Recovery and Conservation Plan for Four Invertebrate Species:

Noel's amphipod (*Gammarus desperatus*), Pecos assiminea (*Assiminea pecos*), Koster's springsnail (*Juturnia kosteri*), and Roswell springsnail (*Pyrgulopsis roswellensis*)

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1.0 ABOUT THE PLAN

The New Mexico Wildlife Conservation Act amendments of 1995 directed the New Mexico Department of Game and Fish to develop recovery plans for species listed as threatened and endangered under the Act (17-2-40.1[A] NMSA 1978). The four-fold purpose of a recovery plan is to: 1) restore and maintain viable populations of a listed species and its habitat, such that the species may be delisted; 2) mitigate adverse social or economic impacts resulting from recovery actions; 3) identify social or economic benefits and opportunities; and 4) use existing resources and funding sources, to the extent possible, to implement the plan (17-2-40.1[E]). Preparation of recovery plans that address several listed species that share a common habitat or that face similar threats is also encouraged in the Act (17-2-40.1[B]).

This Recovery and Conservation Plan addresses four semi-aquatic or aquatic invertebrate species listed as endangered under the Wildlife Conservation Act: Noels' amphipod (*Gammarus desperatus*), Pecos assiminea (*Assiminea pecos*), Koster's springsnail (*Juturnia kosteri*), and Roswell springsnail (*Pyrgulopsis roswellensis*). In New Mexico, all four of these species are currently known to be restricted to aquatic and wetland habitats on Bitter Lake National Wildlife Refuge, Chaves County.

The Department has little jurisdiction over the lands that the four species currently occupy or those where reintroduction would likely be attempted. Therefore, for this recovery effort to be fully successful, the Department must establish cooperative working relationships with other state, federal, and local government entities and private landowners. Accordingly, the first step in implementing this plan is the development and execution of agreements among all stakeholders so that recovery and conservation actions described herein can be developed and implemented.

This plan was developed with input from the public, as required by the Act (17-2-40.1[C and D] NMSA 1978). and in accordance with the long-range plan guidelines in the New Mexico Department of Game and Fish *Guidelines for Writing Long Range, Action, and Operational Plans* (Graves, 2002). The format and organization of the plan follow that guidance.

Section 2.0 of this plan includes background information on the distribution, habitat requirements, biology, and ecology of the four invertebrate species. Section 2.2 includes an analysis of factors that have led to the endangerment of the four species (*Historical Perspective*). Existing and potential future threats to the four invertebrate species are assessed in section 2.3 (*Habitat Assessment*).

Section 3.0 contains the goal for recovery and conservation of the four species, associated objective and objective parameters, issues associated with objective parameters, and strategies. An Action Plan for implementing tasks to achieve the recovery and conservation goal is also provided. The appendices contain a summary of public participation in development of the recovery and conservation plan (Appendix A), Oil Conservation Division regulations for installation of oil and gas wells (Appendix B), and a social and economic analysis (Appendix C).

Literature citation of this document should read as follows:

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2.0 BACKGROUND

Section 2.0 consists of background information on the distribution, status, habitat requirements, biology, and ecology of the four invertebrate species. This information provides the basis for assessing current status, threats to persistence, and the most effective recovery and conservation strategies for the four species.

2.1 NATURAL HISTORY

2.1.1 Description and Taxonomy

Noel's amphipod Noel's amphipod (Figure 1A) was described in 1981 by Cole from a 1967 collection of amphipods from Chaves County, New Mexico (Cole, 1981: 27). The type locality of the description of the species was North Spring on the Roswell County Club. The North Spring collection appeared to be the same species collected from Lander Springbrook in Chaves County by Noel in 1950 and mistakenly identified by her as *Gammarus fasciatus* (Cole, 1981: 27).

Amphipod species are primarily marine, although 900 species occur in fresh water worldwide occurring in subterranean and surface waters, including lakes and ponds and flowing water (streams, springs, etc). There are approximately 150 American species found in freshwater (Smith, 2001: 569). Two families of amphipods, Gammaridae and Hyalellidae, occur in New Mexico (Cole, 1981: 27). Noel's amphipod is in the family Gammaridae. Noel's amphipod is one of three described and four undescribed *Gammarus* species collectively known as the *Gammarus pecos* complex (Cole, 1985). The *Gammarus pecos* complex occurs in the Pecos River basin which extends from Roswell, Chaves County, New Mexico south to Fort Stockton, Pecos County, Texas.

Females of Noel's amphipod are generally smaller than males (Figure 1A). Males range in size from 9.45 mm to 14.8 mm (0.37 in to 0.58 in) while females are 8.5 mm to 12.6 mm (0.34 in to 0.50 in) long (Cole, 1981: 31). The following description is excerpted from Cole (1988a: 3-4):

> "Members of the genus *Gammarus* are easily distinguishable from *Hyalella* species by having the first pair of antennae longer than the second....the first antenna of *Gammarus* has a small accessory flagellum composed of three to seven segments. Thus, the antenna is Y-shaped, recalling the two-branched (biramous) ancestral or primitive crustacean appendage."
>
> (*Gammarus* has) "larger and more elongate eyes....The posterior pair of abdominal appendages, third uropods, are well developed and biramous....The *Gammurus* telson is bilobed and cleft to its base...."

Cole described the following features that distinguish *Gammarus desperatus* from *Gammarus lacustris*, which is the only other described gammarid species in New Mexico (Cole, 1988a: 4):

> "The eye of the (*Gammarus desperatus*) is ...elongate kidney-shaped. The eyes of *G. lacustris* are smaller and rounder...The 5th and 6th segments, especially of the last two pairs of pereopods in *G. desperatus* are setose, appearing hairy. Small spinules on these leg segments are accompanied by many long setae; similar short spinules in *G. lacustris* lack accompanying setae. The green-brown body of Noel's amphipod has bands of red on the sides of the thoracic and abdominal segments, and often a dorsal red strip is present. Red banding is not typical of *G. lacustris*."

In a recent study of genetic diversity in amphipods of the *Gammarus pecos* species complex (which includes *G. desperatus*), Gervasio et al. (2004) demonstrated the distinctness of this species from other closely related amphipods in isolated spring systems of the Chihuahuan Desert.

Pecos assiminea Pecos assiminea (Figure 1B and Figure 2) was described in 1987 from collections made in New Mexico, Texas, and México (Taylor, 1987: 8). The type locality of the species was a seepage area on the west side of Unit 7 on Bitter Lake National Wildlife Refuge. Pecos assiminea is unique in that it is the most inland species of the primarily marine genus *Assiminea*. Pecos assiminea is a very small, nut-brown colored snail in the family Assimineidae, which comprises mostly marine and brackish-water species (Taylor, 1987: 8). Assimineid snails and snails in the family Hydrobiidae, which also occur in New Mexico, are distinguished by internal gills and an operculum that covers the shell aperture (Pennak, 1989). The genus *Assiminea* is distinguishable from snails in the family Hydrobiidae by its almost complete lack of tentacles (Taylor, 1987: 8). The eyes occur instead in the tips of short eye stalks (Figure 2d).

Shell length of Pecos assiminea ranges from 1.36 mm to 2.16 mm (0.05 in to 0.08 in). Shell width ranges from 1.05 mm to 1.51 mm (0.04 in to 0.06 in). Females are larger than males. The following description is excerpted from Taylor (1987: 8):

> "The shell is minute, conical, with a spire angle of 55-60^{o}, and with up to 4½ strongly convex and regularly rounded whorls that are separated by an incised suture. The shell wall is translucent, glossy chestnut brown when fresh, thin but firm. The aperture is broadly ovate, nearly circular. The thin parietal lip is appressed simply to the preceding whorl, and passes smoothly into the thicker columellar lip. This lip is not flared but simply rounded and only slightly encroaches on the umbilicus that is contained in the shell diameter about 9 times. The thicker columellar lip thins as it passes gradually into the outer lip, which meets the parietal lip at an obtuse angle. The protoconch of about one whorl is smooth, glossy, abruptly set off from the later shell with definitive sculpture of fine, close-set, axial threads. These have little relief over most of the shell, but on the base and especially around the umbilicus become stronger, forming delicate, close rugae. Growth lines and plane of aperture are at an angle of about 10^{o} to the axis of coil. Spiral sculpture consists of very fine, irregular, discontinuous striae that commonly interrupt the fine growth-threads.
>
> Operculum corneous, paucispiral, pale amber, slightly concave externally, with no internal thickening."

Koster's springsnail Koster's springsnail (Figure 1C) was described in 1987 from collections made in Chaves County, New Mexico (Taylor, 1987:45). The type locality of the species is Sago Spring on Bitter Lake National Wildlife Refuge. This springsnail is in the family Hydrobiidae, the largest and most diverse family of freshwater snails in North America. The family Hydrobiidae includes approximately 36 genera (Smith, 2001:345). Although initially considered by Taylor (1987: 45) to be in the genus *Tryonia*, the species was reassigned first to the genus *Durangonella* (Hershler, 2001: 15) and then to the new genus *Juturnia* (Hershler et al., 2002: 175).

Shell length of the Koster's springsnail ranges from 2.64 mm to 4.56 mm (0.10 in to 0.18 in). Shell width ranges from 1.60 mm to 2.64 mm (0.06 in to 0.10 in). Females are larger than males (Taylor, 1987: 46). The following description is excerpted from Taylor (1987: 45-46):

> "Shell narrowly conical, with blunt apex and broadly rounded anterior end. Whorls up to 5¾ in larger specimens of both sexes, regularly convex and separated by an incised suture. Aperture broadly ovate, broadly rounded anteriorly and narrowly rounded posteriorly. Parietal part of peritreme simply adnate to preceding whorl, leaving an umbilical chink. Profile of aperture plane slightly oblique to axis of coil, posterior end in advance of anterior end. Sculpture of fine, irregular collabral growth lines. Periostracum pale tan.

Penis a flattened blade with little or no taper, opaque at the tip but generally with weak pigmentation of scattered melanin granules. A single papilla on the left distal margin is markedly variable in shape, averages much wider than long, and has a relatively small gland."

Roswell springsnail Roswell springsnail (Figure 1D) was described in 1987 from collections made in Chaves County, New Mexico (Taylor, 1987: 16). The type locality of the species was a seepage on the west side of Unit 7 of Bitter Lake National Wildlife Refuge. As with Koster's springsnail, this springsnail is in the Family Hydrobiidae. Roswell springsnail was initially considered by Taylor to be of the genus *Fontelicella* (Taylor, 1987: 15) but at about the same time, Hershler and Thompson (1987: 25) allocated the genus *Fontelicella* to *Pyrgulopsis*. Hershler reassigned *Fontelicella roswellensis* to *Pyrgulopsis roswellensis* in 2002 (Hershler, 1994: 63).

Shell length of the Roswell springsnail ranges from 2.4 mm to 3.8 mm (0.10 in to 0.15 in) with four to five whorls. The following description is excerpted from Hershler (1994: 63):

"Shell ovate-conic; height, 2.4-3.8 mm; whorls, 4-5. Protoconch finely punctate. Teleoconch whorls slightly-moderately convex, often strongly shouldered; sculpture of weak-moderate growth lines. Aperture adnate to slightly separated from body whorl. Inner lip complete, thickened; columellar lip reflected. Outer lip slightly prosocline. Umbilicus very narrowly rimate to shallowly perforate. Periostracum light tan.

Operculum ovate, amber, sometimes with internal calcareous smears; nucleus slightly eccentric; dorsal surface weakly frilled. Attachment scar margin thickened all around, broadly so along inner edge and between edge and nucleus; callus well developed.

Cephalic tentacles light-moderate brown. Snout moderate-dark brown. Foot dark along anterior and posterior edges, variably pigmented along sides. Opercular lobe margins dark, especially anterior edge; central region variably pigmented. Neck pale to light brown. Pallial roof, visceral coil dark brown-black."

2.1.2 Historic and Current Distribution

Noel's amphipod Noel's amphipod was historically known from Lander Springbrook, a tributary of the South Spring River near Roswell, where it was collected by Martha S. Noel in 1950 (Noel, 1954: 124) and North Spring on the Roswell Country Club from collections made in August 1967 and August 1978 (Figure 3; Cole, 1981: 27). Noel's amphipod was also collected from a sinkhole and from Bitter Creek (i.e. "Lost River") on Bitter Lake National Wildlife Refuge in 1988 (Cole, 1988b: 2).

The Lander Springbrook population of Noel's amphipod went extinct by about 1960 with drying of the spring (Cole, 1981: 27; Cole, 1988a: 1). The North Spring population of Noel's amphipod appears to have been extirpated as a result of habitat modification that occurred prior to May 1988 (Cole, 1981: 27; Cole, 1988a: 2). The species was not found in North Spring on the Roswell Country Club during a survey in August 2004 (B. Lang, New Mexico Department of Game and Fish, unpublished data). Noel's amphipod currently persists on Bitter Lake National Wildlife Refuge at the Sago Spring wetland complex (including Sinkhole No. 31), Bitter Creek, and along the western boundary of Unit 6 (Figure 3; Lang, 1999: A1; Lang, 2002: A2). Noel's amphipod appears to be declining at Dragonfly Spring at the headwaters of Bitter Creek following the Sandhill Fire that burned through the area in March 2000 (Lang, 2002: A2).

Pecos assiminea When Pecos assiminea was described in 1987, extant populations were found at three isolated localities: Bitter Lake National Wildlife Refuge in Chaves County, New Mexico; Diamond Y Draw in Pecos County, Texas; and in the Bolsón de Cuatro Ciénegas, Coahuila, Mexico (Figure 3; Taylor, 1987: 9). Taylor (1987: 8-9) reported extirpation of two populations in Chaves County: one at North Spring on the Roswell Country Club and the other at the type locality on Bitter Lake National Wildlife Refuge. Taylor (1987: 9) reported fossil Pecos assiminea from along the Pecos River near Grandfalls, Texas and the Rio Monclova, Coahuila, México.

Current status of the species in the Bolsón de Cuatro Ciénegas in Coahuila, México is unknown (U.S. Fish and Wildlife Service, 2002: 6461); it was last found at only one location there (Taylor, 1987: 9). Pecos assiminea persists at Diamond Y Spring in Pecos County, Texas (Lang, 2002: A5). A previously unknown population was discovered at East Sandia Spring in Reeves County, Texas on private lands under stewardship of The Nature Conservancy (Lang, 2000: A3). The species also persists at Bitter Lake National Wildlife Refuge. Populations on Bitter Lake National Wildlife Refuge currently are found in the upper reaches of Bitter Creek near Dragonfly Spring, the lower end of Bitter Creek near Bitter Lake, the lower reaches of the Sago Spring wetland complex near Sinkhole No. 31, on the western perimeter of Unit 7 (very localized), and at a spring in the extreme southwestern corner of Unit 15 (Figure 3; Lang, 2002: A5). The species was not found at North Spring on the Roswell Country Club during a survey in August 2004 (B. Lang, New Mexico Department of Game and Fish, unpublished data)

Table 1. Historic locality records of the four endangered invertebrate species in Chaves County, New Mexico, excluding current and historic localities at Bitter Lake National Wildlife Refuge, as reported in the indicated reference.

Species	Historic Records	Reference
Noel's Amphipod	"Lander Springbrook"	Cole (1981:27)
	North Spring, Roswell Country Club	Cole (1988b:2)
Pecos assiminea	North Spring, Roswell Country Club	Taylor (1987:8)
Koster's Springsnail	"Berrendo River"	Taylor (1987:47)
	North Spring River	Taylor (1987:47)
	South Spring River	Taylor (1987:47)
	"Near new Pecos bridge near Roswell, west side of river, from white marl"	Taylor (1987:47)
Roswell Springsnail	"Berrendo River"	Taylor (1987:16)
	"Pecos River northeast of Roswell"	Taylor (1987:16)
	"Lander Springbrook"	Taylor (1987:16)

Koster's springsnail Fossil shells of Koster's springsnail, presumably of Pleistocene age, have been collected from North Spring River, South Spring River, Berrendo Creek, and the Pecos River near Roswell (Figure 3; Taylor, 1987: 47). Five populations of Koster's springsnail, all from New Mexico, were known when the species was described in 1987. Four of these populations were on Bitter Lake National Wildlife Refuge at the following locations: throughout Bitter Creek; in a 0.4-km (0.25-mi) reach of an unnamed creek along the west side of Unit 3; in a seep draining into a ditch along the west side of Unit 6; and at Sago Spring, the type locality. The fifth population was known from North Spring on the Roswell Country Club from collections made from 1968 to 1981 (Taylor, 1987: 47).

The current distribution of Koster's springsnail appears to be restricted to Bitter Lake National Wildlife Refuge. The status of Koster's springsnail was unknown at the Roswell Country Club following a survey in 1995 due to lack of access to the site (Lang, 1998: B78). However, in August 2004, the site was resurveyed and this species could not be found (B. Lang, New Mexico Department of Game and Fish, unpublished data). Koster's springsnail persists in Lake St. Francis, Dragonfly Spring, Bitter Creek, Sago Spring, Sinkhole No. 31, the southwestern corner of Unit 15, the northwestern border of Hunter Marsh, and in isolated locations along the western boundaries of Units 5, 6, and 7 (Figure 3; Mehlhop, 1992; Lang, 2002: A16). Koster's springsnail has not been found in recent times along the western boundary of Unit 3 (Lang, 2002: A16).

Roswell springsnail Fossil specimens of Roswell springsnail have been collected from Berrendo Creek and the Pecos River northeast of Roswell (Figure 3; Taylor, 1987: 16). Four populations of Roswell springsnail were known when the species was described in 1987. All of these occurred within Chaves County, and three of them were within Bitter Lake National Wildlife Refuge. The latter were located at a seep draining into a ditch along the west side of Unit 6, a seepage area on the west side of Unit 7 (the type locality), and Sago Spring. The fourth population was known from North Spring on the Roswell Country Club grounds from collections made from 1968 to 1981 (Taylor, 1987: 16).

Current distribution of Roswell springsnail appears to be restricted to Bitter Lake National Wildlife Refuge. No specimens of Roswell springsnail have been collected at Roswell Country Club since 1995, and its status there could not be assessed in subsequent years due to lack of access to the site (Lang, 1998: B78). A survey at the Roswell Country Club in August 2004 indicated that the Roswell springsnail was no longer present (B. Lang, New Mexico Department of Game and Fish, unpublished data) Roswell springsnail persists in Bitter Creek, Sago Spring, Sinkhole No. 31, and along the western boundary of Unit 6 (Figure 3; Mehlhop, 1992; Mehlhop, 1993; Lang, 2002: A16). Koster's springsnail has not been found in recent times along the western boundary of Unit 3 (Lang, 2002: A16). The type locality on the western boundary of Unit 7 was reported as being dry in 1992 (Mehlhop, 1992: 5); however, surveys in 2002 documented the persistence of the Roswell springsnail at this site (B. Lang, New Mexico Department of Game and Fish, unpublished data).

All four species have been surveyed for at spring sites at Bottomless Lakes State Park, southeast of Bitter Lake National Wildlife Refuge. Although potentially suitable habitat is available at Bottomless Lakes, no evidence of these species has been found there (B. Lang, New Mexico Department of Game and Fish, unpublished data).

2.1.3 Habitat Requirements

Noel's amphipod Gammarid amphipods typically are found in shallow, cool, well-oxygenated waters of small streams, ponds, ditches, sloughs and springs (Holsinger, 1976: 3; Smith, 2001: 574). Amphipods in general require high dissolved oxygen concentrations and relatively high calcium concentration (Smith, 2001: 574). Acidity is a limiting factor for amphipods, with a *p*H of 6.0 generally constituting a lower threshold and 8.0 an upper threshold (Smith, 2001: 574). They are found in beneath stones and in aquatic vegetation during daylight hours (Cole, 1988a: 5; Smith, 2001: 572-574). Noel's amphipod was found mainly on rubble and rubble-sand substrate at Lander Springbrook and less frequently on silt substrate or vegetation (Noel, 1954: 124). Habitats on Bitter Lake National Wildlife Refuge range from dense beds of emergent aquatic macrophytes to clear, flowing springbrooks with submerged aquatic vegetation, vegetated banks and margins, and clean substrates (Figure 4). Standing water and silt accumulation appear to constitute unsuitable habitat for the species (Lang, 2000: A1). Lang (2002: A2) reported that the addition of stones, which increased stream gradient and current velocity, improved habitat for Noel's amphipod along the western boundary of Unit 6. Salinity in habitats occupied by amphipods of the *Gammarus-pecos* complex is low to moderate, ranging from 0.12 ppt to 5.85 ppt (Cole, 1988a: 5). Cole (1981: 27) reported chemical composition of the water at North Spring to be similar to that described at Lander Springbrook (Noel, 1954: 123): impure gypsum substrate, sulfate- and chloride-rich waters, and calcium as the primary cation.

