Wet Detention Pond
(1001)

Wisconsin Department of Natural Resources
Technical Standard

I. Definition

A permanent pool of water with designed dimensions, inlets, outlets and storage capacity, constructed to collect, detain, treat and release stormwater runoff.

II. Purposes

The primary purposes of this practice are to improve water quality and reduce peak flow.

III. Conditions Where Practice Applies

This practice applies to urban sites where stormwater runoff pollution due to particulate solids loading and attached pollutants is a concern. It also applies where increased runoff from urbanization or land use change is a concern. Site conditions must allow for runoff to be directed into the pond and a permanent pool of water to be maintained.

This standard establishes criteria for ponds to detain stormwater runoff, although some infiltration may occur. In some instances, detention ponds may present groundwater contamination risks, and this standard sets criteria for determining when liners may be necessary to address risks to groundwater. Where the detention pond will be discharging to an infiltration practice, see WDNR Technical Standards 1002-1004.

Application of this standard is not intended to address flood control. Modifications to the peak flow criteria or additional analysis of potential flooding issues may be needed or required by local authorities. For ponds used during the construction period, see WDNR Technical Standard 1064, Sediment Basin.

This practice provides a method to demonstrate that a wet detention pond achieves the total suspended solids (TSS) reduction and peak flow control required by NR 151.12, Wis. Adm. Code, for post-construction sites. Pollutant loading models such as SLAMM, P8, DETPOND or equivalent methodology may also be used to evaluate the efficiency of the design in reducing TSS.

IV. Federal, State and Local Laws

The design, construction and maintenance of wet detention ponds shall comply with all federal, state and local laws, rules or regulations. The owner/operator is responsible for securing required permits. This standard does not contain the text of any federal, state or local laws governing wet detention ponds.

The location and use of wet detention ponds may be limited by regulations relating to stormwater management, navigable waters (Ch. 30, Wis. Stats.), floodplains, wetlands, buildings, wells and other structures, or by land uses such as waste disposal sites and airports. The pond embankment may be regulated as a dam under Ch. 31, Wis. Stats., and further restricted under NR 333, Wis. Adm. Code, which includes regulations for embankment heights and storage capacities.

V. Criteria

The following minimum criteria apply to all wet detention pond designs used for the purposes stated in Section II of this standard. Use more restrictive criteria as needed to fit the conditions found in the site assessment.

A. Site Assessment – Conduct and document a site assessment to determine the site characteristics that will affect the placement, design, construction and maintenance of the pond. Document the pond design. Items to assess include:

1. At the pond site, on a site map:

    a. Identify buildings and other structures, parking lots, property lines, wells, wetlands, 100-year floodplains, surface

[1] Words in the standard that are shown in italics are described in X. Definitions. The words are italicized the first time they are used in the text.

drains, navigable streams, known drain tile, roads, and utilities (both overhead and buried) showing elevation contours and other features specified by the applicable regulatory authority.

b. Show location of soil borings and test pits on site map, characterize the soils, *seasonally high groundwater level*[1], and *bedrock* conditions to a minimum depth of 5 feet below the proposed bottom of the pond or to bedrock, whichever is less. Conduct one test pit or boring per every 2 acres of permanent pool footprint, with a minimum of two per pond. Include information on the soil texture, color, structure, moisture and groundwater indicators, and bedrock type and condition, and identify all by elevation. Characterize soils using both the USDA and USCS classification systems.

Note: USCS characterization is used for soil stability assessment while USDA soil characterization identifies the soil's potential permeability rate.

c. Investigate the potential for *karst features* nearby.

2. In the watershed, on a watershed map:

a. Identify predominant soils, the drainage ways, navigable streams and floodways, wetlands, available contour maps, land cover types and known karst features. Identify the receiving surface waters, or whether the drainage basin drains directly to groundwater.

b. Show channels and overland flow before and after development, contours, and property lines.

c. Refer to the Tc (time of concentration) flow paths and subwatershed boundaries used in runoff calculations.

B. Pond Design – Properly designed wet detention ponds are effective at trapping smaller particles, and controlling peak flows (see App. C, Figures 1-3).

1. Water Quality – Pollutant reduction (TSS and phosphorus) is a function of the permanent pool area and depth, the outlet structure and the active storage volume. The following criteria apply:

a. Permanent Pool – The elevation below which runoff volume is not discharged and particles are stored.

i. Design ponds to include a permanent pool of water. The surface area of the permanent pool is measured at the invert of the lowest outlet. The minimum surface area of the permanent pool must address the total drainage area to the pond.

Note: Use App. A for the initial estimate of the permanent pool area based on drainage area. Prorate values for mixed land uses. Use Equation 1 to solve for q_o and iterate as needed.

ii. The permanent pool surface area is sized based on the particle size and the peak outflow during the 1-yr., 24-hour design storm using Equation 1:

$$\mathbf{S_a = 1.2 * (q_o / \mathit{v}_s)} \quad \text{[Equation 1(a)]}$$

or

$$\mathbf{q_o = (\mathit{v}_s * S_a) / 1.2} \quad \text{[Equation 1(b)]}$$

Where:

$\mathbf{S_a}$ = Permanent pool surface area measured at the invert of the lowest outlet of the wet detention pond (square feet)

$\mathbf{q_o}$ = Post-construction peak outflow (cubic feet/second) during the 1-yr., 24-hour design storm for the principal outlet

$\mathbf{\mathit{v}_s}$ = Particle settling velocity (feet/second)

1.2 = EPA recommended safety factor

iii. Particle settling velocities (v_s) shall be based on representative particle sizes for the desired percent TSS reduction.

- 80% (3 micron): $v_s = 1.91 \times 10^{-5}$ ft./sec.
- 60% (6 micron): $v_s = 7.37 \times 10^{-5}$ ft./sec.
- 40% (12 micron): $v_s = 2.95 \times 10^{-4}$ ft./sec.

Note: Particle settling velocities were calculated assuming a specific gravity of 2.5, a water temperature of 50 degrees Fahrenheit (10 degrees C) and a kinematic viscosity of 0.01308 $cm.^2/sec.$ (Pitt, 2002). The calculations also assume discrete and quiescent settling conditions per Stoke's Law.

b. Active Storage Volume – Volume above the permanent pool that is released slowly to settle particles. Calculate the volume with the following method:

Use a hydrograph-producing method, such as the one outlined in Natural Resources Conservation Service, Technical Release 55 (TR-55), to determine the storage volume for detention ponds. This can be accomplished by using App. B where:

$\mathbf{q_o}$ = Peak outflow during the 1-yr., 24-hour design storm for the principal outlet calculated using Equation 1 (see V.B.1.a.ii).

$\mathbf{q_i}$ = Calculated post-construction peak inflow or runoff rate during the 1-yr., 24-hour design storm.

$\mathbf{V_R}$ = Calculated volume of runoff from the 1-year, 24-hour design storm for the entire contributory area.

