ARM Group Inc.
Earth Resource Engineers and Consultants

June 11, 2013

Mr. Todd Scipioni
Iona Swim Club
1301 Fonderwhite Road
Lebanon, PA 17042

Re: Repair of Poolside Sinkhole
at Iona Swim Club
ARM Project 13236

Dear Mr. Scipioni:

This letter summarizes and documents ARM's observations and recommendations regarding the sinkhole that opened on or about Thursday May 23, 2012 adjacent to the northeast corner of the main pool at the Iona Swim Club.

First Inspection

At the time of ARM's first site inspection on May 24th, the collapsed area was approximately 20 feet by 30 feet in surface extent, and approximately 15 feet deep at the low point. The long dimension of the collapsed area paralleled the north end of the pool, and the collapsed area extended northward to the south end of the adjacent children's pool. The severed end of the pool drain line; long term leakage from which is believed to have been a primary source of the water causing the sinkhole; was exposed in the side of the collapse immediately adjacent to the northeast corner of the pool. The collapse had undermined the concrete paving slabs on the north side of the main pool, and utility lines were exposed beneath the slabs. The near-vertical side of what appeared to be a pinnacle of limestone bedrock was exposed immediately adjacent to the northeast corner of the main pool.

As we discussed on Friday, May 24th, the most reliable sinkhole repairs bear on bedrock. The most favorable scenario with respect to effecting a long term repair of the swim club sinkhole would entail exposing bedrock in the bottom of the collapsed area; pouring a slab or plug of concrete across the bedrock surface in order to provide a secure base for the remainder of the backfill materials; then completing the repair by backfilling with low permeability clayey soil. Such a repair could be characterized as an "impermeable" repair, as opposed to a repair method typically referred to as a "graded filter". Installation of a graded filter entails placement of free-draining materials between the top of rock and whatever material is used to backfill the remainder of the collapse. The intent of a graded filter is to allow water to continue to percolate through soil and into bedrock, but without permitting the transport of soil into bedrock that caused the previous sinkhole. Graded filters should only be installed, however, when the filter can be constructed directly on bedrock.

Based on our discussion it was my understanding that the Club would likely pursue excavation of the collapsed area with the hope and intent of exposing sufficient bedrock to implement an impermeable repair.

Second Inspection

In response to your request of Wednesday June 5th, I inspected the sinkhole on Thursday June 6th. At that point the collapsed area had been excavated to a depth of approximately 18 to 20 feet, which you noted was near the limit to which the available track hoe could reach. The bedrock pinnacle which had been partially exposed during the first inspection of May 24th had been exposed to a depth of approximately 12 feet. No other bedrock had been exposed by the excavation, however, and the gentlemen who had performed the excavation reported that he had not encountered anything he believed to be bedrock in any other portion of the excavation.

Repair Options

We discussed the following two basic repair options while on site on June 6th:

1. Continue excavation in the hopes of encountering bedrock and implementing a repair bearing on bedrock – This would require mobilizing a larger track hoe, possibly in conjunction with benching the excavation on the east side to provide a lower working surface for the track hoe. If bedrock was encountered, presumably a concrete slab or plug could be poured to provide the base for an impermeable repair. Increasing the vertical and lateral extent of the excavation, however, would increase the possibility of settlement or outright collapse of some portion of the adjacent swimming pools. If bedrock was not encountered within say 5 to 10 feet of the present bottom of excavation, at that point the excavation would have grown so large that any further excavation would entail significant risk of damage to the adjacent pools. Based on our discussion it is my understanding that the Club will probably not elect to pursue this option.
2. Construct a repair working from the current bottom of excavation – This would entail removing as much of the soil remaining in the excavation as possible working with the available track hoe, then building a repair. Based on our discussion it is my understanding that the Club may elect to pursue this option.

