Stormwater Best Management Practice

Wet Ponds

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Retention/Detention

Description

Wet ponds (also referred to as stormwater ponds, wet retention ponds, or wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). The primary pollutant removal mechanisms are sediment settling and pollutant uptake, particularly of nutrients, through biological activity in the pond. Traditionally, wet ponds have been a common stormwater control, especially for larger development projects.

Applicability

Wet ponds are widely applicable. Although they have limited applicability in highly urbanized settings and in arid climates, they have few other restrictions.

Regional Applicability

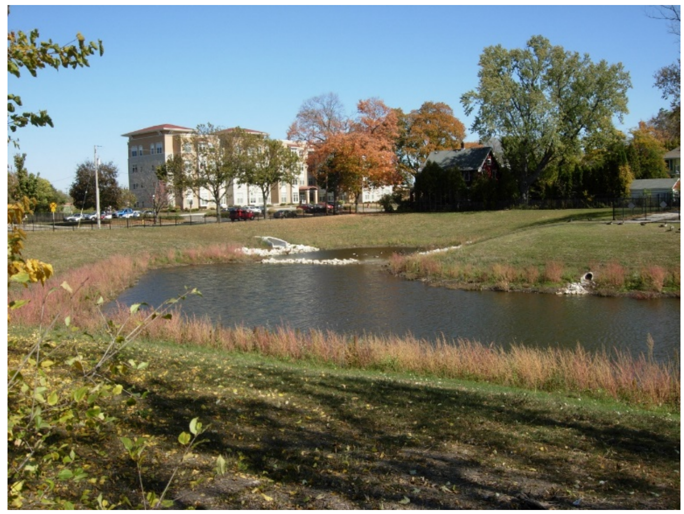
Wet ponds are suitable for most regions of the United States—except arid climates, where water scarcity makes it difficult to justify the use of supplemental water to maintain a permanent pool. Cold climates and karst topography may also call for modifications and design variations (see the "Regional Adaptations" section).

Urban Areas

Wet ponds may not be ideal for urban areas with little pervious area, due to the large continuous land area they need. They can, however, treat stormwater from an urban environment if located just outside a densely developed area.

Stormwater Hot Spots

Stormwater hot spots are areas where certain land uses or related activities generate highly contaminated stormwater. Typical examples include gas stations and industrial areas. Wet ponds can accept stormwater from hot spots—but, if they do, they need significant separation from groundwater.



Wet ponds have traditionally been used for stormwater control in larger development projects such as residential neighborhoods.
Credit: Photo by Aaron Volkening on Flickr (Creative Commons license)

Stormwater Retrofit

A stormwater retrofit is a stormwater control (usually structural) that a community puts into place after development to improve water quality, protect downstream channels, reduce flooding or meet other specific objectives. In the past, many communities constructed detention ponds for only flood control. With a permanent wet pool and an outlet structure modified for channel protection, though, a detention pond can provide water quality control (see "Treatment" under "Design Considerations").

Cold Water (Trout) Streams

Wet ponds pose a risk to cold water systems because of their potential to increase water temperatures. A number of factors affect pond temperature, including shading, depth, and the temperature of the surrounding air. In a study of several urban post-construction stormwater controls near trout habitat in North Carolina, Jones (2008) examined the way a wet pond affected the temperature of stormwater from an urban parking lot and found that the effluent from the wet ponds was significantly warmer than the influent water—meaning that wet ponds can raise surface water temperatures.

Siting and Design Considerations

Siting Considerations

Drainage Area

A wet pond needs enough drainage area to maintain its permanent pool. In humid regions, recommended drainage areas are generally 10–20 acres (NJDEP, 2014), though areas down to 5 acres are permissible in some locations (MDE, 2009). Wet ponds in an arid region may need larger drainage areas. When only small drainage areas are available, design engineers should consider practices that are more suitable for source control, such as bioretention.

Slope

Wet ponds can work at sites with an upstream slope up to about 15 percent. However, the local slope should be relatively shallow. Although there is no minimum slope requirement, there needs to be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system.

Soils/Topography

Wet ponds can work in almost all soils and geology, with minor design adjustments for regions of karst (i.e., limestone) topography. Designers can include liners for soils with high infiltration rates if water loss is a concern.

Groundwater

Unless stormwater hot spots are a concern, ponds can intersect the groundwater table. This contact generally minimizes infiltration losses and maintains saturation during periods of low rainfall. In extreme cases where groundwater inflow is large relative to surface water inflow, the shorter detention time can reduce pollutant removal. However, groundwater flows are typically small and the benefit to pond hydrology is far greater than any reductions in pollutant removal efficiency.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Most wet ponds, though, should have certain design features. These fall into five basic categories: pretreatment, treatment, conveyance, maintenance reduction and landscaping.

