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and constructing landfills in karst geologic settings NCKRI
Symposium 2: Proceedings of the Thirteenth Multidisciplinary
Conference on Sinkholes and the Engineering and Environmental
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NEED FOR A STANDARDIZED APPROACH TO CHARACTERIZING, PERMITTING, AND CONSTRUCTING LANDFILLS IN KARST GEOLOGIC SETTINGS

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Abstract

The challenges presented by geohazards play a significant role in the permitting of environmental facilities, particularly those situated in karst geologic settings. With regards to landfills, and specifically to municipal solid waste (MSW) landfills, regulators have a significant responsibility to protect the environment and must make decisions regarding the siting and permitting of these facilities. While these decisions are based on their objective assessment of site-specific characterization information, their decisions are often scrutinized by the public and by the owner/permittee...entities that often (and usually) have contrasting interpretations of the same site characterization information. The Florida Department of Environmental Protection (FDEP) has initiated an innovative approach to help the agency in the decision-making process by convening a Technical Advisory Group (TAG), comprised of several agency- and industry-recognized experts who are experienced in the investigation, characterization, permitting, and construction of engineered facilities in karst settings. Through a process involving the compilation and assessment of various site-specific factors, the TAG is working with FDEP personnel to develop specific and objective guidelines that can be used by owners, permittees, consultants, and the agency in developing investigation, characterization, design, construction, operations, and monitoring strategies for facilities overlying karst geologic conditions. The activities of FDEP and its TAG are actively reviewed by the public, who have also been requested by FDEP to participate in the process of developing these guidelines. The objectives for making this presentation are twofold, specifically to provide information to and then solicit information from the conference participants (and readers). The approach being taken by FDEP and the TAG focuses on technical

issues regarding the investigation, characterization, design, and construction of engineered facilities in karst geologic settings. The authors recognize that these technical issues impact all engineered facilities, not just those constructed for environmental applications. Therefore, the approach developed by FDEP may benefit other agencies, owners, and consultants who face similar challenges. The participants at this conference likely have specific experiences and can offer recommendations that will ultimately be beneficial to the DEP and the TAG. In this presentation, the authors will actively engage the participants and will request input based of their experience and expertise.

Introduction

It is often said that we can only be certain of two things... death and taxes. Geotechnical and geoenvironmental professionals can safely add three more relative certainties: (i) as a society we continue to generate large amounts of garbage (i.e., MSW) that require safe long-term disposal; (ii) few people want MSW disposal facilities (i.e., landfills) located “in their backyard”; and (iii) geohazards that restrict the location of these unwanted landfills come in all sizes and shapes and exist across the U.S. Regarding modern landfills, which have a nearly 20-year duration track record of demonstrated performance, there is a reticence of the populace to view this as a “societal need” and prefer that the problem be shifted to others at other locations. Regarding geohazards that pose problems to landfills, karst represents one of the most significant geologic hazards in the State of Florida, which is one of the most populated states in the country. Across Florida, and particularly in Central Florida where the karst is prevalent and the population is dense, it is easy to project a major problem when a societal need runs headlong into geologic constraints.

In anticipation of the collision course, the Florida Department of Environmental Protection (FDEP) has taken a proactive course of action to develop technically rigorous recommendations regarding the siting, permitting, design, construction, operations, and monitoring of MSW facilities in the State that need to be located over karst terrain. This paper will identify the State-specific problems that face the geologic, geotechnical, water resources, and geoenvironmental professionals who must deal with the often competing demands placed by society in dealing with the disposal of MSW and the locations of the disposal facilities. The authors will then describe a unique State-initiated proactive strategy for addressing the waste disposal problems caused by the challenging geologic conditions, with an objective of developing technically defensible and objective regulations for MSW disposal facilities in Florida. Finally, the authors will solicit opinions and experiences from the participants of the conference regarding improvements to this initiative, recognizing that “do nothing” or “take the waste elsewhere” is not a sustainable alternative.

