1983). Therefore, effective management practices of disturbed sites, including advancements in revegetation techniques, are vital in preserving and maintaining a healthy ecosystem for present and future generations.

A History of Roadside Management

According to Harris and Dines (1998), a disturbed landscape is "any portion of land surface that has been drastically altered and is not in an attractive, stable, or productive condition." These types of landscapes may be created by both natural and human disturbances, including agricultural activities, floods, fire, land development, mining, and roadway construction (Harris and Dines, 1998). In today's rapidly growing society, the construction of roadways is an on-going process attempting to accommodate the sprawling characteristics of modern cities and has led to a considerable amount of disturbance to the natural environment. In this country and in others, roadways affect the activities of its inhabitants on a daily basis, making the disturbed landscapes adjacent to roadways an important component of modern society.

As early as 1912, various individuals throughout the United States recognized the importance of maintaining the aesthetic qualities of the surrounding landscape despite the growing trend of urbanization. Wilhelm Miller, a trained editor, horticulturalist, and early pioneer in proper roadside management, addressed the Illinois Highway Commission by stating:

> To the ninety million inhabitants of the United States, the most important scenery is the common, everyday, familiar scenery in which we pass our lives...The most important scenery in the world is the roadside scenery, because it affects the most people (Miller, 1913).

Others, particularly in the Midwest, echoed similar sentiments that sought to preserve the aesthetic appeal and symbolic strength of the regional landscape through the protection and use of native plantings along roadways (Egan and Harrington, 1992). A regional landscape style, called the prairie school of landscape gardening, was advocated by a group of landscape architects and ecologists in the Midwest prairie states during the 1920's and 1930's. Jens Jensen, known as the "prairie landscape architect" and recognized as an early pioneer in the roadside beautification movement, stressed that roadsides enabled the public to become acquainted with the country by allowing them to see and become inspired by the surrounding beauty (Jensen, 1924; Brooks, 1993). During this time, the development of roads in response to the increase in automobile travel was viewed as part of the larger social issue of providing for a "stable, aesthetically pleasing, and economically healthy" America. In addition, the engineered road was seen as a symbolic loss of "regional identity and pioneer spirit (Egan and Harrington, 1992)." This notion of regionalism was popular in other parts of the country as well, particularly in Texas, where native grasses and wildflowers were being utilized along disturbed roadsides as early as the 1920's (Johnson and Lees, 1988).

Despite a strong desire by many to maintain naturalistic roadsides, limited resources and technology gave way to gas mowers, herbicides, and brush cutting in the late 1940's (Harrington, 1994). A manicured, "Jardinesque" style of roadside right-of-way planting began to emerge in many parts of the country and led to the concept of the roadside as the "nation's front yard (Johnson and Lees, 1988; Brooks, 1993)." According to Gounveia (1983), the roadsides of Europe, with their neatly mowed edges, intense cultivation, and high levels of fertility, became maintenance role models for America's newly constructed highway system. This new type of roadway system became a vast network of paving and turf, bearing little resemblance to the surrounding countryside. However, by the 1960's and 1970's, increased social interest in the environment paired with the high costs of maintaining the right-of-ways encouraged highway personnel to explore other alternatives to roadside plantings (Harrington, 1994). Unfortunately, many of these alternatives involved the use of agronomic grasses and legumes that still required mowing and herbicide applications throughout the year to maintain a viable vegetative cover. Other programs throughout the country advocated the use of wildflowers in highway projects, though these early programs were often unsuccessful (Harrington, 1994).

More recently, the planting of native vegetation by highway personnel has resurfaced in the Midwestern United States as well as in other parts of the country due to economic conditions, increased environmental awareness, and a strengthened knowledge surrounding the use of native plants (Harrington, 1994). Eagan and Harrington (1992) suggest that this may also be due to the more tangible benefits of native vegetation, including erosion control and lower maintenance, rather than the earlier advocacy of aesthetics, social well-being, and regional identity. Since the 1980's, the native vegetation movement has rapidly grown to encompass numerous highway districts in Texas, Iowa, Illinois, Michigan, Massachusetts, New Mexico, and Arizona (Brooks, 1993; Harrington, 1994).

Roadside Jurisdiction and Management Practices

The preservation, protection, and enhancement of natural and man-made resources through methods such as erosion control and revegetation has been a long-standing responsibility of Arizona's roadside managers. Established in response to the Highway Beautification Act of 1965, the Governor's Commission on Arizona Beauty addressed numerous issues threatening the visual quality of Arizona's roadsides (Brooks, 1993). Aesthetic conditions such as billboard placement, litter control, and the visibility of power lines merged with ecological considerations such as water and species conservation to serve as the framework for proper roadside management in Arizona (Brooks, 1993).

Throughout the United States, roadsides are typically under the jurisdiction of state or county roadside personnel and primarily function as temporary storage for the concentrated flow of surface water from the road pavement and adjacent land (Ehley, 1990; Anderson, 1996). In Arizona, the Arizona Department of Transportation (ADOT) is responsible for the maintenance of state and federal highway roadsides while local governments are responsible for the upkeep of city streets. According to Mortenson (1979), a natural resource planner with ADOT in the late 1970's, one of the principle responsibilities of Arizona roadside management is to minimize erosion and sediment damage to adjacent properties through the establishment of temporary erosion control methods and long-term vegetative growth. Specific revegetation goals typically focus on long-term erosion control, the safety of the traveler, aesthetic improvement, and the importance of matching pre-disturbance plant communities (Harrington, 1994; ADOT, 2001). Other responsibilities of roadside managers are weed control, woody plant control, maintenance of visual quality, reduction of glare, and the creation and maintenance of wildlife habitat (Harrington, 1991).

The maintenance and management of roadsides accounts for a considerable portion of most state transportation department landscaping and revegetation budgets and has been cited as the most important factor in determining the success of roadside revegetation projects (Hansen and McKell, 1991; Anderson, 1996). According to Hansen and McKell (1991), the main function of a maintenance program is typically to improve safety by sustaining a zone adjacent to the roadway that is clear of any potential objects that would obstruct a driver's line of sight. Because typical maintenance procedures involve mowing, brush removal, and the application of herbicides, these authors suggest that close coordination between the maintenance crew and those involved in re-establishing desirable vegetation is essential to the success of a roadside enhancement project. Site-specific recommendations should be included in a project's maintenance program to clearly establish the extent and the timing of maintenance activities to protect desirable vegetation (Hansen and McKell, 1991; Harrington, 1994). To further ensure the success of a revegetation project, Hansen and McKell (1991) suggest that maintenance plans should be based on effective communication between all responsible project personnel, including those involved in design, implementation, and maintenance.

Many studies (e.g., Smith, 1977; Hansen and McKell, 1991; Harrington, 1994; Anderson, 1996) have shown that a reduction in maintenance expenditures can be achieved by simply limiting the amount of mowing that typically takes place within right-of-ways. While mowing continues to be one of the most dominant management practices for controlling roadside vegetation, alternative methods exist that have been shown to be just as effective at a fraction of traditional costs (Harrington, 1994; Anderson, 1996). For example, the promotion of a healthy, native plant community has been widely recognized as the best method for controlling or eliminating undesirable plant populations and has been shown to require little maintenance (Harrington, 1994). Though the use of herbicide is another widespread method used to control vegetation, additional methods (i.e., hot water treatments, biological control agents, and hand eradication) have yet to reach their full potential. Much of the reasoning behind research in alternative vegetation control methods is that traditional mowing practices have been found to cause adverse effects on the landscape. For example, Hansen and McKell (1991) found that mowing could alter species composition if desirable plants are "topped" prior to seed production, effectively eliminating some species after only one year of establishment. These authors and others (IRVM, 1994) also found that persistent and untimely mowing, in addition to the over-application of herbicide, may result in an increase in the presence of invasive weedy species and a decrease in native plant vigor due to the presence of bare ground.

Despite the aforementioned studies and acknowledgment from many transportation offices concerning the limited effectiveness of mowing, state and county highway departments are reluctant to reduce mowing and herbicide application due to the public's perception of "untidy" roadsides (Anderson, 1996). According to a survey conducted in the late 1990's, many roadside managers in the Southwest believe that unmowed vegetation along roadways will distract motorists and compromise public safety (Anderson, 1996). However, in a study done by Oetting and Cassel (1971), 82% of motorists were not likely to notice a difference between mowed and unmowed sections of right-of-way. These authors also found that when the two conditions were pointed out, 72% preferred the cleaner look of the mowed portions but were quick to change their answers when they were informed of the benefits of unmowed right-of-ways. Thus, Oetting and Cassel (1971) recommend programs publicizing the values of unmowed vegetation through the use of informative signage along the roadway and at rest areas. In problem areas or in other areas that must be mowed due to safety reasons, Anderson (1996) suggests mowing a maximum of 10% of the right-of-way immediately adjacent to the roadway to provide adequate safety for travelers while maintaining the cost-effective and environmental benefits of reduced mowing practices.

Roadside management practices have long endeavored to meet the public's assumption that roads will allow for the safe and rapid movement of traffic with minimal economic costs while maintaining aesthetic standards (Snow, 1959; Egan and Harrington, 1992). One of the best ways in which to ensure that these goals are met is through the implementation of a long-term monitoring plan as part of the management process. Often overlooked in roadside revegetation projects, monitoring has the potential to locate problems in current management practices and revegetation activities and suggest new methods for future roadside management (Hansen and McKell, 1991). The most effective monitoring programs combine the efforts of all relevant personnel from the Department of Transportation and regard the process as a "necessary step in quality assurance" and as a "means of attaining project success (Hansen and McKell, 1991)." A more detailed description concerning effective monitoring processes is discussed later in this chapter.

The Potential for Roadsides as Wildlife Habitat

The steady spread of urban development into the surrounding natural environment through the process of urban sprawl has resulted in a fragmented matrix of suitable habitat for indigenous plant and animal life. Often regarded as one of the most serious issues facing the conservation of biodiversity in a given ecosystem, habitat fragmentation is a process that has been difficult to mitigate due to a general lack of empirical studies supporting the effectiveness of designed connective elements (Csuti, 1991; Vermeulen and Opdam, 1995). Numerous studies (e.g., Oetting and Cassel, 1971; Smith, 1977; Vermeulen and Opdam, 1995; Anderson, 1996) have suggested that roadsides may be valuable in serving as these connective elements due to the extensive nature of the roadway system. By 1975, it was estimated that the soil and planted portions of highways, railroads, and utility right-of-ways constituted as many as 50 million ac of the contiguous United States (Egler and Foote, 1975). Not only has this number undoubtedly grown in the more recent decades, this number fails to include the numerous suburban roadsides that encompass a large percentage of this country. It has been suggested that in urban areas throughout the United States, roadsides may provide the only habitat for wildlife due to intense land use in the surrounding areas such as city development or agricultural applications (Oetting and Cassel, 1971; Smith, 1977).

Tucson, Arizona is one of a growing number of urban communities that is concerned with the conservation of wildlife. Through the integrated planning and cooperation of local government agencies and wildlife biologists, many cities are attempting to provide suitable wildlife habitats within metropolitan areas (Livingston et al., 2003). Despite the fact that the preservation of natural open space within the urban setting is one of the most important means of attaining a viable urban wildlife population, many cities have grown to a level that has isolated small pockets of remaining open space. Measures to mitigate the devastating effects of fragmentation have revolved largely upon the use of corridors and landscape linkages to effectively restore a sense of continuity to the surrounding ecosystem. According to Noss (1987), corridors may be the only means of maintaining connectivity in fragmented landscapes for mobile terrestrial animals. This author goes on to suggest that utilizing corridors as connective elements to a network of preserves may be the only way of attaining pre-fragmentation levels of biological interchange within a regional landscape.

Though numerous ecologists have recognized the value of roadside corridors as conduits for the dispersion of both flora and fauna (Reed and Schwarzmeier, 1975; Forman and Godron, 1986; White, 1986), the question of scale has been raised as a genuine argument against the effectiveness of roadside corridors. One ecologist has suggested that right-of-ways may be too narrow to serve as true corridors and that they may be simply acting as artificial edges that have "little ability to sustain themselves without large amounts of energy or management (Csuti, 1991)." In an attempt to answer some of the questions regarding appropriate width and design of these corridor systems, a study was conducted that explored the spatial conditions under which road verges served as dispersal corridors to a group of small ground-dwelling arthropods (Vermeulen and Opdam, 1995). The study found that broad right-of-ways promoted longer dispersal distances than narrow ones due to a decrease in individual losses to surrounding areas that were less conducive to successful reproduction. Including broad sites with suitable habitat within a system of corridors also reduced the effect of population decline on dispersal distances. These served as a local source to support the movement of species and to enlarge the distance over which the corridor functioned. According to the authors, similar conclusions could be obtained for studies on corridor strips in general and for other types of species as well. The study concluded that in order for right-of-ways to effectively connect fragmented landscapes, roadside corridors should have a width of at least 65 ft with adjacent areas of broader proportion to assist in species dispersal.

Other issues that affect the success of habitat along roadways involve the numerous management practices that typically take place within right-of-ways. For a roadside to provide quality wildlife habitat, Anderson (1996) suggests that the management of roadside plant communities be done in such a way to support a "healthy, viable plant community." The use of native plantings in these environments has often been shown as the most effective means of enhancing the ability of wildlife to find sufficient cover and life essentials such as food and water (Harrington, 1994; Anderson, 1996). As discussed in the previous section, maintenance practices such as mowing and the application of herbicides reduce the viability of native roadside communities – thus, a reduction in the frequency of these practices is recommended. Other recommendations for promoting the use of roadsides as wildlife habitat involve the establishment of a diverse plant community in terms of species and life-form (Schmidly and Wilkins, 1977; Smith, 1977; Kuennen, 1986). According to Harrington (1994), a diverse community is better equipped to handle disturbances by containing a mixture of species that can aid the community in terms of recovery. Livingston and others (2003) support the previous statement by adding that diverse plant communities will be able to best suit the varied needs of a diverse wildlife community.

Despite a growing interest in the use of roadsides as habitat linkages for various plant and animal species, this concept has yet to reach widespread acceptance among the roadside management community for a number of reasons. According to a survey done among roadside managers in the late 1990's, the most repeated objection to managing roadsides for wildlife habitat was the idea of increased road kill (Anderson, 1996). However, numerous studies (e.g., Oetting and Cassel, 1971; Crossley, 1990; Anderson, 1996) have shown that the proper management of roadsides for wildlife habitat, such as reduced mowing practices and the use of native plant species, has little effect on animals killed by traffic and that current management practices may actually increase the possibility of road kill. The common practices of controlling roadside vegetation, such as mowing and removing woody plant species, have been found to promote vehicle-wildlife collisions by removing protective cover and thus encouraging wildlife to flush into the roadway (Anderson, 1996). A study conducted in Indiana supports the value of protective cover within roadsides and found that, given the appropriate amount of vegetative cover, 93% of wildlife flushed towards tree or shrub plantings along the right-of-way rather than into the roadway (Anderson, 1996). In separate studies done by Schmidly and Wilkins (1977) and Crossley (1990), both small and large herbivores such as deer or rodents were found more likely to occupy roadsides with frequently mowed vegetation and the subsequent new growth that accompanies it rather than roadsides with a more naturalistic appearance.

Though the presence of small mammals and birds along right-of-ways is not generally thought of as a safety hazard in terms of vehicle-wildlife collisions, deer and other large mammals can cause extensive property damage and the loss of human-life (Smith, 1977). As noted by previous studies (Schmidly and Wilkins, 1977; Crossley, 1990), the practice of extensive mowing to maintain roadside visibility may be promoting vehicle accidents rather than preventing them (Varland, 1985). However, maintaining a small mowed portion immediately adjacent to the roadway is still recommended to allow motorists to observe any large mammals that may be crossing the roadway (Anderson, 1996). Such observations of wildlife entering the roadway despite the appropriate management for wildlife along roadsides suggest that wildlife killed by traffic may actually be a function of movement or population fluctuations rather than the vegetative condition of the right-of-way (Oetting and Cassel, 1971; Michael, 1980; Bouta, 1989). Regardless, the abovementioned studies show that the principal objection to managing roadsides for wildlife due to an increase in vehicle-wildlife collisions is not founded on actual research but more on the presumptions of management officials.

Other issues that concern roadside managers regarding wildlife habitat along roadways include an increase in predatory species within the roadside corridor, an increase in the spread of weed species into adjacent land uses, the occurrence of poaching, and distraction of motorists due to disorderly right-of-ways (Anderson, 1996). As previously discussed, studies have shown that drivers are largely unaware of the vegetative conditions along roadways and would respond favorably to information promoting the importance of naturalistic roadsides for use as wildlife habitat (Oetting and Cassel, 1971). The issue of poaching along roadsides has been discussed by Anderson (1996) and is thought to be a potential though unlikely problem due to the high visibility of such landscapes to the community. Increased predation and the movement of weed species into adjacent lands have also been addressed by a few studies (Joselyn et al., 1968; Anderson, 1996). Research provided by Joselyn and others (1968) suggests that enhancing wildlife habitat along roadways does not significantly increase predation due to the migratory nature of predators. Regarding the issue of weed species, Anderson (1996) suggests spot spraying along roadsides to eliminate undesirable species while preserving the remaining vegetation.

Despite the concerns expressed by roadside managers regarding the use of right-of-ways for wildlife habitat, suburban roadsides offer a viable means of providing connectivity among the fragmented natural open spaces typical of urban environments. Numerous studies (e.g., Oetting and Cassel, 1971; Smith, 1977; Vermeulen and Opdam, 1995; Anderson, 1996) have addressed the potential of roadsides and other right-of-ways to preserve or enhance wildlife habitat while reducing the damaging effects of fragmentation (i.e., loss of biodiversity and increased vulnerability to disturbance). In rapidly growing cities such as Tucson, the integration of these right-of-ways into an interconnected matrix of natural open space is becoming increasingly important to the efforts of conserving the health and vitality of the surrounding ecosystem while allowing for future growth and development (Livingston et al., 2003).

Techniques for Roadside Revegetation in Arid Climates

Until the next major revelation in transportation technology, road construction will be an ongoing process at the forefront of an increasingly mobile and urban society. Though roads provide a relatively efficient means of travel and some show the promising possibility of creating habitat along their edges, the construction process is often regarded as highly detrimental to the immediate surroundings. According to a report prepared for the Utah Department of Transportation, road construction can alter the protective vegetative cover and land use of the impacted landscape and lower its aesthetic appearance (Hansen and McKell, 1991; Brooks, 1993). In addition, the construction process often creates an unprotected soil surface that promotes air pollution from blowing dust and the transport of sediments to regional watersheds through the process of soil erosion. As previously discussed, soil erosion is a highly destructive process that may have serious long-term effects on the landscape by removing invaluable surface soil and potentially preventing the application of future reclamation practices (Hansen and McKell, 1991).

Because of the effects of road construction on the surrounding environment, numerous regulations have been established throughout the United States and in many other countries regarding erosion control and water pollution following construction activities. Many of these regulations require the re-establishment of a vegetative cover following construction to control erosion at "a degree equal to pre-disturbance levels (Harris and Dines, 1998)." In the state of Arizona, the Arizona Department of Environmental Quality (ADEQ) under the Arizona Pollutant Discharge Elimination System (AZPDES) Permit Program (Permit No. AZG2003-001) requires that "Final Stabilization" be met in order for an operator of a construction site to complete a project (ADEQ, 2003). As defined by AZPDES, "Final Stabilization" occurs when either permanent stabilization methods have been employed (i.e., the use of riprap, gabions, etc.) or when a "uniform perennial vegetative cover" has been established on unpaved or permanently uncovered areas following the completion of all soil-disturbing activities (ADOT, 2004). In order to comply with many of the federal, state, and local ordinances, appropriate measures must typically be taken to ensure the success of revegetation following road construction, such as the careful selection of plant materials for survival on a particular site or the site-specific evaluation of appropriate revegetation techniques for project use.

Site Clearing and Preparation

Site clearing and preparation takes place at the onset of a construction project and often consists of stockpiling available surface soil for later use and removing existing vegetation to allow access for construction activities (Hansen and McKell, 1991; Anderson, 1996). The excessive removal of existing vegetation is discouraged to promote the rapid recovery of the site by minimizing its disturbance. One study has suggested the removal of woody plant stems rather than the entire root-ball to promote the re-establishment of woody plant species from reserve seed and plant materials remaining in the soil (Hansen and McKell, 1991). Upon completion of construction activities, surface soil is often added to the disturbed areas of a site to enable the successful establishment of a vegetative cover (Anderson, 1996). Surface soil provides many benefits to vegetation such as increased infiltration rates, better nutrient holding capacity, higher concentrations of essential soil microorganisms, and a supply of native seed. Disturbed areas that have been refurbished with sufficient surface soil have been shown to promote a higher degree of vegetative diversity, productivity, and cover than those with insufficient surface soil, thereby resulting in improved erosion control and lower sediment yields (Hansen and McKell, 1991). However, because arid climates characteristically have limited amounts of surface soil, it may be necessary to utilize subsurface soil or import offsite surface soil for plant establishment (Hansen and McKell, 1991).

Existing plant material that may interfere with seedling establishment is typically removed, chopped, or shredded with a brush chopper or rotary motor and incorporated into the soil (Hansen and McKell, 1991; Anderson, 1996). Incorporating these materials into the soil increases the seed source of native species and aids in soil conservation (Hansen and McKell, 1991; Ecotone, 1995). Undesirable plant species should be permanently removed through the use of herbicides or alternative methods such as hot water treatments, biological control agents, and hand eradication.

Soil Amendments

Information on the condition of the soils present on a project site is vital to the establishment of a revegetation project due to physical and chemical characteristics that can determine a site's ability to support plant growth (Mortenson, 1979; Hansen and McKell, 1991; Brooks, 1993; Harris and Dines, 1998; Martinez, 2001). Soils in the arid Southwest are often deficient in essential plant nutrients such as nitrogen and phosphorus and may have additional deficiencies as a result of the construction process (i.e., excess compaction or excessive accumulation of coarse fragments) (Hansen and McKell, 1991; Brooks, 1993). A soil test can provide valuable information concerning soil texture and structure, pH, salinity, alkalinity, organic matter, cation exchange capacity, bulk density, and porosity (Martinez, 2001). Understanding each of these parameters can aid in the process of preparing favorable conditions for plant establishment by determining the types and amounts of amendments that should be added to existing or imported soils. Soil amendments are typically used during the initial stages of revegetation to supply adequate nutrients during the concurrent establishment of numerous plants species (Hansen and McKell, 1991). According to Hansen and McKell (1991), initial nutrient needs may ultimately differ from those of an established plant community; therefore, adequate planning and communication is required to address these changing issues throughout the course of a roadside maintenance program.

Seed Bed Preparation

Prior to planting or the application of seed to a disturbed site, the physical preparation of the seedbed is necessary. Surface-sown seeds are often exposed to a number of harmful conditions (i.e., predation, seed and seedling desiccation, and lack of radical entry) that may prevent the establishment of many plant species (Winkel et al., 1991). Seedbed preparation often involves the process of manipulating and roughening the soil surface through the use of various techniques to provide a suitable environment for seedling establishment (Martinez, 2001). A roughened soil surface often creates microsites that provide surface-sown seeds with adequate soil moisture and temperature conditions, increased aeration and water infiltration, and improved seed-to-soil contact (Hansen and McKell, 1991; Winkel et al., 1991). Research has shown that microsites can be beneficial in promoting the germination of seeded species in arid situations due to increased moisture and humidity levels that are typical of cracks or depressions in the soil surface or of sites associated with gravel and plant litter (Winkel et al., 1991). Numerous techniques exist that can create these surface conditions and often involve the use of heavy machinery such as bulldozers and tractors that rip, chisel, plow, disk, harrow, or slope chain the soil surface (Martinez, 2001). Ultimately, the goal of seedbed preparation activities should be the creation of a seedbed with a well pulverized, friable soil surface and a firm subsurface. In addition, the seedbed should be relatively free of competitive plant material and should contain moderate amounts of mulch or plant debris within the soil surface (Hansen and McKell, 1991).

Plant Selection

The compatibility of a plant species to regional and situational conditions present on a project site is an important factor in the selection of seeded plant species for use in roadside revegetation projects (Martinez, 2001). In addition to the relatively harsh environmental conditions that often effect the establishment and growth of plants in arid regions such as variable precipitation and temperature extremes, roadside conditions further complicate the survival of seeded species. Roadsides are often characterized by a number of restrictive issues such as limited topsoil, low nutrient levels, excessive or impeded drainage, steep or unstable slopes, susceptibility to weed invasion, and high concentrations of salts, oils, lead, and air pollutants (Mortenson, 1979; Gounveia, 1983; Ehley, 1990; Harrington, 1994; and others). In addition, the linear and fragmented nature of the roadsides themselves compound many of these issues due to the potentially negative effects of small size and isolation on the survival of plant species (Gilpin and Soule, 1986; Noss, 1987; Wilcove, 1987). Because of the aforementioned issues, it is imperative that species selected for use in roadside revegetation projects are adapted not only to the pre-disturbance conditions of a particular ecosystem but also to the adverse conditions typically associated with the roadside environment. Research into the past performance of species used in revegetation programs may provide the best insight as to the most appropriate plant species for use in any given range of site conditions (Martinez, 2001).

The use of native plantings along roadways has long been advocated by numerous landscape architects, horticulturalists, and ecologists throughout the country for their superior ability to withstand the regional conditions of a given project site. Because of the diverse selection pressures that continue to shape the ecological adaptation of these indigenous species, native vegetation has the unique ability to adapt to some of the unfavorable conditions that may be present on drastically disturbed landscapes (Hansen and McKell, 1991). Furthermore, the use of native plants enables a revegetation project to successfully integrate itself with the regional landscape while providing additional habitat opportunities for indigenous plant and animal communities (Harrington, 1994; Livingston et al., 2003). However, despite a general agreement that the use of native plantings offers an ecological approach to right-of-way landscaping, many roadside managers are hesitant to commit to their sole use due to lack of evidence surrounding their cost-effectiveness and proven establishment techniques (Harrington, 1991; 1994). Additional concerns regarding the use of native plants include relatively long establishment periods that can undermine the immediate goals of erosion control and aesthetics, lack of availability, and poor establishment due to excessive competition from more aggressive exotic species (Hansen and McKell, 1991; Harrington, 1994). Thus, further research and knowledge concerning the most effective ways in which to successfully establish native vegetation is necessary to convince roadside managers and planners of the less tangible and long-term benefits of their use (Harrington, 1994).

In addition to the selection of regionally suitable plant species, a factor that is frequently considered during the plant selection process is the intended diversity of the new plant community in terms of both species and growth habit (Brooks, 1993; Martinez, 2001). Studies have suggested that diverse plant communities can withstand temporary site disturbances by naturally adjusting the dynamics of the community to compensate for species loss (Harrington, 1994). Diverse plant communities have also been shown to have a higher visual quality and a greater potential to support a variety of habitat needs for wildlife than those with a simpler composition (Brooks, 1993). Furthermore, the inclusion of a diverse selection of plant life-forms reduces the potential for soil erosion by providing both short term and long term cover through the use of herbaceous and woody species, respectively (Clary, 1983). However, it is important to note that competition from herbaceous species may effectively limit or prohibit the establishment of woody species (Clary, 1983; Hansen and McKell, 1991; Brooks, 1993; Martinez, 2001). Therefore, in areas where erosion control is not an immediate issue, woody species should be planted one growing season prior to herbaceous species to allow for successful establishment (Hansen and McKell, 1991). Woody species such as trees and shrubs can be especially beneficial along roadsides in terms of providing suitable cover and habitat for wildlife. Several studies have also suggested that woody vegetation may enhance the safety of the traffic corridor by defining the road edge for motorists, acting as landmarks for orientation during periods of low visibility, alerting motorists to upcoming turns or bends, and buffering traffic noise and glare (Snow, 1959; Simonson, 1970; Anderson, 1996).

Other factors that should be considered during the plant selection process include species availability and regulatory restrictions (Martinez, 2001). Though the seed industry has made great strides in the acquisition and collection of many native plant species over recent years, some species may not be readily available without advance planning and notice (Martinez, 2001; Agnew, 2004). Therefore, it may be necessary to inform the seed industry years in advance regarding the type of plant materials needed for a given revegetation project (Agnew, 2004). The selection of plant species or substitutions must also abide by current regulatory restrictions as defined by state and federal agencies (Martinez, 2001). The state of Arizona has defined a number of species as either prohibited or restricted noxious-weeds. Prohibited noxious-weeds are typically regarded as being highly detrimental to the surrounding environment and are extremely difficult to control – thus, their use is strictly prohibited by law. Restricted noxious-weeds are highly objectionable as well but are permitted in limited quantities because they are somewhat controllable (Parker, 1972). The use of other species in the Southwest that have not been specifically restricted such as Lehmann's lovegrass (*Eragrostis lehmannii*), fountain grass (*Pennisetum setaceum*), and buffelgrass (*Pennisetum ciliare*) has been limited by ADOT due to their invasiveness and ability to aggressively out-compete native plants (ADOT, 2001).

Seeding Techniques

Under roadside project conditions characterized by limited disturbance within the adjacent landscape, existing vegetation can ideally provide a significant amount of native seed (Hansen and McKell, 1991; Anderson, 1996). However, these conditions are usually rare in the highly modified urban environment. Often times, the vegetation adjacent to a project site has either been previously disrupted to a point in which the native seed source is insufficient/non-existent or the vegetation is largely composed of undesirable plant material (Hansen and McKell, 1991). Therefore, the most frequently used method of establishing roadside vegetation in the arid Southwest is by directly seeding plant material onto the project site (Mortenson, 1979; Willis and Patten, 1983; Hansen and McKell, 1991; Anderson, 1996). The primary advantage of direct seeding is its relatively low cost when compared to other methods for establishing vegetation such as the use of containerized nursery stock or transplants. Disadvantages often include an increased susceptibility to project failure during germination and seedling establishment due to the harsh conditions of the desert environment. Proper seed coverage by soil is essential with direct seeding, thereby lessening the disadvantages associated with seed exposure to site conditions (Hansen and McKell, 1991).

Seeding typically occurs shortly after site preparation and is best performed during the first available seeding window (Hansen and McKell, 1991). As defined by Hansen and McKell (1991), a seeding window is "that period of time most suitable for seeding and offers the best potential for seeding success." Though this time varies by region, seeding windows typically occur prior to a period of adequate moisture for seed germination and seedling establishment and when soil temperatures are adequate for seed growth. Seeding should take place during the first seeding window following site preparation to reduce the time between seedbed preparation and plant establishment. Otherwise, the disturbed site may become increasingly difficult to revegetate due to an increased susceptibility to surface crusting, erosion, and weed infestation (Hansen and McKell, 1991).

The process of direct seeding may consist of any number of methods within the broad categories of drill and broadcast seeding (Hansen and McKell, 1991; Brooks, 1993; Anderson, 1996). Site accessibility, terrain, seedbed characteristics, time of seeding, and species characteristics frequently influence the type of method utilized for a particular site (Hansen and McKell, 1991). Drill seeding is most effective on dry slopes of less than 3:1 and on areas that are not excessively rocky. Consisting of a mechanical device that creates openings in the soil surface, a drill seeder has the ability to place seeds at a specified depth within a network of furrows. The seeds are then covered and packed with a packer assembly that is attached to the drill seeder (Anderson, 1996). Multiple seed boxes are recommended for use in drill seeders so that seeds of varying species can be placed at the optimal depth for each type (Hansen and McKell, 1991; Anderson, 1996). Drill seeding has been shown to be highly effective in arid regions due to improved soil coverage, reduced seeding rates, and the ability to seed into existing stubble (Hansen and McKell, 1991; Anderson, 1996). However, this method has been shown to create rows of vegetation within the landscape that are unappealing and often result in increased competition of species within the row. In addition, drill seeding has been shown to reduce the amount of diversity present within a landscape by having difficulty planting smaller seeded species at desirable depths, essentially eliminating them from the species composition (Hansen and McKell, 1991).

