4.2 Wet Pond BMP Summary Fact Sheet

Description: Constructed storm water wet ponds have a permanent pool, a temporary pool and typically a littoral shelf with planted vegetation. Runoff from each rain event is detained and pollutants are treated in the pond. Temporary storage (live storage) is provided above the permanent pool elevation and is released at a controlled rate. Pollutant removal is primarily accomplished through sedimentation and biological processing.

IMPORTANT CONSIDERATIONS

DESIGN CRITERIA:

- Minimum contributing drainage area of 25 acres, unless a water balance computation is performed that shows the pond does not go more than one foot below permanent pool lelevation.
- A sediment forebay must be provided.
- Inflow energy dispersion structure is required to distribute flow and prevent short-circuiting and resuspension.
- Maximum average depth of permanent pool not to exceed 9 feet. Minimum average permanent pool depth must be 3 feet.
- Side slopes to the basin must not exceed 3:1 (h:v).
- Ten foot littoral shelves (safety ledges) must be provided and wetland plants should be incorporated.
- A landscaping/vegetation and maintenance plan is required.
- Minimum length to width ratio of 1.5:1.

ADVANTAGES/BENEFITS:

- Moderate to high removal rate of urban pollutants.
- High general and technical community acceptance.
- Opportunity for wildlife habitat.
- Can have aesthetic value within developments.
- Extensive experience in using these facilities.

DISADVANTAGES/LIMITATIONS:

- Potential for thermal impacts/downstream warming.
- Dam height design requirements for high relief areas.
- Basin drainage can be problematic for low relief terrain.
- Can increase downstream drainage and flooding problems if not properly designed and sited.
- In soils with high permeability, infiltration devices should be considered instead of wet ponds
- Outlet orifice clogging may be a problem
- Will require maintenance to preserve the aesthetic value.
- Permanent pool elevation should be no higher than 6" above the seasonally high water table (SHWT).

MAINTENANCE CONSIDERATIONS:

- Inspect outlet facilities for damage and clogging.
- Detention basins must be cleaned out after 25 percent of the main pond storage capacity is lost and forebays cleaned out after 50 percent of forebay capacity is lost.
- Adequate access must be provided and maintained for inspection and maintenance.
- General trash removal.

STORMWATER MANAGEMENT SUITABILITY

L = Low **M** = Moderate **H** = High

H | **1-inch, 6-hr Water Quality (WQ_v) Control**

H | **1-yr, 24-hr Channel Protection (CP_v) Control**

H | **Peak Attenuation Control for 10-yr, 6-hr Storm**

H | **Peak Attenuation Control for 25-yr, 6-hr storm**

Wet detention basins facilities are highly effective in controlling pollution removal for the 1-inch, 6-hr storm (WQ_v) and can be designed to control the volume for the 1-yr, 24-hr storm (CP_v) and peak attenuation for the 10- and 25-yr, 6-hr storms.

IMPLEMENTATION CONSIDERATIONS

H | **Land Requirements**

L | **Capital Cost**

M | **Maintenance Cost**

M | **Clogging Issues with Orifices**

PRIMARY POLLUTANT REMOVAL PROCESSES

- Settling

POLLUTANT REMOVAL RATES

Effectiveness	Detention Time	WQ_v/PP_v	Pollutant Removal Rates
Optimal Efficiency	4 days	0.3	85% TSS 70% TP
Standard Efficiency	2 days	0.6	60% TSS 40 % TP
TSS-Only Efficiency	4 days	0.4	85% TSS

4.2 Wet Ponds

4.2.1 General Description

Wet ponds (also referred to as retention basins, storm water ponds, or wet extended detention basins) are constructed storm water basins that have a permanent (dead storage) pool of water throughout the year and a temporary storage pool that fills during storm events. They can be created by excavating an already existing natural depression or through the construction of embankments.

Runoff from each rain event is detained by either displacing the permanent pool or by temporarily filling the temporary pool. Pollutant removal occurs in the permanent and temporary pool through gravitational settling and potentially through biological uptake by the vegetation and plants that surround the permanent pool on the littoral shelf. The permanent pool also serves to protect deposited sediments from re-suspension. The upper stages of a storm water detention basin are designed to provide extended detention of the water quality control volume (WQ_v), channel protection control volume, 1-year, 24 hour storm (CP_v), as well as normal detention of larger storm events to meet Q_p requirements.

Wet ponds are among the most cost-effective and widely used storm water practices. A well-designed and landscaped wet pond can be an aesthetic feature on a development site when planned and located properly. In some cases, wet ponds may be used for irrigation.

For design purpose in this manual, a wet pond is where 100% of the water quality volume is stored in the extended detention (ED) storage (temporary pool) provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 2 to 4 days, depending on the pollutant removal goals of the designer. In addition, the permanent pool volume must be several times greater than the temporary pool volume, also depending on the pollutant removal goals of the designer.

Multiple wet ponds systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways. The benefits of the additional cells can be designed through an assessment of the additional detention time that is provided. Figure 4.2.1 shows a typical local wet pond and Figure 4.2.2 show a schematic of a standard wet pond design.

Figure 4.2.1 Wet Pond Example

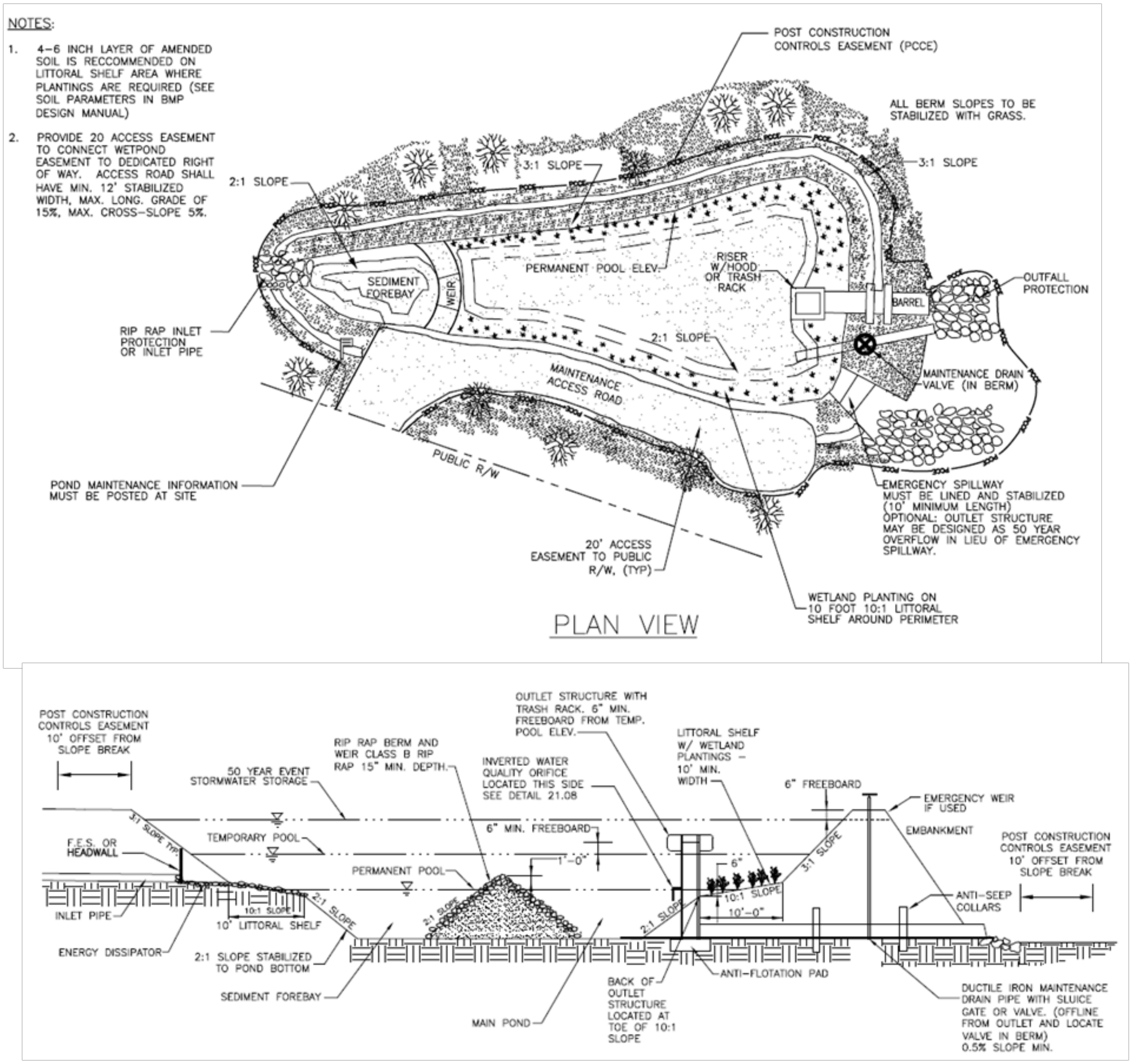


Figure 4.2.2 Wet Pond Schematic

4.2.2 Storm Water Management Suitability

Wet ponds can be designed to control both storm water quantity and quality. Thus, a wet pond can be used to address all of the design storms of interest.

Water Quality

Wet ponds treat incoming storm water runoff by physical, biological, and chemical processes. The primary removal mechanism is gravitational settling of particulates, metals, and organics as storm water runoff resides in the basin. Another potential mechanism for pollutant removal is uptake by wetland plants on the littoral shelf in the permanent pool – particularly of nutrients. Volatilization and chemical activity also work to break down and eliminate a number of other storm water contaminants such as hydrocarbons. Permanent pool elevation should be no higher than 6" above the seasonally high water table (SHWT).

Channel Protection

A portion of the storage volume above the permanent pool in a wet pond can be used to provide for the channel protection volume (CP_v). This is accomplished by releasing the 1-year, 24-hour storm runoff over 24 hours (a minimum of 5 percent of the CP_v must remain within the wetland temporary storage volume 24 hours after the 12^{th} hour, the center of rainfall for projects within Mecklenburg County and the six Towns. Within the City of Charlotte and its ETJ, this release is over 48 hours.

On-Site Flood Control

A wet pond can attenuate the post-development peak flow of the 10- and 25-year, 6-hour storm (if required) (Q_p) to pre-development levels by using the water quality and channel protection storage volume and/or using additional storage volume above the water quality and channel protection volume. The wet pond emergency spillway design is the 50-year storm with 6 inches of freeboard for ponds less than 15 feet in height. More detailed design standards for embankments taller than 15 feet can be found in the North Carolina Dam Safety Regulations.

4.2.3 Pollutant Removal Capabilities

Three wet pond designs have been developed for application in the Mecklenburg County area. The *optimal efficiency design* has the capability to remove 85% of the total suspended solids and 70% of the total phosphorus load. The *standard efficiency design* has the capability to remove 60% of the total suspended solids and 40% of the total phosphorus load. The *TSS-only efficiency design* has the capability to remove 85% of the total suspended solids and negligible total phosphorus load. All of these designs assume urban post-development runoff conditions that has been observed in the Mecklenburg County area and that the facilities are sized, designed, constructed and maintained in accordance with the recommended specifications contained in this manual. The design pollutant removal rates are derived from sampling data and computations completed for the development of this manual. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or "treatment train" approach. Pollution removal rates are affected by the choice of design variables. See Section 4.2.4 for a discussion of design variables and appropriate pollution removal rates for specific designs.

4.2.4 Planning and Design Criteria

The following criteria are to be considered minimum standards for the design of a wet pond. Items listed in Section 4.1.4.A through 4.1.4.H. are requirements and must be addressed in the design. Items listed in Section 4.1.4.I. are recommendations and are optional.

A. Design Requirements

Following is a list of design requirements that must be followed in the design of wet pond facilities.

- Following are the design values that are required for the three wet pond facility designs that are available for application in Mecklenburg County. The appropriate minimum design values and associated pollutant removal rates for each of the three designs are given in Table 4.2.1.

Table 4.2.1 Design Values and Pollution Removal Rates

Threshold	Min. WQ_v Detention Time	WQ_v/PP_v Ratio	Pollution Removal Rate
Optimal Efficiency	**4 days**	**0.3**	**85% TSS** **70% TP**
Standard Efficiency	**2 days**	**0.6**	**60% TSS** **40% TP**
TSS-Only Efficiency	**4 days**	**0.4**	**85% TSS**

- Water quality treatment volume (WQ_v) should be between 30% and 60% of the permanent pool volume, depending on the pollutant removal goals of the BMP. A portion of the WQv may be used for irrigation, which may be approved on a site-by-site basis.

- Five percent of the water quality treatment volume (WQ_v) must remain within the wet pond temporary storage volume for a duration between 2 and 4 days beyond the center of the storm event (center of the 1-inch, 6-hour storm event is assumed to be 3 hours), depending on the pollutant removal goals of the BMP.

- The routing of the channel protection volume (CP_v) is to be designed per this manual. Designs that account for a 4-day detention time for the WQ_v, but which release the additional volume of the CP_v in a manner that does not meet the intent of the slow release rate of the additional volume are not acceptable.

- A wet pond must have a minimum contributing drainage area of 25 acres or more to maintain a permanent pool unless water balance calculations are performed for wet ponds that receive runoff from drainage areas less than 25 acres. The water balance computations must show that the pond will maintain a water level no lower than 1 foot below the permanent pool elevation.

- Permanent pool elevation should be no higher than 6" above the seasonally high water table (SHWT). It is expected that a sufficient analysis will have the following minimum elements: (1) multiple soil samples serving to identify the soil type, (2) multiple field K results, (3) multiple soil samples to establish the SHWT at the proposed pond location, (4) a clear statement of the conservative aspects of the design case subjected to the hydrogeological analysis.

