New York State
Stormwater Management Design Manual

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Acknowledgments

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Forward

On November 16, 1990, the initial federal NPDES stormwater regulations were established. These required certain industrial activities to obtain permit authorization in order to discharge site runoff. DEC, as the NPDES permit issuing authority in this State, promulgated two SPDES general permits for stormwater runoff in 1993, GP-93-05 for the more traditional industrial sites and GP-93-06 for construction sites.

GP-93-06 requires that an operator who is covered under the permit implement a stormwater pollution prevention plan (SWPPP) that has been developed for the particular site. The minimum components of the SWPPP include a variety of requirements, including both structural and non-structural practices, inspections, contractor certifications, compliance with narrative water quality standards and other conditions. The attention, concern and efforts being directed at stormwater management practices at construction sites are constantly growing as new technologies emerge and experiences with older ones is gained. Additionally, construction site runoff is gaining wider attention as the federal NPDES stormwater program progresses. There is an ever-growing need to disseminate information concerning practices that are acceptable in New York.

The scope of attention is broadening on a national scale to smaller construction sites as evidenced by the "Phase 2" stormwater regulations. Phase 2 lowers the threshold to one or more acres of disturbance, the runoff from which requires NPDES authorization for discharges to surface waters. Permitting will be required beginning on March 10, 2003. It's becoming more evident as time passes that there is a greater need for stormwater management practices that are technically effective and viable in New York State. "Spreading the word" to engineers, municipal officials, and the general public is crucial to the success of DEC's efforts in implementing the federal NPDES stormwater regulations and reducing incidences of water quality impairments.

Accordingly, permits that are issued in the future for construction site runoff will rely heavily on this new manual and the practices that are described therein. When properly designed and maintained, the implementation of these practices will become an important component of New York's overall stormwater management program. Adherence to the criteria and practices described will better ensure a successful implementation of stormwater controls and compliance with the SPDES general permit(s) issued for construction site runoff and maintaining water quality.

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Preface

The New York State Stormwater Design Manual is prepared to provide standards for the design of the Stormwater Management Practices (SMPs) to protect the waters of the State of New York from the adverse impacts of urban stormwater runoff. This manual is intended to establish specifications and uniform criteria for the practices that are part of a Stormwater Pollution Prevention Plan (SWPPP).

This manual is intended primarily for engineers and other professionals who are engaged in the design of stormwater treatment facilities for new developments. Users are assumed to have a background in hydrology, hydraulics, and runoff and pollutant load computation. It is not intended to be a primer on any of these subjects. The manual may also be used by reviewing authorities to assess the adequacy of SWPPPs.

The manual is limited to the design of structures. It does not address the temporary control of sedimentation and erosion from construction activities, nor the development of Stormwater Pollution Prevention Plans. The reader is referred to the documents "*Reducing the Impacts of Runoff from New Development*" and "*New York State Guidelines for Urban Erosion and Sediment Control*" for guidance with these subjects.

Recommended Standards, consisting of proven technology, are intended to serve as a guide in the design and preparation of plans and specifications for Stormwater Management Practices, to suggest limiting values for items upon which an evaluation of such plans and specifications may be made by the reviewing authority, and to establish, as far as practicable, uniformity of practice. As statutory requirements and legal authority pertaining to stormwater management are not uniform across the State, and since conditions and administrative procedures and policies also differ, the use of these Standards must be adjusted to these variations.

The terms "shall" and "must" are used where the practice is sufficiently standardized to permit specific delineation of requirements or where safeguarding of the public health justifies such definite action. Other terms, such as "should," "recommend," and "preferred," indicate desirable procedures or methods, with deviations subject to individual consideration.

Chapter 1

Introduction

Chapter 1: Introduction to the Manual

Section 1.1 Purpose of the Manual

The purpose of this manual is threefold:

1. To protect the waters of the State of New York from the adverse impacts of urban stormwater runoff
2. To provide design guidance on the most effective stormwater management practices (SMPs) for new development sites
3. To improve the quality of SMPs constructed in the State, specifically in regard to their performance, longevity, safety, ease of maintenance, community acceptance and environmental benefit

Section 1.2 How to Use the Manual

The *New York State Stormwater Management Design Manual* provides designers a general overview on how to size, design, select and locate SMPs at a development site to comply with State stormwater performance standards. The manual also contains appendices with more detailed information on landscaping, SMP construction specifications, step–by- step SMP design examples and other assorted design tools. The manual is organized as follows:

Chapter 2. Impacts of Stormwater Runoff

This chapter examines the physical, chemical, and biological effects of unmanaged stormwater runoff on the water quality of local streams and waterbodies. This brief overview provides the background for why the stormwater management manual is needed and how the new criteria will help local communities meet water quality standards.

Chapter 3. Permit Requirements

This chapter explains the permitting process for stormwater management facilities, and what permits may be necessary to construct these facilities.

Chapter 4. Sizing Criteria

This chapter explains sizing criteria for water quality, channel protection, overbank flood control, and extreme flood management in the State of New York. The chapter also outlines the basis for design calculations.

Chapter 5. List of Practices

This chapter briefly outlines the five groups of acceptable structural SMPs that can be used to meet water quality sizing criteria. The following are acceptable SMP groups:

- Stormwater Ponds
- Stormwater Wetlands
- Infiltration Practices
- Filtering Systems
- Open-Channel Practices

The chapter also explains the criteria for addition of a new practice to the list of acceptable SMPs, and provides fact sheets for some practices that are not on the list of practices, but can be used to provide supplemental treatment.

Chapter 6. Performance Criteria

This chapter presents specific performance criteria and guidelines for the design of the five groups of structural SMPs. The performance criteria for each group of SMPs are based on six factors:

- Feasibility
- Conveyance
- Pretreatment
- Treatment
- Landscaping
- Maintenance

In addition, the chapter provides guidance on design adjustments that may be required to ensure proper functioning in cold climates.

Chapter 7. Guide to SMP Selection and Location

This chapter presents guidance on how to select the best SMP or group of practices at a development site, as well as environmental and other factors to consider when actually locating each SMP. The chapter contains five comparative matrices that evaluate SMPs based on the following factors:

- Land Use
- Physical Feasibility
- Watershed /Regional Factors
- Stormwater Management Capability
- Community and Environmental Factors

Chapter 7 is designed so that the reader can use the matrices in a step-wise fashion to identify the most appropriate SMP or group of practices to use at a site.

Chapter 8. Design Examples

Design examples are provided to help designers and plan reviewers better understand the new criteria in this manual. The step-by-step design examples demonstrate how the new stormwater sizing criteria are applied, and some of the design procedures and performance criteria that should be considered when planning a new stormwater management practice.

Stormwater Design Appendices

The appendices contain the technical information needed to actually design, landscape and construct an SMP. There are a total of thirteen appendices:

Appendix A. The Simple Method to Calculate Urban Stormwater Loads
This appendix describes a fast and effective way to calculate stormwater runoff pollutant loads. Using impervious cover estimates based on land use, the Simple Method calculates annual runoff volume as a product of annual rainfall, and a runoff coefficient (Rv). Annual runoff can then be combined with readily available stormwater pollutant concentrations to provide a quick estimate of annual pollutant loads. The appendix also discusses the limitations of the Simple Method.

Appendix B. Design Tools
The accurate calculation of stormwater flows may require modifications to some methods to account for small storm hydrology. This appendix provides methodologies to calculate the storage requirements for the channel protection flow event, and a methodology to calculate the peak flow from the small water quality storm.

Appendix C. SMP Construction Specifications
Good designs only work if careful attention is paid to proper construction techniques and materials. Appendix C contains detailed specifications for constructing ponds, infiltration practices, filters, bioretention areas and open channels.

Appendix D. Infiltration Testing

This appendix describes methodologies to test soil infiltration rates, in order to determine if infiltration is an acceptable option on site.

Appendices E-G. Checklists

These three appendices provide example checklists that can be used to assist in the plan review, construction, and operation and maintenance of an SMP.

Appendix H. Landscaping Guidance

Good landscaping can often be an important factor in the performance and community acceptance of stormwater SMPs. Appendix H also includes tips on how to establish more functional landscapes within stormwater SMPs, and contains an extensive list of trees, shrubs, ground covers, and wetland plants that can be used to develop an effective and diverse planting plan.

Appendix I. Cold Climate Sizing Example

This appendix supplies guidance on sizing SMPs to account for cold climate conditions that might hamper performance. Example sizing designs that illustrate how to incorporate cold climate criteria into SMP design are also included.

Appendix J. Geomorphic Assessment

This appendix provides a description of the Distributed Runoff Control (DRC) methodology to size stormwater practices based on downstream geomorphic characteristics.

Appendix K. Miscellaneous Details

The designs of various structures previously discussed in the manual are presented in Appendix K. These structures help enhance the performance of stormwater management practices, especially in cold climates. Schematics of structures such as weirs, trash racks, and observation wells are included.

Appendix L. Critical Erosive Velocities

This appendix provides data on critical erosive velocities for soil and grasses.

Section 1.3 Symbols and Acronyms

As an aid to the reader, Table 1.1 outlines the symbols and acronyms that are used throughout the text. In addition, a glossary is provided at the end of this volume that defines the terminology used in the text.

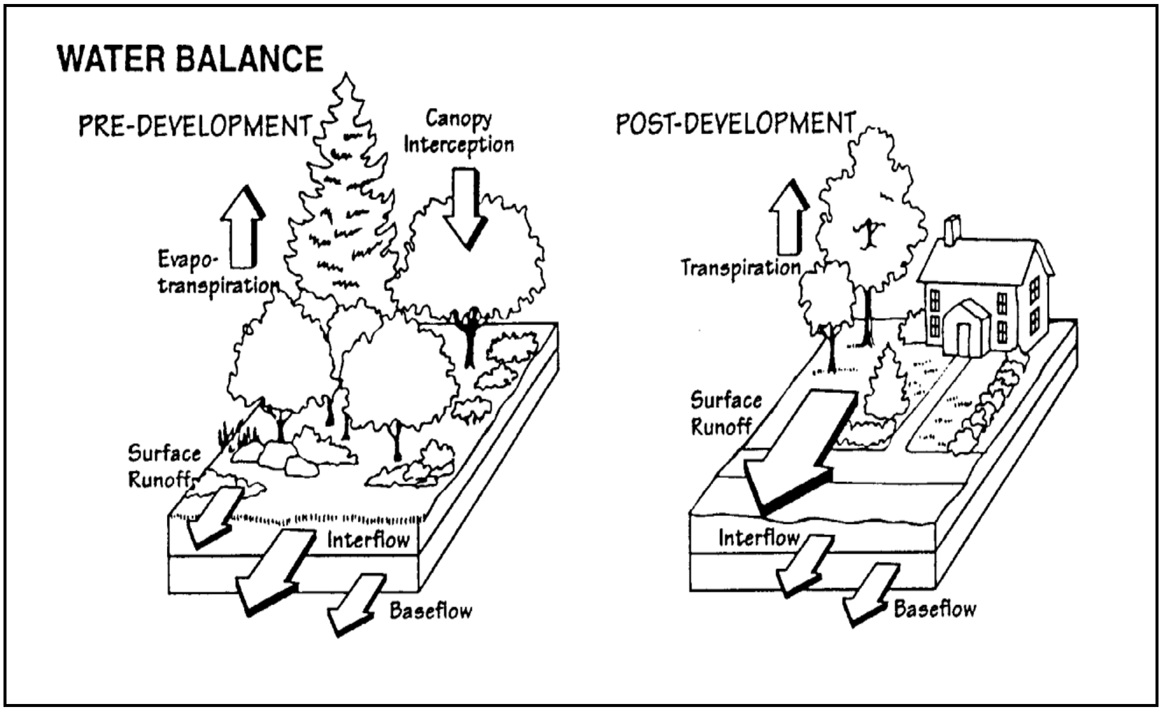
Table 1.1 Key Symbols and Acronyms Cited in Manual			
Symbol	**Definition**	**Symbol**	**Definition**
A	drainage area	**Qf**	extreme flood storage volume
A_f	filter bed area	**Qi**	peak inflow discharge
A_s	surface area, sedimentation basin	**Qo**	peak outflow discharge
cfs	cubic feet per second	**Qp**	overbank flood control storage volume
Cp_v	channel protection storage volume	q_p	water quality peak discharge
CMP	corrugated metal pipe	**qu**	unit peak discharge
CN	curve number	**SMP**	stormwater management practice
Cp_v-ED	extended detention of the 1 year post-development runoff	R_v	volumetric runoff coefficient
d_f	depth of filter bed	**R/W**	right of way
du	dwelling units	**SD**	separation distance
DOT	Department of Transportation	**SPDES**	State Pollutant Discharge Elimination System
DPW	Department of Public Works	t_c	time of concentration
ED	extended detention	t_t	time to drain filter bed
f_c	soil infiltration rate	**TR-20**	Technical Release No. 20 Project Formulation-Hydrology, computer program
fps	feet per second	**TR-55**	Technical Release No. 55 Urban Unit Hydrology for Small Watersheds
h_f	head above filter bed	**TSS**	total suspended solids
HSG	hydrologic soil group	**Vr**	volume of runoff
Ia	initial abstraction	**Vs**	volume of storage
I	percent impervious cover	**Vt**	total volume
K	coefficient of permeability	**Vv**	volume of voids
NYSDEC	New York State Department of Environmental Conservation	WQ_v	water quality storage volume
NRCS	Natural Resources Conservation Service	WQ_v-ED	12 or 24 hour extended detention of the water quality volume
P	precipitation depth	**WSEL**	water surface elevation

Chapter 2

Impacts of New Development

Urban development has a profound influence on the quality of New York's waters. To start, development dramatically alters the local hydrologic cycle (see Figure 2.1). The hydrology of a site changes during the initial clearing and grading that occur during construction. Trees that had intercepted rainfall are removed, and natural depressions that had temporarily ponded water are graded to a uniform slope. The spongy humus layer of the forest floor that had absorbed rainfall is scraped off, eroded or severely compacted. Having lost its natural storage capacity, a cleared and graded site can no longer prevent rainfall from being rapidly converted into stormwater runoff.

