

6/10/2005

## Resolving Sinkhole Issues: A State Government Perspective

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### *Abstract*

Several dramatic and costly sinkhole occurrences within a few years prompted a review of sinkhole policy in Pennsylvania. A committee was created to determine how the state Department of Environmental Protection (PADEP) addresses sinkhole issues throughout all its program areas in order to formulate a comprehensive policy regarding sinkhole prevention and response.

Pennsylvania does not have a formal policy or procedure to address sinkhole problems of any size even if they constitute a public emergency. From 1997 to 2005, the Bureau of District Mining Operations participated in investigations of major sinkholes occurrences relating to quarry operations. This resulted in the preparation of basic repair plans and alerted the Department, in general, to the growing problem of sinkholes associated with water withdrawal, urbanization and storm water handling.

Reporting sinkholes, authorizing repairs, providing information or assistance to the public and private entities, and requirements for permit applications were not consistent across program areas. The committee was able to identify many items that could improve response to sinkhole problems and even address the potential for sinkhole collapse related to permit authorizations in order to prevent costly repairs in the future. Many steps were recommended that could be implemented gradually over all applicable programs. Identified action items included education of staff, determination of best management practices, and increased interagency coordination. Additionally, it was determined there is a need to provide accurate information on sinkhole prevention and remediation to the general public as well as to municipal governments and those involved with geotechnical, residential, and commercial activities. Finally, a response plan must be formulated and funding must be identified in cases of sinkhole situations that pose an imminent threat to health and safety.

This approach can serve as a model for other state government agencies to improve their efforts to effectively deal with sinkhole situations and better serve public needs.

### *Background*

Large areas of central and eastern Pennsylvania are underlain by carbonate bedrock prone to sinkhole development. The major land use for the karst areas is agriculture interspersed with areas of urbanization. Many large aggregate and cement quarries coexist alongside population centers and, in many instances, urbanization has encroached upon these long-established mining operations that must pump out significant amounts of groundwater to operate.

The Pennsylvania Department of Environmental Protection (PADEP) is responsible for administering the state environmental laws which include preventing pollution, maintaining drinking water safety, protecting stream quality and regulating mining operations. In 1997, the Department began experiencing an increase in serious sinkhole situations involving streams and nearby quarry operations. These situations not only caused concern for the environment and public safety but also cost the state

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heavily in staff time to investigate and remediate the problems, funds for highway and road repair, and indiscernible cost to the mining companies, municipalities and individuals for repairs.

### *Major sinkhole situations in Pennsylvania and government response*

Several dramatic and costly environmental situations caused by sinkhole collapse prompted discussion among several Pennsylvania governmental agencies relating to the hazards of karst areas. From 1997 to the 2005, personnel of the PADEP's Bureau of District Mining Operations investigated five major incidents because they were proximal to large quarry operations.

#### Cumberland County

In 1997, stream loss and property damage resulted when sinkholes began to form in and along Cedar Run, a stream with a naturally reproducing fish population. The problems were related in time to the recently established lower mining depth in a nearby limestone aggregate quarry. Private structures were threatened and stream quality deteriorated. Geophysical study by the PADEP determined that there was a structural connection between the quarry pit and Cedar Run resulting in the direct dewatering of the stream and perpetuation of the sinkholes. Simply repairing the holes in the stream was not enough to stem the formation of new holes. As a result, the PADEP required the quarry company to flood the pit to a higher level to increase groundwater levels. Partial flooding showed no discernable rebound in the water table or decrease in the sinkhole incidents. Ultimately, cessation of all pumping lead to a quick water table recovery that stabilized the stream and effectively halted the progression of the sinkholes (Peffer Geotechnical Corp. , 2004).