- An anti-clogging device must be provided for the wet pond outlet. Refer to Chapter 5 for more information.

- A sediment forebay must be provided to allow heavier sediments to drop out of suspension before the runoff enters the permanent pool. All forebays must be sized to hold a volume equal to 0.2 inches per impervious acre of contributing watershed.

- Inflow energy dispersion control structure is required to distribute flow and prevent short-circuiting and re-suspension of pollutants. This is normally accomplished by including a rip-rap apron at the forebay inlet. The pipe invert at the flared end section or endwall should be at the permanent pool, not submerged.

- Wet pond main pond areas must be cleaned out after 25 percent of the storage capacity is lost and forebays cleaned out after 50 percent of storage capacity is lost. The designer must convert these storage <u>volume</u> thresholds to site-specific <u>depth</u> thresholds that can be easily measured in the field.

- To avoid stratification and anoxic conditions, maximum average depth of the permanent pool should not exceed 9 feet. However, deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects.

- Minimum average depth for the wet pond must be 3 feet.

- Side slopes to the wet pond must not be steeper than 3:1 (h:v) without safety precautions. If mowing is anticipated, the side slopes should terminate on a safety bench. The safety bench requirements may be waived if slopes are 4:1 or gentler. See Figure 4.2.3.

- Littoral shelves (aquatic shelf) must be provided around the main permanent pond perimeter as minimum safety benches and to potentially increase biological uptake through recommended shallow water plantings. The minimum width of the littoral shelf is 10 feet with a slope of 10:1 (horizontal : vertical). Half of the shelf should be submerged below the permanent pool, while the other five feet should be above water. Appropriate plantings should be provided on the littoral shelf, but alternate vegetation plans may be submitted for review. Alternative vegetation plans may include floating islands and bank stabilization of wet ponds used for irrigation.

- A landscaping/vegetation and maintenance plan is required.

- The minimum length to width ratio of 1.5:1 is required.

- Wet ponds cannot be located within a stream or any other navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State and/or Federal Permits.

- In no case should a building be located within the impoundment area of the storm water facility

- All embankments shall be designed per the North Carolina Dam Safety Law of 1967, if applicable, and designed according to the requirements in Section 4.0.6. of this manual.

- No utilities (sewer lines, power lines, water lines, etc.) shall be located within or under the storm water facility

- Minimum setback requirements for wet pond facilities (when not specified by other ordinance or criteria):
  - From a property line – 10 feet
  - From a private well – 100 feet; if well is down gradient from a hotspot land use then the minimum setback is 250 feet.
  - From a septic system tank/leach field/spray area – 50 feet

- A water-tight seal (rubber boot or equivalent) must be provided between all riser and pipe joint connections to minimize leakage.

- Outlet structures should have protected access that may be accessed easily from the shore for inspection. Boats and ladders should not be needed to access outlet structures.

B. Physical Specifications/Geometry

In general, wet pond designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for wet pond design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

- Proper geometric design is essential to prevent hydraulic short-circuiting, which results in the failure of the wet pond to achieve adequate levels of pollutant removal. The minimum length-to-width ratio for the permanent pool shape is 1.5:1, and should ideally be greater than 3:1 to avoid short-circuiting. In addition, wet ponds should be wedge-shaped when possible so that flow enters the permanent and temporary storage area and gradually spreads out, improving the sedimentation process. Baffles, wet pond shaping or islands must be added within the permanent pool to increase the flow path, if the minimum length-to-width ratios are not met. The addition of baffles, wet pond shaping or islands must be assessed to ensure that the permanent pool and/or temporary pool design requirements are met.

- The perimeter of all deep pool areas (4 feet or greater in depth) should be surrounded by the aquatic bench (littoral shelf). A littoral shelf (aquatic bench) extends inward from the normal pool edge (5 feet) and has a maximum depth of 6 inches below the normal pool water surface elevation (see Figure 4.2.3). When floating islands are used, the planted area should be between 8 and 10% of the total surface are of the wet pond.

- The contours and shape of the permanent pool should be irregular to provide a more natural landscaping effect.

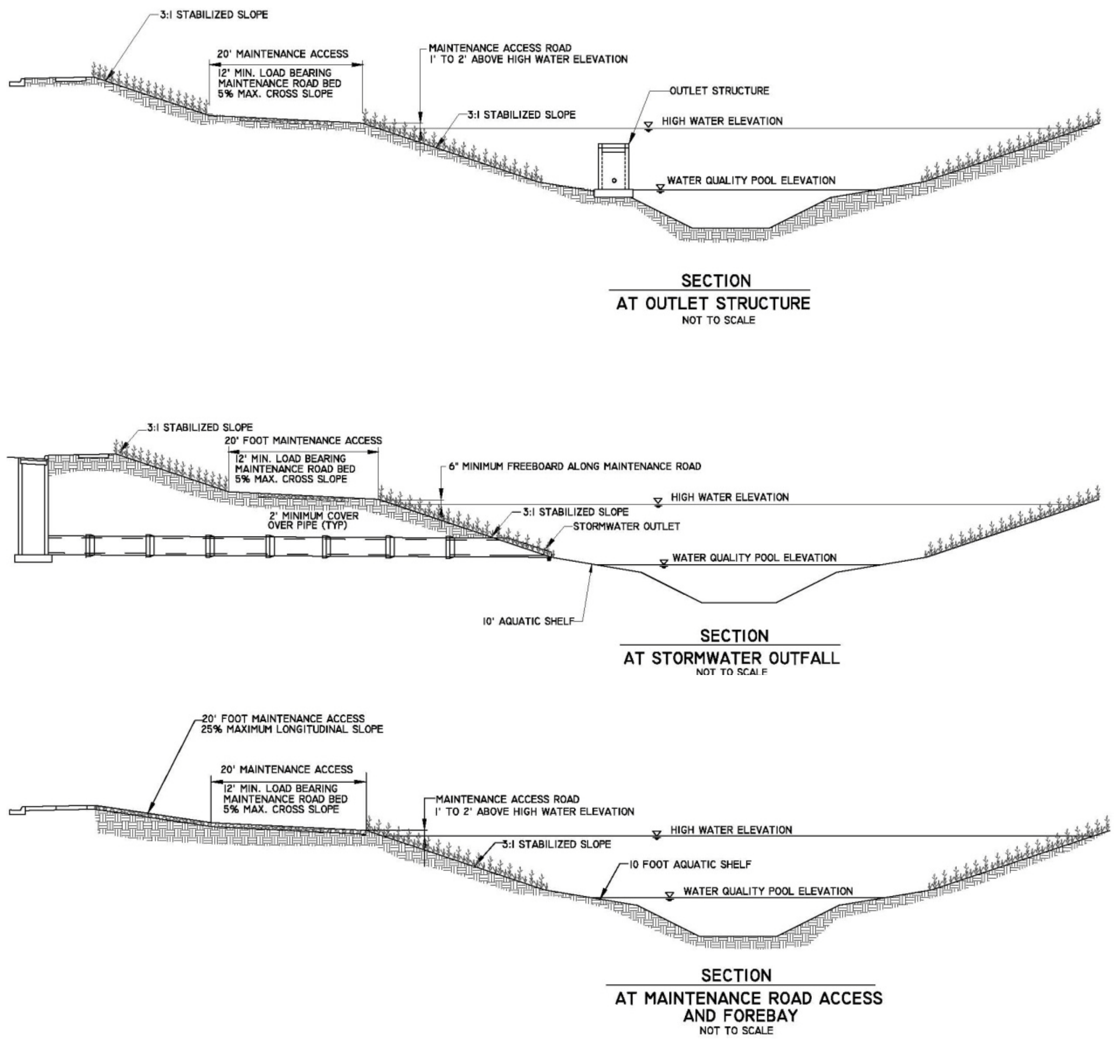


Figure 4.2.3 Typical Wet Pond Side Slope Geometry

C. Pretreatment/Inlets

Each wet pond must have a sediment forebay at each concentrated flow location. A sediment forebay is designed to remove incoming sediment from the storm water flow prior to dispersal in a larger permanent pool. For each major inflow location, the forebay is a separate cell, formed by a barrier to control flow into the main basin.

The forebay is sized to contain 0.2 inches per impervious acre of contributing drainage and should be 4 to 6 feet deep. The pretreatment storage volume is part of the total WQ_v requirement and may be included in WQ_v for permanent pool sizing.

A fixed vertical sediment depth marker must be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier. Information for clean-out depth for forebay should be included on maintenance sign.

Inflow channels are to be stabilized with flared riprap aprons or an equivalent energy dissipation device. Inlet pipes to the wet detention basin cannot be partially submerged. Inflow pipe, channel velocities, and exit velocities from the forebay must be non-erosive.

Forebay berms constructed in fill should have the same compactions and soil standards as the main pond berm. The forebay berm must be constructed to the elevation of the Water Quality Event (WQ_v). A weir is then recommended that is a minimum of five feet wide (or 1/3 the length of the forebay berm, whichever is larger) and located to maximize the flow path of the runoff from the water quality storm. The weir should be lined with NCDOT Class ‘B’ riprap and underlain with an appropriate filter fabric. The top surface of the riprap is recommended to be located at the normal pool of the pond.

D. Outlet Structures

Flow control from a wet pond is typically accomplished with the use of a concrete or aluminized steel riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the bottom of the wet pond with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 4.2.4).

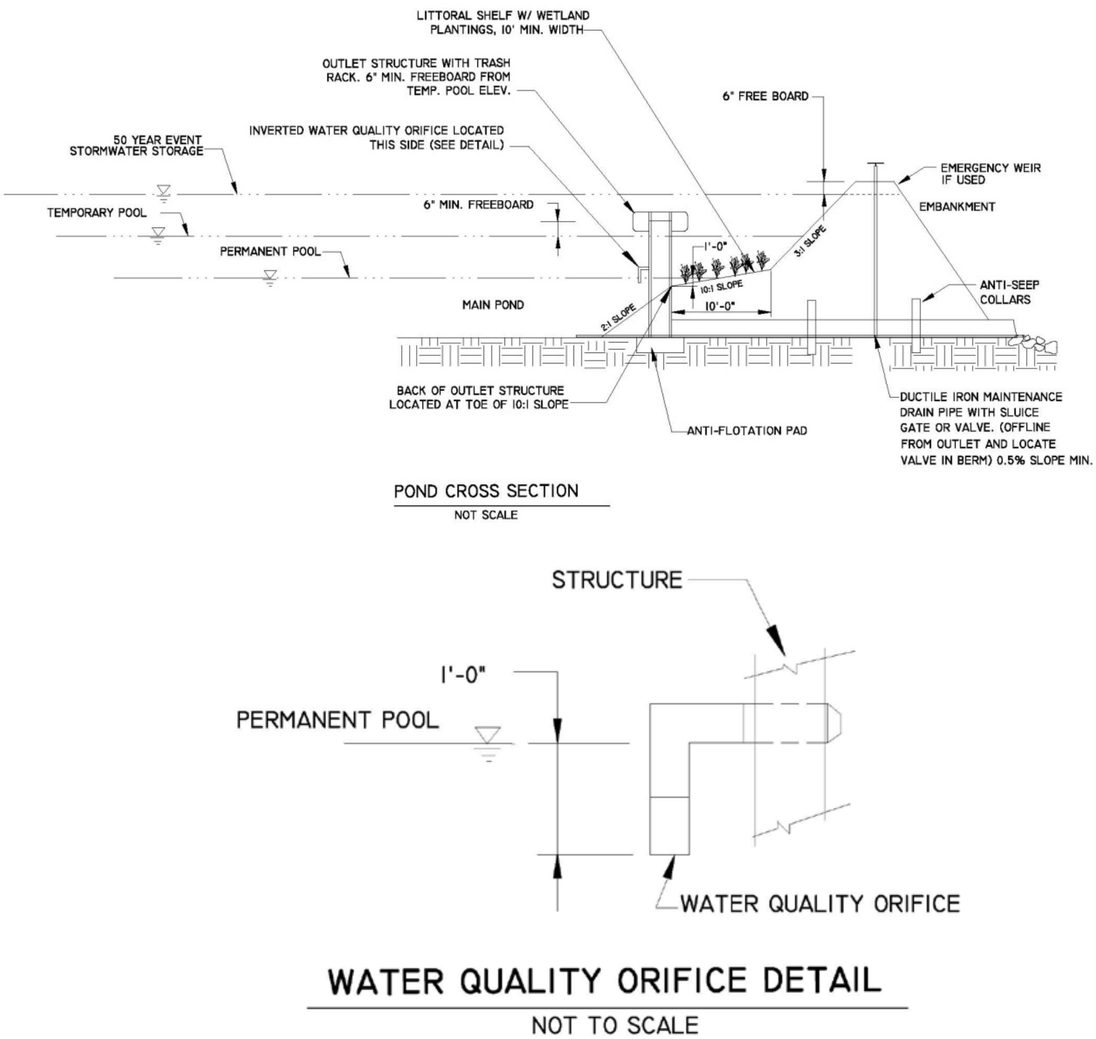


Figure 4.2.4 Typical Wet Pond Outlet Structure

A number of outlets at varying depths in the riser provide internal flow control for routing of the water quality, channel protection volume control, and on-site flood control runoff volumes. The number of orifices can vary and is a function of the wet pond design.

For the wet pond there is a need for an orifice (usually) that is sized to pass the water quality volume (WQ_v) that is temporarily stored on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality volume (WQ_v) in 2 – 4 days, depending on the pollutant removal goals of the BMP design. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water from the surface of the wet detention basin. The next outlet is sized for the release of the channel protection storage volume (CP_v). The outlet (often an orifice) invert is located at or above the peak stage associated with the water quality volume (WQ_v) and is sized to release the channel protection storage volume (CP_v) over a 24-hour period within Mecklenburg County and the six Towns and over a 48-hour period in Charlotte and its ETJ.

Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular weir, V-notch weir, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool. Other approved non-clogging outlet designs are presented in Chapter 5.

Higher flows pass through openings or slots further up on the riser.

After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars must be installed on the outlet barrel to reduce the potential for pipe failure.

Riprap, or other energy dissipators must be placed at the outlet of the barrel to prevent scouring and erosion. If a wet pond outlet daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Chapter 8, Energy Dissipation, in the Charlotte-Mecklenburg Storm Water Design Manual for more guidance.

Each wet pond must have a bottom drain pipe with an adjustable valve that can drain the permanent pool within 24 hours. The bottom drain valve must be accessible by maintenance personnel during the 50-year storm event by either being located within the embankment or through alternative maintenance access. Some jurisdictions may allow the option of mechanical pumping of ponds for maintenance in lieu of providing a bottom drain. This option may not be allowed for BMPs that will be maintained by the jurisdiction.

The wet pond bottom drain should be sized one pipe size greater than the calculated design diameter. It is recommended that the drain valve be a plug valve conforming to AWWA C-504 Section 5.5 and operable from a land-accessible location via a handwheel.

The outlet system must be designed to be water-tight. A water-tight seal (rubber boot or equivalent) must be provided between all riser and pipe joint connections to minimize leakage. This is particularly crucial in the connection between the riser and barrel of the spillway.

E. Emergency Spillway

An emergency spillway must be included in the wet pond design to safely pass the 50-year storm event (or higher storm events, if applicable). The spillway prevents wet pond peak stages from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.

A minimum of 0.5 feet of freeboard must be provided, measured from the peak stage for the 50-year storm event to the lowest point of the dam embankment.

F. Maintenance Access

A maintenance right of way or easement must be provided to a wet pond from a public road or easement. Maintenance access should be at least 12 feet wide, maximum longitudinal slope of 15 percent, and maximum cross slope of 5 percent, and be stabilized to support maintenance vehicles. A 20-foot wide maintenance access easement must be provided to ensure that the access remains in place.

The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, allow vehicles to turn around.

Access to the inside of the riser must be provided by manhole covers, and manhole steps should be within easy reach of valves and other controls. Outlet structures should have protected access that may be accessed easily from the shore for inspection. Boats and ladders should not be needed to access outlet structures.

G. Safety Features

Fencing of wet detention basins is not generally desirable, but may be allowed depending upon the jurisdiction. If a fence is included in the design, access must be provided for inspections. A preferred method to increase the safety features is to manage the contours of the wet detention basin through the inclusion of a safety bench (see Figure 4.2.3) to eliminate dropoffs and reduce the potential for drowning. In addition, the safety bench may be landscaped to deter access to the permanent pool.

The outlet structure openings should not permit access by people not providing maintenance to the facility. Warning signs should be posted near the wet pond to prohibit swimming and fishing in the facility.

H. Landscaping

Aquatic vegetation plays an important role in pollutant removal in a wet pond. In addition, vegetation can enhance the appearance of the wet pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be used in a wet pond design, along the aquatic bench (fringe wetlands), the safety bench and side slopes, and within shallow areas of the permanent pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation.

For planting within wet ponds, it is necessary to determine what hydrologic zones will be created. Hydrologic planting zones describe the degree to which an area is inundated by water. The hydrologic planting zones are illustrates for a typical wet pond in Figure 4.2.5. Plants have differing tolerances to inundation and the six zones described in this section will dictate which plants will survive where. Chapter 6 of this manual provides detailed description of zones.

- In Zone 1 plant material must be able to withstand constant inundation of water of one foot to a maximum of three feet in depth.
- In Zone 2 plant material must be able to withstand constant inundation of water to depths between six inches and one foot deep.
- In Zone 3 plant material must be able to withstand frequent inundation with water, as well as occasional drought.
- In Zone 3 plant will be partially submerged at certain times.
- In Zone 3 plant should be located to reduce human access where there are potential hazards, but should not block the maintenance access.
- In Zone 3 plant should be resistant to disease and other problems which require chemical applications (since chemical application is not advised in storm water ponds). Native plants are preferred because they are low maintenance and disease resistant.
- In Zone 3, where shoreline plants will be susceptible to being smothered by floating trash, provisions for routine maintenance, including removal of trash and other wrack, should be a part

of the maintenance plan.

- If shading is needed along the shoreline, the more rapidly-growing species such as Sycamore are preferred over the more slowly developing species, such as Swamp White Oak. For this purpose, trees should not be planted in Zone 3, but rather in the adjacent Zone 4.
- In Zone 3 and 4 plants material should have very low maintenance requirements, since they may be difficult to access.
- In Zone 4 plants must be able to withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months.
- In Zone 4 plants should stabilize the ground from erosion caused by run-off.
- In Zone 5 plant material should be able to withstand occasional but brief inundation during storms. In between storms, typical moisture conditions may be moist, slightly wet, or even exhibit drought conditions during the dry weather periods.
- In Zone 5 plants should stabilize the basin slopes from erosion.
- Ground cover in zone 5 and 6 should be very low maintenance, since they may be difficult to access on steep slopes or if frequency of mowing is limited.
- In Zone 6 plant material should be able to withstand occasional but brief inundation during storms. In between storms, typical moisture conditions may be moist to slightly wet, with the potential for drought like conditions during extended dry weather periods.
- In Zone 6 plants should be used to stabilize the basin slopes from erosion.

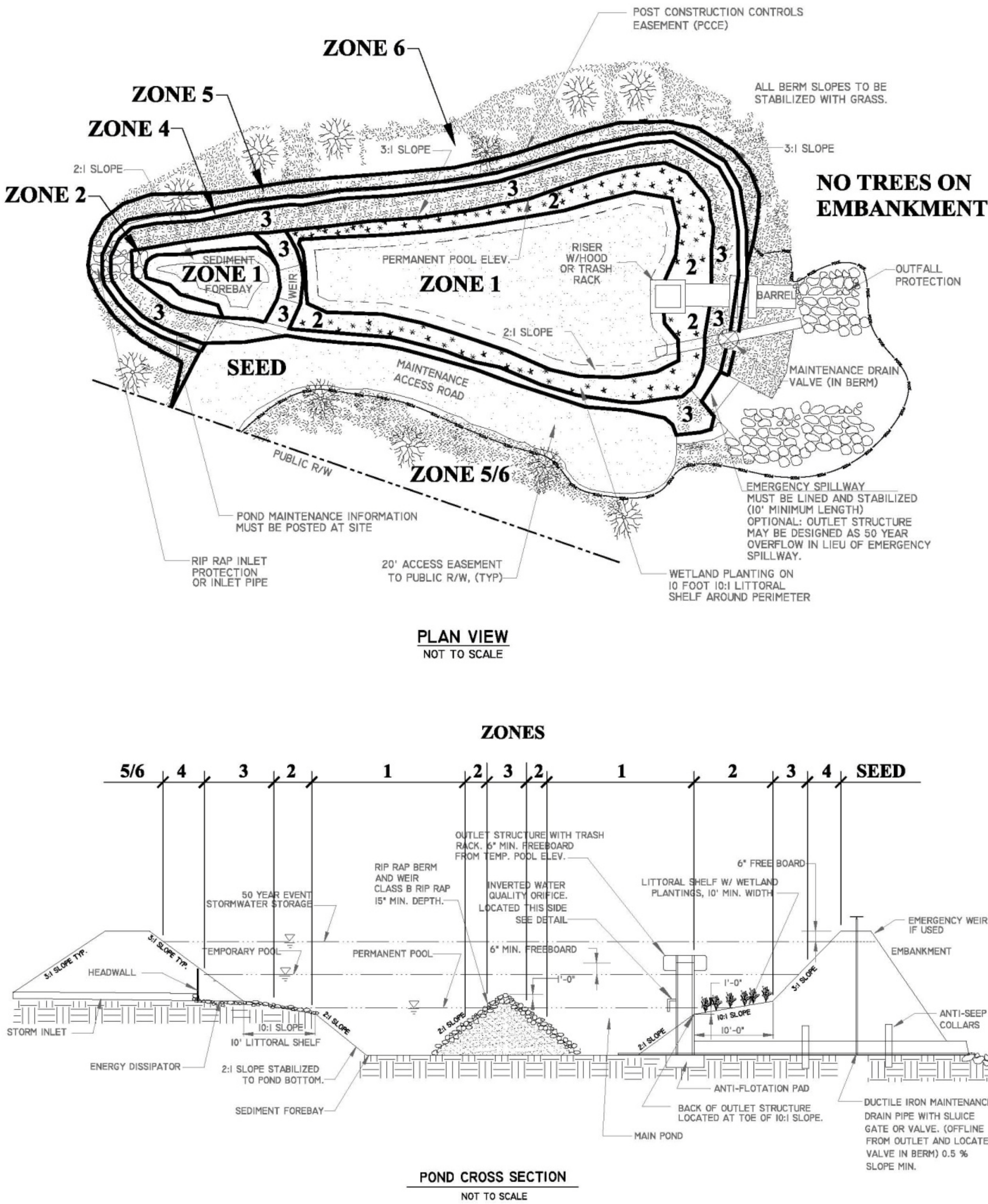


Figure 4.2.5 Wet pond Planting Zones

Woody vegetation must not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.

No buildings should be located within 25 feet of the maximum water surface elevation.

Existing trees must be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to wet ponds. To discourage resident geese populations or other detrimental wildlife, the buffer can be planted with trees, shrubs and native ground covers.

The soils of a wet pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature vegetation mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.

Other Landscaping considerations include the following:

- Plants should be used to stabilize the bottom of the pond, as well as the edge of the pond, absorbing wave impacts and reducing erosion, when water level fluctuates.

- Plants should be used to stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation.

- Plant material should, whenever possible, shade the water surface, especially the southern exposure.

- Plants should be used to shade the low flow channel to reduce pool warming whenever possible.

- Plants should be used to reduce pedestrian access to the deeper pools as a natural barrier.

- Fish can be stocked in a wet pond to aid in mosquito prevention.

- A fountain or solar-powered aerator may be used to oxygenation of water in the permanent pool.

- Compatible multi-objective use of wet ponds is strongly encouraged.

I. Design Recommendations

In addition to the design requirements and parameters, following are some design recommendations that should be considered for wet pond facility design:

- Upstream pre-treatment throughout the contributing watershed is encouraged.

- A wet pond should be sited such that the topography allows for maximum runoff storage at minimum excavation or construction costs. Wet pond siting should also take into account the location and use of other site features such as buffers and undisturbed natural areas and should attempt to aesthetically "fit" the facility into the landscape. Bedrock close to the surface may prevent excavation.

- The principle spillway should be located so that discharges are drawn from the deeper permanent pool areas.

- Wet ponds should be designed with shading to minimize thermal impact.

Additional wet pond design features include an emergency spillway, maintenance access, safety bench, detention basin buffer, and appropriate native landscaping. Wet ponds are generally applicable to most types of new development and redevelopment, and can be used in both residential and non-residential areas. Wet ponds can also be used in retrofit situations. The following criteria should be evaluated to ensure the suitability of a wet pond for meeting storm water management objectives on a site or development.

4.2.5 Design Procedures

Step 1 Using the BMP Selection Matrix presented at the beginning of Chapter 4, determine if the development site and conditions are appropriate for the use of a wet pond.

Step 2 Consider any special site-specific design conditions and any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3 Compute water quality volume (WQ_v) using equations 3.2 and 3.3.

Step 4 Compute site hydrologic parameters using the SCS procedures and/or computer models that use the SCS procedures.

Step 5 Compute water quality peak flow (WQ_p) using equation 3.4 for a modified curve number and the SCS hydrograph procedures with a 1-inch, 6-hr, balanced storm event.

Step 6 Compute channel protection volume (CP_v) using the SCS method and a 1-yr, 24-hr storm event. Estimate approximate storage volume for channel protection volume using the Static method.

Step 7 Compute the release rates for the water quality control (WQ_v) and channel protection control (CP_v) volume.

Step 8 Compute pretreatment volume.

A sediment forebay is provided at each inlet, unless the inlet does not concentrate flow to the wet detention basin. The forebay should be sized to contain 0.2 inches per impervious acre of contributing drainage and should be 4 to 6 feet deep. The forebay storage volume counts toward the total WQ_v requirement and may be subtracted from the WQ_v for subsequent calculations.

Step 9 Compute the permanent pool volume and water quality extended detention volume for either of the three design thresholds for TSS and TP control. Size the extended pool volume to contain the greater of the WQ_v or the CP_v.

Step 10 Determine wet detention basin location and preliminary geometry. Conduct basin grading and determine storage available for permanent pool, extended detention, and flood control.

This step involved initially grading the basin (establishing contours) and determining the elevation storage relationship for the basin.

- Include safety and aquatic benches.
- Set permanent pool elevation and WQ_v elevation for extended wet detention based on volumes calculated earlier.

Step 11 Set basic elevations for pond structures, including pond bottom and pond drain, elevation of the permanent pool, forebay volume, and the elevation of extended detention for water quality control volume and channel system stability control volume.

Step 12 Compute wet detention basin orifice release rate(s) and size(s), and establish CP_v elevation.

Based on the elevations established for the extended wet detention basin portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 2 - 4 days, depending on the selected design threshold. The water quality orifice should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design.

Step 13 The CP_v elevation is then determined from the stage-storage relationship. The invert of the channel protection control orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection control storage volume over a 24-hour period within Mecklenburg County and the six Towns or over a 48-hour period in Charlotte and its ETJ.

