MANAGEMENT PLAN FOR THE CONSERVATION OF RARE AND ENDANGERED KARST SPECIES, CAMP BULLIS, BEXAR AND COMAL COUNTIES, TEXAS

by
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Executive Summary

Camp Bullis is a 113.3-km^2 military training facility under the Fort Sam Houston Command. It is located in north-central Bexar County and southwestern Comal County. Camp Bullis' mission is to provide field training and support for military activities in south Texas, including weapons training, field training and maneuvers, map and compass courses, parachute operations training, combat assault landing training, and field medical training. Soon after the now-listed species were petitioned for endangered listing, Camp Bullis initiated a series of cave and karst investigations that continue to the present in order to pro-actively evaluate the installation's potential to contain the species and manage those species according to the best available scientific information (Veni and Elliott, 1994; Veni et al., 1995, 1996, 1998a, 1998b, 1999, 2000, 2002a, 2002b). To date, three of the species have been found on the installation, *Cicurina* (*Cicurella*) *madla*, *Rhadine exilis*, *Rhadine infernalis*. Additionally, one species on the State of Texas list of threatened species has been found, *Eurycea tridentifera*, plus 15 new or possibly new species known only from Camp Bullis.

The presence of these listed and rare species of concern suggests that Camp Bullis has effectively managed its impact to the environment and these animals. This includes the potential impacts from the installation's live fire ranges where one of the listed species is known to occur in five caves despite several decades of firearm use. With the increasing rate of urban development of the area around the installation, Camp Bullis may become an important refuge where these and other listed and rare species will continue to survive.

The mission requirements of Camp Bullis demand the presence of large tracts of undeveloped land for training operations that are mostly compatible with successfully preserving in perpetuity the ecosystems of the listed species and species of concern. This management plan is designed to minimize and/or direct potentially detrimental impacts away from those species where feasible, including impacts (like fire ant infestation) not resulting from Camp Bullis actions. Where impacts to the species cannot be avoided, Camp Bullis will enter into consultations with U.S. Fish and Wildlife Service (USFWS).

This management plan represents the cumulative efforts of Camp Bullis to eliminate, mitigate, and prevent harm to the four federally or state-listed species and the 15 rare but unlisted species of concern. All of the species are troglobites, known only from caves and related karst voids, and all but the state-listed species are invertebrates. Most of the species are known only from Camp Bullis.

This plan is written in the format of a USFWS recovery plan to best address past and current threats and management actions, and to efficiently propose and coordinate future management action for the species, including an Endangered Species Act Section 7 consultation if necessary with USFWS for the listed species. By proposing a plan that includes non-listed species of concern, Camp Bullis can take a broader and more effective ecosystem-based approach to species management, similar to habitat conservation plans.

This management plan is designed to provide detailed steps for management of the listed karst species and species of concern at Camp Bullis and to outline a general strategy for situations not covered by specific management actions. The management plan has two goals:

1) preservation and protection of the listed karst species and species of concern and their habitat in perpetuity, within the limits possible through the caves, land, and authority of Camp Bullis and its operational and mission requirements;
2) ensure the species' survival, genetic diversity, and evolution in a manner consistent with the delisting or downlisting of endangered and threatened karst species as recognized by the USFWS (1994) recovery plan for related listed species in the Austin, Texas, area.

Below is an outline of the tasks needed to meet the objectives of this plan. Narrative descriptions of the tasks are discussed in the plan followed by specific management recommendations for the 32 karst management areas. Attainment of this plan will proceed as allowed by funding and Camp Bullis' mission and operational requirements.

1. Identify karst management areas needed to meet the management plan criteria.
2. Determine the appropriate size and shape of the karst management areas.
3. Provide protection in perpetuity to the karst management areas.
   - 3.1 Coordinate with USFWS, TPWD, and other agencies.
   - 3.2 Review and update Camp Bullis regulations as needed.
4. Implement conservation measures and manage karst management areas.
   - 4.1 Apply USFWS fire ant management techniques.
   - 4.2 Identify and protect important sources of nutrients into karst ecosystems.
   - 4.3 Determine and implement appropriate means to prevent siltation and/or entry of other contaminants to the karst management areas.
   - 4.4 Determine and implement appropriate means to prevent vandalism, dumping of trash, and unauthorized human entry of caves and karst features.
   - 4.5 Other actions as needed.
5. Additional research.
   - 5.1 Conduct additional karst and biospeleological surveys.
   - 5.2 Continue hydrogeologic studies of karst management areas that are currently incomplete.
   - 5.3 Conduct additional studies on the ecology of the listed species and species of concern.
   - 5.4 Revise the karst species management plan as needed.
6. Education
   - 6.1 Develop educational programs to raise awareness and encourage protection of karst ecosystems by Camp Bullis personnel.
   - 6.2 Develop educational programs on karst ecology and hydrogeology to help

key Camp Bullis personnel with the management of the karst management areas and the listed species and species of concern.

6.3 Develop educational information for public relations.

7. Monitoring

The one notable management issue involves the ability of Camp Bullis to redirect the training at the live fire ranges. Reorienting these firing areas is not feasible within the current Army training doctrine or funding level of the installation. Activities on the ranges that could have a detrimental effect are accidental fires that destroy native vegetation, mowing around the target arrays, bullet strikes around and near cave entrances that damage the vegetation, and the release of potentially harmful levels of heavy metals to the environment. Camp Bullis will mitigate these possible impacts by undertaking the following actions on the live fire ranges:

1) Any accidental range fire will be fought vigorously in the area around any cave on a live fire range to limit the impact to the smallest possible area.
2) A buffer area of 10 meters will not be mowed around cave entrances on the live fire ranges.
3) Camp Bullis will continue to monitor water leaving the live fire ranges for contaminants that may prove detrimental to the cave species.
4) Camp Bullis will enter into consultation with the USFWS if there is a major increase in training activity near any cave with listed species.

Introduction

The Bexar County, Texas, region is hydrogeologically and biologically complex. Species living in the region's caves have become physically isolated from each other through time, resulting in genetic isolation that has produced new species known to occur only within small geographic areas. The northward expansion of San Antonio onto the karst areas where these species occur poses a threat to their survival. This is due to the destruction of caves, sealing of caves, changes in nutrient and moisture input into caves, contaminants introduced into caves, and competition with and predation by non-native species introduced by urbanization (Elliott, 1993a, 2000).

Due to concern about their survival, nine species of karst invertebrates were federally listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in December 2000 (USFWS, 2000a), with critical habitat proposed in August 2002 (USFWS, 2002):

Batrisodes (Excavodes) venyivi	*Neoleptoneta microps*
Cicurina (Cicurella) baronia	*Rhadine exilis*
Cicurina (Cicurella) madla	*Rhadine infernalis*
Cicurina (Cicurella) venii	*Texella cokendolpheri*
Cicurina (Cicurella) vespera	

These species are currently only known from northern and parts of western Bexar County.

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Spiders	*Cicurina* (*Cicurella*) n. sp. 1
	Cicurina (*Cicurella*) n. sp. 2
	Cicurina (*Cicurella*) n. sp. 3
	Neoleptoneta n. sp.
Pseudoscorpions	*Tartarocreagris reyesi*
Harvestmen	*Texella* n. sp. 1
	Texella n. sp. 2
	Texella n. sp. 3
Millipedes	*Speodesmus* n. sp. 1
	Speodesmus n. sp. 2
Entotrophs	*Mixojapyx* sp.
Ground beetles	*Rhadine* sp. 1
	Rhadine sp. 2
	Rhadine sp. 3
Salamanders	*Eurycea* sp.

Additionally, *Eurycea tridentifera*, a cave-adapted salamander on the Texas list of threatened species (Campbell, 1995), is also definitively known from two caves on Camp Bullis, and probably three. For the purposes of this report and consistency with USFWS nomenclature, "listed species" will be used to describe the three federally listed endangered species and the state-listed salamander species, and "species of concern" will be used to describe the 15 new and possibly new species.

The purpose of this investigation is to develop a management plan to conserve the listed species and species of concern to meet or exceed the standards recommended by the USFWS for the recovery of listed species. These standards are not assurances that the species will be considered for downlisting or delisting based on these recommended actions. They are meant to represent sound standards for sustainable survival of the species and preservation of their habitat to the degree possible within the confines of Camp Bullis and the Fort Sam Houston Command. Camp Bullis has actively studied and protected the species, meeting and often exceeding the requirements of the USFWS. It intends to continue such efforts but recognizes those actions could be limited by the installation's mission requirements.

The USFWS recovery criteria for the Bexar County karst invertebrates are currently being designed. Reddell and Veni are members of the recovery team and Cokendolpher is a consultant to the team. We will apply the best available information for this report but cannot assure compliance with the final recovery plan since it is not complete. Camp Bullis exceeds some of the requirements considered for the recovery plan by including rare species in this management plan that are currently not proposed for listing. Such action decreases the likelihood that those species will be petitioned for listing and listed at a later date. This plan updates an earlier version (Veni and Reddell, 1999) with more recent information and USFWS guidance.

This management plan follows the format of the USFWS' recovery plan for related endangered karst invertebrates in Travis and Williamson counties, Texas (USFWS, 1994). It is presented in five main parts:

1) Executive summary;
2) Introductory information;
3) Existing conditions, which includes descriptions of the species, their distribution and ecology, the threats to their survival, and conservation measures;
4) Recommended management plan; and
5) References and appendices.

Appendix A is a glossary of geological, biological, and karst terms used in this report, including taxonomic abbreviations. Appendix B is a conversion index from the International System of Units, used in this report, to English units. Appendix C lists all Camp Bullis caves discussed in this report and their karst feature identification numbers. Appendix D provides biographies of the personnel who contributed to this report.

Project Staff and Contributors

Staff for this project includes karst hydrogeologist Dr. George Veni, cave biologists James R. Reddell and James C. Cokendolpher, and cartographer and karst technician Peter Sprouse. However, our efforts here represent the cumulative efforts, ideas, and contributions of many people who have worked from 1993 to the present on the Camp Bullis cave and karst projects that were previously cited. We are grateful for all of their assistance.

People who worked for or in cooperation with George Veni and Associates in studying the Camp Bullis karst include: James C. Cokendolpher, Rick Corbell, Dr. William R. Elliott, Jerry Fant, Lee Jay Graves, Jean Krejca, Joe Ivy, Bruce Johnson, Rebecca Jones, Jeanette Joost, Niki Lake, Bill Larsen, Gary McDaniel, Logan McNatt, Chris Murray, Linda Palit, Gary Poole, Ian Quigley, James R. Reddell, Marcelino Reyes, Charley Savvas, Peter Sprouse, Chris Thibodaux, Dr. Rickard S. Toomey, III, Terri Treacy, Javier Treviño, Karen Veni, Mike Warton and his staff at Mike Warton and Associates, plus Dennis Glinn, Weldon W. Hammond, III, Ann Scott and the rest of the staff at Prewitt and Associates.

Through the course of the cave and karst projects, the following taxonomists have evaluated the cave fauna from Camp Bullis for authoritative identification and description of the species: Dr. Donald S. Chandler (mold beetles), Dr. Paul Chippindale (salamanders), Dr. Kenneth Christiansen (springtails), James C. Cokendolpher (harvestmen, ants, and spiders), Dr. William R. Elliott (millipedes and crickets), Dr. Lee Herman (rove beetles), Dr. John R. Holsinger (amphipods), Dr. S.A. Marshall (flies and mosquitoes), Dr. William B. Muchmore (pseudoscorpions), James R. Reddell (ground beetles and crickets), Dr. Rowland M. Shelley (centipedes and millipedes), Dr. W. David Sissom (scorpions), Dr. Charles Triplehorn (darkling beetles), and Darrell Ubick (harvestmen and spiders). James Reddell coordinated the distribution of specimens for identification. Some taxa collected at Camp Bullis do not currently have specialists qualified to perform such studies, and those specimens are deposited in the invertebrate zoology collection of the Texas Memorial Museum at The University of Texas in Austin until a specialist becomes available. Dr. Paul Chippindale graciously included Reddell and Marcelino Reyes under his scientific collection permit to collect salamanders.

This and previous cave and karst projects at Camp Bullis by George Veni and Associates were conducted in coordination with Dusty Bruns and Jerry Thompson of the Camp Bullis Environmental Office and Integrated Training Area Management (ITAM) Office and Jackie Schlatter of the Directorate of Safety, Environment, and Fire at Fort Sam Houston. Additional assistance from those offices, for this and related previous projects, was provided by Mike Hilger, Amy Pearson, and Mike Quiroga. Stephen P. Austin and Joseph Murphey of the U.S. Army Corps of Engineers, Fort Worth District, also helped coordinate some of the previous cave and karst projects. Helpful review comments and discussion for this management plan were also provided by attorney Rodney Hudson of Fort Sam Houston, and USFWS (Pine, 2002), especially Tannika Engelhard.

Methodology

Work for this management plan began with reviews of the existing cave and karst research conducted at Camp Bullis, literature related to the species at Camp Bullis or to the project, and consultation with other specialists and environmental management personnel in order to collect all existing information relevant to this project. Recommendations from the cave and karst reports were consolidated as appropriate in the management plan and refined where necessary per the results of more recent research.

Based on the above information, the mapped extent of the individual caves' drainage areas as determined in previous studies and through a concurrent study for USFWS (Veni, in review), this management plan was written to cover general management of the karst areas on Camp Bullis, and specific management actions for the listed species, species of concern, and the individual caves containing them. This plan identifies caves of greatest biological significance, with significance determined by each cave's general biodiversity, diversity of listed species and species of concern, and the number of localities known for each species. Biological significance is then weighed against the quality of each cave's habitat and its risk of degradation. Management recommendations are provided in order of priority, giving those caves of high biological significance and/or high habitat quality first ranking. Should U.S. Army needs require actions which may impact caves with listed species or species of concern, this ranking identifies those caves which would probably be the best to conserve, the areas needed for conservation around each of the caves, and management recommendations for those areas.

This report, its methodology and standards, generally follow the USFWS (1994) recovery plan for endangered cave invertebrates in the Austin, Texas, area. However, this management plan and its recommended actions are not described as "recovery" actions to prevent confusion with recovery actions by the USFWS. Some parts of this management plan do not conform to the USFWS (1994) recovery plan where conditions at Camp Bullis are not addressed in the recovery plan or are sufficiently different to warrant alternative actions.

Existing Conditions Affecting List Species and Species of Concern

Taxonomy, Legal Classification, and Description

Four listed species and 15 species of concern are described below. Some have been fully described and named, while others await further study and classification. Only two of the fully described species have common names: *Cicurina* (*Cicurella*) *madla* (Madla Cave meshweaver) and *Eurycea tridentifera* (Comal Blind Salamander). For clarity, all species will be called by their scientific names in this report.

Some of the described species below are noted as potentially new species or subspecies, given possible anatomical differences and their significant distance from other localities where the species have been found. Many of the invertebrate species are identified primarily from a single gender where distinctive differences are present in the genitalia. Adult invertebrate specimens are needed for identification to species level. Possible listed species or species of concern may exist in some caves where either the gender that cannot be identified to species level was collected, or where immature specimens were collected but could be identified as troglobites (the category of cave adaptation where rare and endangered species are most likely to occur). In each case, the animal can only be identified to genus. In such situations, the status of the species can only be determined by revisiting the cave, collecting adults for identification, or collecting immature specimens and, if possible, raising them to adulthood in a laboratory (e.g. Veni et al., 1999). In the future, DNA studies may result in reclassification of some species, as their relationships are better understood.

Species 1 – Scientific name: *Cicurina* (*Cicurella*) n. sp. 1

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Dictynidae. The placement of the genus *Cicurina* in the family Dictynidae is not settled in the literature, although most modern treatments of the genus place it there. The Dictynidae is a diverse group of small to medium sized web spinners known from throughout the world. The cicurinas are unique members of the family on the basis of the lack of two web making structures (cribellum and calamistrum). Taxonomists opposing the placement of the genus in the Dictynidae insist that cicurinas never had the structures, so they did not lose them during evolution. Cicurinas are the only members of the family to have evolved troglobitic members. The genus *Cicurina* was described on the basis of a species from Europe and later species were added from distant countries. The species from North America have been revised several times with the addition of numerous new species. Currently, the genus is known by 117 named species, of which one is from northern Europe, seven are from eastern Asia, and 109 are from North America. Almost half of the described species are known only from caves. Cicurinas are known from about 70 epigean and cavernicolous species in Texas. Gertsch (1992), in the latest revision of the genus in North America, recognized 51 species from caves in Texas; of which 46 are true eyeless troglobites.

Original description: The species is currently being described (Cokendolpher, in preparation [a]). Veni et al. (1995) first reported it from Isocow Cave on Camp Bullis as *Cicurina* (*Cicurella*) sp. nr. *baronia* Gertsch. Veni et al. (1996) and Veni et al. (1999) reported it as *Cicurina* (*Cicurella*) new species

1. Veni et al. (1999) listed two additional localities on Camp Bullis for this species: Hilger Hole and Root Canal Cave.

Type specimen: The preliminary manuscript by Cokendolpher (in preparation [a]) lists the female holotype from Isocow Cave (11A-22), Zone 3 (top of 3.6 m pit to top of 4.6 m pit), 2 March 1994 (collected by William Elliott and George. Veni), and it is to be deposited in the American Museum of Natural History. Four female paratypes are listed from Root Canal Cave, 20 April 1999 (collected by James Reddell and Marcelino Reyes), and will be deposited in the collection of the Texas Memorial Museum and that of Cokendolpher. Two female paratype is also listed from Hilger Hole, 20 April 1999 (collected by James Reddell and Marcelino Reyes), and will be deposited in the collection of the Texas Memorial Museum. Single female paratypes are also listed from Platypus Pit, 30 March 1995 (collected by James Reddell and Marcelino Reyes) and from Eagles Nest Cave, 1 November 2001 (collected by James Reddell and Marcelino Reyes) and both will be deposited at the Texas Memorial Museum. Until the species is described, the specimens will be retained by the taxonomist (Cokendolpher) and will then be deposited in the collections as described above.

Other taxonomic literature: None.

Selected characteristics: The spider is small to medium-sized (about 3.9 to 5.7-mm total length), cream colored, and eyeless. Specific diagnostic characters pertain to the morphology of the internal genitalia of the female.

Intraspecific variation: No data are available at this time.

Distinctiveness: Troglobitic members of the genus *Cicurina* from Texas cannot be distinguished from each other by external body morphology. All are pale colored, eyeless spiders. Currently, species are recognized only by the morphology of the internal female genitalia. Hopefully, after more males are obtained and studied, the morphology of the male palpus will also be used. Immatures cannot be identified to species. In the field, troglobitic cicurinas are easily confused with the more common *Cicurina varians*. Close examination with a hand lens can separate the two because *C. varians* has eight eyes, and the troglobitic species of *Cicurina* are totally eyeless. Cicurinas are the only totally eyeless spiders known from Camp Bullis. Troglobitic spiders of *Eidmannella rostrata* from Camp Bullis have eyes very reduced in size, but they are not totally eyeless. *Eidmannella* generally hang in small webs whereas *Cicurina* run from their webs as soon as they are disturbed.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 2 – Scientific name: *Cicurina* (*Cicurella*) n. sp. 2

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Dictynidae. See the taxonomic classification for *Cicurina* (*Cicurella*) n. sp. 1.

Original description: The species is currently being described (Cokendolpher, in preparation [a]). Veni et al. (1995) first reported it from Platypus Pit on Camp Bullis as *Cicurina* (*Cicurella*) n. sp. 2. Veni et al. (1996 and 1998) also mention the species. Veni et al. (1999) listed a possible additional locality on Camp Bullis in Up the Creek Cave.

Type specimen: In the manuscript by Cokendolpher (in preparation [a]), the female holotype is from Platypus Pit, 30 March 1995 (collected by James Reddell and Marcelino Reyes). The holotype will be deposited in the American Museum of Natural History. A female paratype is listed from MARS Pit, 29 October 2001 (collected by Jean Krejca and Peter Sprouse) and will be retained in the Cokendolpher collection. A single eyeless male was collected on 10 September 1998 in Up the Creek Cave. It molted to maturity on 18 November 1998. Because no females of eyeless taxa are known from this cave, and males are not known of the other nearby species (*C.* n. spp. 1 and 2), this specimen cannot currently be identified with certainty. Comparisons to known males of troglobitic species in the region (*C. madla* and *C. baronia*) reveal the Up the Creek Cave male most closely resembles that of *C. baronia*. Because the females of *C. baronia* have rounded spermathecae (they are long in *C. madla*), the female of the Up the Creek Cave species probably also has rounded spermathecae. The female of *C.* sp. 2 also has a rounded spermathecae and its only known locality (Platypus Pit) is only about 1.3 km west from Up the Creek Cave. Therefore this male is tentatively listed as *C.* n. sp. 2. Until the species is described, the specimens will be retained by the taxonomist (Cokendolpher) and will then be deposited in the collections as described above.

Other taxonomic literature: None.

Selected characteristics: The spider is medium-sized, about 5 mm in total length, cream colored, and eyeless. Specific diagnostic characters pertain to the morphology of the internal genitalia of the female.

Intraspecific variation: No data are available at this time.

Distinctiveness: See the distinctiveness for *Cicurina* (*Cicurella*) n. sp. 1.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 3 — Scientific name: *Cicurina (Cicurella)* n. sp. 3

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Dictynidae. See the taxonomic classification for *Cicurina* (*Cicurella*) n. sp. 1.

Original description: The species is currently being described (Cokendolpher, in preparation [a]). Veni et al. (2002a) first reported it from Stahl Cave on Camp Bullis as *Cicurina (Cicurella)* sp. immature.

Type specimens: The preliminary manuscript by Cokendolpher (in preparation [a]) lists the female holotype from Stahl Cave, 1 November 2001 (collected by J. Reddell and M. Reyes), which will be deposited in the American Museum of Natural History. This specimen was collected as an immature and was reared to adulthood in the laboratory. It molted 14 December 2001 and 2 August 2002. This is the only adult specimen currently known. Until the species is described, the specimen will be retained by the taxonomist (Cokendolpher).

Other taxonomic literature: None.

Selected characteristics: The spider is small-sized (about 3.5 mm total length), cream colored, and eyeless. Specific diagnostic characters pertain to the morphology of the internal genitalia of the female.

Intraspecific variation: No data are available at this time.

Distinctiveness: See the distinctiveness for *Cicurina* (*Cicurella*) n. sp. 1.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 4 – Scientific name: *Cicurina* (*Cicurella*) *madla*

Common name: Madla Cave meshweaver.

Taxonomic classification: Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Dictynidae. See the taxonomic classification for *Cicurina* (*Cicurella*) n. sp. 1.

Original description: Gertsch (1992). Cokendolpher (in preparation [a]) is redescribing this species.

It is known at Camp Bullis from Headquarters Cave.

Type specimen: Female holotype, collected from Madla's Cave, Bexar County, Texas, on 4 October 1963 by James Reddell and David McKenzie. The type specimen is deposited at the American Museum of Natural History.

Other taxonomic literature: Although not taxonomic in nature, other references to this species are in: Drewy (1994), Jackman (1997), Johnson Linam (1995), Reddell (1993), Stanford and Shull (1993), USFWS (2000), Veni (1994), and Veni et al. (1996, 1998b). Reddell (1993) also reported it as *Cicurina* (*Cicurella*) spp. and Veni et al. (1995) reported it as *Cicurina* (*Cicurella*) n. sp. 1.

Selected characteristics: This medium sized, cream colored, eyeless spider has a body length of 4.8 to 6.6 mm. Its cephalothorax is 2.3 to 3.3 mm long by 1.5 to 2.3 mm wide, its abdomen is 2.5 to 3.4 mm long by 1.5 to 2.0 mm wide, and its cheliceral retromargin has four teeth. The spider's legs are relatively long, with the first femur 2.3 to 3.3 mm long, the fourth femur 2.55 to 3.4 mm, and a first patella-tibia of 2.9 to 4.2 mm, and a fourth patella-tibia of 3.1 to 4.5 mm. Other specific characters pertain to the morphology of the internal genitalia of the female.

Intraspecific variation: No data are available at this time.

Distinctiveness: See the distinctiveness for *Cicurina* (*Cicurella*) n. sp. 1.

Listing status: The USFWS (2000) listed this species as endangered on 26 December 2000.

Management priority: Based on the available information, the species appears be limited to a relatively small geographic area in Bexar County, and only at Headquarters Cave at Camp Bullis. Its management will be among the highest priorities for the karst species at Camp Bullis.

Species 5 – Scientific name: *Neoleptoneta* n. sp.

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Leptonetidae. The leptonetids are small to minute spiders restricted to subterranean and litter habitats in the Mediterranean area (65 species), eastern Asia (60 species), Central America (one species), and North America (45 species). Gertsch (1974) revised the North American fauna. Most species worldwide are known from cave habitats. Because of their small size and uniform general morphology, characters for separating species are difficult to locate and examine. The morphology of the male genitalia appears to be most significant. Gertsch (1974) described or re-described the eight species known from caves in Texas in the genus *Leptoneta*. Later, Brignoli (1983) transferred the Texas *Leptoneta* to *Neoleptoneta*. Cokendolpher (unpublished) recognizes at least three species of *Neoleptoneta* from Bexar County caves. *Neoleptoneta microps*, from Government Canyon Bat Cave 17 km west of Camp Bullis, has reduced eyes and is only known by females, so there is some uncertainty in its identification. *Neoleptoneta* n. sp. 1 from Camp Bullis (Up the Creek Cave and possibly Cross the Creek Cave) does not have the curved tarsus of the male palpus, and palpal tibial setae are shorter and not as bold. It does not have reduced eyes. *Neoleptoneta*

n. sp. 2 is known from the Helotes Karst Fauna Region and the adjacent Government Canyon Karst Fauna Region (as described by Veni, 1994, and USFWS, 2000). The sizes of the eyes are normal. The male palpal tarsus is curved, and the palpal tibial setae are heavy and long. There is another specimen known by a female that may represent another species. This specimen is from Caracol Creek Coon Cave in the Culebra Anticline Karst Fauna Region. Until a male can be obtained, its status is uncertain. Because only males can be identified with any certainty at this time, several other collections from Camp Bullis cannot be definitively placed. They include the female from Cross the Creek Cave that has been tentatively placed with the new species from Up the Creek Cave. Biological surveys at Camp Bullis also found unidentifiable immatures in Breached Dam Cave, which has since been determined to occur just outside of Camp Bullis in Eisenhower Park. These immature specimens could represent the same new species found in Cross the Creek Cave and Up the Creek Cave or the species from the Helotes Karst Fauna Region. A single male known from western Camp Bullis (Constant Sorrow Cave, 6 March 2001, George Veni, Texas Memorial Museum [TMM]) differs from the new species by having seven promarginal teeth, having the setae next to the posterior median eyes straight, and by differences in the pedipalps. The male from Constant Sorrow Cave has the tibial spur on an elongated tubercle and the tarsus lacks a retrolateral enlargement or lobe. This male has not been compared carefully with the new species from Helotes Karst Fauna Region. More study and additional specimens will need to be obtained to be certain of all the specimens occurring on Camp Bullis.

Original description: The species is currently being described (Cokendolpher, in preparation [b]). Veni et al. (1995) first reported it from Cross the Creek Cave and Up the Creek Cave on Camp Bullis. Veni et al. (1998b) reported it also from Breached Dam Cave, which was believed to be on Camp Bullis at the time but a subsequent resurvey of the property line has proved otherwise.

Type specimen: Cokendolpher (in preparation [b]) lists the type series from the following specimens: Up the Creek Cave, 5 October 1995 (collected by James Reddell and Marcelino Reyes), 3 males, 5 females, (TMM); 30 March 1995 (collected by James Reddell and Marcelino Reyes), 4 females, (TMM); 14 November 1995, retained by Cokendolpher (collected by James Reddell and Marcelino Reyes), 1 female (James C. Cokendolpher), 1 female (American Museum of Natural History); 10 September 1998 (collected by James Cokendolpher, Jean Krejca, James Reddell, and Marcelino Reyes), 1 female paratype (laid 3 egg sacs on or near 24 September 1998, preserved 4 October 1998, JCC), 1 male holotype (preserved 4 October 1998, American Museum of Natural History), 1 male paratype (preserved 4 October 1998, TMM), 1 male paratype (molted in captivity 26 September 1998, preserved 4 October 1998, retained by Cokendolpher). Currently, the specimen from Cross the Creek Cave, 31 March 1995, James Reddell, Marcelino Reyes, 1 female (TMM), is not listed as a type specimen because of the uncertainty of the identification. Until the species is described, the specimens will be retained by the taxonomist (Cokendolpher).

Other taxonomic literature: None.

Selected characteristics: This six-eyed spider has a minute body length of 1-2 mm, and is light tan to straw colored. Other specific characters pertain to the morphology of the internal genitalia of the female and the palpus of the male.

Intraspecific variation: No data are available at this time.

Distinctiveness: Troglobitic members of the genus *Neoleptoneta* from Texas cannot be distinguished from each other by external body morphology, except to some extent by the size of the eyes and the ratios of the appendages to the body. All are minute, pale colored spiders. Currently, species are only recognized by the morphology of the male genitalia and to a much lesser extent the internal female genitalia. Immatures cannot be identified to species. In the field, neoleptonetids are easily confused with early instar immatures of other spiders because of their small size. A hand lens generally does not provide sufficient magnification for the inexperienced to verify a spider as a neoleptonetid. With some practice, neoleptonetids can be recognized by the presence of only six eyes, four in a row on the front edge of the cephalothorax, followed by a centrally located pair. Until further males can be obtained from Camp Bullis or new characters can be used to distinguish females, only a single cave population of neoleptonetids can be identified for certain.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described. It is closely related to *Neoleptoneta microps*, which is listed as endangered, but can be distinguished on the basis of eyes. Because *Neoleptoneta microps* is only known for certain from females, it is possible the populations from the Helotes Karst Fauna Region listed above may prove to be that species once males are obtained from the type locality of *N. microps*.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 6 – Scientific name: *Tartarocreagris reyesi*

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Pseudoscorpionida (pseudoscorpions), Family Neobisiidae. The genus *Tartarocreagris* includes 14 species, of which 11 are probably troglobitic. The genus is largely restricted to caves along the Balcones Fault Zone, but one surface species has been found in Arkansas, two occur both on the surface and in caves in Texas, and an undescribable species was collected from Fannin County, Texas.

Original description: Veni et al. (1998b) first reported this species from MARS Pit on Camp Bullis. Veni et al. (1999) described an additional locality on Camp Bullis at Up the Creek Cave. Muchmore (2001) described this species.

Type specimen: The specimen is a female holotype, collected from Young Cave No. 1, Bexar County, Texas, on 6 September 1993 by James Reddell and Marcelino Reyes. It is deposited in the Florida State Collection of Arthropods, Gainesville, Florida.

Other taxonomic literature: Muchmore (2001).

Selected characteristics: This is a medium-sized, eyeless pseudoscorpion, with a female body length of 3.22 to 3.26 mm, and a depth of chelal hand a little greater than breadth; the palpal femur is 0.96

to 1.02 mm, and the depth/breadth ratio of the hand is about 1:5.

Intraspecific variation: There is no notable variation between populations in this species.

Distinctiveness: This species can be distinguished from closely related species only by microscopic examination of slide-mounted specimens. It can be distinguished by an absence of eyes versus the two eyes in the only other known Bexar County pseudoscorpion species, located in Mattke Cave in the Helotes Karst Fauna Region. The absence of eyes will separate this from any other known pseudoscorpion on Camp Bullis.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 7 – Scientific name: *Texella* n. sp. 1

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Opiliones (harvestmen), Suborder Laniatores, Family Phalangodidae. Although harvestmen are superficially similar to spiders (Order Araneae), they are anatomically and evolutionarily quite distinct from spiders and are not correctly referred to as "spiders." Members of the family Phalangodidae are generally small reddish brown to yellowish hard bodied Laniatores. Historically, this family has been a taxonomic dumping ground for most small bodied Laniatores. More recent studies of the genitalia have greatly restricted the number of included genera. There are many cavernicolous representatives of this group, both in Europe and in the USA. The eye mound is located directly on the frontal margin of the prosoma. There are three free tergites. The dorsal scute does not have a deep constriction between the prosoma and the abdomen. All pedipalpal segments are heavily armed with the tarsus being about as long as the tibia. Other significant distinguishing characteristics are based on the male genitalia. Goodnight and Goodnight (1942) erected the genus *Texella* for a troglobitic species (*Texella mulaiki*) known from a cave in Hays County, Texas. Ubick and Briggs (1992) revised the genus and recognized four species from southwestern Oregon and California in the *kokoweef* and *bifurcata* species groups and 17 species in the *mulaiki* species group from Texas and southeastern New Mexico.

Original description: The species is undescribed. It is known with certainty only from Hilger Hole on Camp Bullis (Veni et al., 1999). What is probably this species has recently been collected from Well Done Cave (Veni et al., 2002b).

Type specimen: No type specimen has been designated.

Other taxonomic literature: A taxonomic revision of the genus and a review of the earlier literature were published by Ubick and Briggs (1992). Cokendolpher reviewed the genus in Veni et al. (2002a).

Selected characteristics: This species is blind, with a relatively large eye mound and well-developed secondary sexual characteristics. It is a member of the *T. mulaiki* subgroup (Ubick and Briggs, 1992).

Intraspecific variation: Only a single male is known.

Distinctiveness: Currently, members of the genus *Texella* can only be recognized with certainty by examination of the male genitalia and external secondary sexual characters found on an adult males' genital operculum and the hind legs. Because of this, no females or juveniles can be identified to species unless they are associated with adult males. A single male is known from Hilger Hole, and it presents specific characters to separate it from the other two species known by males from Camp Bullis. These characters are microscopic and not useful for field recognition. Troglobitic *Texella* are small, long-legged, lightly colored harvestmen which are easily confused in the field with juveniles of the much larger troglobitic harvestmen (*Hoplobunus* sp.: family Stygnopsidae) found in caves on Camp Bullis. Although often difficult, *Texella* adults can be distinguished from *Hoplobunus* juveniles in the field by the slightly more yellowish color of *Texella*; juveniles of both *Hoplobunus* and *Texella* are white. Pine (2002) described attempts to distinguish *Hoplobunus* from *Texella* based on spines on the "chelicera" (probably the femur of the palpus), but identifications on that basis should be considered unreliable since fewer than three spines could indicate that the specimen is *Hoplobunus*, that the magnification is not sufficient, the specimen is too immature, or the specimen is damaged and spines were broken off.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described. Its relationship to *Texella cokendolpheri*, which is federally listed as endangered, has not been determined.

Management priority: Based on the available information, the species is only known from a single cave and possibly from a cave about 500 m to the northwest. Since such distribution often makes species extremely vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 8 – Scientific name: *Texella* n. sp. 2

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Opiliones (harvestmen), Suborder Laniatores, Family Stygnopsidae. See the taxonomic classification for *Texella* n. sp. 1.

Original description: The species is undescribed. It is only known with certainty from Winston's Cave on Camp Bullis (Veni et al., 1995).

Type specimen: No type specimen has been designated for this species.

Other taxonomic literature: A taxonomic revision of the genus and a review of the earlier literature were published by Ubick and Briggs (1992). Cokendolpher reviewed the genus in Veni et al. (2002a).

Selected characteristics: This blind *Texella* lacks both secondary sexual processes. It is a member of the *T. mulaiki* subgroup (Ubick and Briggs, 1992) and appears similar to *T. cokendolpheri* but is distinct.

Intraspecific variation: Only a single male is known.

Distinctiveness: Currently, members of the genus *Texella* can only be recognized with certainty by examination of the male genitalia and external secondary sexual characters found on an adult males' genital operculum and the hind legs. Because of this, no females or juveniles can be identified to species unless they are associated with adult males. A single male is known from Winston's Cave and it presents specific characters to separate it from the other two species known by males from Camp Bullis. These characters are microscopic and not useful for field recognition. Troglobitic *Texella* are small, long-legged, lightly colored harvestmen which are easily confused in the field with juveniles of the much larger troglobitic harvestmen (*Hoplobunus* sp.: family Stygnopsidae) found in caves on Camp Bullis. Although often difficult, *Texella* adults can be distinguished from juvenile *Hoplobunus* in the field by the slightly more yellowish color of adult *Texella*; juveniles of both *Hoplobunus* and *Texella* are white. Pine (2002) described attempts to distinguish *Hoplobunus* from *Texella* based on spines on the "chelicera" (probably the femur of the palpus), but identifications on that basis should be considered unreliable since fewer than three spines could indicate that the specimen is *Hoplobunus*, that the magnification is not sufficient, the specimen is too immature, or the specimen is damaged and spines were broken off.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described. Its relationship to *Texella cokendolpheri*, which is federally listed as endangered, has not been determined.

Management priority: Based on the available information, the species is only known from a single cave. Since such distribution often makes species extremely vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 9 — Scientific name: *Texella* n. sp. 3

Common name: None assigned.

Taxonomic classification: Class Arachnida (arachnids), Order Opiliones (harvestmen), Suborder Laniatores, Family Phalangodidae. See the taxonomic classification of *Texella* n. sp. 1.

Original description: The species is undescribed. Veni et al. (1996) first reported it from Headquarters Cave on Camp Bullis.

Type specimen: No type specimen has been designated.

Other taxonomic literature: A taxonomic revision of the genus and a review of the earlier literature were published by Ubick and Briggs (1992). Cokendolpher reviewed the genus in Veni et al. (2002a).

Selected characteristics: This blind *Texella* lacks the secondary sexual process on the fourth leg trochanter but has a small process on the genital operculum of the male. It is a member of the *T. mulaiki* subgroup (Ubick and Briggs, 1992) and appears very similar to *T. cokendolpheri*. The penis of the single known specimen has not been successfully expanded and therefore the relationship to *T. cokendolpheri* cannot be determined. Because of the geological and geographical isolation of Robber Baron Cave in the Alamo Heights Karst Fauna Region, 17 km southeast of Camp Bullis, the two forms are presumably different and the specimen from Headquarters Cave is a separate species.

Intraspecific variation: Only a single male is known.

Distinctiveness: Currently, members of the genus *Texella* can only be recognized with certainty by examination of the male genitalia and external secondary sexual characters found on an adult males' genital operculum and the hind legs. Because of this, no females or juveniles can be identified to species unless they are associated with adult males. A single male is known from Camp Bullis and it presents specific characters to separate it from the other two species known by males from Camp Bullis. These characters are microscopic and not useful for field recognition. Troglobitic *Texella* are small, long-legged, lightly colored harvestmen which are easily confused in the field with juveniles of the much larger troglobitic *Hoplobunus* sp. harvestmen (Family Stygnopsidae) found in caves on Camp Bullis. Although often difficult, *Texella* can be distinguished from *Hoplobunus* in the field by the slightly more yellowish color of adult *Texella*; juveniles of both *Hoplobunus* and *Texella* are white. Pine (2002) described attempts to distinguish *Hoplobunus* from *Texella* based on spines on the "chelicera" (probably the femur of the palpus), but identifications on that basis should be considered unreliable since fewer than three spines could indicate that the specimen is *Hoplobunus*, that the magnification is not sufficient, the specimen is too immature, or the specimen is damaged and spines were broken off.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described. Its relationship to *Texella cokendolpheri*, which is federally listed as endangered, has not been determined.

Management priority: Based on the available information, the species is only known from a single cave. Since such distribution often makes species extremely vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 10 – Scientific name: *Speodesmus* n. sp. 1

Common name: None assigned.

Taxonomic classification: Class Diplopoda (millipedes), Order Polydesmida Family Polydesmidae. The genus *Speodesmus* includes four described and several undescribed species, all of which are troglobitic. The genus is restricted to caves with one species known from Colorado, one from New Mexico and adjacent Culberson County, Texas, and the remainder from central and western Texas.

Original description: It was first reported as *Speodesmus* sp. from MARS Shaft by Veni and Elliott (1994), from Cross the Creek Cave by Veni et al. (1995), and from Root Toupee Cave by Veni et al.

(1999). Specimens from Dos Viboras Cave were erroneously identified as *Speodesmus echinourus* Loomis by Veni et al. (1996). Dr. William R. Elliott has a manuscript in preparation describing this species.

Type specimen: No holotype has been designated but specimens are known from four caves on Camp Bullis

Other taxonomic literature: None.

Selected characteristics: This is a very large (14-16 mm body length) troglomorphic sister species of *S. echinourus*.

Intraspecific variation: There is no notable variation between populations in this species.

Distinctiveness: This species can be distinguished from closely related species only by microscopic examination of the male genitalia. It can be separated from *Speodesmus* n. sp. 2 by its larger size (14-16 mm versus 6-7 mm length).

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 11 – Scientific name: *Speodesmus* n. sp. 2

Common name: None assigned.

Taxonomic classification: Class Diplopoda (millipedes), Order Polydesmida Family Polydesmidae. The genus *Speodesmus* includes four described and several undescribed species, all of which are troglobitic. The genus is restricted to caves with one species known from Colorado, one from New Mexico and adjacent Culberson County, Texas, and the remainder from central and western Texas.

Original description: It was first reported as *Speodesmus* sp. by Veni et al. (1998b). Dr. William R. Elliott has a manuscript in preparation describing this species.

Type specimen: No holotype has been designated but it is only known from Platypus Pit on Camp Bullis.

Other taxonomic literature: None.

Selected characteristics: This is a very small (6-7 mm long) species.

Intraspecific variation: The species is known only from one male and two females.

Distinctiveness: This species can be distinguished from closely related species only by microscopic examination of the male genitalia. It can easily be separated from *Speodesmus echinourus* and *Speodesmus* n. sp. 1 by its smaller size.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 12 – Scientific name: *Mixojapyx* sp.

Common name: None assigned.

Taxonomic classification: Class Entognatha, Order Entotrophi, Superfamily Iapygoidea (earwiglike entotrophs), Family Iapygidae. The family Iapygidae includes a large number of species found throughout the world. Iapygids have internal mouthparts, long, slender antennae, and a pair of stout forceps-like cerci. The forceps are used to capture food. Most species of this genus are comparatively small and live under rocks and in leaf litter. Only a few species have become cave-adapted, with *Mixojapyx reddelli* Muegge (1992) the only New World troglobite. *Mixojapyx reddelli* was described from several caves in the Balcones Fault Zone and Edwards Plateau areas. The type locality of the species is Indian Creek Cave, Uvalde County. It was also reported from one cave each in Bexar, Comal, Kimble, Menard, and Travis counties. Specimens unsuitable for species identification are also known from one cave each in Medina and Schleicher counties.