$\mathbf{V_S}$ = The required active storage volume determined using App. B.

Note: This method may require iterative calculations.

c. Safety – Include a safety shelf (or aquatic shelf) that extends a minimum of 8 ft. from the edge of the permanent pool waterward with a slope of 10:1 (horizontal:vertical) or flatter. The maximum depth of the permanent pool of water over the shelf shall be 1.5 ft.

d. Depth – The average water depth of the permanent pool shall be a minimum of 3 ft., excluding the safety shelf area and sediment storage depth.

e. Length to Width – Maximize the length to width ratio of the flow path to prevent short-circuiting and dead zones (areas of stagnant water). See Section VII, Considerations D and N for options to prevent short circuiting.

f. Sediment Storage – After all construction has ceased and the contributory watershed has been stabilized, one of the following applies:

i. A minimum of 2 ft. shall be available for sediment storage (for a total of 5 ft. average depth, excluding the safety shelf area). For ponds greater than 20,000 sq. ft., 50% of the total surface area of the permanent pool shall be a minimum of 5 ft. deep. For ponds less than 20,000 sq. ft., maximize the area of 5 ft. depth.

ii. Modeling shows that for 20 years of sediment accumulation, less than 2 ft. sediment storage is needed (not to be less than 0.5 feet).

iii. A minimum of 4 ft. shall be available for sediment storage if the contributory area includes cropland not stabilized by any other practice, such as strip cropping, terraces and conservation tillage.

For information on sediment storage in forebays, see Section VII, Consideration C.

Note: Municipalities that use sand in the winter may consider increasing the sediment storage depth.

g. Side Slopes Below Safety Shelf – All side slopes below the safety shelf shall be 2:1 (horizontal:vertical) or flatter as required to maintain soil stability, or as required by the applicable regulatory authority.

h. Outlets – Wet detention ponds shall have both a principal outlet and an emergency spillway.

i. Prevent Damage – Incorporate into outlet design trash accumulation preventive features, and measures for preventing ice damage and scour at the outfall. Direct outlets to channels, pipes, or similar conveyances designed to handle prolonged flows.

ii. Principal Water Quality Outlet – Design the outlet to control the proposed 2-yr., 24-hour discharge from the pond within the primary principal outlet without use of the emergency spillway or other outlet structures. If a pipe discharge is used as the primary principal outlet, then the minimum diameter shall be 4 inches. Where an orifice is used, features to prevent clogging must be added.

iii. Backward Flow – Any storm up to the 10-yr., 24-hour design storm shall not flow backward through the principal water quality outlet or principal outlet. Flap gates or other devices may be necessary to prevent backward flow.

iv. Emergency Spillway – All ponds shall have an emergency spillway. Design the spillway to safely pass peak flows produced by a 100-yr., 24-hour design storm routed through the pond without damage to the structure. The flow routing calculations start at the permanent pool elevation.

v. Peak Flow Control – Design the peak flow control to maintain stable downstream conveyance systems and comply with local ordinances or conform with regional stormwater plans where they are more restrictive than this standard. At a minimum:

   a) The post-development outflow shall not exceed pre-development peak flows for the 2-yr., 24-hour design storm.

   b) Use a hydrograph-producing method such as TR-55 for all runoff and flow calculations.

   c) When pre-development land cover is cropland, use the runoff curve numbers in Table 1, unless local ordinances are more restrictive.

   d) For all other pre-development land covers, use runoff curve numbers from TR-55 assuming "good hydrologic conditions."

   e) For post-development calculations, use runoff curve numbers based on proposed plans.

Note: Local ordinances may require control of larger storm events than the 2-yr., 24-hour storm. In these cases, additional or compound outlets may be required.

Table 1 - Maximum Pre-Development Runoff Curve Numbers for Cropland Areas

Hydrologic Soil Group	A	B	C	D
Runoff Curve Number	55	69	78	83

2. Other Pond Criteria

a. Inflow Points – Design all inlets to prevent scour during peak flows produced by the 10-yr., 24-hr. design storm, such as using half-submerged inlets, stilling basins and rip-rap. Where infiltration may initially occur in the pond, the scour prevention device shall extend to the basin bottom.

b. Side Slopes – All interior side slopes above the safety shelf shall be 3:1 (horizontal:vertical), or flatter if required by the applicable regulatory authority.

c. Ponds in Series – To determine the overall TSS removal efficiency of ponds in series, the design shall use an *approved model* such as DETPOND or P8, that can track particle size distribution from one pond to the next.

d. Earthen Embankments – Earthen embankments (see App. C, Figure 3) shall be designed to address potential risk and structural integrity issues such as seepage and saturation. All constructed earthen embankments shall meet the following criteria.

   i. Vegetation – Remove a minimum of 6 in. of the parent material (including all vegetation, stumps, etc.) beneath the proposed base of the embankment.

ii. Core Trench or Key-way – For embankments where the permanent pool is ponded 3 ft. or more against the embankment, include a core trench or key-way along the centerline of the embankment up to the permanent pool elevation to prevent seepage at the joint between the existing soil and the fill material. The core trench or key-way shall be a minimum of 2 ft. below the existing grade and 8 ft. wide with a side slope of 1:1 (horizontal:vertical) or flatter. Follow the construction and compaction requirements detailed in V.B.2.d.iii below for compaction and fill material.

iii. Materials – Construct all embankments with non-organic soils and compact to 90% standard proctor according to the procedures outlined in ASTM D-698 or by using compaction requirements of USDA Natural Resources Conservation Service, Wisconsin Construction Specification 3. Do not bury tree stumps, or other organic material in the embankment. Increase the constructed embankment height by a minimum of 5% to account for settling.

iv. Freeboard – Ensure that the top of embankment, after settling, is a minimum of 1 vertical foot above the flow depth for the 100-yr., 24-hr. storm.

v. Pipe Installation, Bedding and Backfill – If pipes are installed after construction of the embankment, the pipe trench shall have side slopes of 1:1 or flatter. Bed and backfill any pipes extending through the embankment with embankment or equivalent soils. Compact the bedding and backfill in lifts and to the same standard as the original embankment.

vi. Seepage – Take measures to minimize seepage along any conduit buried in the embankment. Measures such as anti-seep collars, sand diaphragms or use of bentonite are acceptable.

vii. Exterior side slopes shall be 2:1 (horizontal:vertical) or flatter, with a minimum top width of the embankment of 4 ft., or 10 ft. if access for maintenance is needed. The embankment must be designed for slope stability.

e. Topsoil and Seeding – Spread topsoil on all disturbed areas above the safety shelf, as areas are completed, to a minimum depth of 4 inches. Stabilize according to the permanent seeding criteria in WDNR Technical Standard 1059, Seeding for Construction Site Erosion Control.

f. Liners – Use the Liner Flowchart in App. D to determine when a liner is needed. For types of liners, see the Liner Flowchart and specifications in App. D. If a liner is used, provide a narrative that sets forth the liner design and construction methods.