#### Northampton County

Sinkholes periodically affected a state route at the approaches to a bridge over the Bushkill Creek. In fall of 1999, a 30-foot (9.1 m) wide sinkhole opened in the backyard of a private residence adjacent to the creek. At the same time, sinkholes were found under the bridge piers causing the structure to be condemned and eventually, to collapse. Cover collapse sinkholes continued to form along preferred orientations affecting other properties along the creek (Hill, 2000). Collapses occurred upstream and caused a railroad bridge support wall to sink and detach from the structure (Figure 1). Several years prior to this activity, the largest limestone cement and aggregate quarry in the area began experiencing increased pumping needs to keep the active pit dry. In 2001, the Schoeneck Creek, a smaller stream alongside this quarry, was affected by several sinkhole collapses that caused dirty water in the quarry and threatened a municipal sewer line. The flow of the Schoeneck Creek was absorbed entirely a few hundred feet downstream by a (historically) reoccurring series of coalescing sinkholes obliterating about 300 feet (91.4 m) of the stream bed (Hill, 2001).



Figure 1. Railroad support wall collapses into sinkhole.

Subsidence continued regularly, prompting the US Army Corps of Engineers to conduct preliminary geophysical studies in the Bushkill Creek (SAIC, 2002). In 2004, the sinkholes seriously compromised a set of bridges along State Route 33, a major transportation route. The bridges were eventually

reconstructed at significant cost to the state. However, the problem remains unresolved as several factors influence the formation of cover-collapse sinkholes and swallets in the stream:

- Natural structural features associated with deep karst weathering
- Past stream relocation and manipulation
- Quarry dewatering
- Effects from drought followed by heavy rain that flushed previously filled conduits
- Construction/urbanization effects

This ongoing, continuously evolving, hazardous situation prompted the formation of a committee with representatives from state and federal agencies that met regularly. The goal of this group was to exchange information and cooperate on projects to determine the best way to proceed with repairs to sinkholes and structures and to restore the integrity of the stream. Citizen input was valuable in this situation. The local citizens obtained contacts with each agency, including the agency heads, to continuously inform all parties via email about the latest developments around the area and the stream behavior. The area is not yet stabilized and work continues. A large-scale stream-lining project done jointly by the quarry company and the PA Department of Transportation is proposed.

#### York County

The South Branch of Conewago Creek disappeared into a swallet not long after a new, high-volume public supply well began pumping near the creek. Adjacent to the well is a limestone aggregate quarry that dewateres their pit in order to operate at depth below the water table. Both the well and quarry are located within several hundred feet of the creek. The swallet opened during the summer of 2002 during a serious drought. The PADEP bureaus that regulate mining and public water supplies became involved in the investigation working with consultants from the quarry and borough, the landowner, and other state personnel to develop a sinkhole remediation plan. Remediation was postponed due to lack of approval from the property owner to allow access to the stream. High rainfall in the subsequent seasons restored flow in the creek and postponed remediation. The quarry had been dewatered for years. Therefore, preliminary interpretation was that the well pumping triggered the surface collapse that occurred as an indirect result of the lowered water table. A more extensive groundwater investigation is ongoing.

#### Chester County

From 2001, an industrial park periodically experienced sinkhole development in detention basins and related to stormwater runoff. The area is adjacent to two limestone quarries – one of which is actively extracting material and pumping groundwater and the other which is in the process of reclamation with the pit water level rising. Road construction was also taking place in the vicinity. Therefore, a complicated scenario arose involving changing groundwater levels, concentrated and directed drainage, change in recharge areas, and general disruption of the ground surface. The potential for problems related to karst was not fully accounted for or addressed in the engineering of the industrial park facilities. This is a common situation in Pennsylvania where there is urbanization in karst areas.