Original description: The taxonomic status of the specimens from Camp Bullis is unknown, but it is probably an undescribed species. Veni et al. (1998b) first reported it from Platypus Pit on Camp Bullis. Veni et al. (1999) described an additional two localities on Camp Bullis: B-52 Cave and Boneyard Pit.

Type specimen: No type specimen has been designated. It is currently known from B-52 Cave, Boneyard Pit, and Platypus Pit, all of which are on Camp Bullis, and La Cantera Cave No. 1 and La Cantera Cave No. 2 (SWCA, 2001) in the UTSA Karst Fauna Region.

Other taxonomic literature: None.

Selected characteristics: This species is very large, about 40 mm long, with long (about 50 segments) heavily setose antennae; its body is covered with large numbers of setae of all sizes. The body is generally pale, becoming darker posteriorly with heavily-sclerotized reddish forceps-like cerci. All modern iapygids are eyeless.

Intraspecific variation: *Mixojapyx reddelli* as described is a highly variable species and is probably a complex of closely related species. The material from Camp Bullis differs in a number of ways from the holotype as described and illustrated by Muegge (1992). However, these specimens do appear to fall within the range of variation of *M. reddelli*. It will be interesting to compare the Camp Bullis material with the specimen reported from Robber Baron Cave, in the Alamo Height Karst Fauna Region, but this specimen was not available for comparison.

Distinctiveness: *Mixojapyx* can be readily distinguished from all other known iapygids by the extremely long antennae and numerous setae on all surfaces. Most other iapygids have fewer than ten large setae on each tergite, as opposed to 30 to 50 per tergite on *Mixojapyx*. The only other iapygid known from Camp Bullis is a minute soil-dwelling species.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described.

Management priority: Based on the available information and the assumption that this is a new species or subspecies, it appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 13 – Scientific name: *Rhadine* sp. 1

Common name: None assigned.

Taxonomic classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Adephaga, Family Carabidae (ground beetles). The family Carabidae is one of the larger families of beetles and is found worldwide in almost every terrestrial habitat. The vast majority of troglobitic beetles belong to this family. The genus *Rhadine* contains more than 60 eyed and eyeless species in the Great Plains westward to California and south to Oaxaca, Mexico. Eleven described and several undescribed species are troglobites found mostly in caves of the Balcones Escarpment area of central Texas. All are members of the *subterranea* species group, a monophyletic assemblage. This group is closely related to the *perlevis* group, which contains eyed, troglophilic members found in caves of the Edwards Plateau and southern Balcones Fault Zone. The *subterranea* group contains a "robust," or heavy-bodied subgroup and a "slender" subgroup. In Bexar County, the slender group includes *Rhadine exilis* and *R. speca*, as well as the three probable undescribed species included here. The robust group is represented by *R. infernalis*. Both slender and robust species may occur in the same caves, with the slender species usually found in deeper parts of the cave than the robust species.

Original description: The species is undescribed and only known from caves on Camp Bullis. Veni et al. (1998b) first reported it from three caves: Eagles Nest Cave, Meusebach Flats Cave, and Stahl Cave. Veni et al. (1999) reported two additional localities: Flach's Cave and Lone Gunman Pit. Veni et al. (2002b) found it in two more caves: Darling's Pumpkin Hole and Hector Hole.
Type specimen: No type specimen has been designated.

Other taxonomic literature: None.

Selected characteristics: This beetle is reddish-brown, has a total length of about 6.5 to 7.5 mm, and is moderately slender. Its pronotum width/length ratio is about 0.48, and its elytra width/length ratio is about 0.46. The pronotum is not noticeably depressed, and has two pairs of dorsal setae.

Intraspecific variation: There is no significant variation.

Distinctiveness: These populations can be distinguished from *Rhadine exilis* by the larger eye rudiment, more slender and less depressed pronotum, and more sharply produced elytral apexes. The only other species in the range of this species is *Rhadine* sp. cf. *howdeni*, which is darkly pigmented, extremely robust, and has distinct eyes. It is somewhat smaller and with a less constricted neck than *R. speca*. The single male from Eagles Nest Cave exhibits some differences from specimens from other localities and with additional material may prove distinct.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described and its relationship to the two endangered *Rhadine* species is determined

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 14 – Scientific name: *Rhadine* sp. 2

Common name: None assigned.

Taxonomic classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Adephaga, Family Carabidae (ground beetles). See the taxonomic classification of *Rhadine* sp. 1.

Original description: The species may be undescribed. It has only been reported from one cave, Vera Cruz Shaft on Camp Bullis (Veni et al., 1998b).

Type specimen: No type specimen as been designated.

Other taxonomic literature: None.

Selected characteristics: This slender beetle is reddish-brown and has a total length of about 6.2 to 7.5 mm. Its pronotum has a width/length ratio about 0.38, and its elytra width/length ratio is about 0.45. The pronotum is not noticeably depressed and has two pairs of dorsal setae.

Intraspecific variation: Except for total length, there is no significant variation.

Distinctiveness: The status of this species is uncertain, but it is closely related to both *R. exilis* and *R. speca*. The discovery of more specimens should help clarify its taxonomic position. It has a narrower neck and more slender pronotum than *R. speca*. It may be distinguished from specimens of *R. exilis* by the less slender pronotum and wider neck. Further study is needed to properly evaluate the status of this population.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described and its relationship to the two endangered *Rhadine* species is determined

Management priority: Based on the available information, the species is only known from a single cave. Since such distribution often makes species extremely vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 15 – Scientific name: *Rhadine* sp. 3

Common name: None assigned.

Taxonomic classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Adephaga, Family Carabidae (ground beetles). See the taxonomic classification of *Rhadine* sp. 1.

Original description: This species is undescribed. It is currently only known from Cannonball Cave on Camp Bullis.

Type specimen: No type specimen has been designated.

Other taxonomic literature: None.

Selected characteristics: This slender beetle is reddish-brown and has a total length of about 7.5 to 8.8 mm. Its pronotum has a width/length ratio about 0.41. The pronotum is not noticeably depressed and has two pairs of dorsal setae.

Intraspecific variation: Except for total length, there is no significant variation.

Distinctiveness: The status of this species is uncertain, but it is closely related to *Rhadine* sp. 2. The discovery of more specimens should help clarify its taxonomic position. It has a narrower neck and more slender pronotum than *R. speca*. It may be distinguished from specimens of *R. exilis* and *Rhadine* sp. 2 by the less slender pronotum and wider neck. Further study is needed to properly evaluate the status of this population.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described and its relationship to the two endangered *Rhadine* species is determined

Management priority: Based on the available information, the species is only known from a single cave. Since such distribution often makes species extremely vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 16 – Scientific name: *Rhadine exilis*

Common name: None assigned.

Taxonomic classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Adephaga, Family Carabidae (ground beetles). See the taxonomic classification of *Rhadine* sp. 1.

Original description: Barr and Lawrence (1960).

Type specimen: The specimen is a male holotype from Marnock Cave (more commonly known as John Wagner Ranch Cave No. 3), located about 1.6 km north of Helotes, Bexar County, Texas. It was collected on 2 July 1959 by Foye Moore and J.F. Lawrence, and has been deposited in the California Academy of Sciences. It has the most confirmed localities of all the endangered invertebrates in Bexar County (49 caves) and Camp Bullis (21 caves).

Other taxonomic literature: This species was originally described as *Agonum* (*Rhadine*) *exile*. Barr (1974) recognized *Rhadine* as a full genus and re-described *R. exilis*.

Selected characteristics: This is the most slender and depressed species in the genus. It is reddish-brown with an eye rudiment only 0.08 mm in diameter. Body length ranges from 7.0-8.4 mm. The pronotum is one-third as wide as long, widest behind middle, and possesses two pairs of marginal setae.

Intraspecific variation: Reddell (1998) found the species to generally vary from west to east with the more elongate populations in the west, gradually becoming more robust to the east. The mean W/L ratio of the pronotum was 0.31 in the Government Canyon Karst Fauna Region, 0.305 in the Helotes Karst Fauna Region, 0.34 in the UTSA Karst Fauna Region, and 0.36 in the Stone Oak Karst Fauna Region (which includes Camp Bullis), indicating clinal variation. However, there was overlap in each area so that no recognizable subunits could be readily separated from others.

Distinctiveness: *Rhadine exilis* is mostly closely related to *R. speca speca*, which occurs in Comal and Kendall counties. The two species may be most easily separated by the size of the eye rudiment (0.10 to 0.15 mm in *R. speca speca* versus 0.08 mm in *R. exilis*) and the width/length ratio of the pronotum (about 0.40 to 0.45 as wide as long in *R. speca speca* versus about 0.33 in *R. exilis*). The pronotum is also widest behind the middle in *R. exilis* whereas it is widest at or near the middle in *R. speca speca*.

Listing status: The USFWS (2000) listed this species as endangered on 26 December 2000.

Management priority: Based on the available information, the species appears to be limited to the relatively small geographic area of northern Bexar County. Its management will be among the highest priorities for the karst species at Camp Bullis.

Species 17 – Scientific name: *Rhadine infernalis*

Common name: None assigned.

Taxonomic classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Adephaga, Family Carabidae (ground beetles). See the taxonomic classification of *Rhadine* sp. 1.

Original description: Of *Rhadine infernalis infernalis*, Barr and Lawrence (1960); of *Rhadine infernalis ewersi*, Barr (1960).

Type specimen: The specimen for *Rhadine infernalis infernalis* is a holotype male from Madla's Cave, located 5 km north of Helotes, Bexar County, Texas. J.R. Reid and J.F. Lawrence collected it on 6 and 7 July 1959. The specimen for *Rhadine infernalis ewersi* is a holotype male from Headquarters Cave, located in approximate vicinity of the headquarters building at Camp Bullis, Bexar County, Texas. Ralph Ewers collected it on 19 April 1959. Reddell (1998) recognized *Rhadine infernalis* new subspecies, but it does not occur on Camp Bullis and is only known from the Culebra Anticline Karst Fauna Region.

Other taxonomic literature: *Rhadine infernalis* was originally described as *Agonum* (*Rhadine*) *infernale*; *Rhadine infernalis ewersi* was originally described as *Agonum* (*Rhadine*) *infernale ewersi*. Barr (1974) recognized *Rhadine* as a full genus and re-described the two subspecies. Veni et al. (1999) described it as only known from Flying Buzzworm Cave, Headquarters Cave, and Low Priority Cave, all located on the same hill at Camp Bullis.

Selected characteristics: This reddish-brown robust species is about 6.5 to 8 mm in total length, and has a narrow neck that is less than half the greatest width of head. The pronotum is widest in middle, with a length/width ratio of 0.6 to 0.7, and with two pairs of dorsal setae.

Intraspecific variation: This is a highly variable species with two described and one undescribed subspecies recognized. Specimens from the Culebra Anticline area of western Bexar County have narrower and more flattened elytra. The elytral apexes are also more distinctly produced. The pronotum is intermediate between *R. infernalis ewersi* and *R. infernalis infernalis*. The pronotum of *R. infernalis ewersi* is more robust than *R. infernalis infernalis* (W/L ratio of 0.68 versus 0.65).

Distinctiveness: *Rhadine infernalis* is the only robust *Rhadine* species in Bexar County. The shape of the pronotum (widest at middle) separates it from *R. exilis* which has a long slender pronotum that is widest behind the middle. The pronotum W/L ratio of 0.65 to 0.68 separates this species from *Rhadine* sp. 1 (0.48), sp. 2 (0.41), and *R. exilis* (0.30-0.36).

Listing status: The USFWS (2000) listed this species as endangered on 26 December 2000.

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Its management will be among the highest priorities for the karst species at Camp Bullis.

Species 18 – Scientific name: *Eurycea* sp.

Common name: None assigned.

Taxonomic classification: Class Amphibia, Order Urodela (salamanders), Family Plethodontidae. The family Plethodontidae is the largest family of salamanders. Most species are terrestrial, but a few cave forms have invaded the aquatic habitat and become paedogenetic. The genus *Eurycea* contain several troglobitic species in central Texas (Chippindale et al., 2000), including the Texas blind salamander, *E. rathbuni* Stejneger, which is on the U.S. Endangered Species List and occurs in the Edwards (Balcones Fault Zone) Fault below the city of San Marcos. These troglobitic species are depigmented and have the eyes reduced to varying degrees.

Original description: This species is based on specimens collected from Stealth Cave on Camp Bullis (Veni et al., 1998b). It is most closely related to *Eurycea latitans* Smith and Potter, described from Cascade Caverns, Kendall County, and known from several other caves in Kendall County. The final taxonomic status of the material from Stealth Cave must await further study, but it may be an undescribed species.

Type specimen: No type specimen has been designated.

Other taxonomic literature: None.

Selected characteristics: This is a slightly troglomorphic paedogenetic species with reduced eyes and pigmentation. No detailed study of this population has been made.

Intraspecific variation: No analysis has been made, but only two specimens are available for study.

Distinctiveness: This species may be separated from the only other troglobitic *Eurycea* on Camp Bullis (*E. tridentifera*) by the larger eye rudiments, darker pigmentation, and more rounded and less flattened head.

Listing status: The species is not listed as threatened or endangered. It is also not proposed for listing or considered for listing. However, this status may change once it has been fully described. Its relationship to *Eurycea latitans* and *E. tridentifera*, which are on the Texas list of threatened species, has not been determined.

Management priority: Based on the available information, the species is only known from a single cave. Since such distribution often makes species extremely vulnerable to activities in those areas, they are usually considered species of concern by the USFWS.

Species 19 – Scientific name: *Eurycea tridentifera*

Common name: Comal Blind Salamander.

Taxonomic classification: Class Amphibia, Order Urodela (salamanders), Family Plethodontidae. See the taxonomic classification of *Eurycea* sp.

Original description: Mitchell and Reddell (1965).

Type specimen: Holotype female from Honey Creek Cave, Comal County, Texas, 14 January 1965, collected by James R. Reddell and Robert W. Mitchell.

Other taxonomic literature: Wake (1956) removed *E. tridentifera* to the genus *Typhlomolge*. Mitchell and Smith (1972) provided information on the osteology and evolution of the paedogenetic *Eurycea*, including *E. tridentifera* and reassigned *tridentifera* to *Eurycea*. Sweet (1977b) re-investigated the generic status of the Texas paedogenetic salamanders and concluded that *tridentifera* was properly placed in *Eurycea,* but recognized *Typhlomolge* as a distinct genus. Sweet (1984) studied *E. latitans*, *E. troglodytes*, and *E. tridentifera* and concluded that *E. latitans* and *E. troglodytes* were hybrids between *E. tridentifera* and *E. neotenes*. Chippindale et al. (2000), based on recent DNA analyses, rejects these conclusions and accepts all described paedogenetic *Eurycea* as valid species.

Selected characteristics: This is a highly troglomorphic paedogenetic species usually with 14 trunk vertebrate, greatly reduced pigmentation, and non-functional eyes. It may reach up to 85 mm in total length. The head is laterally expanded and depressed.

Intraspecific variation: Adults range from 68 to 85 mm in total length. There is no detailed published analysis of variation among populations, but material from several caves show distinct differences from typical material. Final disposition of all material, including that from Elm Springs Cave, in the Stone Oak Karst Fauna Region of Bexar County, must await further study, particularly DNA analysis.

Distinctiveness: The non-functional, greatly reduced eyes and wide, somewhat flattened snout separates this species from all other paedogenetic *Eurycea*, including *Eurycea* sp. from Stealth Cave.

Listing status: Campbell (1995) includes the salamander on the Texas list of threatened species. Dorinda Scott, of the Texas Parks and Wildlife Department (TPWD), stated that the State's records show the salamander was listed as threatened on 18 July 1977 (personal communication, 1999).

Management priority: Based on the available information, the species appears to be limited to a relatively small geographic area. Since such distribution often makes species highly vulnerable to activities in those areas, they are usually considered species of concern by the USFWS. The State of Texas ranks the species as G1S1 (Dorinda Scott, personal communication, 1999), the most severely endangered status, but that rank predates the discovery of additional localities of the species that may revise its status to G2S2.

Species Distribution

Population Estimates

Population estimates for the listed species and the species of concern are not available due to their inaccessibility, rarity, and sometimes secretive habits. Some species are so secretive and/or their populations so small that even with repeated visits to a cave they may rarely be seen. Seasonal changes in cave microclimatic conditions also affect the likelihood of observing the species. During prolonged periods without rain, or when cold winter air sinks in, caves become drier, and invertebrate species retreat into moister and warmer soils and fractures that are humanly inaccessible.

Some of the limitations on observing the listed species and species of concern were quantified during the biological monitoring of four Camp Bullis caves from October 1995 through April 1998 (Veni et al., 1996, 1998a, 1998b). Each cave was monitored quarterly. The numbers of individuals observed during a particular monitoring trip were found to correlate to seasonal changes and total annual rainfall, and were generally more abundant during moister conditions; however, the statistical significance of the observations was not determined. The secretiveness of some species was well demonstrated by the one-time discovery of *Mixojapyx* sp. in Platypus Pit, despite 12 intensive searches for species during the monitoring effort and three preceding careful searches for fauna. Even widely roaming and generally more visible species like *Rhadine* beetles could be rare during certain periods. A review of the collection records indicate that *Rhadine* are more commonly found during the spring. If rarity in a certain cave proves consistent, it suggests a small population.

The monitoring trips were not intended to make statistically reliable population estimates of each species. Instead, they recorded numbers representative of relative abundance and "observability" which could be graphed to aid in understanding the overall picture of a cave's ecology. Precise population estimates were considered beyond the scope of the study and potentially harmful to the populations. Traditional population measuring techniques, such as marking and recapturing of specimens and quadrant sampling, can be disruptive to small cave communities. For extremely small populations, classical population estimates would not be reliable and could even kill marked specimens. The counts were representative of what a cave biologist would find during an intensive survey, in which each type of microhabitat would be thoroughly searched and specimens noted or collected.

Table 1 provides average approximations of observability of the listed species and species of concern based on the biological monitoring studies and studies in other caves for species that do not occur in the four caves monitored. These approximations assume generally favorable conditions and intensive searches for the species. They are not meant to represent populations or conditions in any particular cave. The intent is to provide at least a gross measure of species' abundance to somewhat quantify the hard-to-quantify data, and as a baseline for future research. The biological monitoring indicated that another general measure of cave species populations is to count cave crickets as they exit caves nightly to forage. Results from the monitoring reveal that while cricket counts cannot suggest the presence or absence of other specific species, higher cricket counts usually occur with more diverse cave ecosystems with greater observable abundances of individual species.

Table 1

TYPICAL NUMBERS OF LISTED SPECIES AND SPECIES OF CONCERN OBSERVED DURING FAVORABLE CONDITIONS BY INTENSIVE BIOLOGICAL SURVEYS

Listed species & species of concern	Typical numbers observed
Cicurina (*Cicurella*) n. sp. 1	0-1
Cicurina (*Cicurella*) n. sp. 2	0-1
Cicurina (*Cicurella*) n. sp. 3	0-1
Cicurina (*Cicurella*) *madla*	1-5
Neoleptoneta n. sp.	0-3
Tartarocreagris reyesi	0-4
Texella n. sp. 1	0-1
Texella n. sp. 2	0-1
Texella n. sp. 3	0-1
Speodesmus n. sp. 1	1-20
Speodesmus n. sp. 2	0-3
Mixojapyx sp.	0-1
Rhadine sp. 1	1-3
Rhadine sp. 2	1-2
Rhadine sp. 3	0-2
Rhadine exilis	2-4
Rhadine infernalis	2-5
Eurycea sp.	1-2
Eurycea tridentifera	1-2

Historic Range

Except for Headquarters Cave, with biological collections dating to 1959, there is no information on the ranges of the listed species and species of concern on Camp Bullis prior to our aforementioned cave and karst studies, which began in September 1993. For Headquarters Cave, all species found in the cave during the first collections in the late 1950s and mid-1960s have been found by subsequent recent investigations. Additional information is available for some of the species with ranges that extend beyond Camp Bullis. However, the data are sporadic through time and demonstrate increased understanding of species ranges with the discovery of new localities, rather than clearly establishing the species' historic distribution.

Current Range

The primary sources of information on the distribution of the listed species and species of concern at Camp Bullis are our previous reports (Veni and Elliott, 1994; Veni et al., 1995, 1996, 1998a, 1998b, 1999, 2000, 2002a, 2002b). However, since some of the species also occur outside of Camp Bullis, other studies locate and/or describe those localities. Veni (1988) provided a comprehensive review of caves throughout Bexar County, including their biology. Reddell (1993) conducted an investigation focused on the invertebrate biology of Bexar County caves. Cokendolpher (1998) described the distribution of *Neoleptoneta* sp. and *Cicurina* sp. spiders in Bexar County caves; Reddell (1998) did the same for *Rhadine* sp. beetles. Veni (1996, 1997a) hydrogeologically evaluated several caves containing the species now listed as endangered. Several consulting reports on the faunas of fewer caves or smaller areas also exist, although not all are available for examination. In addition to the above reports, which focused or exclusively dealt with invertebrates, several other reports discussed localities of the salamander *Eurycea tridentifera*; Chippindale, Hillis, and Price (1992, 1993, 1994) and Chippindale et al. (2000) provided the most current information.

Delineation of Karst Fauna Regions and Subregions at Camp Bullis

Despite the multiple studies of the listed species and species of concern, additional research continues to discover new localities and better define the ranges of the animals. However, the general ranges of the listed invertebrates have been delimited based on geologic factors that would fully or partly confine populations to certain areas, and the new localities occur within those ranges. The same geologic barriers would likely limit the distribution of species of concern that are not listed but occur with the listed species. By comparing troglobite species localities and potential geologic barriers to their distribution, Veni (1994) identified six such karst areas (re-designated as "karst fauna regions" by USFWS, 1998) relative to the presence of rare or endemic karst fauna in Bexar County. Camp Bullis is in the Stone Oak Karst Fauna Region.

Continued research, especially on Camp Bullis, allows for the following refinement of the karst fauna regions into the following regions and subregions on Camp Bullis, listed in approximate north to south order:

- Cibolo Creek Karst Fauna Region
- Upper Glen Rose Biostrome Karst Fauna Region
- Edwards Outlier Karst Fauna Region
  - Camp Bullis/Dominion Subregion
- Stone Oak Karst Fauna Region
  - Camp Bullis Eagles Nest Subregion
  - Camp Bullis Southeast Subregion
  - Camp Bullis Southwest Subregion

The following descriptions of the regions and subregions provide the biological and hydrogeologic justifications for these designations and revisions. Table 2 groups the listed species and species of concern by the caves, regions, and subregions in which they occur; Table 3 provides the legend to abbreviations used in Table 2. Degrees of fire ant infestation listed in Table 2 and described in Table 3 are explained in more detail later in this report in the section "Present or threatened destruction, modification, or curtailment of habitat." The regions and subregions, along with the distribution of the listed species and species of concern, are shown in Figures 1-4 (located in the pocket of this report).

Cibolo Creek Karst Fauna Region. This region was designated in the earlier version of this report by Veni and Reddell (1999). It is delimited by the outcrops in the Cibolo Creek watershed of the lower member of the Glen Rose Formation and, for some aquatic species, by the biostrome horizon of the upper member of the Glen Rose. Veni (1995, 1997b) demonstrated that groundwater within the lower Glen Rose in the Cibolo's surface water drainage basin stayed within the basin, flowed southeast toward the area immediately east of the northeast corner of Camp Bullis, where faulting carries that rock and its groundwater downward until the water flows into the San Antonio Segment of the Edwards (Balcones Fault Zone) Aquifer (hereafter referred to as the Edwards Aquifer) about 10 km southeast of Camp Bullis' southeast corner. One exception to this flow pattern occurs during floods,

when significant rises in the water table overflow groundwater northward to discharge into the Guadalupe River through Honey Creek Cave. The limits of the biostrome horizon are discussed in the section on the Upper Glen Rose Biostrome Karst Fauna Region.

Table 3
LEGEND FOR ABBREVIATIONS USED IN TABLE 2

Species name or other description	Abbreviation
Cicurina (Cicurella) n. sp. 1	C1
Cicurina (Cicurella) n. sp. 2	C2
Cicurina (*Cicurella*) n. sp. 3	C3
Cicurina (*Cicurella*) *madla*	CM
Neoleptoneta n. sp.	N
Tartarocreagris reyesi	T
Texella n. sp. 1	TX1
Texella n. sp. 2	TX2
Texella n. sp. 3	TX3
Speodesmus n. sp. 1	S1
Speodesmus n. sp. 2	S2
Mixojapyx sp.	M
Rhadine sp. 1	R1
Rhadine sp. 2	R2
Rhadine sp. 3	R3
Rhadine exilis	REX
Rhadine infernalis	RIN
Eurycea sp.	E
Eurycea tridentifera	ET
Solenopsis invicta	FA
Total number of listed species	TLS
Total number of species of concern	TSOC
Endangered species presence confirmed	E
Threatened species presence confirmed	T
Species of concern presence confirmed	X
Species presence tentative	P
Fire ant infestation: entrance area and/or light	1
Fire ant infestation: moderate	2
Fire ant infestation: severe	3
Fire ant infestation: estimated	*

The endemic fauna characterizing the Cibolo Creek Karst Fauna Region are *Eurycea* sp. salamanders. Most of their localities occur within 2 km of Cibolo Creek, due to the close distance in that area of about 20-30 m between the land surface and the water table. This distance allows humans to enter and discover the salamanders' habitat with relative ease. As the land surface rises away from the creek and the distance to the water table increases, the potential also increases for obstacles (collapsed areas, constrictions, etc.) to block human access to the water table. Where cave entrances are 40-80 m above the water table in the Cibolo Creek watershed, exploration of those caves has yet to reach the water table and the salamanders' habitat. The presence of *Eurycea tridentifera* salamanders throughout Honey Creek Cave in the Guadalupe River watershed, where much of the cave is more than 40-50 m below the land surface, demonstrates the species occurs in areas with more than 30 m of overburden. However, the salamanders' distribution throughout such parts of the Cibolo watershed is largely undefined. All available hydrogeologic data currently suggest that Honey Creek Cave offers the only significant conduit flowpath between the Cibolo and Guadalupe watersheds. These data are supported by the presence of *Eurycea tridentifera* only in Honey Creek Cave and no other caves or springs along the Guadalupe River.

The Cibolo Creek Karst Fauna Region could be further delineated by both hydrogeologic and biological factors. In the Camp Bullis section of Cibolo Creek, *Eurycea tridentifera* is the only species known. It occurs in 2-3 caves on Camp Bullis (Table 2 and Figure 4) and five caves on private property. About 3 km west of the northwest corner of Camp Bullis near the privately owned show cave, Cascade Caverns, *Eurycea latitans* is the only salamander known (Chippindale, Hillis, and Price, 1992, 1993, 1994). Veni (1997b) discussed a major fault located 1 km west of Camp Bullis' northwest corner, which has played an important role in the local development of the Lower Glen Rose Aquifer, and thus probably affects the distribution of the salamander species. Except for Honey Creek Cave, the groundwater drainage divide between the Cibolo and Guadalupe watersheds probably serves as a northern boundary to *E. tridentifera*. The occurrence of *E. tridentifera* in Elm Springs Cave, located roughly 5.6 km south of Camp Bullis' southern Military Highway entrance and about 19 km south of Cibolo Creek, suggests the possibility that it may be an undescribed subspecies of *E. tridentifera*. Salamanders from that cave have not been examined by the ongoing DNA studies of *Eurycea* by Chippindale, Hillis, and Price (1992, 1993, 1994) and Chippindale et al. (2000). The cave is formed in the Person and Kainer formations of the Edwards Limestone Group and in the recharge zone of the Edwards Aquifer, a location that should hydrogeologically and thus genetically isolate it from groundwater and salamanders in the lower Glen Rose below Cibolo Creek. One potential flowpath that may connect the locations is briefly discussed later in this report, but implies a closer affinity of the Elm Springs Cave population to *E. latitans*. Detailed analyses to precisely define the flowpaths or possible subregions of the Cibolo Karst Fauna Region are beyond the scope of this report.

Upper Glen Rose Biostrome Karst Fauna Region. Until recently, the geologic occurrence of many caves in the upper member of the Glen Rose Formation has been crudely described due to the coarse-scale mapping of that unit. Recent detailed lithologic mapping of the upper Glen Rose on Camp Bullis by the U.S. Geological Survey has provided major insights into the unit's hydrogeology and the distribution of its karst fauna. While the results are still in draft form (Clark, in review), they display excellent correlation with the distribution of caves, with hydrologic and geomorphologic observations (Veni, 1999a; Veni et al., 1999, 2000, 2002a, 2002b), and with biological data (Table 2). Therefore, it is possible to designate two new karst fauna regions that were formerly included in the Stone Oak Karst Fauna Region: Upper Glen Rose Biostrome and Edwards Outlier.

Clark (in review) has tentatively divided the upper Glen Rose into two zones. The lower "fossiliferous zone" is about 41-55 m thick and mostly comprised of an alternating sequence of clay-rich mudstones, grainstones, mudstones, and clays. About 3-9 m below the top of the zone is a 9- to 12-m-thick rudist biostrome. This thickly-bedded limestone forms caves that readily transmit water long distances as seen in Cannonball Cave, Flach's Cave, and Stealth Cave, and various springs.

On Camp Bullis, the Upper Glen Rose Biostrome Karst Fauna Region is defined by the irregularly shaped pattern that the biostrome's outcrop creates. Clark (in review) did not map this outcrop, but rather the inclusive outcrop of the fossiliferous zone. Figures that delimit the biostrome in this report are based on approximating the unit by its known vertical distance from the top of the fossiliferous zone. Relatively thick, impermeable, and cave-poor units that overlie and underlie the unit are important in hydrologically and genetically isolating its fauna. However, in some small areas, thin outcrops of overlying units may collapse into caves in otherwise unexposed sections of the biostrome, and add areas to its karst fauna region that are not apparent by surface geologic mapping. Three such caves are known: Dangerfield Cave, which is not known to contain listed species or species of concern, and Flach's Cave and Meusebach Cave, which do contain species of concern.

Currently, there are eight caves containing species of concern in the Upper Glen Rose Biostrome Karst Fauna Region (Table 2). Six caves represent localities of *Rhadine* sp. 1 and only one cave is known to contain *Rhadine* sp. 3. The eighth cave is the only locality of undetermined *Eurycea* sp. The absence of listed species from the south or related *Rhadine* species from north in the Cibolo area are also significant in establishing these caves as part of a distinct faunal region.

Beyond Camp Bullis, we have observed the biostrome to thicken to 18 m about 7 to 10 km east of Camp Bullis, and contain caves north of Cibolo Creek with *Eurycea tridentifera* salamanders. While this is not directly relevant to species management at Camp Bullis, it demonstrates an overlap in the Cibolo Creek and Upper Glen Rose Biostrome Karst Fauna regions. However, the Cibolo Creek region is based on groundwater fauna, and the Upper Glen Rose Biostrome region is largely based on terrestrial invertebrate karst fauna. A review of our records for those caves east of Camp Bullis reveals no overlap in rare or endemic species with those at Camp Bullis. However, the presence of an undetermined *Eurycea* sp. in Stealth Cave in the biostrome along Salado Creek, which tentatively appears more closely related to *E. latitans* rather than *E. tridentifera*, suggests a genetic division in the biostrome's groundwater fauna that may correlate with groundwater drainage toward Cibolo Creek.

Edwards Outlier Karst Fauna Region. Veni (1994) broadly defined the Stone Oak Karst Fauna Region to include substantial portions of the upper member of the Glen Rose Formation and outlier outcrops of the Kainer Formation portion of the Edwards Limestone due to the inadequate mapping of the upper Glen Rose and insufficient information on that area's karst fauna at the time. Now, Clark's (in review) lithologic mapping, supporting geomorphologic and hydrologic mapping of caves at Camp Bullis and biological studies of those caves (Veni et al., 1995, 1996, 1998b, 1999, 2000, 2002a, 2002b), allow the Stone Oak Karst Fauna Region to be redefined (see discussion in the following section), as well as the UTSA and Government Canyon Karst Fauna regions. Part of this redefinition includes separating and redesignating part of the area into a new region, the Edwards Outlier Karst Fauna Region.

Throughout most of the Edwards Plateau and Balcones Escarpment area, the upper member of the Glen Rose Formation is poorly karsted and considered to form the regional impermeable base of the Edwards Aquifer because there is sufficient interbedded clay and marl to prevent significant groundwater recharge, movement, and storage. However, since work by Veni (1988), a cavernous limestone horizon has been recognized to contain many of the region's largest caves (e.g. Natural Bridge Caverns) in the uppermost portion of the upper Glen Rose in Bexar and parts of Comal and Medina counties. Additional data on that horizon refined its estimated thickness to 40 m and as hydrologically connected to the Edwards Aquifer (Veni, 1995, 1997b). Lithologic mapping by Clark (in review) supports these findings by measuring the tentatively named "cavernous zone" as 39 m thick.

The Edwards Outlier Karst Fauna Region is designated here as the outcrops of Edwards Limestone and upper 39 m of the upper Glen Rose that are physically or hydrologically discontinuous from those units where they occur in the Edwards Aquifer recharge zone. This region is limited to Bexar County until it can be better defined by additional hydrogeologic and biologic data. This region, by its nature, is comprised of discontinuous subregions, each physically or hydrologically separated from each other. Under this definition, the Helotes Karst Fauna Region, designated by Veni (1994), is redesignated as a subregion of the larger Edwards Outlier Karst Fauna Region.

"Physically separated" means that the cavernous units between areas have been removed by erosion (the most common factor), or are vertically separated by sufficient fault displacement, so that cavernous units only contact noncavernous units along the fault. Since karst fauna inhabit conduits formed by local hydrologic processes, where those processes do not occur across certain areas, the areas are "hydrologically separated," even though cavernous units may be present. At this time, no strict limits are defined for what is needed to determine if areas are hydrologically separate. Cave hydrology and morphology data suggest that a groundwater perching zone exists approximately 25-30 m below the top of the upper Glen Rose. Since less permeable rocks occur below this zone than above it, erosion of the land surface to this level probably indicates hydrologic separation. The width of the connecting area of cavernous units will also have a variable impact on genetic isolation of a species. Any connecting area less than 1 km wide should probably be suspected as hydrologically separating areas by diverting groundwater to discharge to adjacent valleys and hillsides rather than flow across the connection. The presence of such multiple springs or seeps, even if only seasonally active, would indicate hydrologic discontinuity between areas. However, differences in karst fauna on either side of the connecting area may not be noticed until sufficient distance from the connecting area is reached. Exactly how far that distance must be is impossible to say at present; greater speciation would be expected along relatively long, narrow areas rather than broad areas extending from the connection.

<u>Camp Bullis/Dominion Subregion</u>**.** At Camp Bullis, one subregion is designated and three possible subregions are identified for the Edwards Outlier Karst Fauna Region. The Camp Bullis/Dominion Subregion is delimited as the outcrops of Edwards Limestone and uppermost 39 m of the upper Glen Rose along the series of hills following Camp Bullis' southwestern boundary with the Dominion housing development. The northern and southern limits of the subregion are along faults, each on or nearly on a road; the northern limit follows Vera Cruz Road and the southern limit follows Camp Bullis Road. Vera Cruz Shaft is the only known locality for *Rhadine* sp. 2 (Table 2) and occurs at the north end of the subregion. Constant Sorrow Cave, at the south end of the subregion, may contain a new species of *Neoleptoneta* spider but requires further study. Peace Pipe Cave occurs roughly in between and seems like it may be extensive and possess a diverse fauna, but will require excavation to provide that supposition. Aue Road Cave occurs in this subregion but off of Camp Bullis and has not been biologically investigated (Veni, 1988). While Vera Cruz Shaft is the only cave on which this subregion is established, the designation is appropriate for two reasons. First, the presence of an endemic species in such a small cave suggests a significant and speciated karst fauna in that area. Second, the occurrence of the endemic species confirms the hydrogeologic expectation that, given the area's relatively long length of 5 km compared to its mean width of about 1 km, that it must almost certainly be a distinctive karst faunal subregion.

Veni and Reddell (1999) identified three possible Edwards Outlier subregions in the clusters of hills comprising Otis Ridge, King Ridge, and McCaskey Ridge in the central section of Camp Bullis. King Ridge and McCaskey Ridge have been searched and no caves or karst features were found (Veni et al., 2002a, 2002b) and are no longer considered subregions. Otis Ridge continues to be surveyed. Veni et al. (2002b) found one small cave (Ides of March Cave) in that possible subregion that excavation might prove more extensive than currently accessible and potentially with a greater troglobite fauna than seen so far.

Stone Oak Karst Fauna Region. Veni (1994) originally defined this region as:

> *Includes the outcrops of the Edwards Limestone and the upper member of the Glen Rose Formation. Bounded to the north by Cibolo Creek and the contact with the lower member of the Glen Rose, to the east by Cibolo Creek, to the south by Balcones faults, and to the west by Leon Creek and intense faulting which narrow the Edwards outcrop. Faulting is moderate to intense.*

This definition is now modified to include only the physically and hydrologically continuous sections of the outcrops of Edwards Limestone and of the upper 39 m of the upper member of the Glen Rose Formation that abut the Edwards Aquifer recharge zone, as per the above discussion on the Edwards Outlier Karst Fauna Region. Further, the region is subdivided into three subregions on Camp Bullis.

<u>Camp Bullis Eagles Nest Subregion.</u> The existence of this subregion is suggested from the distribution of spider and harvestman species listed in Table 2. It is defined to the north by the limit of the Stone Oak Karst Fauna Region, to the west by faulting, and to the east by Blanco Road. This eastern boundary is solely for Camp Bullis management purposes, although the subregion may extend further east off the installation. The subregion's southern boundary is an approximation based on the localities of certain species of concern. There are no apparent hydrogeologic features to explain their distribution. The southwest side of the subregion roughly follows Wilderness Trail, while its southeast side runs south of Eagles Nest Trail until reaching the eastern Camp Bullis boundary at Blanco Road.

Four of the five known occurrences of *Cicurina* n. sp. 1 are north of the southern boundary line. One, possibly two caves contain *Texella* n. sp. 1. Additionally, this is the only other region or subregion outside of the Upper Glen Rose Biostrome Region to contain *Rhadine* sp. 1. Despite the peripatetic lifestyle of *Rhadine*, and its often broad distribution within a region (e.g., *Rhadine exilis*, Table 2), this species also does not occur in the subregion to the south. In contrast, *Cicurina* n. sp. 2, *Neoleptoneta* n. sp., *Tartarocreagris reyesi*, and *Texella* n. sp. 2 only occur south of the boundary and are known from three caves. The spider and harvestman species in the two subregions probably occupy similar ecological niches and mutually exclude each other.

<u>Camp Bullis Southeast Subregion.</u> This subregion is south of the Eagles Nest Subregion. It is designated for its distribution of *Cicurina* n. sp. 2, *Neoleptoneta* n. sp., *Tartarocreagris reyesi*, and *Texella* n. sp. 2, as well as for the absence of *Texella* n. sp. 1 and *Rhadine* sp. 1 and near absence of *Cicurina* n. sp. 1 as described in the preceding paragraph. The Camp Bullis Eagles Nest Subregion defines its northern boundary. The boundaries to the east and south coincide with the boundaries of Camp Bullis and are suggested for management purposes, recognizing that they may in fact extend off the installation. The western boundary is formed along Salado Creek, associated faults, and outcrops of less cavernous

upper Glen Rose. Extensive stream terrace deposits cover much of the bedrock along Salado Creek. Excavation of the deposits at Hunting Headquarters Sinkhole (Veni et al., 1998, 1999) revealed a partially cemented, poor to moderately permeable cobble matrix overlain by a poorly permeable matrix of upward-fining gravels, silts, and clays. These deposits would prevent much recharge from entering any underlying caves, and would likely filter most nutrients, so that the caves could support little or no invertebrate life. The apparent effectiveness of the boundary is demonstrated by the difference in fauna with the Camp Bullis Southwest Subregion on the west side of Salado Creek.

Both the Camp Bullis Eagles Nest and Southeast subregions occur in the Stone Oak Zone 1 area, tentatively defined by Veni (in review) for the USFWS. It roughly extends off Camp Bullis 9 km east to Elm Waterhole Creek, 7.3 km northeast to near the intersection of Bulverde Road and US Highway 281, and south 2.5 km to Highway Loop 1604. Karst Zone 1 areas are known to contain invertebrate karst species federally listed as endangered.

<u>Camp Bullis Southwest Subregion.</u> This subregion is geologically defined to the east by Salado Creek and its associated faulting, less cavernous upper Glen Rose outcrops, and poorly permeable terrace deposits. Much of the northern boundary abuts the southern boundary of the Camp Bullis/Dominion Subregion or otherwise roughly follows Camp Bullis Road. For Camp Bullis management purposes, the installation's western and southern boundaries delimit the subregion in those directions, although it may actually extend further.

Geologically, the subregion is a highly faulted and stream-dissected area of Edwards Limestone and upper Glen Rose. Due to its contiguous outcrop of Edwards Limestone with that in the Edwards Aquifer recharge zone, the Edwards outcrop portion of the subregion was once designated a part of the recharge zone. Hydrogeologic study of caves and springs in the area demonstrated that recharge discharges from adjacent hillsides and valleys, and not into the Edwards Aquifer (Veni and Elliott, 1994; Veni et al., 1995, 1996, 1998b), and the subregion was re-designated a part of the aquifer's drainage zone (Texas Natural Resource Conservation Commission, 1997).

Biologically, the subregion is distinct (Table 2). It is the only area where *Rhadine infernalis ewersi* and *Texella* n. sp. 3 are present. The subregion marks the easternmost extent of *Cicurina madla*, as well as the only location of the spider on Camp Bullis and east of Leon Creek. Additionally, no other troglobitic *Cicurina* are known in the subregion and the relatively widely dispersed *Rhadine exilis* is known only from one cave.

