Benton County Cave Crayfish

(*Cambarus aculabrum* Hobbs and Brown 1987)

5-Year Review:

Summary and Evaluation

U.S. Fish and Wildlife Service

Southeast Region

Arkansas Ecological Services Field Office

Conway, Arkansas

5-Year Review

Benton County Cave Crayfish (*Cambarus aculabrum* Hobbs and Brown 1987)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Region – Kelly Bibb, Southeast Region, (404) 679-7132

Lead Field Office – Pedro Ardapple, Arkansas Ecological Services Field Office, (501) 548-5152

Cooperating Field Office – None (Arkansas endemic)

Cooperating Regional Office- None (Arkansas endemic)

1.2 Methodology used to complete the review:

We announced initiation of this review and requested information from the public in a published *Federal Register* notice with a 60-day comment period on August 6, 2018 (83 FR 38320). During the public comment period, we did not receive any additional new information about the Benton County Cave Crayfish. Peer-reviewed literature, published and unpublished data provided by species experts, and from U.S. Fish and Wildlife Service (Service) files were used in this report. The lead recovery biologist in the Service's Arkansas Ecological Services Field Office (AES) completed this review. Due to the very limited new information, peer-review of this document was not requested. We did not contract any part of this review with an outside party.

1.3 Background:

1.3.1 Federal Register Notice initiating this review: 83 FR 38320 (August 06, 2018).

1.3.2 Species Status: Stable. The most recent surveys conducted at Bear Hollow Cave (2017) suggest a stable or slightly growing population. Abundance during the latest survey (2017) at Logan Cave is lower than historical counts, but additional surveys are necessary to verify any trend. Continued on-the-ground conservation efforts are showing success in protecting cave recharge zones as evidenced by private landowner partnerships and population status.

1.3.3 Listing History
Original Listing
FR Notice: 58 FR 25742

Date Listed: April 27, 1993
Entity Listed: *Cambarus aculabrum*
Classification: Endangered

1.3.4 Associated rulemakings: None.

1.3.5 Recovery Plan or Outline

Name of Plan: Recovery Plan for the Cave Crayfish (*Cambarus aculabrum*)

Date issued: October 30, 1996

1.3.6 Review History

5-Year Reviews
U.S. Fish and Wildlife Service. 2013. Benton County Cave Crayfish (*Cambarus aculabrum*). Conway, Arkansas 15 pp.

In this review, the population was stable. Primary threats to the species were contamination from storm water runoff, excessive nutrient influx from residential septic systems and agricultural operations, physical alteration from mining operations, hydrologic alteration from land practices, and vandalism. No change in the crayfish's listing classification was appropriate.

Status Reviews
Graening, G.O. and A.V. Brown. 2000. Status survey of aquatic cave fauna in Arkansas. A final report submitted to Arkansas Game and Fish Commission. Arkansas Water Resources Center Publication No. MSC-286, Fayetteville, Arkansas.

Graening, G.O., M.E. Slay, A.V. Brown, J.B. Koppelman. 2006. Status and distribution of the endangered Benton County Cave Crayfish, *Cambarus aculabrum* (Decapoda: Cambaridae). Southwestern Naturalist 51(3):376-439.

1.3.7 Species' Recovery Priority Number at start of 5-year review: 5
The degree of threat to *C. aculabrum* caves and recharge zones is high as urbanization and development continue to increase, lands are converted for agricultural purposes, and caving as a recreational activity increases. Recovery potential is low because of the increase in and limited ability to reduce existing threats from urbanization and difficulty implementing conservation actions. Furthermore, we have a poor understanding of the species biology and its groundwater habitat requirements. Therefore, recovery of this species will remain problematic.

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) Policy? Species is an invertebrate. DPS policy is not applicable.

2.2 Recovery Plan and Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measureable criteria? The recovery plan does not contain delisting criteria. We plan to publish an amendment to the species recovery plan with objective, measurable delisting criteria by the end of fiscal year 2019.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the species biology and its habitat? No. Amended delisting recovery criteria that reflect the best available and most up-to date information on the species biology and its habitat are under review.