Pecos assiminea Taylor (1987: 9) described the habitat of Pecos assiminea as "moist earth beside seepages or spring-brooks; never beside standing water" and that they occurred "beneath salt grass or sedges, less often on exposed surfaces." Lang (2002: A5) reported that Pecos assiminea was closely associated with wetland habitats characterized by soils saturated at the surface and vegetation dominated by American three-square (*Scirpus americanus*), common reed (*Phragmites australis*), and spike rush (*Eleocharis* spp.) with inland saltgrass (*Distichlis spicata*) and rushes (*Juncus* spp.) also occurring as common species in the wetland plant community. The snail typically occurs near the surface of the soil beneath litter and vegetation in these habitats. Pecos assiminea occupies wetland habitats along the margin of Bitter Creek, particularly near the mouth at Bitter Lake, at the type locality near Unit 7, and at Sinkhole No. 31 at the lower end of the Sago Spring complex, where the species is most abundant (Figure 5). Although Pecos assiminea is most common in non-inundated wetland habitat, it may also rarely occur in aquatic habitats of Bitter Creek and Sago Spring (Lang, 1998: 13). The snail was found at a density of about $64/m^2$ ($5.95/ft^2$) in water depths ranging from 5.0 cm to 21 cm (0.06 in to 8.27 in) in these aquatic habitats (Lang, 1998: 13). The species does not appear to persist in conditions of fluctuating water level or standing water in wetlands that are subject to winter freezing (Lang, 2000: A2).

Koster's springsnail and Roswell springsnail Both Koster's springsnail and Roswell springsnail are in the Family Hydrobiidae. All nine described hydrobiids of New Mexico (Taylor, 1987; Hershler et al., 2002) are state endemics that typically occur in small, geographically isolated habitats consisting of eurythermal (i.e. fluctuating temperature) springs and spring-fed wetland systems restricted to the southern half of the state (Lang, 1998: B77). Habitat of Koster's springsnail consists of soft substrates of springs and seeps (Taylor, 1987: 47), and Lang (1998: 13) found the species to be most abundant in the deep organic substrates of Bitter Creek. Roswell springsnail, on the other hand, was found to be most abundant on indurate, or hard, gypsum substrate in Sago Spring outflow channels and pools (Lang, 1998: 13).

Both springsnails are found throughout Bitter Creek, which varies in water temperature from the headwaters at Dragonfly Spring to the downstream reaches near the mouth of Bitter Lake. The upstream reaches of Bitter Creek are characterized by a relatively stable temperature regime with a narrow range of fluctuation (Lang, 1998: 15). Water temperature at Dragonfly Spring varied only about 4.6°C (8.3°F) from 13.6°C (56.5°F) to 18.2°C (64.8°F) from October 1996 through June 1998 (Lang, 1998: 16). Water temperature was much more variable during the same period in the lower reach of Bitter Creek, ranging from 0°C (32°F) to 31°C (87.8°F). Water temperature regimes are less variable in the Sago Spring complex than in Bitter Creek (Lang, 1998: 15). Water temperature varied about 3.5°C (6.3°F), from 17.0°C (62.6°F) to 20.5°C (68.9°F) at the headspring of Sago Spring and about 6.1°C (10.9°F) from 15.7°C (60.3°F) to 21.8°C (71.2°F) in the outflow at Sago Spring (Lang, 1998: 20-21). Salinity in Bitter Creek ranged from about 4.5 ppt to near 6 ppt. Dissolved oxygen in Bitter Creek ranged from about 1.0 ppm to over 20 ppm from 1995 to 1998, with lowest levels occurring in summer evening hours and highest levels during daytime hours in spring. Variation in *p*H was from about 6.67 to 8.20 (Lang, 1998: 22-24).

2.1.4 Reproduction

Specific breeding and reproductive characteristics of the four invertebrate species have not been well studied. The following discussion is therefore based largely on general characteristics at higher taxonomic levels that include each of the four species.

Noel's amphipod Most amphipods breed between February and October (Smith, 2001: 572). *Gammarus* males and females pair for one to seven days, feeding and swimming together prior to copulation which lasts less than one minute. Fertilized eggs are retained in a brood pouch, or marsupium, where they incubate for one to three weeks. Young remain in the marsupium for another one to eight days before being released (Smith, 2001: 573). The breeding season for Noel's amphipod is likely from February through October and is dependent on water temperature. Most amphipods live one year or less (Smith, 2001: 574).

Pecos assiminea Pecos assiminea is dioecious (i.e., individual snails are strictly male or female) and fertilization is internal. Eggs are likely deposited in gelatinous masses, as is characteristic of most mesogastropod snails (Barnes, 1980: 372). Some gastropods may reach sexual maturity in as little as six months (Barnes, 1980: 375); however nothing is known about specific development in Pecos assiminea. Similarly, nothing is known about the seasonality, frequency of breeding, fecundity, or other aspects of reproduction of Pecos assiminea.

Koster's springsnail and Roswell springsnail Hydrobiid snails are sexually dimorphic (i.e., males and females differ in external appearance) and the male copulatory organ, commonly called a "verge," projects from the vicinity of the neck and cannot be retracted (Smith, 2001: 330, 337, 338). Little is known about the specific reproductive habits of Koster's or Roswell springsnail. These species breed seasonally from March through September (Lang, 1998: B78). Unlike most hydrobiid snails that lay eggs in adhesive masses, Koster's and Roswell springsnail are ovoviviparous, with serial production of live young as opposed to broods. Thus, population recruitment is continuous throughout the breeding season. Individuals likely live for less than one year (Taylor, 1985: 16).

2.1.5 Food Habits

No detailed studies of any of the four invertebrate species have been conducted, therefore nothing is known of their specific feeding ecology and preferred food items. The following discussion is based on general characteristics at higher taxonomic levels that include each of the four species.

Noel's amphipod Amphipods are omnivorous, feeding on a wide variety of plant and animal matter and detritus. Noel's amphipod is often found in beds of submerged aquatic plants, which indicates that they probably browse on a surface film of algae, diatoms, bacteria, and fungi (Smith, 2001: 572). Juveniles are dependent on microbial foods, such as algae and bacteria, associated with periphyton or aquatic plants (Thorp and Covich, 1991).

Pecos assiminea Mesogastropod snails, which include Pecos assiminea, have a radula, or file-like rasp, situated behind the mouth (Barnes, 1980: 348). The radula is used to scrape food from the foraging surface into the mouth. Pecos assiminea likely forage on live and dead vegetation and coarse organic matter, where they probably consume bacteria, detritus, fungi, and algae (New Mexico Department of Game and Fish, 1988).

Koster's springsnail and Roswell springsnail Freshwater gastropods are chiefly vegetarian, consuming primarily algae, bacteria, and fungi from submerged surfaces. They may also eat dead plant and animal material (Smith, 2001: 332). Taylor (1985: 16), studying species of *Tryonia* (sensu lato; that is, including *Juturnia*) other than *kosteri*, found they were "fine-particle feeders on detritus, and presumably on the bacteria and protists in mud and *aufwuchs* [the community of aquatic organisms and detritus coating submerged objects]."

2.1.6 General Habits

Noel's amphipod Amphipods are nocturnal, as they are extremely light-sensitive, and are strongly thigmotactic (i.e., they orient themselves by contact with the substrate; Smith, 2001: 574). Amphipods respirate primarily through coxal gills (Smith, 2001: 572).

Pecos assiminea Respiration in Pecos assiminea is by direct air breathing, via trapping of an air bubble in the mantle cavity, and the habit of the species is amphibious (Taylor, 1983; Lang, 1998: 26). The gills in Pecos assiminea are vestigial (Taylor, 1983: 14). Pecos assiminea is probably most active at night (Lang, 1998: 26).

Koster's springsnail and Roswell springsnail Koster's and Roswell springsnail are prosobranch snails, which have internal gills for aquatic respiration. A small amount of oxygen absorption may also occur through the mantle (soft body) surface (Smith, 2001: 335, 344). These two springsnails appear to select different substrates, which is a behavior that is well documented in aquatic snails (Brown, 1991: 293).

2.1.7 Population Dynamics

Noel's amphipod Amphipod populations can achieve exceedingly high densities, sometimes in excess of 10,000/m^2 (929/ft^2; Smith, 2001: 574). This species was reported by Noel (1954: 124) to be the most abundant macroinvertebrate at Lander Springbrook, with densities ranging from 2,228/m^2 (207/ft^2) to 10,416/m^2 (968/ft^2). Population density of Noel's amphipod at sites on Bitter Lake National Wildlife Refuge in 1995 and 1996 ranged from 64/m^2 (6/ft^2) to 8,768/m^2. (815/ft^2) at Bitter Creek and 20/m^2 (2/ft^2) to 575/m^2 (53/ft^2) at Sago Spring wetland complex (Lang, 1999: A1). Density of Noel's amphipod at Unit 6 in 1999 was 344/m^2 (32/ft^2; Lang, 2002: A1).

Amphipods generally do not tolerate habitat dessication or other adverse environmental conditions and are thus sensitive to habitat degradation (Smith, 2001: 575). Lang (2002: A2) found this to be true in Noel's amphipod. The Sandhill Fire burned through Dragonfly Spring in March 2000. The fire eliminated vegetation shading at the spring and generated a substantial amount of ash input to the system. Subsequently, water temperature fluctuations and maxima increased and dissolved oxygen levels decreased at the site (Lang, 2002: B4). Dense algal blooms occurred, forming thick floating mats and blankets on the substrate at the spring. A monotypic, dense stand of common reed (*Phragmites australis*), a native perennial grass (Allred, 1993: 163), colonized the burned area (Figure 6). This stand of common reed replaced the pre-fire submerged aquatic macrophyte community as the dominant vegetation at the site. Noel's amphipod was present at a density of 11,625/m^2 at Dragonfly Spring in June 1996, prior to the fire; only four individuals were found at the site following the fire in April 2000 (Lang, 2002: B7).

High population densities in gammarid amphipods are not uncommon and cannibalism may occur at density extremes when food supply becomes limiting (Smith, 2001: 575). Seasonal or long-term movements of amphipods have been reported, indicating that hydrologically connected habitats may be recolonized following local extirpation (Smith, 2001: 575). Predation by fish, birds, and aquatic insects (Smith, 2001: 576) may also play a role in regulating population size of Noel's amphipod.

Pecos assiminea Populations of Pecos assiminea can achieve relatively large size and density (e.g. Taylor, 1985). Little is known about factors regulating population size of Pecos assiminea. Fluctuating surface water levels and winter freezing of inundated areas appears to limit population size and possibly persistence of the species (Lang, 2000: A2).

Taylor (1987: 8-9) reported local extinction of two populations of Pecos assiminea in New Mexico: one at the type locality along the western boundary of Unit 7 on Bitter Lake National Wildlife Refuge and another at North Spring on the Roswell Country Club (Figure 1). Subsequent rediscovery of Pecos assiminea at the type locality indicates that either the population was not extirpated or that the site was recolonized.

Dispersal of the species may rarely occur through downstream transport in stream systems. Lang (1998: 26) reported one live individual in the drift of Sago Spring outflow. However, due to the primarily terrestrial habit of Pecos assiminea and its rarity in aquatic habitat, this mode of dispersal is likely extremely limited. Thus, the potential for natural recolonization of suitable habitat following local extinction is probably very low.

Removal of vegetative cover by burning in habitats of Pecos assiminea has been suggested as an important factor in decline or loss of populations (Taylor, 1987: 9). However, Pecos assiminea persisted at Sago Spring despite burning of the habitat in spring 1997 (Lang, 2000: C3). Pecos assiminea was also discovered at Dragonfly Spring following burning of habitat there during the Sandhill Fire in March 2000. It appears that season of burning, intensity of the fire, and frequency of fire are important determinants of effects on population persistence and abundance (Lang, 1999: A3). It is likely that Pecos assiminea may survive fire or other vegetation reduction if sufficient litter and ground cover remain to sustain appropriate soil moisture and humidity at a microhabitat scale. Complete combustion of vegetation and litter, high soil temperatures during fire, or extensive vegetation removal resulting in soil and litter drying, may eliminate populations and render habitat unsuitable.

Koster's springsnail and Roswell springsnail Resource abundance and productivity appears to be an important factor in regulating population size of snails. Reductions in fecundity and juvenile survival with increases in population size and increased competition for limited food resources has been demonstrated for several freshwater taxa (Thorp and Covich, 1991: 295). Populations of Koster's springsnail may reach very high densities, at which point high incidence of trematode infestation and parasitic castration may regulate reproduction and thus, population size (Taylor, 1987: 47).

Koster's springsnail was found in densities ranging from 704/m^2 (65/ft^2) to 89,472/m^2 (8,315/ft^2) in Bitter Creek in 1995 and 1996. Lower densities were found in Sago Spring, ranging from 51/m^2 (5/ft^2) to 75/m^2 (7/ft^2; Lang, 1999: A10). Conversely, Roswell springsnail occurred at densities ranging from 1,125/m^2 (104/ft^2) to 27,924/m^2 (2,595/ft^2) at Sago Spring and only 64/m^2 (6/ft^2) to 512/m^2 (47/ft^2) at Bitter Creek in 1995 and 1996 (Lang, 2002: A12). This corresponds to the abundance of hard gypsum substrate, which appears to be preferred by Roswell springsnail, at Sago Spring compared to Bitter Creek (Figure 7).

2.2 HISTORICAL PERSPECTIVE

Changes that have occurred in habitat for the four invertebrate species, based on available information, are described in this section. Also, an analysis of changes that likely occurred in distribution and abundance of the four invertebrate species is presented.

2.2.1 Habitat Trends

Changes in Groundwater Hydrology All four invertebrate species are associated with spring systems in desert-grassland near the northern limits of the Chihuahuan Desert region of the southwest United States and north-central México. Changes in water tables resulting from human use and drought have occurred throughout the region, often resulting in diminished discharge from springs or complete loss of surface water. Thus, there has been a trend of diminishing suitable habitat and excessive degradation of habitat quality for the four invertebrate species throughout their range.

In México, large springs in the Parras Basin in southern Coahuila were lost due to mining and resultant changes in groundwater flow in the area (Imlay, 1936: 1097). Minckley (1974: 390) reported rapidly falling groundwater levels and loss of springs and surface water in the Cuatro Ciénegas basin in Coahuila from pumping and diversions. Similar changes in groundwater levels have been observed in Texas. Declining flow in springs in Reeves County, Texas, was reported by Brune (1981) and West Sandia Spring in this county recently ceased flowing (U.S. Fish and Wildlife Service, 2002: 6463). In Pecos County, Texas, pumping of groundwater in the Pecos River valley lowered groundwater levels as much as 120 m (394 ft) from the late 1940s into the late 1970s (Brune, 1981: 356), resulting in the loss of "nearly all" of the springs in the area (Brune, 1981: 356, 360). Leon Springs, located near Diamond Y Spring in Pecos County, Texas, historically flowed at a rate of 790 liters/sec (12,540 gal/min). Flow from Leon Spring declined steadily from 1920 to 1958 when discharge ceased completely and the spring was lost (Brune, 1981: 359). Flow in Comanche Spring (Pecos County, Texas), which historically measured about 1,533 liters/sec (24,305 gal/min), was completely eliminated by 1954 by groundwater pumping (Scudday, 1974: 515).

Groundwater level decline and loss of springs and surface-water flow in streams is also well-documented in the Roswell Artesian Basin in New Mexico. Major springs in the Roswell Basin included North Spring, South Spring, North Berrendo Spring, Middle Berrendo Spring, and South Berrendo Spring. Discharge from each of these springs ranged from about 19.2 million m^3 to 75.8 million m^3 (15,600 to 61,500 acre-feet) of water per year (Fiedler and Nye, 1933). Capture of spring outflow with the Hagerman Canal was initiated in 1879, and the first artesian wells were constructed in 1896. In 1905 there were at least 2,185 artesian wells in operation, and by 1925 all of the major springs were reduced to almost zero flow. The major springs were completely dry by 1931 (Fiedler and Nye, 1933; U.S. National Resources Planning Board, 1942). Groundwater use increased in the 1940s and 1950s and the artesian pressure of the aquifer was largely exhausted by 1953 (Thomas, 1959; Jones and Balleau, 1996; Barroll and Shomaker, 2003). Metering of groundwater pumping began in 1967, and the decline in groundwater levels began to slow. However, the level of the artesian aquifer continued to decline and reached the lowest level in 1970, which was about 21 m (70 ft) below the historic level (Jones and Balleau, 1996). Between 1975 and 1995, groundwater levels began to recover and had risen approximately 9.1 m (30 ft) from the lowest level (Jones and Balleau, 1996).

Reversal since about 1975 of the trend of lowering groundwater levels has not restored any lost springs in the Roswell area. Surface flow at Lander Springbrook, a small tributary of the South Spring River near Roswell (Noel, 1954), was lost in the late 1950s (Cole, 1981: 27) and has not reappeared. North Spring River, South Spring River, and reaches of Berrendo Creek remain dry, and spring flow has not been restored at these locations (Jones and Balleau, 1996: 5). Surface water flow on Bitter Lake National Wildlife Refuge was diminished by groundwater pumping, as evidenced by the dead springs on Salt Creek and documented reduction in spring flows on the refuge (Jones and Balleau, 1996:12). However, the springs that provide habitat to the four species on the Middle Unit of Bitter Lake National Wildlife Refuge continued to flow through the 1950s and 1970s, despite drought conditions during these decades (Jones and Balleau, 1996).

Peak annual pumping of the alluvial aquifer in the Roswell Basin was experienced in the 1950s. Since then, administration and metering of groundwater extraction in the basin by the New Mexico Office of the State Engineer has resulted in stabilization of groundwater levels (Figure 14). Since the basin was fully metered in the mid 1960s, both shallow and artesian pumping levels have stabilized and under current administration are expected to remain at constant levels. The Office of the State Engineer believes that only under extreme drought conditions exceeding those historically observed, would the spring flows on the Middle Unit of Bitter Lake National Wildlife Refuge be threatened (E. Sims, Office of the State Engineer, personal communication).

The U.S. Fish and Wildlife Service is continuing to investigate the acquisition of water rights for wildlife habitat at Bitter Lake National Wildlife Refuge which may serve to further protect existing and potential habitat for the four species (Balleau Groundwater, Inc., 1997, 1999).

Changes in Wetland Vegetation In addition to reduction or loss of flow, wetland vegetation at spring systems that provided habitat for one or all of the four invertebrate species has been modified. Taylor (1987: 9) reported adverse modification of habitat occupied by Pecos assiminea in the Cuatro Ciénegas Basin of Mexico by annual burning of wetland vegetation. North Spring, located on the Roswell Country Club, was enclosed with a brick wall and covered, native vegetation was removed from the margins of the headspring and outflow, and the banks were sodded (Cole, 1988: 2). Since 1995, the brick wall at North Spring has been removed and the spring outflow has been widened (B. Lang, New Mexico Department of Game and Fish, unpublished data). Flow reductions or complete loss of spring flow, which has occurred elsewhere in the basin (see above), has also resulted in widespread loss of wetland vegetation within the Roswell area (Hoagstrom and Brooks, 1999: 12).

Changes in Water Quality Some groundwater contamination from various sources has occurred in the region encompassing the ranges of the four invertebrates. Taylor (1985: 15) concluded that an unidentified groundwater pollutant was responsible for reduction in abundance of *Tryonia* in the headspring and outflow of Diamond Y Spring, Pecos County, Texas. Oil and gas resources were discovered in New Mexico in the early 1920s. Since then, development of subsurface oil and gas resources has resulted in installation, to date, of at least 190 wells in the vicinity of Bitter Lake National Wildlife Refuge (U.S. Fish and Wildlife Service, 2002: 6462). Groundwater contamination from oil and gas wells has occurred in the region. For example, leaking injection-withdrawal gas wells were implicated in sulfide contamination and elevated concentrations of benzene and polycyclic aromatic hydrocarbons (PAH) in wells near Rattlesnake Springs in the Black River Valley (Richard, 1988: 14). However, long-term, detailed chemical data needed to assess changes in surface water or groundwater quality attributable to oil and gas development in the historic range of the four invertebrate species are not available. Trichloroethylene was detected in the alluvial and artesian aquifers on the south side of Roswell, at the former site of Walker Air Force Base, beginning in 1991 (U.S. Army Corps of Engineers, 2002). Perchloroethylene was discovered in the groundwater in Roswell in 1994 (U.S. Fish and Wildlife Service, 2002: 6462).

Several instances of surface and groundwater pollution from dairy farming, presumably from inadequate management of waste, have been reported in the vicinity of Roswell (U.S. Fish and Wildlife Service, 2002: 6463). Increasing salinity levels in surface waters have resulted from reduction of stream flow coupled with irrigation return flow, invasion of saltcedar (Robinson, 1965), and increased evapotranspiration. High salinity levels have rendered many habitats unsuitable even for tolerant mollusc taxa, such as the snail *Physa* (Brune, 1981: 356).