The Camp Bullis Southwest subregion occurs in the Eisenhower Park Zone 1 area, tentatively defined by Veni (in review) for the USFWS. It roughly extends off Camp Bullis as much as 1.2 km south to a northeast-southwest trending fault.

<u>Range of Listed Species and Species of Concern</u>

Figures 1-5 show the ranges of the listed species and species of concern as numbered and presented in Table 2. Continued research will likely reveal additional localities of the species, but our interpretation of the biological and hydrogeological data thus far indicates that nearly all of those localities will be in caves within the bounds of the karst fauna regions and subregions as described for each species below.

Species 1 – *Cicurina* (*Cicurella*) n. sp. 1: This spider is only known from four caves (Eagles Nest Cave, Hilger Hole, Isocow Cave, and Root Canal Cave) in the Camp Bullis Eagles Nest Subregion of the Stone Oak Karst Fauna Region and from Platypus Pit in the Camp Bullis Southeast Subregion (Table 2, Figure 1). As web-spinners, troglobitic spiders of this genus do not travel far within their lifetimes, staying close to or within their webs. All indications are that individuals of this species seldom roam far from the place of birth. It is likely that they reside primarily in caves rather than small interstitial spaces. This promotes speciation through minimal mixing of neighboring populations. The eastern boundary of the Camp Bullis Eagles Nest Subregion is established in this report along the eastern boundary of Camp Bullis for management purposes of the installation. However, Panther Springs Creek is also located roughly along that boundary. It extends as far as 400 m east of Camp Bullis and may prove the physical true boundary for the species and subregion.

Species 2 – *Cicurina* (*Cicurella*) n. sp. 2: This spider is definitively known only from Platypus Pit and MARS Pit, and possibly from Up the Creek Cave (Table 2, Figure 1). The caves are located in the Camp Bullis Southeast Subregion of the Stone Oak Karst Fauna Region; Platypus Pit is in the central section of the subregion's western half with Up the Creek Cave 970 m to the southwest and MARS Pit 1.9 km to the east. As web-spinners, troglobitic spiders of this genus do not travel far within their lifetimes, staying close to or within their webs. All indications are that individuals of this species seldom roam far from the place of birth. It is likely that they reside primarily in caves rather than small interstitial spaces. This promotes speciation through minimal mixing of neighboring populations. The eastern and southern boundaries of the Camp Bullis Southeast Subregion are established in this report along the boundaries of Camp Bullis for management purposes of the installation. However, the physical eastern boundary may actually correlate to Panther Springs Creek, located up to 400 m east of Camp Bullis, or a western tributary of Panther Springs Creek on Camp Bullis marked by the San Antonio River Authority #4 Flood Control Dam and associated reservoir. Continued research is needed in caves in this portion of the subregion to conclusively establish the species' range. The southern boundary of the subregion, also established for management purposes, may have its actual physical limit at major faults located 1 and 2.5 km south of Camp Bullis.

Species 3 – *Cicurina* (*Cicurella*) n. sp. 3: This species is known only from Stahl Cave (Table 2, Figure 1) of the Upper Glen Rose Biostrome Karst Fauna Region. This region has a narrow and sometimes discontinuous outcrop that may limit the spider's distribution. As noted in the two previous paragraphs, troglobitic spiders of this genus are web-spinners that do not travel far within their lifetimes, staying close to or within their webs. It is likely that they reside primarily in caves rather than small interstitial spaces. This promotes speciation through minimal mixing of neighboring populations.

Species 4 – *Cicurina* (*Cicurella*) *madla*: The only known locality for this species on Camp Bullis is Headquarters Cave, which is centrally located in the northern half of the Camp Bullis Southwest Subregion of the Stone Oak Karst Fauna Region (Table 2, Figure 1). As indicated in the previous three range descriptions, troglobitic spiders of this genus do not travel far and probably do not effectively use the interstitial zones that occur between caves, karst fauna regions, and karst fauna subregions. However, this species may be a relatively recent troglobite given that it is more widely distributed than any other troglobitic *Cicurina* in Bexar County. In addition to its occurrence at Camp Bullis, it is also known from seven other caves, all west of Leon Creek. They occur in the UTSA Karst Fauna Region, the Helotes Karst Fauna Region, and as far as 17 km west from Camp Bullis in a cave in the Government Canyon Karst Fauna Region (Cokendolpher, 1998; Veni in review). Given the considerable biological study of caves in subregions east of Headquarters Cave, it seems likely that the Camp Bullis Southwest Subregion represents the eastern limit of the range of this species. The species might be found in the southern end of the Camp Bullis/Dominion Subregion of the Edwards Outlier Karst Fauna Region once more caves in that area are studied. The intense faulting and stream-dissected topography west and south of the Camp Bullis Southwest Subregion likely limits its physical, not management-based, extent by Leon Creek 1 km to the west, and possibly by faults and land surface erosion within a kilometer to the south, although this is less certain.

Species 5 – *Neoleptoneta* n. sp.: This spider is definitively known from one cave of the Stone Oak Karst Fauna Region: Up the Creek Cave in the southwest corner of the Camp Bullis Southeast Subregion (Table 2, Figure 1). Other populations of unidentified members of this genus are recorded from Breached Dam Cave just outside of the southwest corner of the Camp Bullis Southwest Subregion, Cross the Creek Cave in the central section of the Camp Bullis Southeast Subregion, and Constant Sorrow Cave at the southern end of the Camp Bullis/Dominion Subregion of the Edwards Outlier Karst Fauna Region. As web-spinners, troglobitic spiders of this genus do not travel far within their lifetimes, having to stay close to or within their webs, although troglobitic *Neoleptoneta* seem more mobile and less speciated than troglobitic *Cicurina*. Possibly this mobility is due to their much smaller size, which would permit them to travel through smaller interstitial spaces. The eastern and western extents of this species may be limited to the Camp Bullis Southeast and Southwest subregions, although the possible occurrence of two localities in caves in different regions and subregions may suggest somewhat greater distribution.

Species 6 – *Tartarocreagris reyesi*: This species of pseudoscorpion is known from two caves in the Camp Bullis Southeast Subregion of the Stone Oak Karst Fauna Region (Table 2, Figure 2), and from Young Cave No. 1, about 7 km to the west in the UTSA Karst Region. It was discovered at Camp Bullis first in MARS Pit and then 2.9 km west in Up the Creek Cave. It will probably be found in caves in the intervening Camp Bullis Southwest Subregion and possibly in caves of the Edwards Outlier Camp Bullis/Dominion Subregion.

Species 7 – *Texella* n. sp. 1: This harvestman species is definitely known only from Hilger Hole in the Camp Bullis Eagles Nest Subregion of the Stone Oak Karst Region (Table 2, Figure 2). Specimens recently collected from Well Done Cave near Hilger Hole probably also belong to this species but have not yet been studied (Veni et al., 2002b). These locations are bounded by *Texella* n. sp. 2 in Winston's Cave 2.5 km to the east in the Camp Bullis Southeast Subregion and by *Texella* n. sp. 3 in Headquarters Cave in the Camp Bullis Southwest Subregion 3.2 km to the southwest. A probable *Texella* sp. harvestman was seen in Stahl Cave in the Upper Glen Rose Biostrome Karst Fauna Region, but it could not be collected for identification (Veni et al., 1999). Additional attempts will be made to identify that species, which would be the first *Texella* for that karst fauna region and important to expanding or restricting the probable ranges of the *Texella* species.

Species 8 – *Texella* n. sp. 2: This harvestman is known only from Winston's Cave of the Camp Bullis Southeast Subregion (Table 2, Figure 2). Immature specimens from B-52 Cave, also of this subregion, and Pain In The Glass Cave, of the Camp Bullis Eagles Nest Subregion, may be the same species.

Species 9 – *Texella* n. sp. 3: This harvestman is known only from Headquarters Cave in the Camp Bullis Southwest Subregion (Table 2, Figure 2). This species is probably restricted to this subregion, but undetermined specimens from other parts of Bexar County could possibly belong to this species.

Species 10 – *Speodesmus* n. sp. 1: This millipede is known from four caves in the Camp Bullis Southeast Subregion: Cross the Creek Cave, Dos Viboras Cave, MARS Shaft, and Root Toupee Cave (Table 2, Figure 3). This species may be restricted to this subregion or occur further east and south off Camp Bullis elsewhere in the Stone Oak Karst Fauna Region. Its westward extent may be restricted by *Speodesmus* n. sp. 2, but the range of that species is too uncertain to make any definitive estimate of its effect.

Species 11 – *Speodesmus* n. sp. 2: This millipede is known only from Platypus Pit in the Camp Bullis Southeast Subregion (Table 2, Figure 3). The small size of this species suggests that specimens thought to be juveniles and not collected in other caves may prove to be this species, indicating it has a wider range. There is insufficient information to speculate on the limits of that range.

Species 12 – *Mixojapyx* sp.: This entotroph is known from three caves in two subregions of the Stone Oak Karst Fauna Region (Table 2, Figure 3). Its northernmost location is in Boneyard Pit in the Camp Bullis Eagles Nest Subregion. The other localities are respectively 1.6 km south and 1.8 km southwest at B-52 Cave and Platypus Pit in the Camp Bullis Southeast Subregion. The species has generally been found in caves' deep, moist zones, where human access is rarer and where there is less time to observe the fauna. No such deep zones have been found in the Camp Bullis Southwest Subregion from which to determine if the species is present. Two other populations of this genus are known in Bexar County: La Cantera Cave No. 1 and No. 2 of the UTSA Karst Fauna Region, and in Robber Baron Cave of the Alamo Heights Karst Fauna Region. It has not been possible to determine if these are the same species. The Robber Baron Cave population was identified as *Mixojapyx reddelli,* but there is doubt as to the correct identity of this population. Because of the secretive nature of the species (one specimen each from six caves in Bexar County), continued study may find it in other deep caves on Camp Bullis.

Species 13 – *Rhadine* sp. 1: This beetle has an unusual distribution. It is known from six caves in the Upper Glen Rose Biostrome Karst Fauna Region (Darling's Pumpkin Hole, Flach's Cave, Hector Hole, Lone Gunman Pit, Meusebach Flats Cave, and Stahl Cave), but also possibly from Eagles Nest Cave, 7 km to the south in the Camp Bullis Eagles Nest Subregion of the Stone Oak Karst Fauna Region (Table 2, Figure 4). Only a single specimen of the species, and a few *Rhadine exilis*, have been seen in Eagles Nest Cave. No *Rhadine* sp. 1 have been found in the six caves within a 500-m-radius that nearly surround Eagles Nest Cave, suggesting that the species is restricted to the Biostrome Region with a likely isolated occurrence in the Stone Oak Karst Fauna Region. The species may also be restricted within the Biostrome Region to its northeast area. All localities within the region are in a 3.4-km-long by 1.3-km-wide area. Cannonball Cave, located 5.2 km to the southwest contain *Rhadine* sp. 3. Caves in the intervening portion of the Biostrome Region need to be examined to better delineate the range of its *Rhadine* species. Although there is no definite reason to doubt the occurrence of this species in Eagles Nest Cave, the possibility exists that there has been an error in labeling or curating the material. Further efforts will be made to find the species in Eagles Nest Cave.

Species 14 – *Rhadine* sp. 2: This beetle is only known from Vera Cruz Shaft in the Camp Bullis/Dominion Subregion of the Edwards Outlier Karst Fauna Region (Table 2, Figure 4). Its occurrence along this subregion's long, narrow ridge of limestone is not unexpected, but until additional caves in the subregion are located and biologically studied, it is impossible to predict their range through the subregion. If excavated to deeper levels, Peace Pipe Cave seems likely to be an additional locality for *Rhadine* in this subregion. Based on this species' absence from the adjacent Camp Bullis Southwest Subregion of the Stone Oak Karst Fauna Region, where many biological collections and studies have been made in its caves, it appears that the species is restricted to the Camp Bullis/Dominion Subregion.

Species 15 – *Rhadine* sp. 3: This beetle is known only from Cannonball Cave (Table 2, Figure 4) of the Upper Glen Rose Biostrome Karst Fauna Region. This region has a narrow and sometimes discontinuous outcrop that may limit its distribution to create fauna subregions. Caves in the portion of the Biostrome Region between Cannonball Cave and the caves where *Rhadine* sp. 1 occurs 5.2 km to the northeast need to be examined to better delineate the range of the region's *Rhadine* species.

Species 16 – *Rhadine exilis*: This beetle is the most wide-ranging and most commonly found endangered species on Camp Bullis, and the second most broadly distributed of the endangered karst invertebrate species in Bexar County. In addition to its Camp Bullis localities, the beetle is known from 28 caves in the Government Canyon, Helotes, UTSA, and Stone Oak Karst Fauna regions (Veni, in review). It becomes less common westward and shows gradual morphologic variance across its range (Reddell, 1998). On Camp Bullis, the species occurs throughout the three subregions of the Stone Oak Karst Fauna Region. It is especially prevalent in the Camp Bullis Eagles Nest and Southeast subregions; in the Camp Bullis Southwest Subregion, *R. exilis* is only known from Headquarters Cave (Table 2, Figure 4).

Species 17 – *Rhadine infernalis*: This beetle is the most wide-ranging and most commonly found of the endangered karst invertebrate species. In addition to its Camp Bullis localities, the beetle occurs in 31 caves in the Culebra Anticline, Government Canyon, Helotes, UTSA, and Stone Oak Karst Fauna regions. It shows sufficient variation that three subspecies have been identified. *R. infernalis* n. subspecies is known from seven caves in the Culebra Anticline Karst Fauna Region, *R. infernalis infernalis* has been identified from 24 caves in the Government Canyon, Helotes, UTSA, and Stone Oak Karst Fauna regions (Veni, in review), and *R. infernalis ewersi* is only known from three caves in the Camp Bullis Southwest Subregion of the Stone Oak Region (Reddell, 1998; Table 2). On Camp Bullis, the species occurs in Flying Buzzworm Cave, Headquarters Cave, and Low Priority Cave, which are on the same hill within 800-1,000 m of each other (Figure 4). While *R. infernalis ewersi* co-exists with *R. exilis*, as in Headquarters Cave, their occurrence in only one of three caves with listed species in the Camp Bullis Southwest Subregion, and the absence of *R. infernalis ewersi* from the other Camp Bullis subregions strongly suggests that the species is limited on Camp Bullis to the Southwest Subregion.

Species 18 – *Eurycea* sp.: Stealth Cave, situated in the Upper Glen Rose Biostrome Karst Fauna Region, is the only known locality of this salamander on Camp Bullis (Table 2, Figure 5). Preliminary identification suggests that this species is most closely related to *Eurycea latitans*, described from Cascade Caverns and other Kendall County caves, but it may be an undescribed species. The only other probable *Eurycea* sp. locality is Well 2 on Camp Stanley, which is located about 5 km north of the cave. A video log of the 105.2-m-deep well clearly shows a troglobitic cirolanid isopod and a white salamander (Parsons Engineering Science, 1996) that is almost certainly a *Eurycea* sp. The well bore intersects multiple voids and honeycombed zones of the Lower Glen Rose Aquifer. Faulting along Salado Creek, approximately 1 km south of Camp Stanley, places the lower member of the Glen Rose in contact with the upper Glen Rose biostrome, allowing groundwater and aquatic species to move between the units. This suggests that the salamander in Well 2 may be the same species as that in Stealth Cave. Upgradient extrapolation of the Lower Glen Rose flowpath leads to the section of Cibolo Creek where *E. latitans* is present, supporting the preliminary identification of the Stealth Cave species as being related to *E. latitans*. Assuming that this model of groundwater and species movement is correct, following geologic analysis beyond the scope of this report, then other stream caves found along Salado Creek in the Upper Glen Rose Biostrome Karst Fauna Region are likely to contain the *Eurycea* sp. salamanders. Also, stream caves found in the Lewis Creek valley would have a low to moderate chance of containing the salamanders, and stream caves in the Meusebach Creek valley would have little or no chance of containing them. Extrapolating this model downgradient, it provides the most likely route for *Eurycea* to reach Elm Springs Cave, discussed earlier as south of Camp Bullis. It further implies that salamanders in Elm Springs Cave are more closely related to *E. latitans* rather than *E. tridentifera* as currently identified.

Species 19 – *Eurycea tridentifera*: This salamander species is definitely known on Camp Bullis from two confirmed localities, Camp Bullis Cave No. 1 and Camp Bullis Cave No. 3, and one probable locality, Jabba's Giant Sink; all are in the Cibolo Creek Karst Fauna Region (Table 2, Figure 5). Assuming that the tentative identification is correct, the known range of this species on Camp Bullis extends across nearly the entire width of the north end of the installation, from the western boundary east for 7.5 km. The species is also known from caves west, east, and north of Camp Bullis, which place northern Camp Bullis centrally within their range.

Habitat, Ecosystem, and Ecology

Information on the life history, ecology, and habitat requirements for karst fauna is scant. Elliott (1994a) summarized three years of baseline ecological monitoring of endangered species in Williamson County, Texas, which are related to some of the listed species and species of concern at Camp Bullis. He applied the same methodology, from October 1995 through April 1998, to ecologically monitor four Camp Bullis caves containing listed species and species of concern (Veni et al., 1996, 1998a, 1998b). Most research on cave fauna has focused on taxonomy, and on species distribution and behavior. Investigations of this type, as related to the listed species and species of concern at Camp Bullis, includes Barr (1960, 1974), Barr and Lawrence (1960), Brignoli (1977), Chippindale, Hillis, and Price (1992, 1993, 1994), Cokendolpher (1998), Gertsch (1974, 1992), Goodnight and Goodnight (1967), Mitchell and Reddell (1965, 1971), Muchmore (1999), Platnick (1986), Reddell (1965, 1966, 1967, 1970a, 1970b, 1970c, 1993, 1994, 1998), Sweet (1976, 1977a, 1977b, 1984), and Ubick and Briggs (1992). Some research has examined the relationship between species and habitat distribution with hydrogeologic processes, and for the Camp Bullis area includes Veni (1994, 1996, 1997a, 1997b), Veni and Elliott (1994), and Veni et al. (1995, 1996, 1998a, 1998b, 1999, 2000, 2002a, 2002b).

Origin of Caves and Karst Features

Karst is a terrain formed predominantly by the dissolution of the bedrock. It is usually characterized by features such as sinkholes, sinking streams, little or no surface water, underground streams, and caves. Most karst, including all that occurs at Camp Bullis, is in limestone.

Karst landscapes generally start to develop once limestone is exposed to the surface. A typical limestone cave begins to form where water enters the rock along a fracture or bedding plane, and slowly flows downward until discharged at a lower elevation from a spring. Water that enters the ground is charged with carbon dioxide from the atmosphere and soil to create a weak carbonate acid. Over millennia, this weak acid slowly enlarges fractures and bedding planes. As the openings become larger, they drain water more efficiently, and thus can drain larger volumes of water, which enlarge the openings at faster rates. This process self-accelerates until one flowpath toward the spring comes to dominate the local drainage pattern and captures flows from smaller channels. When it becomes large enough for human exploration, that conduit is called a cave.

In the ideal situation, drainage flowpaths through a karst aquifer look like a branching surface stream. The tips of the hydrologic network typically include fractures, sinkholes, and sinking streams that capture surface water and route it underground. In the subsurface, each branch flows downstream to join other branches, eventually forming limbs and then the trunk of the underground drainage network which discharges from a spring. These larger branches of the karst aquifer are frequently caves. However, geologic and hydrologic factors sometimes prevent the development of such ideal flow systems and, even where they do exist, restrictions on human access to such systems limit the delineation of those systems. The type and degree of karst aquifer development, and the extent of human access into caves, is determined by fractures and folds in the rocks, the types of rock encountered, surface and groundwater hydrologic regimes, collapse of caves passages, sediment and speleothem deposition in conduits, and changes over time and distance with each of these factors.

Caves are integral parts of karst aquifers because of their great ability to transmit water, which make them the focus for groundwater convergence for poor to highly permeable flowpaths. In the Camp Bullis area, many caves formed during previous hydrologic regimes are largely unrelated to the modern aquifers that are primarily recharged by younger caves. However, even these older caves, by virtue of being highly permeable features, capture locally available water from the surface to form recharging drips, pools, and streams. Some eventually capture sufficient water to be rejuvenated as significant, hydrologically active recharge sites. Whether a cave captures large or small volumes of water, the rate, volume, and quality of water that flows through it, and the materials carried in the water, directly reflect the conditions and activities on the surface in the cave's drainage basin.

The ability of karst aquifers to rapidly recharge large volumes of water through caves, and even via much smaller conduits, and transmit those waters with effectively no filtration, makes karst aquifers the most sensitive to groundwater contamination. Studies repeatedly show that when significant volumes of contaminants are present in karst areas, they significantly impact the water quality of the underlying karst aquifers. This close hydrologic connection with the surface also makes karst aquifers sensitive to physical changes in the landscape. Increased flooding, decreased runoff, sedimentation, and erosion on the surface are often mirrored by changes in caves and the general behavior of the karst aquifer. Effective engineering solutions to prevent many of the problems that are unique to karst are few and still developing, so it is important that activities in karst areas avoid creating problems in the first place. For comprehensive overviews of cave and karst hydrogeology, see White (1988), Ford and Williams (1989), and Klimchouk et al. (2000). For a discussion of cave and karst hydrogeology for Bexar County, and as it relates to the proposed species, see Veni (1994). For recent overviews of the cave and karst hydrogeology on Camp Bullis, see Veni et al. (1999, 2000, 2002a, 2002b).

Evolution of Troglobites

Troglobites are generally believed to have developed as a result of climatic changes in the Pleistocene epoch (two million to ten thousand years ago). This resulted in the extinction (at least locally) of surface populations, whereas those species inhabiting caves as troglophiles became genetically isolated. In some cases, the surface ancestor no longer inhabits the surface; in other cases, the surface ancestor may have re-invaded the area when climate changes occurred but have become genetically isolated from the cavernicole populations (Barr, 1968; Mitchell and Reddell, 1971; Elliott and Reddell, 1989). Where a single species occupied caves over a broad area, canyon downcutting and faulting led to isolation of different populations and subsequent speciation. This, in some respects, resembles the concept of speciation in islands in that a single ancestor may have given rise to species in isolated "islands" of karst. The occurrence on Camp Bullis of several species of *Cicurina*, *Texella*, and *Rhadine* is a good example of this type of speciation. Three genera on Camp Bullis belong to tropical groups no longer found in the Texas fauna. These three genera, *Hoplobunus*, *Mixojapyx*, and *Texoreddellia* have their closest relatives in Mexico. The evolution of the paedomorphic salamanders of the genus *Eurycea* has apparently resulted in the isolation of different spring populations as surface streams dried and salamanders retreated into caves and survived in isolation.

Habitat Requirements

Moisture and Temperature

Troglobites require high humidity, although some species are more dependent on higher humidity than others. Delicate, highly evolved troglobites such as *Brackenridgia* isopods, *Speodesmus* millipedes, *Tartarocreagris* pseudoscorpions, some spiders, *Hoplobunus* and *Texella* harvestmen, *Mixojapyx* entotrophs, *Texoreddellia* silverfish, and some *Rhadine* beetles are usually found only in the deepest parts of caves where humidity is essentially 100%. Less cave-adapted species of *Cicurina* spiders, *Cambala speobia* millipedes, and less cave-adapted *Rhadine* may be found closer to the entrance where humidity may be significantly lower. Dry caves or dry parts of caves are typically devoid of cave fauna, and troglobites are essentially absent. Under unusually wet conditions, troglobites may venture closer to entrances where food is more abundant, but can be expected to retreat deep into crevices or the soil when drying occurs.

Most troglobites require stable temperatures. When cold air settles into a cave, some species normally found roaming on cave floors might retreat to ceiling pockets where the air temperature is higher. Other species will move into the soil, loose rocks, or interstitial spaces during hot, dry conditions.

Importance of Surface Communities

The absence of green plants in caves means that nutrients for cave fauna must enter from the outside. "Karst ecosystems receive nutrients from the surface in the form of leaf litter and other organic debris that have washed or fallen into the caves, from tree and other vascular plant roots, or through the feces, eggs, or dead bodies of troglophiles and trogloxenes (for example, cave crickets, raccoons)" (USFWS, 1994).

Floodwaters may bring surface species far into caves, but on Camp Bullis, the most biologically diverse caves with respect to troglobites do not suffer significant flooding. Although numerous species may be found in leaf litter, soil, and cave ceilings and walls just inside the entrance of caves that do not flood, low humidity and fluctuating temperatures prevent these species from serving as a food source for the more cave-adapted troglobites. The most significant invertebrate species to Texas cave ecosystems are cave crickets of the genus *Ceuthophilus*. These species may be found in all parts of caves, although they tend to be most abundant near cave entrances. Three species inhabit caves on Camp Bullis. One of these, *Ceuthophilus* (*Geotettix*) *cunicularis* Hubbell, is a floor-dwelling troglophile that rarely leaves the caves. It can be observed in the caves at all times of the year. The other two species, *C.* (*C.*) new species B and *C.* (*C.*) *secretus* Scudder, roost on the ceiling and leave the caves at night to forage for food. Like many cave species, the crickets are opportunistic omnivores. Their preferred diet has not been well studied.

One reason for the high diversity of life in central Texas caves is probably related to the fact that the two species mature at different times of year. As a result, nymphs and eggs of crickets are present in the cave year-round. Some species of *Rhadine* beetle in Travis and Williamson counties are specialized predators of cave cricket eggs laid in pulverulite (Mitchell, 1971b). None of the species of *Rhadine* on Camp Bullis have been observed to search for cave cricket eggs; the fine pulverulite deposits present in Travis and Williamson counties are absent on Camp Bullis, but silts of similar texture that may serve the same biological function occur in some Camp Bullis caves. *Tartarocreagris* and *Cicurina* have both been observed to feed on cricket nymphs, and they are likely a primary food item for *Mixojapyx* and *Hoplobunus*. *Rhadine* have been observed eating dead crickets. Cave cricket droppings develop fungal growth that provides food for springtails (Collembola) and millipedes, which are probably a significant prey of small troglobitic predators.

Bats introduce a significant amount of nutrient input into many caves in the form of guano. Large deposits of guano, however, are not suitable habitat for most troglobites for several reasons. Temperature and pH fluctuations are severe in guano deposits and thus are unsuitable for species evolved for a narrow range of environmental parameters. Guano also harbors large numbers of predators, such as mites and beetles, which may also feed on the cave-adapted fauna. Small deposits of guano, especially of *Myotis velifer*, may be beneficial to the overall cave ecosystem in that it provides an additional food source. While the troglobites may not inhabit the main guano deposits, they may be found in adjacent areas.

The only other vertebrate of any great significance to cave fauna on Camp Bullis is the raccoon, *Procyon lotor*. This species may venture deep into caves where its droppings rapidly develop a thick coating of fungus that supports large springtail colonies. The droppings may also be colonized by fly and beetle larvae, which may serve as prey for specialized troglobitic predators. However, over-utilization of a cave by raccoons may result in excessive nutrient input that supports species that may compete with or prey upon the troglobites.

The maintenance of healthy plant communities on the surface above and in the vicinity of caves is essential to the maintenance of healthy cave ecosystems. Plants provide food for foraging cave crickets and raccoons, reduce the amount of run-off into caves, and buffer the caves from extreme changes in temperature and humidity. A natural plant community also reduces the number of exotic species (particularly fire ants) that may adversely impact cave ecosystems. Excessive growth of Ashe juniper, however, may be detrimental to cave ecosystems by reducing the amount of available moisture and diversity of soil and litter faunas. USFWS (2001) recommended preservation of 238,773 to 400,653 m^2 (59-99 acres) around caves with listed species to maintain a healthy plant community, which include a buffer zone to sustain an adequate core area of native plants. USFWS has since refined their recommended area to 364,230 m^2 (90 acres) (USFWS, 2002).

<u>Use of Interstitial Spaces</u>

The interstitial zone is the area of small, humanly impassable, solutionally enlarged voids that provide potential habitat for cave-dwelling species in the areas between caves. The zone generally extends from caves in the form of micro-conduits that contribute some of the water that forms the caves. Types of interstitial areas include solutionally widened bedding planes and fractures, anastomosed bedding planes and fractures, honeycomb solution zones, non-cemented collapse or fault-brecciate areas, and porous cave sediments. The interstitial zone also includes caves that have been near-completely filled with sediment.

Much of the interstitial zone is characterized by what White (1969) described as the diffuse flow component of karst aquifers. Its most intensive development occurs adjacent to horizontally extensive caves and where cavernous limestone crops out at the surface. The interstitial zone is laterally extensive near caves because caves are sites of flow-path convergence, and because groundwater is injected into interstitial openings when caves flood. The exposure of cavernous limestone at the surface allows for vertical interstitial development associated with epikarstic solution of fractures, which can interconnect with horizontal interstitial zones and horizontal caves. Below the water table, the interstitial zone is the extensive and permeable system that supplies most groundwater to wells.

Based on study and observation throughout the San Antonio region, the interstitial zone is generally vertically and laterally extensive (Veni, 1994). Veni and Elliott (1994) suggested that the Basal Nodular Member of the Kainer Formation may have limited lateral interstitial extent, but that hypothesis does not appear true following more recent research. In some cases, interstitial zones may not hydrologically connect certain caves, but could provide avenues of movement between those caves for some cave-dwelling species.

The interstitial zone is critically important to cave ecosystems, not only for contributing water, but also for food. While many nutrients enter cave ecosystems through cave entrances and sinkholes, the interstitial zone provides most food energy to the deeper parts of caves (Howarth, 1983; Holsinger, 1988, Elliott and Reddell, 1989, USFWS, 1998). Most nutrients are carried as dissolved organic material or organic fragments; some are directly contributed where tree roots reach down into the interstitial zones and caves.

The biological bounds on karst fauna occupying and moving through the interstitial zone are determined by food availability. Adequate moisture is also vital to karst faunas but varies little through interstitial voids whereas food ranges from abundant to absent. The minimum width of interstitial voids, for a significant cavernicole fauna is probably 5-10 mm; this width corresponds to the threshold of turbulent groundwater flow that could carry particles of organic nutrients to cave species. Although some species can traverse smaller openings, the lack of food probably restricts their migration. Collins (1989) found fracture and bedding plane widths to be generally less than 1 mm in the Georgetown Limestone, which is not known to have a cavernicole fauna, while widths in the Edwards Limestone range from "a few millimeters to a few centimeters," and does support a rich cavernicole population. Similar findings in Europe show cave fauna to generally inhabit voids greater than 1 mm in width (Juberthei and Delay, 1981). Yet even with sufficient space, an absence of sufficient nutrients will still result in an absent fauna. Veni and Associates (1992) described caves in the Austin, Texas, area where no significant karst fauna occurs due to poorly permeable strata at the surface that limits nutrient input to underlying caves. Occasionally, construction encounters caves that are completely lined with calcite crystals; nutrients do not enter these caves and karst species are not present. Similarly, fractures and other features sufficiently enlarged to contain fauna may lack karst species if they do not contain nutrients, as suggested by Sherrod's (1991) research, where only one of four drilled boreholes that intersected voids yielded troglobites when baited. Furthermore, the one borehole that did contain troglobites was in an area of fractures and depressions that allowed nutrient input from the surface. A similar study by Reddell (unpublished) in northern Travis and southern Williamson Counties produced a troglobite in only one of seven boreholes, all of which contained cavities. The only borehole containing a troglobite was immediately adjacent to a large shallow sinkhole that drained down into a karst conduit. This indicates that nutrient input from the surface was entering the void intersected by the borehole.

The extent of the interstitial zone on Camp Bullis varies far more around upper Glen Rose caves than around lower Glen Rose or Kainer Formation caves. Interbedded marl in the upper Glen Rose is easily eroded and deposited in small fractures and conduits to prohibit entry by karst invertebrates and reduce their permeability so fewer nutrients can be carried. This occurs both within caves and within karst features exposed on the surface. Sections of the upper Glen Rose where marl interbeds are fewer and thinner have better interstitial development.

Management Considerations

The evolution of karst invertebrates requires adaptation from surface processes where environmental conditions are often in constant and considerable flux, to conditions underground where environmental changes are small to nearly imperceptible, and usually gradual (Howarth, 1983; Holsinger, 1988). The sensitivity of some troglobite species to the narrow range of environmental conditions present in caves is illustrated by moderate to high numbers of laboratory mortalities due to small environmental changes during attempts to raise immature invertebrates to maturity (Veni et al., 1999).

Research in Texas caves to date suggests certain general requirements for the protection of cave ecosystems (Elliott, 1993a, 1994b; USFWS, 1994, 1998, 2001):

- **Maintain stable microclimatic conditions.** High and stable humidity is especially important as indicated by laboratory studies (Veni et al., 1999) and the retreat of fauna into moist zones during dry conditions (Elliott and Reddell, 1989).

- **Maintain an adequate water supply.** Water flowing into caves and their associated karst features is critical to maintaining the caves' humidity and carrying nutrients to their ecosystems. Artificially induced flooding may harm ecosystems by drowning species, altering the nutrient supply, and introducing harmful surface species.

- **Maintain an adequate nutrient supply.** In meeting this requirement, care should be given to prohibit excess nutrients from cave ecosystems that are adapted to food-poor conditions (Barr, 1968; Howarth, 1983). Caves that accept floodwaters, even if they do not completely flood, will receive greater inputs of organic material and generally have smaller and less troglobitically diverse populations than caves that accept few floodwaters.

- **Prevent contaminants from entering the ecosystem.** Contaminants are either carried or washed into caves. People entering caves should not leave materials behind. Trash, non-natural materials, and natural materials in unnatural quantities should not be dumped into caves or karst features. To prevent contaminants from washing into caves requires delineation of the caves' drainage areas. Two types of areas drain into caves. "Surface" drainage flows directly into cave entrances or karst features that are clearly associated with the caves. "Groundwater" drainage flows into more distant fractures and karst features that are determined as hydrogeologically connected to the caves. Contaminants should be kept out of both drainage areas. If such prohibition is not possible, contaminants should be contained and kept to a minimum such that an accidental release would not significantly harm the ecosystem. Maintaining the drainage areas in their natural state provides appropriate nutrient input and prevents contamination.

- **Prevent or control exotic species.** Actions may be needed to eradicate or control non-native species that prey upon or compete with species native to the cave ecosystem. Any methods used should first be carefully considered for their potential adverse impact on the cave ecosystem, which would also likely be sensitive to those actions.

- **Prevent unregulated disturbance of the ecosystem.** Excessive and uncontrolled visitation of caves may unintentionally harm their ecosystems though trampling, compaction of sediments, and introduction of potentially harmful materials, such as batteries (Reddell, 1993; USFWS, 2001). Properly regulated access to caves can prove beneficial by monitoring the ecosystems, removing potentially harmful materials carried or washed in, and restoring areas to their natural conditions when needed (Reddell et al., 1999).

- **Coordinate cave management with other resource management needs.** Management of additional resources may affect the management of cave ecosystems. Examples in the Camp Bullis area include, but are not limited to, rangeland vegetation restoration, archeological sites, and aquifer recharge enhancement. Some needs may conflict. Each will require coordination according to the appropriate regulatory requirements, and for the most benefit with the least harm.

Ecology

Species 1, 2, 3, and 4 – *Cicurina* (*Cicurella*) n. sp. 1, *Cicurina* (*Cicurella*) n. sp. 2, *Cicurina* (*Cicurella*) n. sp. 3, and *Cicurina* (*Cicurella*) *madla*: Cicurinas in caves live solitary lives in webs constructed under and among rocks. Troglobitic *Cicurina* are not found in wet situations but cannot tolerate very dry conditions either. They are able to tolerate a wide range of temperatures but cannot survive long in low humidities. Areas of caves occupied by eyed cicurinas, generally near but not in cave entrances, also are home to many types of invertebrates. Some eyed, non-troglobitic species will be discussed below as possible models of blind cicurinas where information and observations for the troglobites are lacking.

In some caves, larger spiders (lycosids and ctenids) and centipedes are present in entrance areas. Although immatures of these other species could serve as prey for eyed cicurinas, adults of these species would almost certainly eat even adult cicurinas. The numerous isopods, crickets, beetles, and harvestmen found near cave entrances could serve as prey for cicurinas and probably would not harm them except possibly if they were detected while molting. We found a dead *Rhadine* beetle in a *Cicurina* web. Some *Ceuthophilus* crickets also occur in the parts of caves where troglobitic cicurinas occur. Cricket nymphs, as well as a few other cavernicolous invertebrates such as *Brackenridgia* isopods, *Texoreddellia* silverfish, and *Pseudosinella* springtails, probably occur in the diet of blind cicurinas. *Cicurina* are active predators and will eat each other as well as almost anything which might come close to their web retreat. In captivity, they will eat almost any smaller living arthropod; even hard-bodied beetles, wasps, and isopods are accepted.

Cicurinas bite prey with their fangs and hold them tight with the chelicerae. They do not release the prey and allow the venom to act, as do some other spiders. The venom of cicurinas is very potent, as preys have been observed to struggle only for a moment. Likewise, observations of larger cicurinas preying on smaller specimens of the same species reveal little struggle following the bite. These observations suggest the evolution of more potent venom because of food scarcity, but precise toxicological data are not available.

In captivity, the web of the troglophile *Cicurina varians* is a tube that opens into a small sheet. The tube can be forked or multi-branched, depending on the substrate. Large specimens of *C. varians* in captivity will fill a jar with webbing. Both adult males and females will build new webs if their old webs are destroyed. The tube diameter is about the distance of the legs held partially extended, or about ¾ the width of the body. In captivity, the diameter of the web changes as the animal grows, as the web is altered to fit the individual. It is unknown if this happens in the cave, or if the growing animal abandons its web and builds a new one. Abandoned webs are sometimes found in caves, possibly also due to predation. In captivity, the web can also be a simple tube around the base of the wall of the jar. In such cases, the webbing will be attached to the floor and on the adjacent wall of the jar. The webbing is rounded above and the glass beneath the web will not be coated with silk. Several blind specimens from MARS Pit had well developed webs, and in one web a distinct tube could also be detected. Generally, the troglobitic species have delicate webs of only a few strands or maybe a loose flat sheet. A few individuals in captivity never constructed webs, but they were able to catch food and develop. *Cicurina varians* generally hang upside down in the tube area. Unlike agelenid spiders, they do not always sit at the edge of the tube facing out on the sheet. This may be because they have more than one "sheet" web (at least one on each end of the tube, more if a branched tube). The smaller troglobitic forms generally sit on the substrate under the "sheet" or the few strands of webbing. Larger spiders will often hang upside-down on the web. Although it would be interesting to suggest that the troglobitic species have reduced or given up web building because their prey are scarce and that they have to go in search of it, this could be entirely wrong. Because we do not know the ancestor(s) of the troglobitic forms, we cannot assume that they built webs like *C. varians*. Possibly the ancestor(s) of the troglobites also did not use webs as much. On the other hand, it might be advantageous in a rare food environment to sit and wait for such prey because less energy is expended in making a web than in walking around the cave searching for food.

Bennett (1985) reported that epigean *Cicurina bryantae* Exline, from the eastern U.S.A., probably has a life span of two or more years; the immatures take more than a year to mature. His studies suggested some females may be able to produce offspring for two seasons, thus over-wintering as an adult to mate the third year as an adult. *Cicurina varians* can reach sexual maturity in one year in captivity, but the same is not true for troglobitic *Cicurina*. Veni et al (2000) reported two blind cicurinas from Camp Bullis were kept in captivity more than 13 months without reaching maturity. Several small troglobitic immatures in captivity molted once after six months; one spider required 16.5 months before reaching adulthood (Veni et al., 2002a). Larger immatures and adults can go weeks to months without feeding in captivity. One half-grown (determined from size) *Cicurina* sp. (probably *madla*) from Headquarters Cave remained in captivity occasionally feeding for over 11 months before molting once. Not all troglobitic cicurinas grow as slowly. An immature collected in MARS Pit on 9 September 1998 molted on 24 September 1998, 19 December 1998, and 23 January 1999. It died while apparently trying to molt again on 20 March 1999 (Veni et al, 1999). Five other immatures from the same cave each molted only once or twice during that same interval without dying. Possibly rapid growth is not advantageous, even when available food would support such activity. In captivity, attempted matings of *C. varians* can be hazardous as one of the sexes (generally the smaller) will often be eaten. Only one attempt of mating a troglobitic *Cicurina* has been undertaken and the male was quickly killed. In this case, it is uncertain if the female was just hungry or did not want to mate. Since males are so rare, it was removed and preserved before it could be determined if the female would eat it. This is possibly why adult males are seldom encountered in caves. They may serve as a source of sperm as well as a protein source for the production of the eggs.

The eggs of *Cicurina* spp. are laid in a small silken sac that is covered with bits of earth or attached to the inner wall of the retreat, where it remains with the female. *Cicurina varians* egg sacs are placed within the web next to the substrate. An egg sac of a troglobitic species has not been observed.

Predators larger than cicurinas, such as other spider species, are not present in the darker regions of the cave where troglobitic cicurinas occur. The larger predatory *Pseudouroctonus* scorpions and *Theatops* centipedes have rarely been collected in the same cave regions as blind cicurinas. An immature *Cicurina* sp. was found dead in Bunny Hole on 9 September 1998. A pathogenic fungus had killed it. No other parasites or pathogens have been discovered.

Species 5 – *Neoleptoneta* n. sp.: This species (based on observations with specimens from Up the Creek Cave) is found in webs it spins in and under rocks in the dark in relatively moist, but not wet situations. Because the spider is very tiny, it quickly becomes entrapped by and can drown in droplets of water. It is not found in areas of active water dripping. Although the spiders spend much of their time in the web, they are also seen walking on the substrate near the web. Preliminary studies of captive specimens reveal that *Neoleptoneta* females lay a single large egg per egg-sac. The egg-sac is placed in the web and hatches within a month. The female may lay two or three eggs over a period of a few weeks. The egg sacs are white and camouflaged with whatever debris the female can find in or around the web. Covering the egg-sacs with debris is probably a carry-over from when this spider's ancestors lived in environments where predators could see, since camouflage probably serves little function in the dark of a cave under a rock. The spiderlings are white in color and large. Their growth is relatively rapid, and they reach adulthood in about six months. The spiders do not appear to be cannibalistic when adequate food is available. In captivity, mothers and young can be found living in the same webs. In captivity, this spider can be reared to adulthood entirely on small live collembola and non-predatory mites. This spider can tolerate relatively wide fluctuations in temperature, but will desiccate quickly in drier environments.