2.2.2.2 Are all 5 listing factors that are relevant to the species addressed in the recovery criteria? No. Amended delisting recovery criteria that address the 5 factors are currently under review. Land conversion for urban development and agriculture in the recharge areas continues to occur.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information. The recovery plan (USFWS 1996) designates recovery criteria as "*this species will be considered for reclassification to threatened when the two known populations are self-sustaining and are protected to the degree that they are secure from present or foreseeable threats*".

Biannual surveys suggest that the current population is stable and multiple age classes as indicated by the presence of multiple size classes (<1", 1-2", and >2"), have been readily documented. However, contamination from storm water runoff, excessive nutrient influx from residential septic systems and agricultural operations, physical alteration from mining operations, hydrologic alteration from land practices, and vandalism are still threats to species persistence. These threats are discussed in more detail in section 2.3.2.

The recovery plan (USFWS1996) also outlines 6 recovery objectives with sub-objectives. A summary of each objective follows:

<u>Recovery Objective 1.1</u>: TNC developed the Bella Vista Cave Complex Conservation Plan for the cave and its recharge area (TNC 2001). The conservation plan identifies the following threats:

1. Incompatible chemical use/disposal,
2. Hazardous material spill,

3. Incompatible wastewater treatment (individual and municipal),
4. Incompatible livestock practices,
5. Limestone quarrying,
6. Incompatible recreational and scientific access/vandalism, and
7. Incompatible forestry practices.

The plan outlines strategies to minimize and/or alleviate the aforementioned threats. However, insufficient agreements are in place to provide water quality protection within the recharge area at the level necessary to alleviate groundwater contamination, hydrologic alteration, and trampling associated with vandalism and trespassing. TNC acquired ownership of 2.8 hectares (ha) at Bear Hollow Cave including the cave entrance, thus providing perpetual ownership protection. A cave gate is in place, but vandalism to the cave gate and trespass on the property and in the cave continue to be an ongoing problem. Lead concentrations in the Bear Hollow Cave stream are above the Arkansas acute and chronic concentrations criteria threshold for aquatic life (Graening 2005).

Recovery Objective 1.2: The Service developed a Comprehensive Conservation Plan (CCP) for Logan Cave National Wildlife Refuge (USFWS 2008). This plan covers the 49.8 ha refuge and provides general conservation strategies to aid in *C. aculabrum* recovery. The CCP identifies the following as threats:

1. Destruction of habitat including water quality degradation,
2. Disturbance by cavers or trespassers,
3. Collecting, and
4. Low Reproductive potential of cave fauna.

Long-term water quality analysis indicates seasonally elevated fecal coliform bacteria levels in Logan Cave (USFWS 2013). A large portion (86%) of the Logan Cave groundwater recharge zone is highly vulnerable to surface pollutants. The management plan lacks specific management strategies to address these issues and ensure long-term survival and recovery of the species. Currently, there are no long-term protection/management plans in place to provide water quality protection throughout the entire recharge area.

Recovery Objective 1.3: Cave gates and "no trespassing" signs are in place at Logan and Bear Hollow Caves. However, trespass and vandalism continue to be ongoing problems. Installation of remote surveillance systems have not proven effective in identifying individuals responsible for trespass or cave gate and sign vandalism.

Recovery Objective 1.4: Monitoring cave trespass and involving law enforcement agencies in the protection of *C. aculabrum* is ongoing, but evidence of continued illegal entry was documented during the 2017 & 2019 surveys.

Recovery Objective 1.5: Logan and Bear Hollow Cave recharge areas have been delineated, but long-term protection may be difficult to achieve due to rapidly expanding urbanization in northwest Arkansas. At this point, long-term protection through development and implementation of private landowner conservation plans in the recharge areas is not complete.

Recovery Objective 2.1 – 2.4: Public education with area schools, city councils, developers, non-governmental organizations, and recreational cavers is ongoing.

Recovery Objective 3.1: Bi-annual ocular surveys are ongoing in Bear Hollow and Logan Caves. Based on a limited number of individuals observed and consistent survey results, populations appear stable. Survey methodology incorporates techniques to minimize turbidity and coincides with Ozark cavefish surveys.

Recovery Objective 3.2: Water quality monitoring in each cave system is ongoing. No quantitative baseline habitat assessment is available.