Urban encroachment on the west side of Bitter Lake National Wildlife Refuge poses a risk to ground and surface water quality at the refuge from sewage contamination (i.e., septic discharge). Sinkholes west of refuge have been used for unregulated domestic refuse dumping. Refuse in these sinkholes has included domestic contaminants such as pesticides, herbicides, and waste oil (Lang, 2002: A3). Domestic contaminants and septic leachate are known to have contaminated groundwater resources in karst areas elsewhere in the United States (White et al., 1995; Zokaites, 1997) as well as in New Mexico (Bitner and Graves, 1992; McQuillan et al., 1989). The occurrence and extent of groundwater contaminants generated from residences and illegal dumps near the refuge is unknown.

Bitter Lake National Wildlife Refuge manipulates water levels in the refuge impoundments throughout the year, in part to protect water quality in the impoundments and adjacent wetlands (W. Radke, U.S. Fish and Wildlife Service, personal communication). Water quality deteriorates in the refuge wetlands if they are not periodically drained to reduce salinity. Since 1994, periodic “flushing” has been conducted to remove accumulated salts (RMCI, 1998). The refuge also conducts regular water quality monitoring in impoundments to assess the impact of contaminants, such as polychlorinated biphenyls (PCBs) which have been detected in eggs of nesting Least Terns at the refuge (G. Warrick, U. S. Fish and Wildlife Service, personal communication).

2.2.2 Population Trends

Fossil shells and historic collection records indicate that some populations of Noel’s amphipod, Pecos assiminea, Koster’s springsnail, and Roswell springsnail have been extirpated and that the geographic distribution of all four species has diminished (Cole, 1981; Cole, 1988b; Taylor, 1987). The New Mexico Department of Game and Fish has conducted monthly monitoring of population trends since 1995 and has documented dramatic decline of Noel’s amphipod at Dragonfly Spring following the Sandhill Fire in 2000 (Lang, 2000). Populations of all four species in North Spring on the Roswell Country Club have been extirpated within the last two decades (B. Lang, New Mexico Department of Game and Fish, unpublished data).

2.2.3 Use and Demand Trends

There is no evidence to indicate that any of the four invertebrate species were subject to commercial or recreational collection in the past or at the present time. Similarly, no substantial nonconsumptive human uses of any of the four species are apparent. However, there is some public interest in the four invertebrates as rare, endemic species in New Mexico. Members of the public interested in the state's biodiversity are likely to view the species as interesting and important faunal members of the spring systems of the lower Pecos River valley. The continued presence of self-sustaining populations at Bitter Lake National Wildlife Refuge and possibly other sites near Roswell is therefore a demand that must be met at a minimum by maintenance of existing populations. Additional aspects of use and demand are discussed in Section 2.4 below.

The importance of the four invertebrate species as a food source for other wildlife associated with spring systems has been little studied. A dietary study of the state threatened Pecos pupfish (*Cyprinodon pecosensis*) from Bitter Lake National Wildlife Refuge demonstrated that both species of springsnail and Noel's amphipod are consumed at least occasionally by this fish (M. A. Farrington and W. H. Brandenburg, personal communication). It is also likely that many shorebirds and other fishes (including the endangered Pecos gambusia, which is known to feed on amphipods; Propst 1999) may prey on these invertebrates. Predators of the mostly terrestrial Pecos assiminea have not been identified.

2.2.4 Past Management

The New Mexico Department of Game and Fish was granted the authority to list indigenous, non-domestic animals in the state as endangered, as approved by the State Game Commission, under the Wildlife Conservation Act of 1974. The definition of endangered species in the Act was implemented by the New Mexico Department of Game and Fish through establishment of two categories: Endangered, Group 1 species were defined as "taxa whose prospects of survival or recruitment within the state are in jeopardy;" and Endangered, Group 2 species were defined as "taxa whose prospect of survival or recruitment within the state are likely to become jeopardized in the foreseeable future." The 1995 amendments of the Wildlife Conservation Act revised the categories of listed species to include "threatened" and "endangered." The New Mexico Department of Game and Fish implemented this definition by classifying previously-listed Group 2 species as "threatened" and previously-listed Group 1 species as "Endangered."

Noel's amphipod was first listed as State Endangered, Group 2 on 9 January 1988 (Regulation No. 657) and was uplisted to Endangered, Group 1 on 30 November 1990 (Regulation No. 682). The species is currently classified as Endangered by the New Mexico Department of Game and Fish (19 NMAC 33.6.8). Pecos assiminea and Roswell springsnail were listed as Endangered, Group 1 on 22 July 1983 (Regulation No. 624) and are currently classified as Endangered (19 NMAC 33.6.8). Koster's springsnail was listed as Endangered, Group 2 on 22 July 1983 (Regulation No. 624) and is currently classified as Endangered (19 NMAC 33.6.8).

Noel's amphipod was identified as a Category 2 species by the U.S. Fish and Wildlife Service on 22 May 1984 (49 Federal Register 21664). A Category 2 species was defined as one that was considered for listing, "but for which conclusive data on biological vulnerability and threats were not currently available to support a proposed rule." The Category 2 designation was discontinued on 28 February 1996 (61 Federal Register 7956). Pecos assiminea, Koster's springsnail, and Roswell springsnail were identified as Category 1 species by the U.S. Fish and Wildlife Service on 22 May 1984 (49 Federal Register 21664). A Category 1 species was defined as one for which substantial information on biological vulnerability and threats was available to support proposals to list as threatened or endangered. These three species were reclassified as Candidate species on 28 February 1996 (61 Federal Register 7956). Candidate species retained the Category 1 species definition. All four species were proposed for listing as endangered with critical habitat on 12 February 2002 (67 Federal Register 6459; U.S. Fish and Wildlife Service, 2002). As of December 2004, the Service had not made a final decision on the proposed rule for listing the species.

In New Mexico, all four species are currently found only on Bitter Lake National Wildlife Refuge, which is managed by the U.S. Fish and Wildlife Service. North Spring, located on the Roswell Country Club, no longer harbors populations of the four species based on an August 2004 survey (B. Lang, New Mexico Department of Game and Fish, unpublished data).

2.3 HABITAT ASSESSMENT

Noel's amphipod, Koster's springsnail, and Roswell springsnail are aquatic species associated with springs, seeps, and associated outflows. Pecos assiminea is amphibious and is found immediately adjacent to flowing water at springs and seeps in microhabitats characterized by relatively dense vegetation, thick litter, and moist soils.

2.3.1 Status

The only occupied habitat currently remaining within the native range of the four invertebrate species in New Mexico appears to be on Bitter Lake National Wildlife Refuge. Extinction of populations from Lander Springbrook, South Spring River, Berrendo Creek, and North Spring River have all resulted from destruction of aquatic habitat and complete loss of surface water; therefore, these historic habitats are no longer suitable. A recent (August 2004) survey of North Spring indicates that the four species are no longer present (B. Lang, New Mexico Department of Game and Fish, unpublished data

2.3.2 Projections

Groundwater Quantity The springs and seeps that provide habitat for the four invertebrate species are sustained by a combination of shallow alluvial and artesian groundwater discharge. Specifically, springs and seeps on Bitter Lake National Wildlife Refuge are sustained by two hydrostratigraphic units: a shallow aquifer in alluvial deposits and a deeper artesian aquifer (Figure 8).

The artesian aquifer is contained mostly in solutionized San Andres limestone that is partially confined by overlying beds of the Artesia Group. The San Andres Formation consists of Permian dolomite, limestone, gypsum, sandstone, and mudstone. The Artesia Group (Queen and Grayburg Formations) also consists of Permian sedimentary rocks, including dolomite, sandstone, gypsum, and mudstone (Kelley, 1971: 6). The solutionized portion of the San Andres Formation is characterized by karst features, such as sinkholes, springs, and subterranean streams, caused by dissolution of carbonate rocks. The dissolution of the carbonate rocks in the San Andres limestone most likely occurred after the deposition of the Grayburg formation. The solution rate increased during times when the land surface was uplifted above sea-level permitting circulation of groundwater and interaction with the atmosphere, resulting in the production of carbonic acid which dissolved the limestone. Karst features thus developed in the upper layers of San Andres limestone. Sulfuric acid formed by combination of hydrogen sulfide from subsurface oil reservoirs with oxygenated groundwater (White et al., 1995: 453). The shallow alluvial aquifer consists of Holocene and Pleistocene surficial deposits, such as terrace gravels and stream and valley bottom alluvium up to 91 m (300 ft) thick (Kelley, 1971: 6).

Water levels in sinkholes on the Middle Unit of Bitter Lake National Wildlife Refuge are associated with the shallow alluvial aquifer. Flow in Bitter Creek is correlated with fluctuations in head at the Berrendo Well, which is completed in the artesian aquifer, and with water levels in nearby sinkholes. Therefore, it appears that Bitter Creek is fed by both the shallow alluvial aquifer and the artesian San Andres Formation aquifer (Wolford et al., 1999: 25). It seems likely that other springs, including Dragonfly

Spring, Sago Spring, and the seeps along the west boundary of Units 3 through 15, are also fed by water from both the shallow alluvial aquifer and the deeper artesian aquifer.

The 500-year source water capture zone for springs and seeps of Bitter lake National Wildlife Refuge was delineated in 1999 using data on geology, aquifer properties, and potentiometric surfaces in a particle-tracking model (Wolford et al., 1999). The result of this delineation for the Middle Unit of Bitter Lake National Wildlife Refuge is shown in Figure 9. The 500-year source water capture zone for the springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge extends west from the refuge up to about 20 km (12 mi) and is about 29 km (18 mi) north to south at its greatest extent (Figure 9). The source-water capture zone may encompass all or parts of the following 12 townships: T. 8 S., R. 23 E.; T. 8 S., R. 24 E.; T. 8 S., R. 25 E.; T. 9 S., R. 23 E.; T. 9 S., R. 24 E.; T. 9 S., R. 25 E.; T. 10 S., R. 23 E.; T. 10 S., R. 24 E.; T. 10 S., R. 25 E.; T. 11 S., R. 23 E.; T. 11 S., R. 24 E.; and T. 11 S., R. 25 E. (Figure 9). Land ownership in the source-water capture zone consists mostly of private land (about 50%), with the remainder consisting of State Trust land administered by the New Mexico State Land Office (about 30%); and federal land administered by the Bureau of Land Management (about 20%; Figure 10).

There are 4,119 wells that withdraw 272,924,550 m^3 (221,350 acre-feet) of groundwater annually within the 12 townships that encompass the source-water capture zone for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge (Table 2; Office of the State Engineer, 2002). Irrigation wells comprise about 39% of the total number of wells but withdraw 89% of the total volume of groundwater (Table 2; 243,987,273 m^3 [197,881 acre-feet] annually) from the area. Over half of all of the wells in the source-water capture zone are domestic wells, but these wells only account for slightly less than 3% of the total groundwater withdrawal (Table 2). The distribution of wells and groundwater withdrawal volumes in the 12-township area is shown in Figure 11.

The level of the artesian aquifer in the Roswell Basin is rising under existing groundwater development conditions and State administration of the basin. Since 1965, both shallow and artesian pumping levels have remained relatively constant (Figures 13 and 14) and are expected to remain so under current adminstration, provided that groundwater recharge is not curtailed by future severe drought (E. Sims, Office of the State Engineer, personal communication). If groundwater levels continue to rise constantly at the rate observed from 1975 to 1995 (Jones and Balleau, 1996: Figure 2), the historic artesian groundwater level would be reached in about 40 years. If the historic artesian water level is reached, flow of former springs could possibly reappear in the Roswell area. However, continuation of pumping, albeit at a reduced rate, led Brune (1981: 356) to conclude that “a rise of the water table or resumption of flows of the springs is not to be expected” in Pecos County, Texas. This may also be the case in the Roswell Basin (cf. Appendix C, Table 2).

Due to State administration of groundwater use, the potential for future, substantial changes in the amount of groundwater pumping appears to be low. Future residential development in unincorporated Chaves County north of Roswell will consist mainly of large lots (2 ha [5 ac] minimum) with individual domestic wells (G. Pinkerton, Chaves County Land Use Planner, personal communication, 21 August 2002). Domestic wells are permitted to withdraw up to 3,699 m^3 (3 acre-feet) of groundwater annually. There are no plans to extend municipal utilities to unincorporated areas. There are currently only two pending water rights applications for the 12-township area: both involve transferring location of use of water within the same township (File No. RA-680-A-A and RA-6851 into RA-2684-H-E; File No. RA-255 into RA-2544 et al.; Office of the State Engineer, Internet site, 2002). Concentration of new wells in a small area, however, could potentially result in localized depression of groundwater levels that may affect yield from nearby springs, Under present administration of the basin, this scenario is considered unlikely due to the impairment that would result to other water users (E. Sims, Office of the State Engineer, personal communication).

Table 2. Water wells and groundwater withdrawals in the townships encompassing the 500-year source-water capture zone for the Middle Unit of Bitter Lake National Wildlife Refuge, as of 8 October 2002 (compiled from Office of the State Engineer, 2002). The number of wells by use and the total withdrawal (i.e. diversion), in acre-feet, are indicated for each use category. The municipal and industrial category is all uses other than domestic or irrigation.

TOWNSHIP	IRRIGATION		DOMESTIC		MUNICIPAL & INDUSTRIAL		TOTAL		WELL DENSITY
	Number	acre-feet	number	acre-feet	number	acre-feet	number	acre-feet	(no./mi^2)
T. 8 S., R. 23 E.	4	3,156	0	0	8	15	12	3,171	0.33
T. 8 S., R. 24 E.	143	29,068	27	818	7	12	177	29,161	4.92
T 8 S., R. 25 E.	1	298	1	3	2	6	4	307	0.11
T. 9 S, R. 23 E.	10	3,436	13	33	4	12	27	3,481	0.75
T. 9 S., R. 24 E.	41	7,701	35	96	10	21	86	7,818	2.39
T 9 S., R. 25 E.	0	0	3	9	7	12	10	21	0.28
T. 10 S, R. 23 E.	100	15,096	319	897	37	639	456	16,631	12.67
T. 9 S., R. 24 E.	516	58,088	721	2,245	61	1,406	1,298	61,739	36.06
T 9 S., R. 25 E.	35	4,308	59	165	18	36	112	4,509	3.11
T. 9 S, R. 23 E.	58	8,048	308	840	28	5,960	394	14,848	10.94
T. 9 S., R. 24 E.	384	49,458	573	1,482	120	6,603	1,077	57,543	29.92
T 9 S., R. 25 E.	312	19,225	118	294	36	2,602	466	22,121	12.94
TOTALS	1,604	197,881	2,177	6,145	338	17,325	4,119	221,350	
PERCENT OF TOTAL	38.94%	89.40%	52.85%	2.78%	8.21%	7.83%			

Groundwater Quality Groundwater quality in the source-water capture zone for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge ranges in quality from fresh water of suitable quality for drinking water, domestic, irrigation, and other uses to moderately saline water. Shallow water tables and high permeability or transmissivity in aquifers are conditions influencing the frequency and severity of groundwater contamination (New Mexico Water Quality Control Commission, 2002: 85). Both of these conditions exist in the source-water capture zone for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge. Between 1927 and 2001, there were 63 reported point-sources of groundwater contamination in Chaves County (New Mexico Water Quality Control Commission, 2002: 86). Groundwater pollution resulted in contamination of 37 water supply wells and 27 groundwater cleanup efforts in the county (New Mexico Water Quality Control Commission, 2002: 87-88).

The largest source of groundwater contamination in New Mexico is from household septic tanks and leach fields (New Mexico Water Quality Control Commission, 2002: 85). Common pollutants associated with septic tank contamination of groundwater include total dissolved solids, iron, manganese, sulfides, nitrate, organic chemicals, and microbiological contaminants such as bacteria, viruses, and parasites (New Mexico Water Quality Control Commission, 2002: 85). However, widespread contamination of groundwater from septic systems has not been reported in the Roswell area (New Mexico Water Quality Control Commission, 2002: 85). Another potential source of groundwater contamination is leaching of wastes dumped in dry sinkholes. Trash dumping has occurred in several dry sinkholes adjacent to the western boundary of Bitter Lake National Wildlife Refuge (B. Lang, New Mexico Department of Game and Fish, personal communication, 21 August 2002). However, composition of the refuse and potential for contamination of groundwater have not been investigated in detail. Contaminants such as waste oil, household chemicals (e.g., pesticides), paints, solvents, and others could potentially be transported to groundwater from sinkhole dumps by leaching and percolation or rising groundwater levels that come in contact with refuse.

The area immediately west of Bitter Lake National Wildlife Refuge that is undergoing residential development is largely within the extraterritorial zone that extends 3.2 km (2.0 mi) outside of city limits (Z. Montgomery, Roswell City Planner, personal communication, 21 August 2002). In this area, development code allows residential development on 2.0 ha (5.0 ac) minimum lot size with individual septic systems (G. Pinkerton, Chaves County Land Use Planner, personal communication, 21 August 2002). Currently, there are no proposals to extend city utilities outside current city limits. The 2.0 ha (5.0 ac) lot size limitation regulates the maximum density of septic systems within the extraterritorial zone. Agricultural development in this same area is minimal and does not pose a threat to groundwater quality, such as through agricultural pesticide application.

About 13.7% of all reported point-source groundwater contamination cases in New Mexico from 1927 to 2001 were attributable to oil and gas production (New Mexico Water Quality Control Commission, 2002: 89). Leaks of refined petroleum products from underground storage tanks comprise the single largest source of petroleum-product contamination of groundwater in New Mexico (New Mexico Water Quality Control Commission, 2002: 90). Another major source is past disposal of produced water into unlined pits (New Mexico Water Quality Control Commission, 2002: 90; W. C. Olson, Oil Conservation Division, personal communication, 11 October 2002). Spills of raw and refined petroleum products from storage and transmission facilities or from transport vehicles are also a source of petroleum-product contamination of groundwater.

Below-ground leaks at oil or gas wells have not been identified as a major source of groundwater contamination. Two instances where groundwater contamination from below-ground leaks of wells has been documented include natural gas contamination of groundwater near Cedar Hill in San Juan County, New Mexico (New Mexico Water Quality Control Commission, 2002: 90) and sulfide contamination and elevated concentrations of benzene and polycyclic aromatic hydrocarbons in wells near Rattlesnake Springs in the Black River Valley, Eddy County, New Mexico (Richard, 1988: 14).

There are no known cases of groundwater contamination by leaking oil or gas wells in the source-water capture zone for the Middle Unit of Bitter Lake National Wildlife Refuge (W. C. Olson, Oil Conservation Division, personal communication, 11 October 2002). The closest known area of groundwater contamination from petroleum product is the Transwestern facility on the east side of U.S. 285 north of

Roswell (W. C. Olson, Oil Conservation Division, personal communication, 11 October 2002). Contaminated soils and source material have been removed from the site. Petroleum product recovery from contaminated groundwater has been conducted and remediation of contaminated groundwater is underway. The groundwater plume at the site is contained (W. C. Olson, Oil Conservation Division, personal communication, 11 October 2002).

There are 196 natural gas and oil wells in the 12-township area encompassing the source-water capture zone for the Middle Unit of Bitter Lake National Wildlife Refuge (Figure 12; New Mexico Petroleum Research Center, 2002). These wells have produced 25,846,714,000 cubic feet of natural gas and 158,724 barrels of oil since about 1972. About 25,240 m^3 (6,666,408 gal) of water have also been produced from these wells over the same 30-year period (New Mexico Petroleum Research Center, 2002). Three of the 196 wells are listed as plugged and two are cancelled (New Mexico Petroleum Research Center, 2002). The majority of the wells are located in R. 25 E., in Townships 8, 9, and 10 South (Figure 12). Most of the wells are completed in the Pecos Slope, Abo pool. Length of operation of individual wells ranges from 15 days to 23.2 years. Most of the wells (68%) are located on federal land, with 17% located on state land and the remaining 15% on private land (New Mexico Petroleum Research Center, 2002).

Development of additional natural gas and oil wells in the source-water capture zone is possible (but see Section 2.6, Special Considerations). Development of another 91 natural gas and oil wells has been anticipated on lands managed by the Bureau of Land Management within the source-water capture zone (H. Parman, Bureau of Land Management, personal communication, 22 August 2002). Petroleum-product contamination of groundwater from underground leaks in well casings may occur in the future, but existing drilling and casing regulations by the Oil Conservation Division (Appendix B) and requirements of the Bureau of Land Management for oil and gas drilling and operation in cave and karst areas (Bureau of Land Management, 1997: Appendix 3) are likely to substantially reduce this probability. A more likely pathway for petroleum-product contamination of groundwater is from leaking storage and transport facilities from the well site “downstream” to processing facilities. These may include leaking pipelines, overflowing storage tanks, leaking valves, and other sources.

Other Factors. Wildfire and drought are additional factors that can result in impaired water quality, as well as quantity. Neither impact to water quality can be reliably predicted, although current efforts to reduce wildfire risk on and near Bitter Lake National Wildlife refuge can reduce the risk to spring habitats (e.g., RMCI, 1998).