Broadcast seeding consists of any method that scatters the seed directly onto the soil surface and is generally required on slopes steeper than 3:1 or on extremely rocky or inaccessible locations (Cook et al., 1970; Hansen and McKell, 1991). This type of seeding usually entails the additional raking, chaining, or harrowing of a thin layer of soil to ensure adequate seed coverage (Hansen and McKell, 1991). Methods of broadcast seeding may include the use of a spinner plate attached to the underside of a seed container that evenly scatters the seeds over the project site or the use of an aqueous mixture of seed, mulch, and tackifier (often known as hydroseed) that is sprayed onto the landscape (Hansen and McKell, 1991; Anderson, 1996). Broadcast seeding has been shown to have several advantages over drill seeding such as an even dispersal of seeds throughout the project site and the ability to accommodate a wide range of species and project conditions (Hansen and McKell, 1991; Anderson, 1996). However, broadcast seeding usually results in slower germination and seedling establishment and typically requires the use of higher amounts of seed (Hansen and McKell, 1991). In addition, methods of broadcast seeding such as the use of hydroseed are highly dependent on moisture conditions to keep the seed and mulch sufficiently wet during the first few weeks of establishment and have been shown to have limited success in arid climates (Hansen and McKell, 1991; Anderson, 1996).

Planting

Roadside landscapes in arid climates pose a number of difficulties to the successful establishment of seeded species, such as low precipitation or toxic soils (Brooks, 1993). Thus, some studies have recommended the use of container-grown or transplanted plant material to increase the probability of success for a given revegetation project (Clary, 1983; Hansen and McKell, 1991; Brooks, 1993; Anderson, 1996; Martinez, 2001). Container plantings and transplanted stock typically allow for relatively rapid vegetation establishment and soil protection, increased survival rates, and an increased ability to withstand competition when compared to seeded plant materials. However, the use of germinated individuals rather than seed is often more expensive and typically requires additional care during the packing, shipping, storing, and planting processes (USDA Forest Service, 1979; Hansen and McKell, 1991; Anderson, 1996;

Martinez, 2001). Supplemental irrigation may also be required to ensure the survival of containerized and transplanted stock (Brooks, 1993).

Roadside plantings in the Southwest typically involve the use of mature plant transplants, bare-root stock, and/or containerized stock (Hansen and McKell, 1991). The use of mature plant transplants is typically reserved for highly landscaped situations due to the high cost and labor associated with the planting process (Martinez, 2001). Regardless of cost, one study advocates the use of a front-end loader to transplant some shallow-rooted species within a mass of native soil to enhance the success of a revegetation project. These "islands" of native soil have been shown to increase the diversity of indigenous species that may be present within the soil and provide centers for their dispersal (Hansen and McKell, 1991). Bare-root plant material has a complete lack of growing media that surrounds the root system. Bare-root plantings are less expensive and tend to be larger in size than many of the other forms of plant material but are difficult to establish due to the planning and precision involved in the planting process (Anderson, 1996). Though more expensive, container-grown plant material offers greater flexibility in the planting schedule and is widely available throughout the Southwest (Hansen and McKell, 1991; Anderson, 1996). Frequently used along revegetated roadsides, container-grown plants have been shown to be relatively successful in promoting vegetative establishment due to their ability to withstand the fairly harsh conditions associated with many project sites in the arid Southwest (Hansen and McKell, 1991).

Mulch

The presence of detritus on the soil surface of a project site has been shown to greatly enhance the establishment and survival of plant species in arid climates by moderating soil temperature, reducing evaporation, increasing infiltration, and protecting the soil surface (Mortenson, 1979; Jackson et al., 1991; Robinett, 1992; Brooks, 1993). Because disturbed areas in these climates typically lack sufficient material to create an adequate layer of organic litter, surface mulch may be added to a site after the seeding or planting process to aid in the establishment of a revegetation project. Numerous studies have suggested that surface mulches are highly effective in controlling erosion and conserving moisture, thus increasing the probability of seedling establishment in an arid environment (Hansen and McKell, 1991; Brooks, 1993; Anderson, 1996; Martinez, 2001). Many types of surface mulch exist for use along revegetated roadsides in the Southwest, including loose materials such as straw or hay, wood or paper, shredded native grasses or brush, manure or dried sewage sludge, gravel, or plastic films (Hansen and McKell, 1991; Brooks, 1993; Anderson, 1996; Harris and Dines, 1998; Martinez, 2001). Other types of surface mulch may be in the form of blankets or mats made of jute, straw, excelsior, coconut, or synthetic materials (Harris and Dines, 1998). On slopes greater than 3:1, most mulching materials require either a tacking agent or plastic netting to secure the material to the soil surface in the event of strong winds or heavy rain (Hansen and McKell, 1991; Harris and Dines, 1998). Tacking agents may include asphalt, resin, or latex emulsions; natural soil binder; or wood fiber hydromulch (Harris and Dines, 1998). Given the range of options, the selection of the most appropriate mulch and anchoring device for use on a project site is best determined through an evaluation of site conditions and project costs (Martinez, 2001).

Supplemental Irrigation

Seedling establishment in undisturbed arid environments is largely dependent on seasonal rainfall to provide the adequate moisture needed for initial germination and growth. Due to the sporadic nature of precipitation in desert climates, the natural establishment of native vegetation is an infrequent occurrence often accompanied by unusually wet conditions (Jackson et al., 1991). The planned establishment of vegetation in disturbed landscapes is an especially difficult process that may ultimately fail in most years due to the variability of climatic conditions during the onset of a revegetation project (Thacker and Cox, 1990; Jackson et al., 1991; Robinett, 1992). Studies concerning the success of revegetation projects in the Southwest have suggested that those that rely solely on natural precipitation and direct seeding will fail nine out of ten years (Thacker and Cox, 1990; Jackson et al., 1991). Jackson and others (1991) further address this issue by suggesting an alternative approach to typical revegetation practices that involves planting or seeding a fraction of the restoration area every few years until "a good rainfall year occurs." While requiring a long-term commitment, this approach mimics the process of natural succession and ensures that "when a good rainfall does occur, seeds are there to take advantage of it (Jackson et al., 1991)."

The more common approach to establishing vegetation in arid environments is to provide supplemental irrigation during the first few years of a project until an adequate root system has developed to tolerate drier conditions (Hansen and McKell, 1991;

Jackson et al., 1991; Martinez, 2001). However, the use of supplemental irrigation is highly contested among the management community due to the potential establishment of invasive or non-native species and dependence on large amounts of water (Bengsson, 1985; Bowden, 1991). Regardless, many believe that supplemental irrigation is crucial to the success of a revegetation project and that its use enhances seed germination and seedling growth (Bengsson, 1985; Hansen and McKell, 1991; Munshower, 1993). Several types of irrigation systems exist for use on disturbed sites and may include permanent irrigation systems, drip systems, or the use of flood irrigation through a system of water catchments or terraces (Martinez, 2001).

Evaluating Revegetated Landscapes

Successful establishment of vegetation on disturbed landscapes in the arid and semi-arid Southwest is vital to the protection and preservation of the region's natural resources. However, revegetation in desert climates is a difficult process that requires a detailed understanding of the interactions between the region's climatic conditions and the methods used during revegetation. The evaluation of a revegetated landscape following project completion can prove invaluable to future efforts by developing recommendations regarding the improvement of current revegetation activities and management practices (Hansen and McKell, 1991; Martinez, 2001). Further insight concerning the status of past revegetation projects may ultimately provide definitive solutions for effective methods of establishing vegetation in arid regions. Unfortunately, long-term evaluation and monitoring of revegetated landscapes is rarely done due to a lack of economic resources or knowledge concerning appropriate evaluation procedures (Roundy, 1988; Hansen and McKell, 1991; Brooks, 1993; Briggs et al., 1994).

Within the past few decades, numerous efforts have been made to develop effective evaluation procedures for a number of different types of revegetated landscapes in the Southwest, including rangeland, surface-mined land, and urban construction sites (Hansen and McKell, 1991; Brooks, 1993; Anderson, 1996; Martinez, 2001; ADOT, 2004). Because these landscapes typically support a variety of uses and serve differing functions, observations made during the evaluation process should be related to the original project criteria and specifications (Hansen and McKell, 1991; Martinez, 2001). In the case of revegetated roadsides, original project criteria may have included site stabilization, aesthetic and safety improvement, or vegetative establishment to match pre-disturbance communities (Brooks, 1993; ADOT, 2001; Martinez, 2001). While evaluation procedures typically vary by project type and location, most involve the comparison of characteristics such as species diversity, richness, and cover from the revegetated site to those of an undisturbed reference area (Brooks, 1993; Martinez, 2001). Comparisons may also be formulated between the current status of the revegetated site and its intended status as specified by the original revegetation plan (Martinez, 2001). Other observations may include notations on slope stability, erosion control, species establishment and survival, or the presence of indigenous wildlife (Hansen and McKell, 1991).

The initial monitoring and evaluation of a revegetated landscape should ideally occur during the implementation of the revegetation activities and for at least three to five years following project completion (Hansen and McKell, 1991). According to Hansen and McKell (1991), plant mortality is usually minimal following this period; thus, any losses to the project site have generally occurred by this time. However, the dynamics of an arid landscape continue to change beyond the recommended monitoring and evaluation period due to natural and human-induced fluctuations. Therefore, further evaluation is encouraged to successfully capture the long-term stability of the site. Site evaluations generally consist of a reconnaissance of the project area to observe critical site conditions such as site stability, soil loss, the presence of weed species, and the appearance and condition of plantings (Hansen and McKell, 1991). The quantitative collection of data such as plant cover, frequency, diversity, density, and plant survival rates is also an important component of the evaluation process to effectively compare the site conditions with a general undisturbed reference area (Hansen and McKell, 1991; Brooks, 1993; Martinez, 2001).

An in-depth evaluation of revegetated sites may also be conducted through the use of a general index based on site characteristics and variables that can potentially predict a site's suitability for any number of pre-determined functions and be used for site comparisons. One such database that has been developed for the Tucson area is a wildlife habitat suitability index that addresses site potential as urban wildlife habitat (Livingston et al., 2003). Additional indices have been developed for the Tucson area as well as for the Southwest region in hopes of providing accurate descriptions of the types of functions that can be supported by a given landscape (Meyer, 1987; Shaw et al., 1998). With this type of information, future decisions regarding species composition, management practices, and other revegetation activities can be guided towards the successful creation of a sustainable environment suitable for the establishment of indigenous plant and animal species.

Chapter 3

METHODS

Description of the Study Area

Twenty revegetated sites along roadways were selected within a 5-mi radius of the incorporated city of Tucson, Arizona. Located approximately 60 mi north of the Mexican border and 100 mi south of Phoenix, the greater Tucson metropolitan area encompasses 495 mi^2 of eastern Pima County and supports over 750,000 residents. Tucson is located in a valley at approximately 2,400 ft above mean sea level and is surrounded by the Santa Catalina Mountains to the north-northeast, Rincon Mountains to the east, and Tucson Mountains to the west. The climate of Tucson is characterized by hot summers and cool, moderate winters with an average annual temperature of 68°F. Average annual precipitation is 12 in. and generally occurs during the summer and winter months from July through August and December through February (Glueck, 1997).

Tucson is located within an approximately 120,000-mi^2 region of North America known as the Sonoran Desert (Shreve and Wiggins, 1964). An arid region long admired for its diverse plant and animal life, the Sonoran Desert encompasses the southwestern third of Arizona, a portion of southeastern California, most of Baja California, and the western half of Sonora, Mexico (Brown, 1994). The Sonoran Desert is generally regarded as a "lush" desert, with areas receiving an average of between 5 and 12 in. of annual precipitation during two, approximately three-month rainy seasons in summer and winter. While winter precipitation typically occurs in gentle and prolonged storm events from the Pacific Ocean, summer precipitation, while brief, is often torrential and the result of large thunderstorms derived from moisture originating in the Gulf of Mexico (Shreve and Wiggins, 1964). The Sonoran Desert is considered to be one of the hottest of the North American deserts, with daytime temperatures reaching a maximum of 90°F as early as February. Soils in this region are characteristic of most desert climates and generally consist of well-aerated, fine-textured sub-soils and coarse-textured surface soils with low organic matter content and high concentrations of readily soluble salts.

The Sonoran Desert is typically thought to consist of seven distinct subdivisions classified as either Sonoran desertscrub or Sinaloan thornscrub (Shreve and Wiggins, 1964; Brown, 1994). Of these seven subdivisions, only the Colorado River Valley and Arizona Upland divisions are located within Arizona, with the Tucson area specifically within Lower Sonoran desertscrub, Arizona Upland division (Figure 1) (Brown, 1994). The Arizona Upland division comprises the northeastern portion of the Sonoran Desert and includes some of the most famous and picturesque landscapes of the region (Shreve and Wiggins, 1964; Brown, 1994). Described as the least desert-like of North America's desertscrub environments due to an abundance of arborescent and succulent plants, approximately 90% of the Arizona Upland division is characterized by mountainous or sloping terrain (Brown, 1994).

Dominant plant species within the Arizona Upland division include palo verdes (*Cercidium microphyllum, C. floridum*), saguaro (*Carnegiea gigantea*), velvet mesquite (*Prosopis velutina*), ironwood (*Olneya tesota*), desert willow (*Chilopsis linearis*), acacias (*Acacia greggii, A. constricta*), creosote bush (*Larrea tridentata*), jojoba (*Simmondsia chinensis*), desert hackberry (*Celtis pallida*), bursages (*Ambrosia* spp.), brittlebushes

(*Encelia* spp.), saltbushes (*Atriplex* spp.), chollas and prickly pears (*Opuntia* spp.), and barrel cacti (*Ferocactus* spp.) (Shreve and Wiggins, 1964). Other common plant species include fairy duster (*Calliandra eriophylla*), shrubby buckwheat (*Eriogonum fasciculatum*), wolfberry (*Lycium berlandieri*), desert zinnia (*Zinnia acerosa*), and a range of grasses such as three-awns (*Aristida* spp.), bush muhly (*Muhlenbergia porteri*), Arizona cottontop (*Digitaria californica*), and fluff grass (*Erioneuron pulchellum*), which are especially common in the semi-desert grasslands neighboring the Tucson area (Brooks, 1993; Brown, 1994). Despite the diverse range of vegetation found within the region, most undisturbed landscapes consist of a relatively simple composition of three to ten different plant species. More than half of the species in the Sonoran Desert rarely exceed a height of 5 ft, though some notable exceptions such as the saguaro or ironwood may reach a height of 20 ft or more (Shreve and Wiggins, 1964). While some studies have suggested that naturally vegetated areas in arid regions include as much as 40 - 60% bare ground between plants, many portions of the Sonoran Desert are characterized by 70% or more bare ground (Shreve and Wiggins, 1964). However, some areas of the Sonoran Desert support nearly closed stands of vegetation under favorable moisture and soil conditions, though a 25% groundcover by perennial plants is considered sufficient for most semi-arid sites (Shreve and Wiggins, 1964; Brooks, 1993). The vegetation of the Arizona Upland division of the Sonoran Desert is consistent with the aforementioned characteristics, though a greater percentage of the plant species are of larger stature than those in other divisions (Shreve and Wiggins, 1964; Brown, 1994).

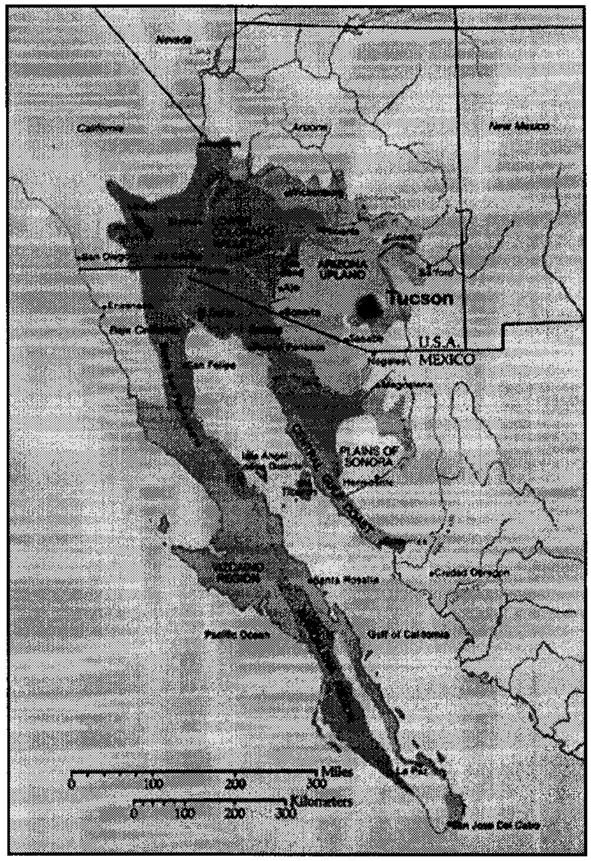


Figure 1. Map of the Sonoran Desert with six of the associated subdivisions and the location of Tucson, AZ (Foothills of Sonora division not shown) (adapted from Arizona-Sonora Desert Museum, 2003).

Many of the animals found in the Sonoran Desert are common throughout the warmer and drier regions of the Southwest and include a number of mammals, birds, and reptiles such as the coyote (*Canis latrans*), desert cottontail (*Sylvilagus auduboni*), roadrunner (*Geococcyx californianus*), cactus wren (*Campylorhynchus brunneicapillus*), desert spiny lizard (*Sceloporus magister*), and western diamondback (*Crotalus atrox*). Other common animal species are generally limited to the Sonoran Desert or its subdivisions and include the round-tailed ground squirrel (*Spermophilus tereticaudus*), Arizona cactus mouse (*Peromyscus eremicus eremicus*), Gambel's quail (*Lophortyx* *gambelii*), Gila woodpecker (*Melanerpes uropygialis*), desert tortoise (*Gopherus agassizi*), and chuckwalla (*Sauromalus obesus*). The structural diversity of the Arizona Upland division enables the persistence of an even greater amount of wildlife than the remaining portions of the Sonoran Desert, including moderate densities of desert mule deer (*Odocoileus hemionous crooki*), javelina (*Dicotyles tajacu*), Harris' hawk (*Parabuteo unicinctus*), and Gila monster (*Heloderma suspectum*) (Brown, 1994).

Data Collection

Twenty revegetated sites along roadways in the greater Tucson metropolitan area were selected for data collection based on project age and the inclusion of Class II seeding practices (Figure 2, Table 1). As defined by the Pima County Department of Transportation (1993b), Class II seeding consists of furnishing or planting range grass seed, flower seed, and/or shrub seed. Prior to seeding operations, all study sites were cleared of existing vegetation and were prepared with the addition of soil conditioner (Gro-Power® or equal) and 16-20-0 fertilizer. Seedbeds were manipulated or roughened by tilling, raking, or disking to a depth of at least 4 in. prior to the application of an aqueous mixture of seed, mulch, and tackifier. In most instances, the study sites received no irrigation upon project completion and were mulched with an additional layer of crimped or tackified straw to ensure soil protection and seedling establishment. However, sites 1, 7a, and 7b were irrigated for approximately one growing season following project completion and did not receive an additional layer of straw mulch (refer to Appendix A and B for further seeding information).

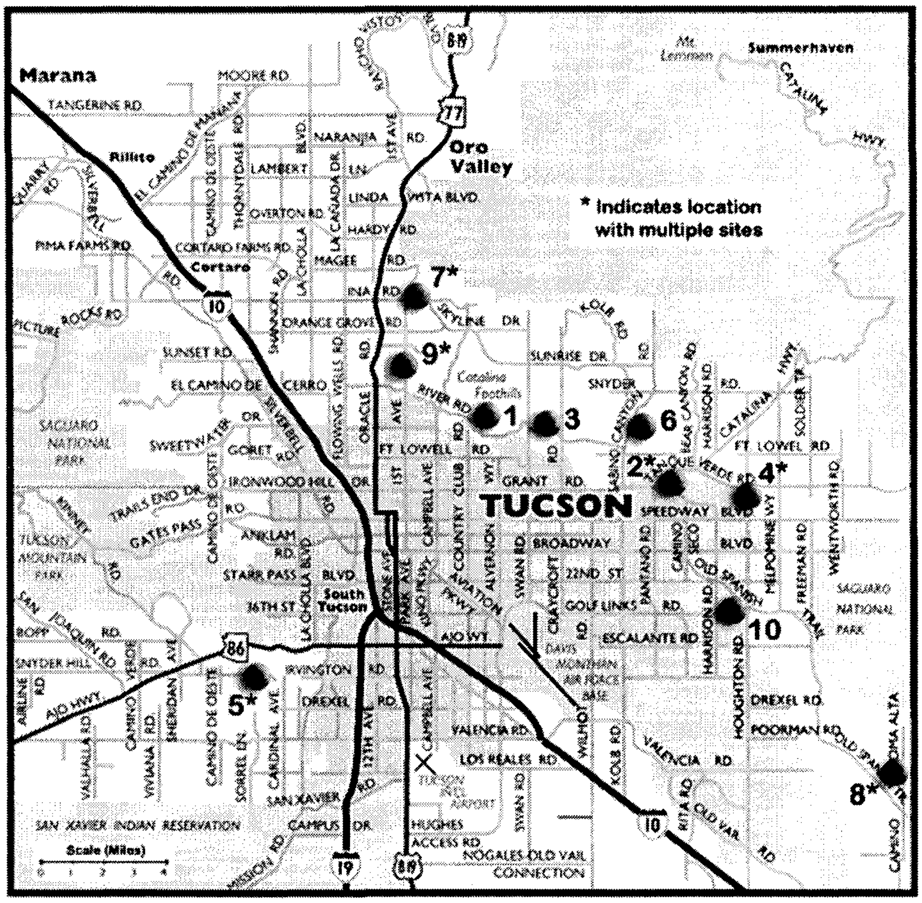


Figure 2. Detailed map of the Tucson area with location of study sites (adapted from University of Arizona, 2004).

Of the 20 study sites, ten were seeded under separate roadway construction contracts. The remaining study sites represent variations within a given construction contract, such as the date seeded or the specified type of seed mix or materials. For example, sites 9a and 9b were seeded with the same seed mix under the same construction contract; however, site 9b was differentiated because it involved the placement of additional erosion control blankets to minimize the effects of its fairly steep slopes (> 3:1). To evaluate the long-term success of revegetation at the study sites and to allow sufficient time for the establishment of woody species, projects were completed a minimum of two years prior to data collection (Hansen and McKell, 1991; Brooks, 1993). Study sites were located through Pima County's Department of Transportation and represent the revegetation standards of the Arizona Department of Transportation at the time of project completion.

Table 1. Summary of study sites with associated project information.

Site ID	Location	Established	Length	Elevation	Seed Mix†
			mi	ft	
1	Hacienda del Sol Rd.	1988	0.7	2,535	HDS
2a 2b 2c 2d	Tanque Verde Rd.: Pantano Rd. to Catalina Hwy.	1989 1990	1.5	2,510	TVR-1 TVR-2 TVR-1 TVR-2
3	River Rd.: Camino Arco to Craycroft Rd.	1991	0.5	2,519	RR
4a 4b	Houghton Rd.: Tanque Verde Rd. to Speedway Blvd.	1993	1.7	2,588	HR-1 HR-2
5a 5b	Irvington Rd.: Camino de Oeste to Mission Rd.	1994	3.5	2,430	IRR-1 IRR-2
6	Sabino Canyon Rd.: Cloud Rd. to Kolb Rd.	1996	1.6	2,522	SC
7a 7b 7c 7d	Ina Rd.: Oracle Rd. to Chula Vista	1996	2.3	2,851	IR-1 IR-2 IR-3 IR-4
8a 8b	Pistol Hill Rd.: Colossal Cave Rd. to Old Spanish Trail	2000	2.3	3,426	PHR-1 PHR-2
9a 9b	First Ave.: River Rd. to Orange Grove Rd.	2002	2.2	2,321	FA-1 FA-2
10	Golf Links Rd.: Bonanza Ave. to Houghton Rd.	2002	0.5	2,671	GLR

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.

Vegetation sampling for the study sites was conducted during late January through early March of 2004. Five stratified transect locations were randomly selected within stands of the specified seed mix for each study site. Data were collected along a 2-ft wide belt transect that extended perpendicular from the edge of the roadway to the project limits. A 2-ft by 2-ft quadrat was systematically located every 5 ft along the total length of the transect (Figure 3). The size of the quadrat was determined in a pilot study conducted in December of 2003 and early January of 2004. In this study, four study sites were sampled using a 3-ft by 3-ft quadrat located at 10-ft intervals and a 2-ft by 2-ft quadrat located at 5-ft intervals along the length of a representative transect. Confirming the conclusions of an earlier study by Daubenmire (1959), the data collected revealed that an increase in the number of plots rather than their size was an adequate and more efficient way to effectively describe the vegetative characteristics of a site. Furthermore, the smaller of the two quadrats proved to be sufficiently adequate in size to contain an average of at least four individual plants within its boundaries, as is recommended in several studies (Lyon, 1968; Brooks, 1993).

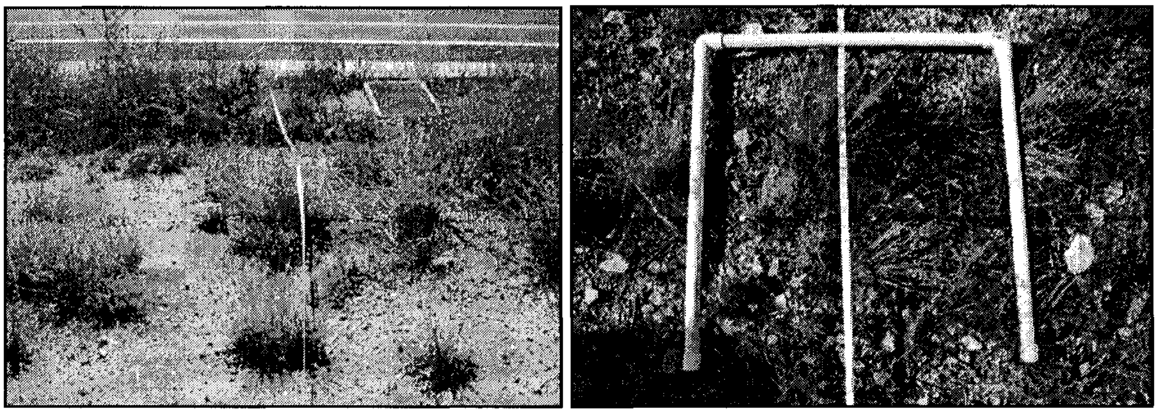


Figure 3. One of five belt transects (left) located along site 10 and an included 2-ft by 2-ft quadrat (right).

Individuals of all annual and perennial plant species (including those that were dormant) were recorded within each of the five transects per study site to derive species information such as origin, vegetative life-form, and invasiveness. Native species were broadly interpreted to represent those originating within the southwestern region of the United States. Exotic species were those that were specifically introduced to the region and often included species with origins in Europe, Africa, or southwest Asia. Woody species were considered as such only if some portion of living plant material was retained at or above ground level through the non-growing season (NRCS, 2004). This broad definition included some species of cacti, vines, and all trees and shrubs. Herbaceous species were described as vascular plants without significant woody tissue and frequently included grasses, forbs, sub-shrubs, and some vines. The desirability of each plant species was interpreted to represent whether a plant was described as invasive or restricted (or limited in use) within the state of Arizona. Density data for woody species were collected along the entire length of the belt transect, while data for herbaceous species were collected within each quadrat and extrapolated to the entire transect. Voucher specimens were collected and verified by a recognized taxonomist (Phil Jenkins, Assistant Curator, University of Arizona Herbarium). While most species were identified, several of the specimens where in such poor condition that reliable identification was not possible. Presence data for additional species located on the study sites but not within the transect area were collected by general observations.

Total canopy cover was estimated for the entire length of each transect in addition to canopy cover for each species found within the quadrats. Canopy cover is defined as an approximation of the area over which a plant exerts its influence on the other components of the surrounding ecosystem (Daubenmire, 1959). It can be best described as the polygonal area that would be created if the canopy of a plant were projected vertically onto the ground (Shreve and Wiggins, 1964). Canopy cover values were based on a broad classification system developed by Daubenmire in 1959 to reduce human error in assigning percent cover (Table 2). Because vegetative communities are composed of superimposed layers of plants, attempts were not made to have the total percent cover for each species add up to 100% when under-story vegetation was present. However, according to Daubenmire (1959), the sum of all canopy cover for each species provides a comparative index of productivity for closely related ecosystems. When estimating total canopy cover for the entire length of the transect, situations involving the growth of several smaller plants under the canopy of a larger plant were estimated by using the overall cover of the larger plant. Cover provided by inert material such as gravel, debris, cobble, and boulders was also noted for each transect.

Table 2. Six cover classes with their ranges of value and the midpoints used in calculations (from Daubenmire, 1959).

Class	Range	Midpoint
	%	
1	0-5	2.5
2	5-25	15
3	25-50	37.5
4	50-75	62.5
5	75-95	85
6	95-100	97.5

Additional data collected from the study sites included evidence of disturbance or wildlife, the presence of slopes steeper than 3:1, and the adjacent land use. Evidence of disturbance observed throughout the study sites frequently consisted of pedestrian and vehicular traffic along the right-of-way, soil erosion, and excessive debris such as fallen branches, waste materials, and remnant construction materials (e.g., excess piles of soil and concrete or asphalt fragments). Wildlife evidence throughout the study sites typically consisted of small insect, reptile, and mammal burrows; droppings; nests; and visual observations of birds, reptiles, mammals, and insects. Additional observations were made regarding the occurrence of either tree or large shrub species that appeared to have established from other sources, such as from adjacent, undisturbed vegetation or from planted species.

Data Analysis

Density and richness data collected in the field were converted to plants ft^{-2} and species 100 ft^{-2}, respectively, and entered into computer spreadsheets for analysis. Mean density for species noted within the study sites was calculated by dividing the total number of individual plants within each species by the total transect area for each study site and for the entire study. Frequency data for each species were derived from the number of transects in which a given species occurred divided by the total number of transects. Richness values were generated for each study site based on the average number of individual plant species collected from each of the belt transects located within the study site. Species information gathered from each of the transects was input into

SAS and used to determine percentages of vegetative life-form, origin, and desirability based on the species richness of each study site (SAS Institute Inc., 1998). Cover data obtained in the field were converted to the midpoint numbers described by Daubenmire (1959) (Table 2) and averaged by study site and by species. These data were compared with similar characteristics from an undisturbed landscape as described by others (Shreve and Wiggins, 1964; Brown, 1994). Density, richness, and cover data were also compared with a number of variables (i.e., year of project completion, the presence of slopes steeper than 3:1, and field observations of wildlife evidence) using Microsoft Excel® to determine if any correlations existed among variables across study sites. A VSI was calculated for each study site based on species richness, origin, and cover data (Shaw et al., 1998; Livingston et al., 2003). Based on the equation [total vegetative cover + 2 (native vegetative cover) + native richness] (adapted from Livingston et al., 2003), an average VSI value was calculated for each study site and categorized as having a low, medium, or high suitability for wildlife habitat. The following classification system of index values was determined from the final calculations: low = 0 – 1.3; medium = 1.4 – 2.6; and high = 2.7 – 4.0.

The species that were present on each study site were compared to those specified in the original construction documents as a measure of species establishment and project success. Specified to non-specified species ratios were determined based on the density and richness of each specified and non-specified species noted within the study sites. Percent establishment and percent cover of each specified species were also examined to better determine the success of the project in terms of initial design. Percent establishment was determined by dividing the number of study sites in which a species appeared to have established by the total number of study sites in which a species was specified. Percent cover for each of the specified species was determined by averaging its cover value over the study sites in which it was specified and in which the species appeared to have established.