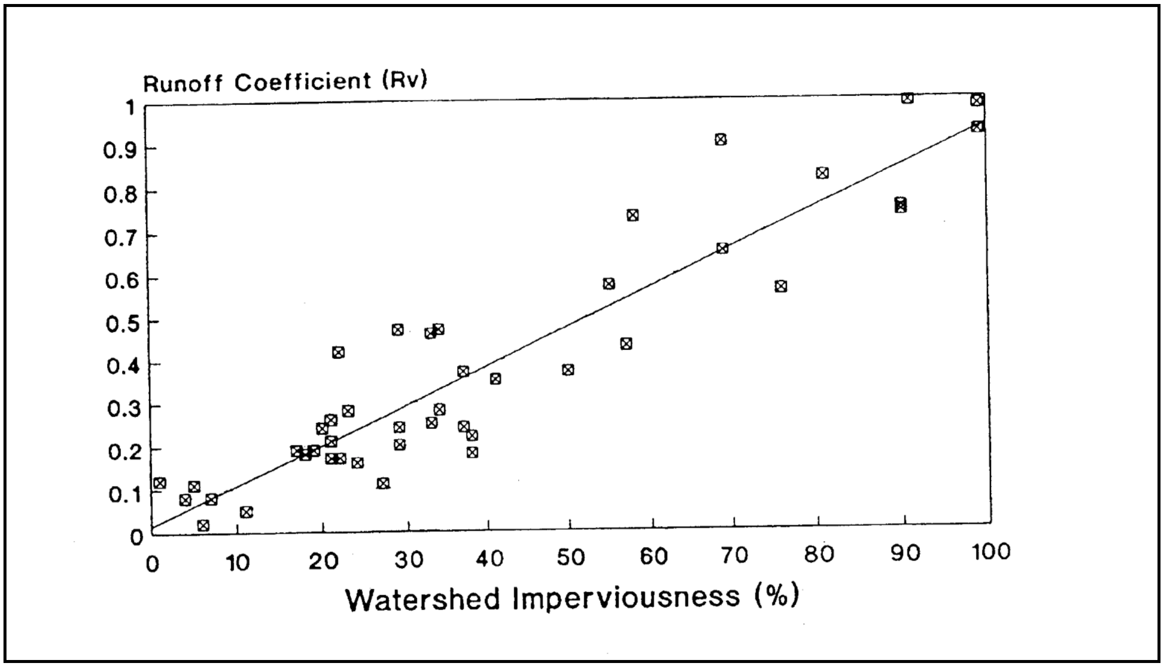
Figure 2.1 Water Balance at a Developed and Undeveloped Site (Schueler, 1987)



The situation worsens after construction. Rooftops, roads, parking lots, driveways and other impervious surfaces no longer allow rainfall to soak into the ground. Consequently, most rainfall is directly converted into stormwater runoff. This phenomenon is illustrated in Figure 2.2, which shows the increase in the volumetric runoff coefficient (R_v) as a function of site imperviousness. The runoff coefficient expresses the fraction of rainfall volume that is converted into stormwater runoff. As can be seen, the volume of stormwater runoff increases sharply with impervious cover. For example, a one-acre parking lot can produce 16 times more stormwater runoff than a one-acre meadow each year (Schueler, 1994).

The increase in stormwater runoff can be too much for the existing drainage system to handle. As a result, the drainage system is often "improved" to rapidly collect runoff and quickly convey it away (using curb and gutter, enclosed storm sewers, and lined channels). The stormwater runoff is subsequently discharged to downstream waters, such as streams, reservoirs, lakes or estuaries.

Figure 2.2 Relationship Between Impervious Cover and Runoff Coefficient (Schueler, 1987)



Section 2.1 Declining Water Quality

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown in from adjacent areas. During storm events, these pollutants quickly wash off, and are rapidly delivered to downstream waters. Some common pollutants found in urban stormwater runoff are profiled in Table 2.1.

Table 2.1 National Median Concentrations for Chemical Constituents in Stormwater

Constituent	Units	Concentration
Total Suspended Solids[1]	mg/l	54.5
Total Phosphorus[1]	mg/l	0.26
Soluble Phosphorus[1]	mg/l	0.10
Total Nitrogen[1]	mg/l	2.00
Total Kjeldhal Nitrogen[1]	mg/l	1.47
Nitrite and Nitrate[1]	mg/l	0.53
Copper[1]	ug/l	11.1
Lead[1]	ug/l	50.7
Zinc[1]	ug/l	129
BOD[1]	mg/l	11.5
COD[1]	mg/l	44.7
Organic Carbon[2]	mg/l	11.9
PAH[3]	mg/l	3.5*
Oil and Grease[4]	mg/l	3.0*
Fecal Coliform[5]	col/100 ml	15,000*
Fecal Strep[5]	col/ 100 ml	35,400*
Chloride (snowmelt)[6]	mg/l	116

* Represents a Mean Value
Source:
1: Pooled NURP/USGS (Smullen and Cave, 1998)
2: Derived from the National Pollutant Removal Database (Winer, 2000)
3: Rabanal and Grizzard 1995
4: Crunkilton *et al*. (1996)
5: Schueler (1999)
6: Oberts 1994

Sediment (Suspended Solids)

Sources of sediment include washoff of particles that are deposited on impervious surfaces and erosion from streambanks and construction sites. Streambank erosion is a particularly important source of sediment, and some studies suggest that streambank erosion accounts for up to 70% of the sediment load in urban watersheds (Trimble, 1997).

Both suspended and deposited sediments can have adverse effects on aquatic life in streams, lakes and estuaries. Turbidity resulting from sediment can reduce light penetration for submerged aquatic vegetation critical to estuary health. In addition, the reflected energy from light reflecting off of suspended sediment can increase water temperatures (Kundell and Rasmussen, 1995). Sediment can physically alter habitat by destroying the riffle-pool structure in stream systems, and smothering benthic organisms such as clams and mussels. Finally, sediment transports many other pollutants to the water resource.

Nutrients

Runoff from developed land has elevated concentrations of both phosphorus and nitrogen, which can enrich streams, lakes, reservoirs and estuaries. This process is known as eutrophication. Significant sources of nitrogen and phosphorus include fertilizer, atmospheric deposition, animal waste, organic matter, and stream bank erosion. Another nitrogen source is fossil fuel combustion from automobiles, power plants and industry. Data from the upper Midwest suggest that lawns are a significant contributor, with concentrations as much as four times higher than other land uses, such as streets, rooftops, or driveways (Steuer *et al*., 1997; Waschbusch *et al*., 2000; Bannerman *et al*., 1993).

Nutrients are of particular concern in lakes and estuaries, and are a source of degradation in many of New York's waters. Nitrogen has contributed to hypoxia in the Long Island Sound, and is a key pollutant of concern in the New York Harbor and the Peconic Estuary. Phosphorus in runoff has impacted the quality of a number of New York natural lakes, including the Finger Lakes and Lake Champlain, which are susceptible to eutrophication from phosphorus loading. Phosphorus has been identified as a key parameter in the New York City Reservoir system. The New York City DEP recently developed water quality guidance values for phosphorus for City drinking water reservoirs (NYC DEP, 1999); a source-water phosphorus guidance value of 15 μg/l has been proposed for seven reservoirs (Kensico, Rondout, Ashokan, West Branch, New Croton, Croton Falls, and Cross River) in order to protect them from use-impairment due to eutrophication, with other reservoirs using the State recommended guidance value of 20 μg/l.

Organic Carbon

Organic matter, washed from impervious surfaces during storms, can present a problem in slower moving downstream waters. Some sources include organic material blown onto the street surface, and attached to sediment from stream banks, or from bare soil. In addition, organic carbon is formed indirectly from algal growth within systems with high nutrient loads.

As organic matter decomposes, it can deplete dissolved oxygen in lakes and tidal waters. Declining levels of oxygen in the water can have an adverse impact on aquatic life. An additional concern is the formation of trihalomethane (THM), a carcinogenic disinfection by-product, due to the mixing of chlorine with water high in organic carbon. This is of particular importance in unfiltered water supplies, such as the New York City Reservoir System.

Bacteria

Bacteria levels in stormwater runoff routinely exceed public health standards for water contact recreation. Some stormwater sources include pet waste and urban wildlife. Other sources in developed land include sanitary and combined sewer overflows, wastewater, and illicit connections to the storm drain system. Bacteria is a leading contaminant in many of New York's waters, and has lead to shellfish bed closures in the New York Bight Area, on Long Island, and in the Hudson-Raritan Estuary. In addition, Suffolk, Nassau, and Erie Counties issue periodic bathing-beach advisories each time a significant rainfall event occurs (NRDC, 2000).

Hydrocarbons

Vehicles leak oil and grease that contain a wide array of hydrocarbon compounds, some of which can be toxic to aquatic life at low concentrations. Sources are automotive, and some areas that produce runoff with high runoff concentrations include gas stations, commuter parking lots, convenience stores, residential parking areas, and streets (Schueler, 1994).

Trace Metals

Cadmium, copper, lead and zinc are routinely found in stormwater runoff. Many of the sources are automotive. For example, one study suggests that 50% of the copper in Santa Clara, CA comes from brake pads (Woodward-Clyde, 1992). Other sources of metals include paints, road salts, and galvanized pipes.

These metals can be toxic to aquatic life at certain concentrations, and can also accumulate in the bottom sediments of lakes and estuaries. Specific concerns in aquatic systems include bioaccumulations in fish and macro-invertebrates, and the impact of toxic bottom sediments on bottom-dwelling species.

Pesticides

A modest number of currently used and recently banned insecticides and herbicides have been detected in urban and suburban streamflow at concentrations that approach or exceed toxicity thresholds for aquatic life. Key sources of pesticides include application to urban lawns and highway median and shoulder areas.

Chlorides

Salts that are applied to roads and parking lots in the winter months appear in stormwater runoff and meltwater at much higher concentrations than many freshwater organisms can tolerate. One study of four Adirondack streams found severe impacts to macroinvertebrate species attributed to chlorides (Demers and Sage, 1990). In addition to the direct toxic effects, chlorides can impact lake systems by altering their mixing cycle. In 1986, incomplete mixing in the Irondequoit Bay was attributed to high salt use in the region (MCEMC, 1987). A primary source of chlorides in New York State, particularly in the State's northern regions, is salt applied to road surfaces as a deicer.

Thermal Impacts.

Runoff from impervious surfaces may increase temperature in receiving waters, adversely impacting aquatic organisms that require cold and cool water conditions (e.g., trout). Data suggest that increasing development can increase stream temperatures by between five and twelve degrees Fahrenheit, and that the increase is related to the level of impervious cover in the drainage area (Galli, 1991). Thermal impacts are a serious concern in trout waters, where cold temperatures are critical to species survival.

Trash and Debris

Considerable quantities of trash and debris are washed through the storm drain networks. The trash and debris accumulate in streams and lakes and detract from their natural beauty. Depending on the type of trash, this material may also lead to increased organic matter or toxic contaminants in water bodies.

Snowmelt Concentrations

The snow pack can store hydrocarbons, oil and grease, chlorides, sediment, and nutrients. In cold regions, the pollutant load during snowmelt can be significant, and chemical traits of snowmelt change over the course of the melt event. Oberts (1994) studied this phenomenon, and describes four types of snowmelt runoff (Table 2.2). Oberts and others have reported that 90% of the hydrocarbon load from snowmelt occurs during the last 10% of the event. From a practical standpoint, the high hydrocarbon loads experienced toward the end of the season suggest that stormwater management practices should be designed to capture as much of the snowmelt event as possible.