#### Berks County

A limestone aggregate quarry adjacent to the Schuylkill River and Maiden Creek began experiencing an increase of clay-laden water after sinkholes appeared in the waterways and in the land between the channels and the quarry wall. This activity appeared in 1999 after a prolonged drought was followed by heavy rains – rapidly washing out the voids filled with dried and shrunken clay. Vortices and “waterfall-like” sinkholes several feet in diameter were documented in the channels. A nearby railroad bridge was threatened by a subsidence. The quarry company expended significant resources on geophysical study, water diversion, sinkhole repair, grouting techniques and stream repair to save the quarry from inundation by water. Injection grouting/grout curtains were not completely successful in permanently lessening the inflow to the quarry but the combination of methods did allow the quarry to remain operational. However, while the pit remains operational, the potential for further sinkhole development or quarry flooding always exists.

In all these examples, significant staff time was used to investigate the problem, collect data, write reports and communicate with interested parties on the progress. With jurisdiction over mining in the thirty-two eastern counties of Pennsylvania, thirteen of which have prevalent karst features<sup>2</sup>, the bulk of the investigation work fell to the Bureau of District Mining Operations Pottsville District Office. Karst features also occur in central Pennsylvania counties. However, higher population density in the eastern counties results in more examples of man-induced sinkhole problems. (See distribution map by Kochanov and Reese, 2003)

The District offices are not equipped to conduct large-scale hydrological investigations. Most state geologists and engineers are not experienced with karst processes. A steep learning curve faces one assigned to investigate a situation and determine the best course of action as soon as possible. The occurrence of so many serious karst-related problems in just a few years highlighted the need for a policy or guidance on how sinkhole problems should be coordinated and resolved in an efficient way.

### *Evaluating Sinkhole Policy*

Other bureaus in the PADEP became aware of the sinkhole situations in the eastern counties through various meetings and presentations. Presentations were given on specific investigations to other technical, legal, policy and executive staff. It was clear to PADEP personnel that state government involvement, funding and delivery of services were largely undefined related to this issue. When the Northampton County situation seriously affected the state infrastructure, the Secretary of the PADEP called for an overview of Pennsylvania procedure related to sinkholes and karst areas. A small committee of individuals was assembled to research the issue. Technical staff from affected bureaus such as mining, water supply, stormwater management and environmental cleanup participated as well as legal, policy, field operations, and Geological Survey personnel.<sup>3</sup>

The main purpose of the committee was to determine how the PADEP addresses sinkholes in current procedures with the goal of ultimately formulating a comprehensive policy. The committee focused on the ability of the permitting process to address potential sinkhole formation and remediation, ways the Department can improve the overall response to sinkhole events, and the possible need to formulate new or modify existing regulations.

The approach considered both the prevention of sinkholes and the reaction to a serious sinkhole event. Also, it was important that the PADEP not duplicate efforts or attempt to develop ideas already undertaken by the Pennsylvania Geological Survey—our primary source of state geological (and sinkhole) information. The Survey previously published a series of county-based “Open File Reports” that show mapped karst features. These reports were compiled into “Density of Mapped Karst Features” maps that show the general trend of these features and can aid in local land use decisions.

The committee was able to identify many items that could improve the PADEP’s response to sinkhole problems and even address the potential for sinkhole collapse related to state authorizations (permits) in order to prevent costly repairs in the future. The committee also launched an internal review to assess the current authority to regulate activities that enhance sinkhole development and by what means the PADEP has to implement sinkhole repairs.

After reviewing individual programs, the committee found that PADEP did not have any formalized policy or procedure to address sinkhole problems of any size even if they are related to a Department authorization (permit) or constitute a public emergency (with the possible exception of the mining program – see below). Pennsylvania’s environmental regulations (*The Pennsylvania Code, Title 25*) contain references to “sinkholes” only relating to the following situations: storage, use or disposal of

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<sup>2</sup> Adams, Berks, Bucks, Chester, Cumberland, Dauphin, Franklin, Lancaster, Lebanon, Lehigh, Mifflin, Northampton, and York.

<sup>3</sup> The Pennsylvania Geological Survey is a Bureau of the Pennsylvania Department of Conservation and Natural Resources (DCNR).

various wastes or nutrients, stormwater discharge plans, and mapping requirements in mining areas. Reporting sinkholes, authorizing repairs, providing information or assistance and information requirements from permit applicants was not consistent across program areas.