Species 6 – *Tartarocreagris reyesi*: No observations have made on the feeding behavior of this species, but other species of *Tartarocreagris* have been observed eating young nymphs of cave crickets (*Ceuthophilus*). This species has been collected from the undersides of rocks in moderately dry sections of caves. Nothing else is known about its ecology.

Species 7, 8, and 9 – *Texella* n. sp. 1, *Texella* n. sp. 2, *Texella* n. sp. 3: Over two-thirds of the described species of *Texella* occur in caves, and the remaining species are found under rocks and logs. Virtually nothing is known about their biology, other than their occurrence is in moist to wet habitats. Troglobitic species of *Texella* appear to be very sensitive to moisture levels and are easily killed by too low levels of humidity. The troglobitic harvestmen *Hoplobunus*, which coexist in many caves with *Texella*, captures and feeds upon live collembola in captivity. *Texella* may also use this small food source. No information is available on the development of any member of this genus: the reproductive potential (number of eggs laid), the rate of growth, nor life expectancy. No observations of predators or diseases have been reported; but troglobitic *Cicurina* spiders are likely predators of juveniles in caves.

Species 10 – *Speodesmus* n. sp. 1: This species is seasonally abundant and may be found in large numbers on moist cave walls, floors, flowstone, and moist substrate. As in other species of the genus it probably builds a mud brood chamber in which it lays its eggs. The species probably feeds on fungal spores and possibly other organic material.

Species 11 – *Speodesmus* n. sp. 2: The small size of this species indicates, as in some other undescribed species of the genus, it inhabits loosely packed soil. It is apparently a more recent troglobite. It also probably feeds on fungal spores and possibly other organic material.

Species 12 – *Mixojapyx* sp.: Surface species of the family Iapygidae, to which this species belongs, are known to dig burrows in soil and rest with the strong forceps-like cerci at the mouth of the burrow. Microarthropods are then captured by the cerci and pulled down to the mouth. The troglobitic species of *Mixojapyx*, however, have always been found roaming across cave walls and floors; it is assumed that the rarity of food in caves has led to a shift in the strategy for locating food. Troglobitic species apparently are active hunters. A similar shift in feeding strategy is known for another primitive insect, *Texoreddellia texensis*. The epigean relatives of this species typically live under rocks, whereas *T. texensis* is an active searcher of food. Nothing is known of the mating behavior or life history of the cave-adapted species.

Species 13 – *Rhadine* sp. 1: This species has been found on silty floors and on cave walls in darkness. Nothing else is known of its habits. As in other species of the genus, it is probably an opportunistic feeder. Mitchell (1971a, 1971b, 1971c) has studied the dispersion, feeding habits, and temperature and humidity preferences of *Rhadine subterranea*. The data for this highly specialized cave cricket egg predator may not be applicable to other species. Numerous observations indicated that the species avoids cave cricket nymphs and staphylinid beetles, indicating that it is not an active predator. It would readily feed on injured and dead cave crickets. It has never been found in direct association with raccoon or other mammal feces.

Species 14 – *Rhadine* sp. 2: This rare species has only been found on silt floors in a small, damp, side passage part way down the entrance of Vera Cruz Shaft. Nothing else is known of its habits. As in other species of the genus, it is probably an opportunistic feeder.

Species 15 – *Rhadine* sp. 3: This rare species has only been found on moist walls and clay floors deep in Cannonball Cave. Nothing else is known of its habits. As in other species of the genus, it is probably an opportunistic feeder.

Species 16 – *Rhadine exilis*: This species is typically found deep in caves on moist flowstone or cave walls. No observations have been made of its food habits. Some other slender *Rhadine* (particularly *R. subterranea* and *R. noctivaga*) primarily feed on cave cricket eggs buried in pulverulite (Mitchell, 1971b). The species is rarer than *R. infernalis*.

Species 17 – *Rhadine infernalis*: This species may be found in all parts of caves, but is usually found nearer entrances than *R. exilis*. Unlike *R. exilis*, it typically occurs in silty areas or other areas with a high organic content. In Headquarters Cave, it has been found on old, decomposed bat guano. It is probably an opportunistic feeder, preying on small arthropods and scavenging on dead arthropods.

Species 18 – *Eurycea* sp.: This species has only been found in a shallow, fast-flowing stream containing considerable leaf litter and other flood debris. No troglobitic crustaceans have been found in the cave, but the stream contained numerous washed-in aquatic insects. The amount of organic material in the cave may be atypically high due to its occurrence behind a flood control dam.

Species 19 – *Eurycea tridentifera*: This species has most often been taken from streams and probably feeds on troglobitic crustaceans, such as amphipods and isopods. It inhabited a deep still pool in Camp Bullis Cave No. 3 and a shallow, muddy pool in Camp Bullis Cave No. 1.

Reasons for Listing and Current Threats

Several threats to karst species exist in the Bexar County area. Most threats share the underlying cause of urban growth into karst regions where species of limited distribution are present. Individually and collectively, the threats result in the loss of habitat for the species as well as impacting the species directly. Generally, these threats or their potential are present in lesser degrees at Camp Bullis than in the surrounding urbanizing areas (see Conservation Measures section). The following discussion addresses threats to the listed species as identified by USFWS (2000a). However, since the non-listed invertebrate species of concern occupy similar habitats, have similar ecological needs, and are harmed by similar factors, the threats are assumed to apply to them as well. In keeping within the USFWS recovery plan format, actions at Camp Bullis that conserve, protect, or otherwise benefit the species follow this discussion of known and potential threats.

The habitat and other requirements of the salamander species are similar in several respects to the invertebrate species, but some significant differences occur. The discussion of threats includes the salamanders unless otherwise stated, in which case exceptions and additional factors relevant to the salamanders are presented. Andy Price, of TPWD, reported that an intensive TPWD records search did not reveal any paperwork describing the reasons for *Eurycea tridentifera*'s listing by the State of Texas as threatened, only that it was an administrative decision based on best available information at that time in an effort to recognize species that are potentially vulnerable to human activities (personal communications, 1999).

Present or Threatened Destruction, Modification, or Curtailment of Habitat

Discovery and destruction of caves has historically occurred and increased in Bexar County as the degree of urban growth onto the karst has increased. Veni (1988) documented 45 of 208 caves then known in Bexar County as sealed or destroyed, and nine caves that were used as trash dumps. Since that time, the number of caves known has grown to 472, and known caves sealed, destroyed, and/or used as trash dumps has reached 106 (Texas Speleological Survey, unpublished data, 2002). While the number of caves reported at a given time is artificial, simply representing those known and not how many really exist, the number of sealed or destroyed caves is not artificial. Of the 106 impacted caves, the fauna of 91 had not been biologically studied, and species listed as endangered may have been present in as many as 10 caves. Three of the caves with listed species on Camp Bullis were only loosely sealed and later reopened, at which time the species were found. Cement Cave on Camp Bullis, which was tightly sealed enough in the mid-1960s to block off most nutrients and moisture, has not biologically recovered into a normal cave ecosystem by 1999 since it was reopened in 1993 (Veni et al., 1999).

A dramatic survey of the impact of urbanization on the karst of Bexar County can be obtained by a review of geologic assessments filed with the Texas Commission on Environmental Quality (TCEQ). Based on examination of perhaps more than 30 assessments and of about as many other developed properties where karst features were known, cumulatively hundreds of karst features have been classified as "insignificant" and are now covered with pavement, building foundations, and other materials that prevent the passage of cave life, water, and nutrients through those features into the underlying ecosystem and aquifers. The caves and karst features are not just sealed, but some are filled with concrete, rock, and dirt, while others have been blasted away. The geologic assessments find few karst features significant. Fewer still, probably less than 5% of the total features, are preserved. Veni (1999b) found that the geologic assessment method required by the Texas Natural Resource Conservation Commission (TCEQ's predecessor agency) at the time was only accurate 33.7% and underestimated the significance of 57.1% of karst features; that method has been revised but not reevaluated for its efficacy. USFWS (1998) documented the rapid rate of urban growth through the karst of Bexar County, which in large part prompted their finding to propose the invertebrate karst species for listing.

During the late-1960s to mid-1970s, an unwritten policy at Camp Bullis required filling any known caves when feasible. This was relayed by former personnel stationed at Camp Bullis during that time (Veni, 1988), and the discovery of five caves that had clearly or likely been covered during the military's ownership of the property: Cement Cave, Eagles Nest Cave, Low Priority Cave, MARS Pit, and National Guard Cave. Three of the five caves are now known to contain species listed as endangered. Camp Bullis caves have also been destroyed and their ecosystems impacted by non-military activities at the installation. Between 1971 and 1975, the San Antonio River Authority constructed three flood control dams at Camp Bullis. Reservoir 7 Cave has been destroyed (covered by a dam), and Flacido Cave, SARA Site 4 Cave, and Stealth Cave are periodically inundated and/or receive large volumes of organic debris, so that their ecosystems have undoubtedly been altered (part of the sedimentation in SARA Site 4 Cave is also probably the result of road construction). None of the caves contain highly evolved invertebrate troglobites as would otherwise be expected and as found in similar nearby caves that are not periodically flooded. Additional impacts on Camp Bullis caves have resulted from ranchers who owned the land prior to its purchase by the federal government. At least five caves were used as domestic trash dumps: Dangerfield Cave, Doeppenschmidt Camp Sinkhole, Haz Mat Pit, Pain in the Glass Cave, and Stahl Cave; since the trash fill was removed from Pain in the Glass Cave in 1994-1995 and Stahl Cave in November 1997, listed species have been found in the former and species of concern have been found in each. The species were found in the unimpacted portions of the caves immediately after the caves were opened; observations of the cave fauna on subsequent trips suggest the ecosystems in each cave have become more robust but this has not been confirmed by monitoring or counting.

While Camp Bullis no longer purposefully seals or destroys caves, other activities and circumstances are potentially harmful to the habitat of the karst species. These can be generally grouped in their probable order of descending impact as: construction, soil erosion, water quality, and training activities.

Construction

During the mid-1990s, national consolidation of U.S. military facilities resulted in the closing of some bases and more intensive use of the remaining installations. As a result, new buildings and training facilities have been constructed at Camp Bullis. More may be built. Most of the construction has been limited to the Cantonment Area, which is on the upper member of the Glen Rose Formation and mostly on sections where caves are less likely to occur. However, construction of the Texas National Guard Armory in the early 1970s did cover National Guard Cave (Veni et al., 1995), and the presence of Hunting Headquarters Sinkhole, near Hunting Headquarters, may reflect in the Cantonment Area a thin but potentially significant and previously unrecognized cavernous horizon in the upper Glen Rose. Various types of training facilities have also been built throughout Camp Bullis in areas where caves occur but either no adverse impacts have occurred or they have not been identified.

Soil Erosion

Some caves on Camp Bullis appear impacted by historic elevated rates of soil erosion. The Camp Bullis and Edwards Plateau region have experienced sustained soil erosion over the past 10,000 years, including an accelerated period during the last 200 years following European settlement and intensive use of the land (Toomey, Blum, and Velastro, 1993). Observations in many Bexar County caves, including several on Camp Bullis, show evidence that soil erosion has ceased or decelerated based on recent erosion of cave soil deposits. However, thick soil deposits in some Camp Bullis caves may reflect continued soil erosion in their drainage areas.

Record Fire 1 Pit, located downhill of the Record Fire 1 Range has deep deposits of washed-in soil, some of which may have been deposited when the live fire range was constructed. Camp Bullis Bad Air Cave, Camp Bullis Bat Cave, and Camp Bullis Cave No. 1 receive runoff from pastureland located off the installation. Veni et al. (1998a) suspected that thick black sediment deposits in the caves may result from off-post soil erosion related to livestock grazing, since Camp Bullis Cave No. 3, located nearby and formed in the same hydrogeological setting, has no significant sediments and is surrounded by undisturbed land. Dusty Bruns (Camp Bullis, Environmental and ITAM Office, personal communication, 2002) suggested that periodic blading to maintain the firebreak road at the Camp Bullis perimeter, may have also contributed sediments to the cave. Any caves located behind the three San Antonio River Authority flood control dams, such as Flacido Cave and Stealth Cave, collect substantial volumes of organic debris during floods, which is typical upstream of dams. SARA Site 4 Cave is not within the floodwater reservoir, but altered drainage patterns associated with one reservoir and construction along a nearby road have caused large volumes of sediment to be washed into the cave. What is not known is if this volume reflects normal, accelerated, or decelerated soil erosion in those watersheds. Study of sediments retained by the dams may provide useful information on general soil stability on Camp Bullis.

Soil erosion has three primary detrimental effects on cave fauna. First, it alters the food chain in caves. Highly evolved troglobites, such as the listed species and species of concern, are adapted to food-poor conditions. The higher food energy levels associated with soil erosion supports the introduction of organisms that can more successfully compete for food and may potentially be predatory on the listed species and species of concern. Second, soil erosion changes habitat conditions in caves. Cave crickets often lay eggs in silty sediments, which are found and eaten by some *Rhadine* beetles. Eroded soils that are deposited in caves often bury those silty sediments under dense clays and organic debris. These clays also tend to plug caves so they drain less efficiently, resulting in periodic and more intensive flooding, and intervening periods of greater moisture and ponded water. Third, soil erosion can eliminate habitat by completely or near completely filling caves. Record Fire 1 Pit is 10 m deep, with the lower 3 m filled with sediments; the bottom of the sediment fill has not been reached (Dale Hudler, personal communication, 1998). West of Camp Bullis, Por Boy Ranch Cave was estimated as over 100 m long in the 1920s, but could only be explored for 10 m in 1983; it appeared to be filled with sediments washed in from Helotes Creek (Veni, 1988).

Water Quality

Karst areas are known as being the most vulnerable to contamination due to the ease and speed at which contaminants enter and travel through their aquifers, usually with effectively no filtration. While most karst water quality research focuses on contaminant transport through large features like caves and sinkholes, several studies have shown that water movement through the diffuse flow portion of karst aquifers also does not filter contaminants or prevent their movement underground. Friederich, Smart, and Hobbs (1982) found soil bacteria moving into a British karst aquifer via diffuse flow waters dripping into a cave. Veni (1997) examined similar drip waters in a Texas cave and found a chemical signature indicative of septic effluent. Ogden et al. (1991) concluded conduit development is of secondary importance to the type of land use in a karst aquifer's recharge area due to high non-conduit permeabilities; if contaminants are present, they will almost certainly reach the aquifer. Successful pollution prevention in karst areas is best achieved by protecting the most vulnerable areas from pollutants, maintaining impervious cover in their drainage basins to 15% or less, and minimizing pollutant loading of the aquifer (Veni, 1999b).

Toxicological studies have not been conducted on the effects of water-borne contaminants on the listed species, species of concern, or closely related species. However, the adverse impacts of a wide array of organic chemicals, heavy metals, and other contaminants on many different organisms suggest probable harmful effects on the karst species. The most likely means of transporting contaminants into caves is in recharging waters. Contaminant sources on Camp Bullis can be divided into two groups: point and non-point.

Point sources release contaminants from specific locations. Three types of potential point sources are known on Camp Bullis: sewage spills, road spills and landfills. Leaks and spills associated with sewage transmission lines to the sewage treatment facility on Camp Bullis, or from the facility itself, could adversely impact the listed species and species of concern through excessive nutrients, and possibly through bacterial or chemical harm. No such impacts are known on Camp Bullis, and their potential for occurrence is low because the sewage facility and transmission lines are limited to the Cantonment Area where few karst features are known.

Traffic accidents or vehicle malfunctions along roadways may result in point source spills of gasoline, diesel, or other harmful chemicals onto the ground, and in sufficient volume where they might flow into a cave or karst feature with listed species and/or species of concern. The potential is increased if the spill occurs during a storm, or if an emergency response crew hoses away contaminants rather than containing and removing them. Nine Camp Bullis caves with listed species and/or species of concern capture drainage from roads. Eagles Nest Cave and Root Canal Cave drain water from paved roads. The drainage areas for Camp Bullis Cave No. 1, Jabba's Giant Sink, Lone Gunman Pit, and Stahl Cave include moderately-well traveled unpaved roads. Flach's Cave, Low Priority Cave, and Pain in the Glass Cave collect water from areas that include little-traveled unpaved roads.

Several closed landfills are present at Camp Bullis (e.g. Earth Technology, 1996), three of which are located near known caves and karst features. Landfill 1 is situated about 300 m upgradient of Hunting Headquarters Sinkhole, which is believed to lead into a cave. No contaminants are known to leak from the landfill, but Veni et al. (1999) recommended that any water encountered if a cave is reached in the sinkhole should be tested for contaminants as a precaution. Landfills 13A and 13B are in the bottom of a valley well below the levels reached by any of the caves known in the surrounding hills. While not exactly a landfill site, groundwater contamination has occurred at the EOD Range but it has not been in association with any caves or sites with listed karst species or species of concern (Veni, 1999a).

Groundwater contamination has been found in association with Landfill 8 overlying the upper Glen Rose biostrome near Lewis Creek. Cannonball Cave is located 1 km south and downgradient of the site. One groundwater sample from the cave has tested negative for contaminants, supporting the hypothesis that the cave does not drain water from the landfill. However, continued exploration downstream may lead to the conduit that transmits contaminants from the landfill to Lewis Valley Cave, located 1.8 km south of Cannonball Cave (Veni et al., 2002b). The site with the highest contaminants concentrations found to date is Well 9D located about 300 m south of Cannonball Cave (MWH, 2002). Based on the intermittent flow from Lewis Valley Cave and other springs in the area, it is likely that some cave passages are intermittently dry and become important areas for the *Rhadine* beetles, as observed in hydrologically and biologically similar passages southwest of Camp Bullis in Isopit, in the Culebra Anticline Karst Fauna Region (Veni, 1997a). Aquatic species, such as the *Eurycea* sp. salamanders, would be more vulnerable to the contaminated groundwater. They have not been found in caves along Lewis Creek but their presence along neighboring Salado Creek suggests they may be present. Excavation of other caves and sinkholes in the Lewis Creek area will likely identify additional localities for *Rhadine* sp. 3, some of which may be related to or affected by contaminated groundwater at Landfill 8, and will help confirm the presence or absence of aquatic fauna in that area.

Non-point source contaminants are derived from broad areas and no single feature or location. Typical non-point sources include bacteria and fertilizers associated with rural land use, and heavy metals and organic chemicals from urban runoff. Camp Bullis lacks agriculture and so does not produce contaminants of that type. Given the presence of roads, parking lots, and associated facilities, some urban-style contaminants are produced on Camp Bullis. However, since the small sizes and low densities of these facilities are surrounded by large sections of undeveloped land, it is unlikely that contaminants reach harmful concentrations. Schueler (1994) found that drainage areas with less than 15-20% impervious cover generally suffer no significant adverse water quality or stream ecology impacts from non-point contaminants. Impervious cover at Camp Bullis is less than 1%.

One atypical potential non-point contaminant source may be from present firearms training in the Impact Area/Maneuver Area 9 and less discriminate past firearms and artillery use that occurred over the entire installation. Contaminant releases should be slow, intermittent, low in volume, and scattered, due to the relatively small size of the ordnance over the broad area, and the different weathering rates based on the ordnance's specific location, type, and date of deposition. Seven caves with listed species and/or species of concern occur within the Impact Area (Boneyard Pit, 40mm Cave, Hilger Hole, Pain in the Glass Cave, Strange Little Cave, Well Done Cave) and two occur immediately downstream (Backhole and MARS Shaft). The U.S. Geological Survey is monitoring water quality of stormwater runoff in one stream that drains that part of that area. To date, no water quality degradation has been detected (Jerry Thompson, Camp Bullis Environmental and ITAM Office, personal communication, 2002).

Point and non-point source protection from contaminants is offered by Camp Bullis regulations that prohibit certain types of training and related activities over the Edwards Aquifer recharge zone (Fort Sam Houston, 1996). However, since 16 of the 37 Camp Bullis caves with listed species or species of concern do not occur in the recharge zone, risk of impact in those locations is greater. The primary risk would be through the use of POL (petroleum, oil, lubrication) products in the vicinity of those caves and their associated karst features. Currently, the risk is low for known localities since personnel at the Camp Bullis Environmental and ITAM Office steer such training activities to different locations. Some risk remains for unknown localities in karst fauna regions beyond the recharge zone unless similar protocols have been established for those areas. The Camp Bullis Environmental and ITAM Office has directed refueling operations away from "karst fauna areas" as identified by Veni and Reddell (1999).

Water quality problems can also occur in caves from activities occurring off of Camp Bullis. Pollutants may enter Camp Bullis water either through groundwater or by surface streams that recharge through caves and into the aquifers. Camp Stanley's Well 1, located on Camp Bullis near the boundary along Salado Creek, has low-level contaminants that might originate on Camp Stanley (Parsons Engineering Science, 2002). Although Camp Bullis cannot regulate external activities, understanding the potential sources for contaminants will assist in managing the listed species and species of concern.

Training Activities

Military training at Camp Bullis poses two types of threats to the karst species not discussed above: deliberate sealing of caves, and trash. An accidental death related to a construction trench at Fort Sam Houston led to concern at Camp Bullis to possibly seal Hunting Headquarters Sinkhole and other potentially hazardous features. Swift action by the Engineering Department placed a gate over the sinkhole to protect it from being filled (Veni et al., 1999). With multiple training and administrative programs at Camp Bullis, including different branches of the military, there is potential that caves and karst features could be filled by well intentioned personnel who perceive the features as potential sources of injury. The chances for such actions are low among the known caves; features that are obviously hazardous and/or in high traffic areas have been fenced (e.g. Backhole) or gated (e.g. Sharron Spring) by the Environmental and ITAM Office.

Despite directives to the contrary, military personnel who discover caves during training sometimes dispose trash into the caves. For example, several hundred bullet blank casings were left in Headquarters Cave (Veni and Elliott, 1994), and trash was regularly dropped down the entrance of Poor Boy Baculum Cave. Trash can upset the nutrient balance of a cave's ecosystem, increase the number of non-native predatory and competitive species, and introduce harmful contaminants to the ecosystem.

Over-utilization for Commercial, Recreational, Scientific or Educational Purposes

None of the karst species in Bexar County are utilized for commercial or recreational purposes. Many caves in the area are used on regular to infrequent bases for recreational exploration, but such usage does not occur at Camp Bullis. Scientific study of the listed species and species of concern often requires collection and preservation of a few individual specimens. These small numbers are not considered sufficient to harm the overall populations of the species (USFWS, 1998, 2000), and since all biological studies of karst species at Camp Bullis have been coordinated under one set of researchers, the potential for inadvertent over-collection is virtually eliminated. Some Camp Bullis caves with listed species and species of concern have been used once or twice a year for cave rescue training and karst hydrology classes, at which time there is potential for species to be accidentally trampled or harmed. Biological monitoring of caves at Camp Bullis showed no effects that were correlated to intervening mapping and geological study trips, which were less intense but somewhat comparable in impact to the training sessions (Veni et al., 1996, 1998a, 1998b).

Disease or Predation

Non-native fire ants pose a major threat to the survival of the listed species and species of concern. These ants are voracious predators that find the temperature and humidity of central Texas caves ideal for some of their needs. While successful fire ant mounds are not known in caves, except for a few in entrances with sufficient soil, fire ants have been observed to travel more than 100 m horizontally into caves and prey upon karst invertebrates (Elliott, 1992, 1993b; Reddell, 1993). In general, caves significantly invaded by fire ants have a substantially lower diversity of native karst species and number of individuals than typically observed in caves lacking fire ants. Likewise, the observed numbers and diversity of karst species in caves has been observed to decline following the entry of fire ants into their ecosystems. These observations are consistent with the findings of Vinson and Sorenson (1986) and Porter and Savignano (1990) that arthropod diversity drops in the presence of fire ants.

Land disturbance from construction areas, plus roadways, lawns, and other areas of human activities facilitate the dispersion of fire ants. While fire ants are present at Camp Bullis, the installation's large area of undeveloped land may reduce or limit the presence of fire ants. The degree of fire ant infestation is presented in Table 2 from data provided by Peter Sprouse based on his two most recent trips to the caves to control fire ant populations (Sprouse, 2002a, 2002b). "Light" infestation is characterized by 1-4 fire ant mounds within the 20-m treatment radius of the cave entrance, "moderate" infestation by 5-9 mounds, and "severe" infestation by 10 or more mounds. An asterisk in Table 2 indicates an estimated rather than actually quantified degree of infestation for caves that have recently been added to the list of those treated and where no data have yet been collected. Table 2 shows that fire ants are generally not known from caves with listed species in the Cibolo Creek Karst Fauna Region. While they have been found within 15 of the remaining 34 caves with listed species and species of concern, the ants have mostly been restricted to entrance areas and/or light infestations. This favorably differs from Reddell's (1993) study of caves in more developed areas of Bexar County where severe fire ant infestations were found in 19 of 43 caves.

Inadequacy of Existing Regulatory Mechanisms

Kipp, Farrington, and Albach (1993) reviewed urban growth and water quality regulations for north Bexar County. They found the area "poised for explosive development" and that with those projections and without additional regulatory protection, that "degradation of water in the Edwards Aquifer is imminent." While some improvements have since been made in the regulations by TCEQ, they are written primarily to protect water quality in the Edwards Aquifer and have no provisions for consideration of rare or endangered species. The City of San Antonio includes regulations for protection of the Edwards Aquifer, some of which are superior to those of TCEQ. The Edwards Aquifer Authority is developing additional protective regulations, but like the City and TCEQ it has no provisions for the endangered or rare karst species and ecosystems that occur in the Edwards recharge zone. Additionally, since many caves with species already listed as endangered occur outside of the Edwards Aquifer recharge zone, they miss whatever benefits the City's and TCEQ's regulations would provide. On 5 November 2002, voters in northern Bexar County approved the formation of an underground water conservation district for the Trinity Aquifer in Bexar County that would cover much of the cavernous area missed by Edwards Aquifer regulations. TPWD regulations, which address many rare and endangered species in Texas, do not contain provisions for invertebrates.

Consequently, regulatory authority for the protection of the species falls to the USFWS, but only after the species have been listed as threatened or endangered. Even then, USFWS has no authority over private lands unless there is some association with Federal action. Ultimately in most cases, protection and management of the species depends almost entirely on the landowner. As previously mentioned, Camp Bullis regulations that may offer some protection to listed species and species of concern are primarily limited to water quality protection of the Edwards Aquifer recharge zone with some limited protection for other parts of the installation (Fort Sam Houston, 1996). USFWS (2002) has proposed draft critical habitat for the listed species from which Camp Bullis will be exempt by successfully executing this management plan, but which will apply to the protection of the listed invertebrate species outside of the installation.

Other Natural or Man-made Factors

Currently, trespassing onto Camp Bullis or its caves is not a significant problem. As the surrounding areas become more urbanized, trespassing may increase in frequency. Children, especially teenagers, living in nearby neighborhoods often seek out and explore caves. In so doing, they often vandalize the caves and their gates, leave trash, trample indiscriminately, harass wildlife, and injure themselves, which may require an organized rescue that results in additional impacts on the cave ecosystem. Camp Bullis is constructing a new fence around the entire installation that will make trespassing more difficult.

Conservation Measures

Several threats and potential threats to the karst listed species and species of concern were identified in the previous section. In this section, conservation actions taken by Camp Bullis to date are described, including several to reverse, mitigate, or prevent the listed threats. While many of the threats are similar to those in karst areas of north Bexar County that are being urbanized around the installation, the threats or their potential are present in lesser degrees at Camp Bullis due to five important differences:

1) there is less intensive utilization of the installation in ways potentially harmful to the listed species and species of concern;
2) self-imposed regulations limit the environmental impacts of military training and other activities;
3) research is regularly funded to define environmental resources and recommend appropriate management strategies;
4) active management and protection of caves with non-listed species of concern that may prevent the need for listing those species in the future; and
5) the Environmental and ITAM Office is present which:
    a) coordinate all Camp Bullis activities to prevent or minimize impacts;
    b) maintain a database of environmental resource information;
    c) conduct programs for preventive and mitigative actions; and
    d) educate the installation's military population on environmental issues and their responsibilities in addressing those issues through continuous dissemination of environmental education information at unit levels through the year.

Following is information on specific measures in effect at Camp Bullis for the conservation of the listed karst species and species of concern.

Management Plan

This report represents the cumulative efforts of Camp Bullis to eliminate, mitigate, and prevent harm to the listed species and species of concern. It is written in the format of a USFWS recovery plan to best address past and current threats and management actions, and to efficiently propose and coordinate future management action for the species, including an Endangered Species Act Section 7 consultation if necessary with USFWS for the listed species. By proposing a plan that includes non-listed species of concern, Camp Bullis can take a broader and more effective ecosystem-based approach to species management, similar to habitat conservation plans.

Karst and Biospeleological Surveys

Studies of caves on Camp Bullis began with biological collections in Headquarters Cave in 1959. Some early reports were by Camp Bullis personnel and civilians who entered the caves without authorization. In the early 1970s, permission was given to the Texas Water Development Board for study of caves and hydrogeology along Cibolo Creek (Byrd et al., 1973), during which time some biological collections and observations were made. Reddell (1964) and Veni (1988) compiled and published information from these reports.

The current phase of cave research began in 1993, when the USFWS contracted studies of cave biology (Reddell, 1993) and geology (Veni, 1994) in Bexar County. Camp Bullis cooperated with that research and allowed access to Headquarters Cave, the only cave known at that time on Camp Bullis to contain now-listed invertebrate species that were then petitioned for endangered listing. Later that year, the first of ten multidisciplinary studies was contracted to investigate the caves, karst, and karst fauna of Camp Bullis.

Veni and Elliott (1994) and Veni et al. (1995, 1996) focused on the Edwards Limestone portion of the Edwards Aquifer recharge zone. All previously known caves and karst features in that area were examined, and a detailed grid search was conducted throughout the recharge zone for additional caves and karst features. The studies entailed surveys of the caves' layout from which all other research could be overlain for meaningful analysis. Biological collections were conducted, often in recognized habitat zones to better understand the caves' ecology. Specimens were sent to taxonomists specializing in those animals for authoritative identification. Hydrogeologic assessments were made of the caves to assess their roles relative to recharging the Edwards Aquifer and to drainage areas around the caves important to protecting both the aquifer and the potentially endangered cave invertebrates. In the second year, paleontological research was added to the investigations to identify the bones found loose on cave floors and during excavation of sediments in caves and sinkholes. Paleontological excavations were not conducted, only excavations that attempted to determine if caves or additional sections of known caves were present in order to biologically and hydrologically define the caves as fully as possible. The last of the three reports included the first year of a three-year sub-study of quarterly biological monitoring of four caves containing the now-listed species. The reports included summary analyses of the implications of the individual cave results on regional cave development, species distribution, and paleoecological interpretation. Each report included recommendations for each cave, plus recommendations for overall management.

During the first three research periods, additional localities were discovered for the listed endangered species. They occurred within the ranges predicted by Veni (1994), but no collections extended beyond those ranges. Veni et al. (1998a, 1998b) extended the research first to known caves and karst features in the lower member of the Glen Rose Formation along Cibolo Creek, and, second, to known caves and karst features in the upper member of the Glen Rose in the central section of Camp Bullis. This work confirmed that the lower Glen Rose was biologically distinct from the Edwards Limestone, but was less clear about the intervening upper Glen Rose where species possibly related to those listed were found. Also, while the first three projects reported any cultural material that was found, an archeologist with Prewitt and Associates, Inc., joined each subsequent project as a full time member of the team to minimize the potential of disturbing cultural material, and to accurately describe any material that was discovered at or in association with the caves and karst features examined.

The goal of Veni et al. (1999) was to complete research in several caves throughout Camp Bullis, and was mostly achieved. As a sub-study, with the biological monitoring complete, biological collections focused on blind troglobitic spiders and harvestmen. Immature specimens, which cannot be identified to species, had been collected during previous studies. This sub-study returned researchers to caves where immatures had been found, to collect adults specimens if possible and, where they were not present, to collect immatures with the intent of rearing them to maturity. Also during that year, both the biological and geological aspects of the study benefited tremendously, as has this management plan, by Camp Bullis funding a detailed stratigraphic mapping study of the upper Glen Rose by the U.S. Geological Survey (Clark, in review). Effective interpretation of caves, hydrology, and biology in the upper Glen Rose had been impossible due to inadequate mapping of the unit. Clark's (in review) work, while in draft form, provided the framework for detailed hydrogeological and biological interpretation and management of the upper Glen Rose area.

The current phase of research (Veni et al., 2000, 2002a, 2002b; plus field work currently in progress) will complete the detailed grid search for caves and karst features for the entire installation. This 10-year period of grid searches meets or exceeds the USFWS' (2000b) karst survey guidelines for endangered invertebrate species. All newly discovered open caves have been mapped, and biologically, geologically, archeologically, and paleontologically examined. Excavation of karst features for new caves have not been conducted except to support groundwater contamination studies in the vicinity of Landfill 8. Biological studies meet the USFWS (2000c) protocols for caves with endangered invertebrate species. They have continued to try and identify potential listed species or species of concern known only from immature specimens and to describe new species found at Camp Bullis. The contract for Veni et al. (2002b) includes funding to support production of a volume the Texas Memorial Museum's Speleological Monograph series that will publish those descriptions.

Beginning in 2001, Camp Bullis has cooperated with a DNA study sponsored by USFWS. The purpose of that work is to collect representatives of the listed species to establish their DNA. The use of DNA sequences to identify species circumvents the problem of collecting immature specimens or specimens of a gender not suitable for identification because the specimens do not have to be adult or gender specific. DNA can also provide answers to questions about the evolutionary dynamics and history of cave-limited species. Understanding these factors has important implications on the conservation and management of the caves and their ecosystems.

Actions Against the Destruction, Modification, or Curtailment of Habitat

Of the six caves known to have been sealed on Camp Bullis in the 1960s and 1970s, four have been reopened and two remain sealed, one under a building and the other beneath a dam. Trash from ranching activities that pre-date Camp Bullis fills several caves and sinkholes. Thus far, trash from five caves has been removed and archeologically evaluated. The trash removal has helped restore the caves' natural ecosystems. Excavation of sinkholes and within caves on Camp Bullis has been vital to understanding and managing the listed species and species of concern. Of the 37 caves containing the karst species, 24 were opened by excavation (including the 10 deliberately sealed by ranchers and previous military commands), and the extents of three were significantly expanded by excavation. Care has been taken in each excavation to not modify the cave more than needed. In most cases, biological collections were made the same day or shortly after the excavations were complete to document the fauna present at such times. Subsequent biological studies did not indicate any degradation of the habitat; if anything, ecosystems were more robust due to slightly greater nutrient input by more efficient cave cricket foraging and entry of raccoons and other mammals. If fire ant infestation at Camp Bullis had been more severe, then the ecosystems may have been negatively impacted by allowing fire ants easy entry.

Bats or evidence of bats has been found in nine Camp Bullis caves. Five contain bats on an infrequent basis, and probably no more than a few or even one at a time: Bullis Hole, Camp Bullis Cave No. 1, Glinn's Gloat Hole, Tall Tales Cave, and Vera Cruz Shaft. Four have known habitat for small bat colonies: Camp Bullis Bat Cave, Eagles Nest Cave, Headquarters Cave, and Low Priority Cave. To facilitate the survival of the colonies, or to reestablish them where entrances had been sealed, vegetation and other obstructions to cave entrances has been removed. Where cave gates are necessary, the gates incorporate a design to allow the easy passage of bats. Backhole, which had no entrance prior to excavation, is surrounded by a protective fence, which in part was selected to allow bats to roost in the cave if they found it suitable habitat. While large bat colonies, such as those of the Mexican free-tailed bat, *Tadarida brasiliensis mexicana*, usually result in excessively high nutrient inputs for highly evolved troglobites like the listed species and species of concern, small bat colonies often provide sufficient nutrients to make the ecosystems for the listed species and species of concern more robust rather than displacing them (USFWS, 1998). None of the caves at Camp Bullis are big enough or provide suitable conditions to harbor large bat colonies. In September 1999, Camp Bullis signed a management contract with the Texas Cave Management Association for inspection and trimming of vegetation away from entrances with known or potential bat habitat; that contract continues to be renewed (Jackie Schlatter, Natural and Cultural Resources, Environmental Division, Fort Sam Houston, personal communication, 2002).

Construction

The construction of new buildings and training facilities is coordinated with the Camp Bullis Environmental Office. Additionally, staff from the Environmental Office field-checks the construction sites, even when environmental impact assessments have been contracted. Veni et al. (1995) had searched the area of the asphalt plant in Maneuver Area 10, and no caves or karst features of significance were found; nonetheless, staff from the Environmental and ITAM Office reexamined the construction site, once it was clear of vegetation, in case anything new would be revealed and before construction began (Dusty Bruns, Camp Bullis Environmental and ITAM Office, personal communication, 1998). Similarly, the area around the quarry in Maneuver Area 11A has been searched for caves and karst features and none have been found. Adverse impacts from the quarry on caves in the area have not been detected and the Environmental and ITAM Office monitors the quarry should it open a previously unknown cave.

Soil Erosion

The Environmental and ITAM Office at Camp Bullis has established a program of prescribed burns to restore rangeland habitat, enhance soil stability, and control the spread of invasive vegetation, primary Ashe juniper or "cedar." Cedar trees are often selectively removed, sometimes by hand, but mainly by mechanical means. Some of the apparatus used cuts down and mulches the trees in place to help stabilize and produce soils. Bulldozers are also used on occasion, which increase soil erosion in the short term until stabilizing vegetation takes root.

Water Quality

No physical actions have occurred to prevent spills of hazardous materials along roadways from entering caves. However, caves that drain roadway areas have been identified and their drainage areas defined. Fort Sam Houston (2000) has developed an emergency spill response plan for Camp Bullis and in revising that plan will add spill prevention and mitigation measures specific to areas containing caves with the listed species and species of concern (Jerry Thompson, Camp Bullis Environmental and ITAM Office, personal communication, 2002). Groundwater near landfills is monitored through a series of wells and springs as a warning system in case leachate is released. Where groundwater contamination has been detected, research has been undertaken (e.g., MWH, 2002) to define the extent of the problem and determine the best course of mitigative action. Camp Bullis is included in a U.S. Geological Survey (USGS) study of surface water quality, and the variety and quantity of non-point source contaminants in the Impact Area is being monitored; results thus far do not indicate any water quality deterioration (Jerry Thompson, Camp Bullis Environmental and ITAM Office, personal communication, 2002). The USGS has not set a limit on the monitoring period; they will continue monitoring for the foreseeable future so long as funds are available. The Camp Bullis command has developed regulations to prohibit training activities on the Edwards Aquifer recharge zone that may pose a risk of groundwater contamination (Fort Sam Houston, 1996). Training outside of the recharge zone, that may pose a risk to groundwater quality, is directed away from known caves and karst features by the Environmental and ITAM Office. By 2003, all of the installation will have been carefully searched for additional caves and karst features.

Training Activities

Some types of training at Camp Bullis require more intensive use of the land. These activities are typically limited to specific areas, such as drop zones for parachute training, road and trails for vehicles, and the Impact Area for firearms. They cover about 8% of Camp Bullis' total area and each is buffered by much larger sections of land used for low-impact training. Several of these areas are mowed on an occasional basis and soil erosion methods are regularly practiced in their use, including the construction of low-erosion roads for certain vehicles. Prescribed burning of vegetation is applied to reproduce the effects of natural fires. Several small fires (usually covering areas less than about 40,000 m^2) occur in the Impact Area each year that are accidentally set by firearm training. They are quickly and easily controlled. Larger fires occur about once every 7-8 years. Fire preparedness measures are practiced regularly to minimize fire damage. The range and intensity of accidental fires is considered when planning prescribed burns for ongoing rangeland restoration efforts.

Eleven gates and one fence have been placed on or around the entrances of Camp Bullis caves. The gates were placed on highly visible caves or caves in high-traffic areas to prevent accidental injury or death during training maneuvers, and thus prevent the reaction to hastily fill the caves in response. Their placement has also greatly reduced and in some cases eliminated trash being tossed into caves. The gates provide the appropriate perception that the caves are something of value and concern, and relates to the unit-level information disseminated by the Environmental and ITAM Office throughout the year about environmental issues at Camp Bullis, which includes information on the importance of caves and cave ecosystems. Placing signs at caves is under consideration by Camp Bullis staff, weighing their benefit of deterrence against impacts caused by attracting unwanted visitation. In September 1999, Camp Bullis signed a management contract with the Texas Cave Management Association to inspect and conduct maintenance on all gated caves (with or without listed species) four times each year, to include repairs, and clearing of flood debris and any trash. That contract is programmed to be renewed annually subject to the availability of funds (Jackie Schlatter, Natural and Cultural Resources, Environmental Division, Fort Sam Houston, personal communication, 2002).

Over-utilization for Commercial, Recreational, Scientific or Educational Purposes

Caves on Camp Bullis are not used for commercial or recreational purposes. All biological studies of karst species have been coordinated under one set of researchers, which with prudent and as-needed collecting of specimens, virtually eliminates the potential for inadvertent over-collection of species. Results from biological monitoring of four caves suggest that annual to semi-annual use of some caves for educational purposes does not measurably harm the listed karst species or species of concern.

Reddell et al. (1999) suggest that educational contact with karst ecosystems is beneficial by fostering public understanding and support of rare and endangered karst species, which Camp Bullis has supported since 1998 by allowing annual karst management classes and at least one conference field trip to visit some of the caves. These events have no consistent visitation to any caves. Those visited to date that contain listed species are Bunny Hole, Eagles Nest Cave, Headquarters Cave, Hold Me Back Cave, Isocow Cave, Poor Boy Baculum, Root Canal Cave, and Up the Creek Cave; Winston's Cave contains species of concern and has also been visited. To date, these caves have been visited no more than one time per year. All trips have been accompanied by persons knowledgeable about the caves and the species. Areas where the species are predominantly found, if such areas have been identified, have been avoided. Some cave entrances have also been visited about once a year as a part of educational efforts, which has no effect on the species since the caves are not entered and surface conditions are not altered.

