RFP Title and Number: Classification and Georeferencing Cave/Karst Resources across the Appalachian LCC (#2013-03)

Project (SOW) Narrative:

As stated in the RFP "developing a consistent classification system for karst habitats is a foundational need for this unique habitat type," but not without familiar antecedents. We build on existing knowledge in order to provide context for the proposed work described in the next section, following the structure in the RFP.

PHASE I

All aspects of phase I will be reviewed on a regular basis by the Technical Oversight Team (TOT), and requests from end users can be made through them or at the annual meeting with the steering committee (June 2014). The PI's are committed to providing the information in open access files, but the Appalachian LCC has not yet specified what software should be used. We are committed to resolving this through continuing discussions.

I-1. Review of existing literature, critical synthesis, evaluation of previous efforts to model species occurrence, richness. This will be a thorough review of all faunal studies for the region, as well as all models of species occurrence. This will point the way forward. Lead investigators: Christman and Culver. Completion date: December 2013 (as pdf file)..

I-2. Habitat classification system: Beginning with Doctor et al's pioneering PHORMS approach for karst classification, a complete list of variables will be listed for review. This will be an ungoing process in consultation with the TOT and steering committee. Lead investigators: Doctor and Weary. Completion date: June 2014 (as pdf file).

I-3a. Distribution of karst types: PHORMS, and other classifiction systems (e.g. single classification models like dip of the rock) will be used to construct karst types within the USGS karst map. This will also be an changing document, once again in consultation with the steering committee. Scale will be dependent on how big an area is being considered. For example (but only by example), the entire area may be divided into 20 X 20 km quadrats; Smaller regions, like a National Forest, will have proportionally smaller quadrats. The limiting factor is the amount of data. Too small a quadrat the the maps are grainy with many gaps. The technique is to minimize black-white joins and other spatial measures. Lead investigators: Doctor, Weary, Young. Completion date: December 2013 (as GIS layers: shapefiles and raster files.

I-3b. Cave density: Cave densities will be put on HUC 8 maps, quadrats (see above), and can be put on even finer scales if there is confidence in the state cave survey data accuracy. Lead investigators: Niemiller, Zigler. Completion date: March 2014 (as GIS raster files).

I-3c (part 1). Karst Hydrology: This task will necessitate an initial survey of the data that exist among different states. Within the USGS Karst Interest Group network, a reasonably representative dataset of the types of hydrologic variability expected within individual Level IV Ecoregions can be obtained and used for classification. Coverage will be partial based on current information available. Lead investigators: Doctor, Young. Completion date: December 2013 (as GIS shapefiles and raster files.

I-3c (part 2). Karst Vulnerability Mapping EPIK/DRASTIC/KARSTIC vulnerability model with intermediate layers; scale to be determined. Lead investigators: Young, Doctor. Completion date: March 2013 (as GIS raster files).

I-3d (part 1). Cave biota data The total number of cave-limited species in this region is not known, but is in excess of 600. We have over 7000 records now (several times the currently published number) and expect to reach 8000 records by the end of the study. Data will be maps, by quadrat, basin, and ecoregion;

with both species richness and distributions of species; undersampled regions will also be identified. Quadrat size will be the smallest possible to produce a non-gappy map (see above descriptions). Lead investigators: Culver, Niemiller, Zigler. Completion date: June 2014 (as GIS shapefiles).

I-3d (part 2) Species diversity maps Spatial distribution based on modeling to predict distribution as a function of karst and related variables (e.g. watershed, cave density etc) and to include estimates of uncertainty. Lead investigator: Christman. Completion date: December 2014 (as GIS raster and shapefiles

I-3e. Species (generic) ranges with confidence estimates Range prediction of genera more useful; many species single site endemics. Lead investigator: Christman. Completion date: December 2014 (as program in R and GIS raster files.

I-3f. Critical subterranean bat habitats: There is a comprehensive dataset on the caves and mines known to have been impacted by WNS in the Appalachians. State Natural Heritage Programs have been tracking significant roost sites, and we already have data in hand for Tennessee and Alabama. Lead investigator: Niemiller. Completion date: March 2015 (GIS raster and shape files).

