SAFETY OF DETENTION AND RETENTION PONDS

By Jonathan E. Jones, James Guo, Ben Urbonas, Rachel Pittinger

Jonathan Jones, P.E., is CEO of Wright Water Engineers Inc. in Denver, CO.
James Guo, Ph.D., P.E., is a professor in the University of Colorado's Civil Engineering Department.
Ben Urbonas, P.E., is manager of the Master Planning Program for the Urban Drainage & Flood Control District in Denver, CO.
Rachel Pittinger is a project engineer with Wright Water Engineers in Denver.

Introduction

Urban stormwater retention and detention ponds are widely used in the United States. Retention ponds, also commonly called wet ponds, refer to facilities that maintain a permanent pool, while detention ponds, often called dry ponds, contain water only in the aftermath of runoff events.

Although retention and detention ponds can be effective for stormwater management and flood control, they can also pose risks to public health, safety, and welfare. Urban storm drainage system planners, designers, facility owners, maintenance staff, and municipalities, including their elected officials and governing bodies, must be aware of such risks and insist on the use of recommended techniques to minimize them. Licensed professional engineers should be especially concerned about the risks that their designs may pose and be knowledgeable of design approaches that reduce such risks, given that their paramount responsibility as licensed professionals is to protect public health, safety, and welfare.

The purposes of this article are to

- review safety hazards that can be associated with retention/detention ponds;
- discuss techniques that can be used to reduce the risk of such hazards; and
- review representative pond safety recommendations and guidance from municipalities, state and federal governments, professional societies, and the general stormwater literature.

Although the focus of the article is on wet and dry ponds, many of the issues and recommendations presented here apply to other stormwater facilities, such as best management practices (BMPs), long underground pipes, and culverts (see the discussion of this topic later in the article). Conceptual designs of a typical wet pond and dry pond are provided in Figures 1 and 2, respectively. Photographs 1 and 2 show examples of typical facilities.

Photo 1: Typical retention pond

Photo 2: Typical detention pond

Overview
Unsafe conditions can occur under both dry and wet weather conditions. These range from readily apparent problems such as outlet pipes that are open (unprotected with trash/safety racks) to less obvious concerns such as outflow pipes that are subject to overwhelming hydrostatic forces due to high headwater depths. A complicating factor is that children are often attracted to stormwater facilities, and this poses special design challenges and risks. For instance, the authors are aware of a case where a dry pond in an office park had a rapid rise, and a child playing in the pond was apparently knocked down by jet flows from an inlet pipe, tumbled by vortex flows, and ultimately dragged into an unprotected outlet pipe by suction forces. These forces were not visible (apparent) when the water depth in the pond covered the pipe entrances and outlet. Although it is not feasible to anticipate every public safety risk, many scenarios are foreseeable and can be accounted for during design. Pond safety issues that do not involve drowning must also be considered. For example, embankment slopes that are too steep can be hazardous to the public and maintenance staff (such as those operating lawnmowers). Another example is high wingwalls or other vertical structures. In the past few years, a serious public health concern that has emerged is related to ponds that create mosquito-breeding habitat due to shallow and stagnant standing water, thus increasing the risk of West Nile virus to the adjacent community.

Specific Safety Deficiencies
The authors have observed the following safety deficiencies in storage facilities:

- Outlets are open and unprotected, they lack trash/safety racks, the racks have openings large enough to pose a danger to the public, and/or the racks are too close to the outlet to provide sufficiently slow flow velocities that will not impinge a person against them.
- Adjacent land uses are incompatible with storage facilities and few, if any, steps have been taken to minimize obvious risks. For example, a nursery school playground without a fence was observed immediately next to a retention pond that had a high concrete wall along one side without a suitable railing.
- The public is effectively invited to spend time near storage facilities because they are located in parks, along bike trails, next to playgrounds, etc., yet the designers fail to recognize that frequent use will occur, and public safety has clearly not been a specific design objective.
- Education of community residents, office and industrial park employees, users of multipurpose recreational facilities, etc., regarding pond hazards is not provided. Signs warning the public of rapidly rising floodwaters and associated danger are not posted.
- Sideslopes of the facility are excessively steep or vertical without suitable safety rails. As a result, it would be very difficult for someone to get out of the pond when water levels are rising.
- Sideslopes within the pond's permanent pool are too steep, and/or ponds lack "safety benches" around their perimeter.
- Pond inflow and outflow pipes are directly across from and in close proximity to one another. In this case, a person can be knocked over by the impulse forces (momentum) of inflows and then sucked into and/or pinned against the outlet structure.
- Pond depths increase very rapidly, and inflow/outflow pipes are quickly inundated and not visible.
- Hydraulic structures are designed and constructed in a manner that makes them hazardous. For example, steel bars on grates are not beveled, rounded, or covered, but have sharp ends. Bolts have jagged, exposed ends. Gaps between steel bars and concrete walls are too wide. Railings either are not used where they should be or are improperly designed.
- Ponds have a "hard edge" appearance, such as a block or cobblestone vertical wall, immediately adjacent to the water surface drop into a pond that has steep sideslopes, so a person who falls in cannot get out without having to swim.
- A variety of problems with spillways have been observed. For example, spillways are undersized. Dams and embankments are not designed to withstand overtopping forces during floods larger than they were designed to detain, despite the presence of homes and businesses in the "dam break" floodplain downstream. This is often the result of designers assessing embankment behavior for the design event, such as the 50-year storm or the 100-year storm, but failing to recognize that larger events can and do occur, and that the consequences of such events have to be considered.

- Inadequate maintenance and monitoring occur, thus leaving the facilities unable to function as designed or intended. For example, when pond outlet structures are fully or partially blocked with debris, the risk of embankment overtopping and failure increases. Orifices in riser pipes that are used to gradually "bleed down" a water-quality design storm typically have small diameters, which leaves them vulnerable to plugging by trash, debris, sediment, algae, etc., unless frequently inspected and maintained. This can lead to prolonged pooling of shallow, stagnant water, which sets the stage for mosquitoes and, potentially, West Nile virus.
- Other drainage facilities adjacent to the pond (designed at the same time as the pond) are unsafe, such as channels, drop structures, energy dissipaters, and culverts.

The key to reducing the observations described above is careful consideration of risks in the design phase, coupled with regular inspection and maintenance of the pond to ensure that the facility is functioning as intended and that unforeseen hazards have not been created.

<u>Design and Operational Techniques to Reduce Risks</u>
The following risk-reduction techniques are recommended (see Photographs 3-10 for examples):

Photo 3: Detention pond outlet with trash/safety racks

Photo 4: Detention pond with safe outlet, placed mid-pond, with mild sideslopes and good visibility from office building

Photo 5: Wetland vegetation in pond bottom promotes water-quality enhancement and tends to discourage public access

Photo 6: Limit the use of vertical walls, have mild sideslopes above and below walls, and use railings where appropriate.

Photo 7: Retention pond with various safety provisions, including mild sideslopes and shallow water around full pond perimeter

Photo 8: Fences have pros and cons as a safety measure; in general, do not rely exclusively on fencing for safety.

Photo 9: There is widespread recognition of public hazards associated with urban-area impoundments and attempts to limit liability.