The mining program did have some sinkhole-specific internal procedures in place. Around 1999, Pottsville District Mining Office regularly begin requesting a sinkhole repair plan as part of the permit documentation for quarries in sinkhole-prone formations. Quarries that had previously experienced sinkhole problems had their staff regularly performing visual surveys of surrounding areas. A few were required as part of permit "special conditions" to report any occurrence of a sinkhole that they found to the PADEP mine inspector or District Office personnel. In 2005, the Pottsville District Mining Office formulated an internal document for staff hydrogeologists and inspectors in order to assist them on investigating a sinkhole complaint. This document included a list of general items to observe in the field, instructions on how to document the complaint, what information should be supplied to citizens, and pertinent references.

The committee determined that there were many steps than can be taken within the PADEP to improve the overall response to sinkhole events. The steps would be implemented gradually over all applicable programs and should include complaint response personnel who often are the first persons who receive the information and the Department's emergency response personnel who may be the first on the scene. Categories of action items would include education, determination of best management practices, and increased interagency cooperation (for example, with the Department of Transportation).

There is a crucial need to provide accurate information to the public – landowners, municipalities, developers, lenders, construction companies, consultants, farmers, etc. – about how to take precaution against, recognize, and deal with a potential or obvious sinkhole problem. The focus of education would be both preventative and reactionary: how can one prevent sinkholes in the first place and what does one do when a sinkhole is evident. This information should be available on the Internet for quick access, and in print form to be distributed as needed at a problem location, by citizen request, or at public informational meetings. In several instances, it was found that a citizen reporting a sinkhole would make several phone calls before reaching a PADEP staff member who could help them. This process can be made more efficient if tools like an Internet site and "fact sheets" were readily available to provide basic information on what to look for and whom to contact. Complaint personnel who receive calls from karst areas should have a list of pertinent questions to ask the citizen in order to more efficiently route the call to the correct person or be able to immediately determine that the citizen must seek private help in dealing with the problem.

Media often request statements from public personnel when sinkhole situations occur. By observing the stories printed in local newspapers, it can be demonstrated that journalists often do not get the technical facts correct or they rely on a non-expert to provide descriptions or opinions. Opinions can be without basis in fact and may promote fear from nearby residents that they may be affected next. The PADEP and other state agencies should make their personnel available to answer technical questions and ensure that the correct information is readily available. In any technical situation, it is imperative that government personnel be able to express a complicated situation with several unknown variables (as is the typical karst situation in urban areas) in a correct and understandable way without losing the overall context. For example, basic terms should be clearly defined as they are used (i.e., "sinkhole" as related to a karst subsidence event and not as a mine subsidence event).

Plans must be formulated and funding must be identified to be used in cases of emergency sinkhole repairs that pose an imminent threat to health and safety. In the Northampton County situation, the interagency task force developed a "Rapid Response Plan" that included typical details of sinkhole repairs based on the location within zones of determined responsibility and dependent upon the location relative to the stream and the determined seriousness of the hazard. Funding in this situation was via the quarry, the Department of Transportation road maintenance funds or through the PADEP's noncoal mining fund that collected penalties from quarry operators. However, these collective sources were not intended to serve as a cache for sinkhole repairs. Quick and effective responses in the future will require a permanent, dedicated source of funding.