Four broad categories were generated to describe the adjacent type and quality of land use surrounding each study site to determine if similarities existed among projects with adjacent comparable land use. The four categories were defined as follows: (1) low-density residential = sites adjacent to residential areas with relatively large lot sizes (> 0.5 ac); (2) natural open space = sites adjacent to large parcels of undeveloped land; (3) high-density residential and light commercial = sites adjacent to mixed-use parcels, including residential neighborhoods or small commercial facilities; and (4) wash and flood plain = sites adjacent to large washes or located within a floodplain. Adjacent land use quality was based on the level of development, potential habitat suitability, and the presence of undisturbed stands of vegetation present within each land use category. Other study site characteristics (i.e., the amount of wildlife evidence, evidence of disturbance, the presence of slopes steeper than 3:1, and the presence of tree or large shrub species that appeared to have established from other sources) were categorized as either very high, high, moderate, low, or very low based on the number of transects per study site in which such events occurred.

Chapter 4

RESULTS AND DISCUSSION

Vegetation Data

Thorough sampling of the vegetation present within the study sites revealed approximately 175 plant species. A number of these species likely established from adjacent, undisturbed native vegetation and included velvet mesquite (*Prosopis velutina*), palo verdes (*Cercidium microphyllum, C. floridum*), creosote bush (*Larrea tridentata*), white-thorn acacia (*Acacia constricta*), desert willow (*Chilopsis linearis*), desert hackberry (*Celtis reticulata*), and graythorn (*Ziziphus obtusifolia*). Several species of exotic vegetation were found to have naturalized on various study sites and included shoestring acacia (*Acacia stenophylla*), Chilean mesquite (*Prosopis chilensis*), African sumac (*Rhus lancea*), and salt cedar (*Tamarix aphylla*). The most frequently encountered species throughout the study was brittlebush (*Encelia farinosa*), a native shrub well adapted to rocky and disturbed soil conditions (Jones and Sacamano, 2000). Similar studies conducted in 1993 (Brooks, 1993) and 2001 (Martinez, 2001) also noted the frequent occurrence of brittlebush on revegetated sites, though densities were noticeably less at roughly 1 plant 100 ft^{-2}. Other common species included desert broom (*Baccharis sarothroides*), desert senna (*Cassia covesii*), triangle-leaf bursage (*Ambrosia deltoidea*), six-weeks three-awn (*Aristida adscensionis*), and globemallow (*Sphaeralcea ambigua*) (Table 3). Though all study sites were vegetated with a greater percentage of native species than with exotic plant material, some of the more common exotic species were red-stemmed filaree (*Erodium cicutarium*), schismus (*Schismus* spp.), medics (*Medicago* spp.), Prickly Russian thistle (*Salsola tragus*), Bigelow's grass (*Poa bigelovii*), and buffelgrass (*Pennisetum ciliare*). Two of the more notoriously invasive exotic species, fountain grass (*Pennisetum setaceum*) and Lehmann's lovegrass (*Eragrostis lehmannia*), were present but in lesser frequencies. A comprehensive list of the remaining plant species identified in this study with their associated frequency and density is listed in Appendix C.

Table 3. Total frequency and mean plant density for six of the most common native and exotic species noted within the study sites.

Native Species

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Encelia farinosa	Brittlebush	46	5.2
Baccharis sarothroides	Desert broom	40	2.3
Cassia covesii	Desert senna	40	2.8
Ambrosia deltoidea	Triangle-leaf bursage	39	1.6
Aristida adscensionis	Six-weeks three-awn	37	113.7
Sphaeralcea ambigua	Globemallow	35	20.6

Exotic Species

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Erodium cicutarium	Red-stemmed filaree	28	13.2
Schismus spp.	Schismus	25	42.2
Medicago spp.	Medic	16	65.0
Salsola tragus	Prickly Russian thistle	16	34.3
Poa bigelovii	Bigelow's grass	12	34.9
Pennisetum ciliare	Buffelgrass	12	3.2

† Frequency data derived from the number of transects in which a given species occurred divided by the total number of transects.

The highest percentage of individual, native plant species was located on site 8a in far southeast Tucson, adjacent to large tracts of relatively undisturbed native vegetation (Table 4). Despite the notion that the general location discouraged the encroachment of exotic species, a lower percentage of the plant species located on site 8b in the same vicinity were classified as native due to infestations of Lehmann's lovegrass and Bermuda grass (*Cynodon dactylon*) along the roadway. Similarly, 90% of site 7c's plant species were classified as native, while lesser percentages of sites 7a and 7d were classified as such despite the similar location. However, while site 7c was located on distinct terraces above the roadway and site 8a was located approximately 50 ft from a newly constructed roadway, the other three study sites (8b, 7a, and 7d) were located immediately adjacent to the pavement. Furthermore, the lowest occurrence of native plant species was noted on site 2a immediately adjacent to Tanque Verde Rd. These data suggest that one of the strongest factors contributing to the presence of exotic species on a revegetated landscape is its proximity to linear corridors such as roads or large washes that enable the rapid transport of such species and support increased water due to excess runoff. A similar study conducted by ADOT supports these conclusions and found that in seven randomly selected revegetated landscapes, all instances of Lehmann's lovegrass and other introduced species were noted directly adjacent to the pavement (Brady, 2003).

Table 4. Summary of general vegetation characteristics (including origin, growth habit, and desirability) based on species richness for sites within the study area.

Site ID	Origin			Growth Habit		Desirability
	Native	Exotic	Unknown†	Herbaceous	Woody	Undesirable‡
	%					
1	87	3	10	64	36	31
2a	49	41	10	88	12	40
2b	60	28	12	78	22	28
2c	54	23	23	80	20	20
2d	54	35	11	72	28	25
3	88	6	6	49	51	31
4a	56	32	12	75	25	31
4b	61	25	14	72	28	21
5a	82	12	6	70	30	24
5b	68	24	8	70	30	32
6	76	13	11	59	41	26
7a	75	20	5	35	65	32
7b	88	9	3	23	77	27
7c	90	5	5	33	67	17
7d	72	15	13	41	59	17
8a	91	6	3	48	52	11
8b	75	17	8	33	67	30
9a	65	24	11	59	41	48
9b	77	15	8	52	48	37
10	83	13	4	61	39	13

† Specimens identified to genus only, origin may vary.
‡ Undesirable species include those with invasive characteristics and those that have been determined noxious or restricted by the state of Arizona.

Herbaceous plants such as six-weeks three-awn, red-stemmed filaree, and purple three-awn (*Aristida purpurea*) dominated the majority of the study sites (Table 4). Site 2a had the greatest percentage of herbaceous species due to a high occurrence of native grasses such as needle grama (*Bouteloua aristidoides*) and six-weeks three-awn and a greater presence of exotic invasive species such as Bigelow's grass, schismus, and numerous mustards (*Brassica* spp., *Sysymbrium* spp.). One of the most successful study sites in terms of the establishment of woody vegetation was site 7b with mostly brittlebush. A relatively strong negative correlation (r = -0.54) was found between project age and the presence of woody species. Reasons for this may include the slow invasion of herbaceous exotics over time or the slow mortality of specified woody plant species that are not naturally re-seeding. A similar study reported an increase in the mixing of indigenous and exotic annuals and perennials over time with the less competitive woody species present onsite (Clary, 1983). Additional studies have suggested that as the percentage of herbaceous species increases over time the percentage of woody species decreases due to increased competition (Jackson et al., 1991; Anderson, 1996). Thus, greater measures should be taken during the initial revegetation process, such as longer monitoring and evaluation periods and additional maintenance, to ensure the continued survival of specified woody plant species.

Vegetation data collected at the study sites revealed a lower percentage of undesirable species than desirable species (Table 4). While this variable was largely linked to the presence of exotic species, overly invasive native species such as six-weeks three-awn increased the level of undesirability for many study sites. Although six-weeks three-awn admittedly provides a rather reliable source of cover and may serve as habitat for some wildlife species, many sites within the study area are in danger of becoming near monocultures of this species. Due to a general loss in visual interest as well as structural integrity and diversity, this grass species may be in danger of becoming a nuisance along many of Tucson's revegetated roadsides. A positive correlation was found between the percent of undesirable species such as Prickly Russian thistle or buffelgrass and the degree of slope and disturbance level. Site 9a was characterized by the highest percentage of undesirable species, due apparently to relatively high disturbance levels, fairly steep slopes (> 3:1), and the ability of many invasive species to successfully establish on such sites.

Plant Density and Cover

Plant density was strongly influenced by the presence of woody or herbaceous species within the study site due to physical differences in plant stature and the growth characteristics of each species. While the average density for the study sites was approximately 9.5 plants ft^{-2}, study sites with more herbaceous species had densities as high as 27.1 plants ft^{-2} as a result of the prolific nature of many grass and forb species (Table 5). Other study sites with higher than average densities were typically characterized by increased available moisture, such as site 4a near the Tanque Verde and Aqua Caliente washes. Generally, study sites with lower densities had more woody species, such as site 7b with the highest percentage of woody species among the study sites but with a density of only 0.7 plants ft^{-2}. Other study sites with low densities seemed to be the result of low overall levels of germination throughout the landscape, especially sites 7c and 2d. However, densities were higher than the findings of a similar study conducted in 2001 by Martinez. While the previous study was performed under a number of different elevations in the foothills and mountains surrounding the Tucson area, density estimations at comparable elevations to this study were as low as 0.4 plants

ft^{-2}. A number of factors, such as the amount of available moisture or the dynamics of the existing vegetative community, could be the source of this variation. Further study in the immediate Tucson area would likely give a clearer indication of the significance of the noted densities in this study.

The average cover values for the study sites were 36% vegetation, 40% inert material such as gravel or debris, and 24% bare ground. According to Shreve and Wiggins (1964), undisturbed areas of the Sonoran Desert generally have anywhere from 40 – 70% bare ground and inert material between plants. An additional study states that a 25% permanent ground cover is considered satisfactory for most desert landscapes (Brooks, 1993). Brook's study also provides correlations between overall vegetative cover and visual quality or structural integrity, stating that the general public considers sites with at least 32% cover visually acceptable and that sites with at least 35% cover showed little signs of erosion. Field observations in the current study showed that less than 1/4 of the study sites showed signs of soil movement (data not shown), indicating an adequately protected soil surface on most of the study sites by either vegetative or inert material.

Sites 3 and 6 had the highest overall cover values, suggesting high site stability and a visually acceptable landscape. Sites 3 and 6 also had elevated values of cover provided by native vegetation. A strong positive correlation ($r = 0.71$) was found between native cover and evidence of wildlife. Thus, sites 3 and 6 appeared to have the highest potential for increased inhabitation by wildlife when compared to the remainder of the study sites due to optimum locations and ample cover provided by native plant species. Sites 2d and 7c had the lowest overall values of vegetative cover and low values of native cover. These two study sites also did poorly in terms of plant densities, suggesting unsatisfactory establishment of the seeded vegetation or high mortality levels.

Table 5. Total plant density and overall vegetative cover and native vegetative cover for 20 revegetated roadsides in Tucson, AZ.

Site ID	Number of Plants	Transect Area	Density	Vegetative Cover	
				Overall	Native
		ft^2	plants ft^{-2}	%	
1	2,770	400	6.9	34	29
2a	7,580	280	27.1	41	20
2b	3,220	188	17.1	30	18
2c	5,010	342	14.6	35	19
2d	700	162	4.3	10	5
3	3,800	374	10.2	50	44
4a	9,710	484	20.1	45	25
4b	5,970	494	12.1	46	28
5a	2,950	268	11.0	35	29
5b	3,840	504	7.6	46	31
6	3,590	386	9.3	48	36
7a	540	564	1.0	32	24
7b	320	436	0.7	38	34
7c	60	114	0.5	20	18
7d	2,910	344	8.5	45	32
8a	2,440	308	7.9	28	26
8b	2,380	250	9.5	38	29
9a	1,730	190	9.1	32	21
9b	2,290	338	6.8	35	27
10	1,030	182	5.7	27	22
		Average	**9.5**	**36**	**26**

Species Richness

While studies have shown that a typical, undisturbed landscape in the Sonoran Desert has between three and ten different plant species (Shreve and Wiggins, 1964), study sites had an average of only 3.5 species 100 ft^{-2} and 2.5 native species 100 ft^{-2} (Table 6). These results suggest inadequate levels of species richness among the vegetation present at most of the study sites. Native species richness was found to have a relatively strong negative correlation with project age, indicating again the encroachment of exotic vegetation over time. For example, site 10 was characterized by the highest amount of species richness and represented the most recently revegetated study site. With a species richness of 4.6 native species 100 ft^{-2}, site 10 best represents the initial quality of a newly revegetated landscape in terms of species composition despite lower than average levels of vegetative cover and plant density. On the other hand, site 1 represented the oldest of the study sites and had the lowest species richness and native species richness. This suggests a general decline in the overall number of different species as a project ages regardless of origin due to the more vigorous species out-competing the remainder of the vegetation over time.

Possibly due to the establishment of vegetation from native seed sources, adjacency to an undisturbed native environment was also shown to promote a higher degree of native species richness as seen by the relatively high proportions of native species richness in study sites adjacent to natural open space (e.g., sites 5a, 5b, 8a, 8b, and 10). Some of the lowest levels of species richness and native species richness were found on study sites adjacent to highly developed areas, such as site 7b. Located near high-density residential and commercial areas, this study site had few native species and total species due perhaps to the adverse conditions associated with a more densely developed environment, such as an increased level of pollutants or reflected heat. The degree of slope was also shown to negatively affect species richness, as seen on site 9b with fairly steep slopes (> 3:1) and low levels of richness despite relatively recent establishment and the use of erosion control blankets. The results of this study suggest that sites with the highest degree of adverse conditions (i.e., slopes steeper than 3:1, project age, and location) have the most difficulty in sustaining a diverse mix of vegetation. Future revegetation projects under similar conditions may consider the inclusion of a more diverse composition of plant material to increase the chances of establishment by a variety of species and an increase in maintenance levels to ensure a richly vegetated landscape.

As previously mentioned, sites 7b, 1, and 7a were irrigated for one growing season following seeding operations. However, results suggest that the initial application of irrigation has little to no effect on long-term individual species composition (i.e., life-form, origin and desirability), plant density, and species richness (Tables 4, 5, and 6). Results support hesitations by the roadside management community to irrigate revegetated landscapes, as little evidence suggests that it aids in the long-term establishment of a rich vegetative cover (Bengsson, 1985; Bowden, 1991).

Table 6. Mean number of individual species (richness) within the total transect area and mean number of total individual species and native species per 100 ft^2.

Site ID	Species Richness†		Native Species Richness
	Total	100 ft^{-2}	100 ft^{-2}
1	6.8	1.7	1.5
2a	9.6	3.4	1.7
2b	9.4	5.0	3.0
2c	11.8	3.5	1.9
2d	6.4	4.0	2.1
3	10.8	2.9	2.5
4a	19.2	4.0	2.2
4b	20.2	4.1	2.5
5a	12.0	4.5	3.7
5b	14.4	2.9	2.2
6	10.8	2.8	2.1
7a	11.6	2.1	1.5
7b	8.0	1.8	1.6
7c	2.6	2.3	2.1
7d	13.6	4.0	2.8
8a	13.2	4.3	3.9
8b	12.0	4.8	3.6
9a	8.2	4.3	2.8
9b	6.6	2.0	1.5
10	10.0	5.5	4.6
Average	**10.9**	**3.5**	**2.5**

† Richness values represent the average number of individual plant species generated from data collected from each of five belt transects located within a given study site.

Vegetation Suitability Index

Results of the vegetation suitability index (VSI) were similar to those for vegetative cover and native cover due to the importance placed on these two variables in index calculations. The values calculated by the VSI enabled the collective examination of all of the vegetation characteristics present on a study site to *best* determine the site's suitability for wildlife. Most study sites were moderately to highly suitable for wildlife habitat, suggesting an adequate degree of protective cover throughout many of the sampled landscapes. Despite relatively low native species richness, sites 3 and 6 were determined to have the highest potential for wildlife habitat due to high native cover values. This suggests that while the overall number of native species was lower than average at these study sites, the cover provided by the present native vegetation was an adequate source of shelter and food. Results of the VSI were associated with visual observations of wildlife evidence (i.e., burrows, nests, droppings, etc.), suggesting the fairly successful determination of the quality of habitat present on a given study site through the calculations depicted in Figure 4.

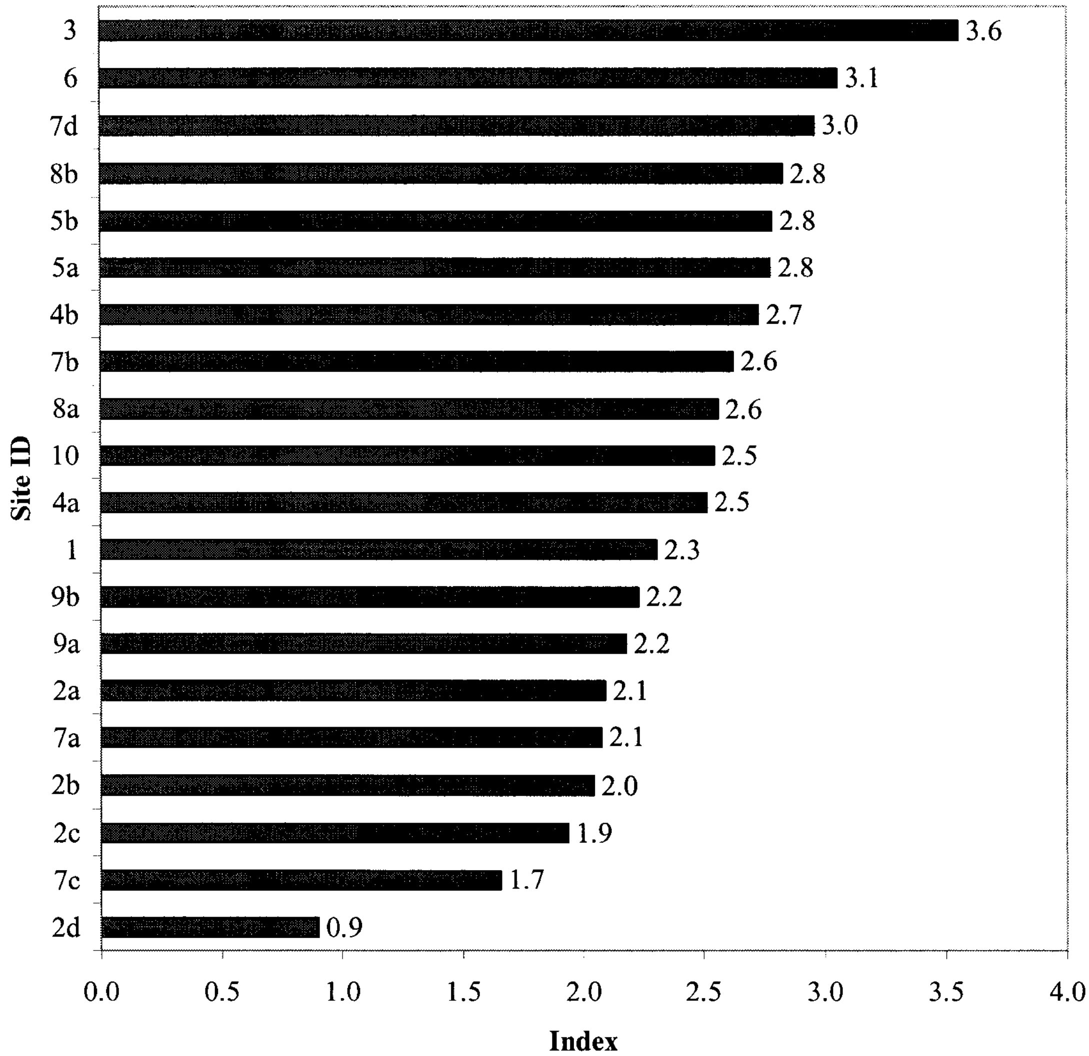


Figure 4. Vegetation suitability index [total vegetative cover + 2 (native vegetative cover) + native richness] for wildlife habitat based on data collected from revegetated roadsides in Tucson, AZ.

Seed Mix Establishment and Survival

All study sites had a higher proportion of species not specified within the original seed mix than specified species in terms of both plant density and species richness (Table 7). Comparable results were reported in a number of different studies that have suggested that planted species often spread beyond the areas that were originally seeded and mix in various proportions with resident plants (Clary, 1983; Glenn et al., 2001). A similar study conducted in 2001 (Martinez, 2001) also reported higher densities of non-specified plants than specified plants due to the establishment of invasive grasses such as buffelgrass, fountain grass, and Lehmann's lovegrass. According to the previous study, these species have proven to be especially detrimental to the quality of a revegetated landscape due to their ability to out-compete seeded and native species and their propensity towards high wildfire fuel production (Roundy, 1995; Martinez, 2001).

A number of study sites, such as sites 4a and 4b, had high densities of exotic species such as medic, schismus, Bigelow's grass, and red brome (*Bromus rubens*). With relatively high non-specified to specified plant density and species richness ratios, sites 4a and 4b were located in an environment with greater access to available moisture. Additional study sites with relatively similar moisture characteristics (e.g., sites 2c and 7d, with much of their area located either in the shadow of a sound wall or in small detention areas) were characterized by high non-specified to specified plant density and species richness ratios. These findings suggest that the presence of non-specified species can be expected to increase with any increases in available moisture due to the adventitious nature of many exotic species and of invasive native species. Likewise, a similar study suggests that the same trend would prevail under conditions of increased site fertility and mulching (Clary, 1983). Thus, preventative measures such as spot spraying or hand eradication should be taken on sites characterized by higher degrees of available moisture or fertility to maximize the survival of the intended species while discouraging the introduction of invasive species. However, study sites that were initially irrigated had lower than average non-specified to specified density and species richness ratios, suggesting that irrigation during the initial establishment period has little long-term effect on the presence of invasive or exotic species. While this may also indicate that the establishment of specified vegetation was greater on these study sites than on the non-irrigated sites, the data more likely are a reflection of current moisture levels.

The lowest non-specified to specified density and species richness ratios within the study were present on many of the drier study sites or on the study sites with low overall density of sown species, such as sites 1, 7b, and 10. Site 7b had the lowest density and species richness ratios and was primarily located on exposed, rocky slopes that may have limited the arrival of additional species. Site 10 showed the highest correlation between the specified plant material and the vegetation present onsite due to its relatively recent establishment. A previous study (Martinez, 2001) has suggested similar results in that the youngest of the sampled projects revealed the highest evidence of specified species (refer to Appendix D for a complete listing of the species noted on site 10 and on the remainder of the study sites).

Site 7c had the highest non-specified to specified species richness ratio due apparently to high levels of exposure to wind and heat. This suggests a complete failure of the specified seed mix with only a few species hardy enough to withstand the severity of the site's conditions. These plants represent excellent species for use on harsh sites and include brittlebush, triangle-leaf bursage and globemallow (Table 8). Burroweed (*Haplopappus tenuisectus*) and six-weeks three-awn were also present on the study site but are not recommended for use despite their high success rates and seed availability due to their ability to out-compete other native species for soil moisture and nutrients (ASLA, 2004).

Table 7. Summary of non-specified and specified plant density and mean species richness with associated ratios.

Site ID	Plant Density		Density Ratio	Species Richness		Species Richness Ratio
	NSPD†	SPD‡	NSPD/SPD	NSSR§	SSR¶	NSSR/SSR
	—— plants ft^{-2}——		plants ft^{-2}	——— total ———		total
1	5.1	1.8	2.8	4.6	2.2	2.1
2a	25.4	1.1	22.5	9	0.6	15.0
2b	16.6	0.6	29.4	7.4	2.0	3.7
2c	14.5	0.1	111.5	10.8	1.0	10.8
2d	3.9	0.4	9.6	5	1.4	3.6
3	8.6	1.6	5.4	5.8	2.4	2.4
4a	19.7	0.3	60.9	17.6	1.6	11.0
4b	11.9	0.2	70.1	18.2	2.0	9.1
5a	10.6	0.4	26.5	8.4	3.6	2.3
5b	7.3	0.3	23.7	9.6	4.8	2.0
6	7.1	2.2	3.3	7.2	3.6	2.0
7a	0.8	0.2	5.0	9.4	2.2	4.3
7b	0.4	0.4	1.1	4.4	3.6	1.2
7c	0.5	0.0	54.0	2.6	0.0	260.0
7d	8.4	0.0	290.4	12.6	1.0	12.6
8a	7.7	0.2	32.4	10.6	2.6	4.1
8b	8.9	0.6	14.3	10.8	1.2	9.0
9a	8.7	0.4	24.4	5.8	2.4	2.4
9b	6.5	0.2	29.1	5.2	1.4	3.7
10	3.5	2.2	1.6	5.8	4.2	1.4
	Average		**40.9**	**Average**		**18.1**

† NSPD, non-specified plant density (plants not listed in the seed mix or construction documents).
‡ SPD, specified plant density (plants listed in the seed mix or construction documents).
§ NSSR, non-specified species richness.
¶ SSR, specified species richness.

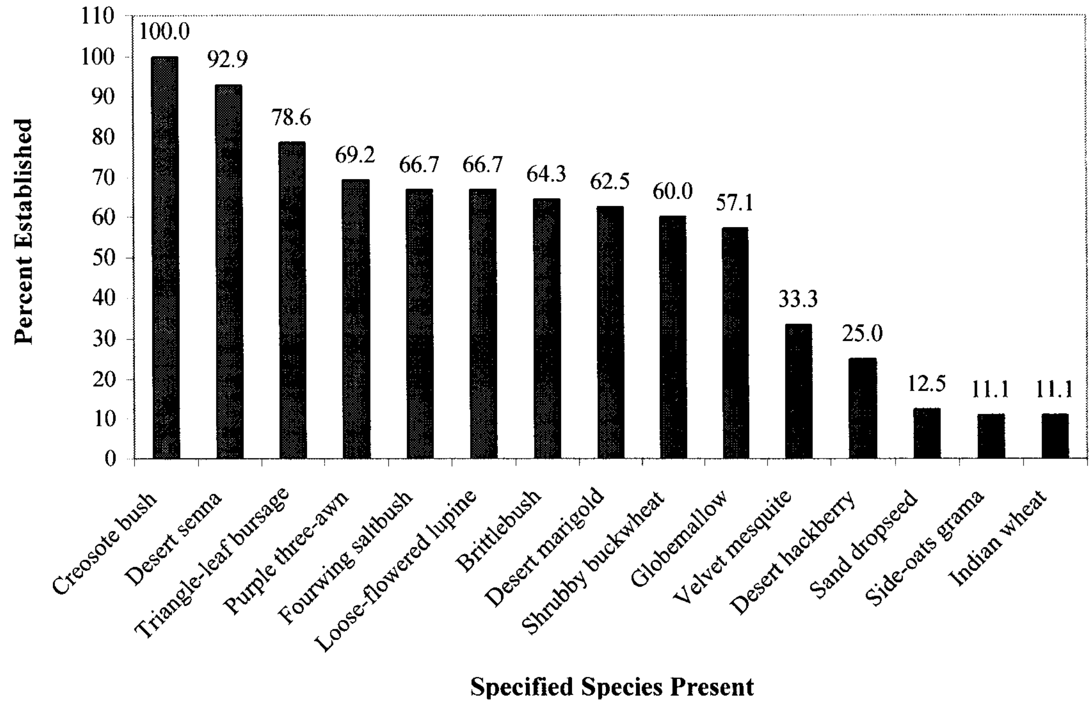
Table 8. Plant density and cover for species not specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista (IR-3 seed mix†, site 7c).

Scientific Name	Common Name	Origin‡	Density	Cover§
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	30.7	6.0
Encelia farinosa	Brittlebush	N	11.4	26.0
Descurainia pinnata	Tansymustard	N	3.5	0.5
Bromus spp.	Brome	I	2.6	0.5
Cryptantha spp.	Cryptantha	N	2.6	0.5
Haplopappus tenuisectus	Burroweed	N	1.8	0.5
Ambrosia deltoidea	Triangle-leaf bursage	N	0.9	0.5
Sphaeralcea ambigua	Globemallow	N	0.9	0.5
Cercidium spp.	Palo verde	N	0.0¶	---
		Non-specified Total	**54.4**	**35.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ N, native; I, introduced.
§ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
¶ Species present onsite but not within transects.

Additional analysis indicated apparent trends in establishment rates and productivity associated with each species. Though specified in only three of the 18 different seed mixes, creosote bush had a 100% establishment rate and frequently appeared on study sites even when not specified (Figure 5, Appendix D). Creosote bush should be considered for greater use in future revegetation projects due to its high establishment rate, value as a native shrub, and value as wildlife habitat. Additional woody species indicated strong establishment rates, including desert senna and triangle-leaf bursage. Brittlebush had a lower establishment rate despite the dominance that the species displayed on many of the study sites. Producing the highest cover value of the specified species, the data suggest that brittlebush has a tendency to dominate a landscape given its successful establishment (Figure 5). As comparisons among the seeding rates in this study offer no further explanation to the establishment of this species, further study into the factors that contribute to the successful establishment of brittlebush would be beneficial to better understand the growth of this native species (refer to Appendix A for seed mix information). Additional plant species that provided a high degree of cover were globemallow, shrubby buckwheat (*Eriogonum fasciculatum*), and fourwing saltbush (*Atriplex canescens*). While globemallow was specified in well over half of the revegetated landscapes sampled in this study, fourwing saltbush and shrubby buckwheat were specified in less than 1/3 of the study sites. Native to the Southwest, both species are relatively attractive and beneficial in providing wildlife habitat and overall cover. The use of these species in future revegetated landscapes is recommended to increase the level of structural and vegetative diversity along area roadways.

Species such as Indian wheat (*Plantago insularis*), side-oats grama (*Bouteloua curtipendula*), and sand dropseed (*Sporobolus cryptandrus*) were frequently specified but rarely established or provided any significant amounts of cover. Other species such as Mexican poppy (*Eschscholtzia mexicana*), California poppy (*Eschscholtzia californica*), desert bluebells (*Phacelia campanularia*), and blue flax (*Linum lewisii*) were frequently specified but appeared in none of the study sites despite appearances of other cool-weather annuals. Thus, the specification of these species should be reconsidered in future revegetation projects due to their limited long-term success. However, encouraging trends were noted for several native species that were present on many of the study sites but were not specified in the original seed mixes. Native grasses such as needle grama, six-weeks grama (*Bouteloua barbata*), and slender grama (*Bouteloua repens*) appeared regularly in the sampled landscapes despite their absence from the seed mixes. Other non-specified species that occurred on a number of study sites should be explored for use in the Tucson area due to their hardiness and relative attractiveness, including fluff grass (*Erioneuron puchellem*), desert zinnia (*Zinnia acerosa*), golden fleece (*Dyssodia pentachaeta*), and sweetbush (*Bebbia juncea*). While seed of many of these species is currently not readily available for use in revegetation projects, further inquiry into their establishment is encouraged to promote a more diverse and successful composition of native species along area roadsides.