Exotic organisms are a consideration in the long-term survival of the four species. At present, no non-native species are known to compete with or prey upon the four species. The introduction of exotic mollusks, namely the New Zealand mudsnail (*Polamopyrgus antipodarum*), red-rim melania (pulmonate snail; *Melanoides tuberculata*) quagga mussel (*Dreissena bugensis*), zebra mussel (*D. polymorpha*), threatens native mollusk populations in the United States (Williams et al. 1993, Neves et al. 1997, Hakencamp and Palmer 1999, Shannon et al. 2004, Lydeard et al. 2004, USFWS 2004), including extant populations and aquatic habitats of these macroinvertebrates at Bitter Lake National Wildlife Refuge. Potential adverse effects posed by non-native mollusks may include: direct or indirect competition for food and space, alteration of species composition and structure of primary producers, and disruption of energy transfer from macroinvertebrates to native fish (Shannon et al. 2004). In the western USA, non-native mollusks are most commonly transported to new systems by passive dispersal, recreationalists, and contaminated equipment (see references cited above).

Non-native saltcedar (*Tamarix* spp.) is present on the refuge, and is currently being controlled where possible by refuge management efforts to protect riparian habitat. Saltcedar does not yet pose a risk to occupied habitat for the four species, but does occur in areas where the four species potentially could be re-introduced. Saltcedar removal methods (e.g., herbicide application) pose a potential risk to occupied habitat through water contamination.

2.4 SUPPLY AND DEMAND ASSESSMENT

This section assesses the current status and projections for the supply of the four species based on existing population levels, distribution, and harvest and use. It also assesses the existing and future demands on users of the four species.

As discussed in Section 2.2.3, none of the four species is subject to any major consumptive use nor is any likely to be used for any consumptive purpose in the foreseeable future. Specimens of all four species have been collected at various times for scientific research. Scientific collecting is regulated by both the U.S. Fish and Wildlife Service (for populations on Bitter Lake National Wildlife Refuge) and by the New Mexico Department of Game and Fish under provisions of the Wildlife Conservation Act. The species are of primary interest to members of the public with a general interest in the biodiversity of New Mexico or those interested in the biology, evolutionary history, or ecology of these species or related organisms. Therefore, supply and demand determinations are strongly determined by those actions necessary to ensure conservation of the four species and their habitats.

Because of their small size, limited area of occurrence, and sedentary habits, the four species are not often considered by the public as observable wildlife at Bitter Lake National Wildlife Refuge. Many visitors to the refuge who are interested in bird watching or other wildlife viewing are likely unaware of the presence of these species. Opportunities may exist, however, to increase public interest and demand in the species by providing improved access, such as foot trails, to areas of the refuge where the organisms occur. When special tours are organized to allow public access to closed refuge areas to view these endemic invertebrate species, there is always much public interest; in addition, the local media have shown interest in these species and reported on them periodically (W. Radke, U. S. Fish and Wildlife Service, personal communication). To address public interest in the four species, the establishment of a public viewing and education facility with a captive population of the four species could be located at the refuge. Such a facility could also be used as a captive refugium for the four species to ensure against extinction in the wild. An example of this type of viewing facility/refugium has been constructed at the Desert National Wildlife Refuge in Nevada for the endangered Pahrump Poolfish (*Empetrichthys latos*), a small spring-dwelling fish. A larger and more elaborate refugium that is also used for occasional public viewing and education was recently constructed at the Albuquerque BioPark for the endangered Rio Grande Silvery Minnow (*Hybognathus amarus*).

2.5 SOCIO-ECONOMIC IMPACTS

A background analysis of social and economic aspects associated with recovery and conservation of the four invertebrate species is provided in a report prepared by Research Management Consultants Inc. (RMCI) contained in Appendix C.

State efforts to conserve and recover the four species of invertebrates are not expected to have an adverse effect on the socioeconomic environment in Chaves County. Under the provisions of the Wildlife Conservation Act, the Department of Game and Fish does not have the authority to prevent habitat-altering activities that might have an adverse effect on state listed species, or to require activities that would benefit these species. (Possible socio-economic effects of federal listing of these species is discussed below under Special Considerations.) Actions proposed to achieve recovery of the species would have to be coordinated with all stakeholders, including federal land management agencies, and any actions that would be carried out on private lands would require the voluntary cooperation of the landowner.

The Wildlife Conservation Act identifies as an important component of recovery efforts "the use of volunteer resources and existing economic recovery and assistance programs and funding available from public and private sources to implement the [recovery] plan." Efforts to improve habitat for the four species at Bitter Lake National Wildlife Refuge may be achievable through a variety of organizations. Although most management activities on the refuge are conducted by the U.S. Fish and Wildlife Service, other entities such as the Department of Game and Fish and local volunteer organizations with interests in habitat conservation have also been involved in refuge management. The refuge solicits volunteers to assist the refuge staff in monitoring of wildlife and habitat management. The Friends of the Bitter Lake National Wildlife Refuge, a local volunteer organization with interests in promoting and supporting the goals of the refuge, is a source for support or guidance in developing a volunteer program to encourage interest in and habitat protection for the four species.

2.6 SPECIAL CONSIDERATIONS

Proposed Federal Listing: A primary consideration in the conservation and recovery of the four invertebrates was the designation of these species in 2002 as "proposed endangered, with critical habitat," under the federal Endangered Species Act (U.S. Fish and Wildlife Service, 2002). At present, it is unclear when or if the species will be federally listed, or if critical habitat would be designated for the species should they be listed. It is also possible that federal listing or critical habitat designation could be implemented for some but not all four of the species. As presently envisioned by the Fish and Wildlife Service, two of the four proposed critical habitat units are nearly contiguous and contained within Bitter Lake National Wildlife Refuge with a surface area of about 1100 acres. The other two proposed critical habitat units are in Texas.

The Fish and Wildlife Service is in the process of developing an Economic Analysis that will assess the effects of the proposed critical habitat designation (FWS 2002). The analysis will consider the two proposed critical habitat units at Bitter Lake National Wildlife Refuge and will assess the effects of critical habitat on activities in or near the units that would require consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act. Activities requiring Section 7 consultation are various but have in common a federal nexus, such as federal funding or regulatory responsibilities. Such activities in the New Mexico portion of the proposed critical habitat area include but are not limited to: management activities at Bitter Lake National Wildlife Refuge; extraction of federally-owned oil, gas, and minerals on federal and other lands in or near the critical habitat areas; Clean Water Act (Section 404) permitting within the groundwater source area for the four species; and interstate pipeline operation and maintenance.

The effects of possible future federal listing or critical habitat designation cannot be assessed within the scope of the current plan. However, the proposed listing of species does affect the way federal agencies and other entities using federal funding may deal with such species in their project planning efforts. For example, actions by federal agencies that potentially would affect a species proposed for federal listing are typically evaluated under provisions of Section 7 of the Endangered Species Act because of the possibility that the species may be listed by the time an action is implemented. An agency may therefore treat a proposed species as if it were already listed so as to ensure that subsequent listing would not cause unexpected impacts to a planned action. Section 7(a)(1) of the Act directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of listed species.

Presence of Federally Listed Species: The presence of the federally endangered Pecos gambusia (*Gambusia nobilis*) in spring runs and other surface waters of the Bitter Lake National Wildlife Refuge affects the management of habitat for the four invertebrates. This fish species occurs in sympatry with all four invertebrate species. The BLM has developed a plan to administratively designate a BLM/Bitter Lake Habitat Protection Zone (HPZ) to protect groundwater resources for the Pecos gambusia on lands west of Bitter Lake National Wildlife Refuge (BLM, 2002). The HPZ would include lands under BLM management and those where mineral resources are federally owned (total of about 22,500 acres). The special management plan would augment protective measures outlined in BLM (1997) and was initiated in response to formal Section 7 consultation with the Fish and Wildlife Service for the Pecos gambusia at Bitter Lake National Wildlife Refuge. In accord with Section 7 requirements, the Fish and Wildlife

Service recommended (in BLM 1997, and its Record of Decision) that the BLM implement Reasonable and Prudent Alternatives (RPAs) to protect the Pecos gambusia, including:

- "Use the best available hydrological information to map movement of water that supplies springs occupied by Pecos gambusia on the [refuge] and the Salt Creek Wilderness. Close the lands within the mapped area to oil and gas leasing unless or until the BLM can demonstrate that mandatory protective measures will ensure no aquifer contamination."

- "For existing leases within the mapped area, apply appropriate measures taken from BLM's *Practices for Oil and Gas Drilling and Operations in Cave and Karst Areas* and any appropriate measures to ensure no contamination of water that supplies springs occupied by Pecos gambusia on the BLNWR [Bitter Lake National Wildlife Refuge] and the Salt Creek Wilderness. Use monitoring procedures that will detect any surface or subsurface accidents soon enough that they can be discovered and corrected before significant harm to the aquifer occurs."

Although these proposed actions are independent of the proposed federal listing of the four invertebrates, it is anticipated that protective measures for the HPZ that would benefit the Pecos gambusia would also protect the habitat of the four invertebrate species.

Other Consideration: Another consideration is the underlying assumption within this plan that recovery and conservation of the four species are achievable by the same actions and on the same timetable. It is important to recognize that, although the four species have similar habitat requirements, they are not identical in their biological constraints or life histories. It is possible that recovery and conservation measures that may benefit one species may not have the same positive effect on another of the four species. This consideration should be kept in mind during implementation of the Recovery and Conservation Strategy described in Section 3.0.

2.7 SUMMARY AND CONCLUSIONS

Noel's amphipod, Pecos assiminea, Koster's springsnail, and Roswell springsnail are endemic invertebrates associated with spring habitats in the Roswell Artesian Basin in Chaves County, New Mexico. Noel's amphipod, Koster's springsnail, and Roswell springsnail are aquatic species that require unpolluted, perennial headspring, spring outflow, and wetland habitats for survival. Pecos assiminea is an amphibious species that lives in moist litter, dense vegetation mats, and saturated soils along the edges of springs, spring brooks, and sinkhole ponds. The imperiled status of all four species has been recognized since the late 1980s.

All four of these species have suffered loss of habitat and contraction of range. Extinction of populations from drying and alteration of springs has been a major factor leading to the decline of these species. The last remaining occupied habitats in New Mexico are all on the Middle Unit of Bitter Lake National Wildlife Refuge. Major potential threats to the four invertebrate species are alteration of aquatic and riparian habitat, reduction or cessation of spring flow, and degradation of water quality from a variety of contaminants.

3.0 RECOVERY AND CONSERVATION STRATEGY

This section of the Recovery and Conservation Plan identifies the goal, objective, objective parameters, issues, and strategies for recovery and conservation of the four species. The section also includes an Action Plan for implementing specific tasks to achieve the identified goal.

3.1 GOAL

A goal is a general statement expressing a desired future condition; it is an outcome that we wish to be an actuality.

The goal of this plan is:

That Noel's amphipod, Pecos assiminea, Koster's springsnail, and Roswell springsnail occur in sufficient numbers within populations, and in a sufficient number of discrete and independent populations, that downlisting and eventual delisting under the Wildlife Conservation Act may be warranted.

3.2 OBJECTIVE

An objective is a quantitative, measurable, and time-limited restatement of the goal; it identifies a single, realistic outcome for a plan.

The objective of this plan is:

That by 2014, viable populations of Noel's amphipod, Pecos assiminea, Koster's springsnail, and Roswell springsnail will be secure within their historic range on Bitter Lake National Wildlife Refuge and in at least two off-refuge sites in New Mexico, and that conservation and protection measures will be in place to prevent against catastrophic extinction of these four species.

Upon achievement of the objective, the four species will be considered for downlisting under the Wildlife Conservation Act.

3.3 OBJECTIVE PARAMETERS

Objective parameters are means or approaches to establish measurable targets, i.e., the intermediate outcomes we believe will foster the stated objective. Parameters for achieving the objective of this Recovery and Conservation Plan are:

Parameter 1: **Conservation.** Maintenance or expansion of the existing distribution and abundance of the four species of invertebrates on Bitter Lake National Wildlife Refuge within the major habitats of: Bitter Creek; Sago Spring complex; seeps along the western boundary of Units 3, 5, 6, 7, and 15; and Lake St. Francis.

Parameter 2: **Restoration.** Repatriation of the four invertebrate species to restored, suitable habitat at two or more sites within their known historic range.

Parameter 3: **Protection.** Establishment and stocking of an artificial (constructed) and secure refugium for the four species of invertebrates to protect against catastrophic loss in the wild.

3.4 ISSUES

Issues are situations that are expected to impede attainment of the objective. The following issues associated with attainment of the objective parameters were identified. The objective parameter(s) that each issue relates to is indicated in parentheses at the end of the issue statement.

Issue 1: Lacking jurisdiction over the aquatic habitats of the Bitter Lake National Wildlife Refuge, or on adjacent private lands that were historically occupied, the Department cannot directly manage the quality and quantity of habitats necessary to recover and secure populations of the four invertebrate species. (Parameter 1: Conservation).

Issue 2: Populations of the four invertebrates respond to changes in habitat and resource abundance that may be subtle; habitat changes may create unsuitable conditions and lead to decline of populations (Parameter 1: Conservation).

Issue 3: Land uses within the source-water capture zone in Chaves County historically have had effects on the quantity and quality of water in aquatic habitats. Future impacts could result in a decline in spring flow or degradation of water quality on Bitter Lake National Wildlife Refuge that may cause invertebrate populations to decline or be extirpated (Parameter 1: Conservation).

Issue 4: Historic range outside of Bitter Lake National Wildlife Refuge consists largely of private lands, which increases the difficulty of establishing populations of an endangered species due to conflicting land use priorities (Parameter 2: Restoration).

Issue 5: Although much about the biology of the four invertebrate species is known, information sufficient to precisely define suitable habitat (for the purposes of habitat restoration or replication) is not available (Parameter 2: Restoration).

Issue 6: A refugium (or multiple refugia) for the four species must be hydrologically isolated from natural habitats on Bitter Lake National Wildlife Refuge, but must also replicate water quality conditions and characteristics of native habitat required by the species (Parameter 3: Protection).

An overriding issue associated with all conservation and recovery efforts is the availability of consistent funding that would support the activities needed to achieve the objective. This issue will be addressed in the Operational Plan for recovery and conservation of these four species, to be developed upon approval of the current plan.

3.5 STRATEGIES

Strategies are the broad approaches or interventions to be used to overcome a problem or take advantage of an opportunity. They are intentionally broad, directional, and nonspecific so as not to constrain the selection of actions or tasks for implementing them. The following strategies address each of the six issues identified in section 3.4. These strategies are listed in order of priority.

Issue 1: Lacking jurisdiction over the aquatic habitats of the Bitter Lake National Wildlife Refuge, or on adjacent private lands which were historically occupied, the Department cannot directly manage the quality and quantity of habitats necessary to recover and secure populations of the four invertebrate species.

Strategy 1: Work with the U.S. Fish and Wildlife Service, private landowners, and other stakeholders to maintain quality habitat for the four species on Bitter Lake National Wildlife Refuge and other public and private lands within the historic range of the species.

Issue 2: Populations of the four invertebrates respond to changes in habitat and resource abundance that may be subtle; habitat changes may create unsuitable conditions and lead to decline of populations.

Strategy 2: Identify the minimum requirements, or information gaps where requirements are not known, for suitable habitat within the current range of the four species.

Issue 3: Land uses within the source-water capture zone in Chaves County historically have had effects on the quantity and quality of water in aquatic habitats. Future impacts could result in a decline in spring flow or degradation of water quality on Bitter Lake National Wildlife Refuge that may cause invertebrate populations to decline or be extirpated.

Strategy 3: Identify off-refuge land uses with known and potential effects to refuge aquatic habitats and, where possible, work to mitigate their impacts to the four species on the refuge.

Issue 4: Historic range outside of Bitter Lake National Wildlife Refuge consists largely of private lands, which increases the difficulty of establishing populations of an endangered species due to conflicting land use priorities.

Strategy 4: Examine the historic range of the four species in New Mexico outside of Bitter Lake National Wildlife Refuge, including on private lands where allowed, and develop approaches to manage the species where present or re-introduce where one or more species are now extirpated.

Issue 5: Although much about the biology of the four invertebrate species is known, information sufficient to precisely define suitable habitat (for the purposes of habitat restoration or replication) is not available.

Strategy 5: Acquire information about the biology of the four species sufficient to allow restoration or replication of their habitat.

Issue 6: A refugium (or multiple refugia) for the four species must be hydrologically isolated from natural habitats on Bitter Lake National Wildlife Refuge, but must also replicate water quality conditions and characteristics of native habitat required by the species.

Strategy 6: Assess potential of establishing suitable refugia (natural or artificial habitats) that are hydrologically isolated from natural range and implement where possible. Such a refugium could serve as a means to protect the four species from extinction should native habitats be impacted, but would not replace efforts to protect the species in their native habitats.

3.6 ACTION PLAN

The Action Plan is a component of the Recovery and Conservation Plan that identifies specific tasks to be carried out. The following actions will be taken to implement the strategies identified in section 3.5. Some strategies in the previous section have been combined here for both clarity and because of redundancy of actions. Those original strategies have been identified in parentheses following each action statement.

Actions proposed for implementation at Bitter Lake National Wildlife Refuge will be fully coordinated with the U.S. Fish and Wildlife Service and refuge personnel. These actions are consistent with and in many instances complement proposed management activities identified in the Service's *Final Comprehensive Conservation Plan and Environmental Assessment: Bitter Lake National Wildlife Refuge* (RMCI, 1998).

Scheduling, staffing, and anticipated costs and funding sources for these actions will be addressed in the Operational Plan, to be developed following finalization and approval of this Recovery and Conservation Plan and its included Action Plan.

Maintain (and where possible, enhance) current habitat and status on Bitter Lake National Wildlife Refuge (strategy 1)

Actions:

1. Continue and, where possible, increase existing cooperative relationship and information exchange between the Department and U.S. Fish and Wildlife Service in support of the four species. Such cooperative efforts may be addressed within the framework of cooperative agreements and Candidate Conservation Agreements with Assurances with adjacent landowners.

2. Assess current information on known distributions and abundance on refuge and identify data gaps.

3. Conduct surveys on refuge to locate any additional populations and determine population sizes.

4. Continue to consult with refuge personnel to identify refuge management activities that may benefit or impact species populations.

5. Work with refuge personnel to develop management guidelines and activities to protect and potentially enhance known populations on the refuge. Component actions include:
    a. Assist refuge personnel in the development and implementation of methods to assess the effectiveness of habitat restoration and protection projects in an adaptive management framework.
    b. Consult with refuge personnel and assist where possible in refuge activities to reduce wildfire threats.
    c. Consult with refuge personnel and assist where possible in refuge activities to control invasive vegetation (e.g., saltcedar, common reed) in habitats that support the four species.

d. Assist the refuge in assessing the effects of water management activities, including manipulation of impoundment levels, to protect and where possible enhance the habitat for the four species.

6. Work with refuge personnel to identify areas of the refuge where habitat for the species may be created by developing a prioritized list of potential habitat restoration sites, restoration criteria for each site, potential restoration techniques (e.g., saltcedar removal, substrate modification [cf. Lang, 2002:A2], vegetation management), and a protocol for establishing populations at restoration sites.

7. Assist refuge personnel in the development and implementation of methods to assess the effectiveness of habitat restoration and protection projects in an adaptive management framework.

8. Assist the U.S. Fish and Wildlife Service in preparing and disseminating information to the public on the status and natural history of the four species.

9. Assist the U.S. Fish and Wildlife Service in developing or enhancing cooperative relationships with other entities, including volunteer groups, that can assist the refuge in habitat management activities.

Improve our knowledge of biological requirements of the four species (strategies 2, 5)

Actions:

10. Continue ongoing research on the four invertebrates at Bitter Lake National Wildlife Refuge by New Mexico Department of Game and Fish personnel as funded through Endangered Species Act Section 6 project grants (NMDGF, 2004). Component actions include:

a. Assess our current knowledge on water quality and quantity requirements, microhabitat use, dietary requirements, reproductive potentials, associations with other fauna, and other biological parameters of the four species.
b. Continue to monitor twice annually the distribution and abundance of known refuge populations, in coordination with refuge personnel.
c. Identify any current inadequacies in monitoring protocols for the four species and develop alternative or supplemental protocols where necessary.

11. Assess current manpower requirements for surveying and monitoring of refuge populations and identify funding sources to increase or improve efforts where necessary.

12. Develop list of additional research activities that may be needed to answer unknowns about the biology of the four species.

13. Evaluate need for contracting researcher(s) to investigate specific aspects of species biology or status.

14. Implement contracts where necessary to address specific questions about species biology or status.

15. Prepare and publish reports and journal articles to disseminate information on the biology of the four species.

Develop better information and cooperative relationships with other entities to address local land uses that may affect the four species (strategy 3)

Actions:

16. Assess current knowledge of existing and future land uses and their known or potential effects on the four species and their habitat.

17. Working with cooperating agencies, organizations, and government entities, identify any inadequacies in available knowledge about local land uses.

18. In coordination with cooperating agencies (e.g., Fish and Wildlife Service, Interstate Stream Commission, Bureau of Land Management, Oil Conservation Division, Environment Department), organizations (e.g., Chaves County Public Lands Advisory Committee), and other entities, develop and implement a source-water capture zone groundwater monitoring program using selected wells available for study of groundwater levels and water chemistry.