Recovery Objective 4.1 – 4.2: Since listing, continual cave surveys and citizen reports in northwest Arkansas identified two additional populations (Elm Springs and Old Pendergrass Cave). Potential to find undiscovered *C. aculabrum* populations still exist.

Recovery Objective 5: Little information is available for *C. aculabrum* life history and ecology due to imminent harm that such studies pose to a cryptic species with very small populations. Males are reproductively active during October – February (Hobbs and Brown 1987). There are no observations of females carrying eggs and young during surveys. The species is probably an opportunistic feeder foraging on organic materials such as plant and animal material and detritus that enters the cave stream.

Recovery Objective 6: Troglophilic and epigeal species and their effects, beneficial or adverse, on *C. aculabrum* are unknown.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

The recovery plan summarizes *C. aculabrum* description and taxonomy (USFWS 1996). No new information pertaining to the species taxonomy, life history or ecology is available since publication of the Recovery Plan.

C. aculabrum occurs in four cave systems in Benton County, Arkansas. Logan Cave is a dendritic stream channel cave located in the Mississippian cherty-limestone, Boone Formation of the Springfield Plateau (Hobbs and Brown 1987). The stream is approximately 1 kilometer (km) in length with a recharge area of 30.1 km^2 (Figure 1). The entire recharge area minus 49.8 ha, which includes the cave entrances, is privately owned (Aley and Aley 1987). The Service manages the 49.8 ha tract as part of its National Wildlife Refuge system (Logan Cave National Wildlife Refuge).

Graening et al. (2006) summarize the range wide status and distribution of *C. aculabrum*. Logan Cave has been surveyed 31 times from 1979 – 2018, but only 10 of these surveys covered the entire accessible portions of the cave stream. Counts range from 1 – 47 individuals with number of individuals observed ranging from 20 – 47 since 2000 (entire accessible stream habitat was not surveyed in 2004 when 20 individuals were observed). The most recent survey (February 22, 2017) documented, 1 small (<1 inch), 18 medium (1-2 inches), and 7 large (>2 inches; Table 1; Tommy Inebnit pers. comm. November 2018).

Bear Hollow Cave is located approximately 38 km from Logan Cave. The stream system within Bear Hollow Cave is approximately 200 meters (m) in length with a total recharge of 4 km^2 (Figure 2). Bear Hollow Cave has been surveyed 35 times from 1985 – 2018, but only 12 of these surveys covered the entire accessible portions of the cave stream. Counts range from 1 – 17 individuals, with number of individuals observed ranging from 5 – 17 since 2000. The most recent survey (February 23, 2017) recorded the highest numbers to date, documenting 2 small, 10 medium and 5 large individuals (Table 1).

In July 2004, one *C. aculabrum* individual was expelled from its sub-surface habitat during a flood event into a desiccating pool (Farris Sink Point) of Brush Creek (Elm Springs, Washington County, Arkansas). The individual observed from this site was a 3.8 cm long female (Graening et al. 2006). Aley and Slay (2006) delineated the groundwater recharge area and mapped vulnerability for *C. aculabrum* at Elm Springs (Figure 3). Groundwater tracing data demonstrate that the most important habitat for *C. aculabrum* extends from Farris Sink Point down gradient to the cluster of five springs on the Hays' property. Suitable habitat also extends up gradient (generally southward) from the Farris Sink Point for some distance (Aley and Slay 2006). There is no surface (cave) entrance to Elm Springs, thus monitoring is not possible.

In Old Pendergrass Cave (Little Sugar Creek watershed, Benton County, Arkansas), two individuals (a female in December 1999 and a male in July 2004) have been observed in the stream at the rear of the cave. Aley and Slay (2007) delineated the recharge area and mapped vulnerability for *C. aculabrum* in the Old Pendergrass Cave system (Figure 4). Monitoring at Old Pendergrass Cave is periodic due to the necessity of timing surveys to coincide with high flow events.

Graening (2000) and Graening and Brown (2003) hypothesized that three trophic levels are normal for cave stream food webs: 1) a food base of benthic detritus; 2) a guild of invertebrate consumers such as isopods, crayfish, and amphipods; and 3) predators such as fish. Graening (2002, 2005) further supported this hypothesis. Fine benthic organic matter in sediments appears to sustain crustacean detritivores such as *C. aculabrum* (Graening 2005).