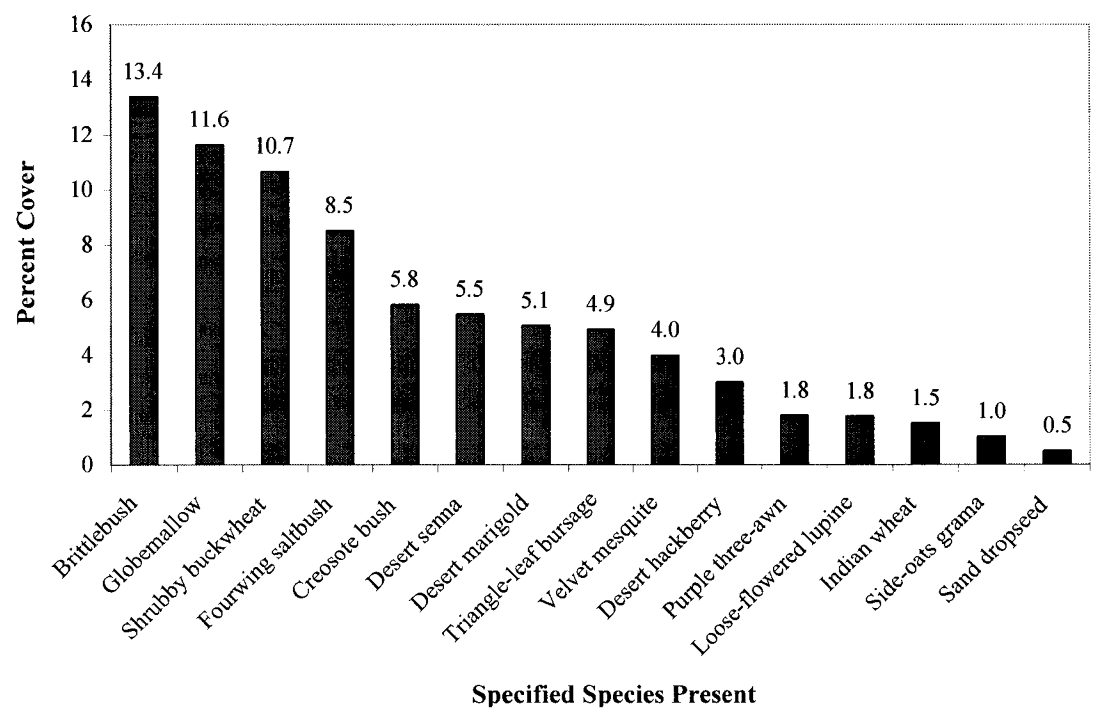


Figure 5. Percent established and percent cover values of specified species located within the study sites.

Site Characteristics and Adjacent Land Use

Study sites classified as "high-density residential and light commercial" were characterized by their adjacency to roadways with heavy traffic use and their proximity to mixed-use parcels, including both residential neighborhoods and small commercial facilities (Table 9). Generally located in the more central and populated portions of Tucson, these study sites typically involved a greater number of seed mixes compared to revegetated landscapes in other locations. This may reflect the wide range of conditions that may be found within these types of disturbance regimes and the desire for visual diversity and public appeal for projects in highly visible areas. The lowest levels of wildlife evidence were found on study sites adjacent to high-density residential and light commercial areas. While all study sites showed more evidence of wildlife than initially anticipated, study sites in this land use category exhibited the least signs of inhabitance due to their proximity to development and to low levels of suitable habitat in the surrounding areas. Similarly, study sites in this land use category had the lowest levels of species that appeared to have established from other sources, most likely due to a lack of sufficient native seed in the surrounding area. Despite increased levels of disturbance to the adjacent areas, study sites under this land use category were generally characterized by low to moderate disturbance, possibly due to the low opportunity for use by unauthorized traffic or to the increased upkeep and maintenance of the landscape due to the public nature of these study sites. While erosion was generally not as severe as expected for the entire study, the most apparent signs of erosion were found in this land use category due to a lack of sufficient space within the right-of-way for a gentler slope on sites 9a and 9b.

Projects adjacent to residential areas with relatively large lot sizes (> 0.5 ac) were characterized as "low density residential." Study sites in this category included moderately traveled roadways with occasional heavy use and were located at the juncture of the native desert landscape and the developing city. Adjacent lots were frequently vegetated with remnant patches of mostly native vegetation, and study sites within this category had additional opportunities for interactions with minor washes and remaining fragments of native habitat. Study sites adjacent to minor washes or detention basins displayed the highest levels of wildlife evidence, suggesting a general abundance of wildlife in the fragments of undisturbed vegetation. However, this may also suggest that wildlife species are being pushed by surrounding development into these corridors as the species move from one remnant fragment to another or as a replacement habitat. The presence of species that appeared to have established from other sources was moderate to high, indicating the movement of propagules into the project area from adjacent vegetation. Surprisingly, study sites in this category were characterized by the highest levels of disturbance. Vehicular traffic and accumulations of woody debris and waste material were frequently noted along revegetated roadsides adjacent to low-density residential areas, possibly due to less maintenance, easier access for unauthorized traffic, and relatively high population. Despite a sense of surrounding open space, these areas are becoming increasingly developed and are perhaps in the most precarious position regarding interactions between the growing urban environment and the existing natural plant and animal communities.

Table 9. Summary of study site characteristics, including adjacent land use†.

Site ID	Adjacent Land Use‡	Level of Disturbance	Presence of Slope	Presence of Wildlife	Presence of Species from Other Sources
1	LDR	High	Moderate	Very High	Very High
2a	RLC	Moderate	High	Moderate	Moderate
2b	RLC	Moderate	Very Low	Low	Low
2c	RLC	Low	High	High	Very High
2d	RLC	Moderate	Very Low	Very Low	Very Low
3	LDR	Moderate	Moderate	Very High	Very High
4a	WFP	High	Very High	High	Very High
4b	WFP	Low	Moderate	Very High	High
5a	NOS	Low	Low	Very High	Very High
5b	NOS	Low	High	High	High
6	LDR	Moderate	Very Low	High	Very Low
7a	RLC	Moderate	High	Very High	Very High
7b	RLC	Low	Very High	Very High	Very High
7c	RLC	Very low	Very Low	Moderate	High
7d	RLC	Moderate	High	High	Very High
8a	NOS	High	Very Low	High	Very High
8b	NOS	Very high	Very Low	High	Very High
9a	RLC	Moderate	High	Low	Low
9b	RLC	Very high	Very High	Low	Very Low
10	NOS	Very low	Low	Moderate	High

† Refer to the section entitled "Data Analysis" in Chapter 3 for information regarding the classification of adjacent land use and a description of the study site characteristics.

‡ LDR, low density residential; NOS, natural open space; RLC, high-density residential and light commercial; WFP, wash and flood plain.

Study sites classified as "natural open space" were adjacent to large parcels of undeveloped land on the outskirts of the city and had moderate to lightly traveled roadways. Study sites were within areas of relatively undisturbed native vegetation and may have been generally drier than areas within the other land use categories as evidenced by an increased presence of native succulents. Though there were numerous signs of wildlife, evidence levels were not as high as expected despite the abundance of undisturbed land surrounding the study sites. These observations suggest that an abundance of undisturbed land may deter many species from occupying right-of-ways, as more suitable habitats exist elsewhere in close proximity. Study sites adjacent to natural open space had the highest level of species that appeared to have established from other sources, due most likely to the ample supply of native seed surrounding the study sites. Moderate to low levels of disturbance were noted in these areas, mainly as a result of unauthorized vehicular traffic. For example, site 8a had particular trouble with vehicles utilizing the revegetated portion of the old roadway, severely disrupting what could possibly have been a fairly successful revegetation effort. Preventing unauthorized traffic should be an integral component of promoting a successful revegetation project in an attempt to minimize further disturbance to an already disrupted landscape.

The final land use category was designated as "wash and floodplain" and had generally moderate to light traffic on the existing roadway. Study sites in this category had presumably greater access to water due to their location and were characterized by the relative abundance of natural vegetation in the surrounding areas. Observations from these study sites revealed relatively high wildlife evidence. According to a study conducted by Livingston and others (2003), wash and riparian areas were determined to be the most valuable environments for wildlife in eastern Pima County. While wildlife evidence was slightly lower in the wash and floodplain areas than on study sites adjacent to low-density residential areas, this may have been due to the fact that only two sites within the same floodplain were evaluated or to missed opportunities for viewing transient wildlife. Regardless, dedicated planning and environmental prioritization for both native plant and animal species should be essential to roadway construction projects in these sensitive areas. Study sites adjacent to washes also had high levels of species that appeared to have established from other sources, likely due to the transport of seed by flood events or from adjacent open space. Past flood events seemed to serve as the main source of disturbance within these study sites, though only moderate levels of debris and other materials were observed.

A positive correlation was found between the presence of wildlife evidence and the overall quality of the adjacent type of land use. Thus, construction projects situated adjacent to more valuable fragments of native habitat should take extra precautions to ensure the quality and suitability of the revegetated landscape for indigenous plant and animal species. The presence of species that appeared to have established from other sources was also found to have a positive correlation with the quality of the adjacent landscape and a strong positive correlation ($r = 0.78$) with the presence of wildlife evidence. Observations of the study sites further suggest a negative correlation between levels of disturbance and the ability of seed to naturally establish from additional sources. Thus, affirmative efforts should be taken during the revegetation process to further encourage the natural establishment of native species such as velvet mesquite or foothills palo verde (*Cercidium microphyllum*) from adjacent seed sources by preserving as much native vegetation as possible along the project boundaries.

Chapter 5

CONCLUSIONS AND FUTURE RESEARCH

Project Summary

The successful revegetation of disturbed lands in arid climates is vital to the complex integration of urban development and the surrounding natural environment. Revegetated roadsides are particularly important in achieving this balance as they have the potential to serve as crucial linkages for indigenous plant and animal species between remnant patches of native habitat within the urban matrix. In addition, roadsides revegetated with a diverse array of native plant materials serve as public representations of regional pride, environmental awareness, and cultural identity. However, the restoration and revegetation of these disturbed landscapes is a difficult process contingent on the careful integration of knowledgeable seeding practices, availability of hardy plant materials, and timely maintenance and monitoring schedules. Therefore, the purpose of this research was to further our knowledge of roadside revegetation in arid environments by evaluating the success of numerous revegetated roadsides in the Tucson area. The primary objectives of this study were to (1) evaluate a sample of revegetated roadsides by assessing site condition and comparing existing vegetation to the species specified in the original planting plan; and (2) develop recommendations for appropriate revegetation practices, including recommendations for appropriate native plant species for use in roadside revegetation in Tucson.

Vegetation data revealed that most of Tucson's revegetated roadsides are characterized by a higher percentage of native species than introduced species.

Brittlebush (*Encelia farinosa*) was the most frequently noted shrub throughout the study and was found on nearly half of the study sites. Other common native species included desert senna (*Cassia covesii*), triangle-leaf bursage (*Ambrosia deltoidea*), six-weeks three-awn (*Aristida adscensionis*), and globemallow (*Sphaeralcea ambigua*). Desert broom (*Baccharis sarothroides*) was also present on many of the study sites and represents the need for greater control of this invasive native species. Other invasive species that were frequently noted included exotic species such as red-stemmed filaree (*Erodium cicutarium*), schismus (*Schismus* spp.), and Prickly Russian thistle (*Salsola tragus*). More exotic species were noted on study sites immediately adjacent to linear corridors such as the roadway pavement, drainage channels, or area washes. Because these corridors serve as conduits for the transfer of seed material from a number of different sources, these areas should be carefully monitored and maintained to prevent the establishment of undesirable species. Steep slopes (> 3:1) and increased levels of disturbance characterized a number of the study sites with relatively high proportions of undesirable native or exotic species. An effort must be made during the initial stages of a revegetation project to ensure that disturbance is minimized to discourage the encroachment of invasive species and promote the growth of desirable species.

Herbaceous plants such as six-weeks three-awn, purple three-awn (*Aristida purpurea*), and red-stemmed filaree dominated the majority of study sites. Six-weeks three-awn was the most frequently noted of these species and dominated many of the study sites that it occupied. Due to its ability to out-compete other native species, this native grass has the potential of becoming a detriment to the visual quality, structural integrity, and diversity of many of Tucson's roadsides. Studies have shown that little invasion occurs on sites where 50% or more of the soil is covered by perennial grass species; thus, higher quantities of other native grass seed such as slender grama (*Bouteloua repens*) or fluff grass (*Erioneuron puchellem*) should be considered for use on project sites to deter invasion by six-weeks three-awn (Clary, 1983).

Project age was found to have a negative correlation with the richness of woody plant species, suggesting the slow invasion of herbaceous species over time and the mortality of woody species. This indicates that the natural re-establishment of seeded woody material is not occurring as the project matures, possibly due to poor maintenance. Conversations with local landscape architects have revealed several instances of woody species such as brittlebush being mowed or cleared as soon as the plant finishes blooming in an attempt to "tidy up the landscape" (Personal conversations with Lori Woods, local practitioner, and Paul Wichmann, Pima County Landscape Architect). These maintenance practices are promoting the eventual failure of these species by removing the seed source for future generations. Thus, better communication between those involved in the design and maintenance of roadside landscapes is essential for the long-term success of revegetation projects in this region.

Average plant density for the study sites was 9.5 plants ft^{-2} and was largely linked to the presence of herbaceous or woody species due to the growth habits of each. Average cover values calculated for each study site revealed that most maintained an adequate level of cover compared to that of an undisturbed native landscape (as described by Shreve and Wiggins, 1964). Correlations were made concerning species richness and project age and suggest that older sites have lower levels of species richness than newer sites due to the more vigorous species eventually out-competing the remainder of the plants. However, with a mean species richness of 3.5 species 100 ft^{-2} and only 2.5 native species 100 ft^{-2}, all study sites showed low signs of species richness regardless of age. Thus, future revegetation efforts are encouraged to promote higher levels of species richness by including a more diverse range of native plant material to compensate for future disturbances to the project site. Results also suggested that the initial application of irrigation had little to no effect on long-term individual species composition (i.e., life-form, origin and desirability), plant density, and species richness. Further research is needed to evaluate the merit of irrigating revegetated roadsides following seeding operations in the Southwest by determining whether irrigation has any long-term effects on site vegetation.

Individual plant density data indicated that all of the study sites had greater proportions of plant material not specified in the original construction documents than specified plant material. This suggests a loss of project identity due to the increased competition afforded by the establishment of resident annuals and perennials over time. Moisture levels were found to have a strong influence on the rate of invasion and suggest that preventative measures (i.e., spot spraying, hand eradication, etc.) should be taken on sites characterized by higher degrees of available moisture to maintain the desired species composition. However, study sites that were initially irrigated had lower than average non-specified to specified density and species richness ratios, suggesting that irrigation during the initial establishment period has little long-term effect on the presence of invasive or exotic species. Of the specified species, creosote bush (*Larrea tridentata*), desert senna, and triangle-leaf bursage had the highest rates of establishment while brittlebush, globemallow, shrubby buckwheat (*Eriogonum fasciculatum*), and fourwing saltbush (*Atriplex canescens*) provided the most vegetative cover. While globemallow and brittlebush are rather common in the Tucson area due to their dependability and vigor, shrubby buckwheat and fourwing saltbush should be considered for additional use to provide structural and vegetative diversity to revegetated landscapes. Other species that were not specified within the study sites but were present should also be considered for use in future revegetation projects, such as needle-grama (*Bouteloua aristidoides*), six-weeks grama (*Bouteloua barbata*), slender grama, fluff grass, desert zinnia (*Zinnia acerosa*), golden fleece (*Dyssodia pentachaeta*), and sweetbush (*Bebbia juncea*). Species that rarely or never appeared in the study sites despite frequent specification included Indian wheat (*Plantago insularis*), side-oats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), desert blue bells (*Phacelia campanulata*), Mexican poppy (*Eschscholtzia mexicana*), California poppy (*Eschscholtzia californica*), and blue flax (*Linum lewisii*). Further use of these species should be reconsidered due to their limited long-term success.

Additional Recommendations

Numerous studies (e.g., Oetting and Cassel, 1971; Smith, 1977; Harrington, 1994; Anderson, 1996) have suggested the successful co-existence between valuable wildlife habitat and the primary functions of the roadway corridor, including motorist safety, erosion control, and aesthetics. For example, Iowa's Integrated Roadside Vegetation Management (IRVM) program has been shown to integrate native vegetation, management techniques, and wildlife habitat by (1) preserving the safe and functional aspect of the roadway; (2) promoting desirable, diverse, and persistent vegetative cover while enhancing or re-establishing the native plant communities; (3) reducing the amount of chemicals used to control undesirable plants; and (4) enhancing the aesthetic qualities of the roadside and their value as wildlife habitat (Harrington, 1994). This study encourages similar directions along many of Tucson's roadways to preserve the rich diversity and scenic beauty of the region's indigenous plants and animals.

Results presented in this study suggest a number of trends in terms of wildlife potential among revegetated sites adjacent to similar types of land use. Wildlife considerations should be factored into the location of the site to determine suitable locations for habitat encouragement while maintaining the safety and integrity of the roadway. Study sites adjacent to low-density residential areas were observed to have the highest potential for wildlife habitat. Future revegetation projects in areas with mixed percentages of open space and residences are encouraged to make a greater effort in combining the needs of the community with the needs of wildlife in adjacent areas. Study sites adjacent to natural open spaces and area washes are also encouraged to promote quality wildlife habitat due to their proximity to critical natural environments. A diverse mixture of small native trees, shrubs, and forbs [e.g., creosote bush, shrubby buckwheat, fourwing saltbush, velvet mesquite (*Prosopis velutina*)] along roadsides in these areas is encouraged to provide beneficial habitat opportunities for wildlife through improved vegetative cover and species diversity. Native seed sources in adjacent areas should also be utilized by limiting the amount of disturbance to the surrounding landscape. A number of species were found to have potentially established from adjacent, undisturbed vegetation, including velvet mesquite, palo verdes (*Cercidium microphyllum, C. floridum*), creosote bush, white-thorn acacia (*Acacia constricta*), desert willow (*Chilopsis linearis*), desert hackberry (*Celtis reticulata*), and graythorn (*Ziziphus obtusifolia*). However, approximately 10% of the roadside immediately adjacent to the pavement should be vegetated with short grasses to ensure visibility and motorist safety (Anderson, 1996). Figure 6 provides an example of the manner in which this vegetation should be seeded in order to allow for safety and aesthetic enhancement.

Sites adjacent to areas with higher levels of development are suggested to include a diverse selection of understory vegetation to accommodate the harsh conditions often associated with these sites, such as reflected heat and increased levels of pollutants. While these sites are not as well suited for wildlife habitation as those in other locations, they still serve as important linkages between valuable habitats. Additional education regarding the importance of landscape linkages and habitat fragmentation due to urbanization would be beneficial in gaining public acceptance of the concept of roadsides as sources of habitat. Further education may also serve to potentially eliminate much of the excess waste material and unauthorized traffic that continues to disrupt these developing landscapes.

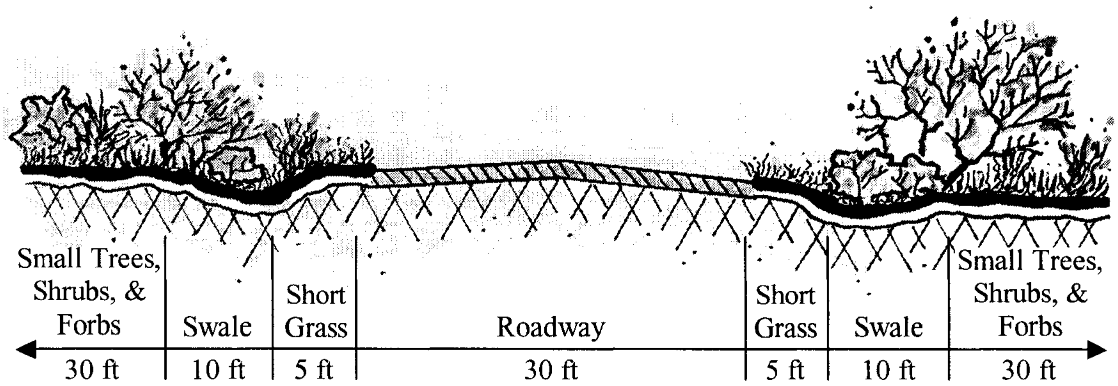


Figure 6. Ideal roadway section for wildlife habitat, including a drainage swale for storm water management and infiltration (adapted from Anderson, 1996).

Suggestions for Future Research

Continued documentation of the conditions at the revegetated sites sampled in this study and at additional locations is recommended to better understand the complexities of roadside revegetation in urban, arid environments. Additional research regarding the trends noted for many of the study sites would be useful in determining the presence and variability of such generalizations. Specific studies pertaining to individual species establishment and survival would also give a better indication of the most successful plant materials for use in local revegetation efforts. Similar studies observing the habits of specific wildlife species are also needed to provide quantitative information regarding the types and frequencies of indigenous wildlife found to occupy the landscapes adjacent to roadways.

Appendix A

SEED MIXES

Sources:

Pima County Department of Transportation. 1986. Tanque Verde Road: Pantano Road to Catalina Highway Landscaping Plans[1]. W.O. 4BTAN3. Contract No. 07-04-M-102426-0381, Pima County, AZ.

Pima County Department of Transportation. 1988. Hacienda del Sol Landscaping Plans[1]. W.O. 4BHDSR, Pima County, AZ.

Pima County Department of Transportation. 1989. River Road: Camino Arco to Craycroft Road, Deadman's Curve Improvement Project Plans[1]. W.O. 4BRBLS. C.I.P. No. TR-87-56, Pima County, AZ.

Pima County Department of Transportation. 1991a. Houghton Road: Tanque Verde Road to Speedway Boulevard Landscaping and Irrigation Improvement Plans and Special Provisions. W.O. 4BHTVC. C.I.P. No. FC-87-18, Pima County, AZ.

Pima County Department of Transportation. 1991b. Irvington Road: Camino de Oeste to Mission Road Planting Plans and Special Provisions. W.O. 4BISCO, Pima County, AZ.

Pima County Department of Transportation. 1993a. Ina Road: Oracle Road to Chula Vista Landscape and Irrigation Plans and Special Provisions. W.O. 4BINOS, Pima County, AZ.

Pima County Department of Transportation. 1993b. Sabino Canyon Road: Cloud Road to Kolb Road Planting Plans and Special Provisions. W.O. 4T8909, Pima County, AZ.

Pima County Department of Transportation. 1998a. First Avenue: River Road to Orange Grove Road Landscape Plans and Special Provisions. W.O. 4BFROG. C.I.P. No. TR89-008, Pima County, AZ.

Pima County Department of Transportation. 1998b. Pistol Hill Road: Colossal Cave Road to Old Spanish Trail Improvement Plans and Special Provisions. W.O. 4TPIST, Pima County, AZ.

Pima County Department of Transportation. 2000. Golf Links Road: Bonanza Avenue to Houghton Road Landscaping Plans and Special Provisions. W.O. 4GLBAH, Pima County, AZ.

[1] Special provisions for these projects were not available; however, personal conversations with Pima County Landscape Architect Paul Wichmann enabled the generation of broad seeding information based on Pima County Department of Transportation records.

Table A.1: TVR-1 Seed Mix
Tanque Verde Rd.: Pantano Rd. to Catalina Hwy. (El. 2510)

Plant Species	Common Name	PLS Rate†
		lbs ac^{-1}
Grasses		
Aristida purpurea	Purple three-awn	3.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	3.0
Cucurbita palmata	Coyote melon	1.0
Eschscholtzia californica	California poppy	4.0
Lupinus sparsiflorus	Loose-flowered lupine	4.0
Oenothera hookeri	Evening primrose	1.0
Penstemon pseudospectablis	Penstemon	2.0
Plantago insularis	Indian wheat	4.0
Proboscidea althearolia	Devil's claw	1.0
Psilostrophe cooperi	Paper flower	1.0
Sphaeralcea ambigua	Globemallow	1.0
Verbena tenuisecta	Verbena	2.0
Trees and Shrubs		
Calliandra eriophylla	Fairy duster	2.0
Cassia covesii	Desert senna	2.0
Eriogonum fasiculatum	Shrubby buckwheat	1.5

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.2: TVR-2 Seed Mix
Tanque Verde Rd.: Pantano Rd. to Catalina Hwy. (El. 2510)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula	Side-oats grama	2.0
Bouteloua eriopoda	Black grama grass	2.0
Schismus barbatus	Mediterraneangrass	2.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	3.0
Cucurbita palmata	Coyote melon	1.0
Eschscholtzia californica	California poppy	4.0
Lupinus sparsiflorus	Loose-flowered lupine	4.0
Oenothera hookeri	Evening primrose	1.0
Plantago insularis	Indian wheat	4.0
Proboscidea althearolia	Devil's claw	1.0
Psilostrophe cooperi	Paper flower	1.0
Sphaeralcea ambigua	Globemallow	1.0
Verbena tenuisecta	Verbena	2.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	2.0
Calliandra eriophylla	Fairy duster	2.0
Cassia covesii	Desert senna	2.0
Encelia farinosa	Brittlebush	2.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.3: HDS Seed Mix
Hacienda del Sol Rd. (El. 2535)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	3.0
Schismus barbatus	Mediterraneangrass	0.5
Setaria macrostachys	Plains bristlegrass	2.0
Sporobolus cryptandrus	Sand dropseed	0.5
Forbs and Vines		
Baileya multiradiata	Desert marigold	2.0
Dyssodia acerosa	Prickleleaf dogweed	0.25
Eschscholtzia californica	California poppy	3.0
Lupinus arizonicus	Desert lupine	1.0
Plantago insularis	Indian wheat	5.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	2.0
Encelia farinosa	Brittlebush	2.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.4: RR Seed Mix
River Rd.: Camino Arco to Craycroft Rd. (El. 2519)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Eragrostis intermedia	Plains lovegrass	2.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	1.5
Eschscholtzia californica	California poppy	2.0
Eschscholtzia mexicana	Mexican poppy	2.0
Kallstroemia grandiflora	Arizona poppy	1.5
Phacelia campanularia	Desert bluebells	2.0
Sphaeralcea ambigua	Globemallow	2.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	2.0
Atriplex semibacata	Australian saltbush	1.5
Cassia covesii	Desert senna	2.0
Encelia farinosa	Brittlebush	2.0
Eriogonum fasiculatum	Shrubby buckwheat	1.5

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.5: HR-1 Seed Mix

Houghton Rd.: Tanque Verde Rd. to Speedway Blvd. (El. 2588)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Bouteloua gracilis 'Hachita'	Blue grama	2.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	2.0
Gaillardia aristata	Indian blanket	1.5
Gaillardia pulchella	Indian flower	1.5
Plantago insularis	Indian wheat	2.0
Trees and Shrubs		
Acacia constricta	White-thorn acacia	1.0
Ambrosia deltoidea	Triangle-leaf bursage	2.0
Atriplex canescens	Fourwing saltbush	2.0
Calliandra eriophylla	Fairy duster	1.5
Cassia covesii	Desert senna	1.0
Celtis pallida	Desert hackberry	2.0
Encelia farinosa	Brittlebush	1.5

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.6: HR-2 Seed Mix†
Houghton Rd.: Tanque Verde Rd. to Speedway Blvd. (El. 2588)

Plant Species	Common Name	PLS Rate‡
		lbs ac $^{-1}$
Forbs and Vines		
Abronia villosa	Sand verbena	2.5
Erigeron divergens	Fleabane	2.0
Eschscholtzia mexicana	Mexican poppy	2.0
Lupinus arizonicus	Desert lupine	2.0
Verbena tenuisecta	Verbena	2.0

† HR-2 to be applied over HR-1 in designated areas.
‡ Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.7: IRR-1 Seed Mix
Irvington Rd.: Camino de Oeste to Mission Rd. (El. 2430)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Setaria macrostachya	Plains bristlegrass	2.0
Sporobolus cryptandrus	Sand dropseed	1.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	1.5
Eschscholtzia mexicana	Mexican poppy	3.0
Linum lewisii	Blue flax	2.0
Psilostrophe cooperi	Paper flower	2.0
Sphaeralcea ambigua	Globemallow	2.0
Trees and Shrubs		
Acacia constricta	White-thorn acacia	1.0
Acacia greggii	Catclaw acacia	1.5
Ambrosia deltoidea	Triangle-leaf bursage	2.5
Atriplex canescens	Fourwing saltbush	3.0
Atriplex lentiformis	Big saltbush	2.0
Atriplex polycarpa	Alkali saltbush	2.0
Cassia covesii	Desert senna	2.0
Celtis pallida	Desert hackberry	2.0
Cercidium floridum	Blue palo verde	1.5
Encelia farinosa	Brittlebush	3.0
Larrea tridentata	Creosote bush	3.0
Prosopis velutina	Velvet mesquite	1.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.8: IRR-2 Seed Mix
Irvington Rd.: Camino de Oeste to Mission Rd. (El. 2430)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	1.5
Eschscholtzia californica	California poppy	2.0
Eschscholtzia mexicana	Mexican poppy	2.0
Linum lewisii	Blue flax	1.5
Phacelia campanularia	Desert bluebells	2.0
Plantago insularis	Indian wheat	3.0
Psilostrophe cooperi	Paper flower	2.0
Sphaeralcea ambigua	Globemallow	2.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	2.5
Atriplex semibacata	Australian saltbush	1.5
Cassia covesii	Desert senna	2.0
Encelia farinosa	Brittlebush	3.0
Eriogonum fasciculatum	Shrubby buckwheat	1.5

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.9: IR-1 Seed Mix
Ina Rd.: Oracle Rd. to Chula Vista (El. 2851)

Plant Species	Common Name	PLS Rate†
		lbs ac^{-1}
Grasses		
Aristida purpurea	Purple three-awn	2.0
Bouteloua gracilis	Blue grama	1.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	2.0
Dimorphotheca sinuate	African daisy	2.0
Eschscholtzia californica	California poppy	2.0
Gaillardia pulchella	Indian flower	2.5
Oenothera speciosa	Mexican primrose	0.5
Penstemon palmeri	Pink penstemon	0.5
Phacelia camanularia	Desert bluebells	1.0
Phylostrophe cooperi	Paper flower	0.25
Sphaeralcea ambigua	Globemallow	1.5
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	1.0
Larrea tridentata	Creosote bush	1.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.10: IR-2 Seed Mix
Ina Rd.: Oracle Rd. to Chula Vista (El. 2851)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	2.0
Setaria macrostachya	Plain bristlegrass	2.0
Sporobolus cryptandrus	Sand dropseed	1.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	2.0
Dyssodia acerosa	Prickleleaf dogweed	0.25
Eschscholtzia mexicana	Mexican poppy	2.0
Lupinus succulentus	Arroyo lupine	2.0
Phacelia campanularia	Desert bluebells	1.0
Sphaeralcea ambigua	Globemallow	1.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	1.0
Atriplex canescens	Fourwing saltbush	3.0
Cassia covesii	Desert senna	2.0
Celtis pallida	Desert hackberry	2.0
Encelia farinosa	Brittlebush	1.5
Larrea tridentata	Creosote bush	1.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.11: IR-3 Seed Mix
Ina Rd.: Oracle Rd. to Chula Vista (El. 2851)

Plant Species	Common Name	PLS Rate†
		lbs ac^{-1}
Forbs and Vines		
Baileya multiradiata	Desert marigold	4.0
Eschscholtzia californica	California poppy	4.0
Lupinus succulentus	Arroyo lupine	4.0
Penstemon palmeri	Pink penstemon	3.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.12: IR-4 Seed Mix
Ina Rd.: Oracle Rd. to Chula Vista (El. 2851)

Plant Species	Common Name	PLS Rate†
		lbs ac^{-1}
Forbs and Vines		
Baileya multiradiata	Desert marigold	2.0
Eschscholtzia mexicana	Mexican poppy	3.0
Lupinus sparsiflorus	Loose-flowered lupine	3.0
Lupinus succulentus	Arroyo lupine	6.0
Penstemon parryi	Desert penstemon	0.05
Phacelia campanalaria	Desert bluebells	1.0
Sphaeralcea ambigua	Globemallow	1.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	4.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.13: SC Seed Mix
Sabino Canyon Rd.: Cloud Rd. to Kolb Rd. (El. 2522)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
<u>Grasses</u>		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Sporobolus cryptandrus	Sand dropseed	1.0
<u>Forbs and Vines</u>		
Baileya multiradiata	Desert marigold	1.5
Dyssodia pentachaeta	Golden fleece	1.0
Eschscholtzia californica	California poppy	2.0
Eschscholtzia mexicana	Mexican poppy	2.0
Linum lewisii	Blue flax	1.5
Phacelia campanularia	Desert bluebells	2.0
Psilostrophe cooperi	Paper flower	1.0
Sphaeralcea ambigua	Globemallow	2.0
<u>Trees and Shrubs</u>		
Ambrosia deltoidea	Triangle-leaf bursage	2.5
Cassia covesii	Desert senna	3.0
Encelia farinosa	Brittlebush	2.0
Eriogonum fasciculatum 'arizonica'	Arizona buckwheat	1.5

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.14: FA-1 & FA-2† Seed Mix
First Ave.: River Rd. to Orange Grove Rd. (El. 2321)

Plant Species	Common Name	PLS Rate‡
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	2.0
Sporobolus cryptandrus	Sand dropseed	1.0
Forbs and Vines		
Eschscholtzia californica	California poppy	3.0
Phacelia campanularia	Desert bluebells	1.5
Plantago insularis	Indian wheat	3.0
Sphaeralcea ambigua	Globemallow	1.0
Trees and Shrubs		
Acacia constricta	White-thorn acacia	2.0
Ambrosia deltoidea	Triangle-leaf bursage	4.0
Cassia covesii	Desert senna	2.0
Cercidium microphyllum	Foothills palo verde	2.0
Encelia farinosa	Brittlebush	2.0
Prosopis velutina	Velvet mesquite	1.5

† FA-2 seeded areas receive additional erosion control blankets.
‡ Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.15: PHR-1 Seed Mix
Pistol Hill Rd.: Colossal Cave Rd. to Old Spanish Trail (El. 3426)

Plant Species	Common Name	PLS Rate†
		lbs ac^{-1}
Grasses		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Setaria macrostachya	Plains bristlegrass	2.0
Sporobolus cryptandrus	Sand dropseed	1.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	1.5
Eschscholtzia mexicana	Mexican poppy	3.0
Helianthus annus	Sunflower	3.0
Linum lewisii	Blue flax	2.0
Sphaeralcea ambigua	Globemallow	2.0
Trees and Shrubs		
Acacia constricta	White-thorn acacia	1.0
Acacia greggii	Catclaw acacia	1.5
Atriplex canescens	Fourwing saltbush	3.0
Atriplex lentiformis	Big saltbush	2.0
Atriplex polycarpa	Alkali saltbush	2.0
Cassia covesii	Desert senna	2.0
Celtis pallida	Desert hackberry	2.0
Cercidium floridum	Blue palo verde	1.5
Encelia farinosa	Brittlebush	3.0
Prosopis velutina	Velvet mesquite	1.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.16: PHR-2 Seed Mix
Pistol Hill Rd.: Colossal Cave Rd. to Old Spanish Trail (El. 3426)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Aristida purpurea	Purple three-awn	3.0
Bouteloua curtipendula 'Vaughn'	Side-oats grama	3.0
Eragrostis intermedia	Plains lovegrass	2.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	1.5
Erigeron species	Erigeron	2.0
Eschscholtzia californica	California poppy	2.0
Eschscholtzia mexicana	Mexican poppy	2.0
Evolvulus arizonicus	Arizona blue eyes	1.0
Linum lewisii	Bue flax	1.5
Phacelia campanularia	Desert bluebells	2.0
Sphaeralcea ambigua	Globemallow	2.0
Trees and Shrubs		
Atriplex semibacata	Australian saltbush	1.5
Cassia covesii	Desert senna	2.0
Encelia farinosa	Brittlebush	2.0
Eriogonum fasiculatum	Shrubby buckwheat	1.5

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Table A.17: GLR Seed Mix
Golf Links Rd.: Bonanza Ave. to Houghton Rd. (El. 2671)

Plant Species	Common Name	PLS Rate†
		lbs ac $^{-1}$
Grasses		
Sporobolus cryptandrus	Sand dropseed	1.0
Forbs and Vines		
Baileya multiradiata	Desert marigold	3.0
Plantago insularis	Indian wheat	3.0
Sphaeralcea ambigua	Globemallow	2.0
Trees and Shrubs		
Ambrosia deltoidea	Triangle-leaf bursage	2.0
Atriplex canescens	Fourwing saltbush	2.0
Cassia covesii	Desert senna	2.0
Encelia farinosa	Brittlebush	3.0

† Quantity of pure live seed (PLS) = Pounds of seed x (purity x germination).