Table 2.2 Runoff and Pollutant Characteristics of Snowmelt Stages (Oberts, 1994)

Snowmelt Stage	Duration/ Frequency	Runoff Volume	Pollutant Characteristics
Pavement Melt	Short, but many times in winter	Low	Acidic, high concentrations of soluble pollutants, Cl, nitrate, lead. Total load is minimal.
Roadside Melt	Moderate	Moderate	Moderate concentrations of both soluble and particulate pollutants.
Pervious Area Melt	Gradual, often most at end of season	High	Dilute concentrations of soluble pollutants, moderate to high concentrations of particulate pollutants, depending on flow.
Rain-on-Snow Melt	Short	Extreme	High concentrations of particulate pollutants, moderate to high concentrations of soluble pollutants. High total load.

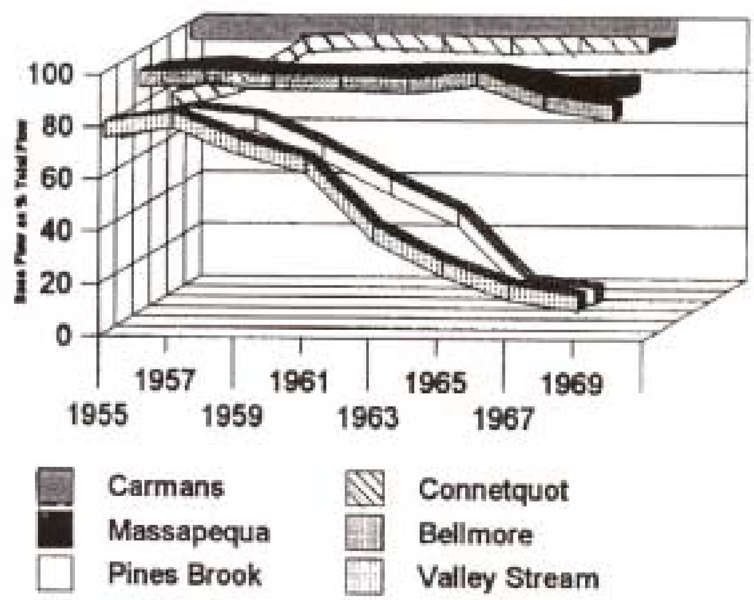
Section 2.2 Diminishing Groundwater Recharge and Quality

The slow infiltration of rainfall through the soil layer is essential for replenishing groundwater. Groundwater is a critical water resource across the State. Not only do many residents depend on groundwater for their drinking water, but the health of many aquatic systems is also dependent on its steady discharge. For example, during periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of non-tidal wetlands.

Because development creates impervious surfaces that prevent natural recharge, a net decrease in groundwater recharge rates can be expected in urban watersheds. Thus, during prolonged periods of dry weather, streamflow sharply diminishes. Another source of diminishing baseflow is well drawdowns as populations increase in the watershed. In smaller headwater streams, the decline in stream flow can cause a perennial stream to become seasonally dry. One study in Long Island suggests that the supply of baseflow decreased in some developing watersheds, particularly where the water supply was sewered (Spinello and Simmons, 1992; Figure 2.3).

Urban land uses and activities can also degrade *groundwater quality,* if stormwater runoff is infiltrated without adequate treatment. Certain land uses and activities are known to produce higher loads of metals and toxic chemicals and are designated as *stormwater hotspots*. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids and some polycyclic aromatic hydrocarbons (PAH's) can migrate into groundwater and potentially contaminate wells. Stormwater runoff from designated hotspots should never be infiltrated, unless the runoff receives full pretreatment with another practice.

Figure 2.3 Declining Baseflow in Response to Development



Notes:

Carmans and Connetquot: Rural/suburban, watersheds are unsewered

Bellmore and Massapequa: Moderately urbanized, not sewered until 1989

Valley Stream and Pine Brook: Urbanized and densely populated watersheds, sewer systems completed in 1960s

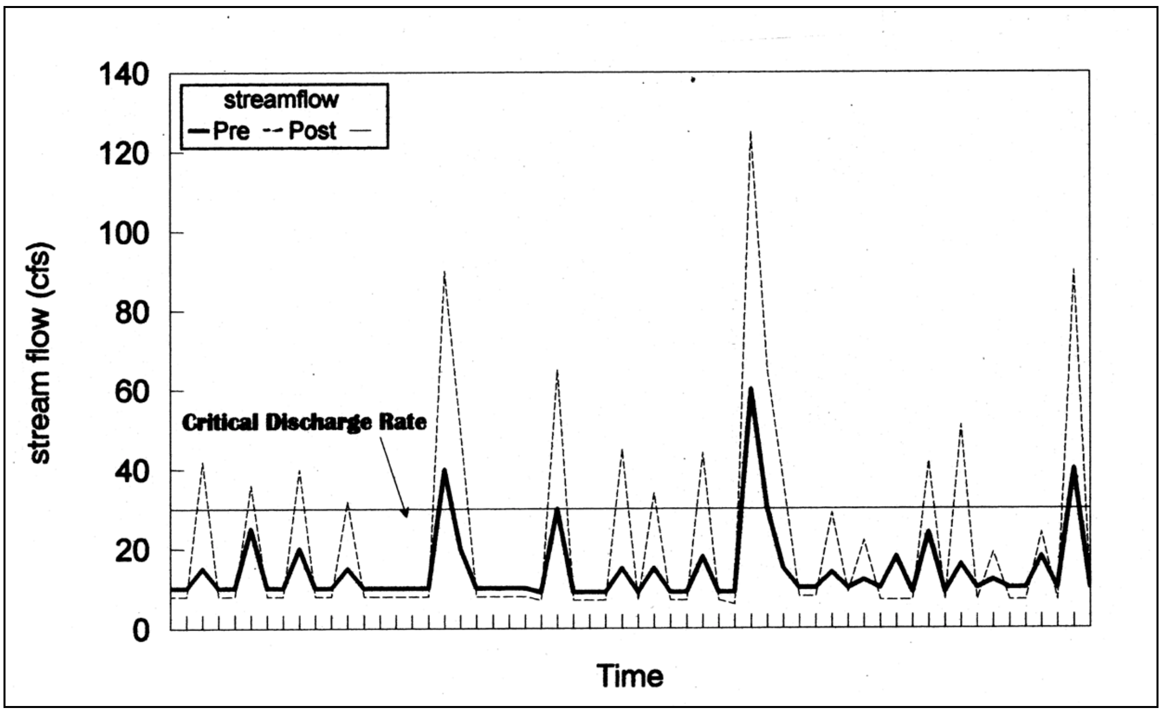
1953-1964: Period of sanitary sewer construction in eastern Nassau County

1962-1966: Drought years

Section 2.3 Impacts to the Stream Channel

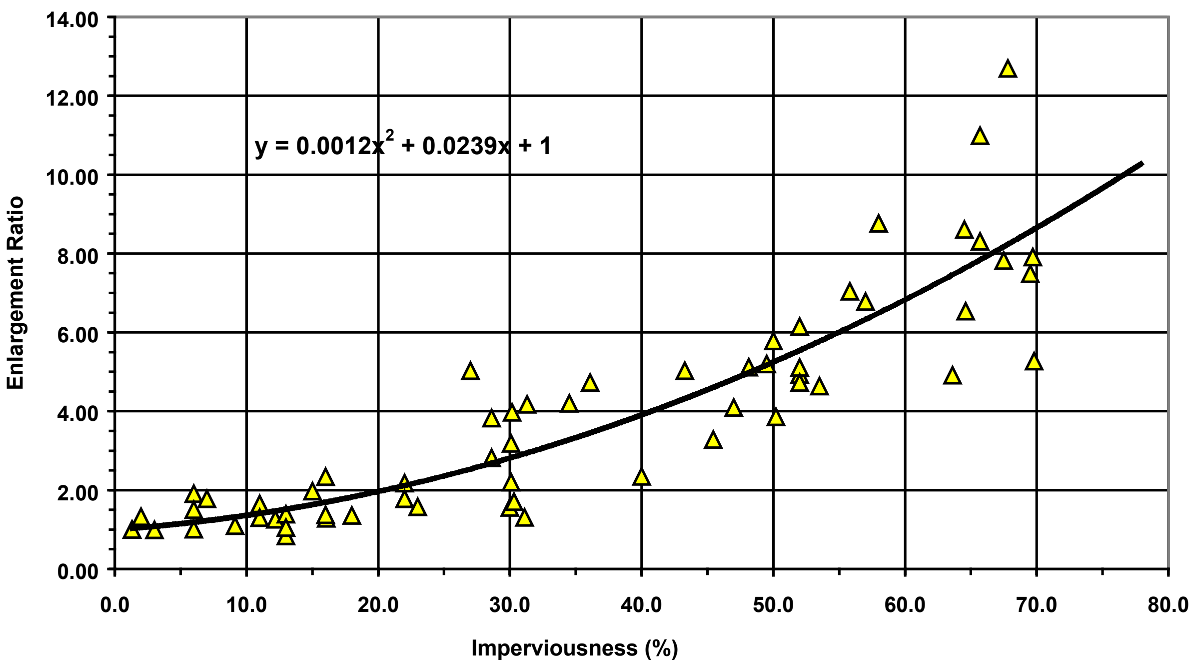
As pervious meadows and forests are converted into less pervious urban soils, or pavement, both the frequency and magnitude of storm flows increase dramatically. As a result, the bankfull event occurs two to seven times more frequently after development occurs (Leopold, 1994). In addition, the discharge associated with the original bankfull storm event can increase by up to five times (Hollis, 1975). As Figure 2.4 demonstrates, the total flow beyond the "critical erosive velocity" increases substantially after development occurs. The increased energy resulting from these more frequent bankfull flow events results in erosion and enlargement of the stream channel, and consequent habitat degradation.

Figure 2.4 Increased Frequency of Erosive Velocities After Development



Channel enlargement in response to watershed development has been observed for decades, with research indicating that the stream channel area expands to between two and five times its original size in response to upland development (Hammer, 1972; Morisawa and LaFlure, 1979; Allen and Narramore, 1985; Booth, 1990). One researcher developed a direct relationship between the level of impervious cover and the "ultimate" channel enlargement, the area a stream will eventually reach over time (MacRae, 1996; Figure 2.5).

Figure 2.5 Relationship Between Impervious Cover and Channel Enlargement



Historically, New York has used two-year control (i.e., reduction of the peak flow from the two-year storm to predeveloped levels) to prevent channel erosion, as required in the 1993 SPDES General Permit (GP-93-06). Research suggests that this measure does not adequately protect stream channels (McCuen and Moglen, 1988, MacRae, 1996). Although the peak flow is lower, it is also extended over a longer period of time, thus increasing the duration of erosive flows. In addition, the bankfull flow event actually becomes more frequent after development occurs. Consequently, capturing the two-year event may not address the channel-forming event.