Table 1. Total number and total number by size class small (<1 inch), medium (1-2 inches), and large (>2 inches) of *Cambarus aculabrum* detected during biannual surveys at Logan Cave (LC) and Bear Hollow Cave (BHC) (U.S. Fish and Wildlife

Service, Arkansas Natural Heritage Commission, and The Nature Conservancy data).

Year	LC (# Individuals)	LC; small: medium: large	BHC (# Individuals)	BHC small: medium: large
1985	-	-	6	-
1985	-	-	7	-
1987	8	-	9	-
1990	10	-	1	-
1995	-	-	4	-
1999	24	-	-	-
2000	42	-	5	-
2000	-	-	7	-
2002	47	-	-	-
2003	38	-	-	-
2004	-	-	9	-
2006	31	4:23:4	6	-
2009	43	5:29:9	-	-
2012	41	3:26:12	13	2:9:2
2015	-	-	9	2:5:2
2017	26	1:18:7	17	2:10:5

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification, or curtailment of its habitat or range

In 1968, the Logan Cave recharge area was 59% forested. By 1987, forested land use decreased to 43 percent and, by 2008, remnant forests were primarily adjacent to creek bottoms or ridge tops where it was too steep for livestock or poultry operations (Aley and Aley 1987; USFWS 2008). Residential development and agriculture are the primary land uses in the Logan Cave recharge area. Associated threats include elevated nutrient concentrations, pesticides, and a variety of storm water contaminants (Aley and Aley 1987; USFWS 2008). Septic field systems introduce contaminants into the groundwater system in karst areas (Graening 2005, Katz et al. 2010). Numerous cattle, swine, and poultry farms operate within the recharge area and produce substantial quantities of animal waste, which is land-applied as fertilizer to enhance pasture production. Leaks and spills associated with increased road density in the recharge area increases the likelihood of water quality contaminants entering the cave system. In Logan Cave recharge area, a substantial amount of groundwater contamination from residential and commercial development occurs from inadequate sewage disposal systems (Bidwell et al. 2009).

Threats to Bear Hollow Cave include contaminants from storm water runoff (incompatible chemical use/disposal, highways, and leaks and spills), excessive nutrient influx from residential septic systems and agriculture operations, physical alteration from mining operations (e.g., limestone quarries), vandalism, and hydrologic alteration from land clearing/conversion activities. Housing within the Bear Hollow Cave recharge area is primarily contained in the Bella Vista Development, a large suburban development that relies almost exclusively on septic field systems. Lead concentrations in the Bear Hollow Cave stream system are above the Arkansas acute and chronic concentration criteria thresholds for aquatic life (Graening 2005). The effects of elevated lead concentrations to *C. aculabrum* are unknown.

Substantial urbanization and commercial development is occurring in the Elm Springs recharge area (Aley and Slay 2006). Lack of or insufficient riparian buffers along streams in the recharge area likely contribute to the introduction of sediment and other water-borne contaminants into the groundwater system supporting *C. aculabrum*. Approximately 7 km of Arkansas Highways 112 and 412 cross the recharge area. Widening of highway 112 from 2 to 4 lanes is in the planning phase. Improved access between Elm Springs and Fayetteville is likely to spur additional development. Storm water runoff and water contaminants derived from highway leaks and spills may adversely affect water quality in the recharge area (Aley and Slay 2006). In 2012, the TNC conducted restoration work on riparian areas and sinks around the Elm Springs property (Kottmyer and Slay 2012). However, no other conservation work has taken place in the Elm Springs recharge area.

Figure 1: Groundwater recharge area for Logan Cave delineated by extremely high, high, moderate, and low vulnerability (USFWS 2013).