Disease or Predation

The preservation of large, undisturbed tracts of land is probably responsible for less fire ant infestation at Camp Bullis than seen in caves in the surrounding urbanized areas. In September 1999, Camp Bullis signed a management contract with the Texas Cave Management Association for bi-annual fire ant treatment of caves with listed karst species and species of concern. That contract is programmed to be renewed annually subject to the availability of funds, with new caves added as species of concern are discovered. Thirty-seven caves are addressed under the current contract (Jackie Schlatter, Natural and Cultural Resources, Environmental Division, Fort Sam Houston, personal communication, 2002). The control methods used meet previous USFWS standards, but not the current USFWS (2001) protocols that are believed to have the least potential harm on the listed species, while being effective in highly reducing the number of fire ants near the caves; those protocols are described in this report's section, "Specific management actions for karst management areas with listed species and species of concern." While infestation of caves at the installation is generally low where fire ants are present, such action reduces the risk of greater infestation as urbanization moves closer and more densely encircles Camp Bullis.

Other Natural or Man-made Factors

To prevent or reduce the impact of trespassing onto Camp Bullis and its caves, three actions are underway. First, the old, short, and easily breached barbwire perimeter fence along the boundaries of the installation is being replaced by a tall, barbed wire topped, difficult to breach chain-link fence. Second, since the terrorist attacks of September 2001, Camp Bullis has become a restricted access facility. The once publicly accessible road through the Cantonment Area has been closed to the general public. Access to the installation is limited to those with appropriate military access identification cards, on pre-approved visitor lists, or by approved escort. Third, should trespassers get past the new fence, or include people with authorization onto Camp Bullis, the caves that are most easily found have been securely gated. The gates are designed to allow the free passage of air, water, and cave life to minimize their impact on the cave ecosystems. Camp Bullis personnel restrict maps and data with cave locations to the files of the Environmental and ITAM Office, and to researchers and other personnel on an as needed basis.

Management Plan

Management Strategy

This management plan is designed to provide detailed steps for management of the listed karst species and species of concern at Camp Bullis and to outline a general strategy for situations not covered by specific management actions. The management plan has two goals:

1) preservation and protection of the listed karst species and species of concern and their habitat in perpetuity, within the limits possible through the caves, land, and authority of Camp Bullis and its operational and mission requirements;
2) ensure the species' survival, genetic diversity, and evolution in a manner consistent with the delisting or downlisting of endangered and threatened karst species as recognized by the USFWS (1994) recovery plan for related listed species in the Austin, Texas, area.

As shown in Figures 1-5, Camp Bullis occurs in four karst fauna regions. The regions, as described earlier in this report, are defined based on geologic and hydrologic continuity and the distribution of troglobitically advanced species. One of the regions, the Stone Oak Karst Fauna Region, is recognized by USFWS (1998, 2000) based on work by Veni (1994). Subsequent work at Camp Bullis and the north Bexar County area allows for delineation of the other karst fauna regions, plus karst fauna subregions. Subregions are zones within karst fauna regions that have troglobitically advanced species not found elsewhere in the region. Hydrogeologic causes for this zonation may not be apparent, as between the Camp Bullis Eagles Nest and Southeast subregions, and may not exist; in such cases, zonation may solely be the result of currently unrecognized ecological factors.

Karst fauna regions and subregions can be further divided into "karst fauna areas." USFWS (1994) described the karst fauna area as "known to support one or more locations of the listed species [to included species of concern for this management plan] and is distinct in that it acts as a system that is separated from other karst fauna areas by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna." The purpose of the karst fauna areas in managing the karst species is to establish areas where a catastrophic event (i.e., contamination, quarrying, flooding, etc.) that may kill species or destroy habitat in one area, would not impact species or habitat in other areas.

The USFWS (1994) recovery plan for related endangered invertebrates in Travis and Williamson counties, Texas, requires protection and preservation of at least three karst fauna areas within each karst fauna region for each listed species. Due to current reevaluation of the term "karst fauna area" by USFWS, that agency recommends that those areas not be defined for Camp Bullis at this time and be delineated once the definition of the term is resolved (Tannika Engelhard, USFWS, personal communication, 2002).

If karst fauna areas were based solely on hydrologic factors, then almost each area would be equivalent to each known cave on Camp Bullis in the Stone Oak and Edwards Outlier Karst Fauna regions. The caves are usually separated by sufficient distances to prevent a catastrophic incident at one from affecting another. Caves in those regions tend to be vertically developed for efficient recharge of their aquifers, and thus have relatively little horizontal extent above the water table that may connect to other caves with listed species or species of concern. Little direct information is available on caves and conduit development below the water table at Camp Bullis, but what is available supports the conceptual model of karst aquifers that many caves will be hydrologically linked. Since all of the two karst fauna regions' invertebrate listed species and species of concern occur above the water table, they will not be directly impacted by a significant groundwater contamination incident in another cave. However, fumes from contaminants spill at one location in the karst are known to rise from the aquifer into caves in other areas, even if the caves do not allow human access to the water table (e.g., Russell, 1987). The direct impact of such fumes on the listed species and species of concern is not known, although with certain fumes, fires and explosions are possible. There is insufficient information to precisely predict groundwater flow paths in most areas of Camp Bullis to be certain where contaminants would or would not travel; therefore, until additional information is available, when karst fauna areas are established, their hydrologic limits should be based on their degree of distinctiveness above the water table.

In the Cibolo Creek and Upper Glen Rose Biostrome Karst Fauna regions, the salamander species occur above the water table in perched streams, at the water table, and probably below the water table. The hydrogeology of the Lower Glen Rose Aquifer in the Cibolo Creek area is complicated and detailed predictions of groundwater flow relative to delineating karst fauna areas and karst management areas are only generally possible. The hydrogeology of the Upper Glen Rose Biostrome seems less complicated, but is poorly studied, and again, only general predictions of groundwater flow can be made.

Table 4 groups the 37 caves with listed species and species of concern by karst fauna regions and subregions into 32 karst management areas. Table 5 identifies the karst fauna regions and subregions in which each species of concern occurs. When karst fauna areas are defined and assigned to Camp Bullis, Table 5 can be reorganized to identify the number and type of species per karst fauna area. The discovery of additional localities for the species in the karst fauna areas may prove important in meeting management goals. This is especially true if activities or accidents require or result in the loss of a karst fauna area. Additional species localities provide Camp Bullis with greater flexibility in management if necessary, and a supportive role for the conservation of species that occur in caves beyond the installation's boundaries.

Should the need arise to target some karst management areas for conservation while others may be impacted or lost, priority will be given to the first three of the following circumstances and subtracted for the fourth:

1) high biodiversity within the karst management area;
2) presence of multiple listed species and/or species of concern within the karst management area;
3) presence of species known from less than three karst management areas;
4) low species populations or habitat of otherwise marginal quality.

The first two points are important to preserving genetic biodiversity of the karst ecosystems, which also protects species not currently known, listed, or considered species of concern. The third point is important where a karst management area may have high general biodiversity and/or multiple listed or non-listed species of concern, but three or more other areas protect its species. In such cases, a cave with less biodiversity and fewer species of concern will receive preferential protection since at least one of its species is known just from that karst management area and perhaps only one more. The fourth point identifies cause for discounting protection of a karst management area if needed, but it will not be a consideration if the karst management area is one of no more than three containing a certain species.

Table 4
BIOLOGICALLY SIGNIFICANT CAVES OF CAMP BULLIS KARST MANAGEMENT AREAS

Karst Management Area	**Caves Containing Listed Species or Species of Concern Within Each Karst Management Area**
Cibolo Creek Karst Fauna Region	
1	Camp Bullis Cave No. 1, Camp Bullis Cave No. 3
2	Jabba's Giant Sink
Upper Glen Rose Biostrome Karst Fauna Region	
3	Cannonball Cave
4	Darling's Pumpkin Hole
5	Flach's Cave
6	Hector Hole
7	Lone Gunman Pit, Stahl Cave
8	Meusebach Flats Cave
9	Stealth Cave
Edwards Outlier Karst Fauna Region: Camp Bullis/Dominion Subregion	
10	Vera Cruz Shaft
Stone Oak Karst Fauna Region: Camp Bullis Eagles Nest Subregion	
11	Boneyard Pit
12	Eagles Nest Cave
13	40mm Cave, Strange Little Cave
14	Hilger Hole
15	Isocow Cave, Root Canal Cave
16	Pain In the Glass Cave
17	Well Done Cave
Stone Oak Karst Fauna Region: Camp Bullis Southeast Subregion	
18	B-52 Cave
19	Backhole
20	Bunny Hole
21	Cross the Creek Cave
22	Dos Viboras Cave
23	Hold Me Back Cave, MARS Shaft
24	MARS Pit
25	Platypus Pit
26	Poor Boy Baculum Cave
27	Root Toupee Cave
28	Up the Creek Cave
29	Winston's Cave
Stone Oak Karst Fauna Region: Camp Bullis Southwest Subregion	
30	Flying Buzzworm Cave
31	Headquarters Cave
32	Low Priority Cave

Table 5
NUMBER OF KARST MANAGEMENT AREAS PER SPECIES

Listed species and species of concern	Karst Fauna Region: Subregion	Number of karst management areas
Cicurina (*Cicurella*) n. sp. 1	Stone Oak: Eagles Nest and Southeast	4
Cicurina (*Cicurella*) n. sp. 2	Stone Oak: Southeast	2
Cicurina (*Cicurella*) n. sp. 3	Biostrome	1
Cicurina (*Cicurella*) *madla*	Stone Oak: Southwest	1
Neoleptoneta n. sp.	Stone Oak: Southeast	1
Tartarocreagris reyesi	Stone Oak: Southeast	2
Texella n. sp. 1	Stone Oak: Eagles Nest	1
Texella n. sp. 2	Stone Oak: Southeast	1
Texella n. sp. 3	Stone Oak: Southwest	1
Speodesmus n. sp. 1	Stone Oak: Southeast	4
Speodesmus n. sp. 2	Stone Oak: Southeast	1
Mixojapyx sp.	Stone Oak: Eagles Nest and Southeast	3
Rhadine sp. 1	Biostrome	5
Rhadine sp. 2	Edwards Outlier: Bullis/Dominion	1
Rhadine sp. 3	Biostrome	1
Rhadine exilis	Stone Oak: all	18
Rhadine infernalis	Stone Oak: Southwest	3
Eurycea sp.	Biostrome	1
Eurycea tridentifera	Cibolo Creek	2

A second important part of the management strategy is the delineation of karst management areas targeted for conservation. The size and shape of a karst management area will be sufficient to maintain microclimatic conditions in its cave(s), water quality and quantity consistent with natural drainage, and a surface area supportive of native plants and animals. If the watershed of a karst management area is sufficiently large, berms, curbs, or other water diversion structures may be used to divert small amounts of potentially contaminated surface water away from the karst management area, while not affecting the overall volume of recharge into the site. The specific actions will be coordinated with the USFWS.

Elliott (1994a) found that cave crickets, which are critical to the maintenance of cave ecosystems, forage mainly within 50 m of cave entrances. Therefore, natural vegetation in karst management areas will be maintained within at least a 50-m-radius of a cave's footprint and sinkholes or other karst features probably connected to the cave. USFWS (2002) proposed that a 364,230-m^2-area (90 acres) be used to protect a natural vegetative core area around a cave with listed invertebrate species. This is supported by biological monitoring data that show karst management areas of about that size and larger seem to maintain healthy cave ecosystems while karst management areas about one-tenth that size do not (USFWS, 2001). Monitoring data for intermediate size karst management areas do not exist. Elliott (1994a) attributed the observed population decreases in small karst management areas to decreased food input from cave crickets and raccoons and greater impacts from fire ants, roaches, pillbugs, and other competitive or predatory non-native species. So long as Camp Bullis retains its predominantly undeveloped setting, maintenance of these naturally vegetated areas should not significantly affect management of its karst management areas or karst species. However, fire ant treatment will continue to be needed at caves throughout the installation as described later in this plan.

The third important part of the management strategy is implementation and education. At Camp Bullis, this would include developing and periodically updating appropriate regulations, launching chain of command notifications and procedures, acquiring funding as needed, continuing the current continual environmental education program, and establishing procedures and personnel responsible for implementing the management plan. Implementation of the management plan recognizes that understanding of the karst species and the complicated karst hydrogeologic environment they inhabit is limited, and in cases of uncertainty, the default action will be to protect and preserve larger areas and more locations. Personnel implementing the plan will allow it to be flexible and modified following acquisition and analysis of new data.

One tool of the management strategy is the redirection of potentially detrimental activities away from caves with listed species and species of concern. However, the ability of Camp Bullis to redirect the training at the live fire ranges is not feasible within the current Army training doctrine or funding level of the installation. Activities on the live fire ranges that could have a detrimental effect are accidental fires that destroy native vegetation, mowing around the target arrays, bullet strikes around and near cave entrances that damage the vegetation, and the release of potentially harmful concentrations of heavy metals to the environment. In addition to the measures described later in this management plan, Camp Bullis will mitigate these possible impacts by undertaking the following actions on the live fire ranges:

1) Any accidental range fire will continue to be fought vigorously in the area around any cave on a live fire range to limit the impact to the smallest possible area.
2) A buffer area of at least 10 m will not be mowed around cave entrances on the live fire ranges. The 10-m-distance reflects the minimum area needed for firing range maintenance and use. Areas up to 50 m away from the cave, the primary area for cave cricket foraging, will not be mowed if they do not obstruct training, maintenance, or safety. The actual unmowed areas will be determined case by case according to the situation for each cave.
3) Camp Bullis will continue to monitor water leaving the live fire ranges for contaminants that may prove detrimental to the cave species.
4) Camp Bullis will enter into consultation with the USFWS if there is a major increase in training activity near any cave with listed species.

Management Objective and Criteria

Objective

The objectives of this plan are to:

1) preserve and protect the listed species and species of concern and their habitat in perpetuity, within the limits possible through the caves, land, and authority of Camp Bullis and its operational and mission requirements;
2) ensure the species' survival, genetic diversity, and evolution in a manner consistent with the delisting or downlisting of endangered and threatened species as recognized for related listed species in the Austin, Texas, area by the USFWS (1994).

Criteria

The objectives of this plan will be satisfied by the following factors:

1. Preservation and protection of the appropriate number of karst fauna areas within each karst fauna region or subregion per USFWS guidelines. Based on protection methods required for related endangered invertebrate species in Travis and Williamson counties, Texas, by USFWS (1994) and current discussions by its karst invertebrate recovery team, a certain number of karst fauna areas will need protection according to the species they contain. Since karst fauna areas are currently being redefined and the number required reassessed, specific actions are not proposed here except to meet the guidelines that will be proposed by USFWS within the limits possible through the caves, land, and authority of Camp Bullis and its operational and mission requirements. In the interim, karst management areas will be established and managed in ways consistent with the most recent guidance from USFWS (2001).

2. Administrative and other appropriate assurances are in place for criterion no. 1 to be carried out in perpetuity. The management plan is intended to assure compliance with the letter and spirit of the Endangered Species Act by proactive actions that will help conserve listed species and species of concern, and by preventative actions to decrease the chance of other species being put at risk and considered for listing. The objectives of this plan will need to be continued in perpetuity, unless circumstances change where the species are no longer at risk and do not require this intervention and within the limits possible through the caves, land, and authority of Camp Bullis and its operational and mission requirements. Should Camp Bullis ever be transferred in whole or in part, local Army officials will request that the Secretary of the Army, or other appropriate authority, review and incorporate provisions from this management plan into the property disposal procedures in order to transfer responsibility for appropriate management of any former Camp Bullis karst management areas to all subsequent owners by deed recordation or other binding instrument.

Management Plan Outline

Below is an outline of the tasks needed to meet the objectives of the plan. Narrative descriptions of the tasks are discussed in the following section and are followed by specific management recommendations for the 32 karst management areas. Attainment of this plan will proceed as allowed by funding and Camp Bullis' mission and operational requirements.

1. Identify karst management areas needed to meet the management plan criteria.
2. Determine the appropriate size and shape of the karst management areas.
3. Provide protection in perpetuity to targeted karst management areas.
   - 3.1 Coordinate with USFWS, TPWD, and other agencies.
   - 3.2 Review and update Camp Bullis regulations as needed.
4. Implement conservation measures and manage karst management areas.
   - 4.1 Apply USFWS fire ant management techniques.
   - 4.2 Identify and protect important sources of nutrients into karst ecosystems.
   - 4.3 Determine and implement appropriate means to prevent siltation and/or entry of other contaminants to the karst management areas.
   - 4.4 Determine and implement appropriate means to prevent vandalism, dumping of trash, and unauthorized human entry of caves and karst features.
   - 4.5 Other actions as needed.
5. Additional research.
   - 5.1 Conduct additional karst and biospeleological surveys.
   - 5.2 Continue hydrogeologic studies of karst management areas that are currently incomplete.
   - 5.3 Conduct additional studies on the ecology of the listed species and species of concern.
   - 5.4 Revise the karst species management plan as needed.
6. Education.
   - 6.1 Develop educational programs to raise awareness and encourage protection of karst ecosystems by Camp Bullis personnel.
   - 6.2 Develop educational programs on karst ecology and hydrogeology to help key Camp Bullis personnel with the management of the karst management areas and the listed species and species of concern.
   - 6.3 Develop educational information for public relations.
7. Monitoring.

Management Plan Narrative Outline

1. Identify karst management areas needed to meet the management plan criteria. Existing land use of Camp Bullis preserves and protects the karst management areas with little additional action and only occasional maintenance. The karst management areas occur within areas that are largely or entirely within their natural states with little or no impact from human activities. The purpose of identifying karst management areas here is to prioritize their importance should circumstances develop that may threaten or harm their ecosystems. The primary considerations in prioritization are biodiversity, number of listed species and/or species of concern present, number of karst management areas known per species, and quality of habitat. Secondary factors to consider include potential threats, present, past, and projected future surrounding land use, management feasibility, and importance to the regional aquifer.

Based on these considerations, Table 6 provides a matrix by which the karst management areas are prioritized for conservation. Should it become necessary to harm or potentially harm one or more the karst management areas, those with greatest ecological value can be identified and protected. Table 6 was designed to primarily weigh the factors reflecting biological richness and threats to the ecosystem, with secondary importance given to management and related factors. The matrix was tested by calculating data in various ways until the results fit our professional assessment of the karst management areas. Among the factors listed above, habitat quality was considered under "Potential threats" and management feasibility was considered approximately equal for all sites and was not included.

The first row of data in the table describes the calculation. The number of listed species in the karst management area is multiplied by ten. That number is added to the product of the number of non-listed species of concern in that karst management area multiplied by seven. Since some of the non-listed species are rarer than the listed species, it is important that they be given a comparably high multiplier. The resulting number is then added to the karst management area's number of troglobites that are neither listed nor species of concern, which is first multiplied by five. This number is then added to the karst management area's number of non-troglobitic invertebrates to produce the karst management area's biodiversity value. If there were no threats or potential management problems affecting the karst management areas, this value could be used for prioritization. However, threats do exist that effect the quality of the ecosystems. "Potential threats" include existing impacts, such as fire ants, and existing conditions that may harm a karst management area, such as spills from a roadway. Since the potential impact of the threats is directly proportional to the biodiversity of a karst management area, the threats are represented on a percentage scale for their likely harm to each ecosystem. Zero is the lowest possible value and 1 (100%) is the highest. The potential threat value is multiplied by the biodiversity value, and the result is subtracted from the biodiversity value. To that number, points may be added or subtracted for land use and aquifer importance to obtain the matrix total value.

For Table 6, potential threats were estimated as: 0.1 for light fire ant infestation in the karst management area, 0.2 for moderate infestation, 0.3 for severe infestation, 0.2 for karst management areas in the live fire ranges where soil erosion or possible ordnance contaminants may occur, and 0.1 to 0.3 for areas in streambeds or along roads where they are susceptible to spills and soil erosion. Land use was assigned three values: -5 for use adverse to the karst ecosystem, 0 for land that is not intensively used or not in clearly harmful ways, and 5 for use that maintains the land in its natural

state that is most beneficial to the ecosystem. Aquifer importance was rated between 0-5 points based on the estimated recharge that occurs in the karst management area, and how vulnerable the aquifer may be to contaminants in that area.

It is important to note that the values given in the tables can be changed. Some may change as additional species are discovered. Major change is possible with karst management areas listed with high potential threats or caves that have received little biological study thus far (i.e. Darling's Pumpkin Hole and Well Done Cave). Management actions may reduce the threat from fire ants, spills, and other activities, thus raising the ecological value of the karst management areas. The potential fire ant threat values have been reduced from those in the previous plan (Veni and Reddell, 1999) in recognition of the regular control efforts. However, variable fire ant threats are still listed since the ants return to the caves after treatment and in varying intensities depending on conditions at each site that favor or discourage their presence.

In the event that an activity is considered that may impact or potentially impact the karst management areas, Table 6 can be used to identity those karst management areas with greatest ecological value and direct the activities to those with the least value. It is vital to stress that "least value" does not mean "low value" or "little importance." Potentially harmful actions will be considered options of last resort and coordinated with the USFWS. Regardless of ranking, impacts will avoid karst management areas that are the only known localities of certain species: karst management areas 3, 7, 9, 10, 25, 28, 29, 31. Table 6 will be reviewed at such times and updated if needed to insure it is as accurate as possible. For the Cibolo Creek Karst Fauna Region, the current order of karst management areas as ranked from highest to lowest ecological value is: 1, 2. For the Upper Glen Rose Biostrome Karst Fauna Region, the current order of karst management areas as ranked from highest to lowest ecological value is: 6, 7, 3, 5, 9, 8, 4. For the Camp Bullis Eagles Nest Subregion the current order of karst management areas as ranked from highest to lowest ecological value is: 12, 15, 11, 13, 17, 16, 14. For the Camp Bullis Southeast Subregion the current order of karst management areas as ranked from highest to lowest ecological value is: 28, 18, 25, 21, 23, 19, 24, 20, 22, 27, 26, 29. For the Camp Bullis Southwest Subregion the current order of karst management areas as ranked from highest to lowest ecological value is: 31, 32, 30. The karst management areas of generally lowest ecological value are those in the Upper Glen Rose Biostrome where no listed species are known and in the Impact Area, especially in areas cleared of much vegetation. The minimal vegetation is assumed to adversely impact cave cricket populations, but this hypothesis has not been tested by careful monitoring.

Additional discoveries of any of the listed species or species of concern will increase the demonstrated likelihood for the species' survival and allows for greater flexibility in their management. The results of Table 6 or otherwise meeting this management plan's goals will not be considered justification to casually impact the karst management areas; the species are still rare and actions will be coordinated with USFWS where required. The tables are meant to help with prioritization when other management avenues to protect the karst management areas are not available.

2. Determine the appropriate size and shape of the karst management areas. Karst management areas will be established and include sufficient area to preserve and protect the nutrient input, moisture, and microclimate of their karst ecosystems, and the water quality and quantity entering the ecosystems. The karst management areas will also prevent or discourage the entry of non-native species harmful to the ecosystems, such as fire ants, and encourage the entry of beneficial native species such as occasional raccoons. USFWS (2001) guidelines for "karst preserve" designs are used to develop the karst management areas described in this management plan. Goals for "natural" conditions within the karst management areas indicate that natural vegetation, fauna, and drainage patterns will be left generally undisturbed and are not negated by activities that leave the karst management areas effectively intact. For the recommended sizes and shapes of the 32 karst management areas, see the following section: Specific management actions for karst management areas with listed species and species of concern.

3. Provide protection in perpetuity to the karst management areas. This task refers to administrative actions and procedures needed to ensure the protection and preservation of the karst management areas and their listed species and species of concern in perpetuity within the limits possible through the caves, land, and authority of Camp Bullis and its operational and mission requirements

3.1 Coordinate with the USFWS, TPWD, and other agencies. Since some of the species are federally listed as endangered or threatened, Camp Bullis should request an Endangered Species Act Section 7 consultation with the USFWS if needed for actions and issues not covered in this management plan. The purpose of the consultation will be to coordinate management actions to assure compliance with the Act, with the goal of minimizing impacts and threats to the species for eventual downlisting or delisting. For *Eurycea tridentifera*, which is listed by the State of Texas as threatened, similar coordination would be sought with the TPWD. Even if species of concern are not listed by USFWS or TPWD, Camp Bullis will periodically consult with the Edwards Aquifer Authority and TCEQ for compliance with relevant groundwater protection regulations and methods, which in turn help protect the karst species and drinking water on Camp Bullis.

3.2 Review and update Camp Bullis regulations as needed. Camp Bullis and its command at Fort Sam Houston have established environmental protection measures for activities at Camp Bullis (Fort Sam Houston, 1996). These regulations will be periodically reviewed and updated as appropriate following generation of new information, and as may be required for compliance with the requests of other agencies.

4. Implement conservation measures and manage karst management areas. This task refers to field actions and procedures needed to ensure the protection and preservation of the karst management areas and their listed species and species of concern.

4.1 Apply USFWS fire ant management techniques. USFWS (2001) described their recommended methods for short-term and long-term control and potential eradication of fire ants that threaten karst management areas. Those methods or superior methods will be followed.

4.2 Identify and protect important sources of nutrients into karst management areas. Karst ecosystems are highly dependent on food input from the surface. This includes fresh and decaying vegetation that falls or washes into caves, plants that provide forage to cave crickets and other trogloxene species, roots that extend into karst ecosystems, and animals that may periodically use caves or otherwise add some form of nutrient energy to the karst ecosystem.

Protecting these nutrient sources may require protection of drainage basins, control of exotic species, prevention of soil erosion, and control of certain human activities.

4.3 Determine and implement appropriate means to prevent siltation and/or entry of other contaminants to the karst management areas. Areas of soil erosion will be identified and appropriate actions taken to reduce or prevent its occurrence in karst management areas. Appropriately designed berms, vegetated zones and swales, and sedimentation basins are methods that will inhibit transport of eroded soil and may also limit the movement of contaminants that may enter the areas; silt fences alone are essentially ineffective (Tenney et al., 1995). Management of vegetation and erosion-producing activities, and of activities that introduce contaminants to the karst management areas, will minimize the need for engineered sediment and contaminant detention structures.

4.4 Determine and implement appropriate means to prevent vandalism, dumping of trash, and unauthorized human entry into caves and karst features. Cave gates and fences are often effective at reducing and eliminating trespassing and its associated problems. Whenever they are built, gates and fences will be designed to allow the free passage of air, water, cave life, and organic debris, and thus minimize the structure's impact on the cave's ecosystem. During construction of a gate or fence, disturbance of the soil and vegetation will be minimized to avoid soil erosion, attraction of fire ants, and catching the attention of potential trespassers. Regardless of the degree of care, a gate may adversely impact a cave's ecosystem. Therefore, gates and fences will only be used where discovery and unauthorized visitation is likely. Caves in remote areas of Camp Bullis, or with small entrances hidden by vegetation or rocks, are unlikely to be found or disturbed and will be left ungated. Placing signs at gated or fenced caves may deter some trespassing but their potential benefits will be weighed case-by-case against the potential for attracting unwanted visitation.

4.5 Other actions as needed. The area surrounding Camp Bullis is used for a variety of purposes ranging from high income housing to ranchland. Much of the area is being urbanized. Some of the karst management areas occur along the Camp Bullis boundaries and may be affected by neighboring land use activities or changes. Camp Bullis personnel will stay abreast of those activities and changes, consider their potential impacts on the karst management areas, and take appropriate action. Some actions may occur solely within the boundaries of Camp Bullis, but others may require coordination with adjacent landowners or their representatives.

5. Additional research. This task answers remaining or arising questions about the status and needs of the listed species and species of concern to ensure their protection and preservation with the most accurate information available.

5.1 Conduct additional karst and biospeleological surveys. Considerable karst and biospeleological research has been conducted at Camp Bullis, yet much more remains to be accomplished. By the end of 2003, all of Camp Bullis will have been searched for caves and karst features and all open caves at least preliminarily studied. Many karst features are known that will likely open to caves if excavated, potentially expanding the knowledge base on the distribution of the listed species and species of concern. When the current phase of karst research began at Camp Bullis, only five caves, three possible caves, and five karst features were known in Maneuver Areas

8B, 9, 10, 11A, and 11B (Veni and Elliott, 1994). As of the work of Veni et al. (2002b), 91 caves and 752 karst features are known throughout Camp Bullis. While this discussion has focused on locating additional caves and karst features, it assumes that appropriate biological, hydrogeological, archeological, and paleontological studies, as conducted thus far, will be conducted in the future to fully evaluate those features.

5.2 Continue hydrogeologic studies of karst management areas that are currently incomplete. Hydrogeologic research is needed to accurately delineate the boundaries of karst management areas 2-9, 13, 15, 17, 19, 29, and 31. Their delineation in this report is therefore tentative until the final studies are completed.

5.3 Conduct additional studies on the ecology of the listed species and species of concern. Biological research in several Camp Bullis caves is incomplete (per Table 2, cave numbers: 3, 14, 21, and 31). The list of caves containing listed species and species of concern may expand or shrink as species collected to date are described. Even some long-studied caves continued to yield new, rare species that require additional trips to the caves and biological research. Some caves not discussed in this plan potentially contain listed species or species of concern and require additional study to fully identity those animals. New species found at Camp Bullis are being described, and additional descriptions, especially when supported with DNA sequencing, will continue to be conducted. Descriptions are needed to determine the species' ecological and legal status. Some new species will prove unrelated to those listed as endangered and would be unaffected by the listing. Others may prove subspecies of those listed and would in turn be considered listed. Results of these studies will likely change the number of species of concern, the number of karst management areas, the prioritized importance of each, and possibly the number of listed species.

5.4 Revise the karst species management plan as needed. This management plan will be reviewed every 3-5 years and revised if needed. The frequency of review will be flexible and will depend on the type and level of research conducted at Camp Bullis, and changes in land use at or surrounding the installation. Within the 3-5 year time frame, some species identifications will likely be verified or determined, new caves with listed or rare species may be found, the boundaries and management needs of existing karst management areas may change, and regulatory changes may also occur. While the bulk of the management plan will probably remain intact, it is likely that several important specific changes or updates will need to be made.

6. Education. This task is aimed at raising the level of awareness about the listed species and species of concern to facilitate their protection and preservation.

6.1 Develop educational programs to raise awareness and encourage protection of karst ecosystems by Camp Bullis personnel. Environmental and endangered species awareness programs and publications are provided to Camp Bullis personnel. These programs and publications will be supplemented with information about the listed species, species of concern, and the karst management areas. Activities allowed or prohibited within the karst management areas would generally be consistent with other management actions required, and are not expected to significantly raise the level of complexity for training or management.

6.2 Develop educational programs on karst ecology and hydrogeology to help key Camp Bullis personnel with the management of the karst management areas and the listed species and species of concern. Personnel with the Environmental and ITAM Office at Camp Bullis are well informed about the issues and needs of the listed species and species of concern. However, educational material or an educational program will be provided to new staff to the Environmental and ITAM Office and to other Camp Bullis or Fort Sam Houston personnel who may play key roles affecting species management. Some Camp Bullis staff have attended courses on karst hydrogeology and management. Appropriate continuing education will continue.

6.3 Develop educational information for public relations. As the city of San Antonio grows northward and encroaches upon Camp Bullis, the value of the installation will need to be demonstrated to the community on a more frequent basis. The role of Camp Bullis in protecting and preserving the listed species and species of concern and their habitat will be included in public relations and education efforts. Information generated for this purpose may also prove useful in coordinating protection of karst management areas with neighboring landowners.

7. Monitoring. All karst management areas will be monitored to determine the success or failure of the management actions that are implemented, and to guard against irreversible declines in the species' status. Monitoring and biological studies of the listed species will meet the guidelines of USFWS (2001) and conducted only by researchers possessing a valid Section 10 (a)(1)(A) scientific permit to cover any potential incidents of take. The status of the listed species and species of concern, their areas both above and below ground, and existing or potential threats to either will be monitored on a basis as recommended by the USFWS. Monitoring criteria will be developed that are as quantitative as possible to minimize sampling or interpretational bias, and for comparison between monitoring periods and other observations. The results of the monitoring will be assessed periodically to determine if changes, additions, or deletions to the conservation program are needed. A report on the results of the monitoring and management of the karst management areas will be submitted to the USFWS at the end of each calendar year.

Biological surveys for the listed species and species of concern will occur every one to three years during the month of May. Good conditions for observing fauna representative of the caves usually occur during this period. The surveys will begin at 3-year increment and may be increased if adverse impacts to the populations are observed, suspected, or possible due to changes in land use or surface conditions. Except for very small caves, three or more sampling stations will be established for repeated surveying and delineated on a map of the cave. During each survey, all species and organic matter encountered within the cave, regardless of listing status, will be quantified, including vertebrates, invertebrates, troglobites, troglophiles, trogloxenes, accidentals, and whether the species are dead or alive. Species will be identified as specifically as possible. The microhabitat for each specimen of the listed species will be described, including whether found close to water, other species, or organic matter (including type), and the type of substrate the specimen was found on including information on rock/soil type or formation type if possible. Organic material found in the cave (scat, bat/cricket guano, dead animals, plant material, fungus) will also be quantified and identified as specifically as possible. Feeding, movement, reproductive, and other behaviors of the listed species and species of concern that the surveying biologist considers of interest will also be reported. Known species will not be collected. If unknown species are encountered, up to three may be collected for identification. If listed species or other species of note (species of concern, fire ants, raccoons, etc.) are noticed outside of the set sampling location or outside of the sampling time, they will be reported and include details on location and microhabitat for the listed species and species of concern, but do not need to be quantified. Additional monitoring of temperature, humidity, cave crickets, vegetation, mammals, and leaf litter fauna will be coordinated with USFWS as needed.

Any monitoring program will take care not to adversely impact cave fauna. It is both impractical and probably harmful to do intensive regular detailed monitoring of many of the small caves. Larger caves, where only selected areas are monitored, can be safely monitored 2-4 times a year. In the event a major land development is planned in the vicinity of a karst management area, one or more detailed biological surveys of the cave will be conducted, with follow-up monitoring after development is complete. Any cave in a potentially impacted karst management area will be studied immediately after the event. Additional surveys will be conducted if there is evidence of an adverse impact on the karst ecosystem or, especially in the event of a spill of hazardous materials, several surveys to determine if pollution is occurring later. Caves will also be monitored if heavily impacted by flooding.

Specific Management Actions for Karst Management Areas with Listed Species and Species of Concern

Karst terrains are well known to have complex groundwater flow paths that are very sensitive to contamination and disturbance. The following recommendations are based on this premise, data from the studies of Veni and Elliott (1994) and Veni et al. (1995, 1996, 1998a, 1998b, 1999, 2000, 2002a, 2002b), and are taken directly from those studies and updated or revised as needed. They also meet or exceed the current USFWS (2001) protocols for establishing preserves around caves with endangered invertebrate species, including updates discussed by USFWS (2002). The following management actions for karst management areas are given in two sections. The first section describes actions that apply to all karst management areas. The second section describes management actions specific to each karst management area, synopsis descriptions of the caves and their fauna, and information on when the caves were biological surveyed. Multiple recommendations are presented in descending order of importance. The karst management areas are presented per their order in Table 4, by karst fauna region and subregion. Table 7 summarizes the recommended actions, except for those common to all karst management areas. Information in the specific karst management area recommendations related to the type and amount training and the presence of habitat for endangered bird species was provided by Jerry Thompson (Camp Bullis Environmental and ITAM Office, personal communication, 2002).

Karst management areas, in keeping with the purpose of karst preserves as recommended by USFWS (2001), are designed as self-sustaining ecological units where listed species in a cave within the karst management areas would survive in perpetuity under the worst-case assumption that all surrounding land was developed in such a way as to be unsuitable for the species in those areas. Although most Camp Bullis caves have relatively small surface and groundwater drainage basins, the karst management areas are often much larger than those basins in order to protect vegetated areas associated with the caves. The karst management areas are designed per USFWS (2001) guidelines except for their size which meet the more recent USFWS (2002) guidelines of 364,230 m^2 (90 acres). Wherever possible, the areas are defined as 680-m-diameter (364,230 m^2) circles (the most compact configuration of USFWS' recommended size) centered on a cave's footprint and/or surface and groundwater basin. Deviations from this configuration, including smaller areas, are for reasons of property boundaries, roads, buildings, ecology, and/or geology.

The following management actions are written to establish karst management areas for each hydrologically distinct cave as delimited by the surface and groundwater basin for each cave or group of caves in that area. Where the area of the groundwater basin includes the surface water basin, only the former is mentioned. Caves that are located in creekbeds and have large surface water drainage basins have their karst management areas defined primarily by their groundwater drainage basins. Large surface areas flowing into caves can be detrimental to the health of karst ecosystems. Flooding is detrimental to the terrestrial troglobites and introduces large volumes of nutrients and competitive species. The effect on aquatic species in caves is similar but possibly less harmful since inundation by itself won't harm those species. Surface streams can also capture contaminants from large areas and recharge them into caves. However, this effect is mitigated by basin size and configuration, character of the storm event, and the degree of recharge prior to the water reaching the cave, and is poorly understood for the caves on Camp Bullis.

The boundaries of the karst management areas and surface and groundwater drainage basins

are provided separately from this report as a digital ArcGIS 8.2 file. Where karst management area boundaries overlap, they will be considered zones of special importance in land management decisions since they support more than one karst management area. The linking of karst management areas also provides important continuity for surface and subsurface fauna, and maintains high quality of water in streams and that recharge the aquifers. The groundwater and surface water drainage basins delineated for the Camp Bullis caves with listed species are from Veni's (in review) critical habitat report for USFWS (permission for use of that draft information was provided by USFWS, Tannika Engelhard, personal communication, 2002). See that report for detailed descriptions of those basins and the rationale used to establish them. The same methodology is used in this report to establish groundwater and surface water basins for the karst management areas that lack listed species.

Management Actions for all Karst Management Areas

1. Preserve the general ecology and water quality and quantity. Karst management areas will be left "undeveloped" and in their "natural state." This plan recognizes these terms to mean that natural vegetation, fauna, and drainage patterns will generally be left undisturbed and are not negated by activities that leave the karst management areas effectively intact. Activities at Camp Bullis that may result in adverse impacts to water, vegetation, fauna, and soil are described elsewhere in this plan and will be prohibited from the karst management areas. The intent of the plan is compliance with the USFWS (2001) guidelines for designing karst preserves, modified to include the current recommended preserve size (USFWS, 2002). The exact boundaries of the karst management areas will vary according to the conditions of each site but have the following attributes:

a) Minimum size of 364,230 m^2 (90 acres) per USFWS (2002); smaller areas might be negotiable with USFWS on a site by site basis and larger sizes might be warranted for extensive caves.
b) The boundaries will include the caves' estimated groundwater drainage basins, which are essential for maintaining adequate nutrient and water flow to the karst ecosystems.
c) The cave(s) will be located as centrally as possible within the karst management areas, which will maintain as compact a shape as feasible.

Sewage and septic systems, electrical transformers, and related equipment or other activities that may contain, use, store, produce, or dispose of hazardous materials will be prohibited from the karst management areas. Most training near and in karst management areas is dismounted (on foot) training where disturbance of vegetation is probably negligible or nil. While compaction of soils from foot-traffic is possible, except for intensely used areas it has not been observed at Camp Bullis due to dispersed traffic at infrequent intervals over specific locations. Wheeled tactical vehicles (e.g., HMMWVs and trucks), which primarily travel on established roads and trails, also travel off-road with minimal vegetative damage. In general, tracked vehicles (e.g., Bradleys) are confined to established roads and trails but infrequently may travel off-road but once again with minimal vegetative damage. Approximately once per year, a major military exercise occurs on Camp Bullis which may cause vegetative damage. Past exercises have demonstrated that the damage is temporary and any disturbed vegetation recovers. In addition, the exercise is closely monitored by the ITAM and environmental staff. If future roads, facilities, or activities must be sited uphill of the karst management areas, they will be designed to result in no appreciable increase or decrease of runoff into the karst management area. Impermeable berms will be placed to prevent potential low-quality runoff or spilled materials (if applicable to the activity or facility) from entering the karst management areas. New construction in locations that may impact caves or karst features potentially related to the karst management areas and their ecosystems will first be coordinated with the USFWS.

2. Preserve surface area for supportive surface ecology. An important factor USFWS (2002) used in defining the minimum size for karst preserves was to establish a sufficient area to maintain surface plant and animal ecology that are critical to the cave ecosystem, especially cave crickets and their support system. Cave crickets are important to the ecology of caves at Camp Bullis. They are recognized to forage within at least a 50-m radius around the footprint of each cave, and other possible points of entry to the cave. Recent mark and recapture studies at Fort Hood have found crickets up to 95 m from the cave entrance (Steve Taylor, Illinois Natural History Survey, personal communication, 2002). To maintain the crickets requires maintaining the vegetative community on which they depend, plus a buffer to mitigate edge effects at karst management area's boundaries. Wherever possible, interconnected open space between the karst management areas will be maintained to sustain viable populations of mammals and other animals that might provide important supportive, but currently poorly understood roles in maintaining the ecosystem. Such areas would generally require little more than ecological maintenance since, by the nature of the U.S. Army's mission at Camp Bullis, such naturally vegetated areas are an integral part of the installation and the training it conducts.