Appendix B

SEEDING SPECIFICATIONS

Sources:

Pima County Department of Transportation. 1986. Tanque Verde Road: Pantano Road to Catalina Highway Landscaping Plans[2]. W.O. 4BTAN3. Contract No. 07-04-M-102426-0381, Pima County, AZ.

Pima County Department of Transportation. 1988. Hacienda del Sol Landscaping Plans[2]. W.O. 4BHDSR, Pima County, AZ.

Pima County Department of Transportation. 1989. River Road: Camino Arco to Craycroft Road, Deadman's Curve Improvement Project Plans[2]. W.O. 4BRBLS. C.I.P. No. TR-87-56, Pima County, AZ.

Pima County Department of Transportation. 1991a. Houghton Road: Tanque Verde Road to Speedway Boulevard Landscaping and Irrigation Improvement Plans and Special Provisions. W.O. 4BHTVC. C.I.P. No. FC-87-18, Pima County, AZ.

Pima County Department of Transportation. 1991b. Irvington Road: Camino de Oeste to Mission Road Planting Plans and Special Provisions. W.O. 4BISCO, Pima County, AZ.

Pima County Department of Transportation. 1993a. Ina Road: Oracle Road to Chula Vista Landscape and Irrigation Plans and Special Provisions. W.O. 4BINOS, Pima County, AZ.

Pima County Department of Transportation. 1993b. Sabino Canyon Road: Cloud Road to Kolb Road Planting Plans and Special Provisions. W.O. 4T8909, Pima County, AZ.

Pima County Department of Transportation. 1998a. First Avenue: River Road to Orange Grove Road Landscape Plans and Special Provisions. W.O. 4BFROG. C.I.P. No. TR89-008, Pima County, AZ.

Pima County Department of Transportation. 1998b. Pistol Hill Road: Colossal Cave Road to Old Spanish Trail Improvement Plans and Special Provisions. W.O. 4TPIST, Pima County, AZ.

Pima County Department of Transportation. 2000. Golf Links Road: Bonanza Avenue to Houghton Road Landscaping Plans and Special Provisions. W.O. 4GLBAH, Pima County, AZ.

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[2] Special provisions for these projects were not available; however, personal conversations with Pima County Landscape Architect Paul Wichmann enabled the generation of broad seeding information based on Pima County Department of Transportation records.

Tanque Verde Rd.: Pantano Rd. to Catalina Hwy. (El. 2510)

SEED MIX I: For Right-of-Way Areas

	Common Name	Botanical Name	Pounds Per Acre
*	Desert Marigold GOLD	Baileya multiradiata	3.0
*	Globe Mallow PEACH	Sphaeralcea ambigua	1.0
*	Evening Primrose PINK	Oenothera hookeri	1.0
*	Lupine PURPLE / BLUE	Lupinus sparsiflorus	4.0
*	Verbena PURPLE	Verbena tenuousecta	2.0
*	California Poppy ORANGE	Eschoitzia californica	4.0
*	Fairy Duster PINK	Calliandra eriophylla	2.0
	Plantago GRASS	Plantago insularis	4.0
*	Paper Flower YELLOW	Psilostrophe cooperi	1.0
*	Devil s Claw ORANGE	Proboscidea altheaefolia	1.0
*	Coyote Melon GOLD	Cucurbita palmata	1.0
*	Desert Senna GOLD	Cassia covesii	2.0
*	Purple Three-Awn Grass	Aristida Purpurea	3.0
	Shrubby buckwheat PINK	Eriogonum fasiculatum	1.5
	Penstemon PINK	Penstemon pseudospectablis	2.0

NOTE: Pounds listed to be pounds of pure live seed.

SEED MIX II: **For Right-of-Way Areas from Station 285 + 00 (approximately) to Station 305 + 50 (approximately) as Noted on Plans.**

	Common Name	Botanical Name	Pounds Per Acre
*	Desert Marigold GOLD	Baileya multiradiata	3.0
*	Globe Mallow PEACH	Sphaeralcea ambigua	1.0
*	Evening Primrose PINK	Oenothera hookeri	1.0
*	Lupine PURPLE / BLUE	Lupinus sparsiflorus	4.0
*	Verbena PURPLE	Verbena tenuousecta	2.0
*	California Poppy ORANGE	Escholtzia californica	4.0
*	Fairy Duster PINK	Calliandra eriophylla	2.0
	Plantago GRASS	Plantago insularis	4.0
*	Paper Flower YELLOW	Psilostrophe cooperi	1.0
*	Devil s Claw ORANGE	Proboscidea altheaefolia	1.0
*	Coyote Melon GOLD	Cucurbita palmata	1.0
*	Desert Senna GOLD	Cassia covesii	2.0
*	Brittle Bush YELLOW	Encelia farinosa	2.0
	Bursage GRAY	Franceria deltoides	2.0
	Black Gramma Grass	Bouteloua eriopoda	2.0
	Side Oats Gramma	Bouteloua curtipendula	2.0
	Purple Three-Awn Grass	Aristida Purpurea	3.0
	Mediterranean Grass	Schismus barbatus	2.0

NOTE: Pounds listed to be pounds of pure live seed.

Hacienda del Sol Rd. (El. 2535)

1). **SPECIFICATIONS: A.D.O.T. STANDARD SPEC. & PIMA COUNTY STANDARD SPEC.**

2). Contractor responsible for hydroseeding all areas disturbed by construction. If disturbed areas exist outside of those areas designated on plans, contractor shall notify county officals of change.

3). Contractor to contact Tucson Water before installing irrigation system for verification of water lines.

4). The Contractor shall be responsible for providing a complete temporary irrigation system, drip and spray, to deliver water to all hydroseeded areas trees, and shrubs. The irrigation system shall be left in place a minimum of 9 -12 months, depending upon time of installation. Contractor shall be responsible for all power and water service applications and fees, coordination with the proper companies, and monthly bills.

5). The Contractor shall submit shop drawings of the proposed irrigation system for approval prior to ordering or installation of equipment. The shop drawings shall show the type, brand, and location of all equipment and pipe to be used.

6). Hacienda del Sol pavement shall not be cut or otherwise damaged by any of the landscaping operations. Side street and driveway pavement may be cut and patched as necessary in order to place sleeves, pipes and wires. All cuts shall be patched according to the patching detail.

7). The Contractor shall operate the irrigation system to the extent necessary for proper plant establishment. The irrigation system shall not spray onto undisturbed proerty, nor onto road and driveways, and shall not create ponding excessive runoff or erosion.

SEED LIST

Franseria deltoides triangle leaf bursage	2 lbs/acre
Plantago insularis indian wheat	5 lbs/acre
Schismus barbatus mediterranean grass	.5 lbs/acre
Aristida purpurea red three-awn	3 lbs/acre
Encelia farinosa brittle bush	2 lbs/acre
Baileya multiradiata marigold	2 lbs/acre
Dyssodia acerosa dyssodia	.25 lbs/acre
eschscholtzia californica california poppy	3 lbs/acre
Lupinus arizonicus desert lupin	1 lbs/acre
Setaria macrostachya plains bristlegrass	2 lbs/acre
Sporobolus cryptandrus sand dropseed	1/2 lbs/acre

NOTE: ALL CUT SLOPES ARE TO BE SCARIFIED TO A DEPTH OF 4" BEFORE HYDROSEEDING

HYDRO-SEED

SLURRY MIX

Seed Mix (see list below) Pure Live Seed	
Fertilizer (16-20-0)	200 lbs/acre
Gro-Power (5-3-1)	1,000 lbs/acre
Az Tac	120 lbs/acre
Mulch	1,800 lbs/acre

River Rd.: Camino Arco to Craycroft Rd. (El. 2519)

Trees

Botanical Name	Common Name	Size
Cercidium floridum	Blue Palo Verde	15 gal.
Prosopis velutina	Velvet Mesquite	15 gal.
Chilopsis linearis	Desert Willow	15 gal.
Acacia greggii	Catclaw Acacia	15 gal.

All trees are available from Parks and Recreation Nursery, 1204 West Silverlake. Call Amy [illegible] 48 hours prior to pickup.

Salvaged trees to be labeled by size, species.

Shrubs

Botanical Name	Common Name	Size
Atriplex lentiformis	Quail Bush	1 gal.
Calliandra eriophylla	Fairy Duster	1 gal.
Celtis pallida	Desert Hackberry	5 gal.
Larrea tridentata	Creosote	1 gal.
Mimosa dysocarpa	Desert Mimosa	5 gal.
Zizyphus obtusifolia	Graythorn	5 gal.

Seed Mix No. 2: Low Growing Mix

Botanical Name	FROM Common Name	PLS/ Acre
Aristida purpurea	Purple Threeawn	3.0
Atriplex semibaccata	Australian Saltbush	1.5
Baileya multiradiata	Desert Marigold	1.5
Bouteloua curtipendula 'Vaughn'	Sideoats Grama	3.0
Cassia covesii	Desert Senna	2.0
Encelia farinosa	Brittlebush	2.0
Eragrostis intermedia	Plains Lovegrass	2.0
Eriogonum fasciculatum	Shrubby Buckwheat	1.5
Eschscholtzia californica	California Poppy	2.0
Eschscholtzia mexicana	Mexican Poppy	2.0
Phacelia campanularia	Bluebells	2.0
Sphaeralcea ambigua	Globe Mallow	2.0
Ambrosia deltoidea	Triangle Bursage	2.0
Kallstroemia grandiflora		1.5

Houghton Rd.: Tanque Verde Rd. to Speedway Blvd. (El. 2588)

SECTION 802 LANDSCAPE GRADING

802-1 Description [Adding]

The work under this item shall also include the grading of water harvest basins as delineated on the project plans and in accordance with the Standard Specifications. A separate pay item for the grading of water harvest basins is included in the contract bidding schedule.

SECTION 805 SEEDING

805-1 Description [Adding]

The seeding shall be Class II.

805-2 Materials

805-2.02 Seed [Adding]

The seed mix shall be designated by Group "A" for the entire site, and Group "B" for the color mix areas. The seed mix shall be as follows:

GROUP "A"

#PLS/Acre	Botanical Name	Common Name
2.0	Bouteloua gracilis hachita	Blue Grama
3.0	Bouteloua curtipendula vaughn	Sideoats Grama
2.0	Baileya multiradiata	Desert Marigold
1.0	Cassia covesii	Desert Senna
1.5	Gaillardia aristata	Indian Blanket
1.5	Gaillardia palchella	Indian Flower
2.0	Plantago insularis	Indian Wheat
1.5	Eucelia farinosa	Brittlebush
2.0	Atriplex canescens	Fourwing Saltbush
1.5	Calliandra eriophylla	Fairyduster
2.0	Celtis pallida	Desert Hackberry
1.0	Acacia constricta	Whitethorn Acacia
2.0	Ambrosia deltoides	Triangle-leaf Bursage

GROUP "B"
(to be applied over Group "A")

#PLS/Acre	Botanical Name	Common Name
2.5	Abronia villosa	Sand Verbena
2.0	Eschscholtzia mexicana	Mexican Poppy
2.0	Erigeron divergens	Aster
2.0	Lupinus arizonicus	Arizona Lupine
2.0	Verbena tennosecta	Purple Verbena

805-2.03 Mulch

(A) General [Adding:]

The slurry mix of seed, fertilizer, and wood cellulose fiber mulch for irrigated areas shall consist of or meet the following proportions:

Material	Rate
Seed	As noted on list
Fertilizer	300 lbs./acre
Wood Fiber Mulch	1,800 lbs./acre
Tacking Agent	120 lbs. active ingredient/acre
Gro-Power or equal	1,000 lbs./acre

For unirrigated areas the slurry mix and soil amendments shall be as follows:

Site Prep

Gro-Power: 5-3-1 slow release fertilizer	1,000 lbs./acre
Ammonium phosphate: 16-20-0	200 lbs./acre

Slurry Mix

Hydrofiber: Cellulose fiber-mulch, Silva or equal	800 lbs./acre
Tackifier:	80 lbs./active ingredient/acre
Starter Fertilizer: Ammonium Phosphate 16-20-0	100 lbs./acre
Seed Mix:	as specified

Straw Mulch

Straw: Clean barley or wheat straw	1.5 tons/acre
Hydrofiber:	400 lbs./acre
Tackifier	150 lbs./active ingredient/acre

(D) Wood Cellulose Fibers [Adding:]

The wood cellulose fiber shall be manufactured so that:

1. After addition and agitation in slurry tanks with fertiliz- ers, seeds, water, and other approved additives, the fibers in the material will become uniformly suspended to form a homogeneous slurry.

2. When hydraulically sprayed on the ground, the material will form a blotterlike cover impregnated uniformly with seed

3. The cover will allow the absorption of moisture and allow rainfall or applied water to percolate to the underlying soil.

Wood cellulose fiber shall be applied at a rate of 300 pounds per acre.

805-2.05 Tacking Agent [Adding:]

Tacking agent shall contain a plantago organic mucilard base, with the active ingredient comprising 70-80% of the agent.

805-2.06 Chemical Fertilizer [Adding:]

Chemical fertilizer shall be a commercially produced pelleted granular form, State inspected to meet 16-20-0 percentages derived from inorganic sources meeting the following guaranteed analysis: Percentage (minimum), Ingredient (Nitrogen, Phosphoric Acid, Water Soluble Potash).

Chemical fertilizer shall be furnished in standard containers with the name, weight, and guaranteed analysis of the contents clearly marked. When a mixed fertilizer is specified, such as 16-20-0, the first number shall represent the minimum percent of soluble nitrogen, the second number shall represent the minimum percent of available phosphoric acid, and the third number shall represent the minimum percent of water soluble potash.

Apply 16-20-0 chemical fertilizer at a rate of 400 pounds per acre.

805-3 Construction Details

805-3.02 Classes of Seeding

(B) Seeding (Class II) [Adding:]

The area to be seeded shall be tilled to an average six-inch (6") depth, by approved methods, along the contours of the slope.

The Contractor shall submit a batch (tank) mix for the Engineer's approval prior to mixing any seed/mulch slurry. Batch mixing and coverage will be monitored throughout seeding operations.

On unirrigated projects, the Contractor shall apply straw at 2,500 pounds per acre upon completion of the seed/mulch slurry application. The straw shall be crimped into the soil, or tackifier applied by approved methods.

805-3.04 Warrantee [Adding the following Subsection:]

The Contractor shall guarantee work covered by this specification to the extent that the planted seed, if irrigated, will yield an average of at least eight (8) healthy germinated plants per square foot, and at least one target perennial per square yard after 90 days. If not irrigated, the Contractor shall guarantee a yield of at least five (5) healthy germinated plants per square foot, and at least one target perennial per square yard after nine (9) months to one year. The Contractor shall reseed areas in which the averages specified above are not reached within the warrantee period.

Irvington Rd.: Camino de Oeste to Mission Rd. (El. 2430)

SECTION 805 - SEEDING

805-2 Materials

805-2.02 Seed [Adding:]

The following typical seed mixes will be used in most instances. On occasion a different mixture will be specified and used. Substitutions must be approved by the Engineer in the event that components are not available.

Seed Mix No. 1: High Growing Mix

Botanical Name	Common Name	PLS/ACRE
Grasses		
Aristida purpurea	Purple Threeawn	3.0
Bouteloua curtipendula "Vaughn"	Sideoats Grama	3.0
Setaria macrostachya	Plains Bristle Grass	2.0
Sporobolus cryptandrus	Sand Drop Seed	1.0
Forbs		
Baileya multiradiata	Desert Marigold	1.5
Cassia covesii	Desert Senna	2.0
Eschscholtzia mexicana	Mexican Poppy	3.0
Psilostrophe cooperi	Paperflower	2.0
Linum lewisii	Blue Flax	2.0
Sphaeralcea ambigua	Globe Mallow	2.0
Shrubs		
Atriplex canescens	Fourwing Saltbush	3.0
Atriplex lentiformus	Quail Brush	2.0
Atriplex polycarpa	Desert Saltbush	2.0
Celtis pallida	Desert Hackberry	2.0
Encelia farinosa	Brittlebush	3.0
Ambrosia deltoides	Triangle Leaf Bursage	2.5
Larrea tridentata	Creosote	3.0
Trees		
Acacia constricta	White Thorn Acacia	1.0
Acacia greggii	Cat Claw Acacia	1.5
Cercidium floridum	Blue Palo Verde	1.5
Prosopis velutina	Velvet Mesquite	1.0

Seed Mix No. 2: Low Growing Mix

Botanical Name	Common Name	PLS/ ACRE
Aristida purpurea	Purple Threeawn	3.0
Atriplex semibacata	Australian Saltbush	1.5
Baileya multiradiata	Desert Marigold	1.5
Bouteloua curtipendula "Vaughn"	Sideoats Grama	3.0
Cassia covesii	Desert Senna	2.0
Encelia farinosa	Brittlebush	2.0
Ambrosia deltoides	Triangle Leaf Bursage	2.5
Eriogonum fasciculatum	Shrubby Buckwheat	1.5
Plantago insularis	Plantago	3.0
Eschscholtzia californica	California Poppy	2.0
Eschscholtzia mexicana	Mexican Poppy	2.0
Psilostrophe cooperi	Paperflower	2.0
Linum lewisii	Blue Flax	1.5
Phacelia campanularia	Bluebells	2.0
Sphaeralcea ambigua	Globe Mallow	2.0

805-2.03 Mulch

(A) General [Adding:]

The slurry mix of seed, fertilizer, and wood cellulose fiber mulch for irrigated areas shall consist of or meet the following proportions:

Material	Rate
Seed	As noted on list
Fertilizer	300 lbs./acre
Wood Fiber Mulch	1,800 lbs./acre
Tacking Agent	120 lbs. active ingredient/acre
Gro-Power or equal	1,000 lbs./acre

For unirrigated areas the slurry mix and soil amendments shall be as follows:

Site Prep

Gro-Power: 5-3-1 slow
release fertilizer 1,000 lbs./acre
Ammonium phosphate: 16-20-0 200 lbs./acre

Slurry Mix

Hydrofiber: Cellulose fiber-mulch, Silva or equal	800 lbs./acre
Tackifier:	80 lbs./active ingredient/acre
Starter Fertilizer: Ammonium Phosphate 16-20-0	100 lbs./acre
Seed Mix:	as specified

Straw Mulch

Straw: Clean barley or wheat straw	1.5 tons/acre
Hydrofiber:	400 lbs./acre
Tackifier	150 lbs./active ingredient/acre

(D) Wood Cellulose Fibers [Adding:]

The wood cellulose fiber shall be manufactured so that:

1. After addition and agitation in slurry tanks with fertilizers, seeds, water, and other approved additives, the fibers in the material will become uniformly suspended to form a homogeneous slurry.

2. When hydraulically sprayed on the ground, the material will form a blotterlike cover impregnated uniformly with seed

3. The cover will allow the absorption of moisture and allow rainfall or applied water to percolate to the underlying soil.

805-2.05 Tacking Agent [Adding:]

Tacking agent shall contain a plantago organic mucilard base, with the active ingredient comprising 70-80% of the agent.

805-2.06 Chemical Fertilizer [Adding:]

Chemical fertilizer shall be a commercially produced pelleted granular form, State inspected to meet 16-20-0 percentages derived from inorganic sources meeting the following guaranteed analysis: Percentage (minimum), Ingredient (Nitrogen, Phosphoric Acid, Water Soluble Potash).

The fertilizer used in conjunction with the hydraulic seeding operations shall be blended and applied as required to provide available nutrients at the following rates:

Nitrogen	2.0 Lbs. per 1,000 Sq. Feet
Phosphate	2.0 Lbs. per 1,000 Sq. Feet
Potash	1.0 Lbs. per 1,000 Sq. Feet

805-3 Construction Details

805-3.02 Classes of Seeding

(B) Seeding (Class II) [Adding:]

The area to be seeded shall be tilled to an average six-inch (6") depth, by approved methods, along the contours of the slope.

The Contractor shall submit a batch (tank) mix for the Engineer's approval prior to mixing any seed/mulch slurry. Batch mixing and coverage will be monitored throughout seeding operations.

On unirrigated projects, the Contractor shall apply straw at 2,500 pounds per acre upon completion of the seed/mulch slurry application. The straw shall be crimped into the soil, or tackifier applied by approved methods.

Seeding (Class II) shall consist of the furnishing and planting of specified range grass, wildflower, shrub, and other plant seeds. Seeds shall be planted using hydraulic planting techniques and equipment approved by the Engineer.

Where equipment can operate, the area to be seeded shall be prepared by disking, harrowing, or by other approved method to loosen the soil to a depth of 4 inches. On sloping areas, all disking, harrowing, and raking shall be directional along the contours of the areas involved.

Elemental sulfur shall be spread on the scarified soil of areas to be seeded at a rate of 10 lbs. per 1,000 square feet. Landscape grading, in accordance with Section 802 of these Specifications, shall be performed in these areas after the placement of elemental sulfur and prior to the commencement of seeding operations.

The seed, fertilizer, mulch, and tacking agent shall be applied to the designated areas using approved hydraulic seeding equipment. Mulch and seed materials which are placed upon trees, shrubs, pathways, structures or other surfaces not designated as to receive seed shall be removed and the surfaces cleaned as directed by the Engineer.

Due care shall be taken during the soil preparation and seeding operations to prevent damage to trees, shrubs, and constructed surface and subsurface improvements. all work shall be performed in accordance with Section 107 of these Specifications.

805-3.04 Warrantee [Adding the following Subsection:]

The Contractor shall guarantee work covered by this specification to the extent that the planted seed, if irrigated, will yield an average of at least eight (8) healthy germinated plants per square foot, and at least one target perennial per square yard after 90 days. If not irrigated, the Contractor shall guarantee a yield of at least five (5) healthy germinated plants per square foot, and at least one target perennial per square yard after nine (9) months to one year. The Contractor shall reseed areas in which the averages specified above are not reached within the warrantee period.

Ina Rd.: Oracle Rd. to Chula Vista (El. 2851)

SUPPLEMENTAL SPECIFICATIONS

SECTION 802 - LANDSCAPE GRADING

802-3.01 Construction Details. [adding]:

Native soil in the areas which were previously paved shall be tested for suitability to support plant materials. The Contractor shall furnish a written soil analysis prepared by an accredited soil analyst for the native soil in areas which were previously paved. The native soil shall be fertile, friable, free draining, nontoxic, contain no soil sterilizers and be capable of sustaining healthy plant growth.

Native soil in areas which were previously paved shall be reasonably free from calcium carbonate, refuse, heavy clay, clods, phytotoxic materials, coarse sand, gravel, large rocks, sticks, litter and other deleterious substances.

SECTION 805 - SEEDING

805-2.02 General. [adding]:

The following seed mixes will be used. Substitutions must be approved by the Engineer in the event that components are not available. Seed mix No. 1 and No. 2 will be irrigated. Seed mix No. 3 and No. 4 will not be irrigated.

Seed Mix No. 1: Parkways

Botanical Name	Common Name	Rate PLS/Acre
Penstemon palmeri	Pink penstemon	.5 lbs.
Phylostrophe cooperi	Paper flower	.25 lbs.
Bouteloua gracilis	Blue grama	1.0 lbs.
Sphaeralcea ambigua	Desert globe mallow	1.5 lbs.
Aristada purpurea	Purple threawn	2.0 lbs.
Ambrosia deltoidea	Bursage	1.0 lbs.
Escholtzia californica	Gold poppies	2.0 lbs.
Dimorphotheca sinuata	African daisy	2.0 lbs.
Oenothera speciosa	Mexican primrose	.5 lbs.
Phacelia campanularia	Bluebells	1.0 lbs.
Gaillardia pulchella	Fire wheels	2.5 lbs.
Baileya multiradiata	Desert marigold	2.0 lbs.
Larrea tridentata	Creosote bush	1.0 lbs.

Seed Mix No. 2: Drainage Channels

Botanical Name	Common Name	Rate PLS/Acre
Lupinus succulentus	Arroyo lupine	2.0 lbs.
Aristada purpurea	Purple threawn	2.0 lbs.
Sporobolus cryptandrus	Sand dropseed	1.0 lbs.
Setaria macrostachya	Plain bristle grass	2.0 lbs.
Cassia covesii	Desert senna	2.0 lbs.

Larrea tridentata	Creosote bush	1.0 lbs.
Atriplex canescens	Fourwing saltbush	3.0 lbs.
Celtis pallida	Desert hackberry	2.0 lbs.
Dyssodia acerosa	Dyssodia	.25 lbs.
Ambrosia deltoidea	Bursage	1.0 lbs.
Encelia farinosa	Brittlebush	1.5 lbs.
Phacelia campanularia	Bluebells	1.0 lbs.
Baileya multiradiata	Desert marigold	2.0 lbs.
Sphaeralcea ambigua	Desert globe mallow	1.0 lbs.
Escholtzia mexicana (multi-colored variety)	California poppy	2.0 lbs.

Seed Mix No. 3: Structural Wall Terraces

Botanical Name	Common Name	Rate PLS/Acre
Lupinus succulentus	Arroyo lupine	4.0 lbs.
Escholtzia californica	Gold poppies	4.0 lbs.
Baileya multiradiata	Desert marigold	4.0 lbs.
Penstemon palmeri	Pink penstemon	3.0 lbs.

Seed Mix No. 4: Medians

Botanical Name	Common Name	Rate PLS/Acre
Peristemon parryi	Peristemon	.05 lbs.
Sphaeralcea ambigua (multicolored variety)	Globe mallow	1.0 lbs.
Ambrosia deltoldea	Bursage	4.0 lbs.
Escholtzia mexicana	California poppy	3.0 lbs.
Phacelia campanalaria	Bluebells	1.0 lbs.
Baileya multiradiata	Desert marigold	2.0 lbs.
Lupinus sparsiflorus or Arizonica (if available substitute)	Lupine	3.0 lbs.
L. Succulentus	Arroyo lupine	6.0 lbs.

805-2.03 Mulch

(A) General. Adding:

The slurry mix of seed, fertilizer, and wood cellulose fiber mulch for irrigated areas shall consist of or meet the following proportions:

Material	Rate
Seed	As noted on the list
Fertilizer	300 lbx./acre
Wood fiber mulch	1,800 lbs./acre
Tacking agent	120 lbs. active ingredient/acre
Gro-power or equal	1,000 lbs./acre

(D) Wood Cellulose Fibers. Adding:

The wood cellulose fiber shall be manufactured so that:

(1) After addition and agitation in slurry tanks with fertilizers, seeds, water, and other approved additives, the fibers in the material will become uniformly suspended to form a homogeneous slurry.

(2) When hydraulically sprayed on the ground, the material will form a blotterlike cover impregnated uniformly with seed.

(3) The cover will allow the absorption of moisture and allow rainfall or applied water to percolate to the underlying soil.

The wood cellulose fiber shall meet the following standards:

Moisture content ....10.0% ± 3.0%
Organic matter..........99.2% ± 0.2%
pH.....................04.8% ± 0.5%
Water holding capacity..1,000 minimum
(gms H_2O/100 gms fiber)

805-2.05 Tacking Agent. [adding]:

Tacking agent shall contain a plantago organic mucilard base, with the active ingredient comprising 70-80% of the agent.