Note: Some municipalities have wellhead protection areas and all municipalities have source water protection areas delineated by WDNR. Consult with the local community about when a liner will be needed if located within one of these areas.

g. Depth to Bedrock – The separation distance from the proposed bottom of a wet detention pond to bedrock will determine which of the following apply:

i. If the separation distance is a minimum of 5 ft. and the soil beneath the pond to bedrock is 10% fines or more, refer to the Liner Flowchart to determine if a liner may be needed for reasons other than proximity to bedrock;

ii. If the separation distance is a minimum of 3 ft. and the soil beneath the pond to bedrock is 20% fines or more, refer to the Liner Flowchart to determine if a liner may be needed for reasons other than proximity to bedrock;

iii. If conditions in (i) or (ii) are not met, then a Type B liner is required at a minimum. Refer to the Liner

Flowchart to determine if a Type A liner may be needed for reasons other than proximity to bedrock (see liner specifications in App. D);

iv. If blasting in bedrock is performed to construct a wet detention pond in bedrock, then a Type A liner is required (see liner specifications in App. D) and an engineering design must be conducted.

h. Separation from Wells – Wet detention ponds shall be constructed 400 feet from community wells (NR 811, Wis. Adm. Code) and 25 feet from non-community and private wells (NR 812, Wis. Adm. Code).

Note: The 25 foot setback from non-community and private wells is a final construction distance. This may not be sufficient to prevent running over the well with heavy equipment during construction of the pond.

i. Wetlands – For wet detention ponds that discharge to wetlands, use level spreaders or rip-rap to prevent channelization, erosion and reduce sedimentation in the wetlands.

j. Off-site runoff – Address off-site runoff in the design of a wet detention pond.

k. Aerators/Fountains – If an aerator or fountain is desired for visual and other aesthetic effects (aerators designed to mix the contents of the pond are prohibited) they must meet one of the first two items (i – ii), and items (iii) and (iv) below.

i. Increase the surface area of the wet detention pond beyond the area needed to achieve compliance with a stormwater construction site permit. The increase in surface area is equal to or greater than the *area of influence* of the aerator/fountain. Use an aerator/fountain that does not have a *depth of influence* that extends into the sediment storage depth (see App. E, Figure 4).

ii. For wet detention ponds where the surface area is no more than required to meet the stormwater construction site permit conditions, the depth of influence of the device cannot extend below the sediment storage elevation. Include in the design an automatic shut-off of the aerator/fountain as the pond starts to rise during a storm event. The aerator/fountain must remain off while the pond depth returns to the permanent pool elevation and, further, shall remain off until such time as required for the design micron particle size to settle to below the draw depth of the pump. (See V.B.1.a.iii for the design micron particle sizes that correlate with a TSS reduction.)

iii. Aerator/fountains are not allowed in wet detention ponds with less than a 5 ft. permanent pool designed depth.

iv. Configure the pump intake to draw water primarily from a horizontal plane so as to minimize the creation of a circulatory pattern from bottom to top throughout the pond.

VI. Operation and Maintenance

Develop an operation and maintenance plan that is consistent with the purposes of this practice, the wet detention pond's intended life, safety requirements and the criteria for its design. The operation and maintenance plan will:

A. Identify the responsible party for operation, maintenance and documentation of the plan.

B. Require sediment removal once the average depth of the permanent pool is 3.5 ft. At a minimum, include details in the plan on inspecting sediment depths, frequency of accumulated sediment removal, and disposal locations for accumulated sediment (NR 500, Wis. Adm. Code).

C. Include inlet and outlet maintenance, keeping embankments clear of woody vegetation, and providing access to perform the operation and maintenance activities.

D. Identify how to reach any forebay, safety shelf, inlet and outlet structures.

E. Address weed or algae growth and removal, insect and wildlife control and any landscaping practices.

F. If a liner is used, show how the liner will be protected from damage during sediment removal or when the liner is undergoing repair.

G. Prohibit excavation below the original design depth unless geotechnical analysis is completed in accordance with V.A.1.b & c.

VII. Considerations

Consider the following items for all applications of this standard:

A. Additional conservation practices should be considered if the receiving water body is sensitive to temperature fluctuations, oxygen depletion, excess toxins or nutrients.

B. To prevent nuisance from geese, consider not mowing around the pond perimeter. To maximize safety and pollutant removal, consider spreading topsoil along the safety shelf to promote plant growth.

C. For ease of maintenance, a sediment forebay should be located at each inlet (unless inlet is < 10% of total inflow or an equivalent upstream pretreatment device exists) to trap large particles such as road sand. The storage volume of the sediment forebay should be consistent with the maintenance plan, with a goal of 5%-15% of the permanent pool surface area. The sediment forebay should be a minimum depth of 3 ft. plus the depth for sediment storage.

D. The length to width ratio of the flow path should be maximized with a goal of 3:1 or greater. The flow path is considered the general direction of water flow within the pond, including the permanent pool and forebay.

E. Consider providing additional length to the safety shelf, above or below the wet pool elevation, to enhance safety.

F. To prevent damage or failure due to ice, all risers extending above the pond surface should be incorporated into the pond embankment.

G. The use of underwater outlets should be considered to minimize ice damage, accumulation of floating trash or vortex control.

H. Watershed size and land cover should be considered to ensure adequate runoff volumes to maintain a permanent pool.

I. Aesthetics of the pond should be considered in designing the shape and specifying landscape practices. Generally, square ponds are aesthetically unappealing.

J. If downstream flood management or bank erosion is a concern, consider conducting a watershed study to determine the most appropriate location and design of stormwater management structures, including consideration of potential downstream impacts on farming practices and other land uses.

K. For wet detention ponds with surface area more than 2 acres or where the fetch is greater than 500 feet, consider reinforcing banks, extending the safety shelf, vegetating the safety shelf or other measures to prevent erosion of embankment due to wave action.

L. To prevent failure, consider reinforcing earthen emergency spillways constructed over fill material to protect against erosion.

M. All flow channels draining to the pond should be stable to minimize sediment delivery to the pond.

N. Baffles may be used to artificially lengthen the flow path in the pond. In some designs, a circular flow path is set up in a pond even when the inlet and outlet are next to each other and no baffles are used. Then the flow path can be calculated using the circular path.

O. Consider using low fertilizer inputs on the embankments and collecting the clippings.

P. Consider providing a method to facilitate dewatering during accumulated sediment removal.

Q. Consider using backflow preventers to minimize fish entrapment.

R. Consider providing a terrestrial buffer of 10-15 feet around the pond if it has low or no embankments.

S. Consider a hard surface for the bottom of the forebay to ease sediment removal.

T. Use of algaecides, herbicides or polymers to control nuisance growths or to enhance sedimentation must receive a permit under NR 107, Wis. Adm. Code. Contact the appropriate DNR specialist.