The Problem...MSW and Geology

Before a strategy can be developed, a sense for the magnitude of the problem needs to be recognized. In Florida (as well as in many parts of the country), the “problem” is a combination of the need for landfill airspace and the prevalence of karst in the underlying geologic formations. A brief summary of these problems follows.

MSW in Florida – Past and Future Trends

Regarding solid waste practices and experiences, Florida follows many of the trends evident across the country. Figure 1 shows the reality of solid waste generation in Florida over the past 20 years.

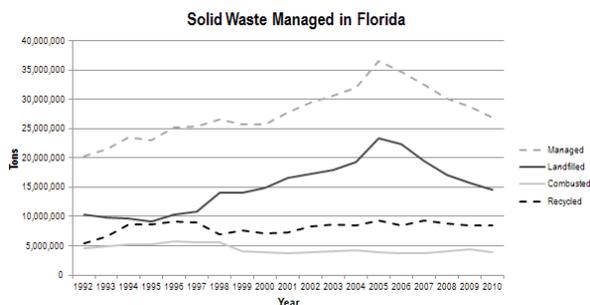


Figure 1. Solid Waste Disposal Trends in Florida (FDEP, 2012, written communication).

The downward trend since 2005 is a combination of country- and State-wide emphasis on waste reduction and on the recent economic conditions in the U.S. If these trends are compared to national trends and coupled with the population, results indicate that in Florida, the waste generation can be represented as approximately 3.5 kg (7.8 pounds) per person per day compared to a national average of 2.0 kg (4.4 pounds) per person per day. Consistent with national trends, prosperity leads to an increase in MSW generation per person. When these trends are coupled with the future estimated population growth in Florida (Figure 2), the impact of population growth on solid waste disposal needs is staggering. Interestingly, the Florida population growth trend of about 250,000 people per year (ppy) is approximately 10% of the projected national population growth trend of 2,500,000 ppy (FAIR, 2006). Clearly, the popularity of the 4th most populated state in the country is projected to increase over the next several generations. As can be seen in Figure 1, it would require an extreme paradigm shift in public policy, public response, and waste disposal practices to have a significant impact on long-term MSW disposal needs.

To further demonstrate the MSW disposal issues facing Florida, consider the locations in Florida where people want to settle. Figure 3 shows the current population density across the State. People clearly like to live in Central Florida.

Finally, over the past several years, most states have seen an overall reduction in the number of solid waste disposal facilities. This is demonstrated in Figure 4, which reports the number of active MSW disposal facilities across the country. The national trend over the past 20 years clearly shows that the number of facilities

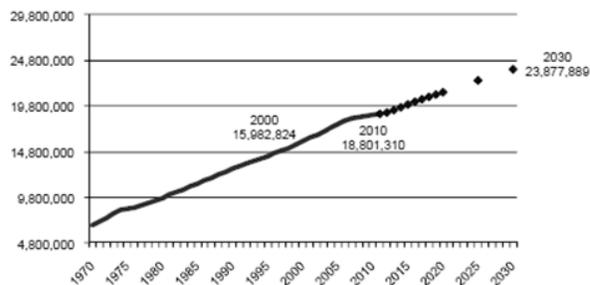


Figure 2. Florida Population Projections (FL EDR, 2011).