Step 14 Calculate Q_p (10-year and 25-year storms – if required) release rate(s) and water surface elevation(s).

Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 10-year and 25-year (if required) storms. Routing procedures must be used in the calculation of release rates and water surface elevations in this step.

Using a hydrologic/hydraulic computer program perform routing calculations of all design storms and make appropriate changes to outlets in order to comply with water quality and quantity requirements. For water quality control the goal is to have 5% of the WQ_v remain in the basin at the end of the design detention time.

Size emergency spillway, calculate 50-year water surface elevation, set top of embankment elevation, and analyze safe passage of the 50-year flood (Q_{50}).

Step 15 Investigate potential wet detention basin hazard classification

Step 16 Assess maintenance access and safety features.

Step 17 Prepare Vegetation and Landscaping Plan

A landscaping plan for a wet detention basin and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

4.2.6 Inspection and Maintenance Requirements

Specific maintenance inspections and requirements are contained in the Administrative Manual of the local jurisdiction.

4.2.7 Design Procedure Form

Design Procedure Form: Wet pond

WET POND FEASIBILITY	NOTES:
1. Is the use of a wet pond appropriate?	
2. Confirm other design criteria and applicability.	
PRELIMINARY HYDROLOGIC CALCULATIONS	
3. Compute, WQ_v water quality volume requirements Compute Runoff Coefficient, R_v Compute WQ_v Volume requirements	 Rv = ______ WQ_v = ______ acre-ft
4. Compute WQ_p peak flow Compute modified SCS curve number	WQ_p = ______ cfs CN = ______
5. Compute CP_v Compute S (maximum retention) Compute 1-yr, 24-hr total rainfall depth Compute Q_d (runoff volume) Compute CP_v (chnnnel protection volume) Estimate t_c (time of concentration) Estimate q_u Compute approximate storage volume	 S = ______ Rainfall Depth = ______ inches Q_d = ______ inches CP_v =__ acre-ft t_c = ______ hours q_u = ______ $cfs/mi^2/inch$ Storage volume = ______ acre-ft
6. Compute release rates Compute WQ_v release rate Compute CP_v release rate	 Release Rate = ______ cfs Release Rate = ______ cfs
7. Compute site hydrologic input parameters Development Conditions Area CN (SCS curve number) Adjusted CN (curve number adjusted for 1-inch storm) Time of concentration	 Pre-developed Post-developed ______ acres ______ acres ______ ______ ______ ______ ______ hours ______ hours
STORM WATER DETENTION BASIN DESIGN	
8. Pretreatment volume Vol_{pre} = Acres of Impervious Area(0.2")(1'/12")	 WQ_{pre} = ______ acre-ft
9. Compute Permanent Pool Volume and Water Quality Extended Volume Compute WQ_v/PP_v Compute PP_v Size extended detention – pool volume is greater of WQ_v or CP_v	 WQ_v/PP_v = ______ PP_v = ______ acre-ft ED Pool Volume = ______ acre-ft
10. Conduction grading and determine storage available for permanent pool (and WQ_v-ED volume if applicable)	Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area (acres)	Average Area (acres)	Depth (ft)	Incremental Volume (acre-ft)	Cumulative Volume (acre-ft)	Volume above Permanent Pool (acre-ft)

12. WQ_v Orifice Computations
    Average ED release rate
    Average head, h = (ED elev. – Permanent pool elev.) / 2
    Area of orifice from orifice equation: $Q = CA(2gh)^{0.5}$

Release Rate = ______cfs
h = ______ft
A = ______ ft^2
Diameter = ______in

13. Compute release rate for CP_v control and
    Establish CP_v elevation
    Release rate
    Average head h = CP_v elev. – Permanent pool elev.) / 2
    Area or orifice from orifice equation: $Q = CA(2gh)^{0.5}$

WSEL = ______ ft
Release Rate = ______cfs
h = ______ft
A = ______ ft^2
Diameter = ______in

14. Calculate Qp release rate and water surface elevation

Set up a stage-storage-discharge relationships.

Peak stage for (WQ_v), the 1-inch, 6-hour storm
Peak stage for (CP_v), the 1-yr, 24-hour storm
Peak Q_{10} – Undeveloped
Peak Q_{10} – Developed
Peak Q_{25} – Undeveloped
Peak Q_{25} – Developed
Size emergency spillway, calculate 50-year WSEL
and set top of embankment elevation

Peak Stage = ______ ft
Peak State = ______ ft
$Q_{10\text{-undev}}$ = ______ cfs
$Q_{10\text{-dev}}$ = ______ cfs
$Q_{25\text{-undev}}$ = ______ cfs
$Q_{25\text{-dev}}$ = ______ cfs

$WSEL_{50}$ = ______ft
Embankment Elevation = ______ft

15. Investigate potential wet detention basin hazard classification

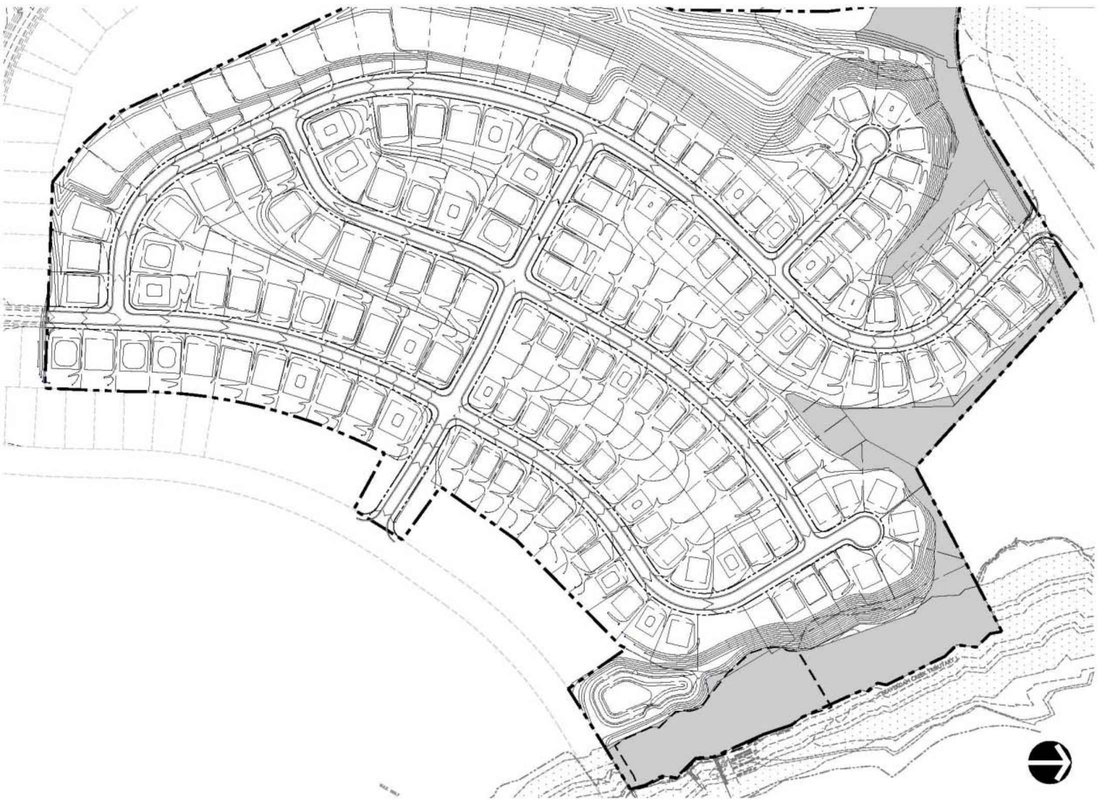
16. Assess maintenance access and safety features.

17. Attach landscaping plan

Notes:

4.2.8 Design Example

The following design example is for a wet pond following the design procedures given in section 4.2. In this design example, the channel protection volume (CP_V) is required to be held for a minimum of 24 hours from the center of the rainfall event (as is the requirement for projects within Mecklenburg County and the six Towns); however, the user should note that within the City of Charlotte, the channel protection volume (CP_V) is required to be held for a minimum of 48 hours from the center of the rainfall event. Figure 4.2.6 shows the site plan for the development and base and hydrologic data that will be used in the design example.



Base Data	Hydrologic Data		
Site Area = Total Drainage Area (A) = 10.0 acre		**Pre**	**Post**
Measured Impervious Area – 3.4 ac; or I=3.4/10=34.2%	CN	65	77.8
Soils Types: 50% “C”, 50% “B”	t_c	0.631 hr	0.202 hr
Zoning: Residential (1/2 acre lots)			

Figure 4.2.6 Example Site Plan for Wet Pond Design

Steps 1, 2 Determine if the development site and conditions are appropriate for the use of a wet pond and consider any site-specific design considerations.

Step 3 Compute Water Quality Volume (WQ_v)

- Compute Runoff Coefficient, R_v, using (Schueler’s Method) Equation 3.1

$R_v = 0.05 + 0.009(I) = 0.05 + (34.2)(0.009) = 0.36$

- Compute Water Quality Volume, WQ_v, using Equation 3.2

  $WQ_v = 1.0R_vA/12$ = (1.0 inches)(0.36)(10.0 acre)(1foot/12 inches) = 0.30 ac-ft

- Convert Water Quality Volume, WQ_v to inches of runoff using Equation 3.3

  $WQ_v = 1.0(R_v) = 1.0(0.36) = 0.36$ inches

Steps 4, 5 Compute Water Quality Peak Flow (WQ_p)

- Compute modified SCS curve number, CN, using Equation 3.4

  $CN = 1000/[10 + 5P + 10WQ_v – 10(WQ_v^2 + 1.25\ WQ_vP)^{0.5}]$
  $CN = 1000/[10 + 5(1.0) + 10(0.36) – 10\{(0.36^2 + 1.25(0.36 \times 1.0)\}^{0.5}] = 91.0$

- Compute WQ_p using SCS the hydrograph procedure documented in the CMSWDM and the HEC-1 model or equivalent hydrologic model as approved by the review engineer. A 1-inch, 6-hour balanced storm event is required.

```
1*****************************************                                                ***************************************
 *                                       *                                                *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                *     U.S. ARMY CORPS OF ENGINEERS    *
 *               JUN   1998              *                                                *     HYDROLOGIC ENGINEERING CENTER   *
 *            VERSION 4.1                *                                                *           609 SECOND STREET         *
 *                                       *                                                *        DAVIS, CALIFORNIA 95616      *
 *  RUN DATE   11MAR07  TIME  17:01:58   *                                                *            (916) 756-1104           *
 *                                       *                                                *                                     *
 *****************************************                                                ***************************************


                                        X     X  XXXXXXX   XXXXX          X
                                        X     X  X        X     X        XX
                                        X     X  X        X               X
                                        XXXXXXX  XXXX     X       XXXXX   X
                                        X     X  X        X               X
                                        X     X  X        X     X         X
                                        X     X  XXXXXXX   XXXXX         XXX


           THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

           THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
           THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
           NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
           DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
           KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                            HEC-1 INPUT                                                        PAGE  1

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1           ID       MECKLENBURG COUNTY BMP DESIGN MANUAL
            2           ID       ANALYZED BY ABC ENGINEERING
            3           ID       DATE: OCTOBER 2006
                        *  ***************************************************************************
                        *
                        *     TIME SPECIFICATION CARD
            4           IT       1       0       0     365
                        *  DIAGRAM
                        *     TIME INTERVAL CARD
            5           IN       5       0       0
                        *
                        *     OUTPUT CONTROL CARD
            6           IO       5       0       0
                        *

            7           KK    PRE1
                        * ***************************************************************************
                        * **************** 1-INCH, 6 HOUR STORM EVENT *********************************
                        * ***************************************************************************
            8           PI    .000    .003    .003    .003    .003    .003    .003    .004    .004    .004
            9           PI    .004    .004    .004    .004    .004    .005    .005    .005    .005    .006
           10           PI    .007    .007    .007    .008    .008    .009    .009    .010    .011    .012
           11           PI    .013    .019    .022    .025    .039    .050    .108    .188    .075    .043
           12           PI    .028    .023    .020    .014    .012    .011    .010    .009    .009    .008
           13           PI    .008    .007    .007    .007    .006    .005    .005    .005    .005    .005
           14           PI    .004    .004    .004    .004    .004    .004    .004    .004    .003    .003
```

```
          15          PI    .003    .003    .003    .000
                      * ******************************************************************************
          16          KM   10-ACRE PRE-DEVELOPED CONDITIONS
          17          KO      5       0       0       0      21
          18          BA   .0156
          19          LS      0    65.0       0
          20          UD   0.378

          21          KK   POST1
          22          KM   10-ACRE POST-DEVELOPED CONDITIONS - ADJUSTED CURVE NUMBER
          23          KO      1       0       0       0      21
          24          BA   .0156
          25          LS      0    91.0       0
          26          UD   0.121
          27          ZZ

1****************************************                                         ***************************************
 *                                       *                                        *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                        *   U.S. ARMY CORPS OF ENGINEERS      *
 *            JUN   1998                 *                                        *   HYDROLOGIC ENGINEERING CENTER     *
 *         VERSION 4.1                   *                                        *         609 SECOND STREET           *
 *                                       *                                        *      DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   11MAR07  TIME  17:01:58   *                                        *          (916) 756-1104             *
 *                                       *                                        *                                     *
 ****************************************                                         ***************************************
                              CHARLOTTE-MECKELNBURG POST CONSTRUCTION DESIGN MANUAL
                              ANALYZED BY ABC ENGINEERING
                              DATE: OCTOBER 2006


                         TLAG        .12  LAG
************************************************************************************************************************************

     TOTAL RAINFALL =    1.00, TOTAL LOSS =     .64, TOTAL EXCESS =     .36

                                                                RUNOFF SUMMARY
                                                        FLOW IN CUBIC FEET PER SECOND
                                                     TIME IN HOURS,  AREA IN SQUARE MILES

                                            PEAK   TIME OF    AVERAGE FLOW FOR MAXIMUM PERIOD      BASIN     MAXIMUM     TIME OF
          OPERATION       STATION          FLOW    PEAK                                             AREA      STAGE     MAX STAGE
+                                                              6-HOUR     24-HOUR     72-HOUR

          HYDROGRAPH AT
+                           PRE1             0.     .00          0.          0.          0.        .02

          HYDROGRAPH AT
+                          POST1             7.    3.27          1.          1.          1.        .02


 *** NORMAL END OF HEC-1 ***
```

Note that the previous HEC-1 model output indicates that the runoff volume is 0.36 inches using the SCS method which matches the Schueler method runoff volume results using Equation 3-2.