Bear Hollow Cave Recharge Area

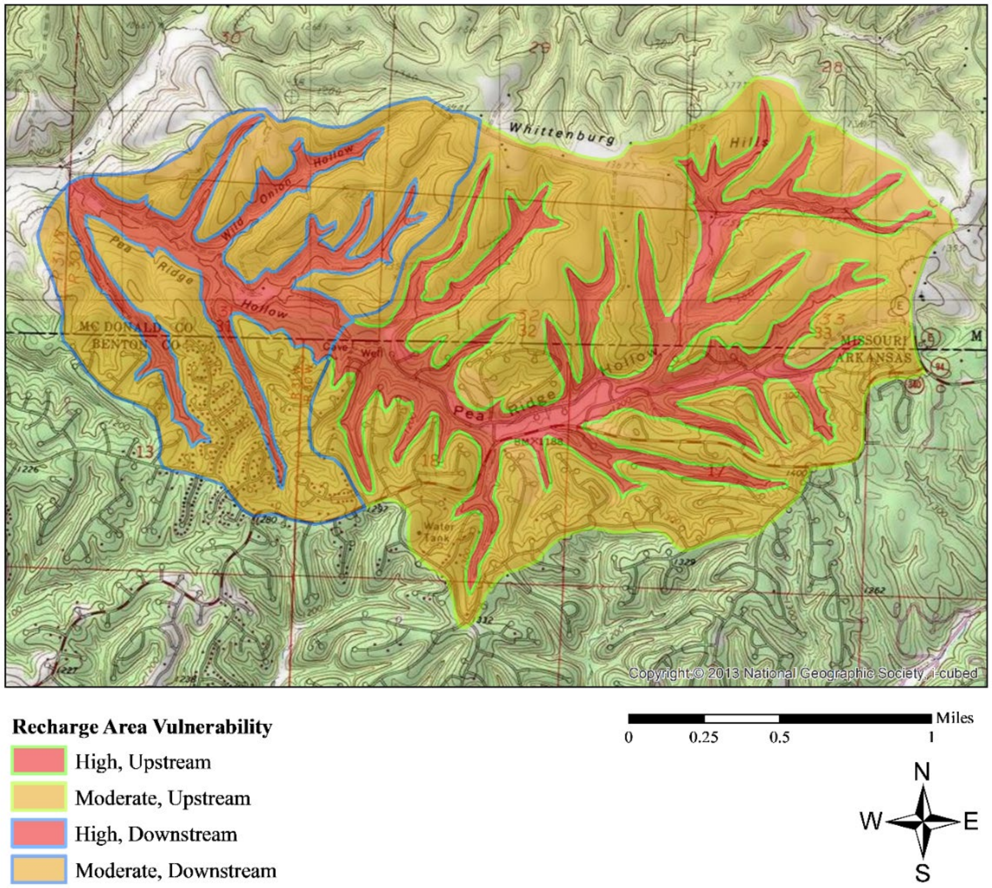

Figure 2: Groundwater recharge area for Bear Hollow Cave delineated by extremely high, high, moderate, and low vulnerability (Aley and Aley 1998).

The vast majority of the Old Pendergrass Cave recharge area is in Bella Vista. Threats to Old Pendergrass Cave are similar to those previously discussed for Bear Hollow Cave. Loch Lomond Lake was completed on April 24, 1981, substantially altering the area's hydrology. The dam is located about 3.2 km southwest of Old Pendergrass Cave. At normal pool, the lake has a surface area of 193 ha and a drainage area of 3,397 ha. Privately owned lands outside of Bella Vista are generally pasture with some woodlands (Aley and Slay 2007).

Aley and Slay (2007) mapped land vulnerability of the Old Pendergrass Cave recharge area. Of the 49.7 km^2 in the recharge area, approximately 89 percent (44 km^2) is in the moderate vulnerability category. Ten percent (5.2 km^2), divided equally, falls into the low and high vulnerability categories. One percent (0.36 km^2) has extremely high vulnerability. Most houses in the Bella Vista Development occur in the moderate vulnerability area. A large golf course exists on high vulnerability lands. Potential water quality issues associated with management of the golf course include increased nutrients and pesticides. There are a number of poultry houses and a large confined swine operation in the southern part of the recharge area outside of the Bella Vista development. Approximately 13.1 km of Arkansas state highways are in or immediately adjacent to the recharge area. Potential threats associated with these land uses include elevated nutrient concentrations, pesticides, and various contaminants yielded from storm water runoff (Aley and Slay 2007).

Figure 3: Groundwater recharge area for Elm Springs (Aley and Slay 2006).

Figure 4: Groundwater recharge area for Old Pendegrass Cave delineated by extremely high, high, moderate, and low vulnerability (Aley and Slay 2007).