Pretreatment

Pretreatment features remove coarse sediment by settling before it reaches the large permanent pool. This reduces the maintenance burden of the pond. Pretreatment typically involves a sediment forebay, a small pool typically about 10 percent of the volume of the permanent pool. Coarse particles stay trapped in the forebay so maintenance staff can primarily clean out the forebay, eliminating the need to dredge the entire pond.

Treatment

The treatment area, or permanent pool, helps a stormwater control remove pollutants. The purpose of most treatment design features is to increase the amount of time that stormwater remains in the pond.

One technique to increase pollutant removal in a pond is to increase the volume of the permanent pool. Typically, designers size ponds to equal the water quality volume (i.e., the volume of water treated for pollutant removal). They may consider using a larger volume to meet specific watershed objectives, such as phosphorus removal in a lake system. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that enough inflow is available to maintain the permanent pool.

Another technique to increase pollutant removal is to increase the amount of time stormwater remains in the practice. To do this—and to eliminate short-circuiting—designers can create ponds with a minimum length-to-width ratio of 1.5:1 and add features (such as underwater berms) that lengthen the flow path through the pond. Similarly, a “treatment train” of several ponds in a series can slow the flow rate as well as providing redundancy.

Enhanced vegetation areas can also increase the effectiveness of wet ponds. Vegetated littoral zones (i.e., nearshore and shallow environments that receive enough sunlight to support vegetative growth) can increase vegetation uptake of pollutants and generate greater aesthetic appeal. The submerged and root zones of vegetation increase microbial activity, which can further enhance pollutant cycling and uptake. Where thermal impacts are a concern, vegetated buffers with shrubs or trees can shade (and thus cool) the pond water.

Stratification (i.e., the formation of distinct water layers) in wet ponds inhibits the mixing of water, which can create anaerobic conditions (i.e., no oxygen) near the pond bottom. This can cause sediment to release compounds such as phosphorus (Song et al., 2013). If pond stratification or phosphorus loading is a concern, designers can install a fountain or other mixing mechanism to mix the full water column and keep it aerobic.

Conveyance

A pond system should convey stormwater safely and in a manner that minimizes erosion potential. Designers should always stabilize the system's outfall to prevent scour, as well as providing an emergency spillway to safely convey water from large floods. Where thermal pollution is a concern, designers should provide shade around the channel at the pond outlet.

Maintenance

One potential maintenance concern in wet ponds is clogging of the outlet. A pond should have a non-clogging outlet such as a reverse-slope pipe or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool, extending in a reverse angle up to the riser, and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, floating debris is less likely to clog them. In addition, orifices should be wider than 3 inches: smaller orifices are susceptible to clogging.

Designers should incorporate features that ease maintenance of both the forebay and the main pool. A pond should have maintenance access to the forebay and a drain to draw down the pond for the more infrequent dredging of the main pond.

Landscaping

Landscaping can make a wet pond an asset to a community and can also improve its ability to remove pollutants. A vegetated buffer around the pond will protect the banks from erosion and remove some pollutants before stormwater enters the pond by overland flow. In addition, a planted littoral zone or an aquatic bench (i.e., a shallow shelf with wetland plants) around the edge can help stabilize the soil at the edge of the pond, enhances habitat and aesthetic value, and possibly provide some pollutant uptake. In all cases, designers should avoid fertilization of plants or turfgrass adjacent to the pond to limit nutrient discharge into the practice.

Design Variations

Design alternatives adapt wet ponds to various sites and account for regional constraints and opportunities.

Wet Extended Detention Pond

In concept, a wet extended detention pond combines wet ponds and dry extended detention ponds. It splits water between a permanent pool and detention storage above that pool. During storms, it detains water above the permanent pool and releases it over 12 to 48 hours. This design consumes less space but provides similar pollutant removal to a traditional wet pond.

Wet extended detention pond designs should maintain at least half the treatment volume in the permanent pool. In addition, designers need to carefully select vegetation for the extended detention zone to ensure that it can withstand both wet and dry periods.

Water Reuse Pond

Stormwater can be a valuable water resource, helping to offset the use of potable water in water-scarce regions (NASEM, 2016; Wanielista, 2007). Some designers have used wet ponds as a water source, usually for irrigation. In this case, a water balance analysis should account for the water that users will take from the pond.