Photo 10: Trash/safety rack on drop inlet pipe at wet pond

1. Inform members of the pond design team that promoting public safety is an essential design objective. Raise the subject regularly while the design is progressing. Educate designers to understand that safety can be addressed without significantly increasing costs or disrupting hydraulic function.
2. After a conceptual or preliminary design for the facility has been prepared, review it with the facility owner, municipality, state staff concerned with dam safety (if relevant), and parties charged with its long-term operation/maintenance for potential safety issues. Modify, as necessary, to reduce risks to the public. Pay particular attention to risks to unattended children. Engineers are advised to design storage facilities in concert with a landscape architect, who will often have excellent suggestions for promoting safety (along with techniques to enhance appearance and maintenance).
3. Outlets pose particular risks and merit special attention. Do not use open, unprotected pipes as outlets. Instead, integrate the outlet pipe into an outlet structure that has smaller openings, and/or utilize a sloping trash/safety rack at the pipe entrance. The rack should have a surface area that is many times larger than the surface area of the outlet pipe to reduce entrance velocities (which is necessary to minimize the risk of a person being pinned against the rack) and to ensure that if debris is a factor, at least some of the surface area of the rack will be open during flooding to enable the pond to drain.

   The Urban Drainage and Flood Control District in Denver, CO, has prepared detailed minimum design guidance for pond outlet racks. The rack should be sloped at 3H:IV or milder. A clear opening at the bottom of 9 to 12 inches will permit small debris at lower flows to go through. The bars on the face of the rack should be spaced to provide 4- to 5-inch clear openings between them. Transverse support bars should be minimized, but they are essential for structural support under heavy hydraulic loads and will enable a person to climb up the rack.

4. When feasible, place the outlet away from areas of heavy public use such as playgrounds, parks, and schoolyards. Screen the outlet so that the public will not be "drawn" to it. Thick shrubs, grading techniques, and aesthetic fencing or railing can be useful in this regard. Ensure that embankment sideslopes adjacent to the outlet structure are not too steep to enable people to scramble away from the structure as pond waters are rising.
5. Grade the overall site with safety in mind. For example, provide mild sideslopes leading to and within the pond and minimize the use of vertical walls. Use safety railings when vertical walls or overly steep slopes are used.
6. Integrate a safety ledge (also referred to as a safety bench) around the perimeter of the permanent pool of a pond. Fortunately, this recommendation is consistent with another technique related to stormwater-quality enhancement: integrating a littoral zone of emergent vegetation around the pond perimeter. Integrating a safety bench with emergent vegetation will discourage people from wading into the pond. This approach can also create wildlife habitat and provide an attractive natural shoreline.
7. Owners are advised to periodically observe the facility to ascertain how the public interacts with it. Owners should also consider the comments received from adjoining property owners. For example, if children are skateboarding on concrete pans in the bottom of a dry basin, they should be told not to do this and warned of the hazard. Signs that say "No Skateboarding" may be helpful, although it may also be necessary to create a rough surface to make skating difficult. For facilities that are on private property, it is often feasible to have them included on security watches. Security staff should be instructed to pay particular attention to them during runoff events.
8. Community education can be a valuable tool. Use signs that warn of rapidly rising floodwater and educational, interpretative signs that explain how the stormwater storage facilities work. Urge local radio and television stations to include short public service announcements that emphasize the hazards posed by storm drainage facilities. Educate schoolchildren to these risks. Distribute flyers. Inform homeowner associations and property owner associations (for commercial areas) of these risks. Ponds are often located near public facilities such as recreation centers, libraries, and fire stations. Staff can be asked to observe the storage facility during dry and wet weather conditions and to identify potential hazards. Similarly, facilities in office parks and industrial complexes are often visible to workers, and they can be asked to identify potential hazards.
9. Attempt to separate certain land uses, such as preschools, from ponds or incorporate obstacles that will assuredly prevent access.
10. Separate inflow and outflow pipes by long distances and ensure that the pipes are not directly across from each other. This will avoid the creation of a continuous flow stream (current), which poses special dangers for the public. If this is not feasible, use an energy dissipater at the outlet where it discharges into the detention facility.
11. Regularly inspect and maintain the detention facility. Anticipate potential problems. Look at the impoundment from the perspective of someone who knows nothing about the risks that such facilities pose. Look for potential hazards and address them.
12. Recognize that detention facility dams can be hazardous and use care in their design. Ensure that all aspects of dam safety, ranging from upstream and downstream sideslopes to spillway adequacy to behavior of the pond during overtopping, are addressed. In particular, acknowledge that floods larger than the 100-year event can and will occur, and determine how the dam will behave under such conditions. If the dam is anticipated to fail during extreme floods, analyze the downstream impact of such failure.
13. Take steps to eliminate shallow, shallow-stagnant water in the bottom of "dry" basins that can be conducive to mosquito breeding. For example, determine maximum groundwater table elevations prior to design. Do not use outlet structure designs that are subject to plugging. Consider the use of gravity underdrains.