Step 6 Compute Channel Protection Volume (CP_v)

- Compute maximum soil retention using SCS methods shown in the Charlotte-Mecklenburg Storm Water Design Manual. Note that the CN value used is the original site CN value, not the adjusted CN value used during the water quality runoff volume computation.

  $$S = 1000/CN-10$$
  $$= 1000/77.8 - 10$$
  $$= 2.85 \text{ inches}$$

  Compute total runoff for the 1-year, 24-hour storm event. Total rainfall depth is 2.58 inches.

  $$Q_d = (P-0.2S)^2/(P+0.8S)$$
  $$= [(2.58 - (0.2)(2.85)]^2/[2.58 + (0.8)(2.85)]$$
  $$= 0.83 \text{ inches}$$

  Compute watershed runoff

  CP_v = (0.83 inches)(10 acres)(1 foot/12 inches) = 0.69 acre-feet

- **Estimate Approximate Storage Volume**

The entire Channel Protection Volume (CP_v) is required to be held within the wet pond dry storage volume above the permanent pool for a minimum of 24 hours. The requirement is in addition to the Water Quality treatment, which requires holding the Water Quality Volume (WQ_v) for four (4) days. A design method that is called the "Static Method" sets the storage volume equal to the runoff volume, assumes that the storage volume fills instantaneously and empties through the outlet structure orifices and weirs. Using the Static Method, the facility would require 0.30 acre-ft storage for the Water Quality Volume (WQ_v) treatment and 0.69 acre-feet for the Channel Protection Volume (CP_v). These values can be used as estimates to develop approximate storage volumes and grading plans, but routing computations must be performed to complete the design.

Step 7a Compute Release Rates for Water Quality Control (WQ_v) and Channel Protection Volume (CP_v) Control

The following outlet hydraulic computations are performed using the Static Method. Routing computations must be performed to refine the design that show that a minimum of 5 percent of the runoff volume is held within the storage volume at the design duration time after the center of the design storm rainfall (3 hours for 1-inch, 6-hour storm event and 12 hours for 1-year, 24-hour storm event).

- Compute the release rate for water quality control.

  The water quality control volume (WQ_v) is to be released over a 4-day duration beyond the center of rainfall (96 hours plus 3 hours) period.

  Release rate = (0.30 ac-ft x 43560 ft^2/acre)/(99 hrs x 3,600 sec/hr) = 0.037 cfs

- Compute the release rate for channel protection volume control.

  The channel protection volume control (CP_v) is to be released over a 24-hour period beyond the center of rainfall (24 hours plus 12 hours) period.

  Release rate = (0.69 ac-ft x 43560 ft^2/acre)/(36 hrs x 3,600 sec/hr) = 0.232 cfs

Step 7b Compute Site Hydrologic Input Parameters

Using SCS hydrologic procedures and/or computer models the following data can be determined for the example development site.

Hydrologic Input Data

Condition	Area (acres)	CN	CN (adjusted) for 1-inch storm	t_c (hours)
Pre-developed	10	65	N/A	0.631
Post-developed	10	77.8	91.0	0.202

Results of Preliminary Hydrologic Calculations
(From Computer Model Results Using SCS Hydrologic Procedures)

Condition	$Q_{1\text{-inch}}$	$Q_{1\text{-year}}$	$Q_{10\text{-year}}$	$Q_{25\text{-year}}$	$Q_{50\text{-year}}$
Runoff	cfs	cfs	cfs	cfs	cfs
Pre-developed	N/A	1.5	13.4	19.3	24.7
Post-developed	5.9	9.8	58.8	77.5	92.4

Step 8 Compute Pretreatment Volume

Size wet forebay to treat 0.2 inch/impervious area.

Forebay volume = (3.4 acres of impervious area)(0.2 inch)((1 foot/12 inches) = 0.06 ac-ft

Note: The forebay volume is included in the WQ_v as part of the permanent pool volume.

<u>Step 9 Compute Permanent Pool Volume and Water Quality Extended Detention Volume</u>

- Size the permanent pool volume so that the $WQ_v/PP_v = 0.3$.

  $PP_v = WQ_v/0.30 = 0.30$ ac-ft/0.30 = 1.00 ac-ft (includes 0.06 ac-ft of forebay volume).

- Size extended detention pool volume to contain the greater of the WQ_v and CP_v.

  Extended detention volume = either 0.30 acre-ft held for 4 day duration beyond 3 hours or 0.69 ac-ft for a duration of 24 hours beyond 12 hours

  Note: This design approach assumes that all of the runoff volume for the 1-inch, 6-hour and 1-year, 24-hour storm events will be in the pond at once. While this will not be the case, since there is a discharge during the early stages of storms, this conservative approach allows for extended detention control over a wider range of storms, not just the target rainfall.

<u>Step 10 Develop Storage-Elevation Table and Curve</u>

Figure 4.2.6 at the beginning of this section shows the pond location on site. Figure 4.2.7 shows the plan view of the pond grading and Table 4.2.2 shows the storage-elevation data that was developed for this example.

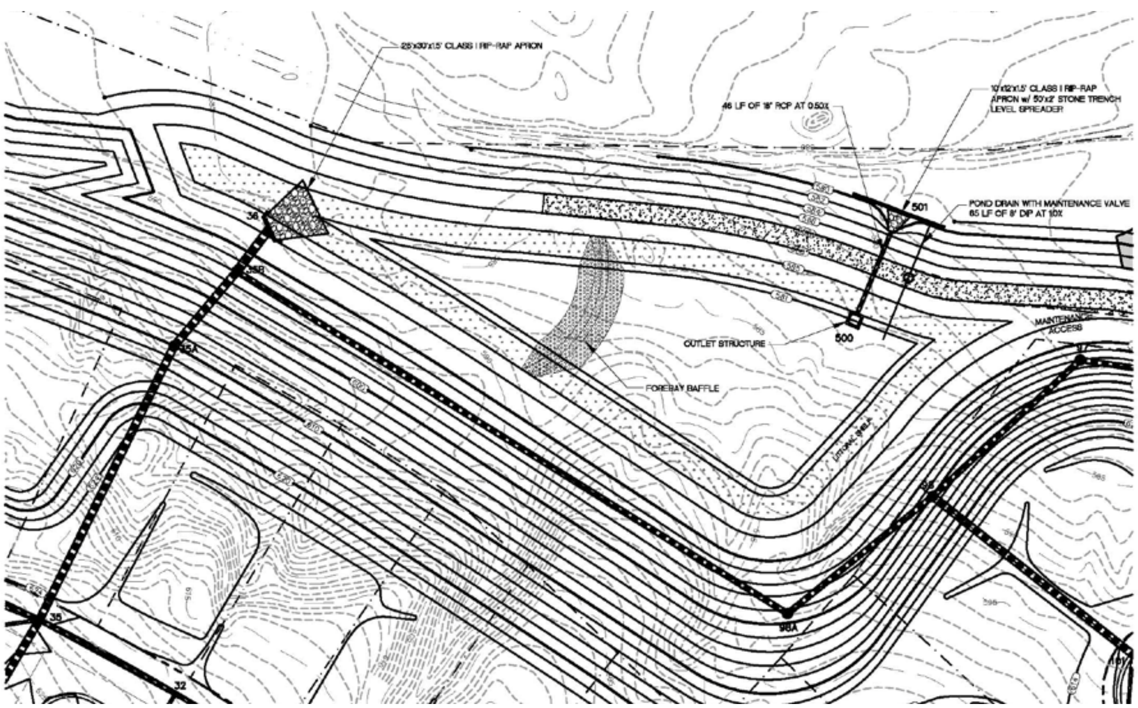


Figure 4.2.7 Plan View of Pond Grading (Not to Scale)

Table 4.2.2 Storage-Elevation Data

Elevation	Area (sf)	Area (ac)	Avg. Area (ac)	Height (ft)	Inc vol (ac-ft)	Acc vol (ac-ft)	Acc vol (ac-ft)
695	6400	0.147				0.000	
695.5	6889	0.158	0.153	0.5	0.076	0.076	
696	7396	0.170	0.164	0.5	0.082	0.158	
696.5	7921	0.182	0.176	0.5	0.088	0.246	
697.0	8464	0.194	0.188	0.5	0.094	0.340	
697.5	9025	0.207	0.201	0.5	0.100	0.441	
698.0	9604	0.220	0.214	0.5	0.107	0.547	
698.5	10201	0.234	0.227	0.5	0.114	0.661	
699.0	10816	0.248	0.241	0.5	0.121	0.782	
699.5	11449	0.263	0.256	0.5	0.128	0.910	
700.0	12100	0.278	0.270	0.5	0.135	1.045	0
700.5	12769	0.293	0.285	0.5	0.143	1.187	0.143
701.0	13456	0.309	0.301	0.5	0.151	1.338	0.293
701.5	14161	0.325	0.317	0.5	0.158	1.496	0.452
702.0	14884	0.342	0.333	0.5	0.167	1.663	0.618
702.5	15265	0.350	0.346	0.5	0.173	1.836	0.791
703.0	16384	0.376	0.363	0.5	0.182	2.018	0.973
703.5	17161	0.394	0.385	0.5	0.193	2.210	1.166
704.0	17956	0.412	0.403	0.5	0.202	2.412	1.367
704.5	18769	0.431	0.422	0.5	0.211	2.623	1.578
705.0	19600	0.450	0.440	0.5	0.220	2.843	1.798

Step 11 Set Basic Elevations For Pond Structures

Set basic elevations for pond structures.

- The pond bottom is set at elevation 695.0.
- Provide gravity flow to allow for pond drain, set riser invert at 694.5.
- Set barrel outlet elevation at 694.0.

Set water surface and other elevations.

- Required permanent pool volume = 1.00 ac-ft. From the elevation-storage table or curve, read the elevation that will have a cumulative volume of 1.00 ac-ft or greater = 700.0. This elevation has a cumulative volume of 1.045 ac-ft which is greater than 1.00 ac-ft to allow for a small safety factor.
- Forebay volume will be provided in two pools, each below the two major inflow location, with an average volume of 0.030 ac-ft in each. This will give the required forebay volume of 0.06 ac-ft.
- The required extended detention volume is the greater of the water quality volume and the channel system protection volume; 0.30 acre-ft held for 4 days beyond 3 hours or 0.69 ac-ft for 1 day beyond 12 hours. From the elevation-storage table or curve (volume above permanent pool), read the elevation that will allow 0.30 acre-ft of storage and 0.69 ac-ft of storage above the permanent pool at elevation 700. The preliminary elevation to hold the Water Quality Volume (WQ_v) is 701.1 and Channel Protection Volume (CP_v) is 702.3.

Perform water balance calculations to confirm pond can maintain a water level no lower than 1 foot below the permanent pool elevation (see Section 3.4 of the BMP Design Manual for example of water balance calculations).

Step 12 Compute Required Outlet Structure and Stage-Discharge for Water Quality Volume (WQ_v)

Compute the required water quality extended detention orifice diameter to release 0.30 ac-ft over 96 hours beyond 3 hours.

- Average extended detention release rate = (0.30 ac-ft)(43,560 ft^2/ac)/(99 hr)(3600 sec/hr) = 0.037 cfs
- Average head = (701.1 – 700.0)/2 = 0.55 ft
- Use orifice equation to compute cross-sectional area and diameter of outlet.
    - $Q = CA(2gh)^{0.5}$, for Q = 0.037 cfs, h = 0.55 ft, and C = discharge coefficient = 0.6
    - Solve for A: A = 0.037 cfs / $[0.6((2)(32.2\ ft/s^2)(0.55))^{0.5}] = 0.010\ ft^2$
    - With $A = \pi d^2/4$, d = 0.113 ft = 1.3 inches
    - Use 1.3 inch orifice plate.

Compute the stage-discharge equation for the 1.3 inch diameter WQ_v orifice.

- $WQ_{v\text{-}ed} = CA(2gh)^{0.5} = (0.6)(0.010\ ft^2)\ [((2)(32.2\ ft/s^2))^{0.5}](h^{0.5}), = 0.048h^{0.5}$
- $WQ_{v\text{-}ed} = (0.048)h^{0.5}$, where h = water surface elevation – 700.05
- Note: account for one half of the orifice diameter when calculating the head (h).

Step 13 Compute Required Outlet Structure and Stage-Discharge for Channel Protection Volume (CP_v)

Compute a preliminary channel protection volume orifice diameter to release 0.69 acre-feet over 24 hours beyond 12 hours.

- Required CP_v = 0.69 ac-ft
- From the elevation storage table or curve, read elevation 702.5 (this includes the WQ_v of 0.30 ac-ft). At elevation 702.3 there is 0.69 ac-ft of storage.
- Set CP_v storage volume at = 702.3

Size the CP_v orifice.