This stream channel erosion and expansion, combined with direct impacts to the stream system, act to decrease the habitat quality of the stream. The stream will thus experience the following impacts to habitat (Table 2.3):

- Decline in stream substrate quality (through sediment deposition and embedding of the substrate)
- Loss of pool/riffle structure in the stream channel
- Degradation of stream habitat structure
- Creation of fish barriers by culverts and other stream crossings
- Loss of “large woody debris,” which is critical to fish habitat

Table 2.3 Impacts to Stream Habitat			
Stream Channel Impact	**Key Finding**	**Reference**	**Year**
Habitat Characteristics			
Embeddedness	Interstitial spaces between substrate fill with increasing watershed imperviousness	Horner *et al.*	1996
Large Woody Debris (LWD)	Important for habitat diversity and anadramous fish.	Spence *et al.*	1996
	Decreased LWD with increases in imperviousness	Booth *et al.*	1996
Changes in Stream Features	Altered pool/riffle sequence with urbanization	Richey	1982
	Loss of habitat diversity	Scott *et al.*	1986
Direct Channel Impacts			
Reduction in 1st Order Streams	Replaced by storm drains and pipes increases erosion rate downstream	Dunne and Leopold	1972
Channelization and hardening of stream channels	Increase instream velocities often leading to increased erosion rates downstream	Sauer *et al.*	1983
Fish Blockages	Fish blockages caused by bridges and culverts	MWCOG	1989

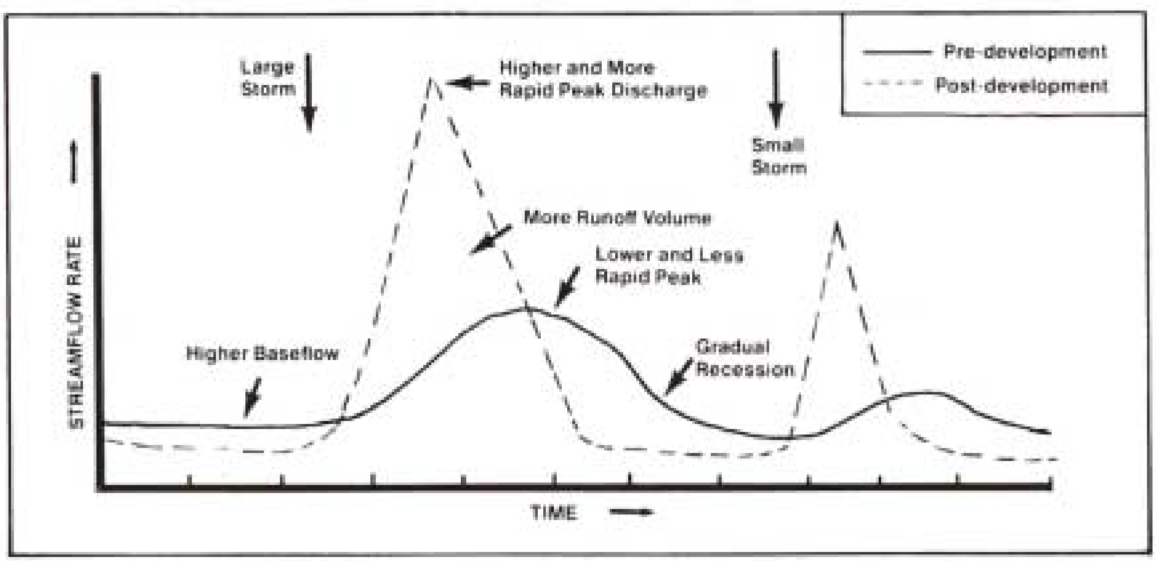
Section 2.4 Increased Overbank Flooding

Flow events that exceed the capacity of the stream channel spill out into the adjacent floodplain. These are termed "overbank" floods, and can damage property and downstream structures. While some overbank flooding is inevitable and sometimes desirable, the historical goal of drainage design in New York has been to maintain pre-development peak discharge rates for both the two- and ten-year frequency storm after development, thus keeping the level of overbank flooding the same over time. This management technique prevents costly damage or maintenance for culverts, drainage structures, and swales.

Overbank floods are ranked in terms of their statistical return frequency. For example, a flood that has a 50% chance of occurring in any given year is termed a "two-year" flood. The two-year event is also known as the "bankfull flood," as researchers have demonstrated that most natural stream channels in the State have just enough capacity to handle the two-year flood before spilling out into the floodplain. Although many factors, such as soil moisture, topography, and snowmelt, can influence the magnitude of a particular flood event, designers typically design for the "two-year" storm event. In New York State, the two-year design storm ranges between about 2.0 to 4.0 inches of rain in a 24-hour period. Similarly, a flood that has a 10% chance of occurring in any given year is termed a "ten-year flood." A ten-year flood occurs when a storm event produces between 3.2 and 6.0 inches of rain in a 24-hour period. Under traditional engineering practice, most channels and storm drains in New York are designed with enough capacity to safely pass the peak discharge from the ten-year design storm.

Urban development increases the peak discharge rate associated with a given design storm, because impervious surfaces generate greater runoff volumes and drainage systems deliver it more rapidly to a stream. The change in post-development peak discharge rates that accompany development is profiled in Figure 2.6. Note that this change in hydrology increases not only the magnitude of the peak event, but the total volume of runoff produced.

Figure 2.6 Hydrographs Before and After Development

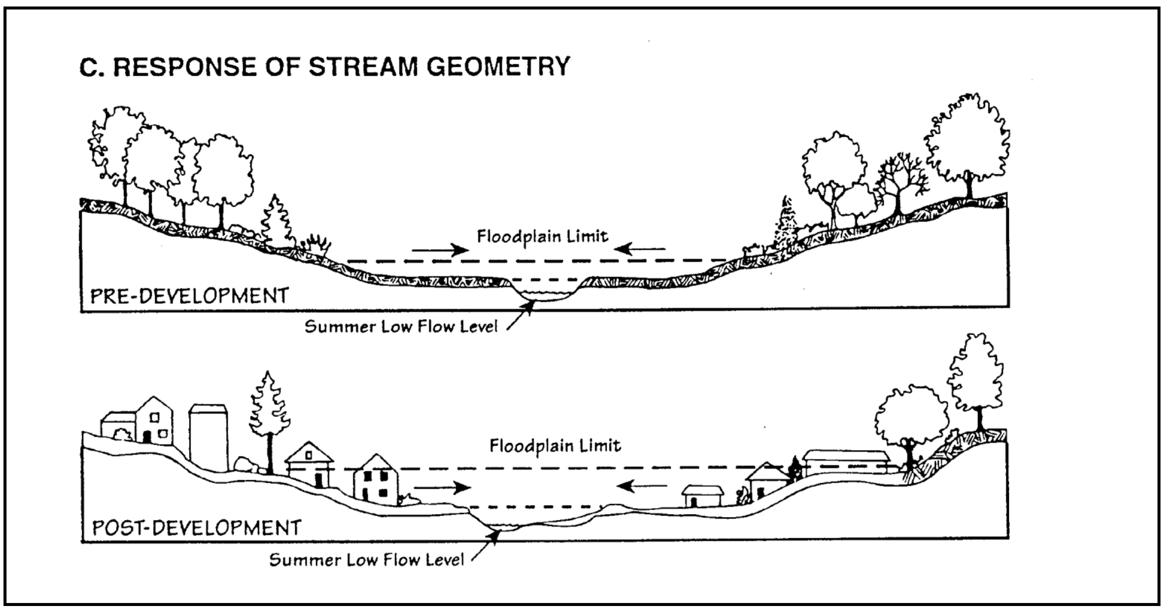


Section 2.5 Floodplain Expansion

The level areas bordering streams and rivers are known as floodplains. Operationally, the floodplain is usually defined as the land area within the limits of the 100-year storm flow water elevation. The 100-year storm has a 1% chance of occurring in any given year. In New York, a 100-year flood occurs after between five and eight inches of rainfall in a 24-hour period (i.e., the 100-year storm). These floods can be very destructive, and can pose a threat to property and human life.

As with overbank floods, development sharply increases the peak discharge rate associated with the 100-year design storm. As a consequence, the elevation of a stream's 100-year floodplain becomes higher and the boundaries of its floodplain expand (see Figure 2.7). In some instances, property and structures that had not previously been subject to flooding are now at risk. Additionally, such a shift in a floodplain's hydrology can degrade wetland and forest habitats.

Figure 2.7 Floodplain Expansion with New Development



Section 2.6 Impacts to Aquatic Organisms

The decline in the physical habitat of the stream, coupled with lower base flows and higher stormwater pollutant loads, has a severe impact on the aquatic community. Research suggests that new development impacts aquatic insects, fish, and amphibians at fairly low levels of imperviousness, usually around 10% impervious cover (Table 2.4). New development appears to cause declining **richness** (the number of different species in an area or community), **diversity** (number and relative frequency of different species in an area or community), and **abundance** (number of individuals in a species).

Table 2.4 Recent Research Examining the Relationship of Urbanization to Aquatic Habitat and Organisms

Watershed Indicator	Key Finding	Reference	Year	Location
Aquatic insects and fish	A comparison of three stream types found urban streams had lowest diversity and richness. Urban streams had substantially lower EPT scores (22% vs 5% as number of all taxa, 65% vs 10% as percent abundance) and IBI scores in the poor range.	Crawford & Lenat	1989	North Carolina
Insects, fish, habitat water quality,	Steepest decline of biological functioning after 6% imperviousness. There was a steady decline, with approx 50% of initial biotic integrity at 45% I.	Horner *et al.*	1996	Puget Sound Washington
Fish, Aquatic insects	A study of five urban streams found that as land use shifted from rural to urban, fish and macroinvertebrate diversity decreased.	Masterson & Bannerman	1994	Wisconsin
Insects, fish, habitat, water quality, riparian zone	Physical and biological stream indicators declined most rapidly during the initial phase of the urbanization process as the percentage of total impervious area exceeded the 5-10% range.	May *et al.*	1997	Washington
Aquatic insects and fish	There was significant decline in the diversity of aquatic insects and fish at 10% impervious cover.	MWCOG	1992	Washington, DC
Aquatic insects and fish	Evaluation of the effects of runoff in urban and non-urban areas found that native fish and insect species dominated the non-urban portion of the watershed, but native fish accounted for only 7% of the number of species found in urban areas.	Pitt	1995	California
Wetland plants, amphibians	Mean annual water fluctuation inversely correlated to plant & amphibian density in urban wetlands. Declines noted beyond 10% impervious area.	Taylor	1993	Seattle

Table 2.4 Recent Research Examining the Relationship of Urbanization to Aquatic Habitat and Organisms

Watershed Indicator	Key Finding	Reference	Year	Location
Aquatic insects & fish	Residential urban land use in Cuyahoga watersheds created a significant drop in IBI scores at around 8%, primarily due to certain stressors that functioned to lower the non-attainment threshold When watersheds smaller than $100mi^2$ were analyzed separately, the level of urban land use for a significant drop in IBI scores occurred at around 15%.	Yoder *et. al.*	1999	Ohio
Aquatic insects & fish	All 40 urban sites sampled had fair to very poor index of biotic integrity (IBI) scores, compared to undeveloped reference sites.	Yoder	1991	Ohio

IBI: Index of Biotic Integrity: A measure of species diversity for fish and macroinvertebrates
EPT: A measure of the richnies of three sensitive macro-invertebrates (may flies, caddis flies, and stone flies), used to indicate the ability of a waterbody to support sensitive organisms.

Chapter 3

Stormwater Permit Requirements

Chapter 3: Department of Environmental Conservation Permits

This chapter provides a summary of the applications that may need to be filed with the Department of Environmental Conservation (DEC) for new development projects. This section identifies general policies and timelines for filing a State Pollutant Discharge Elimination System ("SPDES") General Permit for stormwater discharges from construction activities as well as environmental permits under the Uniform Procedures Act (UPA). More detailed information on the permits and up-to-date regional contact information are available from the DEC web site at the following URLs:

www.dec.state.ny.us/website/dcs/permits_level2.html

www.dec.state.ny.us/website/dcs/upa/upa_permits.html

Section 3.1 Filing for a Stormwater Permit

40 CFR Part 122 prohibits point source discharges of stormwater to waters of the United States without a permit issued under the National Pollutant Discharge Elimination System ("NPDES"). New York State is approved by the EPA to administer its SPDES program in lieu of EPA's NPDES program. The operator of a storm water discharge, which qualifies for coverage under the SPDES General Permit for stormwater, must submit a Notice of Intent (NOI) form to obtain permit coverage. Consult the general permit for any possible restrictions on eligibility of coverage. The permit includes a complete set of instructions for filing an NOI and for filing a Notice of Termination (NOT).