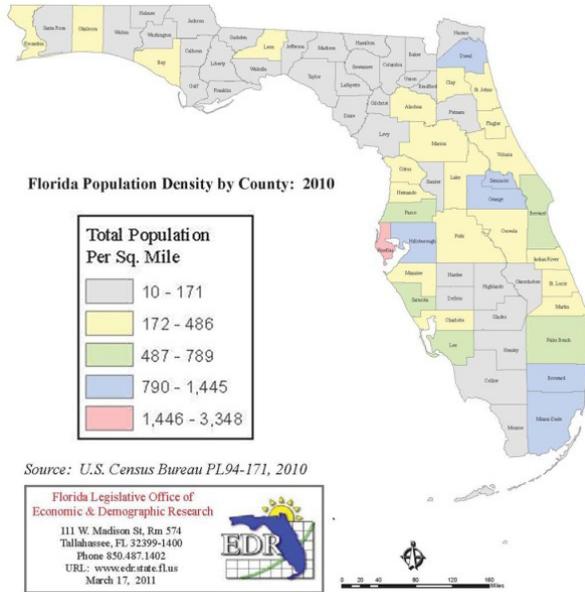


Figure 3. Florida Population Density (FL EDR, 2011).

has precipitously decreased to only (on average) 39 MSW disposal facilities per state. Currently Florida has 40 active landfills and 80 closed facilities. The question is “Where do Floridians place waste in the future and how much capacity is needed?”

Karst Geohazards in Florida

Karst and the underlying problems associated with the geologic conditions are well known to most Floridians, especially to our conference co-organizers from the University Of South Florida in Tampa. Perhaps the most famous (infamous) is the May 1981 “Winter Park Sinkhole” measuring approximately 98-m (320-ft) in diameter and 27-m (90-ft) deep that comprised almost an entire city block. Although detailed formal historical records may be infrequent, the Florida Geologic Survey (FGS) has recently compiled and published records, primarily to assess the impacts of subsidence and sinkholes on groundwater resources. Figure 5 shows the six districts of Florida identified by the FGS and present locations of reported subsidence.

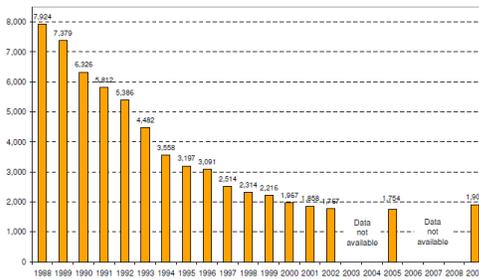


Figure 4. MSW Landfills in the U.S. (USEPA, 2009).

As shown on this figure, the two districts comprising Central Florida (i.e., Southwest District and Central District) account for 85 percent of the nearly 2,300 reported episodes of subsidence. When the Northeast District is added to this list, the locations of nearly 95 percent of the reported episodes are included. Independent records maintained by Florida’s Water Management Districts (WMDs) and verbally provided to the authors provide nearly identical results. Clearly, the problems of subsidence and sinkholes are regionalized. The FGS used data compiled from around the State to develop Florida Aquifer Vulnerability Assessment (FAVA) maps. The FAVA for the prolific Floridan Aquifer is presented in Figure 6.

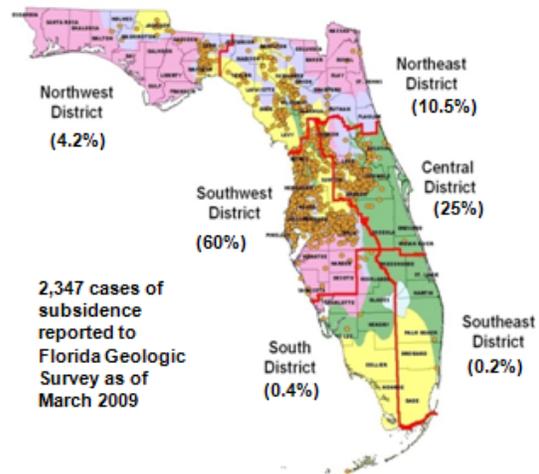


Figure 5. Map Showing Reported Subsidence Areas (FDEP, 2010, written communication).