The plantago organic mulcilard base shall meet the following standards:

Moisture. . . 9%
Ash 3%
Small Volume . . . . in 40 ml/gm - 45 P method
Mucilard purity . . 75% minimum

805-2.06 Chemical Fertilizer. Adding:

Chemical fertilizer shall be a commercially produced pelleted granular form, State inspected to meet 16-20-0 percentages derived from inorganic sources meeting the following guaranteed analysis: Percentage (minimum), Ingredient (Nitrogen, Phosphoric Acid, Water Soluble Potash).

805.3 CONSTRUCTION DETAILS

805-3.02 Class of Seeding

(B) Seeding (Class II). Adding:

The soil shall be ripped to /four (4) inches minimum with ripper spacing not exceeding ten (10) inches. All areas shall be evenly ripped leaving neat lines along the contour. Ripping shall not disturb the subgrade erosion control matting or create pockets, depression, or mounds out of character with the natural neat flow of the terrain. All extraneous debris shall be removed and disposed of. Large rocks and large hard clods brought up with tillage shall be removed or pulverized to maintain a neat and natural appearance prior to seedings.

Hydro seeding shall be done immediately following tillage operations when the soil is still soft and loose. Hydroseed slurry shall be sprayed into the loose surface soil so a mix of slurry and soil results. If the surface has crusted over prior to seeding operations, it shall be light harrowed to create new loose soil surface and then hydroseeded.

The hydro seed shall be applied with a hose by hand on the parkways, structural wall terraces, and on the medians. The Contractor is to clean off any slurry mix spray which falls on surrounding plant material before it dries. This can be done by spraying the plant with water. All seeded areas which are to be irrigated are indicated on the landscape plans. They will be irrigated by the underground low precipitation rate spray system as detailed on the plans. For the first 30 days, the seed is to receive one (1) inch of water per day.

SECTION 807 LANDSCAPE ESTABLISHMENT

807-3.01 Construction Details, General. [adding]:

The work period for landscaping establishment shall be one (1) year from the date of acceptance or replacement.

807-3.02 Construction Details. Planted Stock and Seeding Establishment. [adding]:

The design intent of the median and parkway hydroseeded areas is a well manicured desert groundcover. The maintenance program shall consist of hand weeding or any other method which will preserve the seeded species and eliminate weeds.

The design intent of the drainage channel hydroseeded areas is erosion control and revegetation. The maintenance program shall consist of mowing the groundcovers and trimming the shrubs on an annual basis only if growth inhibits flow in the drainage channels.

SECTION 808 LANDSCAPE IRRIGATION SYSTEM

808-3.02 Construction Requirements. Trenching and Piping. [adding]:

Unless otherwise indicated on the plans, all mainlines shall have a minimum cover of 30 inches, and all lateral lines shall be installed with a minimum cover of 24 inches based on finished grade.

SECTION 810 LANDSCAPE BORROW

810-2.20 Materials. Decomposed Granite. [adding]:

The decomposed granite in planting areas shall be Phoenix-area decomposed granite stone of size 3/4" minus diameter, or approved equal. The decomposed granite for the pedestrian path shall be Phoenix-area decomposed granite stone of size 1/4" minus diameter, or approved equal. The color of the granite shall be Desert Gold. The Contractor shall provide the Engineer with samples of materials before installation.

The Contractor shall apply an application of an approved pre-emergent herbicide on all landscaped areas, excluding seeded areas, following planting.

Sabino Canyon Rd.: Cloud Rd. to Kolb Rd. (El. 2522)

October 4, 1993

SPECIAL PROVISIONS
PPM-PM 000 SS 288 01C
STP-PPM-0(1)

SECTION 805 - SEEDING: of the Standard Specifications is modified to add:

805-1 Description:

The work under this section shall consist of furnishing all materials, preparing the soil and applying the seed to all areas designated on the project plans or established by the Engineer. Seeding shall be Class II and shall be performed in accordance with the requirements of these specifications.

805-2 Materials:

805-2.01 General:

Certificates of Compliance conforming to the requirements found in Section 106 shall be submitted.

805-2.02 Seed:

The species, strain or origin of seed shall be as designated in these Special Provisions.

The seed shall be delivered to the project site in standard, sealed, undamaged containers. Each container shall be labeled in accordance with Arizona Revised Statutes and the U. S. Department of Agriculture rules and regulations under the Federal Seed Act. Labels shall indicate the variety of strain of seed, the percentage of germination, purity and week content, and the date of analysis which shall not be more than 9 months prior to the delivery date.

Legume seed shall be inoculated with appropriate bacteria cultures approved by the Engineer, in accordance with the culture manufacturers' instructions.

Seed that has become moldy, wet, or otherwise damaged, will not be acceptable. Seed shall be called for in pounds of pure, live seed (PLS), where PLS is defined as the product of seed germination (G) and seed Purity (P) all divided by 100.

As the specified seed species may be in short supply during the planting season for the project, the Contractor shall be required to provide a notarized statement from his seed supplier which guarantees the availability of a sufficient quantity of the specified seed species prior to the anticipated seeding date(s) for the project. The Contractor shall provide the required guarantee at the time of the Preconstruction Conference.

Seed Mix No. 1

Botanical Name	Common Name	PLS/ ACRE
Ambrosia deltoides	Triangle Leaf Bursage	2.5
Aristida purpurea	Purple Threeawn	3.0
Baileya multiradiata	Desert Marigold	1.5
Bouteloua curtipendula "Vaughn"	Sideoats Grama	3.0
Cassia covesii	Desert Senna	2.0
Dyssodia pentacheata	Dyssodia	1.0
Encelia farinosa	Brittlebush	2.0

Botanical Name	Common Name	PLS/ ACRE
Eriogonum fasciculatum "arizonica"	Arizona Buckwheat	1.5
Eschscholtzia californica	California Poppy	2.0
Eschscholtzia mexicana	Mexican Poppy	2.0
Linum lewisii	Blue Flax	1.5
Phacelia campanularia	Bluebells	2.0
Psilostrophe cooperi	Paper Flower	1.0
Sphaeralcea ambiguum	Globe Mallow	2.0
Sporobolus cryptandrus	Sand Dropseed	1.0

805-2.03 Mulch:

805-2.03(A) General:

For unirrigated areas the slurry mix and soil amendments shall be as follows:

Site Prep

Material	Rate
Gro-Power: 5-3-1 slow Release Fertilizer	1,000 lbs./acre
Ammonium phosphate: 16-20-0	200 lbs./acre

Slurry Mix

Hydrofiber: Cellulose fiber-mulch, Silva or equal	800 lbs./acre
Tackifier:	80 lbs./active ingredient/acre
Starter Fertilizer: Ammonium Phosphate 16-20-0	100 lbs./acre
Seed Mix:	As specified

Straw Mulch

Straw: Clean barley or wheat straw	1.5 tons/acre
Hydrofiber:	400 lbs./acre
Tackifier	150 lbs./active ingredient/acre

Wood Cellulose Fibers

The wood cellulose fiber shall be manufactured so that:

1. After addition and agitation in slurry tanks with fertilizers, seeds, water, and other approved additives, the fibers in the material will become uniformly suspended to form a homogeneous slurry.

2. When hydraulically sprayed on the ground, the material will form a blotterlike cover impregnated uniformly with seed

3. The cover will allow the absorption of moisture and allow rainfall or applied water to percolate to the underlying soil.

805-2.03(B) Manure:

Manure shall be steer manure that has been well composted and unleached, and shall have been collected from cattle feeder operations. Manure shall be free from sticks, stones, earth, weed seed, substances injurious or toxic to plant growth and visible amounts of undercomposed straw or bedding material. Manure shall not contain lumps or any foreign substances that will not pass a 1/2-inch screen and when specified for lawn use, the material shall be ground or screened so as to pass a 1/4-inch screen.

805-2.03(C) Peat Humus:

Peat humus shall be natural domestic peat of peat humus from fresh water saturated areas, consisting of sedge, sphagnum or reed peat and shall be of such physical condition that it will pass through a 1/2-inch screen. The humus shall be free from sticks, stones, roots and other objectionable materials.

Peat humus shall have a pH from 4 to 7.5 and the minimum organic content shall be 85 percent on a dry weight basis. The ash content, as determined by igniting a five gram sample for 20 hours at a temperature of 900 degrees F., shall not exceed 25 percent by weight.

Peat humus shall be furnished in undamaged commercial bales in an air-dry condition.

805-2.03(D) Wood Cellulose Fibers:

Natural wood cellulose fiber shall have the property of dispersing readily in water and shall haven no toxic effect when combined with seed or other materials. A colored dye which in noninjurious to plant growth may be used. Wood cellulose fiber shall be delivered in undamaged, labeled containers bearing the name of the manufacturer and showing the air-dry water content. Wood cellulose fiber shall be manufactured such that when hydraulically applied, it will form a blotter-like cover impregnated with seed, allow the absorption of moisture and allow rainfall or applied water to percolate to the underlying soil.

805-2.03(E) Straw:

Straw shall be from oats, wheat, rye or other grain corps of current season as approved by the Engineer and shall be free from noxious weeds, molds or other objectionable material. Straw mulch shall be from the current season's crop and in an air-dry condition suitable for placing with mulch blower equipment.

805-2.04 Water:

Water Shall be free of oil, acid, salts or other substances harmful to plants. The source shall be approved by the Engineer prior to use.

805-2.05 Tacking Agent:

Tacking agent shall contain a plantago organic mucilard base, with the active ingredient comprising 70-80% of the agent. An approved tacking agent will have strong adhesive characteristics as well as imparting lubrication to the mixture to allow for the uniform dispersion of the hydroseed slurry. The tacking agent shall also have gelling properties to inhibit the tendency of water and fibber to move downhill as they are sprayed on steep slopes. The stabilizer should be soluble and readily disperse in water without the formation of gel balls or other coagulation or sedimentation. The properties of the tacking agent shall not be adversely affected by the addition of fertilizers or other additives to the slurry mix.

805-2.06 Chemical Fertilizer:

Chemical fertilizer shall be a commercially produced pelleted granular form, State inspected to meet 16-20-0 percentages derived from inorganic sources meeting the following guaranteed analysis: Percentage (minimum), Ingredient (Nitrogen, Phosphoric Acid, Water Soluble Potash).

Chemical fertilizer shall be furnished in unopened standard containers with the name, weight, and guaranteed analysis of the contents clearly marked. When a mixed fertilizer is specified, such as 16-20-0, the first number shall represent the minimum percent of soluble nitrogen, the second number shall represent the minimum percent of available phosphoric acid, and the third number shall represent the minimum percent of water soluble potash.

805-2.07 Soil Conditioner:

Soil conditioner (Gro-Power or equal) shall be derived from organic materials such as decomposed animal, vegetable, and mineral matter; shall be composted, relatively dry, friable, and pass a one-inch sieve; shall not contain poultry, animal or human waste pathogenic viruses, fly larvae, insecticides, herbicides, fungicides, or poisonous chemicals that would inhibit plan growth, and shall have the following guaranteed chemical analysis:

Ingredient	Percentages (Minimum)
Nitrogen	5
Phosphoric Acid	3
Water Soluble Potash	1
Humus	50
Humus Acids	15
Soluble Metallic Iron	1

805-3 Construction Details:

805-3.01 General:

Seeding and application rates shall be as specified herein.

The Contractor shall notify the Engineer at least two days prior to commencing seeding operations.

Seeding operations shall not be performed when wind would prevent uniform application of materials or would carry seeding materials into areas not designated to be seeded.

Preparation of the areas for seeding shall be as specified herein and as shown on the project plans.

Equipment and methods of distributing seeding materials shall be such as to provide an even and uniform application of the seed, much and/or other materials in accordance with the specified rates.

Unless specified otherwise in the Special Provisions, seeding operations shall not be performed on undisturbed soil outside the clearing and grubbing limits of the project or on steep rock cuts.

805-3.02 Classes of Seeding:

805-3.02(B) Seeding (Class II):

Seeding (Class II) shall consist of furnishing and planting range grass seed, flower seed and/or shrub seed, and includes mulching.

Where equipment can operate, the area to be seeded shall be prepared by disking, harrowing or by other approved methods of loosening the surface soil to the depth of six inches (6"). On slopes too steep for equipment to operate, the area shall be prepared by hand raking to the specified depth. On sloping areas, all disking, harrowing and raking shall be directional along the contours of the areas involved. Loose stones having a dimension greater than four inches brought to the surface during cultivation shall be removed and disposed of in a satisfactory manner prior to grading and seeding. All areas which are eroded shall be restored to the specified condition, grade and slope as directed prior to seeding.

On cut and fill slopes the operations shall be conducted in such a manner as to form minor ridges thereon to assist in retarding erosion and favor germination of the seed.

Due care shall be taken during the seeding operations to prevent damage to existing trees and shrubs in the seeding area in accordance with the requirements found in Section 107. Seed shall be drilled, broadcast or otherwise planted in the manner and at the rate specified in these Special Provisions.

The type of mulch, and the manner and rate of application shall be as specified in these Special Provisions.

Mulch material which is placed upon trees and shrubs, roadways, structures and upon any areas where mulching is not specified or is placed in excessive depths on mulching is not specified or is placed in excessive depths on mulching areas shall be removed as directed. Mulch materials which are deposited in a matted condition shall be loosened and spread uniformly over the mulching areas to the specified depth.

During seeding and mulching operations, care shall be exercised to prevent drift and displacement of materials. Any unevenness in materials shall be immediately corrected by the Contractor.

If a tacking agent is specified in order to bind the mulch in place, the type, rate and manner of application shall be as specified in these Special Provisions. Prior to the application of a tacking agent, protective covering shall be placed on all structures and objects where stains would be objectionable. All necessary means shall also be taken to protect the travelling public and vehicles from damage due to drifting spray.

Unless otherwise specified in the Special Provisions, Class II seeding areas shall not be watered after planting.

The Contractor shall submit a batch (tank) mix for the Engineer's approval prior to mixing any seed/mulch slurry. Batch mixing and coverage will be monitored throughout seeding operations.

On unirrigated projects, the Contractor shall apply straw at 2,500 pounds per acre upon completion of the seed/mulch slurry application. The straw shall be crimped into the soil, or tackifier applied by approved methods.

805-3.03 **Preservation of Seeded Areas:**

The Contractor shall protect seeded areas from damage by traffic or construction equipment. Surfaces eroded or otherwise damaged following seeding and prior to final acceptance shall be repaired by regrading, reseeding and remulching as directed by the Engineer.

805-3.04 **Warrantee:**

The Contractor shall guarantee work covered by this specification to the extent that the planted seed, if irrigated, will yield an average of at least eight (8) healthy germinated plants per square foot, and at least one target perennial per square yard after 90 days. If not irrigated, the Contractor shall guarantee a yield of at least five (5) healthy germinated plants per square foot, and at least one target perennial per square yard after nine (9) months to one year. The Contractor shall reseed areas in which the averages specified above are not reached within the warrantee period.

805-4 **Method of Measurement:**

Seeding (Class II) will be measured by the acre of ground surface to the nearest 0.1 acre.

805-5 **Basis of Payment:**

The accepted quantities of seeding, measured as provided above, will be paid for at the contract price for the pay unit specified in the bidding schedule, complete-in-place.

No measurement or direct payment will be made for the preservation of seeded areas.

(MACRT806, 4056/H, 05/01/93)

SECTION 806 **TREES, SHRUBS, AND PLANTS:** of the Standard Specifications is modified as follows:

806-2 **Materials:** is modified to add:

Certificates of Compliance conforming to the requirements of Subsection 106.05 shall be submitted to the Engineer for all contractor furnished materials, unless otherwise specified.

806-3.01 **General:** the second paragraph is hereby deleted.

First Ave.: River Rd. to Orange Grove Rd. (El. 2321)

SECTION 805 - SEEDING: Substitute the following for the Seeding Section of the Standard Specifications:

805-1 Description:

The work under this section shall consist of furnishing all materials, preparing the soil, and applying the seed to all areas designated as HS-1 or HS-2 on the project plans or as established by the Engineer.

The work shall include but not be limited to the following:

Preparation of areas to be seeded.

Application by hydromulching.

Application of erosion control blankets (where indicated as HS-2 on the plans).

805-1.01 Approvals:

All material used for this work is subject to the approval of the Engineer.

805-1.02 Submittals:

Prior to beginning the hydromulching operations, the Contractor shall submit to the Engineer for approval the installation procedures he proposes to use including the quantities of mulch, tackifier and fertilizer proposed. Any proposed change in the seed mix or seed quantities shall also be submitted for approval.

805-2 Materials:

805-2.01 Hydrofiber:

Hydrofiber shall be a mulch material specifically produced for the hydroseeding industry. It shall be produced as virgin wood fiber from whole wood chips and contain a specified range of fiber lengths with a minimum 30% averaging 0.15 inches or longer. It shall conform to the following properties:

Moisture content	10.0% ± 3.0%
Organic matter	99.0% ± 1.0%
Ash content	1.0% ± 0.5%
pH	4.5 to 5.5
Water holding capacity	1,000 g / 100 g water fiber

Material specified is for Conwed or Silva brands.

Rate: 1,800 lbs per acre

805-2.02 Tackifier:

Erosion control material.

Type:	Psyllium mucilloid organic tackifier
Origin:	Derived from <u>Plantago</u> bush
Form:	Hydrophilic water soluble dry powder
Moisture:	Less than 9%
Ash:	Less than 3%
Swell volume:	40 ml/gram - usp method

Purity: Not less than 75% mucilloid
Toxicity: None
Rate: 85 lbs/acre

805-2.03 Soil Conditioner:

Humus base material contains 15% minimum humic acid.

Typical material: Gro Power 5-3-1
Rate: Apply at 1,000 lbs per acre

805-2.04 Fertilizer:

Ammonium phosphate 16-20-0 applied at a rate of 250 lbs per acre.

805-2.05 Erosion Control Blanket:

Erosion control blanket shall be a machine-produced 100% biodegradable mat with a 70% agricultural straw and 30% coconut fiber blend matrix.

The blanket shall be of consistent thickness with the straw and coconut fiber evenly distributed over the entire area of the mat. The blanket shall be covered on the top and bottom sides with 100% biodegradable natural organic fiber netting woven into an approximate 1/2-inch × 1-inch mesh. The blanket shall be sewn with biodegradable thread on 1.5-inch centers.

Straw/coconut fiber erosion control blanket shall be S150 BN as manufactured by North American Green, or approved equal. Straw/coconut fiber erosion control blanket shall have the following properties:

Material Content

Matrix: 70% straw fiber
(.35 lb/y^2) (.19 kg/m^2)

30% coconut fiber
(.15 lb/y^2) (.08 kg/m^2)

Netting: Both sides woven 100% biodegradable natural organic fiber
(9.3 lb/1,000 sq ft approx wt)

Thread: Biodegradable

Physical Specifications (Roll)

Width: 6.0 feet (1.83 m)

Length: 90.0 feet (27.4 m)

Weight: 40 lbs ± 10% (18.1 kg)

Area: 60 sq yds (50 m^2)

805-2.06 **Seed:**

Botanical Name	Common Name	PLS Rate (pounds/acre)
Aristida purpurea	Purple Three Awn	2.0
Cassia covesii	Desert Senna	2.0
Plantago insularis	Indian Wheat	3.0
Sphaeralcea ambigua	Desert Globe Mallow	1.0
Sporobolus cryptandrus	Sand Dropseed	1.0
Acacia constricta	Whitethorn Acacia	2.0
Ambrosia deltoidea	Triangle-Leaf Bursage	4.0
Encelia farinosa	Brittle Bush	2.0
Cercidium microphyllum	Foothills Palo Verde	2.0
Phacelia companularia	Desert Bluebells	1.5
Prosopis velutina	Velvet Mesquite	1.5
Escholtzia californica	California Poppy	3.0

805-3 Construction Details:

805-3.01 **General:**

Areas indicated on the plans as HS-1 and HS-2 shall receive seeding. Areas labeled as HS-2 shall also receive erosion control blankets (see 805-3.03).

805-3.02 **Seeding:**

All seeding operations shall be done by a contractor who has a minimum of three years of experience in this type of work. A list of similar successful projects shall be submitted to the Owner for review if requested.

Soil shall be watered and scarified by tilling or discing to a depth of at least 4 inches. Tilling or scarifying shall be done parallel to the contours.

Tillage operation should not disturb any existing trees, shrubs or irrigation. Determine with the Owner before starting work if area of existing irrigation is to remain or be removed.

Apply seed mix at the specified rates with fertilizer, wood fiber mulch material and organic tackifier. Minimum application shall be 250 pounds/acre of ammonium phosphate 16-20-0.

Hydromulch with a mixture of wood fiber and tackifier at the rate of approximately 1,800 pounds/acre of wood fiber, 85 pounds/acre of tackifier.

805-3.03 **Erosion Control Blankets:**

After soil preparation and the application of the hydromulch, the Contractor shall install erosion control blankets over the hydromulch areas labeled as HS-2.

The blankets shall be a straw and coconut matrix as manufactured by North American Green #SC150BN or an approved equal.

Blankets shall be installed per the manufacturer's recommendations using 6-inch steel stakes from the manufacturer.

Blankets must be anchored in a 6-inch x 6-inch trench at the top of the slope and use a minimum of 1.5 staples per square yard at spacings between staples of about 3 feet O.C. Blankets should be rolled out across the slope with upper blankets lapping over lower ones shingle style. Ends of blankets to overlap 6 inches and sides to overlap 2 inches.

805-3.04 Preservation of Seeded Areas:

The Contractor shall protect seeded areas from damage by traffic or construction equipment. Surfaces eroded or otherwise damaged following seeding and prior to final acceptance shall be repaired by regrading, reseeding and remulching as directed by the Engineer.

805-3.05 Guarantee for Dryland Seeding Revegetation:

Guarantee a minimum of five (5) perennial plants of the target species plant list per square yard be established during or after a favorable season of average or above average rainfall. Establishment shall occur in all areas of the site capable of sustaining growth. Establishment shall be defined herein as a plant having developed at least five (5) true leaves and be in a positive state of growth. At least one-third of the types of species seeded shall be established. In areas where plant establishment does not meet this minimum requirement, the Contractor shall re-seed the area. If rainfall is below average or insufficient for two growing seasons, (1) Spring, (2) Summer-Fall, and the minimum establishment is not achieved, re-seeding will be required unless proven that seeds are still present and viable in significant numbers (seventy percent [70%] of original rates). Areas of solid rock or areas that are incapable of being modified to achieve growth as specified herein (tillage, amendments, etc.) shall not be subject to this guarantee.

Guarantee that mulch materials used be affixed to retain in excess of 90% coverage of original application rates until the plant establishment minimum is achieved. Straw mulch or other mulching materials being eroded or otherwise displaced shall be replaced by the Contractor. Re-seeding shall be done if erosion is great enough to deteriorate the seedbed.

Guarantee that erosion occurring within the plant establishment period be repaired, re-seeded and re-mulched with material as specified herein.

Guarantee that weeds will be removed or treated during the establishment period at a level to reduce competition allowing seeded species to become established. The Contractor shall monitor the site and treat as needed. If weed competition is so great that establishment of target seeded species does not occur following a favorable period of weather, the Contractor shall remove or treat the weeds, re-till if needed, re-seed and re-mulch the affected areas. In no case shall weeds be allowed to grow at excessively competitive densities and in all cases removal or treatment shall be done prior to seed formation.

The plant establishment period will extend for three (3) years when not irrigated after all areas of the site have been seeded. Once plant establishment, as defined herein, has been achieved, the plant establishment period shall end.

805-4 Method of Measurement:

Seeding Type HS-1 and HS-2 will be measured either by the square yard of ground surface to the nearest 100 square yards seeded or by the acre to the nearest 0.1 acre. Erosion control blanket will be measured by the square yard of finished surface.

805-5 Basis of Payment:

The accepted quantities of seeding and erosion control blanket, measured as provided above, will be paid for at the contract price for the pay unit specified in the bidding schedule, complete-in-place.

Pistol Hill Rd.: Colossal Cave Rd. to Old Spanish Trail (El. 3426)

SECTION 805 SEEDING

805-1 DESCRIPTION of the Standard Specifications is modified to add:

The work under this section shall include reseeding areas in which the planted seed average yield specified in Subsection 805-3.04 Warrantee of the Special Provisions are not reached within the warrantee period.

805-2 MATERIALS

805-2.02 Seed of the Standard Specifications is modified to add:

The following typical seed mixes will be used in most instances. On occasion a different mixture will be specified and used. Substitutions must be approved by the Engineer in the event that components are not available.

Seed Mix No. 1: High Growing Mix

Botanical Name	Common Name	PLS/ACRE
Grasses		
Aristida purpurea	Purple Threeawn	3.0
Bouteloua curtipendula "Vaughn"	Sideoats Grama	3.0
Setaria macrostachya	Plains Bristle Grass	2.0
Sporobolus cryptandrus	Sand Drop Seed	1.0
Forbs		
Baileya multiradiata	Desert Marigold	1.5
Cassia covesii	Desert Senna	2.0
Eschscholtzia mexicana	Mexican Poppy	3.0
Helianthus annus	Sunflower	3.0
Linum lewisii	Blue Flax	2.0
Sphaeralcea ambigua	Globe Mallow	2.0
Shrubs		
Atriplex canescens	Fourwing Saltbush	3.0
Atriplex lentiformus	Quail Brush	2.0
Atriplex polycarpa	Desert Saltbush	2.0
Celtis pallida	Desert Hackberry	2.0
Encelia farinosa	Brittlebush	3.0

Botanical Name	Common Name		PLS/ACRE
Trees			
Acacia constricta	White Thorn Acacia	1	0.0
Acacia greggii	Cat Claw Acacia		1.5
Cercidium floridum	Blue Palo Verde		1.5
Prosopis velutina	Velvet Mesquite		1.0
Seed Mix No. 2: Low Growing Mix			
Aristida purpurea	Purple Threeawn		3.0
Atriplex semibacata	Australian Saltbush	1.5	
Baileya multiradiata	Desert Marigold		1.5
Bouteloua curtipendula "Vaughn"	Sideoats Grama		3.0
Cassia covesii	Desert Senna		2.0
Encelia farinosa	Brittlebush		2.0
Eragrostis intermedia	Plains Lovegrass		2.0
Eriogonum fasciculatum	Shrubby Buckwheat	1.5	
Erigeron species	Fleabane		2.0
Eschscholtzia californica	California Poppy		2.0
Eschscholtzia mexicana	Mexican Poppy		2.0
Evolvulus arizonicus	Arizona Blue Eyes		1.0
Linum lewisii	Blue Flax		1.5
Phacelia campanularia	Bluebells		2.0
Sphaeralcea ambigua	Globe Mallow		2.0

805-2.03 Mulch

(A) General of the Standard Specifications is modified to add:

The slurry mix of seed, fertilizer, and wood cellulose fiber mulch for irrigated areas shall consist of or meet the following proportions:

Material	Rate
Seed	As noted on list
Fertilizer	300 lbs./acre
Wood Fiber Mulch	1,800 lbs./acre
Tacking Agent	120 lbs. active ingredient/acre
Gro-Power or equal	1,000 lbs./acre

For unirrigated areas the slurry mix and soil amendments shall be as follows:

Site Prep

Gro-Power: 5-3-1 slow release fertilizer	1,000 lbs./acre

Ammonium phosphate: 16-20-0	200 lbs./acre

Slurry Mix

Hydrofiber: Cellulose fiber-mulch, Silva or equal	800 lbs./acre
Tackifier:	80 lbs./active ingredient/acre
Starter Fertilizer: Ammonium Phosphate 16-20-0	100 lbs./acre
Seed Mix: as specified	

Straw Mulch

Straw: Clean barley or wheat straw	1.5 tons/acre
Hydrofiber:	400 lbs./acre
Tackifier	150 lbs./active ingredient/acre

Adding the following Subsection to Section 805 of the Standard Specifications:

805-3 CONSTRUCTION DETAILS

805-3.04 Warrantee

The contractor shall guarantee work covered by this specification to the extent that the planted seed, if irrigated, will yield an average of at least eight (8) healthy germinated plants per square foot, and at least one target perennial per square yard after 90 days. If not irrigated, the contractor shall guarantee a yield of at least five (5) healthy germinated plants per square foot, and at least one target perennial per square yard after nine (9) months to one year. The contractor shall reseed areas in which the averages specified above are not reached within the warrantee period.

Golf Links Rd.: Bonanza Ave. to Houghton Rd. (El. 2671)

SECTION 805 - SEEDING

805-1 **Description:** of the Standard Specifications is revised to read:

The work under this section shall consist of furnishing all materials, preparing the soil, and applying seeds to areas disturbed by planting operations or the installation of the landscape irrigation system or as established by the Engineer. Seeding shall be Class II seeding and shall be performed in accordance with the requirements of these Specifications.

805-2.02 **Seed:** of the Standard Specifications is modified to add:

The species, variety and sowing rate for seeds shall be as follows;

Botanical Name	Common Name	Rate (P.L.S./Ac.)
Ambrosia deltoidea	Triangle Leaf Bursage	2.0
Atriplex canescens	Four-wing Saltbush	2.0
Baileya multiradiata	Desert Marigold	3.0
Encelia farinosa	Brittlebush	3.0
Plantago insularis	Indian Wheat	3.0
Senna covesii	Desert Senna	2.0
Sphaeralcea ambigua	Globe Mallow	2.0
Sporobolus cryptandrus	Sand Dropseed	1.0

The mulch utilized in conjunction with the seeding shall be wood cellulose fiber.

805-3.02(B) **Seeding (Class II):** of the Standard Specifications is revised to read:

Seeding (Class II) shall consist of the furnishing and planting of specified range grass, wildflower and shrub seeds. Seeds shall be planted using hydraulic planting techniques and equipment as approved by the Engineer.

Where equipment can operate, the area to be seeded shall be prepared by disking, harrowing or by other approved methods of loosening the surface soil to an average depth of six inches (6"). On slopes too steep for equipment to operate, the area shall be prepared by hand raking to the specified depth. On sloping areas all disking, harrowing and raking shall be directional along the contours of the areas involved. Loose stones having a dimension greater than two (2") inches brought to the surface during cultivation shall be removed and disposed of in a satisfactory manner prior to grading and seeding. All areas which are eroded shall be restored to the specified condition, grade and slope as directed prior to seeding.

Elemental sulphur shall be spread on the scarified soil of areas to be seeded at a rate of 10 pounds per 1,000 square feet. Landscape grading, in accordance with Section 802 of the Standard Specifications, shall be performed in these areas after the placement of elemental sulphur and prior to the commencement of seeding operations.

Seeding operations shall not begin until after tree and shrub planting and irrigation system installation.

The contractor shall submit a batch (tank) mix for the Engineer's approval prior to mixing any seed/mulch slurry. Batch mixing and coverage will be monitored throughout seeding operations.
The slurry mix of seed, fertilizer, wood cellulose fiber, tacking agent and water shall consist of or meet the following proportions:

Seed mix	as specified
Fertilizer (16-20-0)	100 pounds per acre
Wood cellulose fiber	1,800 pounds per acre
Tacking agent	80 pounds / active ingredient / acre

Due care shall be taken during the soil preparation and seeding operations to prevent damage to trees, shrubs and constructed surface and subsurface improvements. All work shall be performed in accordance with Subsection 107-12 of these Specifications.

The seed, fertilizer, mulch and tacking agent shall be applied to the designated areas using approved hydraulic seeding equipment. Mulch and seed materials which are placed upon trees, shrubs, drainage structures, traffic control devices, or other surfaces not designated as to receive seed shall be removed and the surfaces cleaned as directed by the Engineer.

805-3.03 **Preservation of Seeded Areas:** of the Standard Specifications is revised to read:

The contractor shall protect seeded areas from damage by traffic or construction equipment. Surfaces eroded or otherwise damaged following seeding and prior to final acceptance shall be repaired by regrading and reseeding as directed by the Engineer.

805-4 **Method of Measurement:** of the Standard Specifications is revised to read:

Seeding (Class II) will be measured by the square yard of ground surface to the nearest Square Yard.