19. In an interagency forum, review groundwater monitoring data on at least an annual basis to allow for early detection and avoidance of potential groundwater impacts to habitats occupied by the four species, and determine whether increased protections against potential groundwater contamination are warranted.

20. Meet with land owners and managers to discuss known or potential off-refuge land uses (including illegal dumping of refuse and hazardous materials) that may impact the habitat of the four species on the refuge.

21. In coordination with land owners and managers, and any regulatory agencies with jurisdiction, assess the impact of current land uses, including illegal dumping, and determine need for actions that would prevent impact to habitat.

22. Develop conservation agreements with other entities that have the necessary jurisdictions and authorities to implement all aspects of this Recovery and Conservation Plan; such agreements should be developed to also address the requirements of the U.S. Fish and Wildlife Service's Policy for Evaluating Conservation Efforts for species that are candidates or proposed for listing under the Endangered Species Act.

23. On at least an annual basis, report to all cooperating agencies, organizations, and interested public on the progress in implementing specific actions within this Action Plan and in a format consistent with the New Mexico Department of Game and Fish's requirements for federal grant reporting.

Pursue the re-establishment or maintenance of the four species in locations other than the habitats at Bitter Lake National Wildlife Refuge (strategies 4, 6)

Actions:

24. Review existing information on the former and possibly current distribution of the four species outside of Bitter Lake National Wildlife Refuge.

25. Identify potentially suitable aquatic habitats outside of current known range but within the historic range.

26. Contact and consult with private land owners or public land managers of identified off-refuge sites and obtain necessary approvals to conduct site surveys. Off-refuge public land sites include but are not limited to Bottomless Lakes State Park, State Trust lands in the vicinity of Bitter Lake National Wildlife Refuge, and private lands along Berrendo Creek.

27. Inventory aquatic sites (where permitted) to determine presence/absence of the four species.

28. Where species are detected, develop a cooperative agreement with land owners or managers to conduct long-term status surveys of the populations.

29. Identify funding sources and partnerships for implementing habitat modification projects that would create suitable habitat for the species.

30. Survey unoccupied sites (where permitted by landowners) to determine potential for repatriation and/or habitat modification/improvement to allow re-introduction.

31. In coordination with the U.S. Fish and Wildlife Service, Department administration, and pertinent landowners or managers, develop and implement a project to re-introduce the four species at suitable but unoccupied sites.

32. Develop and implement a monitoring protocol to assess survival and recruitment of the species in re-introduction sites.

33. Develop an artificial refugium suitable for maintaining a captive population of all four species to ensure against catastrophic extinction at natural sites. Component actions include:

a. Establish a small captive population of the four species in order to develop and refine procedures for captive care and propagation. A possible location is the Albuquerque BioPark, which has experience in constructing and maintaining aquatic refugia.
b. Consult with biologists and wildlife managers in New Mexico and other states to identify requirements and procedures for captive maintenance and artificial refugium construction for other small invertebrates with similar natural histories.
c. Based on information provided by the small captive population, prepare a design plan for an artificial refugium to maintain the four species to prevent their catastrophic loss from natural habitat destruction.
d. Conduct an inventory of potential artificial refugium sites, focusing first on the Roswell artesian basin (e.g., Dexter National Fish Hatchery) and evaluate sites based on suitability, cost, and feasibility.
e. Develop cost estimates and identify funding sources for construction and maintenance of an artificial refugium.

f. Secure funding and implement contracts and cooperative agreements with all involved agencies to establish an artificial refugium for the species.
g. Develop and implement a protocol for monitoring and maintaining the genetic integrity of the refugium population.

3.7 APPROVALS

This Recovery and Conservation Plan for Noel's amphipod, Pecos assiminea, Koster's springsnail, and Roswell springsnail is approved by:

12/27/04

Lisa Kirkpatrick, Conservation Services Division Chief
New Mexico Department of Game and Fish

Date

1-4-05

Dr. Bruce Thompson, Director
New Mexico Department of Game and Fish

Date

1-4-05

Guy Riordan, Chairman
New Mexico State Game Commission

Date

4.0 LITERATURE CITED

Allred, K. W. 1993. A field guide to the grasses of New Mexico. Department of Agricultural Communications, Department of Agriculture and Home Economics, New Mexico State University, Las Cruces, New Mexico.

Balleau Groundwater, Inc. 1997 Annotated abstract of water-rights administration: Bitter Lake National Wildlife Refuge. A report prepared for the U.S. Department of Justice. 22 pp. (with addenda).

Balleau Groundwater, Inc. 1999. Source-water protection zones for Bitter Lake National Wildlife Refuge. A report prepared for the U.S. Department of Justice. 42 pp.

Barnes, R.D. 1980. Invertebrate zoology (fourth edition). Saunders College, Philadelphia, Pennsylvania.

Barroll, P. and J. Shomaker. 2003. Regional hydrology of the Roswell Artesian Basin and The Capitan Aquifer, pp. 23-27 *in* P. S. Johnson, L. A. Land, L. G. Price, and F. Titus (eds.), Water Resources o f the Lower Pecos Region, New Mexico: Science, Policy, and a Look to the Future. New Mexico Bur. Geology and Mineral Resources, Socorro, NM. viii + 145 pp.

Bitner, M. J. and T. Graves. 1992. Effect of lot sizes on potential ground-water contaminants from conventional septic-tank systems: numerical modeling. Policy Coordinating Committee. 47 pp.

Brown, K. M. 1991. Mollusca: Gastropoda. Pages 285-314 *in:* Thorp, J. H. and A. P. Covich (eds.). Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., San Diego, California.

Brune, G. 1981. Springs of Texas (volume 1). Branch-Smith, Inc., Fort Worth, Texas.

Bureau of Land Management (BLM). 1997. Roswell approved resource management plan and record of decision. U.S. Department of the Interior, Bureau of Land Management, Roswell Resource Area, Roswell District, New Mexico. BLM-NM-PT-98-003-1610.

Bureau of Land Managament (BLM). 2002. Habitat Protection Zone Environmental Assessment, EA-NM-060-00-030, Chaves County, New Mexico (with signed Finding of No Significant Impact). BLM Roswell Field Office, Roswell, NM.

Cole, G. A. 1981. *Gammarus desperatus*, a new species from New Mexico (Crustacea: Amphipoda). Hydrobiologia 76: 27-32.

Cole, G. A. 1985. Analysis of the *Gammarus*-*pecos* complex (Crustacea: Amphipoda) in Texas and New Mexico, USA. Journal of the Arizona-Nevada Academy of Science 20:93-103.

Cole, G. A. 1988a. A report on Noel's amphipod (*Gammarus desperatus*). Report submitted to the Endangered Species Program, New Mexico Department of Game and Fish under Professional Services Contract 519-77-02, Santa Fe, New Mexico.

Cole, G. A. 1988b. A report on the status of Amphipoda, including *Gammarus desperatus* in New Mexico. Report submitted to the Endangered Species Program, New Mexico Department of Game and Fish under Professional Services Contract 519-77-02, Santa Fe, New Mexico.

Fiedler, A. G. and S. S. Nye. 1933. Geology and ground-water resources of the Roswell artesian basin, New Mexico. U.S. Geological Survey Water-Supply Paper 639.

Gervasio, V., D. J. Berg, B. K. Lang, N. L. Allan, and S. I. Guttman. 2004. Genetic diversity in the *Gammarus pecos* species complex: implications for conservation and regional biogeography in the Chihuahuan Desert. Limnol. Oceanogr. 49(2):520-531.

Graves, W. D. 2002. Guidelines for writing long-range, action, and operational plans (revised 25 February 2002). New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Hakenkamp, C. C. and M. A. Palmer. 1999. Introduced bivalves in freshwater ecosystems: the impact of Corbicula on organic matter dynamics in a sandy stream. Oecologia 119:445-451.

Hershler, R. 1994. A review of the North American freshwater snail genus *Pyrgulopsis* (Hydrobiidae). Smithsonian Contributions to Zoology, No. 554.

Hershler, R. 2001. Systematics of the North and Central American aquatic snail genus *Tryonia* (Rissooidea: Hydrobiidae). Smithsonian Contributions to Zoology, No. 612.

Hershler, R. and F. G. Thompson. 1987. North American Hydrobiidae (Gastropoda: Rissoacea): redescription and systematic relationships of *Tryonia* Stimpson, 1865 and *Pyrgulopsis* Call and Pilsbry, 1886. The Nautilus 101(1): 25-32.

Hershler, R., H. P. Liu, and C. A. Stockwell. 2002. A new genus and species if aquatic gastropods (Rissooidea: Hydrobiidae) from the North American Southwest: phylogenetic relationships and biogeography. Proceedings of the Biological Society of Washington 115(1): 171-188.

Hoagstrom, C. W. and J. E. Brooks. 1999. Distribution, status, and conservation of the Pecos pupfish, *Cyprinodon pecosensis*. New Mexico Department of Game and Fish, Technical Report No. 2.

Holsinger, J. R. 1976. The freshwater amphipod crustaceans (Gammaridae) of North America. U.S. Environmental Protection Agency, Water Pollution Control Research Series 18050 ELD04/72.

Imlay, R. W. 1936. Evolution of the Coahuila Peninsula, México. Part IV: Geology of the western part of the Sierra de Parras. Bulletin of the Geological Society of America 47: 1091-1152.

Jones, M. A. and W. P. Balleau. 1996. Interrelation of groundwater and surface water at Bitter Lake National Wildlife Refuge. Balleau Groundwater, Inc., Albuquerque, New Mexico.

Kelley, V. C. 1971. Geology of the Pecos country, southeastern New Mexico. New Mexico Bureau of Mines and Mineral Resources, Memoir 24.

Lang, B. K. 1998. Status of aquatic mollusks of New Mexico. Completion Report (E-20-6) submitted to the Division of Federal Aid, U. S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lang, B. K. 1999. Status of aquatic mollusks of New Mexico. Completion Report (E-20-7) submitted to the Division of Federal Aid, U. S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lang, B. K. 2000. Status of aquatic mollusks of New Mexico. Completion Report (E-20-8) submitted to the Division of Federal Aid, U. S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lang, B. K. 2002. Status of aquatic mollusks of New Mexico. Completion Report (E-20, 5-9) submitted to the Division of Federal Aid, U. S. Fish and Wildlife Service, Albuquerque, New Mexico.

Lydeard, C., R. H. Cowie, W. F. Ponder, A. E. Bogan, P. Bouchet, S. A. Clark, K. S. Cummings, T. J. Frest, O. Gargominy, D. G. Herbert, R. Hershler, K. E. Perez, B. Roth, M. Seddon, E. E. Strong, and F. G. Thompson. 2004. The Global decline of nonmarine mollusks. BioScience 54(4):321-330.

McQuillan, D. M., M. J. Jasper, and B. H. Swanson. 1989. Ground-water contamination be septic-tank use: a field study in the Albuquerque South Valley – West Mesa region, Bernalillo County, New Mexico. New Mexico Health and Environment Department, Environmental Improvement Division, Ground Water Bureau.

Mehlhop, P. 1992. Establishment of a rare mollusc inventory and monitoring program for New Mexico. Progress Report. Report prepared under Professional Services Contract 80-519-52. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Mehlhop, P. 1993. Establishment of a rare mollusc inventory and monitoring program for New Mexico. Year II Progress Report prepared under Professional Services Contract No. 80-519-52-Amendment 1. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Minckley, W. L. 1974. Endemic fishes of the Cuatro Ciénegas Basin, northern Coahuila, México. Pages 383-404 *in:* R. H. Wauer and D. H. Riskind (eds.). Transactions of the symposium on the biological resources of the Chihuahuan Desert region, United States and México. U.S. Department of the InteRíor, National Park Service Transactions and Proceedings Series, No. 3.

Neves, R. J., A. E. Bogan, J. D. Williams, S. A. Ahlstedt, and P. W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: A downward spiral of diversity. Pp.43-85, *In* Aquatic Fauna in Peril (George W. Benz and David E. Collins, Eds.). Southeast Aquatic Research Institute Special Publication 1. Lenz Design & Communications, Decatur, Georgia.

New Mexico Department of Game and Fish (NMDGF). 1988. Handbook of species endangered in New Mexico. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

New Mexico Department of Game and Fish (NMDGF). 2004. Conservation of Endangered, Threatened and Sensitive Mollusks and Crustaceans: Project 3: Macroinvertebrates of Bitter Lake National Wildlife Refuge. Project proposal to Endangered Species Act Section 6 Funding Program, U.S. Fish and Wildlife Service, Albuquerque.

New Mexico Petroleum Research Center. 2002. Oil and natural gas administration and revenue (ONGARD) database, 8 October 2002. GO-TECH, New Mexico Institute of Mining and Technology, Socorro, New Mexico. http://octane.nmt.edu/data/ongard/

New Mexico Water Quality Control Commission. 2002. Water quality and water pollution control in New Mexico, 2002. A report prepared for submission to the Congress of the United States by the State of New Mexico pursuant to Section 305(b) of the Federal Clean Water Act. New Mexico Environment Department, Surface Water Quality Bureau, Santa Fe, New Mexico.

Noel, M. S. 1954. Animal ecology of a New Mexico springbrook. Hydrobiologia 6:120-135.

Office of the State Engineer. 2002. Water administration technical engineering resource system (WATERS) database, 8 October 2002. New Mexico Office of the State Engineers, Santa Fe, New Mexico. http://www.seo.state.nm.us/water-info/index.html.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States: Protozoa to Mollusca. John Wiley & Sons, Inc., New York, New York.

Propst, D. L. 1999. Threatened and Endangered Fishes of New Mexico. New Mexico Dept. Game and Fish, Santa Fe, Tech. Report No. 1.

Research Management Consultants, Inc. (RMCI). 1998. Final Comprehensive Conservation Plan and Environmental Assessment: Bitter Lake National Wildlife Refuge. Prepared for U.S. Fish and Wildlife Service.

Richard, M. 1988. Natural gas contamination at Rattlesnake Springs, Carlsbad Caverns National Park: Review of the geohydrology in the vicinity of Rattlesnake Springs and the contamination problem. Report No. 1 of 4. Report submitted to the National Park Service under Contract No. RFQ 7029-8-0025.

Robinson, T. W. 1965. Introduction, spread and areal extent of saltcedar (*Tamarix*) in the western United States. U.S. Geological Survey Professional Paper Np. 491-A.

Scudday, J. F. 1974. Some recent changes in the herpetofauna of the northern Chihuahuan Desert. Pages 513-522 *in:* R. H. Wauer and D. H. Riskind (eds.). Transactions of the symposium on the biological resources of the Chihuahuan Desert region, United States and México. U.S. Department of the InteRíor, National Park Service Transactions and Proceedings Series, No. 3.

Shannon, J. P., E. P. Benenati, H. Kloeppel, and D. Richards. 2004. Monitoring the aquatic food base in the Colorado River, Arizona during June and October 2002. Northern Arizona University Aquatic Food Base Project, Annual Report to the U. S. Geologic Survey, Grand Canyon Monitoring and Research Center.

Smith, D. G. 2001. Pennak's fresh-water invertebrates of the United States: Porifera to Crustacea. John Wiley & Sons, Inc., New York, New York.

Taylor, D. W. 1983. Endangered species: status investigation of mollusks. Report prepared under Project No. E-1-3, New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Taylor, D. W. 1985. Status survey of aquatic molluscs in Diamond Y Draw, Pecos County, Texas. Unpublished report to Bitter Lake National Wildlife Refuge, Roswell, New Mexico.

Taylor, D. W. 1987. Fresh-water mollusks from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources Bulletin 116.

Thomas, H. E. 1959. Causes of depletion of the Pecos River in New Mexico. U.S. Geological Survey Water-Supply Paper 1619-G.

Thorp, J. H. and A. P. Covich (eds.). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, California.

U.S. Army Corps of Engineers. 2002. Restoration advisory board for the former Walker Air Force Base. U.S. Army Corps of Engineers, Albuquerque District, http://www.spa.usace.army.mil/ec/walker-rab /welcome.html

U.S. Fish and Wildlife Service. 2002. Endangered and threatened wildlife and plants; listing Roswell springsnail, Koster's tryonia, Pecos assiminea, and Noel's amphipod as endangered with critical habitat - proposed rule. Federal Register 67(29):6459-6479 (February 12, 2002).

U. S. Fish and Wildlife Service. 2004. Draft biological opinion on construction of a dam and pumping system at Phantom Lake Spring. Austin Ecological Services Field Office, Austin, TX.

U.S. National Resources Planning Board. 1942. The Pecos River joint investigation-reports of participating agencies. U.S. Government Printing Office, Washington, D.C.

Welder, G. E. 1983. Geohydrologic framework of the Roswell ground-water basin, Chaves and Eddy counties, New Mexico. New Mexico State Engineer, Technical Report 42.

White, W. B., D. C. Culver, J. S. Herman, T. C. Kane, and J. E. Mylroie. 1995. Karst lands. American Scientist 83: 450-459.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6-22.

Wolford, R. A., D. M. Romero, S. E. Silver, and W. P. Balleau. 1999. Source-water protection zones for Bitter Lake National Wildlife Refuge. Report prepared by Balleau Groundwater, Inc. for the U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Zokaites, C. 1997. Living on karst: a reference guide for landowners in limestone regions. Cave Conservancy of the Virginias. 25 pp.

APPENDICES

A. SUMMARY OF PUBLIC PARTICIPATION

Two public meetings were held in Roswell, New Mexico in 1998 to assemble an advisory committee and identify important issues with respect to conservation of the four invertebrate species. These efforts were suspended when other endangered species issues took precedence.

Public participation in support of recovery plan development was re-initiated in 2002. A public information meeting was advertised and held in Roswell, New Mexico on 26 June 2002. Six individuals attended the meeting at which New Mexico Department of Game and Fish (Department) representatives made presentations about the development process for the Recovery and Conservation Plan (Plan) and a summary of the status of the four invertebrate species. A review of the potential social and economic impacts was also presented followed by solicitation of comments from attendees regarding potential or perceived impacts.

On 21 August 2002, a presentation to discuss the Plan was made at the monthly Chaves County Public Lands Advisory Committee (PLAC) meeting in Roswell, New Mexico. All nine PLAC members were present along with Chaves County planning and zoning director and the Roswell city planner and seven other interested individuals from the public. A slide presentation, made by Brian Lang of the Department, addressed species descriptions, status, and threats. A discussion among meeting participants followed with particular emphasis on questions to the government planners and PLAC members regarding policies and practices that could have an effect on habitat of the four species. Discussion included topics such as lot size for undeveloped parcels, septic systems, location of municipal wells and city utilities, gas and oil well locations and density, existing measures to protect groundwater from oil and gas well leaks, and other potential risks to invertebrate habitat. Attendees were provided comment forms and invited to send written comments to the Department. No written comments were returned.

An invitation was extended at the public information and PLAC meetings for representatives to serve on a Recovery Plan Advisory Committee (RPAC) to review and comment on the Plan. In addition, letters of invitation to serve on the RPAC were mailed out in late 2002 and early 2003 to approximately 20 individuals, organizations, and agencies with interests in Chaves County. Sixteen individuals expressed interest in serving on the RPAC, and were appointed by the Department Director. Two others asked only to remain on the project information mailing list.

A first draft of the Plan, which included background information on the four species and their habitat and the Social and Economic Analysis (Appendix 3), was provided to the Department by the Department contractors in 2002 and was reviewed internally and revised. The revised first draft was mailed to members of the RPAC in April 2003. In a cover letter to RPAC members, the Department requested that reviewers provide preliminary recommendations on the content of the Recovery and Conservation Strategy section of the Plan, which was to be included in the second draft. Comments were received from six committee members and were used in the preparation of the revised second draft, which included the Recovery and Conservation Strategy section (Section 3.0). This version was submitted to the RPAC for review in early 2004.

Four response letters were received from the RPAC on the revised second draft. The Department also met with representatives of the New Mexico Interstate Stream Commission (ISC) to address language in the

Plan concerning groundwater management in the Roswell Basin. The second draft was revised during summer 2004 to reflect comments received from RPAC members and ISC concerns. This second draft was completed in September 2004 and provided as a PDF document on the Department's website for a final round of review. Letters indicating the availability of the final draft for review were sent to all RPAC members and those who previously indicated a desire to be kept informed of the Plan development.

The Department also met with the U. S. Fish and Wildlife Service and the ISC to discuss aspects of the Service's Policy on Evaluation of Conservation Efforts (PECE) and its possible application to the Plan for the four species, which are proposed for listing under the Endangered Species Act. In late 2004, preliminary discussions among the three above-referenced agencies were initiated to determine if the PECE could be implemented to prevent the need for federal listing through commitments and specific actions by all involved parties. Proposed implementation of the PECE for these species would involve a separate public participation process outside of the scope of the current Plan, but would incorporate many of the elements identified in the Action Plan in this document.