The following recommendations were made by the committee to address the findings listed above:

1. PADEP must ensure that education opportunities and updated training is available and encouraged for staff hydrogeologists. Other staff and management should also be informed about responding to a sinkhole situation.
2. PADEP must provide useful, easily obtainable information to the public on sinkhole hazards in Pennsylvania.
3. Conduct an internal review to find applicable regulations and law that currently exist for use in sinkhole situations.
4. Formulate a Department-wide policy on sinkholes and determine if additional regulations are needed. This task involves the following items:
  - Consolidate PADEP's perspective on sinkholes,
  - Determine practices or "guidance" documents to be used for each program area (i. e. mining, water supply, stormwater management, etc. ),
  - Identify possible gaps in the regulations,
  - Establish a working definition of a "sinkhole" (as applicable to Pennsylvania),
  - Develop a plan to streamline how sinkhole incidents are reported and investigated by the PADEP and,
  - Consider specific activities related to karst that cross program areas (for example: pump tests, dye trace studies) in order to promote uniformity of procedures and prevent an undesired effect.
5. Forge interagency cooperation to establish a statewide protocol for sinkhole repairs. There is a clear need to involve other state and federal agencies to formulate guidance for implementing safe, effective sinkhole repairs. A general repair guidance would help in efficiently permitting this work, protect water quality, and assist in construction projects where sinkholes are a potential problem. This type of documentation would also be valuable to municipalities and property owners in karst areas.
6. Investigate the potential for a permanent, reliable source of emergency funding for sinkhole repairs and other geologic hazards. No funding has been set aside to deal with sinkhole catastrophes that threaten public safety, private and public properties, streams, and transportation structures in Pennsylvania or in any other state. Various legislation introduced in Pennsylvania has demonstrated that establishing funds specifically for sinkhole issues has limited appeal due to the localized nature of the problem. However, including other geologic hazards (for example, landslides) may garner more widespread support. There remains the question of where the fund dollars will originate.
7. Conduct outreach to property owners, municipalities, consultants, construction firms, etc. This can be achieved by providing workshops, literature and contact information to those in hazard areas to highlight karst problems and increase awareness and understanding.
8. Encourage sinkhole prevention and protection for homeowners and developers by utilizing the insurance, banking and realty companies at the initiation of property purchase. The success of the Pennsylvania Mine Subsidence Insurance program, for example, has suggested that this is the most effective method of informing the public about a potential hazard to their home. Currently, in Pennsylvania, sinkhole insurance is not required nor is it regularly offered to landowners in karst areas. Many citizens who may benefit from the insurance do not know it even exists. Some residents have reported that their insurance provider does not offer sinkhole coverage or it is denied to them. While Pennsylvania does not propose instituting their own

Sinkhole Insurance program, the committee proposes that the insurance aspect be considered in the overall policy in Pennsylvania as a means of protection for the citizens from natural occurrences similar to floods or earthquakes.

### *How states handle sinkhole problems*

As part of the committee's research, other states were informally contacted via email to their geological survey or other public personnel familiar with the karst activities in their state. They were requested to answer questions about their own states' response to sinkhole emergencies, regulations, funding and policy. In addition, committee members reviewed the information available on sinkholes via the Internet and in publications for the general public.

Preliminary results showed that states with serious karst problems responded that, basically, they do what they can with the funds they have. Additional funds for efforts, such as updated mapping, were difficult to come by. Many also expressed that karst hazards were an under-appreciated issue. In many cases (like those described previously in Pennsylvania), the existing state laws and regulations attempt to address the potential for groundwater contamination in karst areas but do not have stipulations about preventing cover collapse sinkholes and land subsidence, nor do they contain statutes regarding responsibility or establish funds for repairs.<sup>4</sup>

Investigation of a sinkhole occurrence often defaults to the state agency that gets the initial call. Governmental geologists/engineers can find their investigation results included as part of legal proceeding. No state responded that they have a set investigation plan, but many do site visits as needed or as frequently as they can, depending on circumstances. In times of emergency, the jurisdictional, permitting and funding questions can take an unacceptably long period to work out. Citizens in Northampton County, Pennsylvania expressed frustration in dealing with several state and federal agencies to fix a sinkhole problem when it crossed jurisdictional lines and no immediate "lead" agency was forthcoming. They found through trial and error that no level of state government had a section that dealt with sinkhole issues (Carlson, 2002).