U. Consider additional safety features beyond the safety shelf where conditions warrant them.

V. Consider vegetative buffer strips along drainage ways leading to the detention pond to help filter pollutants.

W. After the site assessment is complete, review and discuss it with the local administering agency at a pre-design conference to determine and agree on appropriate pond design for the site.

X. Design so that the 10-yr., 24-hour design storm does not flow through the emergency spillway. The 10-yr. design criteria protects the embankment from premature failure due to frequent or long-duration flows through the emergency spillway.

Y. Where practical, construct the emergency spillway on original grade.

Z. Conduct a groundwater boring to 15 feet below the pond and consider the historic "mottling marks" in assessing groundwater levels.

AA. For partially or fully submerged inlet pipes, consider using pipe ties or some other method to keep pipes from dislodging during frost movement.

BB. Consider employing a geotechnical engineer if stability of the embankment is a concern and to justify slopes steeper than 2.5:1.

CC. Assess potential environmental hazards at the site from previous land uses. The assessment should use historical information about the site to determine if the potential for environmental hazard exists, e.g., contaminated soils, contaminated groundwater, abandoned dumps or landfills. Contaminated areas can be located by reviewing the Bureau of Remediation and Redevelopment Tracking System (BRRTS), the DNR Registry of Waste Disposal Sites in Wisconsin and the Solid and Hazardous Waste Information System (SHWIMS) available through the WDNR website.

DD. Consider direct and indirect impacts to area wetland hydrology and wetland hydroperiod due to area hydrologic modifications that result from routing wetland source waters through a wet detention pond or releasing the discharge from a wet detention pond directly into a wetland.

EE. Consider conducting more than one test pit or boring per every 2 acres of permanent pool footprint, with a minimum of two per pond, if more are needed to determine the variability of the soil boundary or to identify perched water tables due to clay lenses. For the soils analysis, consider providing information on soil thickness, groundwater indicators—such as soil mottle or redoximorphic features—and occurrence of saturated soil, groundwater or disturbed soil.

FF. Where the soils are fine, consider groundwater monitoring if the groundwater table is less than 10 feet below the bottom of the wet pond because the water table may fluctuate seasonally. Other impacts on the groundwater table elevation may be from seasonal pumping of irrigation wells or the influence of other nearby wells. Monitoring or modeling may be necessary in these situations to identify the groundwater elevation.

GG. For additional guidance on seepage control for embankments, consult sections V.B.1.c and V.B.1.e(2) of NRCS Conservation Practice Standard 378, Pond, particularly if a wet detention pond's embankment is considered to be a dam.

VIII. Plans and Specifications

Plans and specifications shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended use. Plans shall specify the materials, construction processes, location, size and elevations of all components of the practice to allow for certification of construction upon completion.

IX. References

Center for Watershed Protection, *Stormwater BMP Design for Cold Climates*, December 1997.

R. Pitt and J. Voorhees, *The Design and Use of Detention Facilities for Stormwater Management Using DETPOND*, 2000.

United States Department of Agriculture, Natural Resources Conservation Service, Conservation Practice Standard 378, *Pond*, July 2001.

United States Department of Agriculture, Natural Resources Conservation Service, *Engineering Field Handbook.*

United States Department of Agriculture, Natural Resources Conservation Service, *Ponds – Planning, Design, Construction*, Agriculture Handbook 590, revised September 1997.

United States Department of Agriculture, Natural Resources Conservation Service, Technical Release 55, *Urban Hydrology for Small Watersheds*.

United States Department of Agriculture, Natural Resources Conservation Service, *Wisconsin Field Office Technical Guide*, *Section IV*.

United States Department of Commerce, Weather Bureau, *Rainfall Frequency Atlas of the United States, Technical Paper 40*.

University of Wisconsin – Extension, *The Wisconsin Storm Water Manual, Part Four: Wet Detention Basins,* Publication No. G3691-P.

Wisconsin State Legislature, Revisor of Statutes Bureau, *Wisconsin Administrative Code*; for information on the codes of state agencies, including WDNR, see http://www.legis.state.wi.us/rsb/code.htm.

X. Definitions

Approved Model (V.B.2.c) – A computer model that is used to predict pollutant loads from urban lands and has been approved by the applicable regulatory authorities. SLAMM and P8 are examples of models that may be used to verify that a detention pond design meets the desired total suspended solids reduction.

Area of Influence (V.B.2.k.i) – The area of influence of an aerator/fountain is a function of the circular area of impact of the return water and the mixing area of the pump, whichever is greater.

Bedrock (V.A.1.b) – Consolidated rock material and weathered in-place material with > 50%, by volume, larger than 2 mm in size.

Depth of Influence (V.B.2.k.i) – The depth of influence of an aerator/fountain is a function of the impact depth of the return water and the draw depth of the pump, whichever is greater.