The final draft of the Plan was presented to the New Mexico Game Commission for review in late 2004. Additional input from the public was solicited at the December 2004 Commission meeting and several oral comments were submitted. No revision of the final draft was requested by the public or Commission, and the Plan was approved in January 2005.

B. OIL CONSERVATION DIVISION REGULATIONS FOR INSTALLING WELLS

Regulations for plugging wells are found at 19 NMAC 15.5.301 to 19 NMAC 15.5.305
Regulations covering injection wells are found at 19 NMAC 15.9.701 to 19 NMAC 15.9.705

19.15.3.106 SEALING OFF STRATA

A. During the drilling of any oil well, injection well or any other service well, all oil, gas, and water strata above the producing and/or injection horizon shall be sealed or separated in order to prevent their contents from passing into other strata.

B. All fresh waters and waters of present or probable value for domestic, commercial, or stock purposes shall be confined to their respective strata and shall be adequately protected by methods approved by the Division. Special precautions by methods satisfactory to the Division shall be taken in drilling and abandoning wells to guard against any loss of artesian water from the strata in which it occurs, and the contamination of artesian water by objectionable water, oil, or gas.

C. All water shall be shut off and excluded from the various oil- and gas-bearing strata which are penetrated. Water shut-offs shall ordinarily be made by cementing casing.

[1-1-50, 3-1-91…2-1-96; 19.15.3.106 NMAC - Rn, 19 NMAC 15.C.106, 11-15-01]

19.15.3.107 CASING AND TUBING REQUIREMENTS

A. Any well drilled for oil or natural gas shall be equipped with such surface and intermediate casing strings and cement as may be necessary to effectively seal off and isolate all water-, oil-, and gas-bearing strata and other strata encountered in the well down to the casing point. In addition thereto, any well completed for the production of oil or natural gas shall be equipped with a string of properly cemented production casing at sufficient depth to ensure protection of oil- and gas-bearing strata encountered in the well, including the one(s) to be produced.

B. Sufficient cement shall be used on surface casing to fill the annular space behind the casing to the top of the hole, provided however, that authorized field personnel of the Division may, at their discretion, allow exceptions to the foregoing requirement when known conditions in a given area render compliance impracticable.

C. All cementing shall be by pump and plug method unless some other method is expressly authorized by the Division.

D. All cementing shall be with conventional-type hard-setting cements to which such additives (lighteners, densifiers, extenders, accelerators, retarders, etc.) have been added to suit conditions in the well.

E. Authorized field personnel of the Division may, when conditions warrant, allow exceptions to the above paragraph and permit the use of oil-base casing packing material in lieu of hard-setting cements on intermediate and production casing strings; provided however, that when such materials are used on the intermediate casing string, conventional-type hard-setting cements shall be placed throughout all oil- and gas-bearing zones and throughout at least the lowermost 300 feet of the intermediate casing string. When such materials are used on the production casing string, conventional-type hard-setting cements shall be placed throughout all oil- and gas-bearing zones and shall extend upward a minimum of 500 feet above the uppermost perforation or, in the case of an open-hole completion, 500 feet above the production casing shoe.

F. All casing strings shall be tested and proved satisfactory as provided in Subsection I. below.

G. After cementing, but before commencing tests required in Subsection I. below, all casing strings shall stand cemented in accordance with Option 1 or 2 below. Regardless of which option is taken, the casing shall remain stationary and under pressure for at least eight hours after the cement has been placed. Casing shall be "under pressure" if some acceptable means of holding pressure is used or if one or more float valves are employed to hold the cement in place.

(1) Option 1 Allow all casing strings to stand cemented a minimum of eighteen (18) hours prior to commencing tests. Operators using this option shall report on Form C-103 the actual time the cement was in place before initiating tests.

(2) Option 2 (May be used in the counties of San Juan, Río Arriba, McKinley, Sandoval, Lea, Eddy, Chaves, and Roosevelt only.) Allow all casing strings to stand cemented until the cement has reached a compressive strength of at least 500 pounds per square inch in the "zone of interest" before commencing tests, provided however, that no tests shall be commenced until the cement has been in place for at least eight (8) hours.

(a) The "zone of interest" for surface and intermediate casing strings shall be the bottom 20 percent of the casing string, but shall be no more than 1000 feet nor less than 300 feet of the bottom-part of the casing unless the casing is set at less than 300 feet. The "zone of interest" for production casing strings shall include the interval or intervals where immediate completion is contemplated.

(b) To determine that a minimum compressive strength of 500 pounds per square inch has been attained, operators shall use the typical performance data for the particular cement mix used in the well, at the minimum temperature indicated for the zone of interest by Figure 107-A, Temperature Gradient Curves. Typical performance data used shall be that data furnished by the cement manufacturer or by a competent materials testing agency, as determined in accordance with the latest edition of API Code RP 10 B "Recommended Practice for Testing Oil-Well Cements."
(See Temperature Gradient - Page 17A)

H. Operators using the compressive strength criterion (Option 2) shall report the following information on Form C-103:

(1) Volume of cement slurry (cubic feet) and brand name of cement and additives, percent additives used, and sequence of placement if more than one type cement slurry is used.

(2) Approximate temperature of cement slurry when mixed.

(3) Estimated minimum formation temperature in zone of interest.

(4) Estimate of cement strength at time of casing test.

(5) Actual time cement in place prior to starting test.

I. All casing strings except conductor pipe shall be tested after cementing and before commencing any other operations on the well. Form C-103 shall be filed for each casing string reporting the grade and weight of pipe used. In the case of combination strings utilizing pipe of varied grades or weights, the footage of each grade and weight used shall be reported. The results of the casing test, including actual pressure held on pipe and the pressure drop observed shall also be reported on the same Form C-103.

(1) Casing strings in wells drilled with rotary tools shall be pressure tested. Minimum casing test pressure shall be approximately one-third of the manufacturer's rated internal yield pressure except that the test pressure shall not be less than 600 pounds per square inch and need not be greater than 1500 pounds per square inch. In cases where combination strings are involved, the above test pressure shall apply to the lowest pressure rated casing used. Test pressures shall be applied for a period of 30 minutes.

If a drop of more than 10 percent of the test pressure should occur, the casing shall be considered defective and corrective measures shall be applied.

(2) Casing strings in wells drilled with cable tools may be tested as outlined in Subsection I, Paragraph (1) above, or by bailing the well dry in which case the hole must remain satisfactorily dry for a period of at least one (1) hour before commencing any further operations on the well.

J. Well Tubing Requirements

(1) All flowing oil wells equipped with casing larger in size than 2 7/8-inch OD shall be tubed.

(2) All gas wells equipped with casing larger in size than 3 ½-inch OD shall be tubed.

(3) Tubing shall be set as near the bottom as practical and tubing perforations shall not be more than 250 feet above top of pay zone.

(4) The supervisor of the appropriate Division district office, upon application, may grant exceptions to these requirements, provided waste will not be caused.

(5) The supervisor may request that an application be reviewed by the Director. The operator shall submit information and give notice as requested by the Director. Unprotested applications may be approved after 20 days of receipt of the application and supporting information. If the application is protested, or the Director so decides, the application shall be set for hearing.

K. Repealed.

[1-1-50, 5-5-58, 6-26-59, 2-29-64, 2-1-96, 2-26-99; 19.15.3.107 NMAC - Rn, 19 NMAC 15.C.107, 11-15-01]

19.15.3.108 DEFECTIVE CASING OR CEMENTING: If any well appears to have a defective casing program or faultily cemented or corroded casing which will permit or may create underground waste or contamination of fresh waters, the operator shall give written notice to the Division within five (5) working days and proceed with diligence to use the appropriate method and means to eliminate such hazard. If such hazard of waste or contamination of fresh water cannot be eliminated, the well shall be properly plugged and abandoned.

[1-1-50...2-1-96; 19.15.3.108 NMAC - Rn, 19 NMAC 15.C.108, 11-15-01]

19.15.3.109 BLOWOUT PREVENTION: (See Section 114, Subsection B of 19.15.3 NMAC also)

A. Blowout preventers shall be installed and maintained in good working order on all drilling rigs operating in areas of known high pressures at or above the projected depth of the well and in all areas where pressures which will be encountered are unknown, and on all workover rigs working on wells in which high pressures are known to exist.

B. Blowout preventers shall be installed and maintained in good working order on all drilling rigs and workover rigs operating within the corporate limits of any city, town, or village, or within 1320 feet of habitation, school, or church, wherever located.

C. All operators, when filing Form C-101, Application for Permit to Drill, Deepen, or Plug Back, or Form C-103, Sundry Notices, for any operation requiring blowout prevention equipment in accordance with Subsections A and B above, shall submit a proposed blowout prevention program for the well. The program as submitted may be modified by the District Supervisor if, in his judgement, such modification is necessary.

[10-22-74...2-1-96; 19.15.3.109 NMAC - Rn, 19 NMAC 15.C.109, 11-15-01]

19.15.3.110 PULLING OUTSIDE STRINGS OF CASING: In pulling outside strings of casing from any oil or gas well, the space outside the casing left in the hole shall be kept and left full of mud-laden

fluid or cement of adequate specific gravity to seal off all fresh and salt water strata and any strata bearing oil or gas not producing.
[1-1-50...2-1-96; 19.15.3.110 NMAC - Rn, 19 NMAC 15.C.110, 11-15-01]

C. SOCIAL AND ECONOMIC ANALYSIS

Prepared by Research Management Consultants Inc. (RMCI).

Chaves and Eddy Counties Geographic Profile

Population Change:
According to the 1990 Census for Chaves County, there were 57,849 residents. In the 2000 Census, Chaves County, residents numbered 61,382, which was an increase of 6.1% over the past ten years. Additionally, there are 25, 647 housing units located in Chaves County with 3,086 vacant housing units (U.S. Census Bureau, 2000b) .

Economic Indicators for Chaves County indicate that Per Capita personal income increase 19.3% from 1995 to 2000 with a 1995 personal income of $16,467 and a 2000 income of $19,651. The number of business establishments increased 1.5% from 1,485 in 1995 to 1,508 in 2000 (New Mexico Economic Development Department, 2002).

Eddy County in 1990 reported 48,605 residents. In 2000 Eddy County reported 51,658 residents, which was an increase of 6.3%. Additionally, there are 22,249 housing unit located in Eddy County with 2,870 vacant units (U.S. Census Bureau, 2000b).

Economic Indicators for Eddy County indicate that Per Capita personal income increased 22.6% from 1995 to 2000 with a 1995 personal income of $17,136 and a 2000 income of $21,007. The number of business establishments decreased 4.4% from 1,281 in 1995 to 1,225 in 2000 (New Mexico Economic Development Department, 2002).

Within the distribution of occupations, citizens occupy governmental positions in local, state and federal agencies. The percentage of workers employed by a government agency in Chaves County is 18.0% and in Eddy County 16.9% according to the 2000 Census (U.S. Census Bureau, 2000a).

According to the 2000 New Mexico Agricultural Statistics, the number of farms located in Chaves County has decreased from 622 in 1987 to 562 in 1997 which was a decrease of 9.7% (U.S. Department of Agriculture, 2000b). The amount of farmland located within the county is 2,944,354 acres with an average farm size of 5,239 acres. The market value of agricultural products sold is $220,127,000 in the county. Additionally, the top five commodities for the county include dairy products, cattle & calves, hay/silage etc., sheep/lambs & wool, and cotton/cottonseed (New Mexico Economic Development Department, 2002).

Gross receipts from retail trade for Chaves County increased 17.5% from 1997 to 2001. In Eddy County receipts increased 17.9% for the same timeframe. Net taxable property values for

Chaves County increased 28.5% from 1997 to 2001, and for Eddy County increased 42.8% for the same timeframe (New Mexico Economic Development Department, 2002).

In Eddy County the number of farms has decreased from 503 in 1987 to 467 in 1997 which is a decrease of 7.2% (U.S. Department of Agriculture, 2000b). The amount of farmland located within the county is 1,275,527 acres with an average farm size of 2,731 acres. The market value of agricultural products sold is $84,586,000 in the county. Additionally, the top five commodities for the county include dairy products, hay/silage etc., cattle & calves, cotton/cottonseed, and vegetables (New Mexico Economic Development Department, 2002).

Oil & Gas Production

In 2000 Eddy County ranked #3 in the state of New Mexico and Chaves County ranked #5 in gas production, producing 299,880,426 Mcf and 20,327,424 Mcf respectively. Oil production for Eddy County ranked it #2 in the state with 23.1 million barrels produced and Chaves County #5 with 646.7 thousand barrels of production (New Mexico Economic Development Department, 2002).

Natural gas production in the state from 1995 to 2000 remained relatively unchanged. However, the value of natural gas increased from $1.30/Mcf in 1995 to $3.80/Mcf in 2000 (New Mexico Economic Development Department, 2002).

Oil production in the state remained relatively unchanged between 1995 and 2000. However, the price per barrel increased from $16.55 to $28.84 (New Mexico Economic Development Department, 2002).

Water Use

Along with population increases and farm number decreases, the water usage as reported by the New Mexico State Engineers Office also indicates increases and decreases by category. Data in Table C-2 were obtained from the New Mexico State Engineers Office, Technical Report 49, dated September 1997. The data reported is the actual data gathered in 1995. Additionally, comparative values are used from the unpublished 2002 report, which provides data from the 2000 survey.

Sociological Factors

Of the four invertebrate species, three are very tiny snails and one is a small amphipod. All four species are known to exist on the Bitter Lake National Wildlife Refuge (BLNWR) while several of the species may exist on private property near the refuge. Because of their small size and limited distribution, none of the four species is well known to the general public. However, according to BLNWR (personal communication) there is some growing interest in these invertebrate species (Fountain, 2002). BLNWR conducts endangered species tours. These tours are conducted by the refuge personnel and have been taking place over the past two years. According to BLNWR, approximately 100 people in groups of 3 to 4 and up to 10 to 12 at a time participate in the activity. However, this activity is not considered a viable tourism attraction but indicative that there are more people with a real interest in the refuge. Although these visits are considered a nonviable tourist attraction the BLNWR is a main attraction for the Roswell area (U.S. Fish and Wildlife Service & and Research Management Consultants Inc., 1998). Additionally, visitors to the area and BLNWR for non-consumptive uses at wildlife refuges generate far more economic activity than consumptive hunting and fishing activities (U.S. Fish and Wildlife Service, 1997).

Because the species are found primarily on a National Wildlife Refuge where they are already protected, off-refuge factors create the most interest. A potentially important factor is the proposed listing of the species by the U.S. Fish and Wildlife Service (USFWS), as Federally endangered with subsequent delineation of critical habitat. It would be likely that most off-refuge critical habitat would belong to the Bureau of Land Management (BLM), another Federal Agency. The BLM is a "multiple use" agency, having very different mandates than the USFWS. Prior to the proposed listing of the four species, the BLM allowed oil exploration and extraction and other commercial uses on lands adjacent to, and "up-aquifer" from the refuge.

The BLM has recently closed an area to oil exploration (Blue Earth Ecological Consultants, 2002), but there are plans to develop more wells in the area. This closure could have sociological as well as economic implications.

There is privately owned land adjacent to the Refuge which could be developed for housing or other private or commercial uses (Blue Earth Ecological Consultants, 2002; Fountain, 2002). If the use of this land is in any way restricted, it could have sociological as well as economic impacts.

The greatest potential social impact would occur if any use of private property is impacted because it is found to harbor any of the species. (This potential impact would result only if the species of concern is federally listed; at present, none of the four species is listed.) However, if the private landowner and the State were able to work cooperatively to further survival of the affected species, positive social impacts would occur for both the species and the landowner. It is important to note, however, that the species are not known from private land and that the New Mexico Wildlife Conservation Act has no provision for restricting private property use to protect any species.

Economic Factors

Due to the nature and location of the four species, economic factors are of much greater importance than potential sociological impacts. Situations that could cause concern for survival of the species include: groundwater depletion, ground/surface water contamination, and habitat alteration. It is significant that the development of these situations has the most potential to occur off the refuge and is the greatest cause of concern to biologists.

As reported by the U.S. Environmental Protection Agency (EPA) there are nine community water treatment systems in Chaves County that serve the same people year-round (e.g. in homes or business). There are two transient non-community water systems that do not consistently serve the same people (e.g. rest stops, campgrounds, gas stations). There are five non-transient, non-community water systems that serve the same people, but not year-round (e.g. schools that have their own water systems) (U.S. Environmental Protection Agency, 2002a).

In Eddy County the EPA reports that there are 13 community water systems that serve the same people year-round, eight transient non-community water systems, and three non-transient, non-community water systems (U.S. Environmental Protection Agency, 2002b).

Any change in water quality restrictions, water development, or construction of additional water treatment facilities could potentially affect citizens in both counties. Additional water usage of both surface and groundwater could have the potential to negatively affect the environment.

Contamination of both surface and groundwater could potentially impact the socioeconomic aspects of both Chaves and Eddy Counties. The EPA reports that in Chaves County there are 139 facilities that produce and release air pollutants. The EPA has also identified 159 stacks and 391 point sources where contaminants could be released. There are seven facilities that have reported toxic releases and 76 facilities that have reported hazardous waste activities. Also located within the county are three Superfund sites. Throughout the county there are ten companies that have been issued permits to discharge wastewater into rivers (U.S. Environmental Protection Agency, 2002a).

The EPA reports that in Eddy County there are 338 facilities that produce and release air pollutants. The EPA has also identified 913 stacks and 1,178 point sources where contaminants could be released. There are eight facilities that have reported toxic releases and 110 facilities that have reported hazardous waste activities. Also located within the county are five Superfund sites. Throughout the county there are six companies that have been issued permits to discharge wastewater into rivers (U.S. Environmental Protection Agency, 2002b).

Any no-action alternative for restoration and maintenance of the species must include actions already taken by the BLM (at the request of the USFWS) to restrict oil and gas drilling on certain lands. Any further restrictions would be a change from status quo and would be considered an action alternative in recovery and restoration of the species. Restrictions on oil and gas exploration would have a significant economic impact overall, and the most significant economic impact in the short-term. Yates Petroleum (the largest local exploration and extraction company in the area), has had discussions with the BLM and the USFWS in regard to mitigation measures which would ensure environmental safeguards. Implementation of mitigation measures would have some economic impact on the company. While oil and gas exploration occurs on the refuge, the USFWS already has right of consultation to suggest mitigation measures.

Oil and gas activities have the potential to influence each situation (water depletion, contamination, and habitat alteration) but are not the sole cause for concern. Conversion of adjacent privately owned land for housing and associated development could cause depletion and contamination of water sources as well as habitat alteration. Restrictions on land use due to these potentials would have a significant, long-term economic impact.

Most agricultural activities occur in areas that would not significantly impact the four species and no economic impact is anticipated for any recovery alternatives.

Another type of habitat alteration that could have significant economic impact is wildfire. A wildfire in 2000 was restricted primarily to the refuge but adjacent areas are not immune. Wildfire off the refuge that occurred as a result of habitat management efforts on the refuge (such as prescribed burning) could have a significant impact. Fire prevention measures could have a slight, positive economic impact by providing local employment opportunities and through the purchase or rental of machinery and materials.

Any restriction on water use on private land that may harbor the species of concern could have significant economic impact if water use restrictions caused cessation of current, ongoing uses. However, measures to protect water quality that are aimed to protect the habitat of the four species could also protect other economic interests, including those of private land owners, that could be impaired by a degradation of water quality.

TABLE C-1: Occupational, Industry, and Class of Workers

Occupation	Chaves County	Eddy County
Management, professional, and related occupations	27.6%	25.1%
Service occupations	16.2%	17.1%
Sales and office occupations	24.9%	24.9%
Farming, fishing, and Forestry occupations	4.4%	2.1%
Construction, extraction, and maintenance occupations	11.1%	16.4%
Production, transportation, and material moving occupations	15.8%	14.4%

(U.S. Census Bureau, 2000a)

TABLE C-2. Summary of water withdrawals and depletions in acre-feet by category for Chaves County. The surveys were completed in 1995 and 2000. Positive values indicate increases and negative values indicate decreases in usage in units of acre-feet.

Chaves County

Category	WSW	WGW	TW	DSW	DGW	TD	RFSW	RFGW	TRF
Public Water Supply	0.0	-641.0	-641.0	0.0	-619.8	-619.8	0	-21.2	-21.2
Domestic (self-supplied)	0.0	142.6	142.6	0.0	571.5	571.5	0.0	-428.9	-428.9
Irrigated Agriculture	-5,968.0	49,697	43,729	-2,988.0	30,224	27,436	-3180.0	19,473	16,293
Livestock (self-supplied)	66.2	2678.9	2745.1	66.2	3360.4	3426.6	0.0	-681.5	-681.5
Commercial (self-supplied)	0.0	-891.4	-891.4	0.0	-79.5	-79.5	0.0	-811.9	-811.9
Industrial (self-supplied)	0.0	-90.3	-90.3	0.0	-115.3	-115.3	0	25.1	25.1
Mining (self-supplied)	0.0	83.2	83.2	0	84.3	84.3	0.0	-1.1	-1.1
Power (self-supplied)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reservoir Evaporation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent difference between 1995 data and 2000 data	-19.5%	17.3%	13.9%	-18.4	16.3%	13.9%	-21%	19.7%	13.8%

WSW=withdrawal, surface water; WGW=withdrawal ground water; TW=total withdrawal; DSW= depletion, surface water; DGW=depletion, ground water; TD= total depletion; RFSW= return flow, surface water; RFGW=return flow, ground water; TRF=total return flow. (Wilson & Lucero, 1997; Wilson & Lucero, 2002)

TABLE C-3. Summary of water withdrawals and depletions in acre-feet by category for Eddy County. The surveys were completed in1995 and 2000. Positive values indicate increases and negative values indicate decreases in usage in units of acre-feet.