If a repair is constructed working from the current bottom of excavation, my recommendations would be to place the boulders that have already been excavated on the bottom of the excavation and pour concrete around the boulders in order to knit them together to the greatest practical degree. The boulders should be placed in loose layers no thicker than 3 feet before concrete is poured, and vibrated to promote complete filling of the void spaces between the boulders. As many boulders as available should be concreted into the excavation, and the minimum recommended thickness of concreted boulders is 6 feet. If the number of boulders available is not sufficient to produce a 6 foot layer, additional concrete should be placed on the concreted boulders as needed to provide a combined thickness of at least 6 feet. After the concrete has had at least 24 hours to set, low permeability, clayey soil should be used to backfill the remainder of the excavation. Soils used for backfill should contain at least 30 percent silt- and clay-sized particles, and exhibit some cohesion (ARM can assist the Club in making this determination if so

requested). Soil should be placed in lifts not exceeding 8 inches in depth, and should be thoroughly compacted by a sheepsfoot roller and/or oscillating plate compactor (more commonly referred to as a "jumping jack" or "whacker"). When the backfill level reaches the small gap that has opened beneath the bottom of the north edge of the pool and the underlying soil, the gap should be filled as completely as possible with a flowable grout or mortar mix. Building a small dike around the gap opening, or bringing the adjacent fill level slightly above the gap, will be needed to force the grout or mortar to flow into and fill the gap. Care should be taken to backfill tight against the exposed rear face of the pool walls. Based on the portion of the pool wall exposed by the collapse it appears that the pool walls were formed by shotcreting over wire mesh. As we discussed at the site, the pool walls could be displaced forward (i.e. into the pool) by compacting soil tight against the rear face. Accordingly it is recommended that a gap be left between the soil backfill and the exposed pool wall, and that gap filled with grout, mortar, or some similar self-hardening material that can be poured. Replacement of the damaged pool piping and other utility lines damaged or displaced by the sinkhole collapse will also be required. It is recommended that any water-bearing pipes be replaced with as strong and durable a material as practical, such as ductile iron.

Other Considerations and Options

We discussed the feasibility and value of performing some type of geophysical survey(s) in the vicinity of the pools. The intent of such surveys would be to assess the size and extent of voids, saturated soil zones, and similar subsurface features that could be indicative of existing or developing sinkholes. While there is no harm in performing such surveys, the Club should be aware that the accuracy and precision of such surveys are inherently limited. It is certainly possible that a geophysical survey would disclose the presence of a subsurface void or similar sinkhole-related feature that could threaten the integrity of the pool(s) and/or adjacent ground surfaces. Based on my experience with geophysical surveys; and with subsurface conditions in general in sinkhole-prone areas; I would expect a geophysical survey to disclose the presence of at least some subsurface features that could be indicative of past or ongoing sinkhole activity. Such features may or may not pose a present or future threat to the integrity of the pool or the safety of its users. While there may be real value in performing a geophysical survey, if a survey is performed the Club should be prepared for the eventuality of the disclosure of subsurface features that may or may not threaten the pool or its users, and which would require significant effort and funds to further investigate and/or treat.

We discussed drilling relatively small (4 to 6 inch diameter) holes through the pool bottom in order to evaluate the presence of any gaps or voids immediately beneath the pool. I recommend this a worthwhile precautionary measure. If small voids are encountered, they should be gravity-grouted with neat cement grout. If numerous and/or large voids are encountered, further exploration and treatment of subsurface conditions may be warranted. If properly filled with a high quality non-shrink grout I would not expect any significant seepage through the filled holes over the long term.