    Because mosquitoes generally require a stable, shallow, and stagnant water surface for at least three days to reproduce, design ponds to drain the water-quality design storm in less than 72 hours and use fountains or aerators in wet ponds to induce waves. Over the past few years, there have been many articles in stormwater literature about mosquito control, and readers are urged to become familiar with this subject and to address it during design and operations/maintenance.

14. The question of whether to construct fences around detention facilities is complicated, with arguments both for and against the practice. Ultimately, the decision should be site-specific and there should be a good rationale for whatever decision is made.

    Fences certainly discourage some people from accessing ponds. Fences lend themselves to the installation of warning signs. Provided that fencing materials are carefully selected and well maintained, fences can be aesthetic.

    On the other hand, many children or youths will view crossing a fence as a worthy and exciting challenge. The authors have observed many unattractive, poorly maintained fences that are eyesores. It often seems to be the case that ponds surrounded by fences are not as well maintained as those that are in the open and more visible. Ironically, if a situation does occur involving public safety, reaching the person who requires assistance will be impeded by a fence. If the safety issues are addressed using many of the other techniques described in this article, it should not be necessary to fence the facility.

    Isolated lengths of fence can be desirable, provided that they are attractive and properly integrated into the overall site plan (again, this emphasizes the value in engineers working closely with landscape architects during design). For example, it can be valuable to include a fence at the top of a steep slope to discourage access.
15. Concrete pans in pond bottoms should be designed to make them less attractive for skateboarding, such as finishing the concrete with a rough texture and/or narrow V-shaped surface.
16. Reduce the number of small, onsite ponds that are used in new residential and commercial developments by appropriate drainage master planning, minimizing directly connected impervious area, using low-impact development measures, and emphasizing larger, regional storage facilities. It should not be necessary for every new convenience store, gas station, and fast food outlet to have its own dry detention pond, as this needlessly compounds public risks and creates other problems.

Safety Racks at Stormwater-Quality BMPs, Long Underground Pipes, and Culverts

Safety (trash) racks should often be integrated into the outlet structures for BMPs such as wetlands and swales. Although the primary focus of such facilities is water-quality enhancement, designers must concurrently protect public safety.

The use of trash/safety racks at inlets to culverts and long underground pipes should be considered on a case-by-case basis. While there is a sound argument for the use of racks for safety reasons, field experience has shown that when the culvert is needed the most–that is, during heavy runoff–trash racks often become clogged and the culvert is rendered ineffective. A general rule of thumb is that a trash/safety rack will not be needed if one can clearly "see daylight" from one side of the culvert to the other, if the culvert is of sufficient size to pass a 48-inch-diameter object, and if the outlet is not likely to trap or injure a person. By contrast, at entrances to longer culverts and long underground pipes and for culverts not meeting the above-stated tests, a trash/safety rack is necessary (Urban Drainage and Flood Control District 2001).

Conclusion

Public safety must be carefully accounted for when planning, designing, and maintaining urban stormwater detention and retention facilities, BMPs, culverts, and other facilities. Failure to properly address these risks could leave all parties involved with their ownership, design, and maintenance subject to legal liability in the event of injury or death. The potential risks are numerous and significant, but they can be managed. Indeed, the great paradox of designing safe stormwater detention and retention facilities is that if they are attractive, interesting, well maintained, and "inviting," they will be regularly used by people of all ages, and this will promote public safety.