The committee found no evidence that any state had a dedicated sinkhole emergency and/or repair fund that provides relief to homeowners with catastrophic costs. In general, it is the responsibility of the individual homeowner to obtain insurance and/or repair a sinkhole on their property at their own cost unless a legal claim is awarded.

The state of Florida has public reports available regarding the investigation of sinkhole claims and a study of sinkhole insurance. These reports provide good information as a start for other karst states:

- "Geological and Geotechnical Investigation Procedures For Evaluation of the Causes of Subsidence Damage In Florida", compiled by Walt Schmidt, published by the Florida Geological Survey (Special Publication No. 57), dated 2005, is available at <http://www.dep.state.fl.us/geology/publications/sp/sp57d.pdf>
- "Final Report: Insurance Study of Sinkholes" by Patrick F. Maroney, et al, dated April 2005, is available at [http://www.fldfs.com/Companies/pdf/Sinkhole\\_Study\\_042005.pdf](http://www.fldfs.com/Companies/pdf/Sinkhole_Study_042005.pdf)

General sinkhole information is available but not always easily obtainable and depends on if the state in question received funding to supply this information to the public. Because of the lack of state policies, many sinkhole issues are tackled at a municipal level with local ordinances. Some good information has also been prepared at this level for distribution to the public. However, at this level, it is not as accessible to the general public who may find it useful, especially if they are outside of the area.

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<sup>4</sup> States that responded via email were Alabama, Arizona, Arkansas, California, Colorado, Florida, Indiana, Iowa, Kansas, Kentucky, Maryland, Missouri, Ohio, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

There are very few publications readily available to the non-technical reader for purchase through commercial sites (such as conventional or Internet-based bookstores) on sinkholes.<sup>5</sup>

### *Conclusions*

PADEP is attempting an ongoing process to evaluate and improve its response to sinkhole situations in order to minimize the hazard and protect public safety and the environment. Through this exercise of examining the state sinkhole policy, the PADEP committee has learned that there are several key areas of focus that would accomplish the most improvement for the effort in Pennsylvania. Education of the staff and the public on sinkhole hazards – prevention and remediation – would spread awareness and effectively cut the costs (and frustration) of dealing with these problems. State dollars allocated to mapping of karst areas, staff training and educational materials should be considered “well spent” with a return gained in better investigations, planning and repairs in karst problem areas.

The public tends to associate relief from natural hazards with a state or federal initiative. When they find there is nothing in place that addresses this, they feel disenfranchised. Since potential or realized sinkhole damage causes significant costs to industries, property owners, municipal authorities and state agencies, and constitutes a public safety threat via sudden subsidence or contamination, it should be designated as a hazard and addressed as such.

Many of the states surveyed for information expressed interest in this process. It was obvious that there is no organized effort to deal with this hazard which will inevitably worsen as urbanization continues in karst areas. The public would be best served if individual states conduct this examination in order to address the needs of its citizens before critical situations arise and make a decided effort to curb the negative effects of living with karst.

### *Acknowledgments*

The author acknowledges the members of the PADEP Sinkhole Committee whose enthusiasm and efforts were the foundation for this paper – Joseph Seiber, William Kochanov, Kathleen Horvath, Elise Juers, Martin Sokolow, Stuart Gansell, and Michael Conway. The Sinkhole Committee wishes to thank Pennsylvania Department of Environmental Protection Secretary Kathleen McGinty for her interest in the sinkhole problem and her trust in Department staff, Deputy Secretaries Michael D. Sherman and J. Scott Roberts for their excellent support, Michael D. Hill of Pottsville District Mining Office, and the Brookwood citizens’ group for their persistence and day-to-day insight into living with sinkholes.

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<sup>5</sup> This excludes non-technical books on caves and spelunking, which are common, and textbooks on karst hydrology or engineering that are priced significantly higher than popular titles and are harder to obtain.



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