Eddy County

Category	WSW	WGW	TW	DSW	DGW	TD	RFSW	RFGW	TRF
Public Water Supply	-344.7	1,052.0	707.2	-307.0	639.6	332.6	-37.7	412.3	374.6
Domestic (self-supplied)	0.0	-204.8	-204.8	0.0	19.4	19.4	0.0	-224.0	-224.0
Irrigated Agriculture	-19,381	9,681.0	-9,694.0	-13,595	4,687.0	-8,908.0	-5,780.0	4,994.0	-786.0
Livestock (self-supplied)	-42.6	1,509.5	1,467.4	-42.6	1,550	1,467.4	0	0	0
Commercial (self-supplied)	-251.0	765.0	514.2	-246.9	922.4	695.5	-4.1	-177.3	-181.4
Industrial (self-supplied)	0	216.5	216.5	0	234.9	234.9	0	-18.4	-18.4
Mining (self-supplied)	1,790.8	-6,746.5	-4,955.7	537.2	-164.6	372.6	1,253.6	-6,581.9	-5328.3
Reservoir Evaporation	3,660.0	0.0	3,660.0	3,660.0	0.0	3,660.0	0.0	0.0	0.0
Percent difference between 1995 data and 2000 data	-10%	4.4%	-2.9%	- 12%	7.6%	-1.2%	-4.3%	-4.2%	-6.2%

WSW=withdrawal, surface water; WGW=withdrawal ground water; TW=total withdrawal; DSW= depletion, surface water; DGW=depletion, ground water; TD= total depletion; RFSW= return flow, surface water; RFGW=return flow, ground water; TRF=total return flow. (Wilson & Lucero, 1997; Wilson & Lucero, 2002)

TABLE C-4. Breakdown of crops grown on farms as surveyed by the Water Use and Conservation Bureau, Office of the State Engineer. The data listed below is the 1999 Irrigated Crop acreage for both Chaves and Eddy Counties.

Table C-4a

County	Alfalfa	Barley	Beans & Peas	Berries	Chile Peppers	Corn	Cotton	Flower Seeds	Fruit Trees
Chaves	56,140	900	--	--	1,638	9,793	6,354	--	350
Eddy	25,394	--	91	--	856	898	9,996	--	1

Table C-4b

County	Grapes	Lettuce	Melon	Mint	Filberts	Nursery	Oats & Rye	Onion	Pasture/ Hay	Pecans
Chaves	--	--	200	--	--	--	3,000	--	3,150	2,650
Eddy	--	--	1	--	--	--	1,190	--	1,352	1,779

Table C-4c

County	Peanuts	Pista-chios	Potato	Spice	Sor-ghum	Soy-bean	Turf-grass /Sod	Vege-tables	Wheat	Other Crops
Chaves	--	--	--	--	1,376	--	--	105	1,380	--
Eddy	--	1	--	--	1,167	--	--	1	356	80

(U.S. Department of Agriculture, 2000a)

REFERENCES TO APPENDIX C

Blue Earth Ecological Consultants, I. (2002, August 21, 2002). Summary of Presentation to the Chaves County Public Land Advisory Committee, Roswell, NM.

Fountain, J. (2002). Threatened and Endangered Species at Bitter Lake National Wildlife Refuge. In K. Butts (Ed.). Roswell.

New Mexico Economic Development Department. (2002). New Mexico County Statistics. Economic Development Department. Retrieved 10/12/02, 2002, from the World Wide Web: http://www.edd.state.nm.us/COMMUNITIES/ShowCounty.php

U.S. Census Bureau. (2000a). Census 2000 Summary File 3 (sf 3) [electronic]. American FactFinder. Retrieved 10/9/02, 2002, from the World Wide Web: http://factfinder.census.gov

U.S. Census Bureau. (2000b). Profiles of General Demographics Characteristics: 2000 Census of Population and Housing. Department of Commerce. Retrieved 10/9/02, 2002, from the World Wide Web: http://factfinder.census.gov

U.S. Department of Agriculture. (2000a). 2000 New Mexico Agricultural Statistics: 1999 Irrigated Crop Acreage Water Use. Water Use and Conservation Bureau, Office of the State Engineer. Retrieved 10/9/02, 2002, from the World Wide Web: http://www.nass.usda.gov/nm/nmbulletin/Irrcrop.txt

U.S. Department of Agriculture. (2000b). 2000 New Mexico Agricultural Statistics: Farm Numbers and Land in Farms. USDA. Retrieved 10/9/02, 2002, from the World Wide Web: http://www.nass.usda.gov/nm/nmbulletin/Farmnum.txt

U.S. Environmental Protection Agency. (2002a). Envirofacts information about Chaves County, NM. Envirofacts Warehouse. Retrieved 10/9/02, 2002, from the World Wide Web: http://oaspub.epa.gov

U.S. Environmental Protection Agency. (2002b). Envirofacts information about Eddy County, NM. Envirofacts Warehouse. Retrieved 10/9/02, 2002, from the World Wide Web: http://www.epa.gov

U.S. Fish and Wildlife Service. (1997). Banking on Nature: The Economic Benefits to Local Communities of National Wildlife Refuge Visitation. Washington, DC: Division of Economics, USFWS.

U.S. Fish and Wildlife Service, & Research Management Consultants Inc. (1998). Bitter Lake National Wildlife Refuge: Final Comprehensive Conservation Plan and Environment Assessment. Roswell, NM.

Wilson, B. C., & Lucero, A. A. (1997). Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 1995 (Technical Report). Sante Fe, NM: New Mexico State Engineer Office.

Wilson, B. C., & Lucero, A. A. (2002). Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 2000. Sante Fe, NM: New Mexico State Engineer Office.

FIGURES

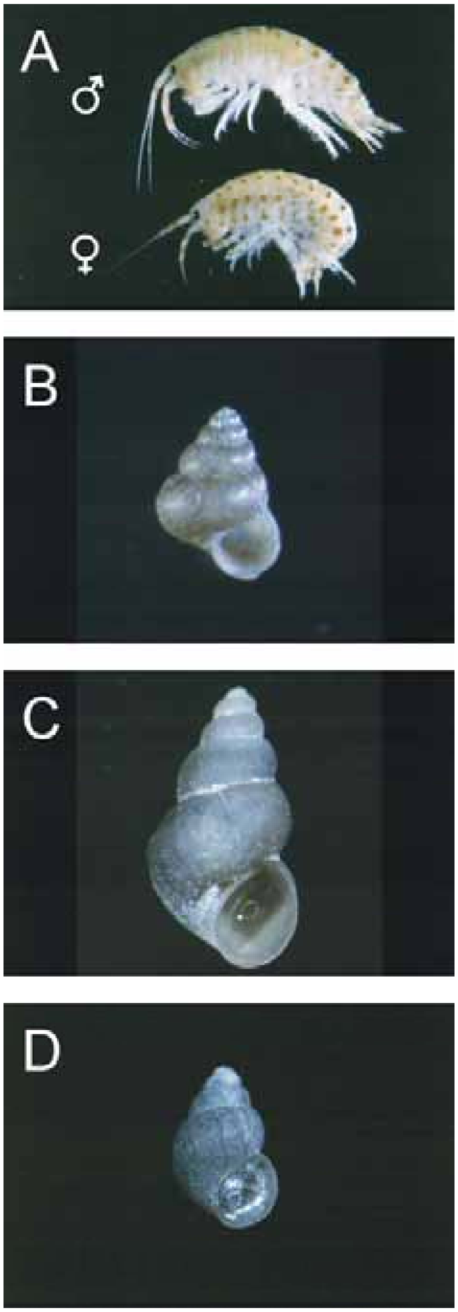

Figure 1. Photographs of the four invertebrate species:

A – **Noel's amphipod** (male above, female below); body lengths are approx. 10-12 mm.

B – **Pecos assiminea**; shell length is approx. 2 mm.

C – **Koster's springsnail**; shell length is approx. 4 mm.

D – **Roswell springsnail**; shell length is approx. 3 mm.

Scale of the photographs is variable; therefore, organism sizes are not comparable. All photos are by B. K. Lang (New Mexico Department of Game and Fish).

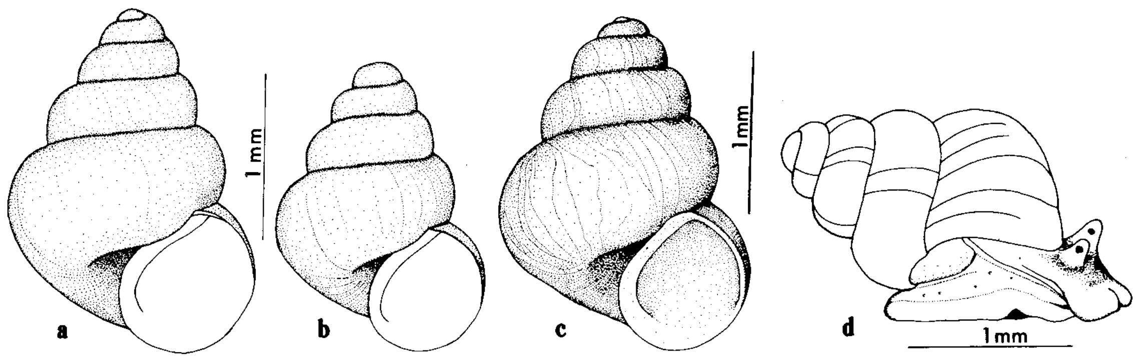

Figure 2. Pecos assiminea (excerpted from Taylor, 1987: Figure 2).

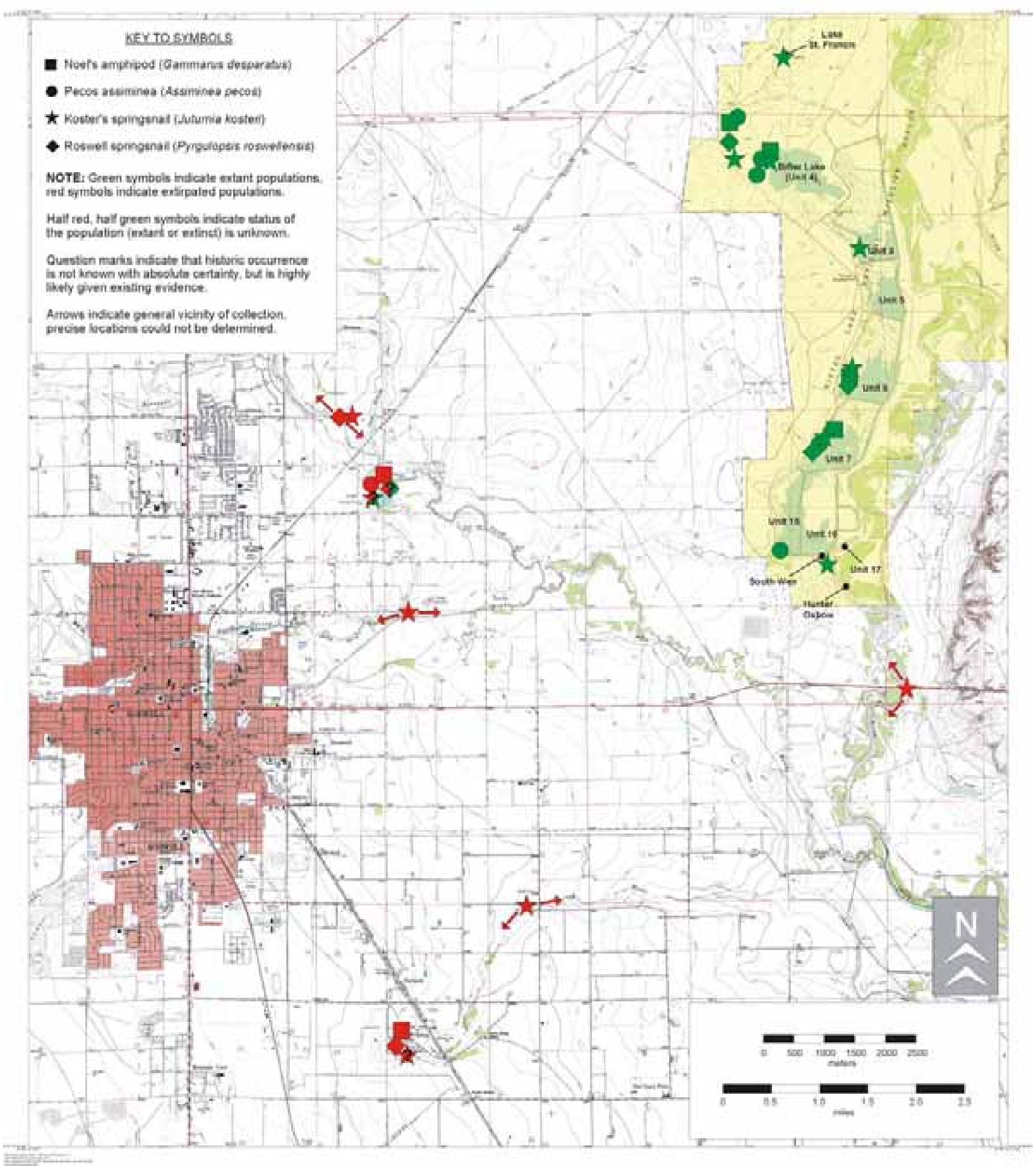

Figure 3. Historic (red symbols) and current (green symbols) distribution of Noel's amphipod (squares), Pecos assiminea (circles), Koster's springsnail (stars), and Roswell springsnail (diamonds). See text for discussion and sources.

Figure 4. Habitat characteristics at Sago Spring, Bitter Lake National Wildlife Refuge. Photo by J. S. Pittenger.

Figure 5. Characteristic microhabitat of Pecos assiminea, consisting of dense, moist litter and saturated soils. A single Pecos assiminea is indicated at the tip of the pen. Photo by K. A. Yori.

Figure 6. Dense, monotypic stand of common reed (*Phragmites australis*) at Dragonfly Spring, Bitter Lake National Wildlife Refuge, August 2002. Photo by J. S. Pittenger.

Figure 7. Gypsum substrate at Sago Spring, Bitter Lake National Wildlife Refuge, colonized by Roswell springsnail (dark spots from center-top to center-bottom of photo). Photo by J. S. Pittenger.

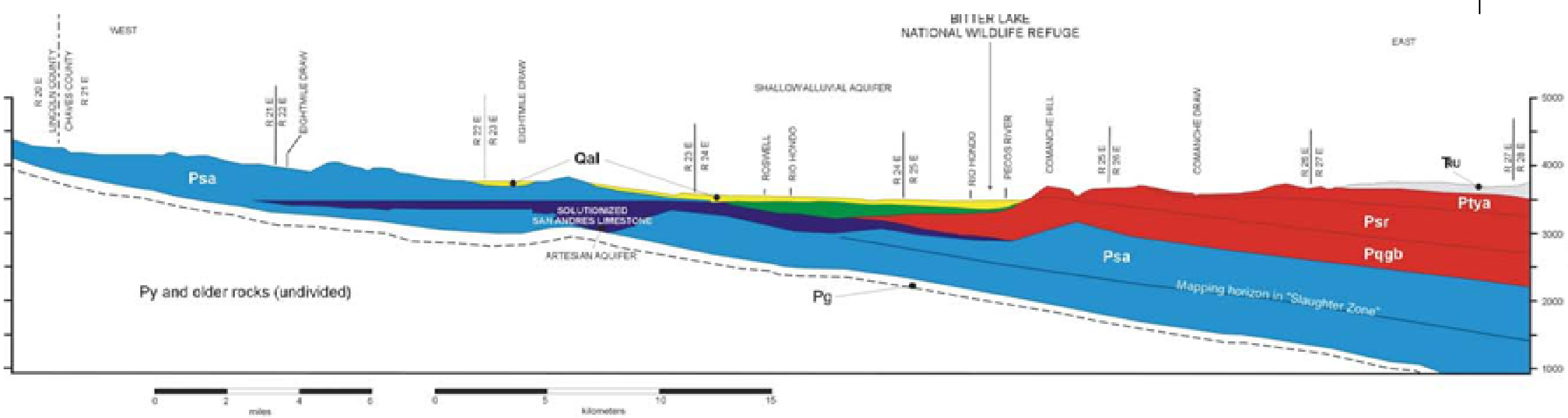

Figure 8. Diagram of a geologic cross section roughly along U.S. Highway 380 from the Lincoln-Chaves county line east through the Pecos River Valley (adapted from Welder, 1983 and Kelley, 1971). Springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge are fed by a shallow, alluvial aquifer and a deeper, carbonate aquifer in solutionized San Andres limestone. This artesian, carbonate aquifer is partially confined by the overlying and relatively impermeable Artesia Group.

EXPLANATION OF SYMBOLS:

Qal = Alluvial deposits
Ŧu = Triassic rocks, undivided
Ptya = Tansill and Yates Formations, undivided
Psr = Seven Rivers Formation
Pqgb = Queen and Grayburg Formations, undivided (includes upper part of San Andres limestone where it is solution-altered)
Artesia Group
Psa = San Andres Limestone
Pg = Glorieta sandstone
Py = Yeso Formation

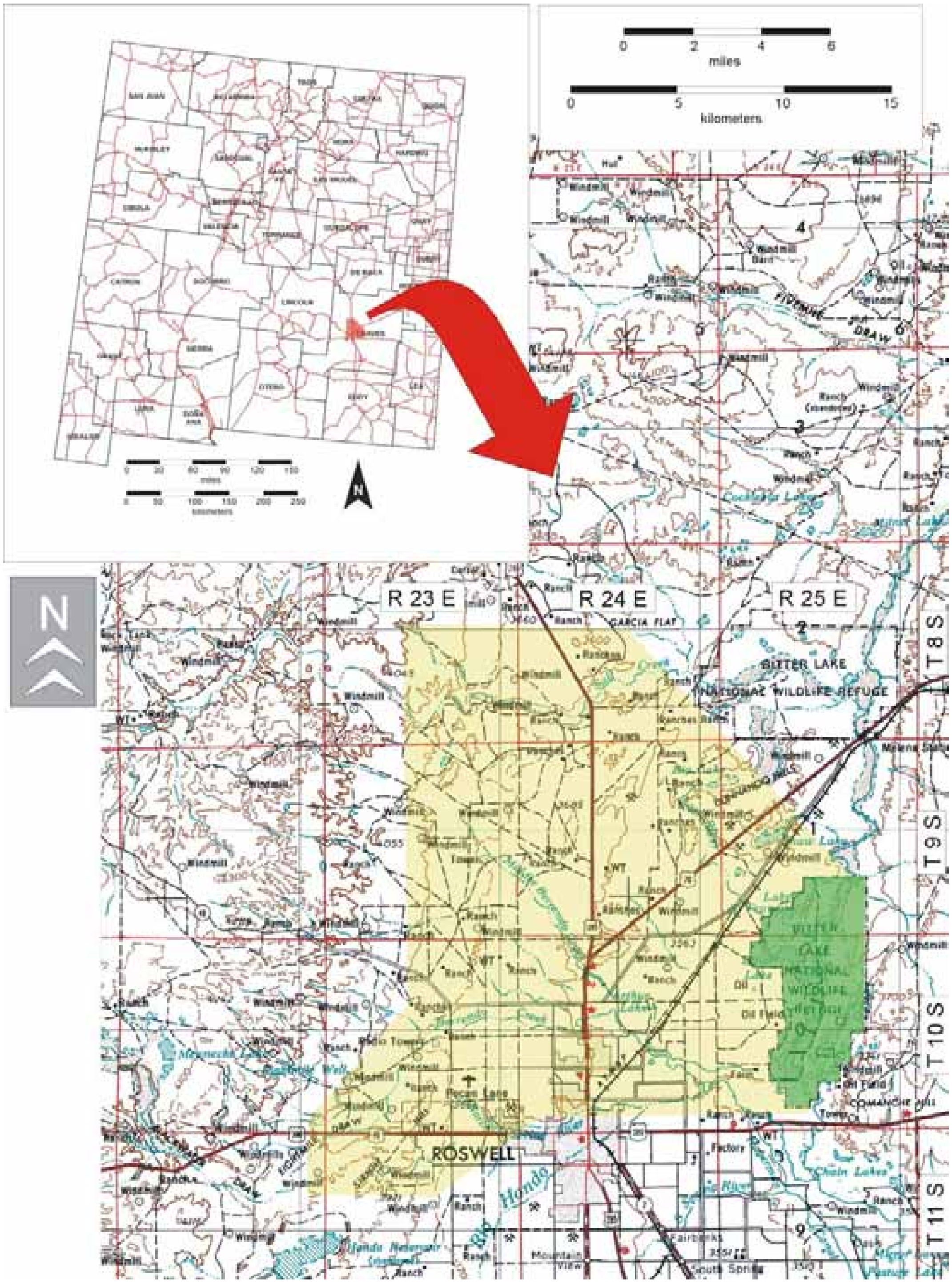

Figure 9. The 500-year source-water capture zone (yellow area) for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge (green area; adapted from Wolford et al., 1999).