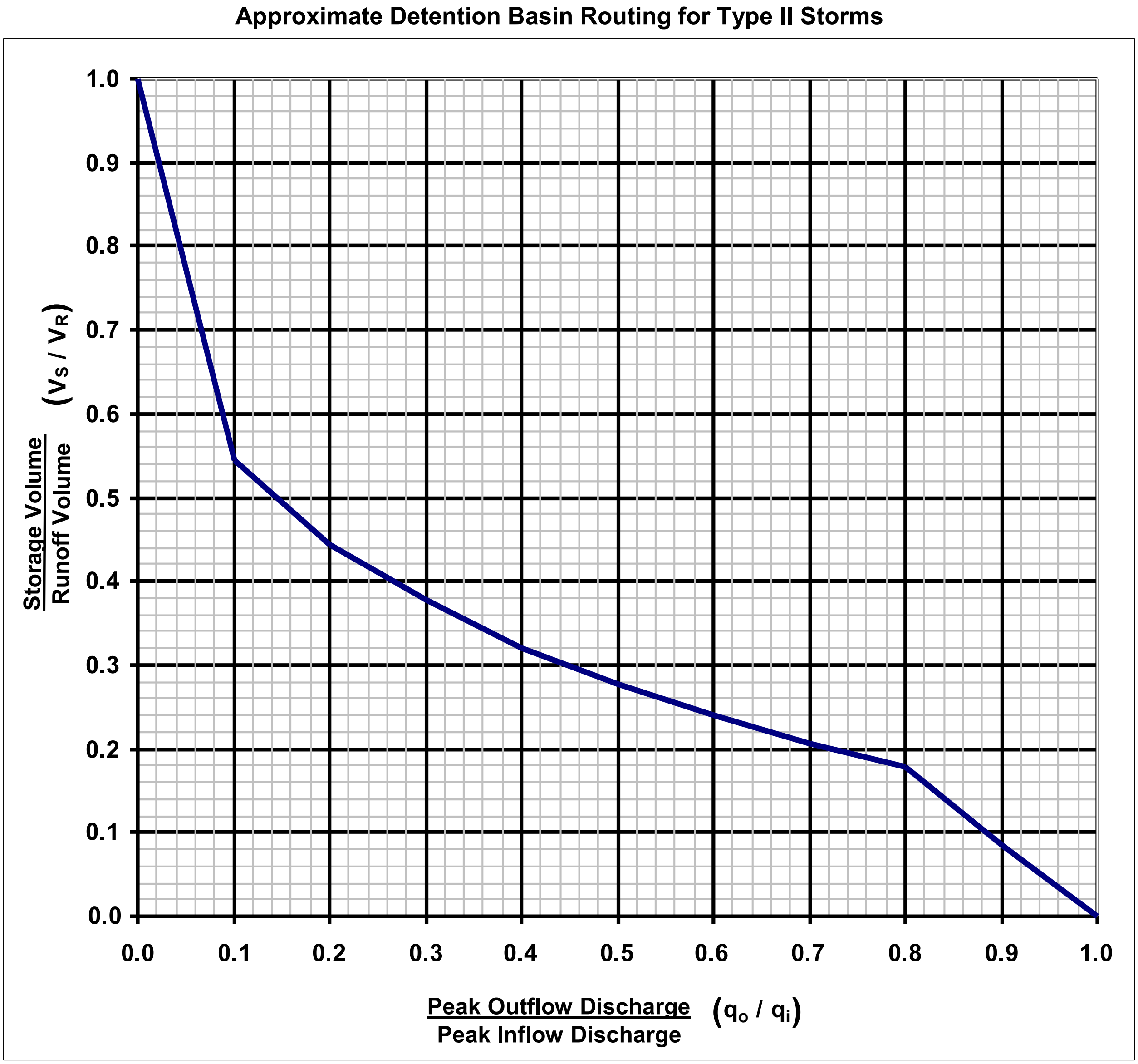
Karst Feature (V.A.1.c) – An area or surficial geologic feature subject to bedrock dissolution so that it is likely to provide a conduit to groundwater. May include caves, enlarged fractures, mine features, exposed bedrock surfaces, sinkholes, springs, seeps, swallets, fracture trace (linear feature, including stream segment, vegetative trend and soil tonal alignment), Karst pond (closed depression in a karst area containing standing water) or Karst fen (marsh formed by plants overgrowing a karst lake or seepage area).

Seasonally high groundwater level (V.A.1.b) – The higher of either the elevation to which the soil is saturated as observed as a free water surface in an unlined hole, or the elevation to which the soil has been seasonally or periodically saturated as indicated by soil color patterns throughout the soil profile.

Appendix A—Calculation of Preliminary Permanent Pool Surface Area for TSS Reduction [1]			
		80%	60%
Land Use/Description/Management[2]	Total Impervious (%)[3]	Minimum Surface Area of the Permanent Pool (% of Watershed Area)	Minimum Surface Area of the Permanent Pool (% of Watershed Area)
Residential • < 2.0 units/acre (>1/2 acre lots) (low density • 2.0 - 6.0 units/acre (medium density) • > 6.0 units/acre (high density)	8 - 28 >28 -41 >41 - 68	0.7 0.8 1.0	0.3
Commercial/Office Park/Institutional/Warehouse/Industrial/Manufacturing/Storage[4] (Non-retail related business, multi-storied buildings, large heavily used outdoor parking areas, material storage, or manufacturing operations	<60 60-80 80-90 >90	1.8 2.1 2.4 2.8	0.6
Parks/Open Space/Woodland/Cemeteries	0-12	0.6	0.2
Highways/Freeways (Includes right-of-way area) • Typically grass banks/conveyance • Mixture of grass and curb/gutter • Typically curb/gutter conveyance	<60 60-90 >90	1.4 2.1 2.8	1.0

[1] Multiply the value listed by the watershed area within the category to determine the minimum pond surface area. Prorate for drainage areas with multiple categories due to different land use, management, percent impervious, soil texture, or erosion rates. For example, to achieve an 80% TSS reduction, a 50 acre (residential, 50% imperviousness) x 0.01 (1% of watershed from table) = 0.5 acre + 50 acres (office park, 85% imperviousness) x 0.024 (2.4% of watershed) = 1.2 acre. Therefore 0.5 acre + 1.2 acre = 1.7 acres for the minimum surface area of the permanent pool.
[2] For offsite areas draining to the proposed land use, refer to local municipalities for planned land use and possible institutional arrangements as a regional stormwater plan.
[3] Impervious surfaces include rooftops, parking lots, roads, and similar hard surfaces, including gravel driveways/parking areas.
[4] Category includes insurance offices, government buildings, company headquarters, schools, hospitals, churches, shopping centers, strip malls, power plants, steel mills, cement plants, lumber yards, auto salvage yards, grain elevators, oil tank farms, coal and salt storage areas, slaughter houses, and other outdoor storage or parking areas.
Source: This table was modified from information in "The Design and Use of Detention Facilities for Stormwater Management Using DETPOND" by R. Pitt and J. Voorhees (2000).

Appendix B



Source: Technical Release 55, United States Department of Agriculture, Natural Resources Conservation Service, Washington, D.C. 1986. NRCS Bulletin No. WI-210-8-16 (Sept. 12, 1988) amended the TR-55 routing graph for Type II storms to include flows outside the original range.

Appendix B (cont'd.)

Rainfall Quantities:

Table 2 provides a summary of the 1-year, 24-hour rainfall totals using NRCS mandated TP-40, which has not been updated since 1961. Table 3 provides a summary of more current data from the Rainfall Frequency Atlas of the Midwest published in 1992. Local requirements may dictate the use of one dataset over the other.

Table 2 – Rainfall for Wisconsin Counties for a 1-year, 24-hour Rainfall[1]

Inches of Rainfall	County
2.1 in.	Door, Florence, Forest, Kewaunee, Marinette, Oconto, Vilas
2.2 in.	Ashland, Bayfield, Brown, Calumet, Douglas, Iron, Langlade, Lincoln, Manitowoc, Menominee, Oneida, Outagamie, Price, Shawano, Sheboygan
2.3 in.	Barron, Burnett, Dodge, Fond du Lac, Green Lake, Marathon, Milwaukee, Ozaukee, Portage, Racine, Rusk, Sawyer, Taylor, Washburn, Washington, Waukesha, Waupaca, Waushara, Winnebago, Wood
2.4 in.	Adams, Chippewa, Clark, Columbia, Dane, Dunn, Eau Claire, Jackson, Jefferson, Juneau, Kenosha, Marquette, Pepin, Pierce, Polk, Rock, St. Croix, Walworth
2.5 in.	Buffalo, Green, Iowa, La Crosse, Monroe, Richland, Sauk, Trempealeau, Vernon
2.6 in.	Crawford, Grant, Lafayette

[1]TP – 40: Rainfall Frequency Atlas of the United States, U.S. Department of Commerce Weather Bureau.