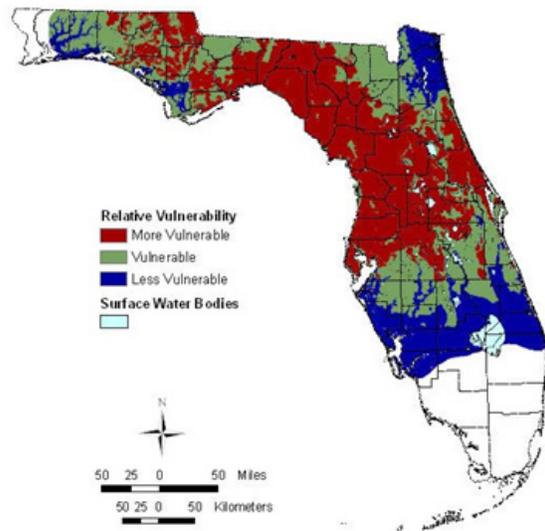


Figure 6. Florida Aquifer Vulnerability Assessment (FAVA) Map for the Floridan Aquifer (FDEP, 2010, written communication).

This map was developed when FGS considered: (i) depth to the groundwater table; (ii) hydraulic head difference in the aquifer; (iii) thickness of the confining unit; (iv) distance to known karst features; (v) overburden soil permeability; and (vi) aquifer system overburden. Comparing Figures 5 and 6 provides the compelling observation that the most valuable groundwater resource in the State is most vulnerable in the areas where virtually 95 percent of the reported subsidence is located.

Finally when one links these findings regarding geologic and hydrogeologic conditions with the previous section regarding solid waste needs, a foreboding observation develops. It is anticipated that the areas where the population density is the highest (Figure 3) are where there will be the largest need for landfill disposal airspace in the future. Further, this area is where the potential for subsidence and sinkholes is highest (Figure 5) and where the Floridan Aquifer is most vulnerable (Figure 6). Furthermore, it is noted that the areas of subsidence and aquifer vulnerability, hereinafter referenced as “sensitive” areas, comprise nearly 60 percent of the total land area in the State. Clearly, a hasty reaction to simply prohibit the siting of landfills in these sensitive areas would place a hardship on other areas of the State where the landfills (likely large landfills) would be sited and would result in significant adverse financial impacts to residence of Central Florida due to high transportation costs. FDEP anticipates that future MSW landfills will be sited within Central Florida. These figures indicate that there are significant technical and environmental challenges across the State. Technical differences of opinions are inevitable between environmental groups, landfill developers, the public, and the FDEP unless consistent, defensible, and fair solid waste policies and guidelines are developed and enforced.

The Solution...Development of FDEP Guidance Documents

The FDEP has developed and currently maintains and enforces solid waste regulations in the State that exceed the U.S. Environmental Protection Agency (USEPA) “Subtitle D” requirements regarding the siting, design, construction, operations, and performance of MSW disposal facilities. The FDEP has followed USEPA guidelines and like other states that experience karst geologic conditions (including Alabama, Arkansas, Kentucky, Minnesota, Pennsylvania, and Tennessee), has taken aggressive regulatory positions regarding the

need for the MSW permit applicant to provide long-term protection of groundwater resources by establishing: (i) landfill design guidelines; and (ii) groundwater monitoring guidelines. With regards to groundwater monitoring requirements, these State regulations acknowledge that the groundwater regime in karst geologic settings is significantly governed by discrete conduit flow, in contrast to continuous porous media flow in aquifers comprised of granular media. The FDEP has taken a strong position that its policies are directed to protecting groundwater and minimizing potential adverse risks to its aquifer systems. Therefore, the FDEP regulations explicitly recognize the importance for the applicant to demonstrate an understanding of the groundwater flow regime and develop a groundwater monitoring system for the site-specific conditions. These regulations apply to sites located in karst and non-karst settings.