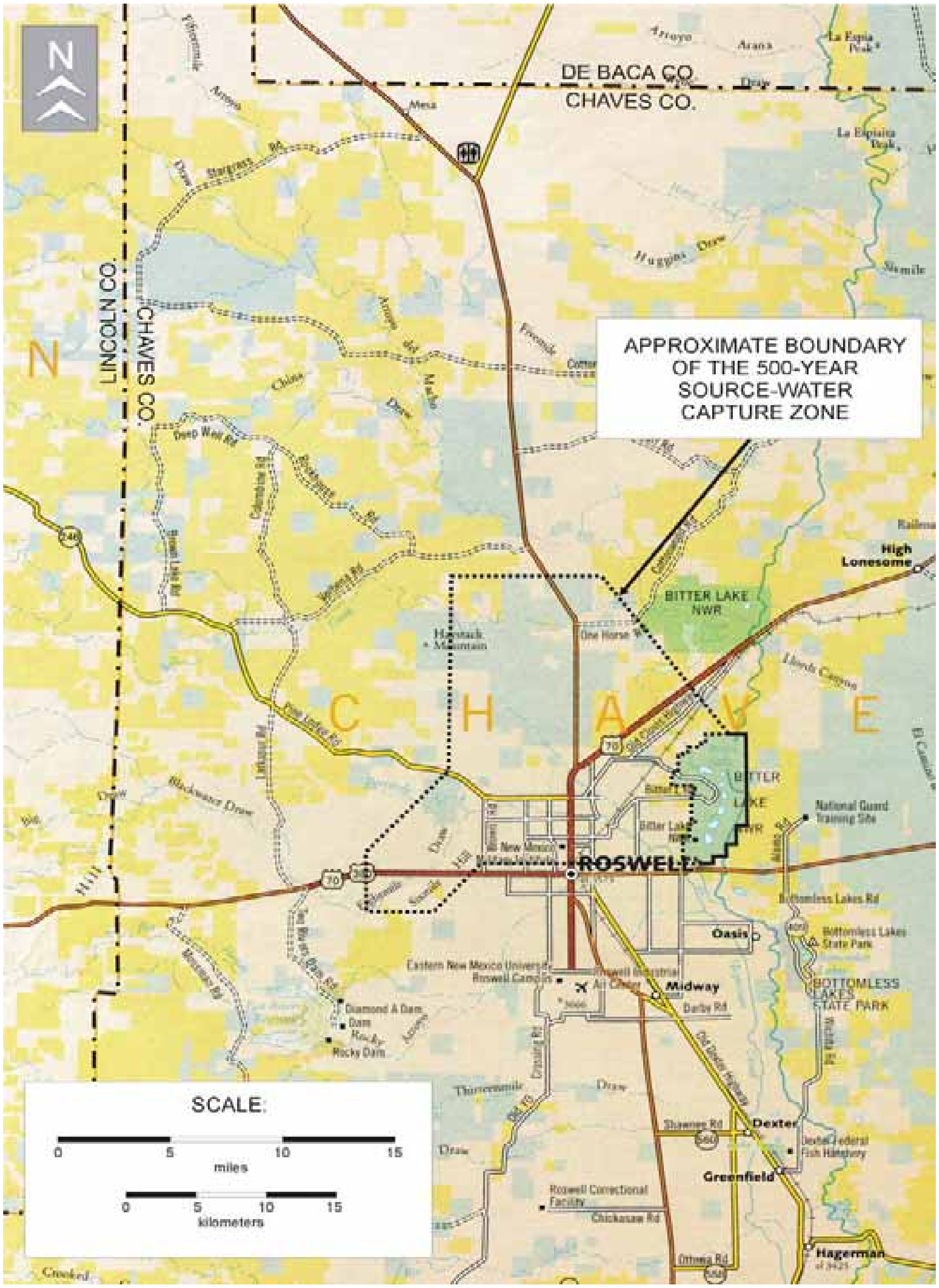

Figure 10. Land status within the 500-year source water capture zone for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge. Tan areas denote private lands, yellow areas are State Trust lands, and blue areas are lands administered by the Bureau of Land Management.

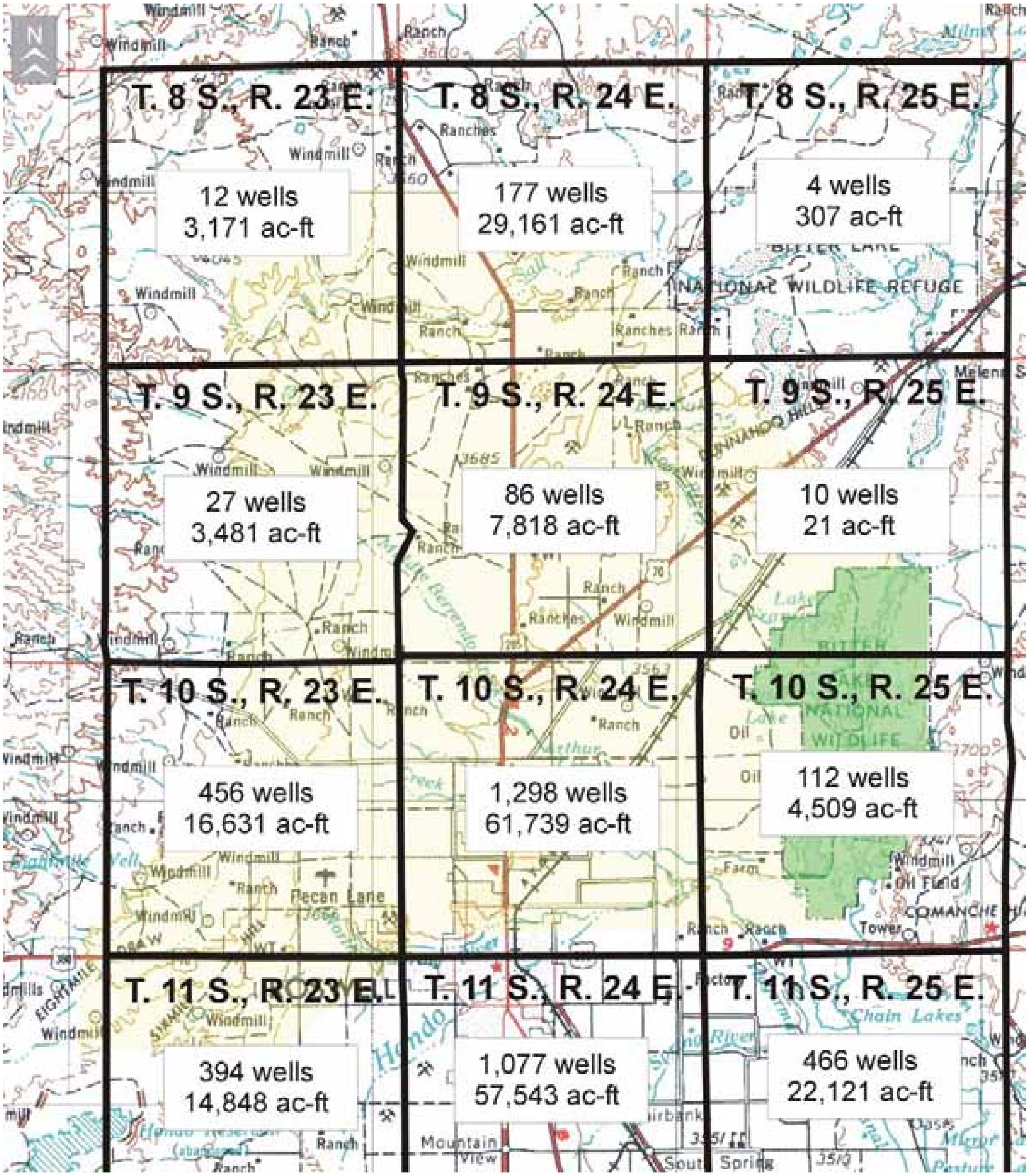

Figure 11. Number of wells and total groundwater withdrawal in the 12 townships that encompass the 500-year source-water capture zone for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge, as of 8 October 2002 (compiled from Office of the State Engineer, 2002). The wildlife refuge is indicated by green shading and the approximate source-water capture zone is shown by yellow shading.

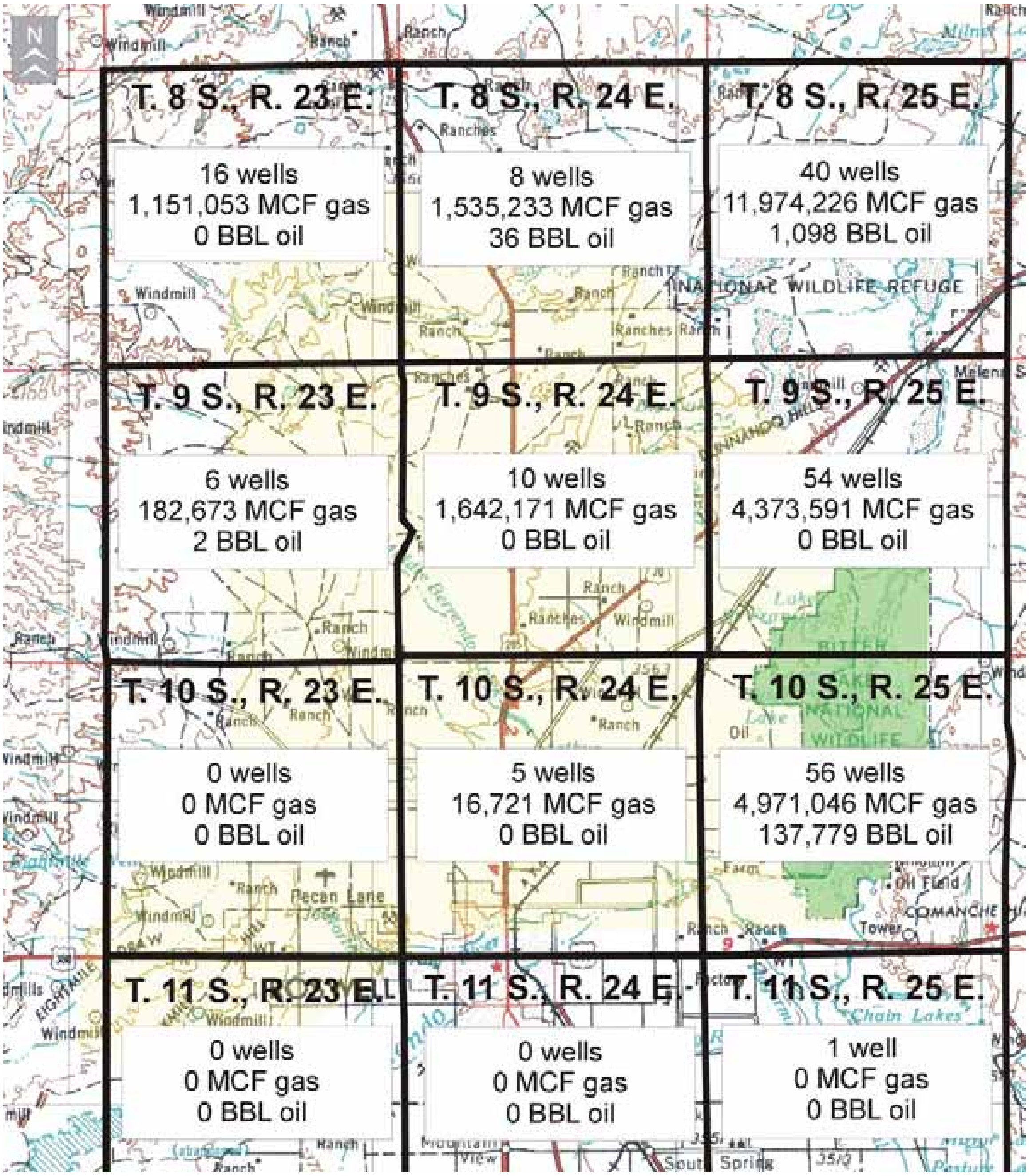

Figure 12. Number of existing wells and total oil and gas production since about 1972 in the 12 townships that encompass the 500-year source-water capture zone for springs and seeps on the Middle Unit of Bitter Lake National Wildlife Refuge, as of 8 October 2002 (compiled from New Mexico Petroleum Research Center, 2002). The wildlife refuge is indicated by green shading and the approximate source-water capture zone is shown by yellow shading. MCF = 1,000 cubic feet and BBL = barrel (42 U. S. gallons).

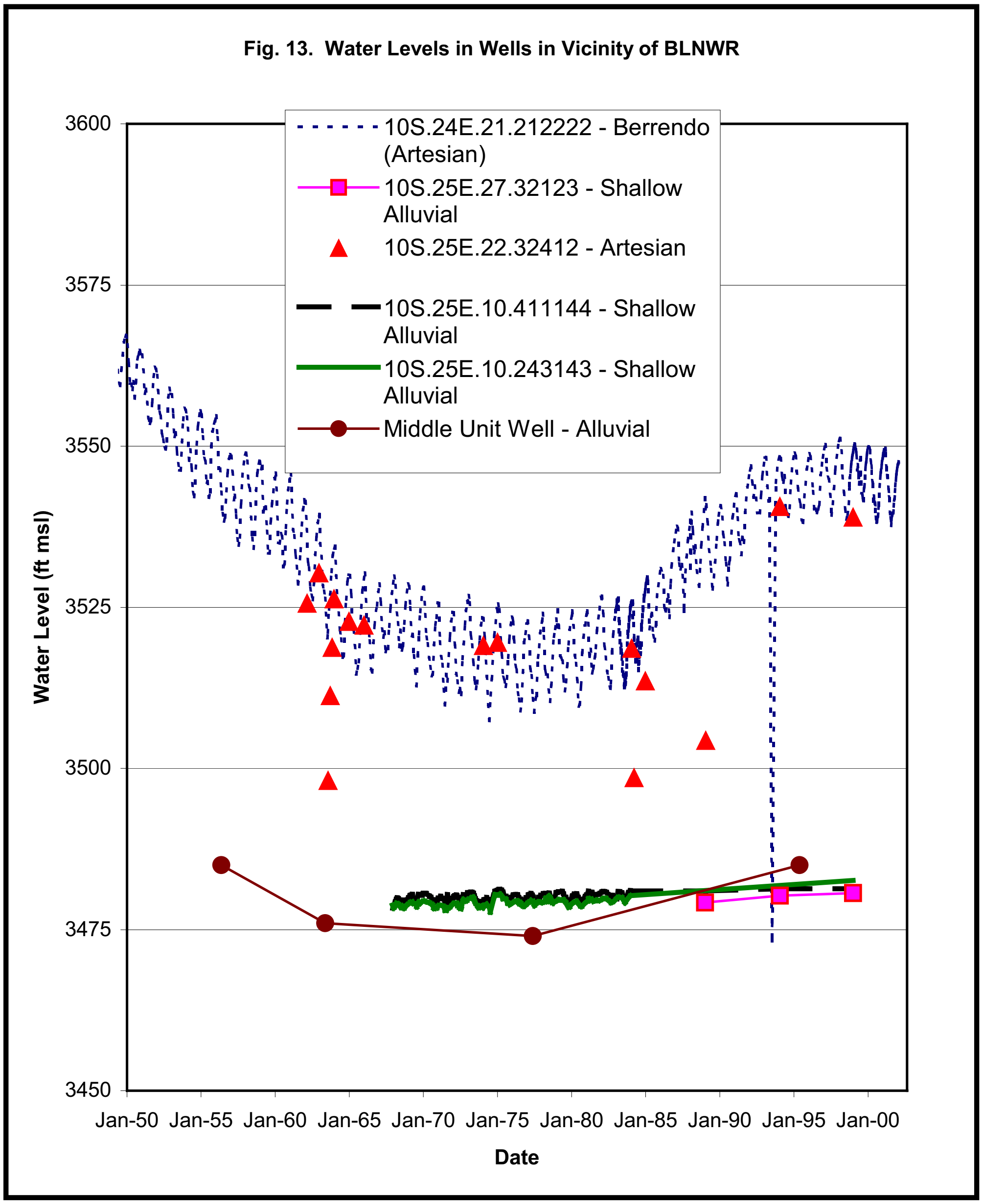

Figure 13. Water levels (in feet above mean sea level) at wells in the vicinity of Bitter Lake National Wildlife Refuge from 1950 to 2000 (figure from New Mexico Office of the State Engineer and Interstate Stream Commission).

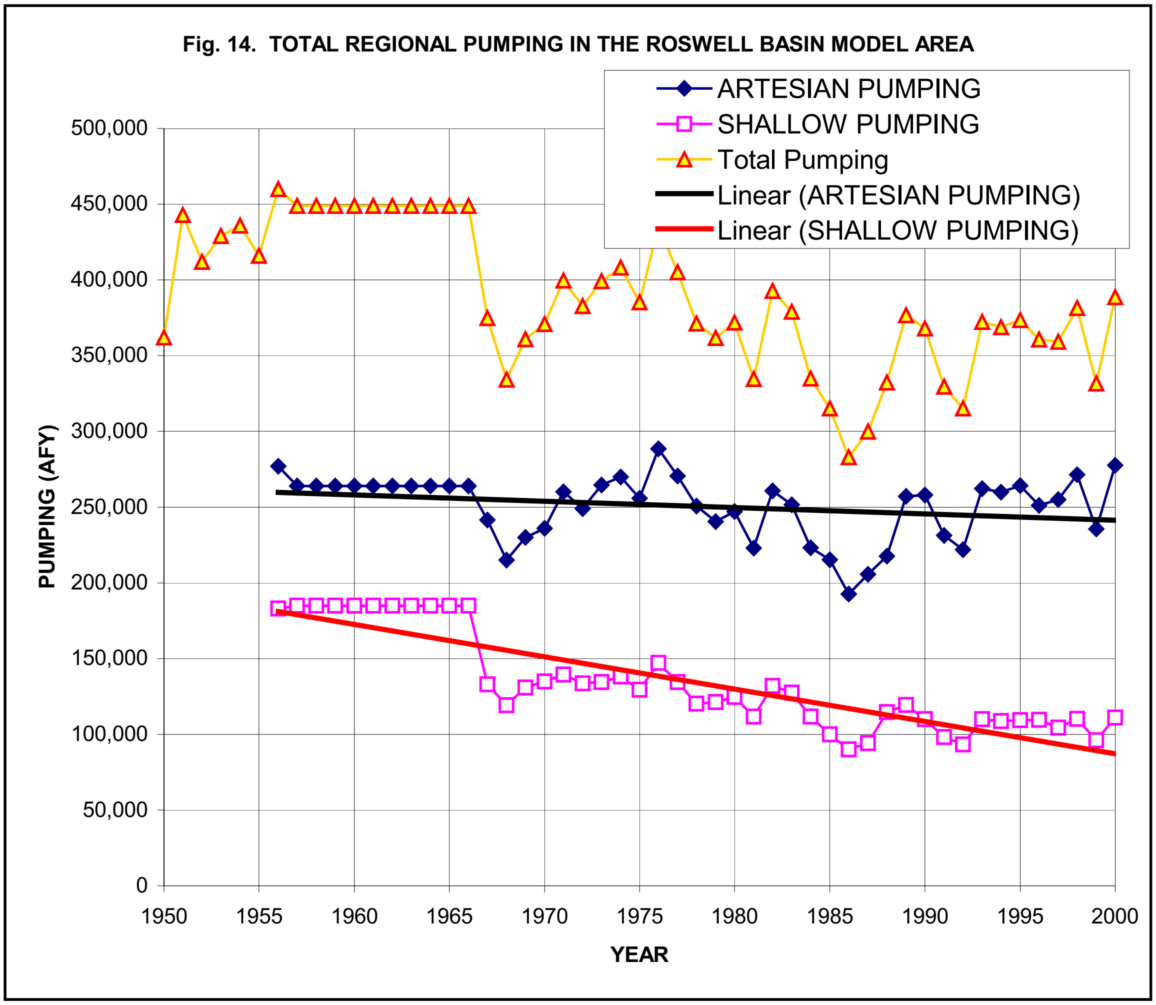

Figure 14. Total regional pumping (in acre-feet per year) of artesian and shallow groundwater in the Roswell Basin Model Area from 1950 to 2000. Lines indicate trends for artesian and shallow groundwater pumping. (figure from New Mexico Office of the State Engineer and Interstate Stream Commission).