805-5 **Basis of Payment**

The accepted quantities of seeding, measured as provided above, will be paid for at the contract price for the pay unit specified in the bidding schedule, complete-in-place.

No direct measurement or payment will be made for the preservation of seeded areas.

Appendix C

TOTAL FREQUENCY AND MEAN PLANT DENSITY

Table C: Total Frequency and Mean Plant Density
Total frequency and mean plant density for species noted within the 20 study sites.

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Acacia constricta	White-thorn acacia	0‡	0.00
Acacia greggii	Catclaw acacia	1	0.02
Acacia spp.	Acacia	9	0.24
Acacia stenophylla	Shoestring acacia	0‡	0.00
Allionia incarnata	Trailing four o'clock	5	0.53
Amaranthus graecizans	Prostrate pigweed	1	0.15
Ambrosia ambrosioides	Canyon ragweed	6	0.47
Ambrosia confertiflora	Slimleaf bursage	8	2.18
Ambrosia deltoidea	Triangle-leaf bursage	39	1.65
Amsinckia intermedia	Coast fiddleneck	1	0.05
Amsinckia spp.	Fiddleneck	4	2.38
Arabis spp.	Rock cress	1	12.88
Aristida adscensionis	Six-weeks three-awn	37	113.71
Aristida purpurea	Purple three-awn	31	38.03
Aristida spp.	Three-awn	6	7.29
Aristida ternipes	Spidergrass	6	6.07
Astragalus nuttallianus	Nuttal milkvetch	7	8.20
Atriplex canescens	Fourwing saltbush	13	0.70
Atriplex elegans	Wheelscale saltbush	1	0.11
Atriplex lentiformis	Big saltbush	1	0.03
Atriplex polycarpa	Alkali saltbush	4	0.50
Baccharis sarothroides	Desert broom	40	2.33
Bahia absinthifolia	Desert bahia	1	0.24
Baileya multiradiata	Desert marigold	31	7.64
Bebbia juncea	Sweetbush	4	0.21
Boerhaavia coccinea	Red spiderling	2	0.24
Boerhaavia coulteri	Coulter spiderling	2	0.24
Boerhaavia erecta	Spiderling	9	1.35
Boerhaavia intermedia	Spiderling	2	0.53
Boerhaavia megaptera	Winged spiderling	2	0.32
Boerhaavia pterocarpa	Winged spiderling	1	0.05
Boerhaavia spp.	Spiderling	2	0.29
Boerhaavia wrightii	Fourwing spiderling	1	0.36
Bouteloua aristidoides	Needle grama	11	46.63
Bouteloua barbata	Six-weeks grama	7	17.45
Bouteloua curtipendula	Side-oats grama	3	1.24

† Frequency data derived from the number of transects in which a given species occurred divided by the total number of transects.
‡ Species present onsite but not within transects.

Table C: Total Frequency and Mean Plant Density, *cont.*
Total frequency and mean plant density for species noted within the 20 study sites.

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Bouteloua repens	Slender grama	8	9.50
Bowlesia incana	Hairy bowlesia	10	10.15
Brassica nigra	Black mustard	2	3.03
Brassica spp.	Mustard	3	0.32
Brassica tournefortii	Asian mustard	1	1.71
Bromus rubens	Red brome	5	14.35
Bromus spp.	Brome	8	3.47
Camissonia chamaenerioides	Longcapsule suncup	1	0.06
Capsella bursa-pastoris	Shepherd's purse	1	0.09
Carlowrightia arizonica	Arizona wrightwort	1	0.21
Cassia covesii	Desert senna	40	2.85
Celtis pallida	Desert hackberry	2	0.05
Centaurea melitensis	Maltese starthistle	1	2.91
Cercidium floridum	Blue palo verde	2	0.08
Cercidium microphyllum	Foothills palo verde	6	0.11
Cercidium spp.	Palo verde	6	0.09
Chenopodium spp.	Lamb's quarters	1	0.09
Chilopsis linearis	Desert willow	1	0.02
Clematis drummondii	Old man's beard	1	1.03
Crassula erecta	Pigmy stonecrop	1	0.05
Cryptantha barbigera	Bearded cryptantha	4	1.42
Cryptantha spp.	Cryptantha	22	18.92
Cynodon dactylon	Bermuda grass	7	26.21
Dactyloctenium aegyptium	Crowfoot grass	1	0.50
Dalea neomexicana	Downy prairie clover	1	0.09
Dasylirion wheeleri	Desert spoon	1	0.02
Datura discolor	Desert thornapple	1	0.03
Descurainia pinnata	Tansymustard	7	7.14
Digitaria sanguinalis	Large crabgrass	2	22.43
Ditaxis neomexicana	New Mexico silverbush	3	0.58
Draba cuneifolia	Wedgeleaf draba	1	0.36
Dyssodia pentachaeta	Golden fleece	13	3.03
Encelia farinosa	Brittlebush	46	5.22
Enneapogon cenchroides	Common nine-awned grass	2	0.11
Ephedra viridis	Mormon tea	1	0.03
Eragrostis cilianensis	Stinkgrass	2	0.68

† Frequency data derived from the number of transects in which a given species occurred divided by the total number of transects.

‡ Species present onsite but not within transects.

Table C: Total Frequency and Mean Plant Density, *cont.*
Total frequency and mean plant density for species noted within the 20 study sites.

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Eragrostis echinochloidea	African lovegrass	3	0.29
Eragrostis lehmannia	Lehmann's lovegrass	9	18.22
Eragrostis mexicana	Lovegrass	1	0.23
Ericameria laricifolia	Turpentine bush	1	0.02
Erigeron divergens	Fleabane	5	1.79
Erigeron spp.	Erigeron	2	0.11
Eriochloa acuminata	Cupgrass	1	0.86
Eriogonum deflexum	Skeleton weed	7	0.83
Eriogonum fasciculatum	Shrubby buckwheat	15	1.51
Erioneuron puchellem	Fluff grass	33	27.88
Erodium cicutarium	Red-stemmed filaree	28	13.20
Erodium texanum	Texas stork's bill	1	0.05
Eucrypta chrysanthemifolia	Spotted hideseed	2	0.23
Euphorbia albomarginata	Rattlesnake weed	4	3.25
Euphorbia arizonica	Arizona sandmat	1	0.89
Euphorbia capitellata	Head sandmat	4	2.50
Euphorbia hyssopifolia	Hyssop spurge	5	0.79
Euphorbia melanadenia	Squaw sandmat	4	1.20
Euphorbia pediculifera	Carrizo Mountain sandmat	1	0.14
Euphorbia polycarpa	Ground spurge	7	2.83
Euphorbia setiloba	Yuma sandmat	2	1.35
Euphorbia spp.	Spurge	1	1.47
Ferocactus spp.	Barrel cactus	4	0.11
Filago californica	California cottonrose	12	22.22
Filago spp.	Cottonrose	2	1.09
Funastrum cynanchoides	Climbing milkweed	1	0.11
Glandularia spp.	Mock vervain	2	4.36
Gnaphalium palustre	Lowland cudweed	2	3.51
Gnaphalium spp.	Cudweed	2	0.21
Gutierrezia sarothrae	Broom snakeweed	2	0.06
Haplopappus tenuisectus	Burroweed	27	1.82
Hordeum pusillum	Little barley	1	0.33
Hymenoclea monogyra	Burrobrush	1	0.02
Hymenothrix wislizeni	Trans Pecos thimblehead	10	11.56
Lactuca serriola	Prickly lettuce	1	0.24
Lappula occidentalis	Western stickweed	8	6.01

† Frequency data derived from the number of transects in which a given species occurred divided by the total number of transects.

‡ Species present onsite but not within transects.

Table C: Total Frequency and Mean Plant Density, *cont.*
Total frequency and mean plant density for species noted within the 20 study sites.

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Larrea tridentata	Creosote bush	12	0.36
Lepidium lasiocarpum	Sand peppergrass	7	1.35
Lepidium medium	Medium pepperweed	2	5.01
Lepidium spp.	Peppergrass	2	0.36
Leptochloa uninervia	Mexican sprangletop	2	1.20
Lotus humistratus	Hill lotus	7	1.82
Lupinus sparsiflorus	Loose-flowered lupine	6	4.63
Lycium berlandieri	Wolfberry	1	0.02
Lycium fremontii	Fremont's desert-thorn	1	0.02
Malva spp.	Mallow	2	0.24
Mammillaria spp.	Pincushion cactus	1	0.02
Marina parryi	False prairie-clover	1	0.17
Medicago spp.	Medic	16	64.97
Melilotus indicus	Annual yellow sweetclover	1	0.39
Melilotus spp.	Sweetclover	2	0.18
Monolepis nuttaliana	Poverty weed	2	0.23
Nicotiana obtusifolia	Desert tobacco	4	1.74
Oligomeris linifolia	Lineleaf whitepuff	1	0.29
Opuntia lindheimeri	Cow's tongue prickly pear	1	0.02
Opuntia spp.	Prickly pear	1	0.02
Parkinsonia aculeata	Mexican palo verde	2	0.05
Parthenium incanum	Mariola	2	0.15
Pectocarya heterocarpa	Chuckwalla pectocarya	1	11.99
Pectocarya recurvata	Arch-nutted comb bur	13	14.01
Pectocarya spp.	Comb bur	5	6.57
Pennisetum ciliare	Buffelgrass	12	3.18
Pennisetum setaceum	Fountain grass	11	1.48
Plagiobothrys arizonicus	Arizona popcorn flower	2	0.15
Plantago insularis	Indian wheat	4	0.74
Plantago spp.	Plantain	2	1.32
Poa bigelovii	Bigelow's grass	12	34.88
Portulaca oleracea	Common purslane	3	0.15
Prosopis chilensis	Chilean mesquite	3	0.09
Prosopis spp.	Mesquite	1	0.03
Prosopis velutina	Velvet mesquite	14	0.41
Psilostrophe cooperi	Paper flower	4	0.15

† Frequency data derived from the number of transects in which a given species occurred divided by the total number of transects.
‡ Species present onsite but not within transects.

Table C: Total Frequency and Mean Plant Density, *cont.*
Total frequency and mean plant density for species noted within the 20 study sites.

Scientific Name	Common Name	Frequency†	Density
		%	plants 100 ft^{-2}
Rhus lancea	African sumac	1	0.02
Salsola tragus	Prickly Russian thistle	16	34.26
Schismus arabicus	Arabiangrass	9	18.40
Schismus barbatus	Mediterraneangrass	3	14.50
Schismus spp.	Schismus	25	42.19
Setaria macrostachya	Plains bristlegrass	1	0.24
Sida spinosa	Prickly fanpetals	1	0.12
Simmondsia chinensis	Jojoba	1	0.03
Sisymbrium irio	London rocket	6	7.02
Sisymbrium spp.	Mustard	3	4.74
Sonchus spp.	Sowthistle	4	0.51
Sphaeralcea ambigua	Globemallow	35	20.64
Sphaeralcea laxa	Caliche globemallow	3	0.50
Sporobolus cryptandrus	Sand dropseed	2	0.82
Sporobolus spp.	Dropseed	1	1.07
Stephanomeria pauciflora	Wire lettuce	1	0.03
Stylocline spp.	Nest straw	1	1.03
Tamarix aphylla	Salt cedar	0‡	0.00
Thelypodium lasiophyllum	California mustard	1	0.11
Tidestromia lanuginosa	Wooly tidestromia	1	3.78
Tiquilia canescens	Shrubby coldenia	1	0.02
Tridens muticus	Slim tridens	1	0.05
Veronica anagallis-aquatica	Water speedwell	1	0.39
Vulpia octoflora	Six-weeks fescue	4	14.88
Yucca spp.	Yucca	1	0.02
Zinnia acerosa	Desert zinnia	6	0.56
Ziziphus obtusifolia	Graythorn	1	0.02

† Frequency data derived from the number of transects in which a given species occurred divided by the total number of transects.
‡ Species present onsite but not within transects.

Appendix D

PLANT DENSITY AND COVER PER SITE

Table D.1: Plant Density and Cover for Site 1 (HDS seed mix)†
Plant density and cover value for species specified and non-specified during the revegetation of Hacienda del Sol Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	169.8	1.5
Ambrosia deltoidea	Triangle-leaf bursage	8.3	19.0
Dyssodia acerosa	Prickleleaf dogweed	4.3	---
Encelia farinosa	Brittlebush	1.0	7.5
Baileya multiradiata	Desert marigold	0.8	---
Eschscholtzia californica	California poppy	0.0	---
Lupinus arizonicus	Desert lupine	0.0	---
Plantago insularis	Indian wheat	0.0	---
Schismus barbatus	Mediterraneangrass	0.0	---
Setaria macrostachys	Plains bristlegrass	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**184.0**	**28.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	314.3	8.0
Erioneuron puchellem	Fluff grass	N	124.3	3.5
Euphorbia setiloba	Yuma sandmat	N	16.3	0.5
Hymenothrix wislizeni	Trans Pecos thimblehead	N	15.3	0.5
Erodium cicutarium	Red-stemmed filaree	I	11.8	---
Bahia absinthifolia	Desert bahia	N	4.0	---
Boerhaavia erecta	Spiderling	N	1.5	0.5
Baccharis sarothroides	Desert broom	N	0.8	8.0
Ferocactus spp.	Barrel cactus	N	0.8	---
Haplopappus tenuisectus	Burroweed	N	0.8	0.5
Dasylirion wheeleri	Desert spoon	N	0.3	0.5
Larrea tridentata	Creosote bush	N	0.3	3.0
Acacia constricta	White-thorn acacia	N	0.0¶	---
Cercidium microphyllum	Foothills palo verde	N	0.0¶	---
	Non-specified Total		**490.0**	**25.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.

§ N, native; I, introduced.
¶ Species present onsite but not within transects.

Table D.2: Plant Density and Cover for Sites 2a and 2c (TVR-1 seed mix)†
Plant density and cover value for species specified and non-specified during the revegetation of Tanque Verde Rd. between Pantano Rd. and Catalina Hwy.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Lupinus sparsiflorus	Loose-flowered lupine	45.0	3.0
Sphaeralcea ambigua	Globemallow	8.2	12.5
Cassia covesii	Desert senna	4.2	11.5
Eriogonum fasiculatum	Shrubby buckwheat	2.9	10.5
Aristida purpurea	Purple three-awn	1.6	0.5
Baileya multiradiata	Desert marigold	0.0	---
Calliandra eriophylla	Fairy duster	0.0	---
Cucurbita palmata	Coyote melon	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Oenothera hookeri	Evening primrose	0.0	---
Penstemon pseudospectablis	Penstemon	0.0	---
Plantago insularis	Indian wheat	0.0	---
Proboscidea althearolia	Devil's claw	0.0	---
Psilostrophe cooperi	Paper flower	0.0	---
Verbena tenuisecta	Verbena	0.0	---
	Specified Total	**61.9**	**38.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Bouteloua aristidoides	Needle grama	N	394.5	17.0
Poa bigelovii	Bigelow's grass	I	196.5	3.0
Vulpia octoflora	Six-weeks fescue	N	153.1	3.0
Arabis spp.	Rock cress	U	136.8	0.5
Schismus arabicus	Arabiangrass	I	78.5	1.0
Bouteloua barbata	Six-weeks grama	N	72.4	7.5
Filago californica	California cottonrose	N	71.4	0.5
Sisymbrium irio	London rocket	I	56.4	7.5
Lepidium medium	Medium pepperweed	N	53.2	1.0
Gnaphalium palustre	Lowland cudweed	N	37.3	0.5

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.2: Plant Density and Cover for Sites 2a and 2c (TVR-1 seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Tanque Verde Rd. between Pantano Rd. and Catalina Hwy.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	37.1	1.5
Schismus spp.	Schismus	I	37.0	1.0
Cynodon dactylon	Bermuda grass	I	32.2	7.5
Medicago spp.	Medic	I	31.0	0.5
Astragalus nuttallianus	Nuttal milkvetch	N	25.7	0.5
Bromus spp.	Brome	I	25.2	1.0
Amsinckia spp.	Fiddleneck	U	15.9	---
Clematis drummondii	Old man's beard	N	10.9	0.5
Bromus rubens	Red brome	I	10.8	3.0
Nicotiana obtusifolia	Desert tobacco	N	10.6	6.0
Eriochloa acuminata	Cupgrass	N	9.2	---
Erigeron divergens	Fleabane	N	8.7	---
Hymenothrix wislizeni	Trans Pecos thimblehead	N	5.5	0.5
Sphaeralcea laxa	Caliche globemallow	N	5.0	0.5
Erodium cicutarium	Red-stemmed filaree	I	4.3	0.5
Boerhaavia megaptera	Winged spiderling	N	3.4	1.0
Erioneuron puchellem	Fluff grass	N	3.2	1.0
Bowlesia incana	Hairy bowlesia	N	3.1	---
Boerhaavia spp.	Spiderling	N	2.7	0.5
Boerhaavia coulteri	Coulter spiderling	N	2.6	3.5
Lappula occidentalis	Western stickweed	N	1.9	---
Lepidium spp.	Peppergrass	N	1.6	---
Haplopappus tenuisectus	Burroweed	N	1.3	4.0
Portulaca oleracea	Common purslane	I	1.3	1.0
Boerhaavia erecta	Spiderling	N	1.1	---
Capsella bursa-pastoris	Shepherd's purse	I	1.0	---
Lepidium lasiocarpum	Sand peppergrass	N	1.0	---
Malva spp.	Mallow	I	1.0	---
Sonchus spp.	Sowthistle	I	1.0	---
Dyssodia pentachaeta	Golden fleece	N	0.6	0.5
Amsinckia intermedia	Coast fiddleneck	N	0.5	---
Baccharis sarothroides	Desert broom	N	0.5	4.0

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.
¶ Species present onsite but not within transects.

Table D.2: Plant Density and Cover for Sites 2a and 2c (TVR-1 seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Tanque Verde Rd. between Pantano Rd. and Catalina Hwy.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Cryptantha spp.	Cryptantha	N	0.5	---
Salsola tragus	Prickly Russian thistle	I	0.3	0.5
Cercidium spp.	Palo verde	N	0.0¶	---
Prosopis spp.	Mesquite	U	0.0¶	---
Rhus lancea	African sumac	I	0.0¶	---
Ziziphus obtusifolia	Graythorn	N	0.0¶	---
		Non-specified Total	**1547.9**	**80.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.3: Plant Density and Cover for Sites 2b and 2d (TVR-2 seed mix)†
Plant density and cover value for species specified and non-specified during the revegetation of Tanque Verde Rd. between Pantano Rd. and Catalina Hwy.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Sphaeralcea ambigua	Globemallow	42.3	23.5
Cassia covesii	Desert senna	3.4	1.5
Baileya multiradiata	Desert marigold	1.7	1.5
Lupinus sparsiflorus	Loose-flowered lupine	1.7	0.5
Ambrosia deltoidea	Triangle-leaf bursage	0.3	0.5
Aristida purpurea	Purple three-awn	0.0	---
Bouteloua curtipendula	Side-oats grama	0.0	---
Bouteloua eriopoda	Black grama grass	0.0	---
Calliandra eriophylla	Fairy duster	0.0	---
Cucurbita palmata	Coyote melon	0.0	---
Encelia farinosa	Brittlebush	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Oenothera hookeri	Evening primrose	0.0	---
Plantago insularis	Indian wheat	0.0	---
Proboscidea althearolia	Devil's claw	0.0	---
Psilostrophe cooperi	Paper flower	0.0	---
Schismus barbatus	Mediterraneangrass	0.0	---
Verbena tenuisecta	Verbena	0.0	---
	Specified Total	**49.4**	**27.5**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Filago californica	California cottonrose	N	265.7	9.0
Erodium cicutarium	Red-stemmed filaree	I	144.6	10.0
Aristida adscensionis	Six-weeks three-awn	N	129.7	13.0
Bouteloua repens	Slender grama	N	124.9	6.5
Cryptantha spp.	Cryptantha	N	124.9	2.0
Schismus spp.	Schismus	I	97.1	9.0
Medicago spp.	Medic	I	38.3	5.0

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.3: Plant Density and Cover for Sites 2b and 2d (TVR-2 seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Tanque Verde Rd. between Pantano Rd. and Catalina Hwy.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Cynodon dactylon	Bermuda grass	I	22.3	3.5
Haplopappus tenuisectus	Burroweed	N	4.0	2.5
Lepidium spp.	Peppergrass	N	4.0	0.5
Lepidium lasiocarpum	Sand peppergrass	N	3.4	0.5
Astragalus nuttallianus	Nuttal milkvetch	N	3.1	0.5
Malva spp.	Mallow	I	2.9	---
Descurainia pinnata	Tansymustard	N	2.3	0.5
Sisymbrium irio	London rocket	I	2.3	0.5
Erioneuron puchellem	Fluff grass	N	1.7	0.5
Boerhaavia erecta	Spiderling	N	1.4	0.5
Plantago spp.	Plantain	U	0.9	0.5
Portulaca oleracea	Common purslane	I	0.6	0.5
Ditaxis neomexicana	New Mexico silverbush	N	0.3	0.5
Larrea tridentata	Creosote bush	N	0.0¶	---
Prosopis spp.	Mesquite	U	0.0¶	---
Tamarix aphylla	Salt cedar	I	0.0¶	---
		Non-specified Total	**974.3**	**65.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.4: Plant Density and Cover for Site 3 (RR seed mix)†
Plant density and cover value for species specified and non-specified during the revegetation of River Rd. between Camino Arco and Craycroft Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	132.6	4.0
Eriogonum fasiculatum	Shrubby buckwheat	7.0	12.0
Encelia farinosa	Brittlebush	5.1	7.0
Ambrosia deltoidea	Triangle-leaf bursage	4.6	9.5
Baileya multiradiata	Desert marigold	4.0	0.5
Sphaeralcea ambigua	Globemallow	3.5	---
Cassia covesii	Desert senna	2.9	1.5
Atriplex semibacata	Australian saltbush	0.0	---
Bouteloua curtipendula 'Vaughn'	Side-oats grama	0.0	---
Eragrostis intermedia	Plains lovegrass	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Kallstroemia grandiflora	Arizona poppy	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
	Specified Total	**159.6**	**34.5**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	666.6	9.5
Bouteloua barbata	Six-weeks grama	N	74.6	0.5
Aristida spp.	Three-awn	N	19.8	0.5
Erioneuron puchellem	Fluff grass	N	15.2	0.0
Euphorbia polycarpa	Ground spurge	N	12.0	0.5
Allionia incarnata	Trailing four o'clock	N	3.2	0.5
Baccharis sarothroides	Desert broom	N	2.1	4.5
Boerhaavia erecta	Spiderling	N	1.9	1.0
Brassica spp.	Mustard	I	1.6	---
Cryptantha spp.	Cryptantha	N	0.8	---

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.
¶ Species present onsite but not within transects.

Table D.4: Plant Density and Cover for Site 3 (RR seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of River Rd. between Camino Arco and Craycroft Rd.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Dyssodia pentachaeta	Golden fleece	N	0.8	---
Pennisetum setaceum	Fountain grass	I	0.8	---
Celtis pallida	Desert hackberry	N	0.5	3.0
Cercidium spp.	Palo verde	N	0.5	1.0
Haplopappus tenuisectus	Burroweed	N	0.5	1.0
Prosopis spp.	Mesquite	N	0.0¶	---
		Non-specified Total	**801.1**	**22.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.
¶ Species present onsite but not within transects.

Table D.5: Plant Density and Cover for Site 4a (HR-1 seed mix)†
Plant density and cover value for species specified and non-specified during the revegetation of Houghton Rd. between Tanque Verde Rd. and Speedway Blvd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Baileya multiradiata	Desert marigold	28.9	4.5
Atriplex canescens	Fourwing saltbush	3.3	13.5
Cassia covesii	Desert senna	0.2	0.5
Acacia constricta	White-thorn acacia	0.0	---
Ambrosia deltoidea	Triangle-leaf bursage	0.0	---
Bouteloua curtipendula 'Vaughn'	Side-oats grama	0.0	---
Bouteloua gracilis 'Hachita'	Blue grama	0.0	---
Calliandra eriophylla	Fairy duster	0.0	---
Celtis pallida	Desert hackberry	0.0	---
Encelia farinosa	Brittlebush	0.0	---
Gaillardia aristata	Indian blanket	0.0	---
Gaillardia pulchella	Indian flower	0.0	---
Plantago insularis	Indian wheat	0.0	---
	Specified Total	**32.5**	**18.5**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Medicago spp.	Medic	I	485.1	3.5
Schismus spp.	Schismus	I	310.3	8.0
Schismus barbatus	Mediterraneangrass	I	150.2	0.5
Poa bigelovii	Bigelow's grass	I	132.9	1.5
Sphaeralcea ambigua	Globemallow	N	128.3	31.0
Bromus rubens	Red brome	I	122.3	0.5
Schismus arabicus	Arabiangrass	I	91.9	0.5
Sisymbrium spp.	Mustard	I	64.7	1.5
Aristida adscensionis	Six-weeks three-awn	N	63.8	1.0
Bouteloua aristidoides	Needle grama	N	48.6	0.5
Descurainia pinnata	Tansymustard	N	36.0	3.5
Dyssodia pentachaeta	Golden fleece	N	24.4	3.0

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.

Table D.5: Plant Density and Cover for Site 4a (HR-1 seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Houghton Rd. between Tanque Verde Rd. and Speedway Blvd.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Cryptantha spp.	Cryptantha	N	24.0	1.0
Astragalus nuttallianus	Nuttal milkvetch	N	23.8	0.5
Erodium cicutarium	Red-stemmed filaree	I	18.4	1.0
Erioneuron puchellem	Fluff grass	N	18.0	0.5
Filago californica	California cottonrose	N	17.2	---
Salsola tragus	Prickly Russian thistle	I	17.2	3.5
Sisymbrium irio	London rocket	I	11.0	0.5
Euphorbia polycarpa	Ground spurge	N	8.7	0.5
Erigeron spp.	Erigeron	N	9.1	---
Boerhaavia wrightii	Fourwing spiderling	N	5.0	3.00
Lepidium lasiocarpum	Sand peppergrass	N	4.8	---
Bowlesia incana	Hairy bowlesia	N	4.1	---
Euphorbia hyssopifolia	Hyssop spurge	N	3.5	1.00
Ambrosia confertiflora	Slimleaf bursage	N	3.3	---
Aristida purpurea	Purple three-awn	N	3.3	0.50
Lotus humistratus	Hill lotus	N	2.7	---
Melilotus spp.	Sweetclover	I	1.7	0.50
Baccharis sarothroides	Desert broom	N	1.5	14.00
Eriogonum fasciculatum	Shrubby buckwheat	N	1.5	7.50
Prosopis velutina	Velvet mesquite	N	1.5	8.00
Boerhaavia erecta	Spiderling	N	1.0	0.50
Haplopappus tenuisectus	Burroweed	N	1.0	3.50
Digitaria sanguinalis	Large crabgrass	I	0.6	---
Enneapogon cenchroides	Common nine-awned grass	N	0.6	---
Eragrostis cilianensis	Stinkgrass	I	0.6	---
Eragrostis lehmannia	Lehmann's lovegrass	I	0.6	---
Filago spp.	Cottonrose	N	0.6	---
Sporobolus cryptandrus	Sand dropseed	N	0.6	---
Atriplex lentiformis	Big saltbush	N	0.4	3.00
Atriplex polycarpa	Alkali saltbush	N	0.4	3.00
Lycium fremontii	Fremont's desert-thorn	N	0.2	0.50
		Non-specified Total	**1845.0**	**107.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.

Table D.6: Plant Density and Cover for Site 4b (HR-1 and HR-2 seed mix)†
Plant density and cover value for species specified and non-specified during the revegetation of Houghton Rd. between Tanque Verde Rd. and Speedway Blvd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Baileya multiradiata	Desert marigold	7.1	1.0
Erigeron divergens	Fleabane	4.9	---
Cassia covesii	Desert senna	3.0	4.0
Atriplex canescens	Fourwing saltbush	1.4	13.5
Encelia farinosa	Brittlebush	0.6	0.5
Abronia villosa	Sand verbena	0.0	---
Acacia constricta	White-thorn acacia	0.0	---
Ambrosia deltoidea	Triangle-leaf bursage	0.0	---
Bouteloua curtipendula 'Vaughn'	Side-oats grama	0.0	---
Bouteloua gracilis 'Hachita'	Blue grama	0.0	---
Calliandra eriophylla	Fairy duster	0.0	---
Celtis pallida	Desert hackberry	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Gaillardia aristata	Indian blanket	0.0	---
Gaillardia pulchella	Indian flower	0.0	---
Lupinus arizonicus	Desert lupine	0.0	---
Plantago insularis	Indian wheat	0.0	---
Verbena tenuisecta	Verbena	0.0	---
	Specified Total	**17.0**	**19.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Medicago spp.	Medic	I	322.9	3.5
Schismus spp.	Schismus	I	118.6	6.5
Pectocarya recurvata	Arch-nutted comb bur	N	86.2	0.5
Sphaeralcea ambigua	Globemallow	N	78.3	16.5
Bouteloua aristidoides	Needle grama	N	59.9	0.5
Astragalus nuttallianus	Nuttal milkvetch	N	51.8	---
Poa bigelovii	Bigelow's grass	I	49.4	1.0

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).

Table D.6: Plant Density and Cover for Site 4b (HR-1 and HR-2 seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Houghton Rd. between Tanque Verde Rd. and Speedway Blvd.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Salsola tragus	Prickly Russian thistle	I	49.2	0.5
Aristida purpurea	Purple three-awn	N	48.0	1.0
Brassica nigra	Black mustard	I	40.5	0.5
Erodium cicutarium	Red-stemmed filaree	I	25.1	1.0
Brassica tournefortii	Asian mustard	I	22.9	0.5
Euphorbia polycarpa	Ground spurge	N	20.2	0.5
Cryptantha spp.	Cryptantha	N	19.8	0.5
Sporobolus spp.	Dropseed	N	14.4	3.0
Descurainia pinnata	Tansymustard	N	8.9	---
Boerhaavia erecta	Spiderling	N	8.7	3.0
Eriogonum fasciculatum	Shrubby buckwheat	N	7.5	28.0
Dactyloctenium aegyptium	Crowfoot grass	I	6.7	---
Sonchus spp.	Sowthistle	I	4.9	---
Eriogonum deflexum	Skeleton weed	N	4.7	---
Bouteloua barbata	Six-weeks grama	N	3.4	---
Erioneuron puchellem	Fluff grass	N	3.4	---
Lepidium lasiocarpum	Sand peppergrass	N	3.4	---
Hymenothrix wislizeni	Trans Pecos thimblehead	N	3.2	0.5
Bowlesia incana	Hairy bowlesia	N	2.8	---
Baccharis sarothroides	Desert broom	N	2.8	11.0
Gnaphalium spp.	Cudweed	U	2.8	---
Lotus humistratus	Hill lotus	N	2.8	---
Euphorbia hyssopifolia	Hyssop spurge	N	2.2	---
Eragrostis echinochloidea	African lovegrass	I	2.0	---
Plagiobothrys arizonicus	Arizona popcorn flower	N	2.0	---
Prosopis velutina	Velvet mesquite	N	1.6	9.0
Atriplex elegans	Wheelscale saltbush	N	1.4	3.0
Allionia incarnate	Trailing four o'clock	N	1.4	---
Haplopappus tenuisectus	Burroweed	N	1.4	6.5
Boerhaavia coccinea	Red spiderling	N	1.0	0.5
Enneapogon cenchroides	Common nine-awned grass	N	0.8	---
Melilotus spp.	Sweetclover	I	0.8	0.5
Chilopsis linearis	Desert willow	N	0.2	0.5
		Non-specified Total	**1088.5**	**98.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.

‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).