Table 3 - Rainfall for Wisconsin Counties for a 1-year, 24-hour Rainfall[2]

Zone	Inches of Rainfall	County
1	2.22	Douglas, Bayfield, Burnett, Washburn, Sawyer, Polk, Barron, Rusk, Chippewa, Eau Claire
2	2.21	Ashland, Iron, Vilas, Price, Oneida, Taylor, Lincoln, Clark, Marathon
3	1.90	Florence, Forest, Marinette, Langlade, Menominee, Oconto, Door, Shawano
4	2.23	St. Croix, Dunn, Pierce, Pepin, Buffalo, Trempealeau, Jackson, La Crosse, Monroe
5	2.15	Wood, Portage, Waupaca, Juneau, Adams, Waushara, Marquette, Green Lake
6	1.96	Outagamie, Brown, Kewaunee, Winnebago, Calumet, Manitowoc, Fond du Lac, Sheboygan
7	2.25	Vernon, Crawford, Richland, Sauk, Grant, Iowa, Lafayette
8	2.25	Columbia, Dodge, Dane, Jefferson, Green, Rock
9	2.18	Ozaukee, Washington, Waukesha, Milwaukee, Walworth, Racine, Kenosha

[2]Bulletin 71: Rainfall Frequency Atlas of the Midwest, Midwest Climate Center and Illinois State Water Survey, 1992.

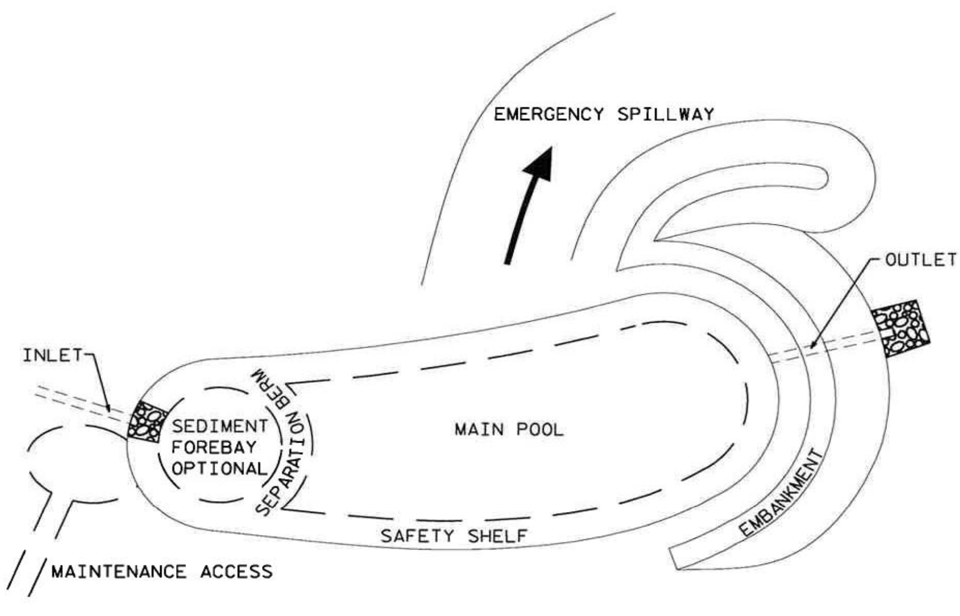
Appendix B (cont'd.)

Table 4 – Runoff for Selected Curve Numbers and Rainfall Amounts[1]											
	Runoff Depth in Inches for Curve Number of:										
Rainfall (inches)	50	55	60	65	70	75	80	85	90	95	98
1.9	0.00	0.01	0.04	0.11	0.20	0.33	0.50	0.72	1.01	1.39	1.68
1.96	0.00	0.01	0.05	0.12	0.23	0.36	0.54	0.77	1.06	1.44	1.73
2.1	0.00	0.02	0.08	0.16	0.28	0.43	0.62	0.87	1.18	1.58	1.87
2.15	0.00	0.03	0.09	0.18	0.30	0.46	0.66	0.91	1.22	1.63	1.92
2.18	0.00	0.03	0.10	0.19	0.31	0.47	0.68	0.93	1.25	1.65	1.95
2.2	0.00	0.04	0.10	0.19	0.32	0.48	0.69	0.94	1.27	1.67	1.97
2.21	0.00	0.04	0.10	0.20	0.32	0.49	0.69	0.95	1.28	1.68	1.98
2.22	0.00	0.04	0.10	0.20	0.33	0.49	0.70	0.96	1.28	1.69	1.99
2.23	0.01	0.04	0.11	0.20	0.33	0.50	0.71	0.97	1.29	1.70	2.00
2.25	0.01	0.04	0.11	0.21	0.34	0.51	0.72	0.98	1.31	1.72	2.02
2.3	0.01	0.05	0.12	0.23	0.36	0.54	0.75	1.02	1.35	1.77	2.07
2.4	0.02	0.07	0.15	0.26	0.41	0.59	0.82	1.10	1.44	1.87	2.17
2.5	0.02	0.08	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
2.6	0.03	0.10	0.20	0.34	0.50	0.71	0.96	1.26	1.62	2.06	2.37