3.1.1 Where to File the NOI Form

Completed NOIs should be sent to:

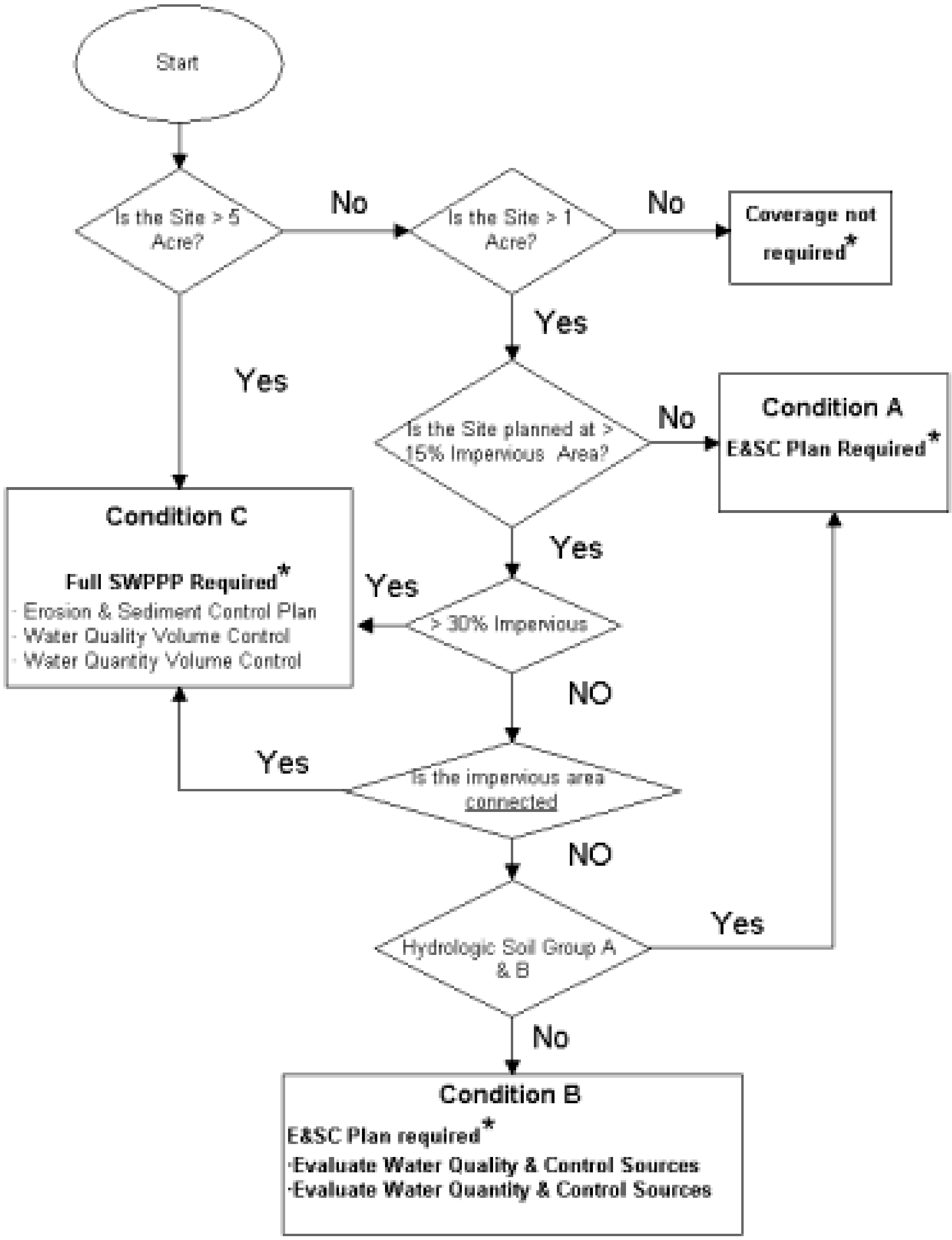
NYS DEC – Notice of Intent
Bureau of Water Permits
625 Broadway
Albany, NY 12233-3505

3.1.2 Stormwater Pollution Prevention Plan

The applicant must check whether the project will be a small or large one and whether the plan conforms to either NYSDEC or local Municipal Separate Storm Sewer System (MS4) requirements. The flow chart in Figure 3.1 identifies what components of the Stormwater Pollution Prevention Plan need to be prepared depending on the size and complexity of the site.

If one wishes to seek some variance from either local or NYSDEC requirements, then the information in Section V of the NOI must be filled out. The purpose of this section is to give NYSDEC some preliminary information. Based on the information provided, DEC will determine if other information is required. Only operators who state that their plan will NOT conform to either NYSDEC or local MS4 requirements need to fill out this section.

Figure 3.1 Stormwater Pollution Prevention Plan Component Requirements



* Under any of the above conditions other permits may be required.

3.1.3 Review and Approval

Once the Notice of Intent (NOI) has been reviewed by DEC, an acknowledgement letter will be returned to the sender. Filing of an NOI does not supercede or negate the necessity to comply with other local laws and other state or federal requirements, which affect stormwater management. It is the responsibility of the operator to comply with any and all such regulations. Operators are encouraged to have their Stormwater Pollution Prevention Plan reviewed by the local Soil and Water Conservation District.

New York City has enacted various land use controls that affect certain construction projects in areas tributary to their drinking water reservoirs. Similarly, the Lake George Park Commission and the Adirondack Park Agency (APA) have enacted regulations which impact construction activity. The APA has jurisdiction over private lands within the Adirondack Park and requires environmental review for most land development projects. It also administers the State's Wild and Scenic Rivers and Freshwater Wetlands programs on these lands. Development within the APA's jurisdiction is not subject to SEQR. For more information, please contact the APA at 518-891-4050.

Other municipalities and agencies of New York State may have adopted similar legislation. It is the responsibility of the operator to comply with any and all such regulations. Table 3.1 provides a summary table describing the permits issued by DEC that may apply to the new development.

Section 3.2 Filing Other Permit Applications

Most other environmental permits are administered under the UPA, which establishes uniform review procedures for the DEC's major regulatory programs and provides time periods for DEC action on applications for environmental protection permits. Generally permits identified under the UPA need to be filed through the DEC Regional Office. (See Figure 3.2 for regional contact information). If more than one permit is required, the applicant should submit all applications at one time. In addition, the applicant must list permits of other agencies that he or she knows to be applicable, together with a statement of the status of approval of the review under the State Environmental Quality Review (SEQR).

3.2.1 What Other Permits Do I Need to File?

Several permits under the UPA may be applicable to a particular development project. Table 3.1 lists many of permits required under the UPA that may apply to new residential, commercial, and industrial development in New York State, and provides a brief description of each. Please note that the table includes only the permits that are directly applicable to the stormwater and site plan development. Thus several UPA permits may be required that are not included on this table, including Long Island Wells, Water Supply, 401 Water Quality Certification, Air Pollution Control, Mined Land Reclamation, Hazardous Waste Management Facilities, and Waste Transporter.

Table 3.1 Summary of Environmental Permits Issued by DEC That May Apply to New Development

3.1 Permit Title	3.2 Implementation Authority	3.2.1 Applicability	3.2.2 Regulated Activities
State Pollutant Discharge Elimination System	ECL Article 17 Division of Water	• Construction sites disturbing one acre or more.	*Regulated:* Stormwater discharge associated with industrial activity, including new construction; point source discharges and disposal systems *Exempted:* Agricultural discharge[1], discharge of sewage effluent to groundwater less than 1,000 gallons a day.
Dam Safety	ECL Article 15-0503 see *Guidelines for Design of Dams*	• Applies to on-stream and off-stream structures having height > 6' and storage capacity > 3MG, or height ≥ 15' and storage capacity ≥ 1 MG.	*Regulated:* Construction, reconstruction, repair or removal of dams or impoundment. *Exempted:* Structures for treatment or storage of wastewater, or materials other than water.
Freshwater Wetlands	ECL Article 24 Division of Fish, Wildlife and Marine Resources	• Freshwater wetlands appearing on New York State freshwater wetland maps • Generally limited to 12.4 acres or greater, but stricter requirements in the Adirondack Park	*Regulated:* Construction of buildings, roadways, septic systems, dams, docks; filling, draining, or excavating; vegetation removal *Exempted:* Ordinary maintenance and repair of existing structures; recreational activities
Tidal Wetlands	ECL Article 25 NY DEC, Tidal Wetlands Regulatory Program	• Official DEC tidal wetlands maps. • Anywhere tidal inundation occurs on a daily, monthly, or intermittent basis, including but not exclusively within the salt wedge (salt marshes, vegetated flats, and shorelines)[2] • Adjacent areas extend up to 300 ft. inland from wetland boundary (NYC 150 ft)	*Regulated:* Residences and condos; accessory structures; commercial and industrial buildings; roadways and parking lots; boat ramps; septic systems; drainage structures; erosion control structures (groins, sea walls); docks, piers, etc. Clearing/clear cutting; beach nourishment; dredging, excavation, and grading.
Protection of Waters	Title 5, ECL Article 15 Division of Fish, Wildlife and Marine Resources	Bed or banks of protected streams	*Regulated*: Modification or disturbance of the bed or banks of protected streams, including removal of sand or gravel; filling dredging in navigable waters; construction/modification/ repair of

[1]- Eligible for coverage under Concentrated Animal Feeding Operation (CAFO)

[2] Applicable to Rockland and Westchester Counties, NYC and Long Island.

Table 3.1 Summary of Environmental Permits Issued by DEC That May Apply to New Development			
			certain dams, docks, and mooring areas. *Exempted:* Ordinary maintenance
Coastal Erosion Hazard Areas	ECL Article 34 Division of Water	• Lands adjacent to Lakes Erie and Ontario; the St. Lawrence, Niagara, Harlem, East, and Hudson Rivers; Kill van Kull; Arthur Kill; Atlantic Ocean; and connective water-bodies. • Natural Protective Features (NPF) nearshore areas; and landward Structural Hazard Areas (SHA)	*Regulated*: Construction/ modification/ restoration of structures, e.g. buildings, docks, piers, walkways; Filling, draining or excavating; Construction/modification/restoration of erosion control structures *Exempted:* Ordinary maintenance and repair of existing structures
Wild, Scenic, & Recreational Rivers	Title 27, ECL Article 15 Division of Fish, Wildlife and Marine Resources	All or portions of DEC-designated waterways: Three levels of classification include recreational rivers, scenic rivers, wild rivers	*Regulated*: Specifics depend on classification, but includes construction of residential, non-residential, accessory structures, and roads; Water quality, wastewater treatment, disposal; Vegetative cutting and agriculture; Recreational uses and development; Commercial and industrial uses. *Exempted*: Continuation of existing land uses; Maintenance and repair--without changes
* UPA permits not included in this table are Long Island Wells, Water Supply, 401 Water Quality Certification, Air Pollution Control; Mined Land Reclamation, Hazardous Waste Management Facilities, Waste Transporter Source URL:(http://www.dec.state.ny.us/website/dcs/upa/upa_permits.html)			

3.2.2 Schedule for DEC Review

The time for permit approval depends on whether a project is determined to be UPA major or UPA minor. Each of the permits included in the UPA process has specific definitions of what constitutes UPA major and UPA minor projects. DEC first determines if an application is complete, and then begins the review process. For most projects, DEC must determine completeness within 15 days and for federally delegated permits within 60 days. For UPA minor projects, DEC must make a decision on the permit within 45 days of determining the application complete.

For UPA major projects, the length of time for review depends on whether a public hearing is required. If no hearing is required, DEC must make a decision within 90 days of determining the project complete. If a hearing is required, DEC notifies the applicant and the public of a hearing within 60 days of the completeness determination. The hearing must commence within 90 days of the completeness determination. Once the hearing ends, DEC must issue a final decision on the application within 60 days after receiving the final hearing record.

- **Dam Safety**

Constructing, reconstructing, repairing, or modifying dams and water impounding structures that permanently or temporarily impound water as a result of a structure placed across a watercourse or overland drainage way or which receive water from an external source such as drainage diversion or pumping of groundwater require a dam safety permit. Some examples of activities requiring this permit are: siting and constructing a new dam or water impounding structure, reconstruction, modification or maintenance which may affect the structural integrity or functional capability of a dam or impounding structure.

- **Freshwater Wetlands/Tidal Wetlands**

A freshwater or tidal wetlands permit may be required for work in or adjacent to wetlands designated by the State. Official tidal wetlands maps showing the locations of New York's regulated tidal wetlands are on file at DEC regional offices in Regions 1, 2, and 3, and in the County Clerks' Offices of Nassau, Suffolk, Bronx, Kings, New York, Queens, Richmond, Rockland, and Westchester Counties. They are also available at local assessing agencies in these areas. Official freshwater wetlands maps showing the locations of New York's wetlands are on file at DEC regional offices, the Adirondack Park Agency, and local government offices.

Wetlands permit applications require analysis of alternatives. Even when a development is adjacent to a regulated wetland, the site plan and stormwater management plan need to be modified to adequately protect these resources.

- **Protection of Waters**

This permit applies to the dredging and filling in navigable waters and dams and work on the banks of protected streams. The permit also regulates the construction of dams in both waterways and overland drainage ways. When a site plan includes dam construction as a part of a quantity or quality control requirement, a permit will be required unless the following conditions are met:

- Maximum height is six feet or less (maximum height is measured as the height from the downstream (outside) toe of the dam at its lowest point to the highest point at the top of the dam).
- Maximum impounding capacity is one million gallons or less (maximum impounding capacity is measured as the volume of water impounded when the water level is at the top of the dam).
- Maximum height is between six feet and 15 feet and the maximum impounding capacity is less than three million gallons.

- **Coastal Erosion Hazard Areas**

This permit is required where coastal erosion is a concern, and applies to Natural Protective Features (NPFs), such as sand dunes, and a Shoreline Hazard Area (SHA) defined based on the annual recession rate of the coast. The permit is required for construction of any structures within the SHA, and the permitee must demonstrate that the proposed project does not contribute to coastal erosion.