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes

Due to permit restrictions on collection of individuals, overutilization for scientific and educational purposes is no longer a threat. Trampling of *C. aculabrum* is a continuing, but minimal threat to this species

There is no surface access to Elm Springs, thus overutilization is not a threat. There is no cave gate or fence at Old Pendergrass Cave, but difficulty accessing the cave via the entrance serves as a natural limiting factor. While Old Pendergrass Cave is posted "no trespassing", trespass and vandalism are still possible for experienced cave goers. Overutilization is not a threat at Old Pendergrass Cave.

2.3.2.3 Disease or predation

While disease threats are unknown, cave species' endemicity suggests that there is potential for transport of unknown parasites or diseases from cave to cave by researchers or recreational cavers. Service policy requires cleaning and decontaminating all cave gear prior to entering a different cave. There is one documented occasion inside Logan Cave of a banded sculpin (*Cottus carolinae*) consuming *C. aculabrum* (Brown et al. 1994). Numerous surface crayfish and fish enter these systems as well as small mammals, so predation is likely, but is believed to be a minimal threat to the continued existence of the species.

2.3.2.4 Inadequacy of existing regulatory mechanisms

Regulatory mechanisms (e.g. Clean Water Act Section 106) are in place to protect water quality and habitat for *C. aculabrum*. Arkansas Department of Environmental Quality (ADEQ) groundwater staff develop guidelines to address both point and nonpoint sources of pollution. However, existing regulatory mechanisms regarding the protection of groundwater resources are limited compared to surface waters. ADEQ conducts groundwater quality monitoring throughout the state, but cavefish sites are not on their scheduled sampling.

Agencies are also requiring storm water management plans under the Environmental Protection Agency's (EPA) MS4 phase 2 regulations for activities greater than 0.81 ha in size. The EPA has regulations and standards outlining water quality conditions for groundwater based on human health standards. However, regulations and management guidance necessary to protect groundwater from non-point source pollution do not exist. Water quality threats are typically non-point source derived and difficult to regulate. In general, regulations are not specific enough to provide protection, they contain no guidance on how to protect, and enforcement is understaffed.

2.3.2.5 Other natural or manmade factors affecting its continued existence

C. aculabrum are cave stream obligates that require sufficient stream flow for long-term survival. Research suggests that climate change will affect availability of ground and surface water, but the impacts to specific areas are hard to predict (Kumar 2012). The species range is confined within the Ozark Aquifer which is currently being depleted (ANRC 2007). If climate change negatively effects ground and surface water availability in the area or depletion of the aquifer for anthropogenic purposes continues it may threaten species persistence. The limited species range and low genetic diversity are likely to inhibit the ability of *C. aculabrum* to adapt to changing habitat conditions further increasing the likelihood of extirpation.

2.4 Synthesis

C. aculabrum occurs with broader distribution than originally described. From 2012 to 2017, survey results at Logan Cave declined 37 percent while the survey results at Bear Hollow Cave increased 31 percent. Historically, survey results have fluctuated similarly and the long-term trend is increasing. At this time, these populations appear stable. However, direct enumeration of populations does not assure that populations are in fact stable due to the extreme difficulty of conducting surveys and variable numbers found during these surveys. Threats within the delineated recharge areas have increased since listing. Future conservation efforts should focus on private landowner, city, county, and AHTD coordination, thereby ensuring their knowledge of site sensitivity and building cooperative management strategies for conservation of groundwater resources.

3.0 RESULTS

The status of *C. aculabrum* should remain unchanged.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The following priority actions will promote recovery:

1) continue efforts to prevent human disturbance to cave systems containing *C. aculabrum* through the use of outreach, signage, surveillance, and gating,

2) continue to establish partnerships with private landowners, local businesses, and city and county officials,

3) continue searching for additional populations,

4) conduct recharge delineations if new locations are identified,

5) continue efforts to purchase conservation easements or acquire lands within recharge zones, and

6) continue biannual monitoring efforts.

5.0 REFERENCES

Arkansas Natural Resources Commission [ANRC]. Arkansas Ground Water Protection and Management Report for 2007. 186pp

Aley, T. and C. Aley. 1998. Recharge area study: Bear Hollow Cave, Benton County, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 60pp. + appendices.