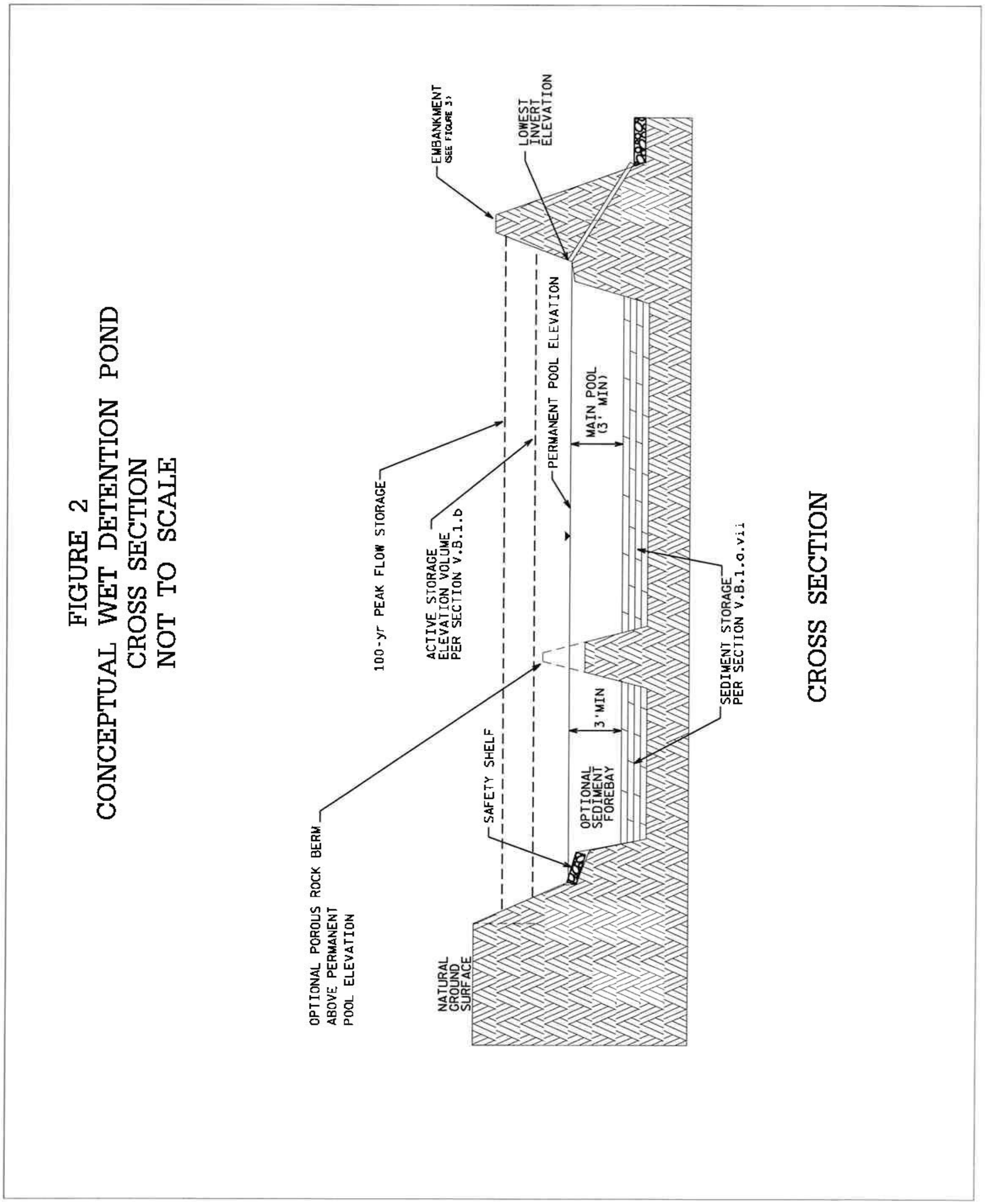
[1]NRCS TR-55, Equations 2-1 to 2-4 used to determine runoff depths.

Appendix C—Pond Geometry

FIGURE 1
CONCEPTUAL WET DETENTION POND
PLAN VIEW
NOT TO SCALE



Appendix C—Pond Geometry (cont'd.)



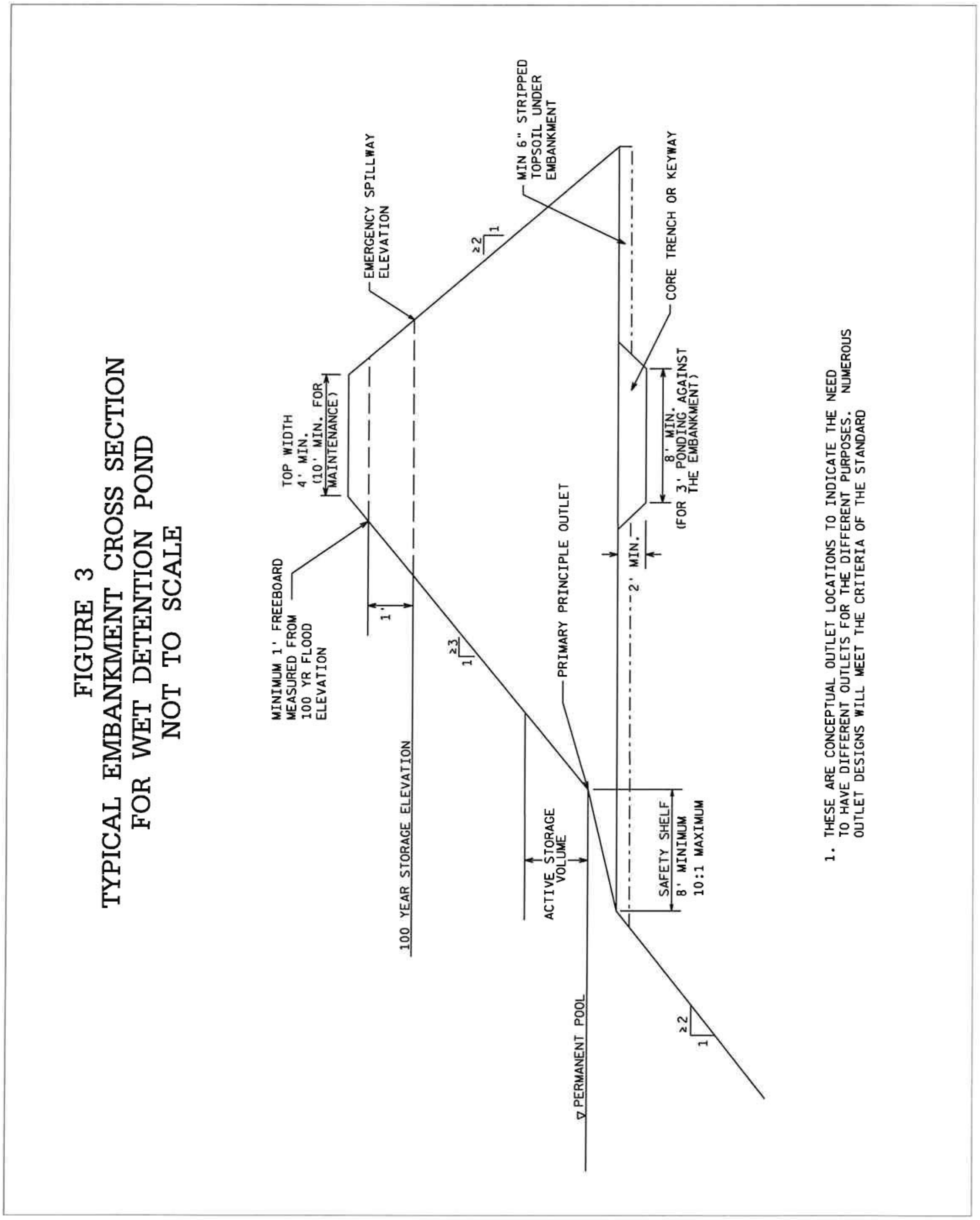


FIGURE 3
TYPICAL EMBANKMENT CROSS SECTION
FOR WET DETENTION POND
NOT TO SCALE

Appendix D—Pond Liner Design, Decision Flowchart

Pond Liner Design Specifications for Three Levels of Liners

A. Type A Liners—for sites with the highest potential for groundwater pollution. They include:
   - Clay (natural soil, not bentonite)
   - High Density Polyethylene (HDPE)
   - Geosynthetic Clay Liners (GCL)

   1. Clay liner criteria (essentially the same as the clay below landfills but not as thick):
      a. 50% fines (200 sieve) or more.
      b. An in-place hydraulic conductivity of 1 x 10^{-7} cm./sec. or less.
      c. Average liquid limit of 25 or greater, with no value less than 20.
      d. Average PI of 12 or more, with no values less than 10.
      e, Clay installed wet of optimum if using standard Proctor, and 2% wet of optimum if using modified Proctor.
      f. Clay compaction and documentation as specified in NRCS Wisconsin Construction Specification 300, Clay Liners.
      g. Minimum thickness of two feet.
      h. Specify method for keeping the pool full or use of composite soils below liner.
   2. HDPE liner criteria:
      a. Minimum thickness shall be 60 mils.
      b. Design according to the criteria in Table 3 of the NRCS 313, Waste Storage Facility technical standard.
      c. Install according to NRCS Wisconsin Construction Specification 202, Polyethylene Geomembrane Lining.
   3. GCL liner criteria:
      a. Design according to the criteria in Table 4 of NRCS 313, Waste Storage Facility technical standard.
      b. Install according to NRCS Wisconsin Construction Specification 203, Geosynthetic Clay Liner.