- **Wild, Scenic, & Recreational Rivers**

This regulation applies strict regulations, which restrict certain uses for development bordering wild, scenic, or recreational rivers in New York State. Furthermore, the applicant must demonstrate that no reasonable alternative exists, and that the proposed activity will not have an undue adverse environmental impact. Listed waterways include:

<u>Scenic Rivers</u>

Carmans River	Grasse River
Peconic River	Oswegatchie River
East Canada Creek	GenesseeRiver

<u>Recreational Rivers</u>

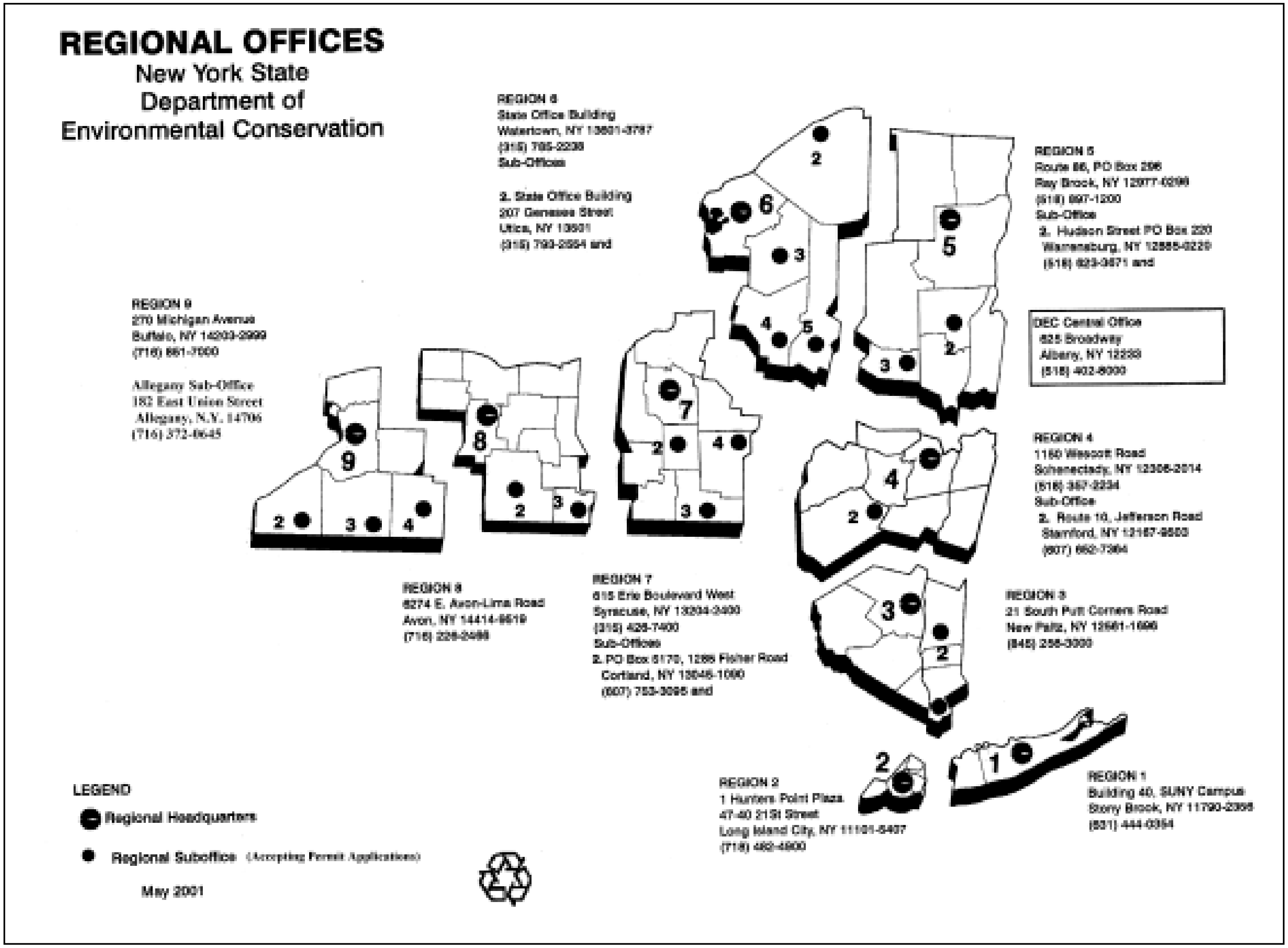
Carmans River	Ramapo River
Connetquot River	Shawangunk Kill
Nissequogue River	Ausable River
Peconic River	Fall Creek

- **State Environmental Quality Review Act (SEQR)**

Many projects are subject to SEQR. It is important that operators inform local governments about their projects and obtain necessary local approvals before starting work. Projects, for which only a general permit is needed, are not subject to SEQR. If any other permits are required, the applicant must submit applications, which are reviewed in accordance with SEQR.

All agencies involved (state and local), must consider the environmental impacts of construction projects before approving, funding, or directly undertaking an action. Development projects subject to SEQR will require an Environmental Assessment Form. If a project may have a significant environmental impact, an Environmental Impact Statement (EIS) will be required. Projects will require public involvement as a part of this process.

Figure 3.2 New York State Regional Contact Information



Chapter 4

Unified Stormwater Sizing Criteria

Chapter 4: Unified Stormwater Sizing Criteria

Section 4.1 Introduction

This chapter presents a unified approach for sizing SMPs in the State of New York to meet pollutant removal goals, reduce channel erosion, prevent overbank flooding, and help control extreme floods. For a summary, please consult Table 4.1 below. The remaining sections describe the four sizing criteria in detail and present guidance on how to properly compute and apply the required storage volumes.

Table 4.1 New York Stormwater Sizing Criteria	
Water Quality (WQ_v)	**90% Rule:** $WQ_v = [(P)(R_v)(A)]\ /12$ $Rv = 0.05+0.009(I)$ I = Impervious Cover (Percent) Minimum Rv = 0.2 P = 90% Rainfall Event Number (See Figure 4.1) A = site area in acres
Channel Protection (Cp_v)	**Default Criterion:** Cp_v = 24 hour extended detention of post-developed 1-year, 24-hour storm event. **Option for Sites Larger than 50 Acres:** Distributed Runoff Control - geomorphic assessment to determine the bankfull channel characteristics and thresholds for channel stability and bedload movement.
Overbank Flood (Q_p)	Control the peak discharge from the 10-year storm to 10-year predevelopment rates.
Extreme Storm (Q_f)	Control the peak discharge from the 100-year storm to 100-year predevelopment rates. Safely pass the 100-year storm event.
Note: *The local review authority may waive channel protection, overbank flood, and extreme storm requirements in some instances. Guidance is provided in this chapter.*	

Section 4.2 Water Quality Volume (WQ_v)

The Water Quality Volume (denoted as the WQ_v) is designed to improve water quality sizing to capture and treat 90% of the average annual stormwater runoff volume. The WQ_v is directly related to the amount of impervious cover created at a site. Contour lines of the 90% rainfall event are presented in Figure 4.1.

The following equation can be used to determine the water quality storage volume WQ_v (in acre-feet of storage):

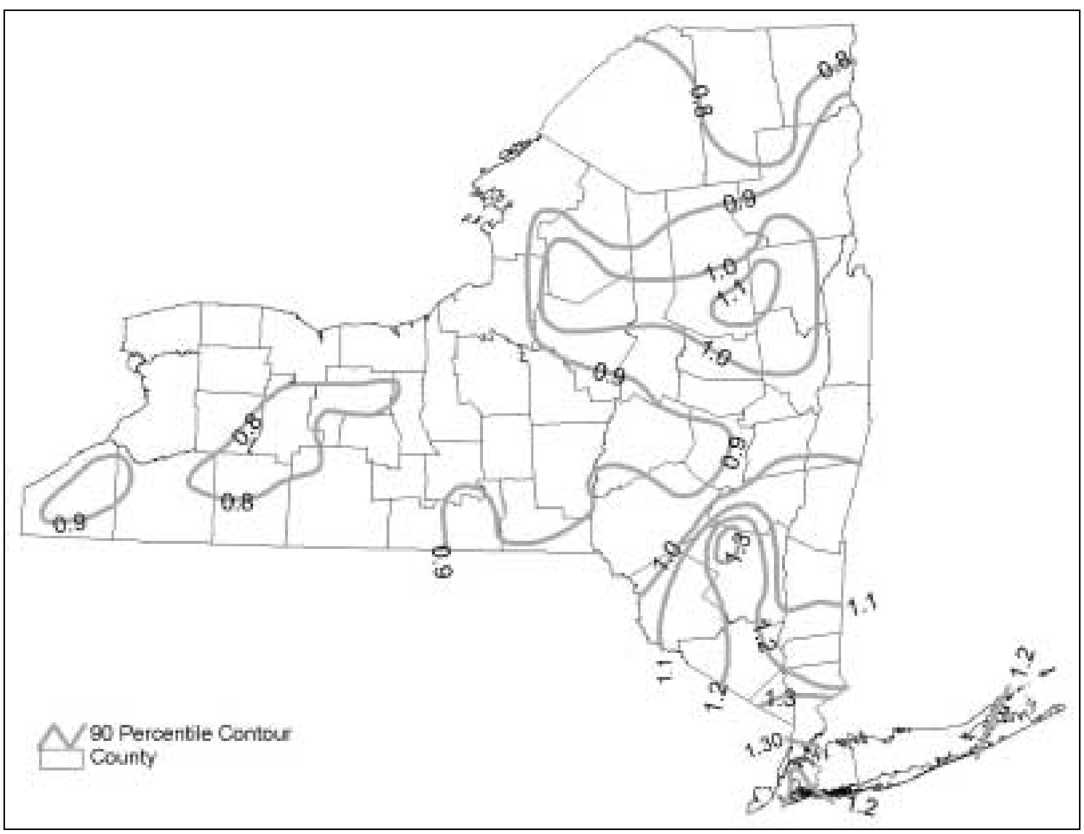
$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

where:

- WQ_v = water quality volume (in acre-feet)
- P = 90% Rainfall Event Number (see Figure 4.1)
- R_v = 0.05 + 0.009(I), where I is percent impervious cover
- A = site area in acres

A minimum WQ_v of 0.2 inches per acre shall be met at residential sites that have less than 17% impervious cover.

Figure 4.1 90% Rainfall in New York State



It is assumed that by meeting the WQ_v requirements through employment of the practices presented in Table 5.1 a project will, by default, meet water quality objectives. In some jurisdictions, on-site load calculations are required to demonstrate removal of specific pollutants. As an aid to communities, Appendix A of this manual includes a discussion of a method for calculating pollutant export loads from development sites. This method, known as the "Simple Method," provides estimates for stormwater runoff pollutant loads for urban areas using a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. Please consult Appendix A for a more detailed discussion of the Simple Method and its applications for water quality determinations. Please note that the Simple Method is intended as an analysis tool, and should not be used to guide the design of SMPs.

Basis Of Design for Water Quality

As a basis for design, the following assumptions may be made:

- *Measuring Impervious Cover*: the measured area of a site plan that does not have permanent vegetative or permeable cover shall be considered total impervious cover. Impervious cover is defined as all impermeable surfaces and includes: paved and gravel road surfaces, paved and gravel parking lots, paved driveways, building structures, paved sidewalks, and miscellaneous impermeable structures such as patios, pools, and sheds. Porous or modular block pavement may be considered 50% impervious. Where site size makes direct measurement of impervious cover impractical, the land use/impervious cover relationships presented in Table 4.2 can be used to initially estimate impervious cover.

Table 4.2 Land Use and Impervious Cover (Source: Cappiella and Brown, 2001)

Land Use Category	Mean Impervious Cover
Agriculture	**2**
Open Urban Land*	**9**
2 Acre Lot Residential	**11**
1 Acre Lot Residential	**14**
1/2 Acre Lot Residential	**21**

Table 4.2 Land Use and Impervious Cover (Source: Cappiella and Brown, 2001)	
Land Use Category	**Mean Impervious Cover**
1/4Acre Lot Residential	**28**
1/8 Acre Lot Residential	**33**
Townhome Residential	**41**
Multifamily Residential	**44**
Institutional**	**28-41%**
Light Industrial	**48-59%**
Commercial	**68-76%**
* Open urban land includes developed park land, recreation areas, golf courses, and cemeteries. ** Institutional is defined as places of worship, schools, hospitals, government offices, and police and fire stations	

- *Aquatic Resources*: More stringent local regulations may be in place or may be required to protect drinking water reservoirs, lakes, or other sensitive aquatic resources. Consult the local authority to determine the full requirements for these resources.

- *SMP Treatment*: The final WQ_v shall be treated by an acceptable practice from the list presented in this manual. Please consult Chapter 5 for a list of acceptable practices.

- *Determining Peak Discharge for WQ_v Storm*: When designing flow splitters for off-line practices, consult the small storm hydrology method provided in Appendix B.

- *Extended Detention for Water Quality Volume*: The water quality requirement can be met by providing 24 hours of the WQ_v (provided a micropool is specified) extended detention. A local jurisdiction may reduce this requirement to as little as 12 hours in trout waters to prevent stream warming.

- *Off-site Areas:* Provide treatment for off-site areas in their current condition. If water quality treatment is provided off-line, the practice must only treat on-site runoff.