- Average extended detention release rate = (0.69 ac-ft)(43,560 ft^2/ac)/(36 hr)(3600 sec/hr) = 0.232 cfs
- Average head = (702.3 – 700.0)/2 = 1.15 ft
- Use orifice equation to compute cross-sectional area and diameter of outlet.
    - $Q = CA(2gh)^{0.5}$, for Q = 0.232 cfs, h = 1.15 ft, and C = discharge coefficient = 0.6
    - Solve for A: A = 0.232 cfs / $[0.6((2)(32.2\ ft/s^2)(1.15))^{0.5}] = 0.045\ ft^2$
    - With $A = \pi d^2/4$, d = 0.239 ft = 2.9 inches
    - Use 2.9 inch orifice plate.

Compute the stage-discharge equation for the 2.9 diameter CP_v orifice.

- $Q = CA(2gh)^{0.5} = 0.6(0.045\ ft^2)[2(32.2\ ft/s^2)]^{0.5}(h^{0.5})$
  $Q = 0.22h^{0.5}$ Where h = wsel – 700.12
  (Note: Account for one half of the orifice diameter when calculation head).

Step 14 Calculate Q_{10} and Q_{25} (if required) Release Rate(s) and Water Surface Elevation(s)

In order to calculate the 10-year and 25-year (if required) release rate(s) and water surface elevation(s), the designer must set up a stage-storage-discharge relationship for the control structure for each of the low flow release pipes (WQ_v and CP_v) plus the 10-year and 25-year (if required) storm(s).

The first step is to route the 1-inch, 6-hour storm event through the facility using the orifice and stage-storage developed by the preceding Static Method design. The following HEC-1 output file illustrates the results. Note that the peak stage for the 1-inch, 6-hour storm event is 700.98 which is less than 701.1, the peak stage assumed during the Static Method design. In addition, export of the outflow hydrograph through the TAPE21 or HEC-DSS function indicates that 22% of the runoff volume remains within the basin at 4 days beyond the center of rainfall (3 hours), therefore, additional iterations of the 1-inch storm event design could be performed. The goal of the additional iterations could be to increase the outlet size and reduce the storage volume so that only 5% of the runoff volume remained in the basin at 4 days beyond the center of rainfall (3 hours). In addition, a reduced amount of storage volume could be used for the 1-inch storm event by performing the iterative routing design and re-sizing the outlet orifice.

```
1***************************************                              ***************************************
 *                                      *                              *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                              *   U.S. ARMY CORPS OF ENGINEERS      *
 *            JUN   1998                *                              *   HYDROLOGIC ENGINEERING CENTER     *
 *            VERSION 4.1               *                              *         609 SECOND STREET           *
 *                                      *                              *      DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   25MAY07  TIME  13:54:52  *                              *          (916) 756-1104             *
 *                                      *                              *                                     *
 ****************************************                              ***************************************


                           X     X  XXXXXXX   XXXXX         X
                           X     X  X        X     X       XX
                           X     X  X        X              X
                           XXXXXXX  XXXX     X       XXXXX  X
                           X     X  X        X              X
                           X     X  X        X     X        X
                           X     X  XXXXXXX   XXXXX        XXX


           THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

           THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
           THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
           NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
           DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
           KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                                  HEC-1 INPUT                                            PAGE  1

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1           ID       MECKLENBURG COUNTY BMP DESIGN MANUAL
            2           ID       ANALYZED BY ABC ENGINEERING
            3           ID       DATE: OCTOBER 2006
                        *  ***************************************************************************
                        *
                        *     TIME SPECIFICATION CARD
                        *     TOTAL COMPUTATION PERIOD - 99 HOURS
            4           IT       4 08MAY99       0    1485
                        *  DIAGRAM
                        *     TIME INTERVAL CARD
            5           IN       5       0       0
                        *
                        *     OUTPUT CONTROL CARD
            6           IO       5       0       0
                        *

            7           KK    PRE1
                        * ****************************************************************************
                        * *************** 1-INCH, 6 HOUR STORM EVENT ********************************
                        * ****************************************************************************
            8           PI    .000    .003    .003    .003    .003    .003    .003    .004    .004    .004
            9           PI    .004    .004    .004    .004    .004    .005    .005    .005    .005    .006
           10           PI    .007    .007    .007    .008    .008    .009    .009    .010    .011    .012
           11           PI    .013    .019    .022    .025    .039    .050    .108    .188    .075    .043
           12           PI    .028    .023    .020    .014    .012    .011    .010    .009    .009    .008
           13           PI    .008    .007    .007    .007    .006    .005    .005    .005    .005    .005
           14           PI    .004    .004    .004    .004    .004    .004    .004    .004    .003    .003
           15           PI    .003    .003    .003    .000
                        * ****************************************************************************
           16           KM   10-ACRE PRE-DEVELOPED CONDITIONS
           17           KO       5       0       0       0      21
           18           BA   .0156
           19           LS       0    65.0       0
           20           UD   0.378

           21           KK   POST1
           22           KM   10-ACRE POST-DEVELOPED CONDITIONS - ADJUSTED CURVE NUMBER
           23           KO       1       0       0       0      21
           24           BA   .0156
```

```
LS       0    91.0       0
UD   0.121
ZW   A=OUT B=POST1  C=FLOW

KK  DETE10
KO       5       0       0       0      21
KM   DETENTION BASIN DESIGN FOR 1-INCH, 6-HOUR STORM EVENT, HELD FOR 96 HOURS
KM   POST-DEVELOPED WITH CONTROLS
KM   1.30 INCH ORIFICE TO ELEVATION 701.1; 2.9 INCH ORIFICE TO ELEVATION 702.3
KM   BASED ON STATIC METHOD
RS       1    ELEV     700
SV       0    .143    .293    .324    .452    .618    .721    .791    .973   1.166
SE     700   700.5     701   701.1   701.5     702   702.3   702.5     703   703.5
SQ    0.00   0.030   0.043   0.045   0.259   0.303   0.341   0.375   0.406   0.462
ZW   A=OUT B=DETE10  C=FLOW
ZZ
```

```
1*****************************************                                                              ***************************************
 *                                       *                                                              *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                              *   U.S. ARMY CORPS OF ENGINEERS      *
 *             JUN   1998                *                                                              *   HYDROLOGIC ENGINEERING CENTER     *
 *           VERSION 4.1                 *                                                              *         609 SECOND STREET           *
 *                                       *                                                              *      DAVIS, CALIFORNIA 95616        *
 * RUN DATE   25MAY07  TIME  13:54:52    *                                                              *          (916) 756-1104             *
 *                                       *                                                              *                                     *
 *****************************************                                                              ***************************************



                               MECKLENBURG COUNTY BMP DESIGN MANUAL
                               ANALYZED BY ABC ENGINEERING
                               DATE: OCTOBER 2006

 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


             *************
             *           *
   21 KK     *     POST1 *
             *           *
             *************

    TOTAL RAINFALL =    1.00, TOTAL LOSS =     .64, TOTAL EXCESS =     .36
1
                                                    RUNOFF SUMMARY
                                             FLOW IN CUBIC FEET PER SECOND
                                          TIME IN HOURS,  AREA IN SQUARE MILES

                                        PEAK    TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD     BASIN     MAXIMUM     TIME OF
          OPERATION      STATION        FLOW     PEAK                                            AREA      STAGE     MAX STAGE
+                                                              6-HOUR     24-HOUR     72-HOUR

          HYDROGRAPH AT
+                           PRE1          0.      .00          0.          0.          0.        .02

          HYDROGRAPH AT
+                          POST1          6.     3.27          1.          0.          0.        .02

          ROUTED TO
+                         DETE10          0.     5.93          0.          0.          0.        .02
+                                                                                                       700.98       6.33


 *** NORMAL END OF HEC-1 ***
```

The second step is to route the 1-year, 24-hour storm event through the facility using the orifice and stage-storage developed by the preceding Static Method design. The following HEC-1 output file illustrates the results. The designer may adjust the top of weir control that was set at 701.1 during the Static Method to control the 1-inch storm design to 700.98, the peak stage of the 1-inch, 6-hour storm event determined from routing.

The peak stage of the 1-year, 24-hour storm event was computed to be 701.56. In addition, export of the outflow hydrograph through the TAPE21 or DSS function or indicates that 45% of the runoff volume remains within the basin after 36 hours (24 hours after the center of rainfall for the 1-year, 24-hour storm event), therefore, additional iterations of the 1-year storm event design could be performed. The goal of the additional iterations could be to increase the outlet size and reduce the storage volume so that only 5% of the runoff volume remained in the basin after 36 hours. In addition, a reduced amount of storage volume could be used for the 1-year, 24-hour storm event by performing the iterative routing design and re-sizing the outlet orifice.

```
1*****************************************                                                              ***************************************
 *                                       *                                                              *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                              *   U.S. ARMY CORPS OF ENGINEERS      *
 *             JUN   1998                *                                                              *   HYDROLOGIC ENGINEERING CENTER     *
 *           VERSION 4.1                 *                                                              *         609 SECOND STREET           *
 *                                       *                                                              *      DAVIS, CALIFORNIA 95616        *
 * RUN DATE   25MAY07  TIME  14:06:29    *                                                              *          (916) 756-1104             *
 *                                       *                                                              *                                     *
 *****************************************                                                              ***************************************
```

```
                              X     X  XXXXXXX   XXXXX          X
                              X     X  X        X     X        XX
                              X     X  X        X               X
                              XXXXXXX  XXXX     X        XXXXX  X
                              X     X  X        X               X
                              X     X  X        X     X         X
                              X     X  XXXXXXX   XXXXX         XXX


     THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

     THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
     THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
     NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
     DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
     KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                       HEC-1 INPUT                                              PAGE  1

          LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1        ID       MECKLENBURG COUNTY BMP DESIGN MANUAL
            2        ID       ANALYZED BY ABC ENGINEERING
            3        ID       DATE: OCTOBER 2006
                     *  ***************************************************************************
                     *
                     *     TIME SPECIFICATION CARD
                     *     TOTAL COMPUTATIONAL DURATION 36 HOURS
            4        IT      4       0       0     540
                     *  DIAGRAM
                     *     OUTPUT CONTROL CARD
            5        IO      5       0       0
                     *

            6        KK    PRE1
            7        IN      6
            8        PB    2.58
                     * ******************************************************************************
                     * **************** 1-YEAR, 24-HOUR STORM EVENT ******************************
                     * ********* 6 MINUTE TIME INCREMENT,24-HOUR STORM EVENT **********************
                     * ******************************************************************************
            9        PI   .0000   .0010   .0010   .0010   .0011   .0010   .0011   .0010   .0011   .0011
           10        PI   .0011   .0011   .0011   .0011   .0012   .0011   .0012   .0011   .0012   .0012
           11        PI   .0012   .0012   .0012   .0013   .0012   .0012   .0013   .0012   .0013   .0013
           12        PI   .0013   .0013   .0013   .0013   .0014   .0013   .0014   .0014   .0013   .0014
           13        PI   .0014   .0014   .0014   .0015   .0015   .0015   .0015   .0015   .0015   .0016
           14        PI   .0016   .0016   .0016   .0017   .0017   .0016   .0018   .0017   .0017   .0018
           15        PI   .0018   .0018   .0018   .0019   .0019   .0018   .0020   .0019   .0019   .0020
           16        PI   .0020   .0020   .0020   .0021   .0021   .0021   .0021   .0021   .0021   .0022
           17        PI   .0022   .0022   .0024   .0024   .0026   .0026   .0028   .0029   .0029   .0030
           18        PI   .0032   .0032   .0032   .0032   .0032   .0032   .0033   .0034   .0036   .0038
           19        PI   .0039   .0041   .0044   .0046   .0048   .0051   .0054   .0058   .0062   .0066
           20        PI   .0070   .0077   .0086   .0096   .0106   .0115   .0238   .0476   .0764   .1371
           21        PI   .0951   .0190   .0166   .0144   .0122   .0098   .0084   .0080   .0074   .0068
           22        PI   .0064   .0060   .0056   .0054   .0052   .0048   .0046   .0044   .0042   .0040
           23        PI   .0038   .0037   .0036   .0035   .0034   .0034   .0033   .0033   .0032   .0031
           24        PI   .0030   .0030   .0029   .0028   .0027   .0027   .0026   .0026   .0025   .0024
           25        PI   .0023   .0023   .0022   .0023   .0022   .0022   .0022   .0021   .0021   .0021
           26        PI   .0021   .0020   .0020   .0020   .0019   .0020   .0019   .0019   .0018   .0018
           27        PI   .0018   .0018   .0017   .0018   .0017   .0017   .0016   .0017   .0016   .0016
           28        PI   .0015   .0016   .0015   .0015   .0015   .0014   .0014   .0014   .0013   .0014
           29        PI   .0013   .0013   .0013   .0013   .0013   .0012   .0013   .0013   .0012   .0013
           30        PI   .0012   .0013   .0012   .0013   .0012   .0012   .0013   .0012   .0012   .0012
           31        PI   .0012   .0012   .0012   .0012   .0012   .0011   .0012   .0012   .0011   .0012
           32        PI   .0011   .0012   .0011   .0012   .0011   .0011   .0012   .0011   .0011   .0011
           33        PI   .0011
           34        KM   10-ACRE PRE-DEVELOPED CONDITIONS
           35        KO      5       0       0       0      21
           36        BA   .0156
           37        LS      0    65.0       0
           38        UD   0.378
1                                       HEC-1 INPUT                                              PAGE  2

          LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


           39        KK   POST1
           40        KM   10-ACRE POST-DEVELOPED CONDITIONS
           41        KO      1       0       0       0      21
           42        BA   .0156
           43        LS      0    77.8       0
           44        UD   0.121

           45        KK  DETE10
           46        KO      5       0       0       0      21
           47        KM   DETENTION BASIN DESIGN FOR 1-INCH, 6-HOUR STORM EVENT, HELD FOR 96 HOURS
           48        KM   POST-DEVELOPED WITH CONTROLS
           49        KM   1.30 INCH ORIFICE TO ELEVATION 701.0; 2.9 INCH ORIFICE TO ELEVATION 702.3
           50        KM   BASED ON STATIC METHOD
           51        RS      1    ELEV     700
           52        SV      0    .143    .293    .452    .618    .721    .791    .973   1.166
           53        SE    700   700.5     701   701.5     702   702.3   702.5     703   703.5
           54        SQ   0.00   0.030   0.043   0.259   0.303   0.326   0.341   0.375   0.406
           55        ZZ
1*****************************************                                  ***************************************
 *                                       *                                  *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                  *   U.S. ARMY CORPS OF ENGINEERS      *
 *           JUN   1998                  *                                  *   HYDROLOGIC ENGINEERING CENTER     *
 *          VERSION 4.1                  *                                  *          609 SECOND STREET          *
 *                                       *                                  *       DAVIS, CALIFORNIA 95616       *
 *  RUN DATE   25MAY07  TIME  14:06:29   *                                  *           (916) 756-1104            *
 *                                       *                                  *                                     *
*****************************************                                  ***************************************


                         CHARLOTTE-MECKELNBURG POST CONSTRUCTION DESIGN MANUAL
```

```
                              ANALYZED BY USINFRASTRUCTURE
                              DATE: OCTOBER 2006

 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
  39 KK   *    POST1   *
          *            *
          **************

 ******************************************************************************************************************************************

   TOTAL RAINFALL =    2.58, TOTAL LOSS =    1.75, TOTAL EXCESS =     .83

                                                    RUNOFF SUMMARY
                                              FLOW IN CUBIC FEET PER SECOND
                                           TIME IN HOURS,  AREA IN SQUARE MILES

                                        PEAK   TIME OF    AVERAGE FLOW FOR MAXIMUM PERIOD     BASIN     MAXIMUM     TIME OF
         OPERATION       STATION        FLOW     PEAK                                          AREA      STAGE    MAX STAGE
+                                                           6-HOUR     24-HOUR     72-HOUR

         HYDROGRAPH AT
+                           PRE1          1.   12.47          0.          0.          0.        .02

         HYDROGRAPH AT
+                          POST1         10.   12.13          1.          0.          0.        .02

         ROUTED TO
+                         DETE10          0.   17.60          0.          0.          0.        .02
+                                                                                                       701.56       19.00


 *** NORMAL END OF HEC-1 ***
```