3. Control or eradicate fire ants. Unless monitoring proves treatment is not needed, fire ants will be controlled or eradicated in all of the karst management areas with the following methods recommended by the USFWS (2001). Only boiling water will be used within a 50-m radius of a cave's footprint. Fire ant mounds will not be disturbed prior to treatment, but as the boiling water is being poured, the mounds will be excavated to ensure that the bottoms of the mounds have been saturated. After treating with boiling water, commercial poisonous chemical fire ant bait (e.g., Logic, Amdro, etc.) will be placed between 50-150 m from a cave entrance (boiling water can also be used in this area, but is not always logistically feasible). Small amounts will be used to prevent the bait from being introduced into the karst ecosystem by cave crickets or other species. However, sufficient quantities will be used to discourage ants missed by the boiling water or new colonies of ants from re-infesting the area; the specific amount needed will depend on mound size and activity. Bait will only be placed near fire ant mounds, not native ant mounds, and set on sheets of paper or foil that are held to the ground by rocks or stakes. The sheets allow for easy removal of unconsumed bait before cave crickets can eat it. In some cases, it is useful to attract the fire ants with non-toxic bait like tuna, cheese, peanut butter, or meat, and replace it with the toxic bait once discovered. Beyond 150 m, chemical bait will be broadcast at a concentration no greater than 168 kg/km^2. Boiling water treatments will be conducted in mid-mornings as the sun is starting to warm the mounds and when most ants (including the queens) will be near the top. Baits will be placed before noon, but after morning dew has dried, and any excess picked up before nightfall. Baits will be placed during clear, dry weather with no forecast of rain for that day. Karst features and caves within karst management areas that are not known to contain listed species or species of concern but have been recorded to contain any species of cave cricket will also be treated for fire ants by use of boiling water within a 50-m radius of the feature; no chemical baits will be used.

Fire ant treatments will be performed at least twice each year, during the spring and fall when fire ants are most active. Every cave with listed or rare species will have the area within 10 m of its entrance checked monthly for fire ant mounds. Any mounds observed within 10 m of a cave entrance during fire ant surveys, routine maintenance, any other management or monitoring activity, or during biological investigations will be reported. Mounds found within 10 m of an entrance to a cave with endangered or rare invertebrates will be treated within 15 days of discovery. The frequency of fire ant control will be increased if during any routine survey the fire ant densities are greater than 80 mounds/8,100 m^2 (50-m-radius). Biannual treatment of fire ants will resume when the density of mounds decreases to less than 80/8,100 m^2.

If more intensive treatment is needed, it will be coordinated with the USFWS; a permit may be needed if some of the species are listed as endangered. Since infestation is light at Camp Bullis and its large area of generally undisturbed soil discourages the occurrence of fire ants, less intensive treatment and/or treatment of smaller areas may be appropriate around some caves and will be coordinated with the USFWS.

4. Cave gates. Certain caves may warrant gating or fencing if they are near the boundaries of Camp Bullis or in locations where they will likely be vandalized and their ecosystems harmed. Gates and fences will only be constructed according to the best designs recommended by the USFWS, and will permit the free flow of air, water, nutrients, and cave-related animals. Any caves harboring bats, or which could reasonably be expected to be recolonized by bats will not be gated unless absolutely necessary. In such a case, the design will be suitable for the passage of bat species inhabiting or most likely to inhabit the cave, with few vertical supports and horizontal angle iron bars about 15 cm apart. Some bat species will not tolerate gates. If experience shows that certain caves are well known and their gates are frequently tampered with, then signs will be posted stating the commander's restrictions on access, the reasons for the karst management area and gate, and both the military and civilian penalties for violating the commander's directive, harming rare or endangered cave species, tampering with the gate, or other pertinent statutes. Signs will not be posted if they would draw attention to caves that are not otherwise known. All cave gates, fences and signs will be regularly inspected, especially following storms if floodwaters course through and may clog the gates or fences with debris.

5. Prohibit use of chemicals at nearby locations. The application of pesticides, herbicides, and other related harmful chemicals will be prohibited within each karst management area unless authorized by a qualified biologist approved by the USFWS. Pesticides for fire ant infestations will be used as described above in item 3 of this section. For karst management areas along the boundaries of Camp Bullis, cooperation from neighboring landowners may be needed. This action is especially important for karst management areas near urban developments where pesticide and herbicide usage is often high.

6. Encourage xeriscapes at nearby locations. New construction within a 150 m radius of each karst management area will be placed in a xeriscape setting to minimize the risk of contamination from fertilizers and pesticides, and primarily to minimize the proliferation of nonnative fauna (especially fire ants) that may prey upon or compete with the karst species.

7. Control new growth juniper in karst management areas. Although there are no specific data on the impact of Ashe juniper growth on karst invertebrates, there is sufficient evidence to demonstrate that dense juniper growth reduces the infiltration of water into the subsurface (Thurow and Taylor, 1995). Young, dense stands of juniper will be removed or thinned in karst management areas. Removal of older juniper trees is not recommended because of excess disturbance to soil and the potential of increasing fire ant activity. In addition to the reduction of water infiltration into caves, juniper growth crowds out grasses and other plant species. Surveys of invertebrates in the soil and under rocks in juniper thickets have demonstrated a major reduction in the variety of species present versus those in other types of vegetation. Berlese samples of leaf litter from cave entrances or that has washed deeper into caves contain a greatly reduced number and diversity of invertebrates when the litter is mostly composed of juniper litter when compared with the litter of other species (unpublished observations). This obviously decreases the available food supply for the true cavernicole fauna.

In the following recommendations for the specific karst management areas, control of Ashe juniper is recommended where stands are especially dense, but all karst management areas will be monitored and thinned of juniper as needed. Juniper removal is recommended with either a heavy mower or by hand within 150 m of the cave. Reddell (personal observations) has found that hand-clearing of the juniper is probably better for the cave ecosystem because mulch from the heavy mower may inhibit or slow the growth of underlying vegetation that may be important cave cricket forage.

Dr. Richard Patrock (The University of Texas at Austin, personal communication, 2002), recommends clearing Ashe juniper in November and December when fire ants are less active and forbs and grasses will likely still sprout to diminish the soil's disturbed character that is attractive to fire ants. Brush piles created by clearing Ashe juniper by hand or mechanized methods will be located at least 150 m from the caves to minimize attracting fire ants into the caves and to prevent development of underlying unvegetated areas that would reduce forage for cave crickets. Following the first storm that follows Ashe juniper removal, the area will be inspected for fire ant mounds as soon as feasible, and by the following morning if possible. If few mounds are present, and none within 50 m of the cave's footprint, treatment for fire ants can wait until the scheduled treatment in the spring. A high density of mounds, per USFWS' (2001) threshold of concern at a density of 99/ha will be treated immediately.

Prescribed burns are often used on Camp Bullis to control Ashe juniper. While burns will decrease forage for cave crickets, the effect is probably short-term and of little long-term effect on cave ecosystems. This hypothesis has not been rigorously tested but seems reasonable since natural fires once regularly occurred in the area and did not lead to the extinction of the listed species or species of concern. A recent intense crown fire at Fort Hood over Tippit Cave, which Reddell has studied for several years, has resulted in no observable harm to the cave's ecosystem to date. The washing of large volumes of ash into a cave by storms might be somewhat harmful so prescribed burns will be conducted when there is little chance for heavy rainfall in the forecast, allowing time for vegetation to regrow and stabilize the soil. Prescribed burns at Camp Bullis over the past 25 years have results in no observed soil erosion.

Since some stands of Ashe juniper support habitat for federally listed endangered bird species, juniper control efforts will only occur in areas outside of the endangered bird habitat. If dense stands of juniper in endangered bird habitat appear to be harming the listed cave species, Camp Bullis will coordinate with USFWS to determine what action, if any, will be taken.

8. Impact Area firing range management. Listed species and species of concern that occur in caves in the Impact Area have survived several decades with the area's firearms training. Monitoring data are not available to conclusively state that no adverse impacts are occurring, but the presence of the species suggests probably little direct harm from the ordnance, range fires, vegetation clearing, and similar training-related activities. However, since fire ants have entered the region, indirect harm may be occurring. The disturbed soil conditions favored by fire ants may be promoted by ordnance striking the ground but especially by the clearing of vegetation to improve target visibility. These effects can be reduced in three ways: fire ant control methods around the caves as discussed above in item 3 of this section, hand clearing vegetation and/or use of the heavy mower that minimizes ground disturbance under the conditions described in item 7 of this section, and more tightly arranged targets to focus impacts in smaller areas and potentially away from the caves. This last action is in development for the firing range in which 40 mm Cave and Strange Little Cave are located (Jerry Thompson, Camp Bullis Environmental and ITAM Office, personal communication, 2002).

**Management Actions for Karst Management Areas –
Cibolo Creek Karst Fauna Region**

Karst Management Area No. 1: Camp Bullis Cave No. 1 and Camp Bullis Cave No. 3

Management area summary. These caves contain the Comal Blind Salamander, *Eurycea tridentifera*, which is on the State of Texas list of threatened species. A small, intermittent stream ends at the narrow pit entrance to Camp Bullis Cave No. 1, which has 64 m of passages ending in a room with thick deposits of washed-in soil. A tight water crawl at the base of the room may connect to Grosser's Sink, an extensive cave that extends under Camp Bullis from two off-post entrances. Biological collections were made in the Camp Bullis Cave No. 1 on 22 October 1996, 21 November 1996, 1 April 1998, 8 April 1998, 26 May 1998, 18 January 2000, and 25 January 2000.

Camp Bullis Cave No. 3 is a series of short pits that drop to a water-filled passage at a depth of 22 m. The cave captures the seasonal flow of a normally dry creek to recharge the Edwards Aquifer. The pool at its base contains *Eurycea tridentifera*. Biological collections were made in the cave in March 1963, and on 29 October 1996, 21 November 1996, 1 April 1998, 8 April 1996, 25 January 2000

1. Boundaries. The drainage basin boundaries for this karst management area are from Veni and Reddell (1999). They encompass the surface drainage area that flows down to Camp Bullis Cave No. 3 within the Camp Bullis boundary lines, and thus also includes Camp Bullis Cave No. 1, Camp Bullis Bat Cave, and Snakeskin Pit. Ideally, the drainage area should be extended off of Camp Bullis to include the upper end of the drainage basin. For practical management purposes based on the limit of Camp Bullis' authority, the property line defines the uphill end of the surface water basin and the karst management area. The groundwater basin for the cave is less well known and almost certainly encompassed by the surface drainage area.

The karst management area boundaries, partly shaped by the property line, form a square that is 600 m on a side, and extends southeast from the margin of the vegetated area next to the perimeter road near the installation's northwest corner. They include the same caves as the surface drainage area, plus Just Now Cave, Washington Cave, and several other karst features.

2. Outside landowners. Veni et al. (1998a) showed evidence that Grosser's Sink probably connects to Camp Bullis Cave No. 1 and Snakeskin Pit. However, the two entrances to Grosser's Sink are on private property, while parts of the cave extend under Camp Bullis. The cave is a known locality of *Eurycea tridentifera*, and except for the property line, it would be naturally included within the karst management area. The cave's owner(s) will be contacted to coordinate management of the karst management area and its species since drainage flows from that property onto Camp Bullis, and actions that may impact the salamander within Grosser's Sink will almost certainly affect the species within Camp Bullis Cave No. 1 and possibly Camp Bullis Cave No. 3. While presently there is no apparent threat to the species, the Grosser's Sink property is in a prime location for purchase and conversion into a housing subdivision. Advanced contact with the owner(s) may be critical to prevent or minimize adverse impacts on the karst management area from such a development through a conservation easement, land purchase, or other form of agreement.

3. Spill plan. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from the nearby perimeter road.

4. Cave gates. The caves within this karst management area are located within an easy walk of the Camp Bullis property line, and they will likely be discovered by trespassers should a housing development be built on the adjacent property. Camp Bullis Cave No. 1 has been gated, but Camp Bullis Bat Cave, Camp Bullis Cave No. 3, and Snakeskin Pit have not. These caves contain vertical entrances that could potentially be dangerous to trespassers unskilled in proper cave exploration technique. Consequently, should the neighboring property experience suburban development, these entrances should be gated or fenced to prevent injury of trespassers, to protect the karst management area and its ecosystem, and to reduce the liability of Camp Bullis. If a gate or fence is built at Camp Bullis Bat Cave, special consideration will be given to allow continued access by bats.

5. Soil erosion. Blading or other clearing of the firebreak perimeter road will be minimized and/or conducted in a fashion and frequency to minimize soil erosion and loss of sediment into the caves of this karst management area.

6. Training and administrative issues. No impacts on military training are anticipated from the management actions for this karst management area. Its boundaries fall completely within known habitat for the endangered Golden-cheeked warbler.

7. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of Camp Bullis Cave No. 1 and No. 3 and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known from Camp Bullis Bad Air Cave, Camp Bullis Bat Cave, Just Now Cave, and Snakeskin Pit (Veni et al., 2002b).

Karst Management Area No. 2: Jabba's Giant Sink

Management area summary. A large excavated sinkhole in the bank of Cibolo Creek leads into this 100 m long cave that runs in a nearly straight line to the southeast and extends 60 m under Comal County. The cave is an important recharge site for the Edwards Aquifer and likely contains the Comal Blind Salamander *Eurycea tridentifera*, which is listed by the State of Texas as a threatened species. Biological collections were made in the cave on 18 November 1996, five days after it was dug open, and on 22 November 1996.

1. Boundaries. The location of Jabba's Giant Sink in Cibolo Creek makes it difficult to define the drainage basin boundaries for this karst management area. The creek's drainage basin is much larger than the small portion under the control of Camp Bullis and the surface water drainage basin for the cave is consequently not shown in the ArcGIS coverage. Flow studies are not available in that section of the creek to determine which flows enter the cave, and what lengths of the creek's reach are needed to dilute different concentrations of contaminants so they would no longer be harmful by the time they reach the cave. Further, the distribution of *Eurycea tridentifera* is less understood than many invertebrate karst species. Consequently, the tentative recommended boundaries of this karst management area follow the estimated groundwater drainage basin for the cave, which extend 100 m from the footprint of the cave in all directions, except to the southeast where it extends 400 m downstream along the cave's axis; areas where those boundaries would extend beneath the full thickness of the alluvial terrace deposits on the south side of Cibolo Creek are also excluded from the groundwater basin. These boundaries will be revised if needed following additional study of the cave, flow in Cibolo Creek, and the distribution of the salamander.

The karst management area boundaries follow the bed and floodplain of Cibolo Creek over the cave and its probable downstream continuation beyond the limit of study for about 900 m south of its entrance. Only about 400 m of the upstream portion of Cibolo Creek is included since contamination of its flow would likely be beyond the ability of Camp Bullis to manage, although dilution from uncontaminated waters contributed at Camp Bullis will assist in mitigating any contaminants' effects. About 400 m of a tributary to Cibolo Creek downstream of the cave are also included. The karst management area covers the cave's entrance and the area directly over the cave and its probable extent since that is where the cave is most vulnerable to surface activities and Camp Bullis has direct control on those activities.

2. Entrance stabilization. The sinkhole entrance to the cave is unstable, and collapses and fills the entrance following floods. It will be stabilized for two purposes:

a) Protect archeological site 41BX1211. This historic rock wall is situated approximately 3 m from the eroding west edge of the sinkhole. The wall is directly associated with the nearby farmstead to the south. Its protection from impacts is prudent since the farmstead has been determined as eligible for listing on the National Register of Historic Places; its prehistoric component was determined as ineligible for listing (Jerry Thompson, Camp Bullis Environmental and ITAM Office, personal communication, 2002).

b) Preserve access to the cave. Veni et al. (1999) reported that, in coordination with the Camp Bullis Environmental and ITAM Office, there will be no further attempts to enter the cave until the entrance is permanently stabilized. Access to the cave is needed to verify the presence of the salamander as *Eurycea tridentifera*, to monitor the ecosystem, and more accurately delineate the boundaries of its groundwater drainage basin and karst management area. The entrance will be stabilized as follows:

- All loose rock and dirt filling the entrance sinkhole must be removed to fully expose the bedrock sinkhole leading into the cave and to uncover other possible openings.
- The unconsolidated terrace alluvium surrounding and adjacent to the sinkhole would have to be cut back and stabilized with gunnite, concrete, limestone blocks, or other similar means in order to minimize future terrace bank erosion; this task would also be required to

stabilize the entrance sinkhole for protection of the historical wall.

- Concrete walls will be built vertically above the pit. Their base must have a water-tight cemented seal to the bedrock. The concrete walls along the creekbed will extend up along the bedrock walls of the sinkhole to where they meet the creek's bedrock floor, then turned horizontally to form a concrete skirt that is at least 3 m wide; field conditions during construction may show that a greater width is required. The skirt will rise about 0.5 m above the creek bed's alluvial floor but extended down to bedrock where it would fill all openings in the bedrock; leaving open holes below the structure may undermine and damage it. Where the concrete walls rise along the alluvial cliff, they will extend to the top of the cliff, unless other engineering means are available or determine that their further collapse into the cave entrance is unlikely.
- Baffles will be placed into the concrete skirt to capture flood debris and divert it away from the cave entrance. Boulders will also be strategically placed a few meters upstream of the cave to divert flood debris. The elevated concrete skirt would divert some sediment from entering and potentially clogging the cave, and, more importantly, it would prevent the first pulse of streamflow from entering. Known as the "first flush," it carries the highest concentration of contaminants in stormwater runoff.
- Since the cave is located near a boundary of Camp Bullis, a gate will be incorporated into the design of the concrete structure, and as part of the net to trap flood debris. The gate will be designed so it does not clog with debris and become damaged.

With relatively little additional work in stabilizing the entrance, the cave could be developed to enhance groundwater recharge if there is high confidence that the creek will maintain high water quality. In that case, the shallow alluvium covering the creekbed near the cave would be dug to bedrock and extended to the main channel in the creekbed to maximize stream capture; concrete lining of the channel would probably be necessary, as would additional baffles. Such action will only be considered following consultation with the TPWD and USFWS to consider the potential impact on the salamander versus the potential benefit to the aquifer. The flooding and in-washing of catfish will likely harm the cave's salamander population. However, this salamander species is widely distributed through the Cibolo Creek watershed and has not been reported to suffer adverse impacts in that area. If significant additional impacts on the salamander do not occur in the region, it may be likely that the salamander population as a whole will not experience a significant adverse impact from the accelerated, but otherwise natural phenomenon of the cave capturing part of the stream's flow. Caves along Cibolo Creek, including Jabba's Giant Sink, are exposed by natural erosion in the floodplain and developed or redeveloped into aquifer recharge sites.

3. Salamander verification. The cave will be examined to verify that the observed salamanders are in fact the threatened *Eurycea tridentifera*.

4. Cave and hydrogeologic delineation. Exploration and study of the downstream section of the cave will continue to better delineate the boundary of the karst management area.

5. Outside landowners. Further study of the cave will likely demonstrate that certain sections of the Cibolo Creek drainage basin outside of Camp Bullis may affect the quality and quantity of water entering the cave. At such a time, the adjacent landowner(s) will be contacted to coordinate management of the karst management area and its species, since drainage flows from those areas onto

Camp Bullis. Contact with the owner(s) prior to suburban development, which is occurring with many properties in the vicinity, may be critical to prevent or minimize adverse impacts on the karst management area.

6. Spill plan. Fuel or hazardous material transport vehicles will not use the road that crosses Cibolo Creek 50 m upstream of the cave's entrance. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from the nearby road.

7. Safety. The cave floods completely and will not be entered if there is a reasonable chance of rain during the time expected to be spent underground.

8. Training and administrative issues. Few or no impacts on military training are anticipated from the management actions for this karst management area. The upstream third of this karst management area falls within known habitat for the endangered Golden-cheeked warbler.

9. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Management Actions for Karst Management Areas –
Upper Glen Rose Biostrome Karst Fauna Region

Karst Management Area No. 3: Cannonball Cave

Management area summary. With a length of 119 m, Cannonball Cave is one of the longest caves on Camp Bullis. It has at least minor hydrologic significance and a rich troglobite fauna including the species of concern *Rhadine* sp. 3. A small amount of excavation will open additional sections of the cave. Biological surveys were made in the cave on 6-7 November 2001, 21 November 2001, and 15 April 2002

1. Boundaries. The study and mapping of Cannonball Cave is not complete. Tentatively, the groundwater drainage basin boundaries for the karst management area will extend 150 m northeast from the cave's entrance along the cave's axis to the probable uppermost reaches of its main drainage passage, about 100 m southwest of the downstream mapped end of the cave, also following the cave's axis, and 50 m northwest and southeast, perpendicularly from the footprint and the axis. The southwest end of that area intersects a major fault that apparently contains locally permeable flow paths as indicated by a tracer test and well data (MWH, 2002). The cave is probably a tributary to that system, extends northwest, but mostly southeast and then turning south to southwest. Tracer testing suggests that it may extend at least 400 m northwest and 1.5 km to the south. The groundwater basin boundaries are more conservatively drawn and will be reviewed and revised if needed following additional study.

The boundaries of the karst management area are delimited to the north by Cowgill Road, the east by Lewis Creek, to the south by the limits of Cannonball Cave's groundwater basin, and to the west by Lewis Valley Road. The karst management area includes Tin Pot, a cave of potential cultural, hydrologic, and biological significance, plus several karst features, some of which may open to caves if excavated. It does not include the northern and western limits of the cave's drainage basin that extend beyond the two paved roads. The karst management area includes Landfill 8 Monitoring Well 9D along its southern margin. Vehicular access to the well for monitoring and research purposes will not be prevented. This area is about one-third the size of that recommended by USFWS (2002) since the cave's entrance and footprint are close to paved roads and extending the karst management area further east or south is unlikely to improve the vegetative community for the cave.

2. Cave and hydrogeologic delineation. Attempts will be made to further explore this cave and excavate karst features in this area. Should more caves or passages be discovered, they would be surveyed, and hydrogeologically, biologically, and paleontologically evaluated. Such work will more accurately define its groundwater drainage basin and role in understanding and researching the groundwater contamination associated with Landfill 8.

3. Biological research. Additional biological studies are needed to more fully evaluate the cave's fauna for troglobitic *Cicurina*, but especially in evaluating nearby caves for additional localities of *Rhadine* sp. 3, which will require excavation of caves and karst features.

4. Control Ashe juniper. Moderate to dense stands of regrowth Ashe juniper occur throughout the karst management area, which are occupied by the endangered Golden-cheeked warbler. Any removal of the juniper will be coordinated in advance with USFWS and, if approved, removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil. Care will be taken to not increase the cave's visibility from Cowgill Road.

5. Safety. Due to dangerously high levels of carbon dioxide, the cave will be visited only in the winter or early spring if possible. Regardless of the season, fresh air may be needed to blow into the cave to facilitate work and safety.

6. Spill plan. The cave will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from Cowgill Road and Lewis Valley Road that could occur within the cave's groundwater drainage basin.

7. Cave gates. The cave is located near the center of Camp Bullis where it is unlikely to be discovered by trespassers. However, it's location within 25 m of Cowgill Road may require its gating if entry by Camp Bullis personnel cannot otherwise be controlled.

8. Training and administrative issues. Few or no impacts on training are anticipated from the management actions for this karst management area since it is seldom used. The karst management area falls entirely within known habitat for the endangered Golden-cheeked warbler.

9. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known from Karst Feature 6A-41 and Tin Pot (Veni et al., 2002a).

Karst Management Area No. 4: Darling's Pumpkin Hole

Management area summary. This cave consists of two short pits that reach a depth of 5.4 m. The cave is probably more extensive than currently known based on the volume of water it captures and the limited but troglobitically advanced fauna which include the species of concern *Rhadine* sp. 1. The cave's only biological survey was conducted on 11 April 2002.

1. Boundaries. The study and exploration of Darling's Pumpkin Hole is not complete. Only the entrance pit is known; the cave's extent and direction below that pit is unknown. Tentatively, the groundwater drainage basin boundaries for the karst management area will extend 150 m radially from the cave's entrance. Those boundaries will be reviewed and revised if needed following additional study. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It overlaps to the northwest with the karst management area for Hector Hole and to the southeast with the karst management area for Meusebach Flats Cave.

2. Cave and hydrogeologic delineation. Attempts will be made to further explore this cave and excavate karst features in this area. Should more caves or passages be discovered, they would be surveyed, and hydrogeologically, biologically, and paleontologically evaluated. Such work will more accurately define its groundwater drainage basin.

3. Biological research. Additional biological studies are needed to more fully evaluate the cave's fauna, but also in evaluating nearby caves for additional localities of *Rhadine* sp. 1, which will require excavation of caves and karst features.

4. Soil erosion. The recent clearing of Ashe juniper may increase soil erosion and result in its deposition in the cave. The effect should be short-term until vegetation stabilizes the soil, but soil deposition in the cave will be monitored and, if it appears significant, soil stabilization efforts will be enacted.

5. Cave gates. Increased military training is anticipated in this karst management area. A gate will be considered for the cave to eliminate the potential hazard of its pit entrance and possibly reduce the volume of trash that might be discarded into it.

6. Training and administrative issues. Moderate impacts on training may occur from the management actions for this karst management area. It is located in Maneuver Area 5C which had about 800 person-days of use in 2001. As a result of brush control in 2001 and 2002, utilization of this area will likely increase in the coming years. About half of the karst management area falls within known habitat for the endangered Golden-cheeked warbler.

7. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known from Karst Feature 5C-33 (Veni et al., 2002b).

Karst Management Area No. 5: Flach's Cave

Management area summary. This cave is an excavated 6-m-deep pit into a seasonally flowing stream passage that extends about 100 m northeast to water and a constriction. It has local hydrogeologic significance as one of the few stream caves known in the upper Glen Rose, and a potentially very rich collection of paleontological material, including some dating to the Pleistocene and some human remains. The species of concern *Rhadine* sp. 1 occurs in the cave. Biological collections were made in the cave on 24 March 1998, before the entrance excavation was completed, and afterward on 2 February 1999. High levels of carbon dioxide in the cave's air prevented an additional collection on 21 April 1999.

1. Boundaries. The study and exploration of Flach's Cave is not complete. Tentatively, the groundwater drainage basin boundaries for the karst management area will extend 100 m southwest from the cave's entrance along the cave's axis, 200 m northeast of the downstream mapped end of the cave, also following the cave's axis, and 50 m northwest and southeast, perpendicularly from the footprint of the cave and the 100 and 200 m long extensions along the cave's axis. These boundaries will be reviewed and revised if needed following additional study of the cave. The cave captures no appreciable surface water via its entrance so a surface water drainage area is not drawn in ArcGIS. However, during a major flood event the nearby creek may flow into the cave. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's groundwater basin, meeting USFWS' (2002) size requirement, preferred shape, and location.

2. Cultural considerations. Veni et al. (1999) found fragments of a human vertebra that may have been washed into the cave. However, since mortuary information is lacking, no final determination and/or assessment regarding this material can be made. Testing of the floor at the base of the entrance pit is recommended to assist in determining the presence or absence of additional human remains. No entry of the cave or excavations will proceed without coordination with the Environmental and ITAM Office at Camp Bullis, or without monitoring by an archeologist. Once coordination and agreement with local Native American tribes are in place, investigations involving nondestructive means, e.g., mapping or biological collecting or monitoring, will proceed without monitoring by an archeologist since these actions will not impact any known significant cultural deposits.

3. Biological research. Additional biological studies are needed to evaluate the cave's fauna, to include the stream fauna, which has not yet been sampled.

4. Cave and hydrogeologic delineation. Exploration and study of the downstream section of the cave will continue pending satisfactory resolution of the cave's cultural considerations. If rubble on the floor of the entrance pit is removed for archeological testing, exploration should then be possible in the upstream (southwest) direction of the cave's stream passage. Study in this area will help define the source of the water that flows through the cave, as well as the sources for both the human and the potentially rich deposit of non-human bones.

5. Paleontological research. This cave is potentially an important paleontological site. Pending satisfactory resolution of the cave's cultural considerations, a paleontologist will examine the cave's sediments and depositional patterns to determine if the bones are in a primary context and if there is mixing of bones with different ages. An attempt would then be made to date some of the bones using AMS radiocarbon techniques. Should excavation be allowed in the cave, it should be considered a high priority for a careful, stratigraphically controlled excavation in the area from which the bones were recovered to determine if further bones are present.

6. Cave gate. The cave is located near and is clearly visible from a jeep trail. It will be considered for gating given its species of concern, cultural resources, important paleontological deposits, the seasonally dangerous levels of high carbon dioxide, and the moderate use of that area for military training. The gate will be constructed by excavating the soil around the entrance to bedrock and attaching the gate to bedrock to include a concrete seal that will prevent undercutting by soil and water. The gate would prevent soils from eroding around its entrance and being deposited in the cave.

7. Safety. Due to dangerously high levels of carbon dioxide, the cave will be visited only in the winter or early spring if possible. Regardless of the season, fresh air may be needed to blow into the cave to facilitate work and safety.

8. Spill plan. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from the nearby jeep trail. If possible, the trail will be rerouted west of the cave away from its entrance and estimated groundwater drainage basin. Metal reflector posts called "Seibert stakes" could be used to mark the area as environmentally sensitive and limit its entry to foot-traffic.

9. Training and administrative issues. Moderate impacts on training may occur from the management actions for this karst management area. It is located in Maneuver Area 5C which had about 800 person-days of use in 2001. As a result of brush control in 2001 and 2002, utilization of this area may increase in the coming years. The karst management area contains no habitat for endangered bird species.

10. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 6: Hector Hole

Management area summary. This cave consists of a small upper level passage with a short pit into a 60-m-long passage. It has at least minor hydrologic significance and a moderately significant troglobite fauna that includes the species of concern *Rhadine* sp. 1. The cave's only biological survey was conducted on 15 April 2002.

1. Boundaries. The study and mapping of Hector Hole is not complete and may also be modified if a cave is discovered in nearby Accident Sink or passages found at the bottom of Darling's Pumpkin Hole. Tentatively, the groundwater drainage basin boundaries for the karst management area will extend 120 m northeast and southwest along the cave's axis and 60 m perpendicularly from the footprint of the cave and the axis. These boundaries will be reviewed and revised if needed following additional study of the cave. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It overlaps to the southeast with the karst management area for Darling's Pumpkin Hole.

2. Cave and hydrogeologic delineation. Attempts will be made to further explore this cave and excavate karst features in this area, especially Accident Sink. Should more caves or passages be discovered, they will be surveyed, and hydrogeologically, biologically, and paleontologically evaluated. Such work will more accurately define Hector Hole's groundwater drainage basin.

3. Biological research. Additional biological studies are needed to more fully evaluate the cave's fauna, but especially in evaluating nearby caves for additional localities of *Rhadine* sp. 1, which will require excavation of caves and karst features.

4. Soil erosion. The recent clearing of Ashe juniper may increase soil erosion and result in its deposition in the cave. The effect should be short-term until vegetation stabilizes the soil, but soil deposition in the cave will be monitored and, if it appears significant, soil stabilization efforts will be enacted.

5. Cave gates. Increased military training is anticipated in this karst management area. A gate will be considered for the cave to eliminate the potential hazard of the pit inside its entrance and possibly reduce the volume of trash that might be discarded into it. Metal reflector posts called "Seibert stakes" could also be used to mark the area as environmentally sensitive and limit its entry to foot-traffic.

6. Training and administrative issues. Moderate impacts on training may occur from the management actions for this karst management area. It is located in Maneuver Area 5C which had about 800 person-days of use in 2001. As a result of brush control in 2001 and 2002, utilization of this area will likely increase in the coming years. About half of the karst management area falls within known habitat for the endangered Golden-cheeked warbler.

7. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the area (Veni et al., 2002b).

Karst Management Area No. 7: Lone Gunman Pit and Stahl Cave

Management area summary. The air in 11.5-m-deep Lone Gunman Pit has occasionally high levels of carbon dioxide. The cave has a diverse fauna for its small size. Biological surveys were made in the cave on 23 October 1997, 10 November 1997, 24 March 1998, 8 September 1998, 21 April 1999, 14 December 2000, and 1 November 2001. Stahl Cave is about 15 m long and extends to a depth of 14.5 m. The entrance was used as a historic period trash dump. The fill was removed in November 1997. Biological surveys were made in the cave on 18 November 1997, 24 March 1998, 8 September 1998, 21 April 1999, 14 December 2000, and 1 November 2001. Both caves contain the species of concern *Rhadine* sp. 1 and Stahl Cave contains *Cicurina* n. sp. 3.

1. Boundaries. The groundwater drainage basin boundaries for this karst management area will be tentatively defined as the zone extending 150 to 300 m west of the eastern boundary of Camp Bullis along Blanco Road to an unnamed creek below the level of known cave development, and north 150 m and south 150 m from the road that heads west to the old Stahl Homestead from Blanco Road (and which also marks the boundaries between Maneuver Areas 5B and 5E). These boundaries include Lone Gunman Pit and Stahl Cave, two additional caves (Bathtub Sink and Haz Mat Pit), and nine karst features, some of which will likely prove to be caves after excavation. While Lone Gunman Pit and Stahl Cave show no apparent connection, the density of surrounding caves and karst features strongly suggests that they are all hydrologically and biologically related.

The karst management area boundary extends 490 m north of the road that leads to the old Stahl Homestead, 320 m south of that road, and from the perimeter boundary 300 to 490 m west to dirt roads that extend north and south from the homestead. The greater northward extent of the karst management area is to encompass a larger number of karst features that are potentially biologically and hydrologically significant, and for closer proximity to the floodplain of Meusebach Creek. The karst management area boundaries will be reviewed and revised if needed following additional study.

2. Biological research. Additional biological studies are needed to evaluate the caves' fauna. A sight record of a possible *Texella* harvestman in Stahl Cave will be verified. This is possibly a distinct species. Lone Gunman Pit will be further evaluated for troglobitic *Cicurina*.

3. Cave and hydrogeologic delineation. Attempts will be made to further explore and excavate the caves and karst features in this area. Should more caves or passages be discovered, they will be surveyed, and hydrogeologically, biologically, and paleontologically evaluated. The hydrogeology of the caves has not been reevaluated since the geologic mapping of the area by Clark (in review).

4. Control Ashe juniper. Dense stands of regrowth Ashe juniper will be removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil. Care will be taken to not increase the cave's visibility from the Blanco Road. Coordination with USFWS is not needed since the area contains no habitat for endangered bird species.

5. Spill plan. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from the fire-break and Maneuver Area boundary road.

6. Cave gates. The caves are located near the Camp Bullis property line and may be discovered by trespassers as suburban housing developments are built nearby. The short pits inside the caves and the seasonal bad air could be potentially dangerous to trespassers unskilled in proper cave exploration technique. Consequently, should there be sufficient suburban development and resulting trespassing, the caves would be gated to prevent injury of trespassers, protect the caves and their ecosystems, and to reduce the liability of Camp Bullis.

7. Safety. Due to potential dangerously high levels of carbon dioxide, the caves will be visited in the winter or early spring if possible. Regardless of the season, fresh air may need to be blown into the cave to facilitate work and safety.

8. Training and administrative issues. Few impacts on training are anticipated from the management actions for this karst management area since it is seldom used. The area contains no habitat for endangered bird species.

9. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of Lone Gunman Pit, Stahl Cave, and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area from Haz Mat Pit (Veni et al., 2002b).

Karst Management Area No. 8: Meusebach Flats Cave

Management area summary. This 10-m-long by 5-m-deep cave contains the species of concern *Rhadine* sp. 1. Its atmosphere contain high levels of carbon dioxide. Biological collections were made in the cave on 14 November 1997, 21 November 1997, and 25 March 1998.

1. Boundaries. The tentative groundwater drainage basin boundary for this karst management area is defined as a 150-m-radius from the footprint of Meusebach Flats Cave. While there has been no further study of the cave since Veni and Reddell (1999) recommended a 50-m radius, recent study of geologically similar caves in the area indicates that the 150-m-radius is more appropriate. The boundary will be reviewed and revised if needed following additional study. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It overlaps to the northwest with the karst management area for Darling's Pumpkin Hole.

2. Biological research. Additional biological studies are needed to evaluate the cave's fauna.

3. Cave and hydrogeologic delineation. An attempt will be made to excavate the end of the cave and determine if additional passages can be reached and evaluated. Should more passages be discovered, they will be surveyed, and hydrogeologically, biologically, and paleontologically examined. The hydrogeology of the cave has not been reevaluated since the geologic mapping of the area by Clark (in review).

4. Safety. Due to dangerously high levels of carbon dioxide that occur seasonally in the cave's lower level, it will be visited in the winter or early spring if possible. Regardless of the season, fresh air may need to be blown into the cave to facilitate work and safety.

5. Cave gates. Increased military training is anticipated in this karst management area. A gate will be considered for the cave to eliminate the potential hazard of untrained personnel encountering high levels of carbon dioxide inside and possibly reduce the volume of trash that might be discarded into it. Metal reflector posts called "Seibert stakes" could also be used to mark the area as environmentally sensitive and limit its entry to foot-traffic.

6. Training and administrative issues. Moderate impacts on training may occur from the management actions for this karst management area. It is located in Maneuver Area 5C which had about 800 person-days of use in 2001. As a result of brush control in 2001 and 2002, utilization of this area will likely increase in the coming years. About half of the karst management area falls within known habitat for endangered bird species.

7. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area from Karst Feature 5C-6 (Veni et al., 2002b).

Karst Management Area No. 9: Stealth Cave

Management area summary. This cave is one of the longest on Camp Bullis with a length of 138 m and depth of 7.7 m. It has a criss-crossing network of passages for an upper level and a 90-m-long lower level stream passage that is about as long as the only perennial surface stream on the installation. The cave is hydrologically significant, biologically significant due to the presence of the blind *Eurycea* salamander species of concern, and culturally significant due to the presence of a Caddoan potsherd and other prehistoric artifacts. It is periodically inundated by the Reservoir #7 Flood Control Dam. Biological collections have been made in the cave on 29 October 1997, 4 December 1997, 1 April 1998, 26 May 1998, 14 December 2000, 20 December 2000, 18 January 2000, and 25 January 2000.

1. Boundaries. While the mapping of Stealth Cave may be complete, its hydrogeologic evaluation is not. The cave's location in the bank of and under Salado Creek, and within the flood limits of the Reservoir #7 Flood Control Dam, makes defining drainage basin boundaries for this karst management area difficult. Much of the creek's 29.5-km^2 drainage basin upstream of the cave is on Camp Stanley, and some of the drainage basin extends further north onto private property. Flow studies have not been conducted to determine what lengths of the creek's reach are needed to dilute different concentrations of contaminants so they would no longer be harmful by the time they reach the cave. Observations within the cave indicate that any flow in the creekbed near the cave would readily flow into the cave's stream along solutionally enlarged fractures and other conduits in the creekbed. Further, the distribution of *Eurycea* sp. is poorly understood. It could be the same species observed in a well on Camp Stanley, and hydrologic evidence reported by Veni et al. (1998b) indicate a significant part of the underground stream exists upstream of Stealth Cave. The presence of 29 known karst features within 400 m of the cave suggests the existence of an extensive conduit flow system below the Salado Creek valley; in addition, potential hydrologically related karst features occur as far as 2 km upstream of the cave and 860 m downstream. One downstream feature appears to be a spring formed by the discharge of water recharged into the karst features on the upstream side of the dam. Consequently, the tentative drainage boundaries of this karst management area include the biostrome area for 2.3 km upstream of the dam and 500 m downstream of the dam, including some non-biostrome downstream areas that seem hydrologically connected to the biostrome.

The karst management area boundaries are delimited as the area between Marne Road and Monterey Road, and about 800 m upstream of the flood control dam to where a dirt road crosses the valley. This area encompasses the high number of karst features near Stealth Cave that have the greatest apparent hydrologic and biological significance to the cave. The area nearly approximates the karst preserve area size recommended by USFWS (2002). The karst management area boundaries will be revised following additional study of the cave, flow in Salado Creek, and the distribution of the salamander.

2. Biological research. The salamander collected from the cave is currently being identified. More salamanders are needed to properly evaluate the taxonomic status of this species. Additional research may be warranted pending the results of the identification. Notably, an attempt will be made to collect and identify salamanders from Well 2 on Camp Stanley. Also, a hand-dug well located in the Salado Creek valley about 2.8 km north of Stealth Cave will be sampled for salamanders. The stream in Stealth Cave will be sampled to determine if other troglobitic aquatic species are present.

3. Cave and hydrogeologic delineation. A hydrogeologic study will be conducted to delineate the drainage area of the stream in Stealth Cave. This would include excavation of karst features, review of any available water well data, review of broader scale water table mapping, tracer testing, hydrograph analyses, and groundwater chemical analyses. The studies will also determine the probable destination and hydrologic conditions of the downstream flowpath. Such information is critical to accurately delineate the karst management area. Should more caves be discovered during this work, they will be surveyed, and hydrogeologically, biologically, and paleontologically evaluated.

4. Spill plan. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials that could flow into Salado Creek from the roads surrounding and crossing the karst management area.

5. Cultural considerations. The recovery of a Caddo rim sherd from Stealth Cave may be important to understanding prehistoric trade networks and suggestive of more intensive cave usage than currently recognized. Recent flooding of the cave due to the flood control dam has deposited sediments that cover the floor and prevent visual examination for additional cultural materials. Further study and excavation of sediments in the cave will be considered. The rim sherd shows no evidence of floodwater transport, and additional pieces and other material may be present. Investigations involving nondestructive methods, e.g., mapping or biological collecting or monitoring, will proceed without monitoring by an archeologist since these actions will not impact any known significant cultural deposits.

6. Safety. The cave floods completely and will not be entered if there is a chance of rain. Dangerously high levels of carbon dioxide can occur seasonally in the cave's stream passage, possibly requiring it be visited in the winter or early spring. Regardless of the season, fresh air may need to be blown into the cave to facilitate work and safety.

7. Cave gates. Despite considerable training within the general area, there is little or no apparent visitation in the cave. However, a gate may be warranted to prevent large pieces of organic flood debris from entering the cave, possibly clogging the passage, and further increasing its unnaturally high nutrient levels. The gate will be sturdy enough withstand the pressure of being several meters underwater, blocked with debris, with water trying to flow into the cave

8. Training and administrative issues. Although Maneuver Area 7 receives considerable use each year, the nature of the training suggests it will suffer little or no impact from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

9. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area from karst features 7-29, 7-31, 7-38, and 7-40 (Veni et al., 2002b).

Management Actions for Karst Management Areas –
Edwards Outlier Karst Fauna Region: Camp Bullis/Dominion Subregion

Karst Management Area No. 10: Vera Cruz Shaft

Management area summary. This cave is an 8-m-deep pit with a 5-m-long side passage. Despite its small size, it is significant for its fauna and unusual geologic occurrence. It is notable as the only known locality for the species of concern *Rhadine* sp. 2. Biological collections were made in the cave on 28 October 1997, 23 March 1998, 9 September 1998, 22 April 1999, and 15 December 2000.