B. Type B Liners—for sites with medium potential for groundwater pollution or where need for a full pool level is high. They include:
   - All liners meeting Type A criteria
   - Clay
   - HDPE
   - Polyethylene Pond Liner (PPL)

   1. Clay liner criteria:
      a. 50% fines (200 sieve) or more.
      b. An in-place hydraulic conductivity of 1 x 10^{-6} cm./sec. or less.
      c. Average liquid limit value of 16 or greater, with no value less than 14.
      d. Average PI of 7 or more with no values less than 5.
      e. Clay compaction and documentation as specified in NRCS Wisconsin Construction Specification 204, Earthfill for Waste Storage Facilities.
      f. Minimum thickness of two feet.
      g. Specify method for keeping the pool full or use of composite soils below liner.
   2. HDPE liner criteria:
      a. Minimum thickness shall be 40 mils.
      b. All other criteria same as for Type A HDPE liner.
   3. PPL liner criteria:
      a. Minimum thickness shall be 30 mils.
      b. All other criteria same as for Type A HDPE liner.

C. Type C Liners—for sites with little potential for groundwater pollution or where the need for a full pool is less important. They include:
   - All liners meeting Type A or B criteria
   - Silts and clays
   - HDPE (<40 mil)
   - PPL (20-24 mil)
   - PVC (30-40 mil)
   - EPDM (45 mil)

   1. Silt/Clay liner criteria:
      a. 50% fines (200 sieve), or 20% fines and a PI of 7.
      b. Soil compaction and documentation as specified in NRCS Wisconsin Construction Specification 204, Earthfill for Waste Storage Facilities.
      c. Minimum thickness of two feet.
      d. Specify method for keeping the pool full or use of composite soils below liner.

D. Liner Elevation—All liners must extend above the permanent pool up to the elevation reached by the 2-yr., 24-hour storm event.

E. For synthetic liners, follow the manufacturers' recommendations for installation.

Appendix E—Aerators/Fountains

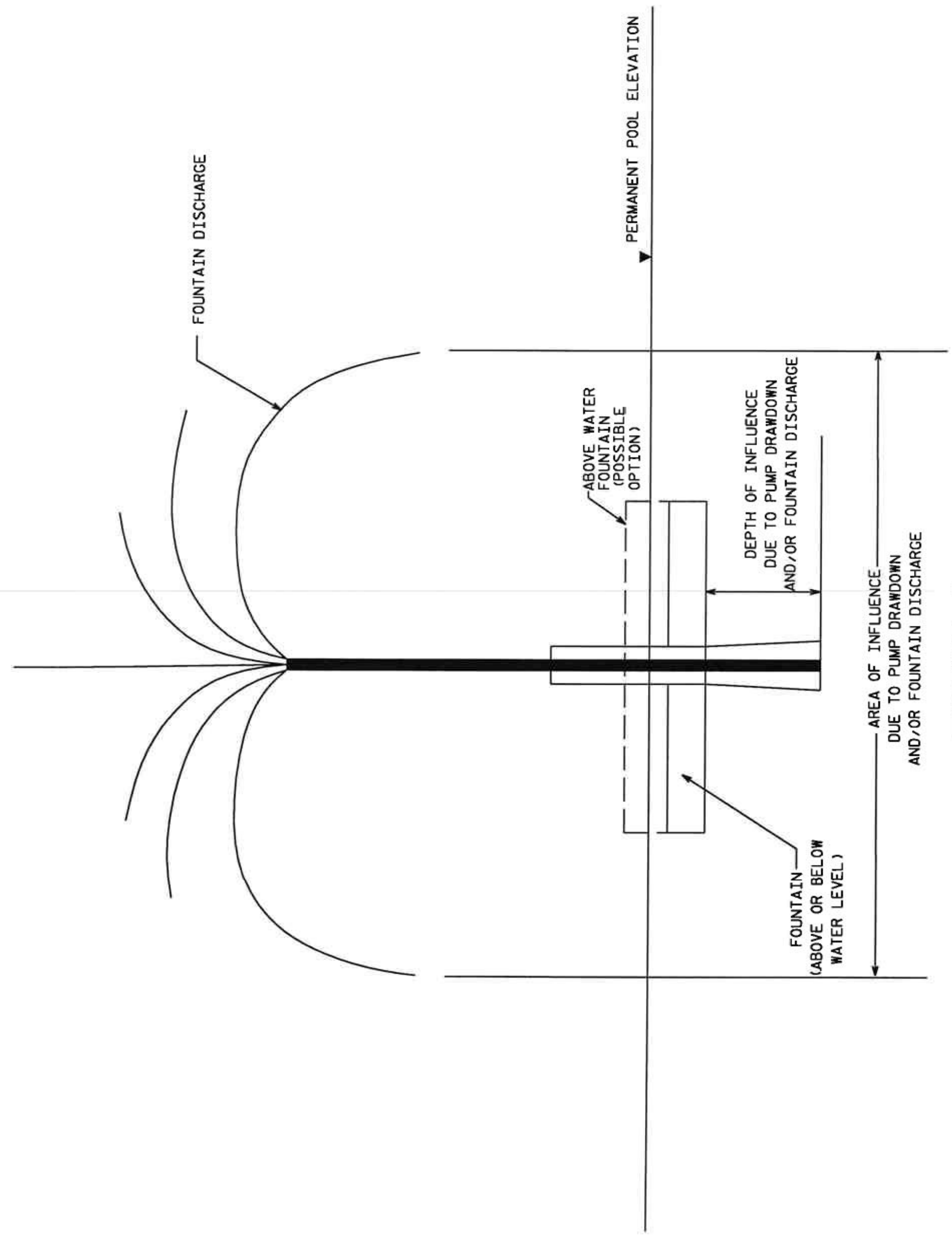


FIGURE 4
AERATORS/FOUNTAIN DETAIL
(NOT TO SCALE)