Regional Adaptations

Semiarid Climates

Wet ponds are not feasible in arid climates, but may work in semiarid climates if designers give the permanent pool a supplemental water source or design the pool to vary seasonally. However, they should consider how much water the pool needs to stay permanent. For example, Saunders and Gilroy (1997) reported that a permanent pool of only 0.29 acre-feet in Austin, Texas, needed 2.6 acre-feet per year of supplemental water.

Cold Climates

Cold climates present many challenges to wet pond designers. Spring snowmelt quickly generates a large volume of water with a relatively high pollutant load. Cold winters may also cause the permanent pool or the inlet and outlet areas to freeze. In addition, high salt concentrations and sediment loads from road salting and road sanding may affect pond vegetation. If the facility receives water from roads, designers should consider planting the pond with salt-tolerant vegetation.

One option to address high pollutant loads and water volumes during spring snowmelt is the use of a seasonally operated pond to capture snowmelt during the winter and keep the permanent pool during warmer seasons. In this option, the pond has two water quality outlets, both with gate valves (Oberts, 1994; MPCA, 2019). The property owner or maintenance staff close the lower outlet during the summer and open it during the fall, and throughout the winter, to draw down the permanent pool. As the spring melt begins, they close the lower outlet again to provide extra detention volume. This method can act as a substitute for using a minimum extended detention storage volume. When wetlands preservation is a downstream objective, seasonal manipulation of pond levels may not be appropriate. Designers should analyze the effects on downstream hydrology before considering this option. In addition, the manipulation of this system requires some labor and vigilance—calling for a thorough maintenance agreement.

Several other modifications can improve the performance of ponds in cold climates, including:

- "Online" designs that allow continuous flow, which help prevent outlets from freezing.
- Outlets that are resistant to freezing. Examples include weirs or pipes with large diameters.
- Extended detention to retain usable treatment area above the permanent pool when it freezes.

Karst Topography

In karst topography, a wet pond needs an impermeable liner to prevent groundwater contamination or sinkhole formation and to help maintain the permanent pool.

Limitations

Limitations of wet ponds include the following:

- Wet pond construction can cause loss of wetlands or forest if planners choose the wrong location.
- Wet ponds are often inappropriate in dense urban areas because each pond generally needs a large continuous area.
  - The need to supplement the permanent pool restricts wet ponds' use in arid and semiarid regions.
  - In cold water streams, wet ponds are not feasible due to the potential for stream warming.
  - Wet ponds may pose safety hazards.
- If ponds are too deep and they stratify, they risk mobilizing and exporting dissolved phosphorus.

Maintenance Considerations

Though design features can minimize their maintenance needs, wet ponds still need regular maintenance and inspection. Table 1 outlines these practices. (Note that designers may need to adjust the listed frequencies based on local climate, activities in the drainage area, and community.)

Table 1. Typical maintenance activities for wet ponds.

Frequency	Inspection Items	Maintenance Actions
Once, after the first year	■ Check for 50% plant survival in the littoral zone ■ Check for invasive plants	■ Replant vegetation as necessary ■ Remove invasive plants
Monthly to quarterly, or after major storms	■ Inspect orifices and pipes for clogging ■ Check shoreline, inflows and discharges for erosion ■ Check for floating debris	■ Mow ■ Remove debris ■ Repair eroded areas, replant bare soil

Frequency	Inspection Items	Maintenance Actions
Semiannual to annual	■ Monitor wetland plant composition and health ■ Ensure mechanical components are functional	■ Clean up trash and debris ■ Remove invasive plants ■ Harvest wetland plants that are overgrown ■ Repair broken mechanical components
Every 1–3 years	■ Inspect all mechanical components, including pipes and risers ■ Monitor sediment deposition in facility and forebay	■ Repair broken mechanical components ■ Remove sediment from facility and forebay if needed

Source: Adapted from U.S. EPA, 2009

Effectiveness

Structural stormwater management, in general, is a way to pursue four broad resource protection goals: flood control, channel protection, groundwater recharge and pollutant removal. Wet ponds can provide flood control, channel protection and pollutant removal.

Flood Control

One objective of stormwater controls can be to reduce the flood hazard associated with large storms by reducing peak flow from these storms. Designers can easily customize a wet pond for flood control by providing flood storage above the level of the permanent pool.

Channel Protection

One result of urbanization is the landscape/geomorphic changes—such as eroded stream channels—that occur in response to modified hydrology. Traditionally, wet pond basins have provided control of the 2-year storm for channel protection. However, it appears that this control has been relatively ineffective for channel protection, and research suggests that control of a smaller storm, such as the 1-year storm, might be more appropriate (MacRae, 1996; Tillinghast et al., 2011). Most current regulations therefore require that channel protection features provide control of the 1-year storm event (e.g., MDE, 2009).