Table D.7: Plant Density and Cover for Site 5a (IRR-1 seed mix)†

Plant density and cover value for species specified and non-specified during the revegetation of Irvington Rd. between Camino de Oeste and Mission Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Encelia farinosa	Brittlebush	17.2	23.0
Cassia covesii	Desert senna	13.8	12.0
Baileya multiradiata	Desert marigold	3.7	4.0
Ambrosia deltoidea	Triangle-leaf bursage	3.4	4.5
Atriplex canescens	Fourwing saltbush	1.5	3.5
Larrea tridentata	Creosote bush	0.4	0.5
Acacia constricta	White-thorn acacia	0.0	---
Acacia greggii	Catclaw acacia	0.0	---
Aristida purpurea	Purple three-awn	0.0	---
Atriplex lentiformis	Big saltbush	0.0	---
Atriplex polycarpa	Alkali saltbush	0.0	---
Bouteloua curtipendula 'Vaughn'	Side-oats grama	0.0	---
Celtis pallida	Desert hackberry	0.0	---
Cercidium floridum	Blue palo verde	0.0§	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Linum lewisii	Blue flax	0.0	---
Prosopis velutina	Velvet mesquite	0.0§	---
Psilostrophe cooperi	Paper flower	0.0	---
Setaria macrostachya	Plains bristlegrass	0.0	---
Sphaeralcea ambigua	Globemallow	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**39.9**	**47.5**

Non-specified

Scientific Name	Common Name	Origin¶	Density	Cover‡
			plants 100 ft^{-2}	%
Salsola tragus	Prickly Russian thistle	I	363.4	6.5
Bromus rubens	Red brome	I	107.8	7.5
Bowlesia incana	Hairy bowlesia	N	87.7	0.5

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ Species present onsite but not within transects.
¶ N, native; I, introduced.

Table D.7: Plant Density and Cover for Site 5a (IRR-1 seed mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Irvington Rd. between Camino de Oeste and Mission Rd.

Non-specified, *cont.*

Scientific Name	Common Name	Origin¶	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	77.2	6.0
Lappula occidentalis	Western stickweed	N	60.8	1.0
Euphorbia capitellata	Head sandmat	N	60.5	1.0
Cryptantha spp.	Cryptantha	N	36.6	---
Schismus spp.	Schismus	I	36.6	0.5
Pectocarya recurvata	Arch-nutted comb bur	N	34.7	1.0
Euphorbia melanadenia	Squaw sandmat	N	22.4	0.5
Aristida ternipes	Spidergrass	N	16.0	0.5
Boerhaavia intermedia	Spiderling	N	11.9	0.5
Atriplex spp.	Saltbush	N	11.6	18.0
Aristida spp.	Three-awn	N	10.5	0.5
Erioneuron puchellem	Fluff grass	N	8.6	0.5
Pennisetum ciliare	Buffelgrass	I	6.7	0.5
Eucrypta chrysanthemifolia	Spotted hideseed	N	5.6	0.5
Monolepis nuttaliana	Poverty weed	N	5.6	---
Carlowrightia arizonica	Arizona wrightwort	N	5.2	---
Cryptantha barbigera	Bearded cryptantha	N	4.1	---
Marina parryi	Parry's false prairie-clover	N	4.1	0.50
Euphorbia hyssopifolia	Hyssop spurge	N	3.0	0.50
Camissonia chamaenerioides	Longcapsule suncup	N	1.5	0.50
Zinnia acerosa	Desert zinnia	N	0.4	0.50
Ziziphus obtusifolia	Graythorn	N	0.4	0.50
		Non-specified Total	**982.8**	**48.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ Species present onsite but not within transects.
¶ N, native; I, introduced.

Table D.8: Plant Density and Cover for Site 5b (IRR-2 Mix)†

Plant density and cover value for species specified and non-specified during the revegetation of Irvington Rd. between Camino de Oeste and Mission Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	16.9	1.0
Encelia farinosa	Brittlebush	5.4	21.0
Baileya multiradiata	Desert marigold	2.4	2.5
Eriogonum fasciculatum	Shrubby buckwheat	2.4	9.5
Cassia covesii	Desert senna	1.6	2.0
Ambrosia deltoidea	Triangle-leaf bursage	1.0	1.0
Plantago insularis	Indian wheat	0.6	---
Sphaeralcea ambigua	Globemallow	0.6	1.0
Atriplex semibacata	Australian saltbush	0.0	---
Bouteloua curtipendula 'Vaughn'	Side-oats grama	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Linum lewisii	Blue flax	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Psilostrophe cooperi	Paper flower	0.0	---
	Specified Total	**30.8**	**38.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Cynodon dactylon	Bermuda grass	I	193.1	10.50
Aristida adscensionis	Six-weeks three-awn	N	184.3	11.00
Salsola tragus	Prickly Russian thistle	I	122.4	4.00
Glandularia spp.	Mock vervain	U	57.1	0.50
Centaurea melitensis	Maltese starthistle	I	38.1	0.50
Pectocarya recurvata	Arch-nutted comb bur	N	19.6	0.50
Lappula occidentalis	Western stickweed	N	17.3	0.50
Cryptantha barbigera	Bearded cryptantha	N	16.5	---
Hymenothrix wislizeni	Trans Pecos thimblehead	N	11.3	---

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.

‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.

§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).

¶ Species present onsite but not within transects.

Table D.8: Plant Density and Cover for Site 5b (IRR-2 Mix)†, *cont.*
Plant density and cover value for species specified and non-specified during the revegetation of Irvington Rd. between Camino de Oeste and Mission Rd.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Sisymbrium irio	London rocket	I	9.9	0.50
Schismus arabicus	Arabiangrass	I	7.1	---
Ditaxis neomexicana	New Mexico silverbush	N	6.8	0.50
Haplopappus tenuisectus	Burroweed	N	6.8	6.00
Vulpia octoflora	Six-weeks fescue	N	6.2	---
Melilotus indicus	Annual yellow sweetclover	I	5.2	---
Veronica anagallis-aquatica	Water speedwell	N	5.2	---
Hordeum pusillum	Little barley	N	4.4	---
Oligomeris linifolia	Lineleaf whitepuff	N	3.8	---
Boerhaavia coccinea	Red spiderling	N	2.2	---
Pennisetum ciliare	Buffelgrass	I	1.6	---
Prosopis chilensis	Chilean mesquite	I	1.2	8.50
Allionia incarnate	Trailing four o'clock	N	0.8	---
Baccharis sarothroides	Desert broom	N	0.8	1.50
Euphorbia melanadenia	Squaw sandmat	N	0.8	---
Nicotiana obtusifolia	Desert tobacco	N	0.8	3.00
Sonchus spp.	Sowthistle	I	0.8	---
Bowlesia incana	Hairy bowlesia	N	0.6	---
Prosopis spp.	Mesquite	U	0.4	0.50
Acacia spp.	Acacia	U	0.0¶	---
Cercidium spp.	Palo verde	N	0.0¶	---
		Non-specified Total	**724.8**	**48.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.9: Plant Density and Cover for Site 6 (SC Mix)†

Individual plant density and cover value for species specified and non-specified during the revegetation of Sabino Canyon Rd. between Cloud Rd. and Kolb Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	175.9	4.5
Baileya multiradiata	Desert marigold	36.3	1.0
Sphaeralcea ambigua	Globemallow	28.2	33.5
Cassia covesii	Desert senna	7.8	15.5
Ambrosia deltoidea	Triangle-leaf bursage	2.3	6.5
Bouteloua curtipendula 'Vaughn'	Side-oats grama	0.0	---
Dyssodia pentacheata	Golden fleece	0.0	---
Encelia farinosa	Brittlebush	0.0	---
Eriogonum fasciculatum 'arizonica'	Arizona buckwheat	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Linum lewisii	Blue flax	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Psilostrophe cooperi	Paper flower	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**250.6**	**61.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	224.1	17.5
Eragrostis lehmannia	Lehmann's lovegrass	I	133.7	3.0
Erioneuron puchellem	Fluff grass	N	56.5	1.5
Schismus arabicus	Arabiangrass	I	52.1	0.5
Cryptantha spp.	Cryptantha	N	50.3	---
Bouteloua repens	Slender grama	N	38.6	3.0
Euphorbia spp.	Spurge	N	25.1	0.5
Plantago spp.	Plantain	U	21.8	0.5
Eragrostis cilianensis	Stinkgrass	I	10.9	0.5

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.

‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.

§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).

Table D.9: Plant Density and Cover for Site 6 (SC Mix)†, *cont.*

Individual plant density and cover value for species specified and non-specified during the revegetation of Sabino Canyon Rd. between Cloud Rd. and Kolb Rd.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Haplopappus tenuisectus	Burroweed	N	8.8	18.5
Zinnia acerosa	Desert zinnia	N	8.6	6.5
Bromus spp.	Brome	I	4.4	0.5
Filago californica	California cottonrose	N	2.9	0.5
Funastrum cyanchoides	Climbing milkweed	N	1.8	---
Baccharis sarothroides	Desert broom	N	1.6	8.0
Lepidium lasiocarpum	Sand peppergrass	N	0.8	---
Ephedra viridis	Mormon tea	N	0.5	7.5
Gutierrezia sarothrae	Broom snakeweed	N	0.3	0.5
Larrea tridentata	Creosote bush	N	0.3	0.5
Rhus lancea	African sumac	I	0.3	0.5
		Non-specified Total	**643.0**	**70.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).

Table D.10: Plant Density and Cover for Site 7a (IR-1 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	13.1	1.0
Larrea tridentata	Creosote bush	2.0	16.0
Ambrosia deltoidea	Triangle-leaf bursage	0.9	2.0
Baileya multiradiata	Desert marigold	0.0	---
Bouteloua gracilis	Blue grama	0.0	---
Dimorphotheca sinuata	African daisy	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Gaillardia pulchella	Indian flower	0.0	---
Oenothera speciosa	Mexican primrose	0.0	---
Penstemon palmeri	Pink penstemon	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Psilostrophe cooperi	Paper flower	0.0	---
Sphaeralcea ambigua	Globemallow	0.0	---
	Specified Total	**16.0**	**19.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Erioneuron puchellem	Fluff grass	N	20.0	0.5
Encelia farinosa	Brittlebush	N	14.2	33.0
Pennisetum ciliare	Buffelgrass	I	9.6	1.0
Schismus barbatus	Mediterraneangrass	I	4.8	---
Pennisetum setaceum	Fountain grass	I	4.1	0.5
Schismus spp.	Schismus	I	4.1	---
Pectocarya spp.	Comb bur	N	3.0	---
Lotus humistratus	Hill lotus	N	1.8	---
Atriplex canescens	Fourwing saltbush	N	1.6	8.0
Baccharis sarothroides	Desert broom	N	1.4	2.0
Ambrosia confertiflora	Slimleaf bursage	N	1.2	---
Amsinckia spp.	Fiddleneck	U	1.2	---

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.10: Plant Density and Cover for Site 7a (IR-1 Mix)†, *cont.*
Individual plant density and cover value for species specified and non-specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Prosopis velutina	Velvet mesquite	N	0.7	11.0
Acacia spp.	Acacia	U	0.5	7.5
Boerhaavia pterocarpa	Winged spiderling	N	0.5	0.5
Cercidium spp.	Palo verde	N	0.5	4.0
Dyssodia pentachaeta	Golden fleece	N	0.5	1.0
Cassia covesii	Desert senna	N	0.4	1.0
Simmondsia chinensis	Jojoba	N	0.4	0.5
Ambrosia ambrosioides	Canyon ragweed	N	0.2	0.5
Boerhaavia erecta	Spiderling	N	0.2	0.5
Bebbia juncea	Sweetbush	N	0.2	0.5
Lycium berlandieri	Wolfberry	N	0.2	0.5
Mammillaria spp.	Pincushion cactus	N	0.2	0.5
Chilopsis linearis	Desert willow	N	0.0¶	---
		Non-specified Total	**71.5**	**73.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.11: Plant Density and Cover for Site 7b (IR-2 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	17.7	1.5
Encelia farinosa	Brittlebush	11.0	21.5
Ambrosia deltoidea	Triangle-leaf bursage	2.3	4.0
Atriplex canescens	Fourwing saltbush	2.1	3.5
Cassia covesii	Desert senna	1.4	3.5
Larrea tridentata	Creosote bush	0.5	1.0
Celtis pallida	Desert hackberry	0.2	3.0
Baileya multiradiata	Desert marigold	0.0	---
Dyssodia acerosa	Prickleleaf dogweed	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Lupinus succulentus	Arroyo lupine	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Setaria macrostachya	Plains bristlegrass	0.0	---
Sphaeralcea ambigua	Globemallow	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**35.1**	**38.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Cryptantha spp.	Cryptantha	N	14.7	---
Pennisetum setaceum	Fountain grass	I	10.3	4.00
Bebbia juncea	Sweetbush	N	2.8	15.00
Ambrosia ambrosioides	Canyon ragweed	N	2.1	8.00
Baccharis sarothroides	Desert broom	N	2.1	7.00
Euphorbia pediculifera	Carrizo Mountain sandmat	N	2.1	---
Cercidium microphyllum	Foothills palo verde	N	0.9	1.50
Pennisetum ciliare	Buffelgrass	I	0.9	---
Gutierrezia sarothrae	Broom snakeweed	N	0.7	3.00
Prosopis velutina	Velvet mesquite	N	0.5	1.00
Acacia greggii	Catclaw acacia	N	0.2	0.40
Parkinsonia aculeata	Mexican palo verde	N	0.2	3.00
	Non-specified Total		**37.4**	**42.9**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.

Table D.12: Plant Density and Cover for Site 7c (IR-3 Mix)†

Plant density and cover value for species specified and non-specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Baileya multiradiata	Desert marigold	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Lupinus succulentus	Arroyo lupine	0.0	---
Penstemon palmeri	Pink penstemon	0.0	---
	Specified Total	**0.0**	**0.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	30.7	6.0
Encelia farinosa	Brittlebush	N	11.4	26.0
Descurainia pinnata	Tansymustard	N	3.5	0.5
Bromus spp.	Brome	I	2.6	0.5
Cryptantha spp.	Cryptantha	N	2.6	0.5
Haplopappus tenuisectus	Burroweed	N	1.8	0.5
Ambrosia deltoidea	Triangle-leaf bursage	N	0.9	0.5
Sphaeralcea ambigua	Globemallow	N	0.9	0.5
Cercidium spp.	Palo verde	N	0.0¶	---
		Non-specified Total	**54.4**	**35.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.
¶ Species present onsite but not within transects.

Table D.13: Plant Density and Cover for Site 7d (IR-4 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Ambrosia deltoidea	Triangle-leaf bursage	2.6	4.5
Baileya multiradiata	Desert marigold	0.3	0.5
Eschscholtzia mexicana	Mexican poppy	0.0	---
Lupinus sparsiflorus	Loose-flowered lupine	0.0	---
Lupinus succulentus	Arroyo lupine	0.0	---
Penstemon parryi	Desert penstemon	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Sphaeralcea ambigua	Globemallow	0.0	---
	Specified Total	**2.9**	**5.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Pectocarya heterocarpa	Chuckwalla pectocarya	N	230.2	---
Bowlesia incana	Hairy bowlesia	N	109.6	0.5
Hymenothrix wislizeni	Trans Pecos thimblehead	N	84.3	0.5
Descurainia pinnata	Tansymustard	N	70.4	0.5
Schismus barbatus	Mediterraneangrass	I	59.3	0.5
Lappula occidentalis	Western stickweed	N	39.2	0.5
Aristida adscensionis	Six-weeks three-awn	N	29.9	3.0
Pectocarya spp.	Comb bur	N	29.1	0.5
Filago spp.	Cottonrose	N	20.1	---
Cryptantha spp.	Cryptantha	N	19.2	0.5
Euphorbia arizonica	Arizona sandmat	N	17.2	0.5
Bromus spp.	Brome	I	15.1	0.5
Pennisetum ciliare	Buffelgrass	I	15.1	0.5
Amsinckia spp.	Fiddleneck	U	14.8	1.0
Schismus arabicus	Arabiangrass	I	13.4	0.5
Nicotiana obtusifolia	Desert tobacco	N	13.1	---
Draba cuneifolia	Wedgeleaf draba	N	7.0	---

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.13: Plant Density and Cover for Site 7d (IR-4 Mix)†, *cont.*
Individual plant density and cover value for species specified and non-specified during the revegetation of Ina Rd. between Oracle Rd. and Chula Vista.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Encelia farinosa	Brittlebush	N	7.0	16.5
Euphorbia setiloba	Yuma sandmat	N	7.0	---
Ambrosia ambrosioides	Canyon ragweed	N	5.2	15.0
Boerhaavia erecta	Spiderling	N	4.4	3.0
Baccharis sarothroides	Desert broom	N	3.8	6.0
Erodium cicutarium	Red-stemmed filaree	I	2.6	0.5
Pennisetum setaceum	Fountain grass	I	2.6	7.5
Thelypodium lasiophyllum	California mustard	N	2.0	---
Erioneuron puchellem	Fluff grass	N	1.7	0.5
Cercidium floridum	Blue palo verde	N	1.5	10.5
Pectocarya recurvata	Arch-nutted comb bur	N	1.2	---
Acacia spp.	Acacia	U	0.9	4.0
Crassula erecta	Pigmy stonecrop	I	0.9	---
Cercidium microphyllum	Foothills palo verde	N	0.9	4.0
Eriogonum deflexum	Skeleton weed	N	0.9	0.5
Schismus spp.	Schismus	I	0.9	0.5
Cassia covesii	Desert senna	N	0.9	0.5
Datura discolor	Desert thornapple	N	0.6	0.5
Parkinsonia aculeata	Mexican palo verde	N	0.6	3.0
Dyssodia pentachaeta	Golden fleece	N	0.3	0.5
Ferocactus spp.	Barrel cactus	N	0.3	0.5
Haplopappus tenuisectus	Burroweed	N	0.3	0.5
Larrea tridentata	Creosote bush	N	0.3	0.5
Opuntia lindheimeri	Cow's tongue prickly pear	I	0.3	0.5
Celtis pallida	Desert hackberry	N	0.0¶	---
Prosopis spp.	Mesquite	U	0.0¶	---
		Non-specified Total	**833.4**	**84.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.14: Plant Density and Cover for Site 8a (PHR-1 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of Pistol Hill Rd. between Colossal Cave Rd. and Old Spanish Trail.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	11.4	---
Sphaeralcea ambigua	Globemallow	4.9	11.0
Cassia covesii	Desert senna	2.6	3.5
Bouteloua curtipendula 'Vaughn'	Side-oats grama	2.0	---
Baileya multiradiata	Desert marigold	1.6	1.5
Prosopis velutina	Velvet mesquite	1.3	4.0
Acacia constricta	White-thorn acacia	0.0	---
Acacia greggii	Catclaw acacia	0.0	---
Atriplex canescens	Fourwing saltbush	0.0	---
Atriplex lentiformis	Big saltbush	0.0	---
Atriplex polycarpa	Alkali saltbush	0.0	---
Celtis pallida	Desert hackberry	0.0	---
Cercidium floridum	Blue palo verde	0.0§	---
Encelia farinosa	Brittlebush	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Helianthus annus	Sunflower	0.0	---
Linum lewisii	Blue flax	0.0	---
Setaria macrostachya	Plains bristlegrass	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**23.7**	**20.0**

Non-specified

Scientific Name	Common Name	Origin¶	Density	Cover‡
			plants 100 ft^{-2}	%
Eragrostis lehmannia	Lehmann's lovegrass	I	148.1	6.0
Erioneuron puchellem	Fluff grass	N	132.1	4.5
Hymenothrix wislizeni	Trans Pecos thimblehead	N	99.4	---
Aristida adscensionis	Six-weeks three-awn	N	79.6	4.0
Aristida ternipes	Spidergrass	N	77.6	4.0

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ Species present onsite but not within transects.
¶ N, native; I, introduced.

Table D.14: Plant Density and Cover for Site 8a (PHR-1 Mix)†, *cont.*
Individual plant density and cover value for species specified and non-specified during the revegetation of Pistol Hill Rd. between Colossal Cave Rd. and Old Spanish Trail.

Non-specified, *cont.*

Scientific Name	Common Name	Origin¶	Density	Cover‡
			plants 100 ft^{-2}	%
Poa bigelovii	Bigelow's grass	I	63.6	3.0
Pectocarya spp.	Comb bur	N	53.6	0.5
Lotus humistratus	Hill lotus	N	23.4	0.5
Aristida spp.	Three-awn	N	14.0	---
Ambrosia confertiflora	Slimleaf bursage	N	11.7	2.0
Lupinus sparsiflorus	Loose-flowered lupine	N	6.5	0.5
Dyssodia pentachaeta	Golden fleece	N	4.9	2.0
Allionia incarnate	Trailing four o'clock	N	3.9	0.5
Euphorbia melanadenia	Squaw sandmat	N	3.9	0.5
Bouteloua barbata	Six-weeks grama	N	2.9	---
Psilostrophe cooperi	Paper flower	N	2.9	4.0
Parthenium incanum	Mariola	N	2.9	3.0
Ambrosia deltoidea	Triangle-leaf bursage	N	1.3	4.0
Haplopappus tenuisectus	Burroweed	N	1.3	3.5
Ditaxis neomexicana	New Mexico silverbush	N	1.0	---
Erigeron spp.	Erigeron	N	1.0	---
Ferocactus spp.	Barrel cactus	N	1.0	3.5
Tridens muticus	Slim tridens	N	1.0	---
Cercidium spp.	Palo verde	N	0.3	0.5
Opuntia spp.	Prickly pear	N	0.3	0.5
Yucca spp.	Yucca	N	0.3	0.5
Larrea tridentata	Creosote bush	N	0.0§	---
		Non-specified Total	**738.3**	**47.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ Species present onsite but not within transects.
¶ N, native; I, introduced.

Table D.15: Plant Density and Cover for Site 8b (PHR-2 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of Pistol Hill Rd. between Colossal Cave Rd. and Old Spanish Trail.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Bouteloua curtipendula 'Vaughn'	Side-oats grama	30.4	1.0
Aristida purpurea	Purple three-awn	26.4	1.0
Sphaeralcea ambigua	Globemallow	5.6	10.5
Atriplex semibacata	Australian saltbush	0.0	---
Baileya multiradiata	Desert marigold	0.0	---
Cassia covesii	Desert senna	0.0	---
Encelia farinosa	Brittlebush	0.0	---
Eragrostis intermedia	Plains lovegrass	0.0	---
Eriogonum fasiculatum	Shrubby buckwheat	0.0	---
Erigeron spp.	Fleabane	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Eschscholtzia mexicana	Mexican poppy	0.0	---
Evolvulus arizonicus	Arizona blue eyes	0.0	---
Linum lewisii	Bue flax	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
	Specified Total	**62.4**	**12.5**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Cynodon dactylon	Bermuda grass	I	192.4	3.5
Erioneuron puchellem	Fluff grass	N	149.2	5.0
Aristida spp.	Three-awn	N	134.8	4.0
Eragrostis lehmannia	Lehmann's lovegrass	I	91.6	4.0
Pectocarya spp.	Comb bur	N	60.8	0.5
Aristida ternipes	Spidergrass	N	47.6	1.0
Ambrosia confertiflora	Slimleaf bursage	N	34.0	8.0
Leptochloa uninervia	Mexican sprangletop	N	31.6	1.0
Stylocline spp.	Nest straw	N	27.2	---

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.15: Plant Density and Cover for Site 8b (PHR-2 Mix)†, *cont.*
Individual plant density and cover value for species specified and non-specified during the revegetation of Pistol Hill Rd. between Colossal Cave Rd. and Old Spanish Trail.

Non-specified, *cont.*

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Aristida adscensionis	Six-weeks three-awn	N	26.4	0.5
Bouteloua repens	Slender grama	N	16.8	0.5
Dyssodia pentachaeta	Golden fleece	N	13.2	0.5
Pectocarya recurvata	Arch-nutted comb bur	N	12.4	---
Euphorbia hyssopifolia	Hyssop spurge	N	6.4	0.5
Lactuca serriola	Prickly lettuce	I	6.4	---
Setaria macrostachya	Plains bristlegrass	N	6.4	0.5
Eragrostis mexicana	Lovegrass	N	6.0	0.5
Acacia spp.	Acacia	U	3.6	9.5
Eragrostis echinochloidea	African lovegrass	I	3.6	0.5
Sida spinosa	Prickly fanpetals	N	3.2	0.5
Dalea neomexicana	Downy prairie clover	N	2.4	---
Euphorbia melanadenia	Squaw sandmat	N	1.2	---
Lotus humistratus	Hill lotus	N	1.2	---
Prosopis velutina	Velvet mesquite	N	0.8	3.0
Sphaeralcea laxa	Caliche globemallow	N	0.8	1.0
Stephanomeria pauciflora	Wire lettuce	N	0.8	0.5
Bebbia juncea	Sweetbush	N	0.4	3.0
Baccharis sarothroides	Desert broom	N	0.4	0.5
Eriogonum deflexum	Skeleton weed	N	0.4	0.5
Ericameria laricifolia	Turpentine bush	N	0.4	0.5
Haplopappus tenuisectus	Burroweed	N	0.4	0.5
Psilostrophe cooperi	Paper flower	N	0.4	0.5
Parthenium incanum	Mariola	N	0.4	0.5
Cercidium spp.	Palo verde	N	0.0¶	---
Prosopis spp.	Mesquite	U	0.0¶	---
		Non-specified Total	**883.6**	**51.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).
¶ Species present onsite but not within transects.

Table D.16: Plant Density and Cover for Site 9a (FA-1 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of First Ave. between River Rd. and Orange Grove Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Aristida purpurea	Purple three-awn	31.1	1.0
Encelia farinosa	Brittlebush	2.1	1.5
Ambrosia deltoidea	Triangle-leaf bursage	1.6	1.5
Cassia covesii	Desert senna	1.6	1.5
Acacia constricta	White-thorn acacia	0.0§	---
Cercidium microphyllum	Foothills palo verde	0.0§	---
Eschscholtzia californica	California poppy	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Plantago insularis	Indian wheat	0.0	---
Prosopis velutina	Velvet mesquite	0.0	---
Sphaeralcea ambigua	Globemallow	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**36.3**	**5.5**

Non-specified

Scientific Name	Common Name	Origin¶	Density	Cover‡
			plants 100 ft^{-2}	%
Salsola tragus	Prickly Russian thistle	I	181.1	5.0
Aristida adscensionis	Six-weeks three-awn	N	163.2	1.0
Tidestromia lanuginosa	Wooly tidestromia	N	131.6	0.5
Cryptantha spp.	Cryptantha	N	81.6	0.5
Pennisetum setaceum	Fountain grass	I	9.5	1.0
Brassica spp.	Mustard	N	7.9	0.5
Baccharis sarothroides	Desert broom	N	7.4	9.5
Amaranthus graecizans	Prostrate pigweed	N	5.3	7.5
Pennisetum ciliare	Buffelgrass	I	5.3	0.5
Eriogonum deflexum	Skeleton weed	N	3.7	3.5
Erodium cicutarium	Red-stemmed filaree	I	2.6	0.5
Haplopappus tenuisectus	Burroweed	N	2.6	7.5
Bowlesia incana	Hairy bowlesia	N	1.6	---
Boerhaavia spp.	Spiderling	N	1.1	---
Hymenoclea monogyra	Burrobrush	N	0.5	3.0
Larrea tridentata	Creosote bush	N	0.0§	---
		Non-specified Total	**604.7**	**40.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ Species present onsite but not within transects.
¶ N, native; I, introduced.

Table D.17: Plant Density and Cover for Site 9b (FA-2 Mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of First Ave. between River Rd. and Orange Grove Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Encelia farinosa	Brittlebush	17.8	33.5
Cassia covesii	Desert senna	4.4	3.0
Sphaeralcea ambigua	Globemallow	0.3	0.5
Acacia constricta	White-thorn acacia	0.0	---
Ambrosia deltoidea	Triangle-leaf bursage	0.0	---
Aristida purpurea	Purple three-awn	0.0	---
Cercidium microphyllum	Foothills palo verde	0.0	---
Eschscholtzia californica	California poppy	0.0	---
Phacelia campanularia	Desert bluebells	0.0	---
Plantago insularis	Indian wheat	0.0	---
Prosopis velutina	Velvet mesquite	0.0	---
Sporobolus cryptandrus	Sand dropseed	0.0	---
	Specified Total	**22.5**	**37.0**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Digitaria sanguinalis	Large crabgrass	I	437.6	3.0
Bouteloua barbata	Six-weeks grama	N	117.8	1.0
Bouteloua aristidoides	Needle grama	N	28.4	1.0
Baccharis sarothroides	Desert broom	N	18.9	9.5
Pennisetum ciliare	Buffelgrass	I	18.9	3.5
Medicago spp.	Medic	I	6.8	---
Eriogonum deflexum	Skeleton weed	N	6.2	3.5
Erioneuron puchellem	Fluff grass	N	5.3	0.5
Aristida adscensionis	Six-weeks three-awn	N	3.0	---
Chenopodium spp.	Lamb's quarters	I	1.8	---
Dyssodia pentachaeta	Golden fleece	N	1.8	0.5
Ambrosia ambrosioides	Canyon ragweed	N	0.9	0.5
Boerhaavia intermedia	Spiderling	N	0.9	0.5
Cryptantha spp.	Cryptantha	N	0.9	---
Atriplex canescens	Fourwing saltbush	N	0.3	0.5
Salsola tragus	Prickly Russian thistle	I	0.3	0.5
Rhus lancea	African sumac	I	0.0¶	---

Non-specified Total	**649.7**	**24.5**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced.
¶ Species present onsite but not within transects.

Table D.18: Plant Density and Cover for Site 10 (GLR seed mix)†
Individual plant density and cover value for species specified and non-specified during the revegetation of Golf Links Rd. between Bonanza Ave. and Houghton Rd.

Specified

Scientific Name	Common Name	Density	Cover‡
		plants 100 ft^{-2}	%
Baileya multiradiata	Desert marigold	145.1	33.5
Sporobolus cryptandrus	Sand dropseed	28.0	0.5
Plantago insularis	Indian wheat	25.3	1.5
Encelia farinosa	Brittlebush	9.3	5.0
Cassia covesii	Desert senna	6.6	11.5
Ambrosia deltoidea	Triangle-leaf bursage	1.7	1.0
Sphaeralcea ambigua	Globemallow	0.6	0.5
Atriplex canescens	Fourwing saltbush	0.0	---
	Specified Total	**216.5**	**53.5**

Non-specified

Scientific Name	Common Name	Origin§	Density	Cover‡
			plants 100 ft^{-2}	%
Pectocarya recurvata	Arch-nutted comb bur	N	150.0	1.5
Euphorbia albomarginata	Rattlesnake weed	N	118.1	4.5
Erodium cicutarium	Red-stemmed filaree	I	35.7	1.5
Lepidium lasiocarpum	Sand peppergrass	N	15.4	---
Cryptantha spp.	Cryptantha	N	5.5	---
Lotus humistratus	Hill lotus	N	4.4	0.5
Larrea tridentata	Creosote bush	N	4.4	6.5
Schismus spp.	Schismus	I	3.3	---
Euphorbia capitellata	Head sandmat	N	1.7	---
Erodium texanum	Texas stork's bill	N	1.7	0.5
Zinnia acerosa	Desert zinnia	N	1.7	1.0
Acacia spp.	Acacia	U	0.6	0.5
Tiquilia canescens	Shrubby coldenia	N	0.6	0.5
	Non-specified Total		**342.9**	**17.0**

† Refer to Appendix A for detailed seed mix information and Appendix B for seeding specifications.
‡ Species cover values reflect the estimated canopy cover for each individual species and may include overlapping species within transects.
§ N, native; I, introduced; U, specimens identified to genus only (origin may vary).

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