We discussed injecting grout into the soils around the sinkhole and/or adjacent areas in order to fill voids and densify soils. The grouting technique commonly used to mitigate sinkhole-related conditions is referred to as "compaction grouting". Compaction grouting entails the injection of

stiff grout under relatively high pressure to fill open voids and densify soft or loose soil. A compaction grouting program typically involves injecting grout into the ground through 3- to 5-inch diameter steel pipes that are drilled or driven to refusal on bedrock. Each hole is grouted in a series of steps, or "stages", as the grout pipe is withdrawn in increments of a foot or two. The volume of grout, and the pressure required to inject it, are monitored during the grouting process. Grouting continues at each stage until either a predetermined volume of grout has been injected; until a predetermined pressure has been achieved; or until ground heave or structure movement is detected. Compaction grouting offers the advantage of accessing and treating voids and zones of disturbed soil without opening large excavations. In the case of the swim club sinkhole, compaction grouting could be performed as a precautionary measure in the areas around the repaired sinkhole; through the sinkhole repair in an effort to treat any disturbed soil and/or voids that underlie the repair; or in response to a geophysical survey that discloses the presence of subsurface features warranting remedial treatment.

Wherever concrete paving is replaced around the pools, the pavement should be sloped to grade away from the pools and the joints between slabs made as watertight as possible.

Monitoring of the completed repair was also discussed. If any further sinkhole activity occurs at the site, it would most likely be manifested by ground settlement in advance of actual ground collapse. The concrete paving around the pools, as well as the pools themselves, will tend to span underlying settlement and mask its presence. After new concrete pavement has been poured, however, small diameter pipes with removable caps could be flush-mounted within holes drilled through the slabs. If ground settlement beneath the slab occurred, hopefully any gap developing between the bottom of paving and the underlying ground surface would be disclosed by periodic monitoring through the pipes. Periodic inspection of the pool bottoms and walls for the development of cracking, depressions, or similar signs of movement or distress is also recommended. Any unexplained drops in water level within the pools should be investigated immediately, and the pools should not be used until the reason for the drop has been identified and corrected.

Risk Considerations

The potential for recurring sinkhole activity on the grounds of the Club, and particularly in the vicinity of the pools is of course a significant concern for the Club. No sinkhole repair can be guaranteed, and ground collapse beneath a water-filled pool could obviously be associated with some very dire consequences. Generally speaking, the more effort and money expended on a sinkhole repair, the more reliable that repair will prove over the long term. If the Club had essentially unlimited resources to expend on sinkhole repair and desired to minimize the potential for, and risks associated with, future sinkhole activity; I would recommend an extensive compaction program extending across the entire area that the Club wished to address, in concert with replacing the existing pools with pile-supported reinforced concrete structures capable of spanning between pile supports in the event of underlying soil collapse. While such measures would provide a high degree of reliability, the cost of implementing such measures would be equally high.

As we discussed at the site on June 6, sinkhole repairs that do not extend to bedrock are common, and as often as not they prove effective over the long term. In those cases where sinkholes recur after repairs have been made, in the large majority of such cases any surface collapse is preceded by measurable surface settlement. In my opinion, repairing the sinkhole from the current bottom of excavation (in the manner outlined above) is not unreasonable or irresponsible, provided that the repaired area is closely monitored thereafter for any signs of continuing or recurring movement. That being said, regardless of how conscientiously the repair work and monitoring are performed, the potential for a sudden collapse of some portion of one or both pools will still exist. I believe that possibility to be remote, however the Club needs to make its own assessment of the level of risk it is willing to accept, and act accordingly.

If the Club desired to enhance the reliability of a sinkhole repair that does not extend to bedrock, my recommendation would be to perform compaction grouting through the completed repair in order to treat whatever problem conditions might still underlie the repair. The cost of such a grouting program would depend upon a number of variables such as depth to rock and the volume of grout injected, but I would expect the program to cost in the range of $20,000 to $40,000. Compaction grouting could be performed at essentially any time after completion of the initial repair, in the event the Club wished to make provisions for a grouting program in its extended financial planning.

Please don't hesitate to contact me at 717-508-0529 if you have any questions or comments regarding the matters discussed herein. ARM appreciates the opportunity to provide our services to the Iona Swim Club, and is available to provide consultation through completion of repair activities

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Sincerely,

ARM Group Inc.

John C. Masland, P.E.
Vice President - Geotechnical Services