Groundwater Recharge

Wet ponds can only provide groundwater recharge in limited cases, and in soils with high infiltration rates. Generally, the buildup of debris at the bottom of the pond limits infiltration rates.

Pollutant Removal

Wet ponds can be very effective at removing stormwater pollutants, particularly those associated with settleable solids. A wide range of research is available to estimate the effectiveness of wet ponds. Table 2 summarizes pollutant removal data from a database of stormwater control performance (Clary et al., 2017).

Table 2. Typical pollutant removal rates of wet ponds.

Pollutant	Influent Concentration (Median)	Effluent Concentration (Median)
Total copper (µg/L)	8.24	4.00
Total zinc (µg/L)	22.60	12.00
Total suspended solids (mg/l)	38.9	12.0
Total nitrogen (mg/L)	1.50	1.31
Nitrate (mg/L)	0.45	0.22
Total phosphorus (mg/L)	0.18	0.10
E. coli (most probable number/100 mL)	780	180

Source: Adapted from Clary et al., 2017

Cost Considerations[1]

The construction costs associated with wet ponds can vary considerably. King and Hagan (2011) estimate that the construction cost of a wet pond can range from $35,000 to $75,000 per acre of impervious surface treated.

Ponds do not take up a large area relative to the drainage size of the watershed: typically 1–3 percent of the contributing drainage area (MPCA, 2019). They are still large, though, and they need a relatively large contiguous area. Other practices, such as filters or swales, may be better suited for small areas.

King and Hagan (2011) estimates the typical annual cost of routine maintenance for wet ponds at about 3 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the "Maintenance Considerations" section. Ponds are long-lived (typically lasting longer than 20 years): a community can consider its initial investment in light of this long life span.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

Clary, J., Jones, J., Leisenring, M. Hobson, P., & Strecker. E. (2017). *International Stormwater BMP Database: 2016 summary statistics*. Alexandria, VA: Water Environment & Reuse Foundation.

Jones, M. P. (2008). *Effect of urban stormwater BMPs on runoff temperature in trout sensitive regions* (Doctoral thesis, North Carolina State University).

King, H., & Hagan, P. (2011). *Costs of stormwater management practices in Maryland counties*. University of Maryland Center for Environmental Science.

MacRae, C. (1996). Experience from morphological research on Canadian streams: Is control of the two-year frequency runoff event the best basis for stream channel protection? In L. Roesner (Ed.), *Effects of watershed development and management on aquatic ecosystems* (pp. 144–162). Snowbird, UT: American Society of Civil Engineers.

Maryland Department of the Environment (MDE). (2009). *2000 Maryland stormwater design manual Volumes I & II*.

Minnesota Pollution Control Agency (MPCA). (2019). Design criteria for stormwater ponds. In *Minnesota stormwater manual*.

National Academies of Sciences, Engineering, and Medicine (NASEM). (2016). *Using graywater and stormwater to enhance local water supplies: An assessment of risks, costs, and benefits*. Washington, DC: National Academies Press.

[1] Prices updated to 2019 dollars. Inflation data obtained from the Bureau of Labor Statistics CPI Inflation Calculator website: https://data.bls.gov/cgi-bin/cpicalc.pl.

New Jersey Department of Environmental Protection (NJDEP). (2014). *New Jersey stormwater best management practices manual*.

Oberts, G. L. (1994). Performance of stormwater ponds and wetlands in winter. *Watershed Protection Techniques, 1*(2), 64–68.

Saunders, G., & Gilroy, M. (1997). Treatment of nonpoint source pollution with wetland/aquatic ecosystem best management practices. Austin, TX: Texas Water Development Board.

Song, K., Xenopoulos, M. A., Buttle, J. M., Marsalek, J., Wagner, N. D., Pick, F. R., & Frost, P. C. (2013). Thermal stratification patterns in urban ponds and their relationships with vertical nutrient gradients. *Journal of Environmental Management, 127*, 317–323.

Tillinghast, E. D., Hunt, W. F., & Jennings, G. D. (2011). Stormwater control measure (SCM) design standards to limit stream erosion for Piedmont North Carolina. *Journal of Hydrology*, *411*(3–4), 185–196.

U.S. Environmental Protection Agency (EPA). (2009). *Stormwater wet pond and wetland management guidebook*.

Wanielista, M. P. (2007). Stormwater—an alternative water supply. In K. C. Kebbes (Ed.), *World Environmental and Water Resources Congress 2007: Restoring our natural habitat* (pp. 1–14). Tampa, FL: American Society of Civil Engineers.