GENERAL ISSUES

The consultative process is important both to us and to LCC. We plan to rely heavily on the Technical Oversight Team and the LCC Steering Committee. We will take advice from any interested party but need some formal structure to keep things organized. We believe and TOT and the Steering Committee will serve that purpose. We suggest that sharing of our progress report at quarterly intervals will be a good way to keep interested parties informed. We are happy to share our information with neighboring LCC staff and that decision is up to the Appalachian LCC. An annual meeting with the steering committee (tentatively one in June 2014 and one at the completion in March 2015) will be an important forum as well.

A recurring question in discussions has been sharing location information. This is of course a highly sensitive area, and for the most part we have access to but cannot share (without permission) location information. Most of the data are held by state natural heritage programs often in consultation with state cave surveys. Our experience is that broad requests are the most difficult to get approval for, and that focused requests are more easily accommodated. We will be happy to arrange meetings with the data holders and end users, but can make no promises about the outcome. Short of exact locations, general location (in quadrats for example) will be readily available, and useful for all but very local modeling and decisions. Once again, we will try to arrange data access for local areas.

PHASE II: A consultative process is likely best accomplished by testing a region of high data density that is well described in all aspects necessary for karst classification (geology, physiography, hydrology, and database of karst features). The karst areas of Virginia and Kentucky would provide a useful test case, encompassing regions with a variety of karst types, and a high data density of known karst features as well as well-described biological resources. Meetings will likely be held at USGS in Reston, VA.

PHASE III: We will provide GIS mapping products in digital GIS (e.g. shapefile) and ASCII/open source formats, as well as cartographic products in PDF format that can be hosted on the AppLCC.org website. These mapping products will provide information on the (generalized) location, density, and potential vulnerability of karst and cave resources (akin to the DRASTIC or EPIK methods) as well as maps of the richness and diversity of karst and cave biota. These compiled map products can be used as a geospatial information base and to support a variety of management decision support needs. We will use the outcome of Phase II consultations to provide a set of interpretative map products that combine base

mapping data together in flexible ways that highlight particular karst issues. Fully compliant FGDC metadata will be provided with all generated geospatial data products.

Timeline and Specific Deliverables

Overall, the project will begin September 1, 2013 and end March 31, 2015, a period of 18 months.
Phase I (1) 1 December 2013; (2) June 2014; (3a) December 2014; (3b) March 2014; (3c) December 2014; (3d) June 2014; (3e) December 2014; (3f) March 2015;
Phase II September 2014
Phase III March 2015

Budget:

Category	Funds Requested	Amer. Univ. Contribution**
Culver salary	11,452	14,600
AU research assistant	14,000	
AU fringe benefits	2036	3695
Niemiller stipend	7500	
Zigler stipend	7500	
Christman stipend	15,000	
USGS* (Doctor, Weary, Young)	25,000	
Travel	8,000	
Supplies	7,000	
TOTAL DIRECT COSTS	97,538	18,295
INDIRECT COSTS (17.5%)	13,534	
TOTAL	110,862	18,295

All USGS overhead costs will be matched by in-kind contributions from USGS funding obtained through appropriated funds to the USGS KARST project, totaling $14,774.
**5% of academic year salary (approx.. $146,000)*

Investigators and Capacity:

Project Manager and Principal Investigator*:* **David C. Culver** has studied and written about cave fauna for decades. He received his Ph.D. from Yale University and is Professor of Environmental Science at American University. He has a long standing interest in describing and accounting for the global and U.S. pattern of species richness. He has co-authored species lists for the caves of Virginia and West Virginia. He has authored or co-authored more than 100 articles on subterranean biology and written three books, including the widely used *Biology of Caves and Other Subterranean Habitats,* written with Tanja Pipan and published by Oxford University Press. Co-Principal Investigators: **Mary C. Christman** is a statistician with extensive experience in collaborating and consulting with biologists and environmental scientists. She received her Ph.D. from George Washington University, and currently holds courtesy appointments in the Departments of Biology and Statistics at the University of Florida. She is the author of widely cited articles on the relationship of habitat and species richness in the cave fauna, and on estimating the unknown part of species richness in caves. She will do all statistical modeling. **Daniel H. Doctor** is a research geologist and karst hydrogeologist, with geologic mapping experience in several karst regions of the Appalachians. He received his Ph.D. from Univesity of Minnesota. He has worked toward a quantitative, universal karst classification system in conjunction with compiling the National Karst Map of the United States, and has published on karst in *Hydrogeology Journal, Acta Carsologica, Carbonates and Evaporites, Proceedings of the 15th International Congress of Speleology*, and a number of USGS publications. Together with David Weary, he will assemble the geologic, hydrologic, and other abiotic data. **Matthew L. Niemiller** studies the ecology, evolution and

conservation of cave life. He received his Ph.D. from the University of Tennessee and is a Donnelley Postdoctoral Fellow at Yale University. He has published more than 25 articles and book chapters on subterranean biology, including seminal articles on molecular evolution and phylogeny of North American cave fish. Together with Kirk Zigler, he will assemble the biological data. **David Weary** has a MS in Geology from Virginia Tech as well as a Professional Certificate in GIS from Northern Virginia Community College. Since 1988 David has worked for the USGS as a geologic mapper, specializing in geohydrologic framework studies in karstic terrains of the Northern Great Valley of VA and WV and the Ozarks of southern Missouri. He is Project Chief of the USGS KARST Project. One of the tasks of the KARST project is compilation of a new national karst map. **John A. Young** is a Research Biologist (Biogeographer) at the US Geological Survey's Leetown Science Center, Aquatic Ecology Branch. He received his B.A. and M.S. degrees in Geography from Virginia Tech in 1987 and 1992 respectively. He specializes in watershed and landform characterization techniques using GIS to examine landform influences on the distribution of plants and animals. He will serve as the GIS expert. **Kirk S. Zigler** studies the ecology and evolution of cave animals. He received his doctorate from Duke University and is Associate Professor of Biology at the University of the South. Over the past year he and Matthew Niemiller developed a cave biodiversity database for Tennessee, Alabama and Georgia, more than doubling the known records of troglobionts and stygobionts for the region. He is a member of the Tennessee, Alabama and Georgia Cave Surveys. Together with Matt Niemiller, he will assemble the biological data. **Jan Idyll** will provide financial oversight for American University. She is Senior Grants and Contracts Manager for the Office of Sponsored Programs.

Partner Contributors:
The PI's have close ties with both state cave surveys and natural heritage programs. We have not entered into any cooperative agreements with them because in fact we have in in much of the information we need, and we believe it is more appropriate to seek more information for well-defined questions. In particular, we have in hand most cave location information.

Related Peer-reviewed Publications:
Christman, M.C., and D.C. Culver. 2001. The relationship between cave biodiversity and available habitat. **Journal of Biogeography** 28:367-380.

Culver, D.C., L.L. Master, M.C. Christman, and H.H. Hobbs III. 2000. Obligate cave fauna of the 48 contiguous United States. **Conservation Biology** 14:386-401.

Doctor, D.H., B.F. Schwartz, and M.O. Gary. 2009. Preliminary development of a statistically-based karst classification system, pp. 843-848. In W.B. White [ed.], **Proceedings of the 15th International Congress of Speleology, Vol. 2**, National Speleological Society, Huntsville, AL.

Niemiller, M.L., and K.S. Zigler. *In review.* Patterns of cave biodiversity and endemism in the Appalachians and Interior Plateau of Tennessee, USA. **PLoS One**.

Weary, D.J., and D.H. Doctor. 2009. A new karst map of the United States, pp. 457-460. In W.B. White [ed.], **Proceedings of the 15th International Congress of Speleology, Vol. 2**, National Speleological Society, Huntsville, AL.