FDEP Rules and Regulations

In addition to its influence on the groundwater flow regime, karst can also impact the structural stability of the landfill itself. The FDEP regulations (as well as the regulations in most other states) address issues of structural stability. Specifically, several specific sections of the Florida Administrative Code (FAC) are cited to provide examples of how regulations (and regulators) address issues related to landfill stability (*italics added by authors for emphasis*):

- Rule 62-701.300(2)(a) regarding *prohibition for siting requirements* for all solid waste disposal facilities states... “unless authorized by a Department permit or site certification in effect on May 27, 2001, or unless specifically authorized by another Department rule or a Department license or site certification based upon site-specific geological, design, or operational features, no person shall store or dispose of solid waste.... in an area where geological formations or other subsurface features will not provide support for the solid waste;”
- Rule 62-701.340(3)(a) regarding the *location requirements* for all landfills states that ...”the site shall provide structural support for the facility including total wastes to be disposed of and structures to be built on the site;”
- Rule 62-701.400(3)(a)2 regarding the *design requirements* for all landfills states that composite soil and geosynthetic liners shall be ...”installed upon a base and in a geologic setting capable

of providing structural support to prevent overstressing of the liner due to settlements and applied stresses;” and

- Rule 62-701.410(2)(b) regarding *geotechnical site investigation requirements* for all landfills and construction and demolition (C&D) debris disposal facilities states the ...”prior to any construction on the landfill site, the engineer shall define the engineering properties of the site that are necessary for the design, construction, and support of the landfill and all installations of the facility and shall...explore and address the presence of muck, previously filled areas, soft ground, lineaments, and sinkholes.”

These regulations leave significant latitude for the applicant to make the requisite demonstrations and there are opportunities for subjective judgment. For example, with regards to *geotechnical site investigation requirements* above, one engineer may believe that the site can be adequately characterized using 1 boring per hectare (2.4 borings per acre), while another may believe that variability at the site warrants a density of greater than 4 borings per hectare (10 borings per acre). In many cases, the regulations leave decisions to the discretion of the professionals tasked with preparing the permit application. The FDEP, however, recognizes that even comprehensive site-specific geotechnical investigation and geologic characterization studies require the educated judgment and opinions of professionals regarding an interpretation of data and facts. This interpretation of these study results must be provided in an application prepared on behalf of the applicant that demonstrates compliance with the FDEP regulations. To issue an FDEP permit for an MSW facility, the applicant must provide “reasonable assurance” to the FDEP that the proposed project will comply with the State regulations. Rule 62-701.200(94) importantly states that ...“reasonable assurance” means the existence of a substantial likelihood, although not an absolute guarantee, that the proposed activity and applicant will comply with agency rules, laws, orders and permit conditions. It does not mean proof that a facility will not fail.” It is noted that this section of the regulations recognizes that the permitting test is for “reasonable assurance” not for “absolute assurance.”

The landfill permitting process in Florida (and all other states) requires that professional engineers and geologists prepare technical applications that provide the previously stated “reasonable assurance.” The

permitting applications are first reviewed by the FDEP for regulatory compliance and are subject to the permit test for reasonable assurance. The permit application and the FDEP comments are then subject to public review and scrutiny. In many cases the interpretations of the geotechnical investigation and geologic characterization studies, as well as the FDEP opinions, are subject to an independent assessment by the public reviewers regarding regulatory compliance and reasonable assurance. In addition, particularly for permits involving controversial sites, the findings and interpretations of the public’s review (often by other qualified professionals) will differ from those of the FDEP and the applicant’s professionals. This often leaves the FDEP in the middle of technical disagreement between qualified professionals and the reality that regardless of its decision as a “referee”, the FDEP will be the subject of rebuke and potential litigation from either the applicant or the public. The FDEP has successfully faced the realities of this “regulatory environment” since the promulgation of the USEPA’s Subtitle D regulations. For sites and topics where controversy or technical challenges are anticipated, FDEP (and regulators in other states) have taken the initiative to develop “Technical Guidelines” to assist the applicant’s understanding of the State’s expectations regarding the permitting process.