1. Boundaries. The groundwater drainage basin boundary for this karst management area is defined as a 50-m-radius from the footprint of Vera Cruz Shaft. Since the cave is located about 3 m north of the Camp Bullis property line, the karst management area only extends north of the boundary; it is limited to the north and west by the Vera Cruz perimeter road and the boundary with Camp Stanley. To the east the karst management area is delimited by a dirt road located about 400 m east of the cave. Normally the karst management area would not include the perimeter road, but the road along the southern boundary is included in this case since the cave is located in a narrow gap between the fence line and road and has no immediately adjacent naturally vegetated area. While most of the karst management area extends below the elevation of the cave, that area is still critical to preserve its vegetative community. A surface water drainage area is not drawn in ArcGIS because the entrance captures no appreciable recharge.

2. Revegetation. The cave is located in a firebreak along the property line and little vegetation is available in the immediate area for cave cricket forage. This is especially true for cricket nymphs that cannot easily travel to areas with intact vegetation. The slope above the firebreak, where the cave is located, will be revegetated by bringing in soil and an appropriate mix of native plant seed; some terracing will be needed to hold the soil in place. Presently, the cave has a small population of crickets and other invertebrates. Monitoring the cave fauna, at least through periodic counts of the crickets as they exit the cave at dusk, should indicate if the revegetation will be effective in fortifying the cave's ecosystem. Should soil be brought into the area, it will be free of chemicals and care will be exercised to not introduce additional fire ants.

3. Outside landowners. Almost half of the cave's groundwater drainage basin extends under private property south of the Camp Bullis boundary. Attempts will be made to gain a cooperative agreement with the neighboring landowner(s), ensuring use of appropriate land management practices. If such an agreement is not possible and adverse practices may affect the cave, a berm will be placed along the fence line to prevent potentially harmful runoff from entering the cave and karst management area. Seepage in the cave and nearby along the road is probably the result of landscape irrigation or a water line leak on the adjacent property and will be sampled for pesticide, fertilizers, and chemicals indicative of a drinking water or sewage effluent. The property owners will be contacted to either fix the leak, if it exists, or reduce irrigation and any chemical use to levels that do not adversely impact the cave. A conservation easement or other agreement may be appropriate.

4. Spill plan. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials along the Camp Bullis boundary road. While spills in that area will not flow into the cave's entrance, they will enter the cave along fractures and other small openings in the rock.

5. Training and administrative issues. No impacts on training are anticipated from the management actions for this karst management area since the cave is located in a narrow strip between the firebreak road and the property boundary. The karst management area contains no habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Management Actions for Karst Management Areas –
Stone Oak Karst Fauna Region: Camp Bullis Eagles Nest Subregion

Karst Management Area No. 11: Boneyard Pit

Management area summary. The cave is a series of five pits connected by short sections of horizontal passage, and reaches a depth of 48 m. It contains a diverse fauna, including *Rhadine exilis*, which is federally listed as endangered, and the species of concern, *Mixojapyx* sp. The most notable feature is the occurrence of hundreds of bones, especially from the room at the bottom of the cave, some of which are probably of paleontological significance. One pit in the cave has yet to be explored or studied. Biological collections were made in the cave on 5 December 1994, 5 October 1995, and 7 September 1998.

1. Boundaries. The groundwater drainage basin boundary for this karst management area is delimited by a 50-m radius from the footprint of Boneyard Pit and will be revised if needed following additional study of the cave.

The karst management area for the cave includes about a quarter of the 0.21-km^2 natural drainage area of the creek that flows into the cave's entrance. Following major floods, the cave captures overflow from a reservoir behind a dam located 900 m to the north; the spillway channel from the reservoir drains into the creek that flows to the cave. The reservoir has a catchment area of 4.9 km^2. If the reservoir overflows, the cave will be examined soon afterward for potential adverse impacts. Dusty Bruns (Camp Bullis Environmental and ITAM Office, personal communications, 1999) reported that from 1975 to 1999, the reservoir overflowed through the spillway channel only once or twice.

The boundary of the karst management area is defined as a 680-m-diameter circular area, meeting USFWS' (2002) size requirement and preferred shape. The karst management area is set off-center from Boneyard Pit and its groundwater drainage basin. A centered location covers a significant portion of impacted area within the Field Fire Range. However, shifting the karst management area to the southeast edge of a dirt road in the northeast part of the live fire range provides greater coverage of unimpacted and better vegetated areas. While this shift results in Eagles Nest Trail cutting through the southeast edge of the area, it overlaps with two karst management areas to the east and south and adds it to a series of 15 other karst management areas that extend about 1.5 km northeast and 2.9 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Cave and hydrogeologic delineation. The cave is incompletely evaluated and requires enlargement of the pit off the 15.3-m-deep pit and of the pits near the base of the 11-m-high dome for exploration, survey, and hydrogeological and biological study.

3. Paleontological research. This cave may provide an important addition to the vertebrate faunal record of central Texas. The brown clay deposit at the bottom will be examined, stratigraphically sampled for screen-washing, and radiocarbon dated by a qualified paleontologist.

4. Control Ashe juniper. Dense stands of regrowth Ashe juniper located in the karst management area will be removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil. Coordination with USFWS is not needed since the area contains no habitat for endangered bird species.

5. Training and administrative issues. Few or no impacts on training are anticipated from the management actions for this karst management area since it is shifted to avoid the Field Fire range. The karst management area contains no habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 12: Eagles Nest Cave

Management area summary. A small stream channel ends at the cave's sinkhole entrance. The cave is primarily an irregular-shaped room about 30 m long, 14 m wide, and 1-3 m high. The federally listed endangered species *Rhadine exilis* is known from the cave as is the species of concern *Cicurina* n. sp. 1 and possibly *Rhadine* sp. 1. A small group of bats roosted in the cave until its entrance was temporarily sealed at an unknown date. The entrance was reopened in September 1993. The cave was biologically monitored four times a year from the fall of 1995 until the spring of 1998. Biological surveys were made on 9 November 1993, 15 November 1993, 15 March 1994, 23 October 1995, 5 April 1996, 20 October 1997, 9 September 1998, 20 April 1999, 31 October 2000, 14 December 2000, and 1 November 2001. A collection of leaf litter was recovered on 20 April 1999 for Berlese funnel extraction.

1. Boundaries. The drainage basin boundaries of this karst management area are estimated as Veni's (in review) groundwater basin for the cave, which extends 40 m (the end-to-end length of the cave) from the cave's footprint and probable footprint east of its entrance collapse area, plus an additional 40 m to the south to account for the cave's drain. Parts of the surface water drainage basin that capture runoff and potential road spills along Eagles Nest Trail will be diverted away through the use of existing dirt mounds, modified with berms, a culvert, and a storm water diversion channel as proposed below. The berms and drainage structures will be designed to divert water from at least a 100-year probability flood.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. Eagles Nest Trail and the Record Fire Range access road cut through the middle of the karst management area. While roads are generally not incorporated within karst management areas, Eagles Nest Trail will be considered as dividing the area into separate northwest and southeast sections. These sections are effectively enlarged and made viable by overlapping with a series of 15 other karst management areas that extend about 700 m north and 4 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Biological research. Additional biological studies are needed to evaluate the cave's fauna. It is important to obtain additional specimens of *Rhadine* sp. 1 to allow a more adequate interpretation of the species. The cave was the subject of ecological monitoring and would be interesting to monitor again to determine the impact of subsequent floods.

3. Cave and hydrogeologic delineation. Following record flooding in October 1998, some changes occurred in the size and shape of the passage that drains water from the cave. This passage will be reevaluated; an attempt to excavate it in search of additional passages may be warranted. Should more passages be discovered, they will be surveyed, and hydrogeologically, biologically, and paleontologically evaluated.

4. Spill plan. Until the cave is protected from spills of hazardous materials along Eagles Nest Trail, as shown by Veni and Elliott (1994), the karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials along the road.

5. Training and administrative issues. Few or no impacts on training are anticipated from the management actions for this karst management area since the cave is located near a road in Maneuver Area 11A where in 2001 there were only about 400 person-days of training. The karst management area contains no habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area from Hanging Rock Cave (Veni et al., 2002b).

Karst Management Area No. 13: 40mm Cave and Strange Little Cave

Management area summary. 40mm Cave is a 5-m-deep pit into a 7-m-diameter room. Biological collections were made in the cave on 29 November 1993 and 5 October 1995. Located 50 m to the west, Strange Little Cave is a 10-m-long series of crawlways that reaches a depth of 4.1 m. It has a rich fauna for its size. Strong airflow at the explored end of the cave indicates that excavation will reveal a significantly greater volume of cave than that which is currently known. Biological collections were made in Strange Little Cave on 29 November 1993 and 5 October 1995. Both caves contain the beetle *Rhadine exilis*, which is federally listed as endangered

1. Boundaries. The drainage basin boundaries of this karst management area are estimated as Veni's (in review) combined groundwater basin for the caves, which extend as a 30-m-radius from the footprint of both caves and Karst Feature 9-24, plus an additional 25-m-wide area west of Karst Feature 9-24 to include a nearby major fault. These boundaries will be revised if needed following additional study of the caves and karst features. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the caves' groundwater basin, meeting USFWS' (2002) size requirement, preferred shape, and location.

2. Cave and hydrogeologic delineation. Study of 40mm Cave is complete, but airflow from the small hole at the back of Strange Little Cave suggests a significant section of the cave has not yet been entered. The passage will be excavated so the cave can be fully explored and studied, and then more definitive recommendations can be made. Nearby Karst Feature 9-24 also seems likely to open to a cave if excavated.

3. Training and administrative issues. Historical utilization of the karst management area included the firing of mortars using high-explosive ammunition. Mortars have high, arched trajectories designed to hit target areas on the opposite sides of hills and structures. The caves are located in former target areas on the far side of a hill. Once the caves and their listed species were discovered, Camp Bullis adjusted the mortar fire to avoid the caves and their drainage areas. The firing range has been converted to a Multi-purpose Machinegun range. Only the M60 machinegun and smaller weapons are now fired on the new range. The weapons are non-explosive and engage targets directly, striking only smaller targets on the opposite side of the hill from the caves. This change should improve surface conditions at the caves by reducing soil disruption in general and limiting it to areas generally 100-300 m away or greater. Prescribed burns control vegetation and maintain a grassland community. Few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

4. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 14: Hilger Hole

Management area summary. One of the more geologically unusual caves on Camp Bullis, this 13-m-long cave contains *Rhadine exilis*, a beetle on the federal list of endangered species, and the species of concern *Cicurina* n. sp. 1 and *Texella* n. sp. 1. Biological collections were made in the cave on 11 November 1997, 1 April 1998, 7 September 1998, 30 April 1999, 15 December 2000, and 15 April 2002.

1. Boundaries. The drainage basin boundaries of this karst management area are estimated as Veni's (in review) groundwater basin for the cave, which extends as a minimum radius of 30 m from the footprint of the cave. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It overlaps to the northwest with the karst management area for Well Done Cave.

2. Training and administrative issues. The cave is located directly downrange of Meter 1. However, the majority of bullets are intercepted by a berm behind the live fire range. Prescribed burns control vegetation and maintain a grassland community. Few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

3. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 15: Isocow Cave and Root Canal Cave

Management area summary. *Rhadine exilis* beetles, federally listed as endangered species, and the species of concern *Cicurina* n. sp. 1 have been found in both Isocow Cave and Root Canal Cave.

Soil, rocks, and roots were excavated to gain access into Root Canal. It is a complicated set of three interconnected series of pits and passages that extend to a total depth of 38 m and with a summed length of 115 m. Airflow from most of the unexplored passages and pits indicates that substantial portions of the cave remain to be found beyond constrictions that presently block exploration. Its bone-rich clay deposits hold significant Early to Middle Holocene faunal remains. Biological collections were made in the cave on 15 November 1994, 30 November 1994, 26 October 1995, 7 September 1998, 20 April 1999, 28 January 1999, and 26 October 2001

Isocow Cave was discovered by the excavation of a small sinkhole. It is a series of pits that reach a depth of 42 m. It holds clay deposits with Pleistocene bones and preliminary analysis suggests the cave may be an internationally significant paleontological site. Biological collections were made in the cave on 15 December 1993, one week after it was dug open, and on 19 and 20 September 1994, and 2 March 1995.

1. Boundaries. The study of this karst management area is incomplete. It includes Isocow Cave and Root Canal Cave, where research and exploration are extending the latter cave south toward Isocow. Until research in Root Canal Cave is complete, the groundwater basins for the caves are combined as estimated by Veni (in review) and extend 35 m from the footprint of Isocow Cave and 50 m from the mapped footprint of Root Canal Cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. Eagles Nest Trail and the Record Fire Range access road cut through the middle of the karst management area. While roads are generally not incorporated within karst management areas, the roads will be considered as dividing the karst management area into separate northwest and southeast sections. These sections are effectively enlarged by overlapping with a series of 15 other karst management areas that extend about 1 km north and 3.7 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern. However, the positive impact of a karst management area around Root Canal Cave is uncertain given its location near the intersection of the two roads.

2. Cave and hydrogeologic delineation. Hydrogeologic study of Isocow Cave is complete, but substantial airflow and several unexplored passages remain in Root Canal Cave. These passages will be fully explored and studied, and then more definitive recommendations can be made.

3. Spill plan. The karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials along Eagles Nest Trail and the road to the Record Fire range. At a minimum, berms to deflect spills from entering the cave entrances will be constructed until the groundwater drainage basin boundaries can be firmly defined.

4. Paleontological research. Isocow Cave is the most paleontologically significant cave known on Camp Bullis, and further research may reveal a Late Pleistocene fauna that is of international importance. The faunal remains from the cave will likely provide important information on the Pleistocene paleoenvironments and faunas of the area. Therefore, the cave's deposits will be carefully and systematically tested to determine their significance, to include several radiocarbon dates on each deposit. To protect the deposits until they can be studied, additional trips into the cave will be restricted. An archeologist will evaluate Isocow Cave prior to any additional fieldwork. Brown silt and clay deposits in Root Canal Cave also contain a proven significant deposit of Holocene fauna remains that will also be carefully excavated and studied.

5. Control Ashe juniper. Dense stands of regrowth Ashe juniper will be removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil. Some the juniper along Eagles Nest Trail will be left intact so the cave entrance is not obvious from the road. Coordination with USFWS is not needed since the area contains no habitat for endangered bird species.

6. Training and administrative issues. Few or no impacts on training are anticipated from the management actions for this karst management area since the caves are located near a road in locations that are seldom used. The karst management area contains no habitat for endangered bird species.

7. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area from Banzai Mud Dauber Cave, Record Fire 1 Pit, and Karst Feature 9-9 (Veni et al., 2002b).

Karst Management Area No. 16: Pain in the Glass Cave

Management area summary. In 1995, this trash-filled pit was excavated to a depth of 9.7 m to where it opened near the top of a 14-m-deep pit, followed by a 3-m-deep pit. *Rhadine exilis*, a ground beetle on the federal list of endangered species, was found in the cave. Pleistocene bones recovered from the entrance fill were initially assumed to have been collected elsewhere and dumped here with the trash, but red-brown clay deposits have since been found with potentially intact significantly old bones and require further investigation. Biological collections were made as the entrance to the cave was excavated on 9 December 1994 and 9 January 1995 and within the cave as soon as it was opened on 12 September 1995. Additional collections were made on 20 September 1995 and 9 October 1995. Further studies have been prevented by a collapse of rocks and sediment at the entrance.

1. Boundaries. The drainage basin boundaries of this karst management area are estimated as Veni's (in review) groundwater basin for the cave, which extends as a 30-m-radius from the cave's footprint, plus the surface water basin that extends 10 m further to the northwest.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It marks the northeast end of a series of 16 overlapping karst management areas that extend about 4.5 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Entrance stabilization. The entrance pit has been temporarily stabilized with lumber (Veni et al., 2002a) but will be permanently secured to include reestablishing access to the cave for necessary further study of the endangered species within. This work will be performed in conjunction with a detailed paleontological excavation and study of the sediments that appear to include intact, significant, bone-bearing Pleistocene deposits.

3. Biological research. Additional biological studies are needed to evaluate the cave's fauna. The principal need is to obtain adult male *Texella* and troglobitic *Cicurina*.

4. Paleontological research. In addition to the study of bone-bearing deposits in the cave's entrance pit, the red-brown clay deposit that fills the passage off the 14-m-deep pit inside the cave will be examined and possibly excavated for bones. Bones found on the floor of the 14-m-deep pit will continue to be collected and examined as possible Pleistocene or Early Holocene material.

5. Cave gate. The cave's entrance is large and potentially hazardous and will be considered for gating. Since it is approached by relatively few people, education of those individuals on the importance of not entering the cave and not dumping trash into it may preclude the need for a gate. If a gate is found necessary, it will follow stabilization of the entrance since that work would be more efficient with unrestricted access.

6. Training and administrative issues. The cave is located directly downrange of Record Fire 2. Vegetation control methods maintain a grassland community. Few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

7. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 17: Well Done Cave

Management area summary. This small cave consists of two rooms connected by a 3-m-long passage. The first room is 6 m in diameter and up to 1 m high. The second room is 4 m in diameter and up to 2.2 m high. Excavation may open additional passages. A troglobitic harvestman that is probably the species of concern *Texella* n. sp. 1 was discovered on 15 April 2002 during the only biological survey conducted in the cave.

1. Boundaries. Based on initial studies by Veni et al. (2002b), the groundwater drainage basin boundaries of this karst management area are estimated to extend 20 m northwest along the cave's axis from the entrance to where its full known vertical extent is truncated by the hillside, 30 m (about twice the cave's end-to-end length) from the cave's footprint perpendicular to the axis, and 50 m (about triple the cave's end-to-end length) to the southeast from the footprint along the axis. These boundaries may need to be revised following additional study of the cave. The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It overlaps to the southeast with the karst management area for Hilger Hole.

2. Cave and hydrogeologic delineation. The exploration and hydrogeologic study of Well Done Cave is incomplete. Excavation of at least one passage is needed to determine if it opens to additional passages and habitat that is more suitable for the listed species and species of concern.

Following additional research, more definitive recommendations can be made.

3. Biological research. Additional biological studies are needed to evaluate the cave's fauna. Only one preliminary evaluation has been conducted.

4. Cave gate. This cave has a potentially rich troglobite fauna. Portions of the cave that may be accessible by excavation may contain endangered invertebrate species. However, the extensive use of the cave by mammals reduces the quality of habitat for such species. While the mammals are natural in the ecosystem, the unnatural impacts on the endangered invertebrates in the Camp Bullis area and Stone Oak Karst Fauna Region may warrant gating or fencing the cave to prevent access by medium to large mammals and promote habitat conditions favorable to the listed invertebrates. Such actions will be considered in consultation with the U.S. Fish and Wildlife Service. A gate or fence on this cave will have no impact on Camp Bullis operations.

5. Training and administrative issues. The cave is located downrange of Meter 1. However, the majority of bullets are intercepted by a berm behind the live fire range. Prescribed burns control vegetation and maintain a grassland community within 20 m of the cave. Few or no impacts on training are anticipated from the management actions for this karst management area. About one-third of the karst management area contains habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area at Karst Feature 9-85 (Veni et al., 2002b).

Management Actions for Karst Management Areas –
Stone Oak Karst Fauna Region: Camp Bullis Southeast Subregion

Karst Management Area No. 18: B-52 Cave

Management area summary. Strong airflow from a sinkhole led to the excavation and opening of this cave. It is currently the longest (344 m) and deepest (59 m) cave on Camp Bullis, and the most complicated. The passage leading from its 2-m-deep dug entrance heads one way to a 10-m-diameter by 0.8-m-high room, and the other way to a 9-m drop into a room that is also about 10 m in diameter but 7 m high. A crawlway leads west from the larger room to a geologically complex maze of pits, domes, and passages that almost reach the local water table. Several troglobites occur in the cave, including *Rhadine exilis,* which is federally listed as endangered, and *Mixojapyx* sp., which is a species of concern. The cave also contains significant Early to Middle Holocene bone deposits. Biological collections have been made in the cave on 1 December 1994, 6 December 1994, 31 March 1995, 1 December 1997, 10 September 1998, and 29 October 2001.

1. Boundaries. The drainage basin boundaries of this karst management area are estimated as Veni's (in review) groundwater basin for the cave, which extends as a 50 m radius from the cave's footprint, but extended an additional 30 m southwest along the trend of the Bone Lake Passage, and an additional 50 m to the northeast along the trend of As Goo As It Gets. The cave's surface water basin extends 110 m northwest beyond the groundwater basin boundaries.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It is one of 16 overlapping karst management areas that extend about 2.8 km north and 2.7 km west. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Paleontological research. The cave has a significant deposit of vertebrate materials that could yield important paleoclimatic information. A stratigraphically controlled paleontological excavation of the red-brown sediments in the Gordian Room, and elsewhere in the cave as warranted, will be planned.

3. Biological research. The cave's lowest levels flood periodically with rises in the Edwards Aquifer's water table. At such times it may be possible to collect aquatic fauna present in the aquifer at that location, to potentially include *Eurycea* sp. salamanders. Few such sampling locations are known in the Bexar County region. Attempts will be made to sample for aquatic fauna when rainfall and aquifer conditions suggest that the water table has risen into the known sections of the cave. Additionally, the cave will be further examined for troglobitic *Cicurina*.

One tool of the management strategy is the redirection of potentially detrimental activities away from caves with listed species and species of concern. However, the ability of Camp Bullis to redirect the training at the live fire ranges is not feasible within the current Army training doctrine or funding level of the installation. Activities on the live fire ranges that could have a detrimental effect are accidental fires that destroy native vegetation, mowing around the target arrays, bullet strikes around and near cave entrances that damage the vegetation, and the release of potentially harmful concentrations of heavy metals to the environment. Camp Bullis will mitigate these possible impacts by undertaking the following actions on the live fire ranges:

1) Any accidental range fire will be fought vigorously in the area around any cave on a live fire range to limit the impact to the smallest possible area.
2) A buffer area of 10 meters will not be mowed around cave entrances on the live fire ranges.
3) Camp Bullis will continue to monitor water leaving the live fire ranges for contaminants that may prove detrimental to the cave species.
4) Camp Bullis will enter into consultation with the USFWS if there is a major increase in training activity near any cave with listed species.

4. Cave and hydrogeologic delineation. Significant sections of the cave probably remain undiscovered, but the chance of reaching them seems poor. The southernmost dome off the 7-m-diameter room east of Cataract Chamber will be climbed. If activities are planned for the surface that may impact the cave, then excavation of the currently impassably low continuation of As Goo As It Gets, and perhaps of other locations in the cave, would be warranted.

5. Training and administrative issues. The cave is located within Maneuver Area 11B which received a little less than 600 person-days of training in 2001. Its position on a steep hillside and near a proposed City Public Service powerline will likely reduce the use of this immediate area for training so Few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are known in the karst management area at Karst Feature 11B-57 (Veni et al., 2002b).

Karst Management Area No. 19: Backhole

Management area summary. The cave is a 25-m-deep pit into a large room. Located in a creekbed, it captures drainage from an approximate 1.2 km^2 area and is an important recharge site into the Edwards Aquifer. *Rhadine exilis*, a species of beetle federally listed as endangered, occurs here. The first biological survey was conducted during the initial exploration of the cave on 31 January 1994 soon after the cave was dug open. Subsequent collections were made on 7 June 1994, 20 September 1994, 9 September 1998, and 26 October 2001.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends as a 70 m radius from the cave's footprint. This boundary will be revised if needed following additional study of the cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It is one of 16 overlapping karst management areas that extend about 1.4 km north and 3.6 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Cultural considerations. The presence or absence of a possibly human mandible will be confirmed and inspected by an archeologist or osteologist. No entry of the cave or excavations will proceed without coordination with the Environmental and ITAM Office at Camp Bullis or without monitoring by an archeologist.

3. Biological research. Additional biological studies are needed to evaluate the cave's fauna, notably the presence of troglobitic *Cicurina*.

4. Cave and hydrogeologic delineation. The cave is incompletely evaluated. Periodic flooding is opening passages into the breakdown at the bottom of the cave that will be surveyed, and biologically, hydrogeologically, and paleontologically studied.

5. Control Ashe juniper. Dense stands of regrowth Ashe juniper located will be removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil; however, mechanical removal would be difficult due to the rocky surface. Coordination with USFWS is not needed since the area contains no habitat for endangered bird species.

6. Spill plan. This karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from Eagles Nest Trail, including during at least a 100-year probability flood.

7. Training and administrative issues. The cave is located within Maneuver Area 11A which received about 440 person-days of training in 2001. Training in this area is not expected to rise during the next few years and a locked chainlink fence surrounds the cave, preventing human incursion. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

8. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 20: Bunny Hole

Management area summary. Natural fill was excavated from a 3.4-m-deep pit to gain access to the cave, a maze of crawlways totaling 198 m in length but no more than 5 m in depth. The cave contains a rich ecosystem, including *Rhadine exilis* beetles, federally listed as endangered. Numerous pieces of worked chert have been washed into the cave from a surface archaeological site. The cave may also hold potentially significant paleontological remains. Biological collections were made when the cave was opened on 2 February 1995. Additional collections were made in the cave on 31 March 1995, 10 October 1995, 24 October 1995, 9 September 1998, 18 September 1998, and 2 November 2001. The status of the cave's troglobitic species of *Cicurina* spider, relative to the *Cicurina* species federally listed as endangered, has not been determined.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which is twice the cave's length along its axis, or 80 m, 40 m perpendicular to the axis to the south, and 60 m perpendicular to the axis to the north. These boundaries will be revised if needed following additional study of the cave. The boundaries include the cave's surface water basin which extends 43 m further to the southeast

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It is one of 16 overlapping karst management areas that extend about 3.6 km northeast and 1.4 km west. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Biological research. Additional biological studies are needed to evaluate the cave's fauna. The primary need is to obtain adult eyeless *Cicurina*.

3. Cave and hydrogeologic delineation. The sinkhole located 5 m northeast of the cave's entrance does not appear to be accounted for in the known section of the cave. It will be excavated and any passages that are revealed will be surveyed, and biologically, hydrogeologically, and paleontologically studied. The cave is located within the boundaries of a prehistoric archeological site, so excavations will not be conducted without the supervision of an archeologist, even though the site is not currently eligible for inclusion in the National Register of Historic Places.

4. Control Ashe juniper. Moderate to dense stands of regrowth Ashe juniper occur throughout the karst management area, which are occupied by the endangered Golden-cheeked warbler. Any removal of the juniper will be coordinated in advance with USFWS and, if approved, removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil.

5. Training and administrative issues. The cave is located within Maneuver Area 10 and in a section that receives little training due to dense vegetation. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area is located entirely within habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at karst features 10-18, 10-19, 10-21, 10-25, 10-26, and 10-34 (Veni et al., 2002b). Crickets were also observed in 10-5 but further study determined it was not a karst feature so fire ant treatment is not warranted there (Veni et al., 1995).

Karst Management Area No. 21: Cross the Creek Cave

Management area summary. The cave is above a creekbed and extends via three short drops and 4 m of crawlways to a 3-m-diameter room containing *Rhadine exilis* beetles, which are federally listed as endangered. The cave also contains the species of concern *Speodesmus* n. sp. 1. The cave reaches a depth of 7.8 m. Biological collections were made in the cave on 22 March 1995, within a month of when the cave was dug open, and again on 31 March 1995, 6 October 1995, 14 November 1995, 10 September 1998, 21 April 1999, 31 October 2000, and 1 November 2001. The status of the cave's troglobitic species of *Cicurina* spider and *Neoleptoneta* spider, relative to the *Cicurina* and *Neoleptoneta* species federally listed as endangered, has not been determined.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 20 m from the footprint of the cave, plus the cave's surface water drainage basin which extends 6 m further south.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. Wilderness Trail cuts through the northern third of the karst management area. While roads are generally not incorporated within karst management areas, the road will be considered as dividing the area into separate north and south sections. These sections are effectively enlarged by overlapping with a series of 15 other karst management areas that extend about 2.4 km north and 2.8 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Biological research. Additional biological studies are needed to evaluate the cave's fauna. The primary need is to obtain adult eyeless *Cicurina* and *Neoleptoneta*.

3. Control Ashe juniper. Moderate to dense stands of regrowth Ashe juniper occur throughout the karst management area, which are occupied by the endangered Golden-cheeked warbler. Any removal of the juniper will be coordinated in advance with USFWS and, if approved, removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil.

4. Training and administrative issues. The cave is located within Maneuver Area 11B and in a section that receives little training due to dense vegetation and the nearby presence of Wilderness Trail. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area. About half the karst management area is located within habitat for endangered bird species.

5. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at NBC Cave (Veni et al., 2002b). Crickets were also observed in karst features 11B-9, 11B-11, and 11B-26 but further study determined they were not karst features so fire ant treatment is not warranted there (Veni et al., 1996).

Karst Management Area No. 22: Dos Viboras Cave

Management area summary. The cave is a series of three pits reaching a depth of about 13.5 m where excavation is needed to continue. Airflow suggests that much of the cave has yet to be found and evaluated. *Rhadine exilis*, which is federally listed as endangered, has been found in the cave as has the millipede species of concern *Speodesmus* n. sp. 1. Biological collections were made on 14 December 1994, 9 January 1995, 14 September 1995, and 6 October 1995.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 40 m from the footprint of the cave. Unlike the default circular karst management area boundaries of nearby caves, the amount of area recommended by USFWS is redistributed as a 1,000-m-long by 364-m-wide rectangle to provide overlap and continuity between two karst management areas to the southwest with nine karst management areas to the east and northeast. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Cave and hydrogeologic delineation. The cave may be incompletely evaluated. Additional excavation is needed at the bottom. If new passages are opened, they will be surveyed, and biologically, hydrogeologically, and paleontologically studied.

3. Control Ashe juniper. Moderate to dense stands of regrowth Ashe juniper occur throughout the karst management area, which are occupied by the endangered Golden-cheeked warbler. Any removal of the juniper will be coordinated in advance with USFWS and, if approved, removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil.

4. Training and administrative issues. The cave is located within Maneuver Area 11B and in a section that receives little training due to dense vegetation. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area. About two-thirds of the karst management area is located within habitat for endangered bird species.

5. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at karst features 10-17, 10-18, 11B-37, and 11B-57 (Veni et al., 2002b). However, habitat for cave crickets was marginal in 11B-37 and was eliminated following excavation to assess the feature. Crickets were also observed in karst features 10-5 but further study determined is was not karst features (Veni et al., 1996). Fire ant treatment is only warranted in karst features 10-17, 10-18, and 11B-57.

Karst Management Area No. 23: Hold Me Back Cave and MARS Shaft

Management area summary. Hold Me Back Cave is one of the deepest known on Camp Bullis. Its sinkhole entrance leads to a 31.4-m-deep pit, followed by passages and a breakdown area that give the cave a total length of 110 m and depth of 54 m. A room off the pit has unusually long and delicate speleothems. The cave contains small but potentially paleontologically significant bone deposits. A federally listed endangered species, *Rhadine exilis*, has been found in the cave. Biological collections were made in the cave when it was dug open on 1 December 1993, and subsequently on 3 March 1994, 21 September 1994, 23 September 1994, 18 October 1994, 9 and 10 November 2000, and 25 October 2001.

MARS Shaft is located 227 m southwest of Hold Me Back Cave along the edge of a creekbed where it is an important recharge site into the Edwards Aquifer. It is a 28.4-m-deep pit that contains the federally listed endangered species, *Rhadine exilis*. Biological collections were made in the cave on 4 March 1994, 7 June 1994, 20 September 1994, 9 November 2000, and 25 October 2001.

1. Boundaries. Mapping of Hold Me Back Cave and MARS Shaft shows the caves as probably hydrologically distinct above the water table. However, the density of karst features near Hold Me Back Cave, the presence of potential significant geologic and karst features between it and

MARS Shaft, and a very similar troglobite fauna (five of the six troglobites in Hold Me Back Cave account for all five troglobites known in MARS Shaft) suggest these caves may be linked through the interstitial zones and possibly by larger conduits.

The drainage basin boundaries for this karst management area are based on Veni's (in review) groundwater basin for Hold Me Back Cave, which extends along a fault trace for 130 m west and 100 m east of the footprint of the cave, and 50 m north and 60 m south of the cave's footprint, and for MARS Shaft's groundwater drainage basin which was estimated to extend at least 30 m from the cave's footprint.. The karst management area also includes the surface water drainage basin of Hold Me Back Cave, which extends 80 m north beyond the cave's groundwater basin.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the caves' footprints, meeting USFWS' (2002) size requirement, preferred shape, and location. It is one of 16 overlapping karst management areas that extend about 1.8 km north and 3.1 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Spill plan. This karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials from Eagles Nest Trail, including during at least a 100-year probability flood.

3. Paleontological research. Paleontological deposits in Hold Me Back Cave are potentially significant and will be examined further with larger stratigraphically controlled and screen-washed samples. An archeologist will evaluate the cave prior to any additional fieldwork.

4. Training and administrative issues. The caves are located within Maneuver Area 11A and in a section that receives little direct training, but training occurs at a nearby quarry. No impacts from the quarry have been observed at the caves, which are upstream and upgradient of the quarry. As long as the quarry continues to enlarge away from the caves, Few or no impacts on training are anticipated from the management actions for this karst management area. However, this could change if the quarry intersects a currently unknown cave that proves to contain listed species or species of concern. The karst management area contains no habitat for endangered bird species.

5. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 24: MARS Pit

Management area summary. The entrance to the cave was a rubble-filled pit. Excavation revealed a crawlway to a 13-m-deep pit that leads into two rooms. Excavation of a constriction in the second room opened passages and a room that doubled the cave's length to 70 m and increased its depth to 31 m. Enlargement of a constriction at that depth revealed additional pits and passages that extended to a depth of 54 m, almost reaching the local water table, and increased the cave's length to 130 m. The cave is hydrogeologically significant and may have paleontological significance. It contains *Rhadine exilis* beetles, which are federally listed as endangered, and the species of concern *Cicurina* n.

sp. 2 and *Tartarocreagris reyesi*. Before excavation of the cave's entrance was complete, a small collection of invertebrates was made on 29 March 1995. A second collection was made on 9 October 1995, about one month after the cave had been dug open. Additional collections were made on 23 October 1995, 4 April 1996, 10 September 1998, and 29 October 2001. The cave was biologically monitored four times a year between Fall 1995 and Spring 1998.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 50 m from the footprint of the cave and a notable fracture exposed on the surface that roughly parallels fractures that guide the development of the cave. These boundaries will be revised if needed following additional study of the cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area, meeting USFWS' (2002) size requirement and preferred shape. In its typical position, centered over the cave's groundwater basin, about half of the karst management area would be overlapped by the karst management areas for B-52 Cave and Cross the Creek Cave. As a result, the karst management area for MARS Pit is shifted about 100 m northeast to still overlap with those karst management areas but to also overlap with the karst management area for Poor Boy Baculum Cave. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Biological research. The cave's lowest levels flood periodically with rises in the Edwards Aquifer's water table. At such times it may be possible to collect aquatic fauna present in the aquifer at that location, to potentially include *Eurycea* sp. salamanders. Few such sampling locations are known in the Bexar County region. Attempts will be made to sample for aquatic fauna when rainfall and aquifer conditions suggest that the water table has risen into the known sections of the cave.

3. Paleontological research. The cave may contain significant deposits of vertebrate materials that could yield important paleoclimatic information. More detailed paleontological study and test excavation of sediments in the cave is warranted to confirm or refute this potential.

4. Cave and hydrogeologic delineation. Significant sections of the cave probably remain undiscovered, but the chance of reaching them seems poor. If activities are planned for the surface that may impact the cave, then excavation of the currently impassably low crawlway at the southwest end of Level 6 and of the blockage in Level 9 at the bottom of the cave would be warranted.

5. Training and administrative issues. The cave is located within Maneuver Area 11B which received a little less than 600 person-days of training in 2001. Its position near a proposed City Public Service powerline will likely reduce the use of this immediate area for training so Few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at Buzzard Egg Cave and MARS Cave (Veni et al., 2002b). Buzzard Egg Cave also occurs in Karst Management Area No. 27 for Poor Boy Baculum Cave. Crickets were also observed in karst features 11B-11 but further study determined they were not karst features so fire ant treatment is not warranted there (Veni et al., 1996).

Karst Management Area No. 25: Platypus Pit

Management area summary. The cave is a 55-m-long series of short pits connected by short passages leading to a room at a depth of 31 m. It contains *Rhadine exilis*, a beetle that is federally listed as endangered, and several species of concern: *Cicurina* n. sp. 1, *Cicurina* n. sp. 1, *Speodesmus* n. sp. 2, and *Mixojapyx* sp. Biological collections were made in the cave on 30 March 1995, 5 September 1995, 24 October 1995, 4 April 1996, 21 October 1997, 11 March 1998, and 21 November 2001. The cave was biologically monitored four times a year from October 1995 through April 1998.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 20 m from the footprints of the cave's upper level passages and 40 m from the footprint of the room at the bottom of the cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area centered on the cave's footprint, meeting USFWS' (2002) size requirement, preferred shape, and location. It is one of 16 overlapping karst management areas that extend about 3.4 km northeast and 1.2 km west. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Training and administrative issues. The cave is located within Maneuver Area 10 and in a section that receives little training due to dense vegetation. The training that does occur is dismounted. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area.

3. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at karst features 10-26 and 10-45 (Veni et al., 2002b). Crickets were also observed in karst features 10-60 but further study determined they were not karst features so fire ant treatment is not warranted there (Veni et al., 1995).

Karst Management Area No. 26: Poor Boy Baculum Cave

Management area summary. Two consecutive pits, each about 2 m deep, lead down to a 5-m-long crawlway that ends at the top of a 5.4-m-deep pit. A short passage at the base of the pit leads to the top of a 33-m-deep pit — the deepest in Bexar County. The pit has three types of speleothems not previously known in Bexar County. The cave contains *Rhadine exilis*, a beetle that is federally listed as endangered. Biological collections were made in the cave on 10 October 1994, 19 October 1994, 27 October 1994, and 15 December 1994.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 40 m from the cave's footprint along its axis and 20 m from the cave's footprint perpendicular to the axis. These boundaries will be revised if needed following additional study of the cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area, meeting USFWS' (2002) size requirement and preferred shape. It is shifted about 60 m west from its typical position, centered over the cave's groundwater basin, to keep it all on Camp Bullis and exclude an area that would be comprised mostly by Blanco Road, its right-of-way, and the Camp Bullis perimeter road. This shift also establishes a better connection with the karst management areas to the southwest. Wilderness Trail cuts through the middle of the Poor Boy Baculum karst management area. While roads are generally not incorporated within karst management areas, the road will be considered as dividing the area into separate north and south sections. These sections are effectively enlarged by overlapping with other karst management areas that extend about 2.5 km north and 3.8 km southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Cave and hydrogeologic delineation. The cave may be incompletely evaluated. Additional excavation may be needed at the bottom. If new passages are opened, they will be surveyed, and biologically, hydrogeologically, and paleontologically studied. An archeologist will evaluate the cave prior to any additional fieldwork.

3. Biological research. Additional biological research is needed in the cave. It probably contains a more diverse fauna than presently known.

4. Training and administrative issues. The cave's karst management area is located within Maneuver Areas 11A and 11B which had 1,032 combined person-days of training in 2001. The part of the karst management area in MA11A is often used in training by large numbers of tactical vehicles. Consequently, there is potential for moderate impacts on training from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

5. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at Buzzard Egg Cave, which also occurs in Karst Management Area No. 24 for MARS Pit (Veni et al., 2002b).

Karst Management Area No. 27: Root Toupee Cave

Management area summary. The cave drops 1.8 m to a 5-m-long passage that drops down three short pits to a total depth of 13 m. It contains the ground beetle *Rhadine exilis* that is federally listed as endangered. Biological collections were made in the cave on 5 December 1994, 14 September 1998, 5 October 1998, 17 November 1998, 20 April 1999, and 1 November 2000. The cave was dug open in stages and only the collections beginning in November 1998 were able to include its lower reaches where troglobites were found.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 20 m from the footprint of the cave along a 73º-bearing fracture, and 10 m from the footprint of the cave perpendicular to that trend. These boundaries will be revised if needed following additional study of the cave and its nearby karst features.

The boundary of the karst management area is defined as a 680-m-diameter circular area, meeting USFWS' (2002) size requirement and preferred shape. It is shifted about 190 m west from its typical position, centered over the cave's groundwater basin, to keep it all on Camp Bullis and exclude an area that would include Blanco Road, its right-of-way, and the Camp Bullis perimeter road. This shift also establishes a better connection with the karst management areas to the west. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Biological research. Additional biological research is needed in the cave. It probably contains a more diverse fauna than presently known.

3. Cave and hydrogeologic delineation. While Root Toupee Cave is completely evaluated, some nearby karst features may open to caves with excavation and affect the interpretation of Root Toupee Cave, the karst management area, and their hydrologic boundaries. Karst features that will be excavated and evaluated, in descending order of priority are 9-33, 9-30, 9-31, 9-32, 9-36, 9-35, and 9-38.

4. Training and administrative issues. The cave is located within Maneuver Area 11A and in a section that receives little training due to its proximity to Blanco Road. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

5. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Karst Management Area No. 28: Up the Creek Cave

Management area summary. The cave is a roughly 11 by 5 by up to 1.7-m-high room extending into a creekbank. It contains habitat for *Rhadine exilis*, a species of ground beetle on the federal list of endangered species, and for the species of concern *Neoleptoneta* n. sp., *Tartarocreagris reyesi*, and possibly *Cicurina* n. sp. 2. Biological collections were made in the cave on 30 March 1995, 5 September 1995, 6 October 1995, 14 November 1995, 10 September 1998, 22 April 1999, 31 October 2000, and 21 November 2001.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 30 m from the footprint of the cave.