The third and fourth step is to route the 10-year and 25-year, 6-hour storm events through the facility using an iterative process so that the post-development discharge rates are less than the pre-development conditions. The following HEC-1 output file illustrates the results of the iterative process. Intermediate steps are not presented. The fifth step is to design the emergency spillway for the 50-year storm event. The elevation of the emergency spillway is set above the peak stage of the routed 25-year storm event. A freeboard of 6 inches above the 50-year peak stage to the top of embankment is required.

```
1*****************************************                                                     ***************************************
 *                                       *                                                     *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                     *   U.S. ARMY CORPS OF ENGINEERS      *
 *              JUN   1998               *                                                     *   HYDROLOGIC ENGINEERING CENTER     *
 *           VERSION 4.1                 *                                                     *         609 SECOND STREET           *
 *                                       *                                                     *      DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   25MAY07  TIME  14:27:41   *                                                     *          (916) 756-1104             *
 *                                       *                                                     *                                     *
 *****************************************                                                     ***************************************



                                          X     X  XXXXXXX   XXXXX         X
                                          X     X  X        X     X       XX
                                          X     X  X        X              X
                                          XXXXXXX  XXXX     X       XXXXX  X
                                          X     X  X        X              X
                                          X     X  X        X     X        X
                                          X     X  XXXXXXX   XXXXX        XXX



            THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

            THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
            THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
            NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
            DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
            KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                              HEC-1 INPUT                                                  PAGE  1

           LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

             1           ID       MECKLENBURG COUNTY BMP DESIGN MANUAL
             2           ID       ANALYZED BY ABC ENGINEERING
             3           ID       DATE: OCTOBER 2006
                         *  ***************************************************************************
                         *
                         *     TIME SPECIFICATION CARD
                         *     TOTAL COMPUTATIONAL DURATION 6 HOURS
             4           IT       1       0       0     365
                         *  DIAGRAM
                         *     OUTPUT CONTROL CARD
             5           IO       5       0       0
                         *

             6           KK    PRE1
                         * ****************************************************************************
                         * **************** 10-YEAR, 6-HOUR STORM EVENT ******************************
                         * ****************************************************************************
             7           PI    .000    .011    .011    .012    .012    .012    .012    .013    .013    .013
             8           PI    .014    .014    .015    .015    .016    .016    .017    .018    .018    .023
             9           PI    .024    .025    .026    .027    .029    .036    .039    .042    .045    .049
            10           PI    .054    .079    .089    .103    .161    .201    .395    .590    .275    .177
```

```
          11          PI   .112    .095    .084    .057    .051    .047    .043    .040    .038    .030
          12          PI   .028    .027    .025    .024    .023    .019    .018    .017    .017    .016
          13          PI   .016    .015    .015    .014    .014    .013    .013    .013    .012    .012
          14          PI   .012    .011    .011    .000
                      * ****************************************************************************

          15          KM   10-ACRE PRE-DEVELOPED CONDITIONS
          16          KO      5       0       0       0      21
          17          BA   .0156
          18          LS      0    65.0       0
          19          UD   0.378

          20          KK   POST1
          21          KM   10-ACRE POST-DEVELOPED CONDITIONS
          22          KO      1       0       0       0      21
          23          BA   .0156
          24          LS      0    77.8       0
          25          UD   0.121

          26          KK  DETE10
          27          KO      5       0       0       0      21
          28          KM   DETENTION BASIN DESIGN FOR 1-INCH, 6-HOUR STORM EVENT, HELD FOR 96 HOURS
          29          KM   POST-DEVELOPED WITH CONTROLS
          30          KM   1.30 INCH ORIFICE TO ELEVATION 701.0; 2.9 INCH ORIFICE TO ELEVATION 702.3
          31          KM   15-INCH ORIFICE TO ELEVATION 704.0, 20 FOOT EMERGENCY SPILLWAY
          32          RS      1    ELEV     700
          33          SV      0    .143    .293    .452    .618    .721    .791    .973   1.166   1.367
          34          SE    700   700.5     701   701.5     702   702.3   702.5     703   703.5     704
          35          SQ   0.00   0.030   0.043   0.259   0.303   0.326   8.432   9.481  10.425  11.290
          36          ZZ
1*****************************************                                                   ***************************************
 *                                       *                                                   *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *   U.S. ARMY CORPS OF ENGINEERS      *
 *             JUN   1998                *                                                   *   HYDROLOGIC ENGINEERING CENTER     *
 *          VERSION 4.1                  *                                                   *         609 SECOND STREET           *
 *                                       *                                                   *      DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   25MAY07  TIME  14:27:41   *                                                   *          (916) 756-1104             *
 *                                       *                                                   *                                     *
 *****************************************                                                   ***************************************



                              MECKLENBURG COUNTY BMP DESIGN MANUAL
                              ANALYZED BY ABC ENGINEERING
                              DATE: OCTOBER 2006

    *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

            **************
            *            *
   20 KK    *    POST1   *
            *            *
            **************

   ****************************************************************************************************************************

    TOTAL RAINFALL =    3.72, TOTAL LOSS =    2.07, TOTAL EXCESS =    1.65

                                                              RUNOFF SUMMARY
                                                        FLOW IN CUBIC FEET PER SECOND
                                                     TIME IN HOURS,  AREA IN SQUARE MILES

                                            PEAK    TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD      BASIN     MAXIMUM     TIME OF
            OPERATION       STATION         FLOW     PEAK                                             AREA      STAGE     MAX STAGE
+                                                              6-HOUR      24-HOUR      72-HOUR

            HYDROGRAPH AT
+                              PRE1          13.    1.10          1.           1.           1.         .02

            HYDROGRAPH AT
+                             POST1          59.     .77          3.           3.           3.         .02

            ROUTED TO
+                            DETE10          10.    1.12          2.           2.           2.         .02
+                                                                                                             703.11        1.12


 *** NORMAL END OF HEC-1 ***


1*****************************************                                                   ***************************************
 *                                       *                                                   *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *   U.S. ARMY CORPS OF ENGINEERS      *
 *             JUN   1998                *                                                   *   HYDROLOGIC ENGINEERING CENTER     *
 *          VERSION 4.1                  *                                                   *         609 SECOND STREET           *
 *                                       *                                                   *      DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   25MAY07  TIME  14:29:03   *                                                   *          (916) 756-1104             *
 *                                       *                                                   *                                     *
 *****************************************                                                   ***************************************



                                                   X     X  XXXXXXX   XXXXX          X
                                                   X     X  X        X     X        XX
                                                   X     X  X        X               X
                                                   XXXXXXX  XXXX     X       XXXXX   X
                                                   X     X  X        X               X
                                                   X     X  X        X     X         X
                                                   X     X  XXXXXXX   XXXXX         XXX



           THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

           THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
           THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
```