For reasons described previously, there is significant applicant and public “response” regarding recent MSW landfill permit applications for sites in Central Florida. In addition, FDEP recognizes future challenges facing this region as summarized in the previous section of this paper. To address these issues, the next section describes a proactive approach that FDEP has taken regarding the siting, permitting, design, construction, operation, and monitoring of MSW disposal facilities located in karst geologic settings.

Development of a Technical Advisory Group (TAG)

To assist the agency in this initiative, the FDEP has commissioned a Technical Advisory Group (TAG) comprised of a number of engineers, geologists, and scientists from both the public and private sectors with expertise in karst assessment to help the agency in the development of additional technical guidance. This guidance will assist: (i) the applicant in its preparation of MSW permit applications; (ii) the FDEP personnel responsible for technical review of the permit application

to verify compliance and reasonable assurance; and (iii) the public in its review and critique of the permit applications. The charge to the TAG is to assist the FDEP in the development of technical guidance for the siting, permitting, design, construction, operation, and monitoring of MSW disposal facilities sited in karst settings. The two primary objectives of this technical guidance includes specific recommendations that will help: (i) the FDEP decide how to evaluate these permit applications and then issue the solid waste disposal permits; and (ii) the applicant know what information should be submitted in these permit applications. Importantly, the FDEP required that site- and region-specific recommendations be provided but acknowledged that in developing the guidance, there needs to be a balance between “cost of assessment and investigation” and the “risk of failure.” Furthermore, the guidance needs to apply both “good science” and “reasonable judgment” when making recommendations. Finally, because the TAG members represent a diverse group of professionals, FDEP required that members set aside personal interests, if any exist, and focus on what is really “good” for Florida.

Specific Objectives of the TAG

Recall that the primary objective of the USEPA and FDEP regulations was protection of groundwater resources. FDEP recognized the USEPA findings that essentially validated the intention of the Subtitle D regulations. Specifically, the findings presented in Bonaparte, et al, (2002) demonstrated that the composite liner system design and the leachate management system design and operations requirements promulgated by the Subtitle D regulations resulted in landfill liner systems that were protective of groundwater. As mentioned previously, the challenge in the geologic setting in Central Florida is to assure the structural integrity of the liner system. Therefore, the FDEP charge to the TAG was to provide specific guidance to help the FDEP gain “reasonable assurance” that the foundation below the landfill would provide sufficient strength to maintain the structural integrity of the landfill liner system. To accomplish this objective, the FDEP requested that the TAG develop specific guidance regarding (in order of priority): (i) using physical and geophysical techniques for characterizing sinkhole potential of a site; (ii) determining if potential sinkhole risks for a site are low, moderate, or high; (iii) deciding when a site cannot be used or can be used if properly stabilized; (iv) stabilizing a site and

determining that stabilization was achieved; and (v) monitoring a disposal facility for sinkhole formation. A brief discussion of the approach used to address each of these tasks and preliminary recommendations by the TAG follow.

Characterizing Site for Sinkhole Potential

The first and most important step is to adequately characterize the potential site. At a minimum, this task includes: (i) review of geologic information regarding the area, particularly the conditions within a 16-km (10-mile) radius of the site; (ii) review of historical aerial photographs of the area within a 16-km (10-mile) radius spanning several years (or decades when possible) followed by physical inspection of the site with photos “in hand”; (iii) geophysical investigation along several transects, including orthogonal transects that intersect at the location of specific invasive subsurface borings/soundings; and (iv) physical invasive investigation, sampling, and in situ testing. This strategy recognizes that the potential for sinkhole development starts at a region-wide level before it eventually gets to a site-specific consideration. If there are reported subsidence features within the 16-km (10-mile) radius, reports should be cited and details of the features should be included in the permit application. With regards to the geophysical testing, electrical resistivity and ground penetrating radar (GPR) seem to be common techniques that have been used successfully in Florida. Other techniques will be considered. It is critically important that these non-invasive tests be “calibrated” at specific locations by having the transects intersect select boring/sounding locations. Invasive testing can include hollow stem auger or mud rotary drilling, with the latter being preferred due to the ability to note “rod drop” and “slurry loss.” Soil samples and rock cores should be collected. In situ testing can include the Standard Penetration Test (SPT) or the Cone Penetrometer Test (CPT). The TAG is currently considering the recommended minimum number of geophysical transects, the depth and extent of coring, and the minimum number of borings/soundings, as well as the recommended laboratory tests. The recommendations will vary depending on the findings from the geological and aerial photograph review.