Aley, T. and C. Aley. 1987. Water quality protection studies, Logan Cave, Arkansas. Ozark Underground Laboratory, Protem, Missouri.

Aley, T. and M. Slay. 2007. Groundwater recharge area delineation and vulnerability mapping for Old Pendergrass Cave and an associated population of *Cambarus aculabrum*, the Benton Cave Crayfish, Benton County, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 29pp. + appendices.

Aley, T. and M. Slay. 2006. Groundwater recharge area delineation and vulnerability mapping for a population of *Cambarus aculabrum*, a cave crayfish, near Elm Springs, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 41pp.

Bidwell, J. R., C. Becker, S. Hensley, R. Stark, M.T. Meyer. 2009. Occurrence of organic wastewater and other contaminants in cave streams in northeastern Oklahoma and northwestern Arkansas. Archives of Environmental Contamination and Toxicology 58(2): 286-298.

Brown, A.V., W.K. Pierson, K.B. Brown. 1994. Organic carbon resources and the payoff-risk relationship in cave ecosystems. Second International Conf. on Ground Water. U.S. Env. Prot. Ag. pp.67-76.

Graening, G.O. 2005. Trophic structure of Ozark cave streams containing endangered species. Oceanological and Hydrobiological Studies 34(3):3-17.

Graening, G.O. 2002. Trophic dynamics and pollution effects in Ozark cave streams containing endangered species. Unpubl. Report submitted to the U.S. Fish and Wildlife Service, Arkansas Ecological Services Field Office. 20pp + appendices.

Graening, G.O. 2000. Ecosystem dynamics of an Ozark cave. Ph.D. Dissertation, University of Arkansas, Fayetteville, Arkansas. 98pp.

Graening, G.O., M.E. Slay, A.V. Brown, and J.B. Koppelman. 2006. Status and distribution of the endangered Benton Cave Crayfish, *Cambarus aculabrum* (Decapoda: Cambaridae). SW Naturalist 51(3):376-381.

Graening, G.O. and A.V. Brown. 2003. Ecosystem dynamics and pollution effects in an Ozark cave stream. Journal of the American Water Resources Association 39(6):1497-1507.

Graening, G.O. and A.V. Brown. 2000. Status survey of aquatic cave fauna in Arkansas. Arkansas Water Resources Center. Publication No. MSC-286. 41pp.

Hobbs, H.H. and A.V. Brown. 1987. A new troglobitic crayfish from northwestern Arkansas (Decapoda: Cambaridae). Proc. Biol. Soc. Wash. 100(4):1041-1048.

Katz, B.G., D.W. Griffin, P.B. McMahon, H.S. Harden, E. Wade, R.W. Hicks, and J.P. Chanton. 2010. Fate of effluent-borne contaminants beneath septic tank draifields overlying a Karst aquifer. Journal of Environmental Quality 39(4):1181-95.

Kottmyer, M. and M. E. Slay. 2012. Cattle and riparian restoration to protect the endangered cave crayfish, Cambarus aculabrum, one of the rarest crayfishes in the world. 16pp.

Kumar, C.P. 2012. Climate change and its impact on groundwater resources. International Journal of Engineering and Science 1(5): 43-60.

The Nature Conservancy [TNC]. 2001. Bella Vista cave complex site conservation plan. The Nature Conservancy, Greenland, Arkansas. 24pp.

U.S. Fish and Wildlife Service [USFWS]. 2013. Logan Cave habitat management plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 66pp.

U.S. Fish and Wildlife Service [USFWS]. 2008. Logan Cave National Wildlife Refuge comprehensive conservation plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 96pp.

U.S. Fish and Wildlife Service [USFWS]. 1996. Recovery plan for the cave crayfish (*Cambarus aculabrum*). U.S. Fish and Wildlife Service. Atlanta, Georgia. 36pp.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Benton County Cave Crayfish (*Cambarus aculabrum)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable.

Review Conducted By: Pedro Ardapple, Arkansas Ecological Services Field Office

FIELD OFFICE APPROVAL

Lead Field Supervisor, Fish and Wildlife Service

Approve MELVIN TOBIN Digitally signed by MELVIN TOBIN Date: 2019.06.20 15:01:10 -05'00' Date________