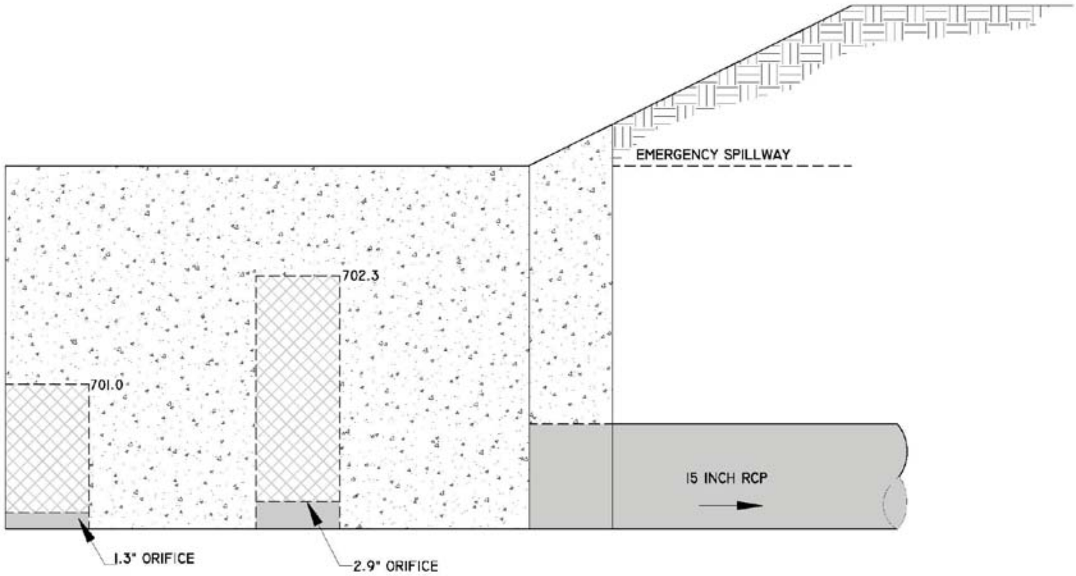
```
         NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
         DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
         KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                             HEC-1 INPUT                                           PAGE  1

         LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1           ID       MECKLENBURG COUNTY BMP DESIGN MANUAL
           2           ID       ANALYZED BY ABC ENGINEERING
           3           ID       DATE: OCTOBER 2006
                       *  ****************************************************************************
                       *
                       *     TIME SPECIFICATION CARD
                       *     TOTAL COMPUTATIONAL DURATION 6 HOURS
           4           IT       1       0       0     365
                       *  DIAGRAM
                       *     OUTPUT CONTROL CARD
           5           IO       5       0       0
                       *

           6           KK     PRE1
                       * ******************************************************************************
                       * **************** 25-YEAR, 6-HOUR STORM EVENT ******************************
                       * ******************************************************************************
           7           PI    .000    .014    .014    .014    .015    .015    .015    .016    .016    .017
           8           PI    .017    .018    .018    .019    .019    .020    .021    .022    .023    .025
           9           PI    .027    .028    .029    .031    .033    .043    .046    .049    .053    .058
          10           PI    .064    .093    .104    .120    .189    .235    .466    .680    .324    .208
          11           PI    .131    .111    .098    .067    .061    .055    .051    .048    .045    .034
          12           PI    .032    .030    .029    .027    .026    .023    .022    .021    .021    .020
          13           PI    .019    .019    .018    .017    .017    .016    .016    .016    .015    .015
          14           PI    .014    .014    .014    .000
                       * ******************************************************************************
          15           KM   10-ACRE PRE-DEVELOPED CONDITIONS
          16           KO       5       0       0       0      21
          17           BA   .0156
          18           LS       0    65.0       0
          19           UD   0.378

          20           KK   POST1
          21           KM   10-ACRE POST-DEVELOPED CONDITIONS
          22           KO       1       0       0       0      21
          23           BA   .0156
          24           LS       0    77.8       0
          25           UD   0.121

          26           KK  DETE10
          27           KO       5       0       0       0      21
          28           KM   DETENTION BASIN DESIGN FOR 1-INCH, 6-HOUR STORM EVENT, HELD FOR 96 HOURS
          29           KM   POST-DEVELOPED WITH CONTROLS
          30           KM   1.30 INCH ORIFICE TO ELEVATION 701.0; 2.9 INCH ORIFICE TO ELEVATION 702.3
          31           KM   15-INCH ORIFICE TO ELEVATION 704.0, 20 FOOT EMERGENCY SPILLWAY
          32           RS       1    ELEV     700
          33           SV       0    .143    .293    .452    .618    .721    .791    .973   1.166   1.367
          34           SE     700   700.5     701   701.5     702   702.3   702.5     703   703.5     704
          35           SQ    0.00   0.030   0.043   0.259   0.303   0.326   8.432   9.481  10.425  11.290
          36           ZZ
1***************************************                                                    **************************************
 *                                      *                                                    *                                    *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                                    *   U.S. ARMY CORPS OF ENGINEERS     *
 *            JUN  1998                 *                                                    *   HYDROLOGIC ENGINEERING CENTER    *
 *          VERSION 4.1                 *                                                    *         609 SECOND STREET          *
 *                                      *                                                    *      DAVIS, CALIFORNIA 95616       *
 * RUN DATE   25MAY07  TIME  14:29:03   *                                                    *          (916) 756-1104            *
 *                                      *                                                    *                                    *
 ***************************************                                                    **************************************



                            MECKLENBURG COUNTY BMP DESIGN MANUAL
                            ANALYZED BY ABC ENGINEERING
                            DATE: OCTOBER 2006

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

             **************
             *            *
   20 KK     *    POST1   *
             *            *
             **************

  ***************************************************************************************************************************

     TOTAL RAINFALL =    4.38, TOTAL LOSS =    2.20, TOTAL EXCESS =    2.18
                                                 RUNOFF SUMMARY
                                             FLOW IN CUBIC FEET PER SECOND
                                          TIME IN HOURS,  AREA IN SQUARE MILES

                                         PEAK   TIME OF    AVERAGE FLOW FOR MAXIMUM PERIOD      BASIN    MAXIMUM    TIME OF
          OPERATION       STATION        FLOW    PEAK                                            AREA      STAGE    MAX STAGE
+                                                            6-HOUR     24-HOUR     72-HOUR

          HYDROGRAPH AT
+                           PRE1          19.    1.08           2.          2.          2.        .02

          HYDROGRAPH AT
+                          POST1          78.     .77           4.          4.          4.        .02

          ROUTED TO
+                         DETE10          11.    1.15           2.          2.          2.        .02
+                                                                                                          703.93       1.15


 *** NORMAL END OF HEC-1 ***


1***************************************                                                    **************************************
 *                                      *                                                    *                                    *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                                    *   U.S. ARMY CORPS OF ENGINEERS     *
```

```
*             JUN  1998              *                                                         *     HYDROLOGIC ENGINEERING CENTER    *
*           VERSION 4.1              *                                                         *           609 SECOND STREET          *
*                                    *                                                         *        DAVIS, CALIFORNIA 95616       *
*  RUN DATE   25MAY07  TIME  14:36:13  *                                                       *            (916) 756-1104            *
*                                    *                                                         *                                      *
**************************************                                                         ****************************************




                                        X     X  XXXXXXX   XXXXX         X
                                        X     X  X        X     X       XX
                                        X     X  X        X              X
                                        XXXXXXX  XXXX     X       XXXXX  X
                                        X     X  X        X              X
                                        X     X  X        X     X        X
                                        X     X  XXXXXXX   XXXXX        XXX




         THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

         THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
         THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
         NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
         DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
         KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                       HEC-1 INPUT                                                    PAGE  1

         LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1        ID      MECKLENBURG COUNTY BMP DESIGN MANUAL
           2        ID      ANALYZED BY ABC ENGINEERING
           3        ID      DATE: OCTOBER 2006
                    *  ****************************************************************************
                    *
                    *     TIME SPECIFICATION CARD
                    *     TOTAL COMPUTATIONAL DURATION 6 HOURS
           4        IT      1       0       0     365
                    *  DIAGRAM
                    *     OUTPUT CONTROL CARD
           5        IO      5       0       0
                    *

           6        KK    PRE1
                    * *****************************************************************************
                    * ****************** 50-YEAR, 6-HOUR STORM EVENT ******************************
                    * *****************************************************************************
           7        PI    .000    .016    .016    .016    .017    .017    .018    .018    .019    .019
           8        PI    .020    .020    .021    .022    .022    .023    .024    .025    .026    .031
           9        PI    .032    .033    .035    .037    .039    .049    .053    .056    .061    .066
          10        PI    .073    .103    .116    .133    .209    .260    .513    .749    .356    .231
          11        PI    .145    .124    .109    .077    .069    .063    .058    .054    .051    .040
          12        PI    .038    .036    .034    .033    .031    .026    .025    .024    .023    .023
          13        PI    .022    .021    .021    .020    .019    .019    .018    .018    .017    .017
          14        PI    .017    .016    .016    .000
                    * ******************************************************************************
          15        KM   10-ACRE PRE-DEVELOPED CONDITIONS
          16        KO      5       0       0       0      21
          17        BA   .0156
          18        LS      0    65.0       0
          19        UD   0.378

          20        KK   POST1
          21        KM   10-ACRE POST-DEVELOPED CONDITIONS
          22        KO      1       0       0       0      21
          23        BA   .0156
          24        LS      0    77.8       0
          25        UD   0.121

          26        KK  DETE10
          27        KO      5       0       0       0      21
          28        KM   DETENTION BASIN DESIGN FOR 1-INCH, 6-HOUR STORM EVENT, HELD FOR 96 HOURS
          29        KM   POST-DEVELOPED WITH CONTROLS
          30        KM   1.30 INCH ORIFICE TO ELEVATION 701.0; 2.9 INCH ORIFICE TO ELEVATION 702.3
          31        KM   15-INCH ORIFICE TO ELEVATION 704.0, 20 FOOT EMERGENCY SPILLWAY
          32        KM   TOP OF EMBANKMENT 705.00
          33        RS      1    ELEV     700
          34        SV      0    .143    .293    .452    .618    .721    .791    .973   1.166   1.367
          35        SV   1.798
          36        SE    700   700.5     701   701.5     702   702.3   702.5     703   703.5     704
          37        SE    705
          38        SQ   0.00   0.030   0.043   0.259   0.303   0.326   8.432   9.481  10.425  11.290
          39        SQ  64.847
          40        ZZ
1**************************************                                                         ****************************************
*                                    *                                                         *                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                      *     U.S. ARMY CORPS OF ENGINEERS     *
*             JUN  1998              *                                                         *     HYDROLOGIC ENGINEERING CENTER    *
*           VERSION 4.1              *                                                         *           609 SECOND STREET          *
*                                    *                                                         *        DAVIS, CALIFORNIA 95616       *
*  RUN DATE   25MAY07  TIME  14:36:13  *                                                       *            (916) 756-1104            *
*                                    *                                                         *                                      *
**************************************                                                         ****************************************


                              MECKLENBURG COUNTY BMP DESIGN MANUAL
                              ANALYZED BY ABC ENGINEERING
                              DATE: OCTOBER 2006

 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

              *************
              *           *
   20 KK      *   POST1   *
              *           *
              *************
```

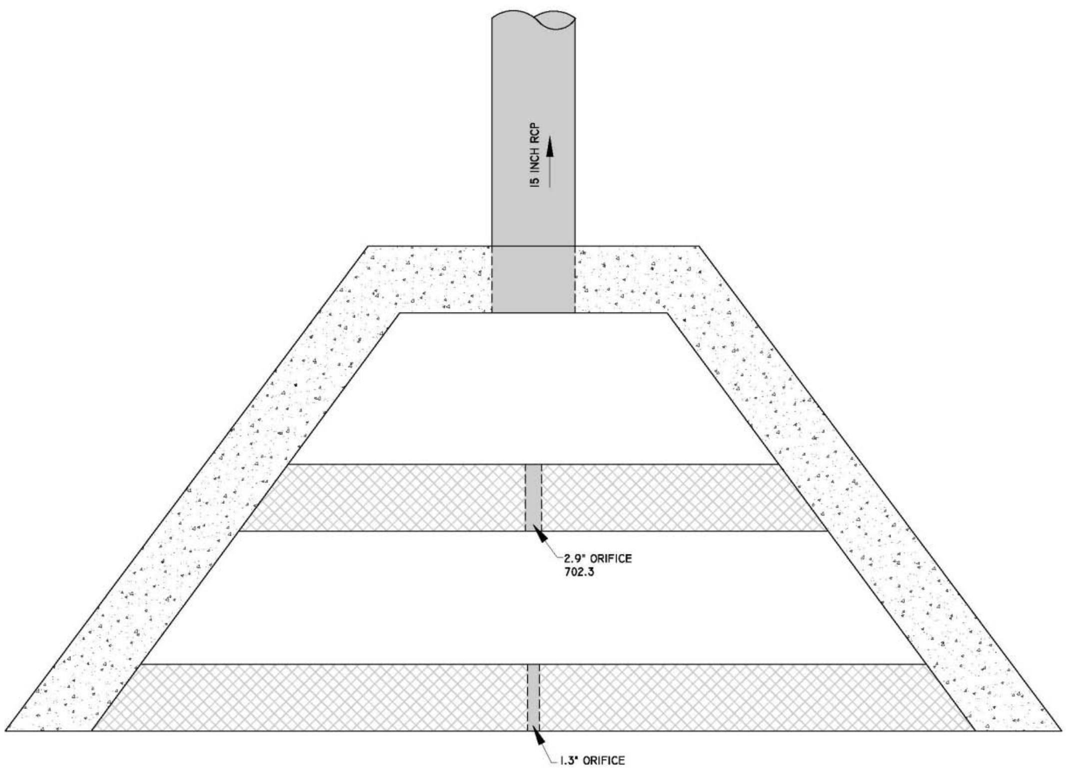
```
*******************************************************************************************************************************

     TOTAL RAINFALL =     4.92, TOTAL LOSS =     2.29, TOTAL EXCESS =     2.62

                                              FLOW IN CUBIC FEET PER SECOND
                                           TIME IN HOURS,  AREA IN SQUARE MILES

                                       PEAK   TIME OF         AVERAGE FLOW FOR MAXIMUM PERIOD        BASIN    MAXIMUM     TIME OF
          OPERATION        STATION     FLOW     PEAK                                                  AREA     STAGE     MAX STAGE
+                                                            6-HOUR       24-HOUR       72-HOUR

          HYDROGRAPH AT
+                            PRE1        25.    1.08            3.           3.            3.          .02

          HYDROGRAPH AT
+                           POST1        92.     .77            4.           4.            4.          .02

          ROUTED TO
+                          DETE10        25.    1.00            3.           3.            3.          .02
+                                                                                                            704.26        1.00


 *** NORMAL END OF HEC-1 ***
```

Table 4.2.3 Summary of Controls Provided

Control Element	Type/Size of Control	Stor. (ac-ft)	Peak Elev. (MSL)	Disc. (cfs)	Remarks
Permanent Pool	N/A	1.00	700.00	N/A	3.33 times 1-inch storm event volume
Forebay	Riprap weir wall	0.06	700.00	N/A	Two forebays, one at each major inflow point
Water Quality Extended Detention (WQ_v)	1.3-inch orifice at 700.0 and 1.00-foot tall weir	0.29	700.98	0	22% of runoff volume remains in basin at 99 hours (96 hours after center of rainfall)
Channel Protection (CP_v)	2.9-inch orifice at 700.0 and 2.30-foot tall weir	0.47	701.56	0	45% of runoff volume remains in basin at 36 hours (24 hours after center of rainfall)
Overbank Flood Protection Q_{10}	15-inch orifice at 700.0	1.01	703.11	10	Same orifice control was designed for the 10- and 25-year storm events
Overbank Flood Protection Q_{25}	15-inch orifice at 700.0	1.34	703.93	11	Same orifice control was designed for the 10- and 25-year storm events
Extreme Flood Protection Q_{50}	20-foot weir at 703.00	1.48	704.26	25	Top of embankment is set at 705.



TYPICAL SECTION
NOT TO SCALE



PLAN VIEW
NOT TO SCALE

Figure 4.2.8 Schematic of Wet pond Outlet Structure

Step 15 Investigate Potential Pond Hazard Classification

The following table is copied from the North Carolina Department of Environment and Natural Resources (NCDENR) to assist the design with determining the potential hazard classification. The total height of proposed embankment is ten (10) feet (705.0 – 695.0). The receiving stream system and floodplain exhibits relative wide overbanks that are not developed and are located on a greenway system, therefore the potential for downstream development is minimal. Therefore, the designer feels that the embankment should be classified in a low hazard classification. Additional discussion with the appropriate NCDENR office may be necessary.

Hazard Classification	Description	Quantitative Guidelines
Low	Interruption of road service, low volume roads	Less than 25 vehicles per day
	Economic damage	Less than $30,000
Intermediate	Damage to highways, Interruption of service	25 to less than 250 vehicles per day
	Economic damage	$30,000 to less than $200,000
High	Loss of human life*	Probable loss of 1 or more human lives
	Economic damage	More than $200,000
	*Probable loss of human life due to breached roadway or bridge on or below the dam.	250 Vehicles per day at 1000 feet visibility 100 Vehicles per day at 500 feet visibility 25 Vehicles per day at 200 feet visibility

Step 16 Assess Maintenance Access and Safety Features

A 12-foot wide stable maintenance access route must be provided. The access route must be contained within a 20-foot wide maintenance access easement from the BMP facility to public right-of-way.

Step 17 Prepare Vegetation and Landscaping Plan

A landscaping plan for the wet pond area must be prepared to indicate how the wet pond area will be stabilized and established with vegetation. Diverse and native plant species designed for the littoral shelf should be used. Plan must also include an invasive species prevention plan. Vegetation and landscaping plan must include plans for the first year of operation and full maturity (i.e. 3-year duration).