Assessing Sinkhole Potential Risks

Perhaps the most difficult task facing the TAG is the assessment of the risk of a sinkhole developing at the proposed MSW disposal site. The FDEP would like

the assessment to report a “high,” “medium,” or “low” risk to the landfill stability in the event of sinkhole activation. Essentially this implies pre-formation information regarding the potential size of the sinkhole, as large sinkholes present significant challenges to the landfill liner integrity. The TAG is considering a detailed assessment of the FGS and WMD files regarding the location and size of the reported subsidence features so that regional lessons can be reported based on past performance. At a minimum, the TAG hopes to adopt or develop objective criteria that defines high, medium, and low risk.

Evaluating Site Suitability

One of the objectives from the previous task (i.e., assessing risk should a sinkhole develop) is to develop objective evaluation criteria to assess site suitability for a MSW disposal facility. Although in its preliminary state, the TAG anticipates that there will be a strong correlation between the high, medium, and low classification in the previous step and the assessment of site suitability. The TAG recognizes the argument from applicants that “all sites are potentially suitable for development provided there is sufficient stabilization and adequate engineering control.” The FDEP does not necessarily want to “condemn” a site *a priori*, but clearly wants to make the applicant aware that certain geologic conditions will render a site essentially “unsuitable” “due to the likelihood of sinkhole development and the risk of the sinkhole on the integrity of the landfill liner system. Figure 7 provides an example of a potentially “unsuitable” site. This aerial map, when combined with historical photos from the previous 20 years, showed a gradual and steady development of large sinkholes that extend to the ground surface and “grow” over time. For most sites (and in particular this site), it is important to understand the geologic setting and the sinkhole-forming mechanism to assess whether it is economical to “arrest” future sinkhole development or better to simply abandon the site.

Defining Site Stabilization Measures

One of the major contributions of the TAG will be to help the FDEP define minimal stabilization efforts that may be required to improve the suitability of the site to a level that provides “reasonable assurance” to the FDEP that the site can be developed in compliance with the FDEP regulations. Depending on specific site conditions, techniques may include (but are not

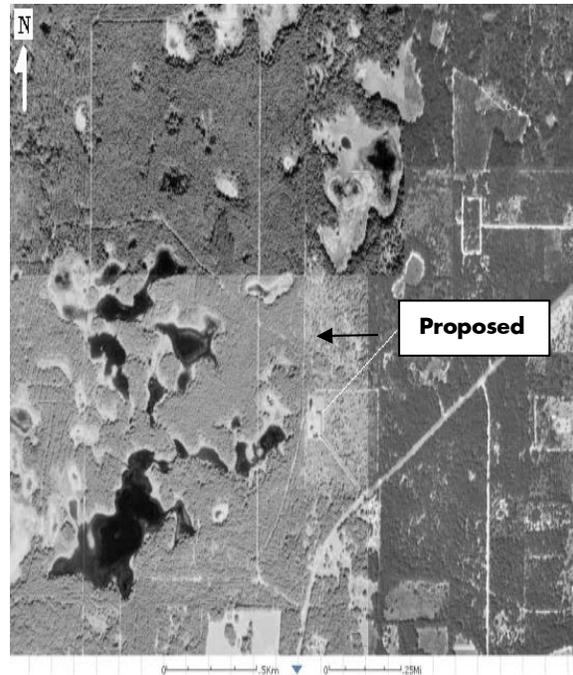


Figure 7. Example of a Potentially Unsuitable Site.