Section 4.3 Stream Channel Protection Volume Requirements (Cp_v)

Stream Channel Protection Volume Requirements (Cp_v) are designed to protect stream channels from erosion. In New York State this goal is accomplished by providing 24-hour extended detention of the one-year, 24-hour storm event. Trout waters may be exempted from the 24-hour ED requirement, with only 12 hours of extended detention required to meet this criterion.

For developments greater than 50 acres, with impervious cover greater than 25%, it is recommended that a detailed geomorphic assessment be performed to determine the appropriate level of control. Appendix J provides guidance on how to conduct this assessment.

The Cp_v requirement does not apply in certain conditions, including the following:

- Recharge of the entire Cp_v volume is achieved at a site.
- The site discharges directly tidal waters or fourth order (fourth downstream) or larger streams. Within New York State, streams are classified using the following:
  New York State Codes Rules and Regulations (NYCRR)
  Volumes B-F, Parts 800-941
  West Publishing, Eagan, MN
- A downstream analysis reveals that channel protection is not required (see section 4.7).

Detention ponds or underground vaults are methods to meet the Cp_v requirement (and subsequent Q_{p10} and Q_f criteria). Schematics of typical designs are shown in Figures 4.2. and 4.3. Note that, although these practices meet water quantity goals, they are unacceptable for water quality because of poor pollutant removal, and need to be coupled with a practice listed in Table 5.1. The Cp_v requirement may also be provided above the water quality (WQ_v) storage in a wet pond or stormwater wetland.

Basis for Determining Channel Protection Storage Volume

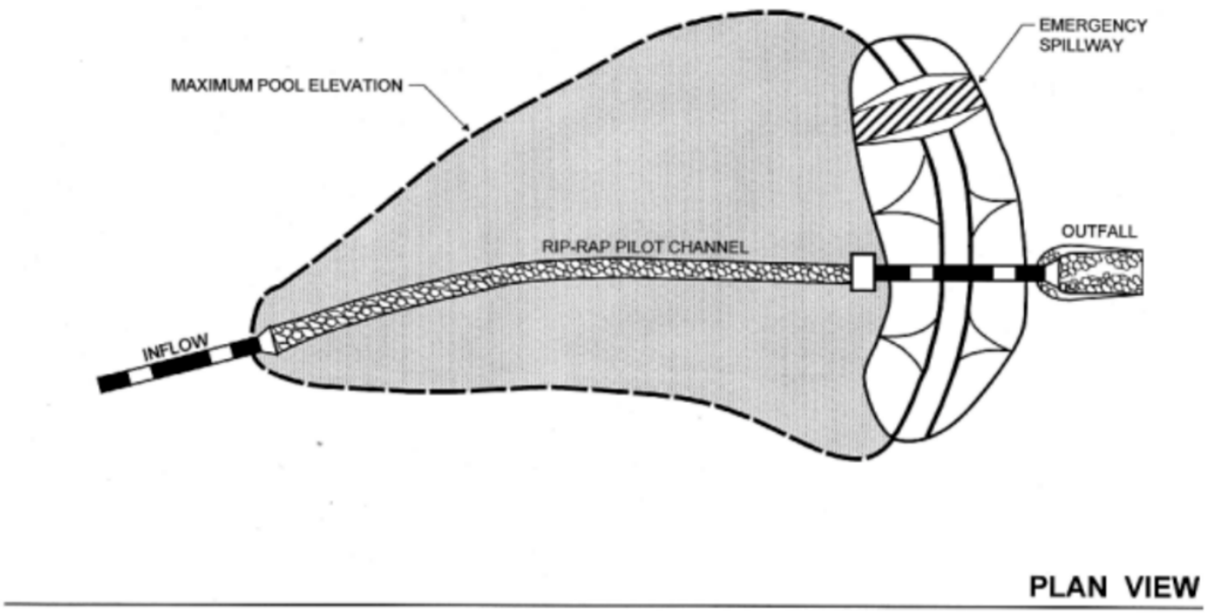
The following represent the minimum basis for design:

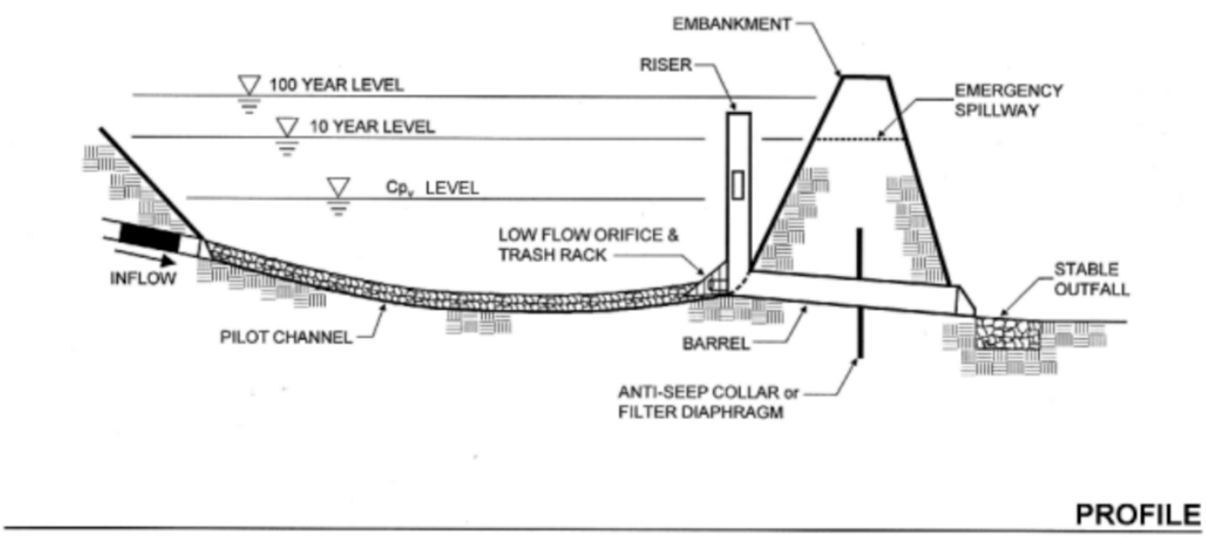
- TR-55 and TR-20 (or approved equivalent) shall be used to determine peak discharge rates.
- Rainfall depths for the one-year, 24 hour storm event are provided in Figure 4.4.
- Off-site areas should be modeled as "present condition" for the one-year, 24 hour storm event.
- The length of overland flow used in time of concentration (t_c) calculations is limited to no more than 100 feet for post development conditions.
- Cp_v is not required at sites where the resulting diameter of the ED orifice is too small to prevent clogging. (A minimum 3" orifice with a trash rack or 1" if the orifice is protected by a standpipe

having slots with an area less than the internal orifice are recommended to prevent clogging. See Figure 3 in Appendix K for design details).

- Extended detention storage provided for the channel protection (Cp_v-ED) does not meet the WQ_v requirement. Both water quality and channel protection storage may be provided in the same SMP, however.
- The CP_v detention time for the one-year storm is defined as the time difference between the center of mass of the inflow hydrograph (entering the SMP) and the center of mass of the outflow hydrograph (leaving the SMP). See Appendix B for a methodology for detaining this storm event.

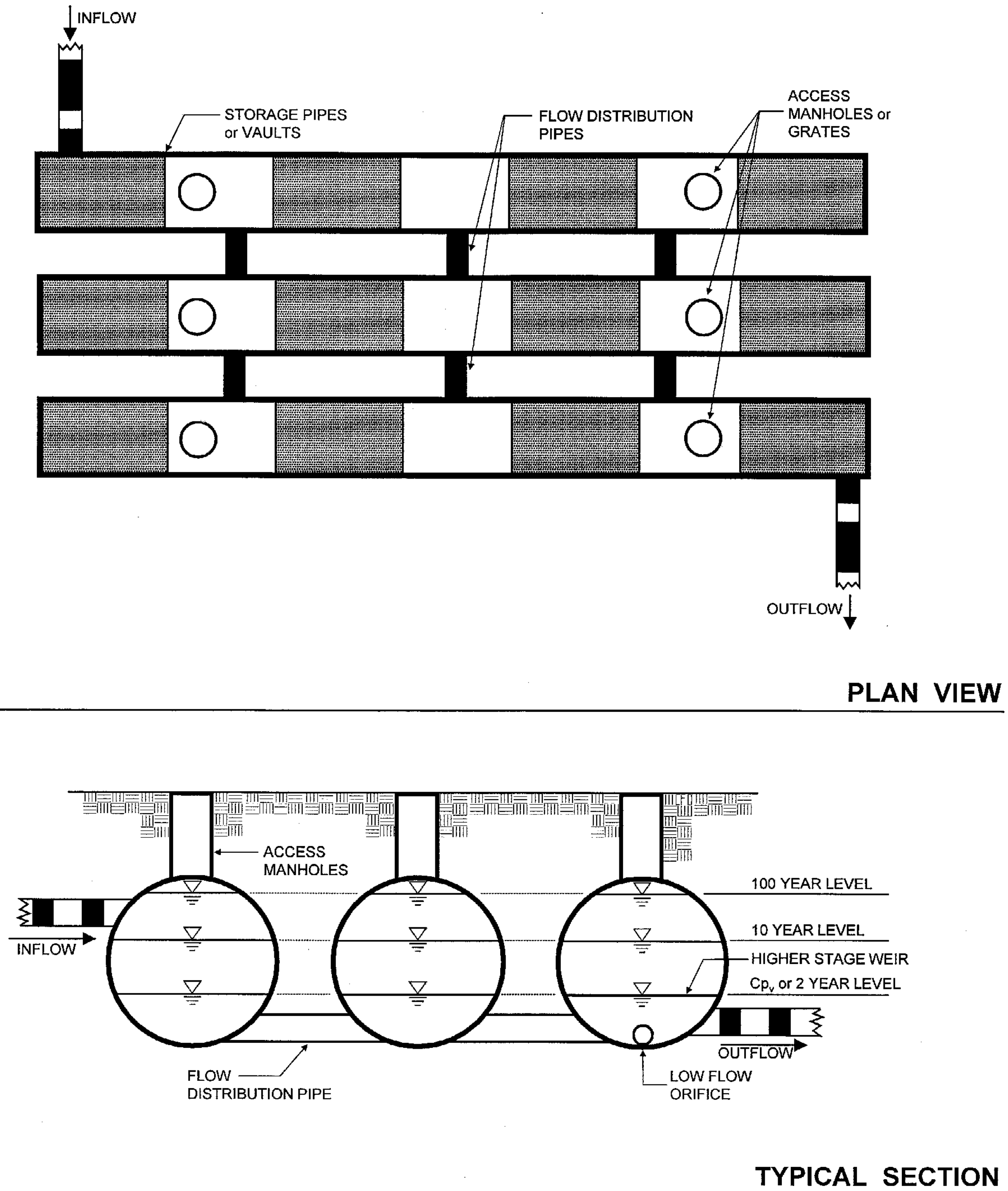
Figure 4.2 Example of a Conventional Stormwater Detention Pond