The establishment of the default circular karst management area centered on the cave is prevented by the cave's location in the narrow end of a wedge of undisturbed land between an unpaved section of Wilderness Trail and the Camp Bullis perimeter road. Unlike most parts of the perimeter road, this segment is located about 170 m away from the Camp Bullis fence line. The karst management area is delineated as extending south 230 m to the fence line, west about 130 m to the curving perimeter road and associated dirt roads, north as much as 300 m along the edge of Wilderness Trail, and then east about 800 to merge with the karst management areas for Bunny Hole and Platypus Pit. It is not known if the vegetated area south of the cave, past the perimeter road, will be useful in sustaining the cave's ecosystem. Linking this karst management area to the others creates more sustainable, unfragmented ecological conditions for the listed species and species of concern, and encompasses some caves and karst features that seem likely to prove hydrologically and biologically significant if excavated.

2. Biological research. Further biological studies are needed to evaluate the cave's fauna and confirm or disprove the presence of *Cicurina* n. sp. 2.

3. Training and administrative issues. The cave is located within Maneuver Area 10 and in a section that receives little training due to dense vegetation. Consequently, few or no impacts on training are anticipated from the management actions for this karst management area. The karst management area is located entirely within habitat for endangered bird species.

4. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at Charley's Cute Little Hole (Veni et al., 1995), Two Hit Cave, and karst features 10-73, 10-74, 10-88, and 10-90 (Veni et al., 2002b). However, habitat for cave crickets was marginal in 10-88 and 10-90 and was eliminated following excavation to assess the features (Veni et al., 1995) so fire ant treatment is not warranted there.

Karst Management Area No. 29: Winston's Cave

Management area summary. This cave is one of Camp Bullis' deeper and larger caves. From the entrance a series of short, narrow pits open at a depth of 20 m into the Commander's Conference Room, the second largest chamber in Bexar County. A pit on the opposite side of the chamber leads to the cave's deepest point 42 m below the surface. Drainage into the cave flows down a narrow breakdown passage in the middle of the well-decorated chamber. An adjoining room and pit have yet to be explored. Potentially significant Holocene bone deposits occur in the cave. A rich troglobite fauna is present, including the species of concern *Texella* n. sp. 2. Biological collections were made in the cave immediately after it was dug open on 13 December 1993. Additional biological collections were made on 1 February 1994, 21 September 1994, and 11 November 2000.

1. Boundaries. Per the recommendations of Veni and Reddell (1999), the tentative groundwater drainage basin boundaries for this karst management area are delimited by a 50-m radius from the footprint of Winston's Cave. These boundaries will be revised if needed following additional study of the cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area, meeting USFWS' (2002) size requirement and preferred shape. It is shifted about 90 m west from its typical position, centered over the cave's groundwater basin, to keep it all on Camp Bullis and exclude an area that would mostly be comprised of Blanco Road, its right-of-way, and the Camp Bullis perimeter road. This shift also establishes a better connection with the karst management areas to the south and west. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Cave and hydrogeologic delineation. A new section of the cave was found that might provide access to the water table or to other significant sections of the cave (Joe Ivy, personal communication, 1999). These passages will be surveyed, and biologically, hydrogeologically, and paleontologically studied. Additionally, small karst features on the surface near the cave have recently washed open and will be evaluated, possibly excavated, and appropriately studied if they lead to new caves or into Winston's Cave. An archeologist will evaluate the cave and surrounding karst features prior to any additional fieldwork.

3. Paleontological research. The cave contains significant deposits of vertebrate materials that could yield important paleoclimatic information. More detailed paleontological study and test excavation of sediments in the cave is warranted.

4. Training and administrative issues. The cave is located within Maneuver Area 11A which had about 448 person-days of training in 2001. This area is often used in training by large numbers of tactical vehicles. Consequently, there is potential for moderate impacts on training from the management actions for this karst management area. The karst management area contains no habitat for endangered bird species.

5. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets are not known from any other karst features in the karst management area (Veni et al., 2002b).

Management Actions for Karst Management Areas –
Stone Oak Karst Fauna Region: Camp Bullis Southwest Subregion

Karst Management Area No. 30: Flying Buzzworm Cave

Management area summary. The cave is a 1-m-long passage that leads from its entrance to a 9-m-deep pit. The bottom of the pit has a rich and potentially important early to late Holocene bone deposit. The cave contains the beetle *Rhadine infernalis ewersi*, which is federally listed as endangered. Biological collections were made in the cave on 9 January 1995 and 17 November 1997.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 50 m from the cave's footprint along the axis of a 61° fracture and 25 m from the footprint perpendicular to that trend. These boundaries will be revised if needed following additional study of the cave.

The boundary of the karst management area is defined as a near-circular 680-m-diameter area, meeting USFWS' (2002) size requirement and preferred shape. However, the cave is located near the edge of this karst management area due to its location near the Camp Bullis perimeter road and property boundary. The karst management area boundary is modified in this area from its otherwise circular shape. The karst management area is not centered on the cave, since much of that area would extend off Camp Bullis, but is shifted northwest to establish a better connection with the Headquarters Cave karst management area. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Paleontological research. A systematic paleontological excavation of the brown clay deposits in the cave would probably yield significant information on the paleoenvironmental and faunal history of the area. Trips into the cave will be avoided to prevent damage to the potentially paleontologically significant sediment deposits until paleontological studies are completed or would not be impacted by other research and exploration.

3. Cave and hydrogeologic delineation. Paleontological excavations would likely open new significant parts of the cave, which will then be surveyed, and biologically, hydrogeologically, and paleontologically studied. Such work will only be conducted once paleontological excavations are complete or would not be affected by other work.

4. Cave gate. The cave is located near the Camp Bullis property line and will likely be discovered by trespassers as suburban developments are built nearby. The short pits inside the cave could be dangerous to trespassers unskilled in proper cave exploration technique. Consequently, should there be sufficient suburban development and resulting trespassing, the entrance would be gated to prevent injury of trespassers, protect the cave and its ecosystem, and reduce the liability of Camp Bullis.

5. Training and administrative issues. The cave is located within Maneuver Area 8B which had about 264 person-days of training in 2001. This maneuver area is often used by the Texas National Guard for land navigation and Bradley driver training and encompasses landfills 13A, 13b, and the Air Force ammunition storage bunkers. However, the position of the cave and its karst management area within the maneuver area will likely result in little or no impact on training from the management actions for this karst management area. The karst management area is almost entirely contained within habitat for endangered bird species.

6. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at Valley of Death Cave and karst features 8B-53, 8B-55, and 8B-64 (Veni et al., 2002b). However, habitat for cave crickets was marginal in 8B-53 and 8B-64 and was eliminated following excavation to assess the features. Crickets were also observed in 8B-59 but further study determined it was not a karst feature (Veni et al., 1996). Fire ant treatment is only warranted in Valley of Death Cave and Karst Feature 8B-55.

Karst Management Area No. 31: Headquarters Cave

Management area summary. The cave totals 54 m in length and consists of two rooms separated by a short crawlway. It is the type locality for the beetle *Rhadine infernalis ewersi*, which is federally listed as endangered. It also contains the endangered beetle *Rhadine exilis*, the endangered spider *Cicurina madla*, and the species of concern *Texella* n. sp. 3. The cave was first investigated biologically on 19 April and 10 May 1959 when the now-endangered beetles were collected. Prior to the current series of investigations, additional biological collections were made on 24 April 1966 and on 17 June 1993. The most recent and intensive series of biological collections were made on 29 November 1993, 26 October 1995, 14 November 1995, 24 January 1996, 5 April 1996, 20 October 1997, 12 March 1998, and 8 September 1998. USFWS has also conducted some recent collections in the cave. The cave was biological monitored four times a year between Fall 1995 and Spring 1998.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends 50 m from the footprint of the cave.

The boundary of the karst management area is defined as a 680-m-diameter circular area, meeting USFWS' (2002) size requirement and preferred shape. It is shifted about 75 m south from its typical position, centered over the cave's groundwater basin, to exclude Camp Bullis Road and a vehicle staging area. This shift also establishes a better connection with the karst management areas to the southeast and southwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

2. Biological research. Further biological studies are needed to evaluate the cave's fauna. Additional specimens of *Texella* are needed to provide a more adequate analysis of the species.

3. Training and administrative issues. The cave is located within Maneuver Area 8B which had about 264 person-days of training in 2001. This maneuver area is often used by the Texas National Guard for land navigation and Bradley driver training and encompasses landfills 13A, 13b, and the Air Force ammunition storage bunkers. However, the position of the cave and its karst management area within the maneuver area will likely result in little or no impact on training from the management actions for this karst management area. The karst management area is entirely contained within habitat for endangered bird species.

4. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at Karst Feature 8B-31 (Veni et al., 2002b). Crickets were also observed in 8B-18 but further study determined it was not a karst feature so fire ant treatment is not warranted there (Veni et al., 1996).

Karst Management Area No. 32: Low Priority Cave

Management area summary. The entrance to this cave had been filled but was dug open. It extends downward about 2 m into a 10-m-long passage containing a former bat roost and *Rhadine infernalis,* a federally listed endangered species. A more extensive lower level probably exists, but gaining access to it would require difficult and potentially dangerous excavation. Biological surveys were made in the cave on 14 December 1994, 9 January 1995, 29 March 1995, 4 October 1995, 8 September 1998, 22 April 1999, 1 November 2000, and 2 November 2001.

1. Boundaries. The drainage basin boundary for this karst management area is estimated as Veni's (in review) groundwater basin for the cave, which extends at least 40 m from the footprint of the cave along the cave's axis and for 30 m from the footprint perpendicular to that axis. Veni and Reddell (1999) included Breached Dam Cave in this karst management area but a resurvey of the Camp Bullis property line placed it outside of Camp Bullis within the boundaries of the City of San Antonio's Eisenhower Park.

The boundary of the karst management area is defined as a near-circular 680-m-diameter area, meeting USFWS' (2002) size requirement and preferred shape. However, the cave is located near the edge of this karst management area due to its location near the Camp Bullis property boundary. The karst management area boundary is modified along the boundary from its otherwise circular shape. The perimeter road in this area is not located along the fence line but about 150 m north, northeast, and northwest of the cave. It is not known if the vegetated area north of the perimeter road will be useful in sustaining the cave's ecosystem. The karst management area is not centered on the cave, since much of the area would extend off Camp Bullis, but is shifted northeast to establish a better connection with the Headquarters Cave karst management area. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern.

Low Priority Cave is located near the edge of this karst management area due to its location near the property boundary. This shift from the default central location establishes a better connection with the Headquarters Cave karst management area to the northwest. This linking of karst management areas creates more sustainable, unfragmented ecological conditions for the listed species and species of concern. The karst management area's otherwise circular area is modified along the edge of the property line. The perimeter road in this area is not located along the fence line but about 150 m north, northeast, and northwest of the cave. It is not known if the vegetated area north of the perimeter road will be useful in sustaining the cave's ecosystem.

2. Biological research. Additional biological studies are needed to evaluate the cave's fauna, notable troglobitic *Cicurina*.

3. Control Ashe juniper. Moderate to dense stands of regrowth Ashe juniper occur throughout the karst management area, which are occupied by the endangered Golden-cheeked warbler. Any removal of the juniper will be coordinated in advance with USFWS and, if approved, removed by hand cutting or by the heavy mower, which can cut and mulch the trees without disturbing the soil.

4. Spill plan. This karst management area will be specifically addressed within the installation's emergency spill response plan (Fort Sam Houston, 2000) to contain and remove accidental spills of hazardous materials along the dirt road that runs within 5 m uphill of Low Priority Cave.

5. Training and administrative issues. The cave is located within Maneuver Area 8B which had about 264 person-days of training in 2001. This maneuver area is often used by the Texas National Guard for land navigation and Bradley driver training and encompasses landfills 13A, 13b, and the Air Force ammunition storage bunkers. However, the position of the cave and its karst management area within the maneuver area will likely result in little or no impact on training from the management actions for this karst management area. The karst management area is entirely contained within habitat for endangered bird species.

4. Fire ant treatment. Per the protocols for fire ant treatment described earlier in this plan, treatment is required within 50 m of the cave and any other caves or karst features within the karst management area reported to contain cave crickets. Cave crickets have been reported in the karst management area at karst features 8B-6 and 8B-8 (Veni et al., 2002b). Crickets were also observed in 8B-13 but further study determined it was not a karst feature so fire ant treatment is not warranted there (Veni et al., 1996).

Management Plan Implementation Schedule

The implementation schedule in Table 8 follows the actions outlined for the management plan; specific management actions for the karst management area are addressed under task 4. The schedule is intended as a guide for meeting the plan's objectives. It prioritizes task importance based on the species' needs, which may be direct, such as mitigating a threat, or indirect, such as understanding their needs through research. The priorities for each task are in agreement with USFWS (1994) priorities for recovery of related karst invertebrates in Travis and Williamson counties, Texas. Priorities in the first column of Table 8 are defined per those of the USFWS (1994):

Priority 1: An action that must be taken to prevent extinction or to prevent the species from irreversibly declining in the foreseeable future.

Priority 1• : An action that by itself will not prevent extinction, but which is needed to carry out a Priority 1 task.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to meet the recovery objectives.

Table 8

MANAGEMENT PLAN:
IMPLEMENTATION PRIORITY AND SCHEDULE

Priority number	Task number	Task Description	Implementation and completion period (years)
1	1.	Identify karst management areas needed to meet the management plan criteria.	<1
1	2.	Determine the appropriate size and shape of the karst management areas.	1-3
1	3.	Provide protection in perpetuity to the karst management areas.	ongoing
1	3.1	Coordinate with USFWS, TPWD, and other agencies.	1 initially, then ongoing
1	3.2	Review and update Camp Bullis regulations as needed.	ongoing
1	4.	Implement conservation measures and manage the karst management areas.	ongoing
1	4.1	Apply USFWS fire ant management techniques.	ongoing
1	4.2	Identify and protect important sources of nutrients into karst ecosystems.	1-3
1	4.3	Determine and implement appropriate means to prevent siltation and/or entry of other contaminants to the karst management areas.	1-3 initially, then ongoing
1	4.4	Determine and implement appropriate means to prevent vandalism, dumping of trash, and unauthorized human entry.	ongoing
1•	4.5	Other actions as needed.	ongoing
1•	5.2	Continue hydrogeologic studies of karst management areas that are currently incomplete.	1-3
1•	5.4	Review the karst species management plan.	3-5
2	6.1	Develop educational programs to raise awareness and encourage protection of karst ecosystems by Camp Bullis personnel.	ongoing
2	6.2	Develop educational programs on karst ecology and hydrogeology to help key Camp Bullis personnel with the management of the karst management areas and the listed species and species of concern.	ongoing
2	6.3	Develop educational information for public relations.	ongoing
2	7.	Monitoring	ongoing
3	5.1	Conduct additional karst and biospeleological surveys.	6-10
3	5.3	Conduct additional studies on the ecology of the listed species and species of concern.	8-12

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APPENDIX A
Glossary of Geologic, Karst, Biological, Archeological, and Paleontological Terminology

This glossary is broad in scope to assist nonspecialists reviewing this report, but is not meant to cover all possible terms. Additional karst definitions and geologic terms can be found in the geologic dictionary of Jackson (1997); for biospeleological terms see Culver (1982).

Accidental: A species of animal that normally does not normally occur in caves, but has fallen, wandered, been washed or carried into a cave; not a part of the true cave fauna but may be an important food source for cavernicoles.

Alluvium: Stream-deposited sediments, usually restricted to channels, floodplains, and alluvial fans.

Anastomoses: Small interconnecting conduits that fork and rejoin, usually along bedding planes and joints.

Aquiclude: Rocks or sediments, such as shale or clay, which do not conduct water in significant quantities.

Aquifer: Rocks or sediments, such as cavernous limestone and unconsolidated sand, which store, conduct, and yield water in significant quantities for human use.

Aquitard: Rocks or sediments, such as cemented sandstone or marly limestone, that transmit water significantly more slowly than adjacent aquifers and that yield at low rates.

Artesian: Describes water that would rise above the top of an aquifer if intersected by a well; sometimes flows at the surface through natural openings such as fractures.

Arthropod: An animal of the Phylum Arthropoda; member species are invertebrate, have segmented bodies and jointed legs, and include animals such as insects, crustaceans, and arachnids.

Attitude: The position of a bed of rock with respect to the horizontal plane; typically measured as strike and dip.

Base level: The level to which drainage gradients (surface and subsurface) are adjusted, usually a surface stream, relatively impermeable bedrock, or water table. Sea level is the ultimate base level.

Baseflow: The "normal" discharge of stream when unaffected by surface runoff; derived from groundwater flowing into the stream channel.

Bearing: The azimuthal direction of a linear geologic feature, such as the axis of a fold or the orientation of a fracture; commonly used to denote specific orientations rather than average or general orientations. See trend for comparison.

Beds: See strata.

Bedding plane: A plane that divides two distinct bedrock layers.

Biostrome: A bedded, laterally extensive unit of rock created by the dense growth and later fossilization and lithification of sedentary organisms such as corals and shelled animals.

Borehole: A drilled hole, commonly used for fluid or mineral extraction and injection, or for the monitoring or testing of geologic parameters.

Borrow pit: A small quarry, often in poorly or unconsolidated materials. The term is common on U.S. Geological Survey topographic maps.

Breakdown: Rubble and boulders in a cave resulting from collapse of the cave ceiling.

Breccia: A rock composed of broken, angular fragments of a pre-existing rock that were cemented to form the present rock unit.

Calcite: The predominant mineral in limestone. It is relatively soluble compared to other common minerals, and allows for the dissolution of limestone and the precipitation of calcite speleothems.

Carbonate aquifer: An aquifer developed in predominantly carbonate rock, usually limestone or dolomite.

Cave: A naturally occurring, humanly enterable cavity in the earth, at least 5 m in length and/or depth, in which no dimension of the entrance exceeds the length or depth of the cavity (definition of the Texas Speleological Survey).

Cavernicole: A species of animal that spends at least part of its life cycle in the subterranean environment.

Cephalothorax: The portion of the arachnid body that consists of the fused head and thorax. Insects have the head and thorax separate.

Cerci: Terminal appendages extending from the abdomen; slender and segmented in some groups; forceps-like in the family Iapygidae.

Chamber: See room.

Chelae: The pincer-like claw of a scorpion's or pseudoscorpion's pedipalp.

Chelicerae: The first pair of appendages in front of the mouth of an arachnid; used for grasping and cutting food, and usually claw-like.

Chert: A microcrystalline silica rock, often found as nodules or small lens in limestone and dolomite; it is essentially the same as "flint."

Conduit: A subsurface bedrock channel formed by groundwater solution to transmit groundwater;

often synonymous with cave and passage, but generally refers to channels either too small for human entry, or of explorable size but inaccessible. When used to describe a type of cave, it refers to base level passages that were formed to transmit groundwater from the influent, upgradient end of the aquifer to the effluent, downgradient end.

Conduit flow: Groundwater movement along conduits; usually rapid and turbulent.

Conduit groundwater divide: Where the baseflow of a cave passage splits to flow downstream in two different conduits, and often to two different destinations. Divides can occur both above and below the water table.

Confined: Pertaining to aquifers with groundwater restricted to permeable strata that are situated between impermeable strata.

Cretaceous: A period of the geologic time scale that began 135 million years ago and ended 65 million years ago.

Depth: In relation to the dimensions of a cave or karst feature, it refers to the vertical distance from the elevation of the entrance of the cave or feature to the elevation of its lowest point. See vertical extent for comparison.

Dip: The angle that joints, faults or beds of rock make with the horizontal; colloquially described as the "slope" of the fractures or beds. "Updip" and "downdip" refer to direction or movement relative to that slope.

Diffuse flow: Laminar and very slow groundwater movement within small voids of primary and secondary porosity, excluding conduit and fissure flow; "intergranular" flow.

Discharge: The water exiting an aquifer, usually through springs or wells; also the amount of water flowing in a stream.

Downdip: See dip.

Drainage basin: A watershed; the area from which a stream, spring, or conduit derives its water.

Drainage divide: Location where water diverges into different streams or watersheds. On the surface they usually occur along ridges or elevated areas. In aquifers, they occur along highs in the potentiometric surface between groundwater basins.

Dye trace: The injection of a non-toxic dye into a groundwater system, and its recovery at a downgradient location (usually a spring). This technique is commonly used in karst areas to define groundwater flow paths and travel times.

Ecotone: A transitional zone between ecological communities; usually contains species representation of each community.

Elytra: The hardened front wings in beetles that cover and protect the delicate hind wings when the insect is not flying. Troglobitic beetles cannot fly and the hind wings are absent.

Endemic: Biologically, refers to an organism that only occurs within a particular locale.

Endogean: Pertaining to species living beneath the surface of the earth, although not necessarily in a cave.

Epigean: Pertaining to species living on the surface of the earth.

Epikarst: The highly solutioned zone in karst areas between the land surface and the predominantly unweathered bedrock.

Eye rudiment: The non-functional elements of eyes, usually associated with reduction for life in cave or other endogean habitats.

Fault: Fracture in bedrock along which one side has moved with respect to the other.

Floodplain: The flat surface that is adjacent and slightly higher in elevation to a stream channel, and which floods periodically when the stream overflows its banks.

Footprint: The outline of the cave in plan view; generally refers to defining the horizontal limits of the cave as they relate to the land surface.

Fracture: A break in bedrock that is not distinguished as to the type of break (usually a fault or joint).

Geomorphology: The branch of geology that studies the shape and origin of landforms.

Gouge: The finely ground material that forms along some fault planes by the grinding of one plane against the other.

Grade: The continuous descending profile of a stream; graded streams are stable and at equilibrium, allowing transport of sediments while providing relatively equal erosion and sedimentation. A graded profile generally has a steep slope in its upper reaches and a low slope in its lower reaches.

Head: The difference in water level elevations that creates the pressure for water movement down a gradient.

Headward: In the direction of greater elevation; typically refers to upstream or up a hydraulic gradient.

Historic: One of four temporal/technological periods recognized by archeologists for the central Texas region. It is generally recognized as the beginning of permanent European and/or American contact and settlement up to the mid-20th century.

Holocene: An epoch of the Quaternary Period of the geologic time scale that began about 10,000 years ago and continues to the present.

Holotype: The primary specimen selected as representative of a species by the taxonomist who described the species. The specimen must be deposited in a scientific collection and available for study by qualified scientists.

Honeycomb: An interconnected series of small voids in rock, commonly formed in karst by near-surface (epikarstic) solution, or by phreatic groundwater flow.

Hydrogeology: The study of water movement through the earth, and the geologic factors that affect it.

Hydrograph: A graph illustrating changes in water level or discharge over time.

Hydrology: The study of water and its origin and movement in atmosphere, surface, and subsurface.

Impermeable: Does not allow the significant transmission of fluids.

Instar: A stage in the development of an arthropod, separated from other instars by molting.

Interstitial zone: Conduits of an aquifer and/or cave that are too small for human access; can be located both above and below the water table. Generally used to describe a type of habitat for cavernicole fauna. May include inferred conduits of probable humanly passable dimensions, but which are inaccessible for study.

Joint: Fracture in bedrock exhibiting little or no relative movement of the two sides.

Karren: Furrows, pits, steps, and other solutional features found on exposed limestone outcrops; each feature is general only a few millimeters or centimeters in size, although meter-scale features are not uncommon in certain settings.

Karst: A terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock. Karst areas commonly have few surface streams; most water moves through cavities underground.

Karst fauna area: An area known to support one or more locations of endangered species and is distinct in that it acts as a system that is separated from other karst fauna areas by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna. The purpose of the karst fauna areas in managing the karst species is to establish areas where a catastrophic event (i.e., contamination, quarrying, flooding, etc.) that may kill species or destroy habitat in one area, would not impact species or habitat in other areas

Karst fauna region: Regions defined by the U.S. Fish and Wildlife Service, based on hydrogeological barriers and/or restrictions to the migration of troglobites over evolutionary time, that result in speciation between regions and the creation of similar groups of troglobites within the caves of a particular region.
Karst feature: Generally, a geologic feature formed directly or indirectly by solution, including caves;

often used to describe features that are not large enough to be considered caves, but have some probable relation to subsurface drainage or groundwater movement. These features typically include but are not limited to sinkholes, enlarged fractures, noncavernous springs and seeps, soil pipes, and epikarstic solution cavities.

Karst management area: An area that can preserve the ecosystem of a cave, group of caves, or karst fauna area in perpetuity. These areas meet the requirements of the U.S. Fish and Wildlife Service and may vary slightly in character based on site-specific issues and factors.

Knickpoint: An interruption or break in the slope of a stream. Often associated with changes in lithology, stream discharge, or base level.

Laminar flow: Smooth water movement along relatively straight paths, parallel to the channel walls.

Length: In relation to the dimensions of a cave or karst feature, it refers to the summed true horizontal extent of the cave's passages or the feature's extent.

Lineament: A linear feature, usually observed in aerial photographs, which likely represents a geologic feature such as a fault, joint, or lithologic contact.

Lineation: A linear alignment of features that may indicate control by fractures or other geologic features or processes.

Lithology: The description or physical characteristics of a rock.

lower Glen Rose: Pertaining to the lower member of the Glen Rose Formation.

Lower Glen Rose: Pertaining to the Lower Glen Rose Aquifer.

Marl: Rock composed of a predominant mixture of clay and limestone.

Nodular: Composed of nodules (rounded mineral aggregates).

Normal fault: A fault where strata underlying the fault plane are higher in elevation than the same strata on the other side fault plane.

n. sp.: Taxonomic abbreviation for "new species;" used when a species name has not been published.

Operculum: An opening in the body of an arthropod; usually combined with genital to describe the genital opening.

Paedomorphic: The condition in which an animal may become sexually mature while retaining larval characteristics; sometimes referred to as neotenic.

Paleodrainage: An earlier pattern or condition of surface or groundwater flow.

Paleokarst: A karst area that has been buried by sediments that may also fill the existing caves.

Paleospring: A once-active spring that no longer discharges groundwater, usually because the water table has lowered, or because it has been truncated from its recharge zone.

Palpal: Refers to the pedipalps.

Palpus: See pedipalp.

Passage: An elongate, roofed portion of a cave or karst feature; usually a conduit for groundwater flow.

Pedipalps: The second pair of appendages at the mouth of arachnids, the bases of which provide a jaw-like function; they provide a grasping or pinching function for handling food.

Perched groundwater: Relatively small body of groundwater at a level above the water table; downward flow is impeded within the area, usually by impermeable strata.

Permeable: Allows the significant transmission of fluids.

Permeability: Measure of the ability of rocks or sediments to transmit fluids.

Phreatic: The area below the water table, where all voids are normally filled with water.

Piracy: The natural capture of water from a watershed, stream, aquifer, or cave stream, and its transmission to a different watershed, stream, aquifer, or cave stream.

Piping: See suffosion.

Pit: A vertical cavity extending down into the bedrock; usually a site for recharge, but sometimes associated with collapse.

Pleistocene: An epoch of the Quaternary Period of the geologic time scale that began 2 million years ago and ended about 10,000 years ago. Colloquially called the "Ice Age" due to its episodes of continental glaciation.

Porosity: Measure of the volume of pore space in rocks or sediments as a percentage of the total rock or sediment volume.

Potentiometric surface: A surface representing the level to which underground water confined in pores and conduits would rise if intersected by a borehole. See water table.

Pronotum: In insects, the upper (dorsal) side of the front (anterior) part of the thorax; in *Rhadine* beetles it is elongated like a neck.

Prosoma: The anterior portion of the body; the head in insect and the cephalothorax in arachnids.

Quaternary: A period of the geologic time scale that began 2 million years ago and continues to the present.

Reach: The length of a stream or stream segment; often used to denote similar physical characteristics.

Recent: A term often used by archeologists to describe cultural materials or artifacts dating from the mid-20th century to the present.

Recharge: Natural or artificially induced flow of surface water to an aquifer.

Room: An exceptionally wide portion of a cave, often at the junction of passages; commonly indicative of either the confluence of groundwater flowpaths or of slow, nearly ponded, groundwater flow. Generally synonymous with chamber, except that chamber is usually reserved for relatively large rooms.

Sclerotize: The hardening of the exoskeleton in arthropods.

Scute: The hardened plate on the upper side of some harvestmen's bodies.

Secondary sexual processes: Structures that are restricted to males but are not a part of the genital structures; probably related to species recognition by the female of a conspecific male.

Seep: A spring that discharges a relatively minute amount of groundwater to the surface at a relatively slow rate; typically a "trickle."

Setae: Hairs on invertebrates.

Shaft: See pit.

Sheetwash: Surface water runoff that is not confined to channels but moves across broad, relatively smooth surfaces as thin sheets of water.

Sink: See sinkhole.

Sinkhole: A natural indentation in the earth's surface related to solutional processes, including features formed by concave solution of the bedrock, and/or by collapse or subsidence of bedrock or soil into underlying solutionally formed cavities.

Sinking stream: A stream that losses all or part of its flow into aquifer. See swallet.

Solution: The process of dissolving; dissolution.

sp.: Taxonomic abbreviation for "species;" when following a genus name, it indicates lack of identification to species level. Plural is spp.

Speleothem: A chemically precipitated secondary mineral deposit (e.g., stalactites and stalagmites) in a cave; usually calcite but can form from gypsum and other minerals.

Spermathecae: Sacs used for sperm storage in female invertebrates.

Spring: Discrete point or opening from which groundwater flows to the surface; strictly speaking, a return to the surface of water that had gone underground.

Stage: The water level elevation or height measured in a stream or a well.

Strata: Layers of sedimentary rocks; usually visually distinguishable. Often called beds. The plural of stratum.

Stratigraphic: Pertaining to the characteristics of a unit of rock or sediment.

Stratigraphy: Pertaining to or the study of rock and sediment strata, their composition and sequence of deposition.

Strike: The direction of a horizontal line on a fracture surface or on a bed of rock; perpendicular to dip.

Structure: The study of and pertaining to the attitude and deformation of rock masses. Attitude is commonly measured by strike and dip; deformational features commonly include folds, joints, and faults.

Stump hole: A depression that resembles a sinkhole, but is formed by tree growth and is present after the tree has rotted away; often maintains a sinkhole-like appearance by burrowing mammals.

Taxa: Taxonomic categories, such as species, genus, etc.; taxon is a singular category.

Taxonomy: A system for classifying organisms into related groups and in descending order.

Tergite: The upper plate of an arthropod's abdominal segment.

Terrace: A relatively narrow, flat topographic surface; with reference to streams it usually marks the elevation of a form, higher, water level, and is composed of and formed by the deposition of unconsolidated sand, gravel, and related material.

Tibia: In arthropods, the fourth joint of a leg.

Trend: The azimuthal direction of a linear geologic feature, such as the axis of a fold or the orientation of a fracture; commonly used to denote average or general orientations rather than specific orientations.

Trochanter: In arthropods, the second joint of a leg.

Troglobite: A species of animal that is restricted to the subterranean environment and which typically exhibits morphological adaptations to that environment, such as elongated appendages and loss or reduction of eyes and pigment.

Troglophile: A species of animal that may complete its life cycle in the subterranean environment but which may also be found on the surface.

Trogloxene: A species of animal that inhabits caves but which must return to the surface for food or other necessities.

Type locality: The location or area from which a species is first found and described, or where a section or unit of bedrock is described as the typical example; more commonly called type area or type section when used in a geologic context.

Unconfined: Pertaining to aquifers having no significant impermeable strata between the water table and the land surface.

Updip: See dip.

upper Glen Rose: Pertaining to the upper member of the Glen Rose Formation.

Upper Glen Rose: Pertaining to the Upper Glen Rose Aquifer.

Vadose: Pertaining to the zone above the water table where all cavities are generally air-filled, except during temporary flooding.

Vertical extent: In relation to the dimensions of a cave, refers to the vertical distance from the highest elevation to the lowest elevation of the cave. Generally used when a portion of a cave extends above its entrance. See depth for comparison.

Vug: A small cavity in rock, often lined with crystals, and generally not significantly related to groundwater movement.

Water table: The boundary of the phreatic and vadose zones. A potentiometric surface but the term is used only in unconfined aquifers.

APPENDIX B

Conversions:
International System of Units to English Units

MULTIPLY	BY	TO GET
Length:		
centimeters (cm)	0.3937	inches (in)
meters (m)	3.281	feet (ft)
kilometers (km)	0.621	miles (mi)
Area:		
square meters (m^2)	10.76	square feet (ft^2)
square kilometers (km^2)	0.3861	square miles (mi^2)
square kilometers (km^2)	247.1	acres (ac)
Volume:		
liters (L)	0.264	gallons (gal)
cubic meters (m^3)	264.17	gallons (gal)
cubic meters (m^3)	0.00081	acre-feet (a-f)
Flow:		
liters per second (L/s)	0.0353	cubic feet per second (cfs)
liters per second (L/s)	15.85	gallons per minute (gpm)
cubic meters per second (m^3/s)	35.31	cubic feet per minute (cfm)
cubic meters per second (m^3/s)	0.000158	gallons per minute (gpm)
cubic meters per second (m^3/s)	70.05	acre-feet per day (a-f/d)
Temperature:		
degrees Celsius	multiply by 1.8 then add 32	degrees Fahrenheit

APPENDIX C

Camp Bullis Caves Discussed in this Report and Their Karst Feature Identification Numbers

Alphabetical listing by cave name		Numerical listing by karst feature number	
Cave name	ID Number	ID Number	Cave name
Accident Sink	05C-034	01A-019	Washington Cave
B-52 Cave	11B-052	01A-020	Snakeskin Pit
Backhole	11A-024	01A-022	Just Now Cave
Banzai Mud Dauber Cave	09-012	01A-026	Camp Bullis Cave No. 3
Bathtub Sink	05B-003	01A-027	Camp Bullis Cave No. 1
Boneyard Pit	09-015	01A-028	Camp Bullis Bat Cave
Bullis Hole	01B-001	01B-001	Bullis Hole
Bunny Hole	10-028b	01B-003	Doeppenschmidt Camp Sinkhole
Camp Bullis Bat Cave	01A-028	01B-025	Glinn's Gloat Hole
Camp Bullis Cave No. 1	01A-027	02D-001	Jabba's Giant Sink
Camp Bullis Cave No. 3	01A-026	02D-012	Tall Tales Cave
Cannonball Cave	06A-038	05B-003	Bathtub Sink
Cement Cave	C1-F9	05B-006	Stahl Cave
Constant Sorrow Cave	08A-005	05B-010	Flach's Cave
Cross the Creek Cave	11B-010	05C-003	Hector Hole
Dangerfield Cave	09-037	05C-009	Meusebach Flats Cave
Darling's Pumpkin Hole	05C-032	05C-032	Darling's Pumpkin Hole
Doeppenschmidt Camp Sinkhole	01B-003	05C-034	Accident Sink
Dos Viboras Cave	11B-061	05E-001	Haz Mat Pit
Eagles Nest Cave	11A-020	05E-003	Lone Gunman Pit
Flach's Cave	05B-010	06A-037	Tin Pot
Flacido Cave	07-008	06A-038	Cannonball Cave
Flying Buzzworm Cave	08B-F4	06B-002	Lewis Valley Cave
40 mm Cave	09-022	07-001	Vera Cruz Shaft
Glinn's Gloat Hole	01B-025	07-004	Reservoir 7 Cave
Haz Mat Pit	05E-001	07-005	Stealth Cave
Headquarters Cave	08B-065	07-008	Flacido Cave
Hector Hole	05C-003	07-059	Peace Pipe Cave
Hilger Hole	09-027	08A-005	Constant Sorrow Cave
Hold Me Back Cave	11A-021	08B-007	Low Priority Cave
Hunting Headquarters Sinkhole	C4-001	08B-065	Headquarters Cave
Ides of March Cave	09-091	08B-F4	Flying Buzzworm Cave
Isocow Cave	11A-022	09-001	Pain in the Glass Cave
Jabba's Giant Sink	02D-001	09-012	Banzai Mud Dauber Cave
Just Now Cave	01A-022	09-015	Boneyard Pit
Lewis Valley Cave	06B-002	09-017	Root Canal Cave

APPENDIX C (continued)

Camp Bullis Caves Discussed in this Report and Their Karst Feature Identification Numbers

Alphabetical listing by cave name		Numerical listing by karst feature number	
Cave name	**ID Number**	**ID Number**	**Cave name**
Lone Gunman Pit	05E-003	09-022	40 mm Cave
Low Priority Cave	08B-007	09-023	Strange Little Cave
MARS Pit	11B-116	09-025	Record Fire 1 Pit
MARS Shaft	11A-018	09-027	Hilger Hole
Meusebach Flats Cave	05C-009	09-037	Dangerfield Cave
National Guard Cave	C4-002	09-084	Well Done Cave
Pain in the Glass Cave	09-001	09-091	Ides of March Cave
Peace Pipe Cave	07-059	10-028b	Bunny Hole
Platypus Pit	10-038	10-038	Platypus Pit
Poor Boy Baculum Cave	11B-077	10-087	Up the Creek Cave
Record Fire 1 Pit	09-025	11A-004	Root Toupee Cave
Reservoir 7 Cave	07-004	11A-018	MARS Shaft
Root Canal Cave	09-017	11A-019	Winston's Cave
Root Toupee Cave	11A-004	11A-020	Eagles Nest Cave
SARA Site 4 Cave	11B-114	11A-021	Hold Me Back Cave
Snakeskin Pit	01A-020	11A-022	Isocow Cave
Stahl Cave	05B-006	11A-024	Backhole
Stealth Cave	07-005	11B-010	Cross the Creek Cave
Strange Little Cave	09-023	11B-052	B-52 Cave
Tall Tales Cave	02D-012	11B-061	Dos Viboras Cave
Tin Pot	06A-037	11B-077	Poor Boy Baculum Cave
Up the Creek Cave	10-087	11B-114	SARA Site 4 Cave
Vera Cruz Shaft	07-001	11B-116	MARS Pit
Washington Cave	01A-019	C1-F9	Cement Cave
Well Done Cave	09-084	C4-001	Hunting Headquarters Sinkhole
Winston's Cave	11A-019	C4-002	National Guard Cave

APPENDIX D

Biographies of Research Personnel

The appendix provides brief biographical information on the personnel who wrote or conducted key research for the report. This appendix also meets the U.S. Fish and Wildlife Service guidelines for biographical data on personnel associated with the collection, study, and related research on the endangered karst invertebrates that occur in the study area (USFWS, 2000a, 2000b, 2000c). In meeting with those guidelines, the lead author of this report certifies direct responsibility for this report, that it is true, complete, and accurate, to the best of his knowledge, that the personnel involved were capable of performing their assigned tasks and did so as best as reasonably possible, and that non-supervisory personnel were supervised when needed.

James C. Cokendolpher has a Master's degree in biology and an Associates degree in chemical technology. He is a recognized taxonomist, specializing in arachnids in general, spiders and harvestmen in particular, and also in ants and *Rhadine* beetles. His research on these species began in the late 1970s. He began studying and exploring caves in the mid-1980s and began professional consultation as a biologist in 1993. His research projects include biological surveys, species descriptions, and laboratory studies of invertebrate karst species in New Mexico, Texas, and Great Smoky Mountains National Park. He has published over 30 papers on cave biology, including descriptions and revisions of numerous species. He holds U.S. Fish and Wildlife Service Permit TE035143-0 (expires 31 March 2003) to collect and study federally listed endangered Texas karst invertebrate species. He is currently employed as a Research Associate in the Museum of Texas Tech University, and has worked as a subcontractor to George Veni and Associates since 1995.

James R. Reddell is internationally recognized as the foremost authority on the cave and karst fauna of Texas, Mexico, and northern Central America. Forty-two species and three genera have been named in his honor. He received his Bachelor's degree from The University of Texas in 1962 and conducted graduate studies in biology through 1978. Since 1983 he has primarily been employed as the Curator of Invertebrate Zoology for the Texas Memorial Museum and has worked as a consultant since 1987 when he began working for George Veni and Associates. Although specializing in the study of cave crickets and *Rhadine* beetles, he has described 61 invertebrate species. He has published nearly 90 papers and books on caves and cave biology, compiles the New World Bibliography of Biospeleology, and is a director of the nonprofit Texas Speleological Survey which he co-founded in 1961. The federally listed endangered invertebrate cave species in Texas were so designated primarily based on his studies.

Peter Sprouse began exploring and studying caves in 1970. He is internationally renown for leading the survey and study of numerous caves throughout the U.S. and Mexico, including Sistema Purificación, one of the longest and deepest caves in the world. Since 1991 he has worked as a karst technician and cartographer, subcontracting primarily to George Veni and Associates since 1993 but also working independently. He began collecting karst species for taxonomists to study in 1977 and has discovered several new species, some of which are named in his honor. In 1993 he co-authored a paper on cave biology, and since 1992, has conducted monitoring under contract for the longest-running endangered cave fauna population study in Texas. He is particularly familiar with the listed invertebrate species around Austin and manages more than 30 caves with rare and endangered species in both the Austin and San Antonio areas. His work as a karst technician has included grid-searches for caves, excavation of caves and karst features, cave gate construction, dye tracing, cave surveying, downhole camera evaluations, fire ant control, and collection of invertebrate karst species for study. A two-time medal recipient in national cave cartographic salons, he has been the chief cartographer for George Veni and Associates since 1995 and has expertise in several computer drafting and GIS programs. He is also a nationally recognized and published cave photographer. He holds U.S. Fish and Wildlife Service Permit TE014168-0 (expires 30 April 2005) to collect and study federally listed endangered Texas karst invertebrate species.

Dr. George Veni is an internationally recognized hydrogeologist specializing in caves and karst terrains. He received his Master's degree from Western Kentucky University in 1985 and his Ph.D. from the Pennsylvania State University in 1994. Since 1987 he has owned and served as principal investigator of George Veni and Associates. Much of his work has been in central Texas, but he has also conducted extensive karst research throughout the United States and in several other countries. He serves as a doctoral committee advisor for geological and biological dissertations at The University of Texas and teaches karst geoscience courses as an adjunct professor for Western Kentucky University. He has taken college level biology courses, including Karst Ecology at Western Kentucky University, and has been collecting cave species and assisting in the study of cave ecosystems since 1976. Three cave-dwelling species have been named in his honor. He has published and presented over 80 papers, including four books, on hydrogeology, biology, and environmental management in karst terrains. He holds U.S. Fish and Wildlife Service Permit TE026436-0 (expires 31 August 2005) to collect and study federally listed endangered Texas karst invertebrate species.