limited to) deep dynamic densification, local or large-scale grouting, reinforcement, and over-excavation and replacement. The stabilization efforts will require that the applicant demonstrate the effectiveness of the selected stabilization remedy. With reference to Figure 7, it is difficult to envision any strategy that does not completely over-excavate and replace all of the soil overburden soil followed by treatment of the foundation bedrock. One aspect of stabilization that concerns the TAG is what is referenced as “The Dutch Boy Solution,” in which the plugging of one hole in the dike simply caused a new hole to form. Stabilization alternatives will need to consider “site wide” stabilization efforts or at least the impacts of “localized” stabilization efforts on overall site stability.

Monitoring for Sinkhole Formation

The FDEP acknowledges that the construction of a landfill, particularly large facilities, can alter the pre-development groundwater flow regime. The landfill has a beneficial effect of loading the foundation soils and restricting the vertical infiltration of water. However, site development plans can have adverse effects. Specifically, the design of surface water management ponds, localized infiltration of surface water, and excavation (i.e., unloading) the foundation soils can increase the potential for sinkhole development. The TAG anticipates

that there will be recommendations for monitoring the site, as well as the surrounding parcels of land, for early indications of new sinkhole formation. Unfortunately, simple settlement monitoring is insufficient because the solid waste itself decomposes over time resulting in significant mass loss and self-weight compression. These recommendations will include provisions by the applicant for modifying operations and addressing these features should they occur.

This section identified the overall strategy being undertaken by the TAG to assist the FDEP. The primary objective of the TAG is to provide objective recommendations and minimum expectations regarding exploration and investigation programs that are based on regional- and site-specific conditions. The goal is that these efforts and objective recommendations will provide a “level playing field” for all MSW permit applicants.

The Solicitation...Obtaining Feedback and Recommendations from Karst Experts

The purpose of this paper was to describe a strategy currently being implemented by the FDEP to improve the MSW landfill permitting process in karst geologic settings. Several of the charges to the TAG involve attempting to quantify a complex geologic phenomenon. The authors recognize that the participants at this conference (and readers of the proceedings) may have specific experience that could benefit the FDEP and its TAG. Therefore, the authors explicitly solicit feedback and suggestions regarding the strategy identified. Specifically, are the participants/readers aware of or have recommendations regarding: (i) other similar efforts by other agencies that would benefit the TAG, (ii) specific experience regarding the karst systems in Florida that need to be considered; (iii) geophysical testing techniques or test frequencies/densities that should be considered; (iv) stabilization options that have (or have not) worked effectively; and (v) specific experience regarding the characterization and monitoring of MSW landfills that should be considered. The authors recognize that the experience may be region-, formation-, and/or site-specific, but the experience of the participants will be useful in helping complete the TAG’s mission.

Conclusion

The FDEP has developed and currently maintains and enforces solid waste regulations in the State that exceed the national standards but desires to improve the MSW landfill permitting process. The State of Florida is currently the 4th most populated State and Floridians generate solid waste at a rate that exceeds the national average. MSW landfills are a necessary component of Florida’s future anticipated growth. Unfortunately, Central and Northeast Florida comprise nearly 60 percent of the total land area in the State and is founded on geologic formations that have experienced significant subsidence due to sinkholes. These same areas are within zones where the valuable groundwater resources are considered most vulnerable and include areas of the highest population density. The FDEP has developed a strategy for providing MSW landfill permit applicant with objective recommendations for investigating future potential landfill disposal sites. It is the hope of the FDEP and its TAG that these recommendations will help the permit applicants provide the FDEP a “reasonable assurance” that the siting, design, construction, operations, and monitoring of the proposed facility is in compliance with FDEP regulations. The authors solicit feedback from conference participants (and proceedings readers) regarding techniques to improve the strategies identified in this paper.

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