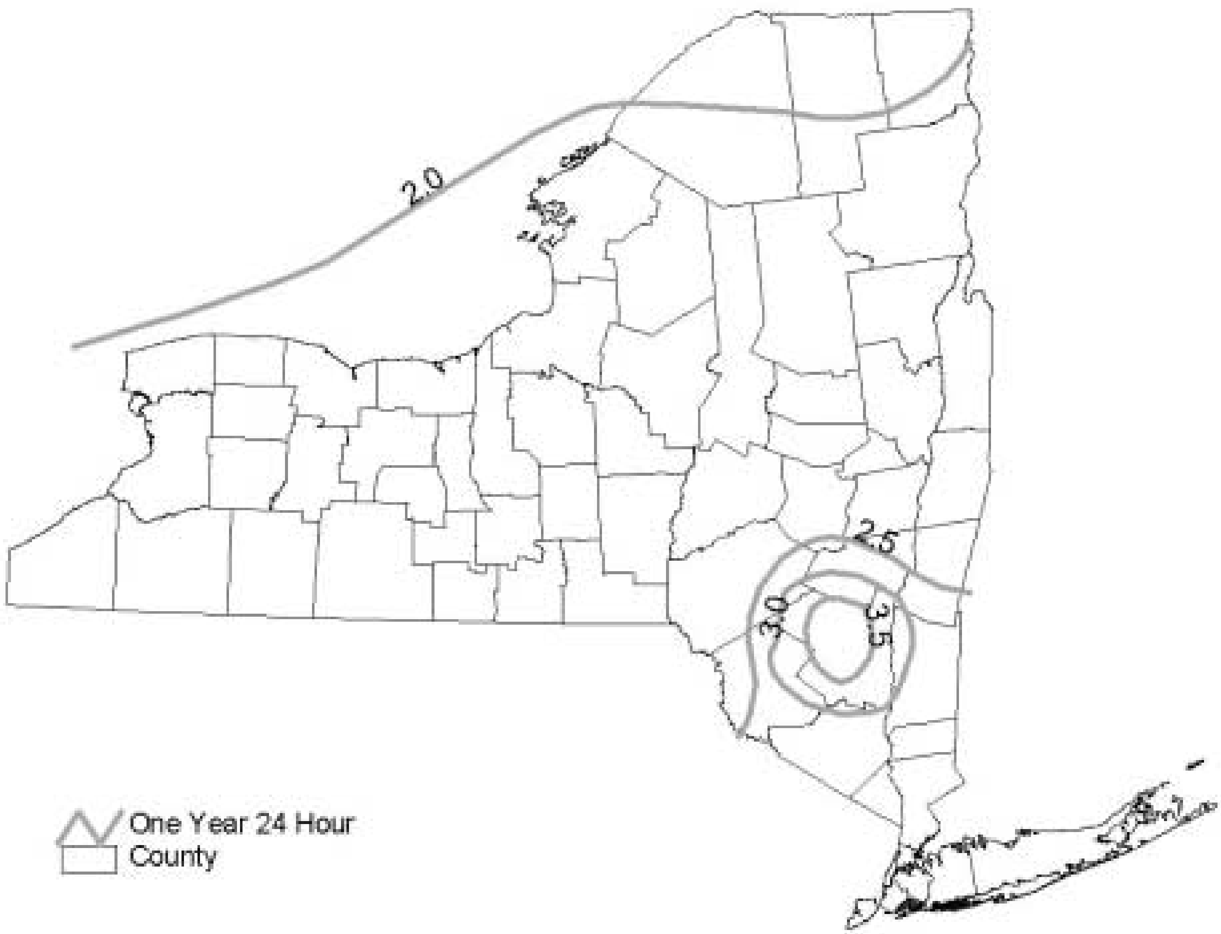
A typical detention facility provides channel protection control (Cp_v) and overbank control (Q_p) but no water quality control (WQ_v). If this practice is used, WQv must be provided in a separate facility listed in Table 5.1.

Figure 4.3 Example of Stormwater Detention Provided by an Underground Pipe System



An underground pipe system or vaults may be used to provide Cp_v, Q_p and Q_f controls but not WQ_v.

Figure 4.4 One-Year Design Storm



Section 4.4 Overbank Flood Control Criteria (Q_p)

The primary purpose of the overbank flood control sizing criterion is to prevent an increase in the frequency and magnitude of out-of-bank flooding generated by urban development (i.e., flow events that exceed the bankfull capacity of the channel, and therefore must spill over into the floodplain).

Overbank control requires storage to attenuate the post development 10-year, 24-hour peak discharge rate (Q_p) to predevelopment rates.

The overbank flood control requirement (Q_p) does not apply in certain conditions, including:

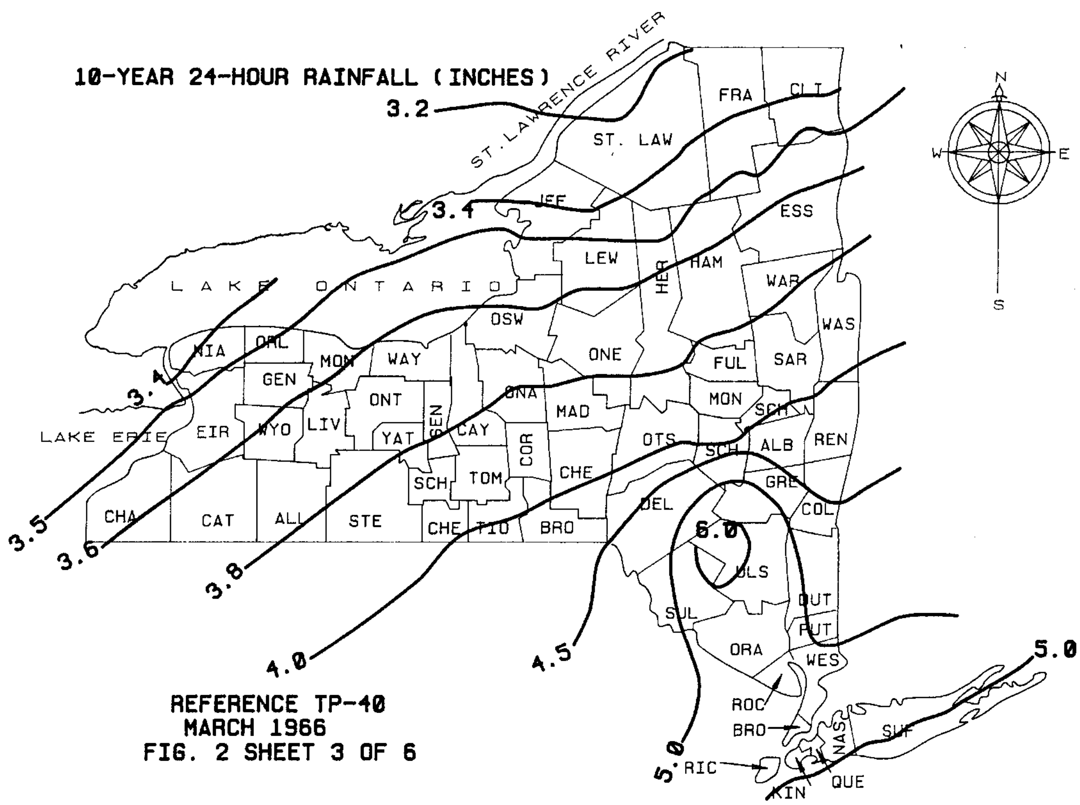
- The site discharges directly tidal waters or fourth order (fourth downstream) or larger streams. Within New York State, streams are classified using the following:
  New York State Codes Rules and Regulations (NYCRR)
  Volumes B-F, Parts 800-941
  West Publishing, Eagan, MN
- A downstream analysis reveals that overbank control is not needed (see section 4.7).

Basis for Design of Overbank Flood Control

When addressing the overbank flooding design criteria, the following represent the minimum basis for design:

- TR-55 and TR-20 (or approved equivalent) will be used to determine peak discharge rates.
- When the predevelopment land use is agriculture, the curve number for the pre-developed condition shall be derived from the recommended five-year crop rotation for a region, from the local Soil Conservation Service, or from the historical five-year crop rotation for the site, whichever results in a lower curve number value.
- Off-site areas should be modeled as "present condition" for the 10-year storm event.
- Figure 4.5 indicates the depth of rainfall (24 hour) associated with the 10-year storm event throughout the State of New York.
- The length of overland flow used in t_c calculations is limited to no more than 150 feet for predevelopment conditions and 100 feet for post development conditions. On areas of extremely flat terrain (<1% average slope), this maximum distance is extended to 250 feet for predevelopment conditions and 150 feet for postdevelopment conditions.

Figure 4.5 10-Year Design Storm



Section 4.5 Extreme Flood Control Criteria (Q_f)

The intent of the extreme flood criteria is to (a) prevent the increased risk of flood damage from large storm events, (b) maintain the boundaries of the predevelopment 100-year floodplain, and (c) protect the physical integrity of stormwater management practices

100 Year Control requires storage to attenuate the post development 100-year, 24-hour peak discharge rate (Q_f) to predevelopment rates.

The 100-year storm control requirement can be waived if:

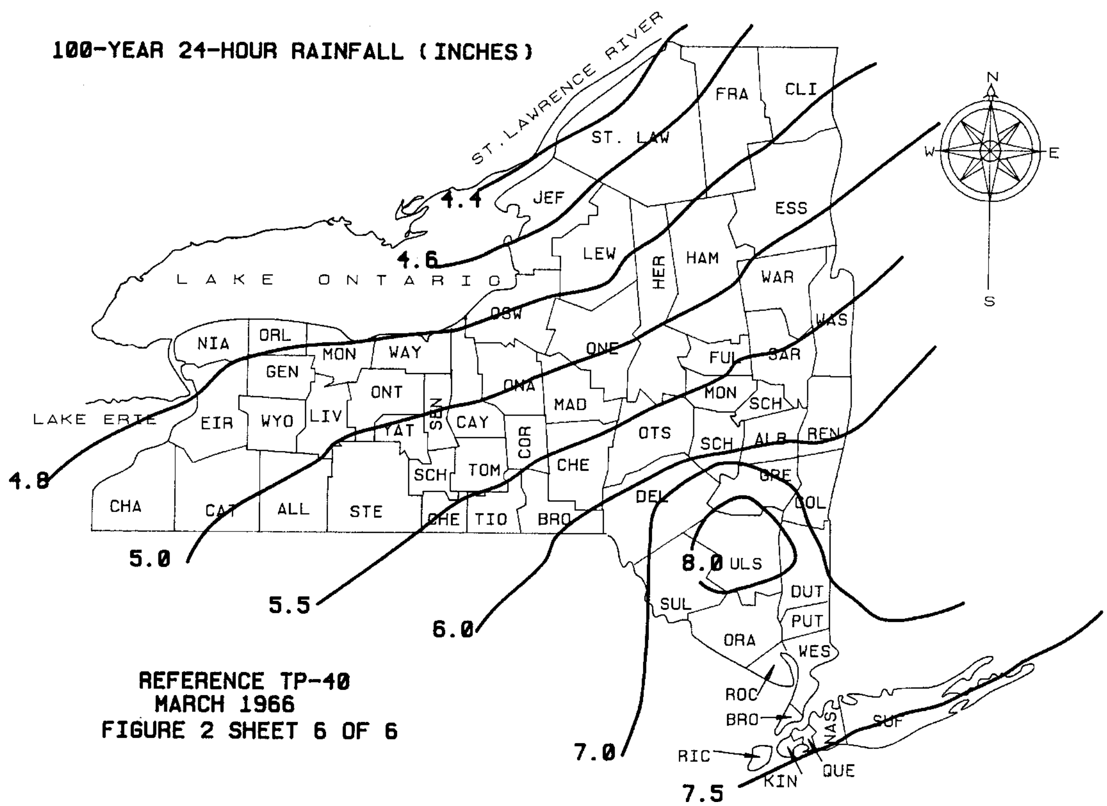
- The site discharges directly tidal waters or fourth order (fourth downstream) or larger streams. Within New York State, streams are classified using the following:
  New York State Codes Rules and Regulations (NYCRR)
  Volumes B-F, Parts 800-941
  West Publishing, Eagan, MN
- Development is prohibited within the ultimate 100-year floodplain
- A downstream analysis reveals that 100-year control is not needed (see section 4.7)

Detention structures must provide safe overflow of the 100-year flood, as discussed in the New York State Department of Environmental Conservation publication: "Guidelines for the Design of Dams," available from the Bureau of Flood Protection at 518-402-8151.

Basis for Design for Extreme Flood Criteria

- Consult with the appropriate review authority *including the local municipality's flood protection permit administrator,* to determine the analysis required for the Q_f storm.
- The same hydrologic and hydraulic methods used for overbank flood control shall be used to analyze Q_f.
- Figure 4.6 indicates the depth of rainfall (24 hour) associated with the 100-year storm event throughout New York State.
- When determining the storage required to reduce 100-year flood peaks, model off-site areas under current conditions.
- When determining storage required to safely pass the 100-year flood, model off-site areas under ultimate conditions.

Figure 4.6 100-Year Design Storm



Section 4.6 Conveyance Criteria

In addition to the stormwater treatment volumes described above, the manual also provides guidance on safe and non-erosive conveyance to, from, and through SMPs. Typically, the targeted storm frequencies for conveyance are the two-year and ten-year events. The two-year event is used to ensure non-erosive flows through roadside swales, overflow channels, pond pilot channels, and over berms within practices. Figure 4.7 presents rainfall depths for the two-year, 24-hour storm event throughout New York State. The 10-year storm is typically used as a target sizing for outfalls, and as a safe conveyance criterion for open channel practices and overflow channels. Note that some agencies or municipalities may use a different design storm for this purpose.

Section 4.7 Downstream Analysis

A community may waive the channel protection, overbank, and extreme flood requirements based on the results of a downstream analysis. In addition, such an analysis is recommended for larger sites (i.e., greater than 50 acres) to size facilities in the context of a larger watershed. The analysis will help ensure that storage provided at a site is appropriate to when combined with upstream and downstream flows. For example, detention at a site may in some instances exacerbate flooding problems within a watershed. This section provides brief guidance for conducting this analysis, including the area of stream to be evaluated and minimum elements to be included in the analysis.

Downstream analysis can be conducted using the 10% rule. That is, the analysis should extend downstream to the point where the site represents 10% of the total drainage area. For example, the analysis point for a 10-acre site would be analyzed to the nearest downstream point with a drainage area of 100 acres.

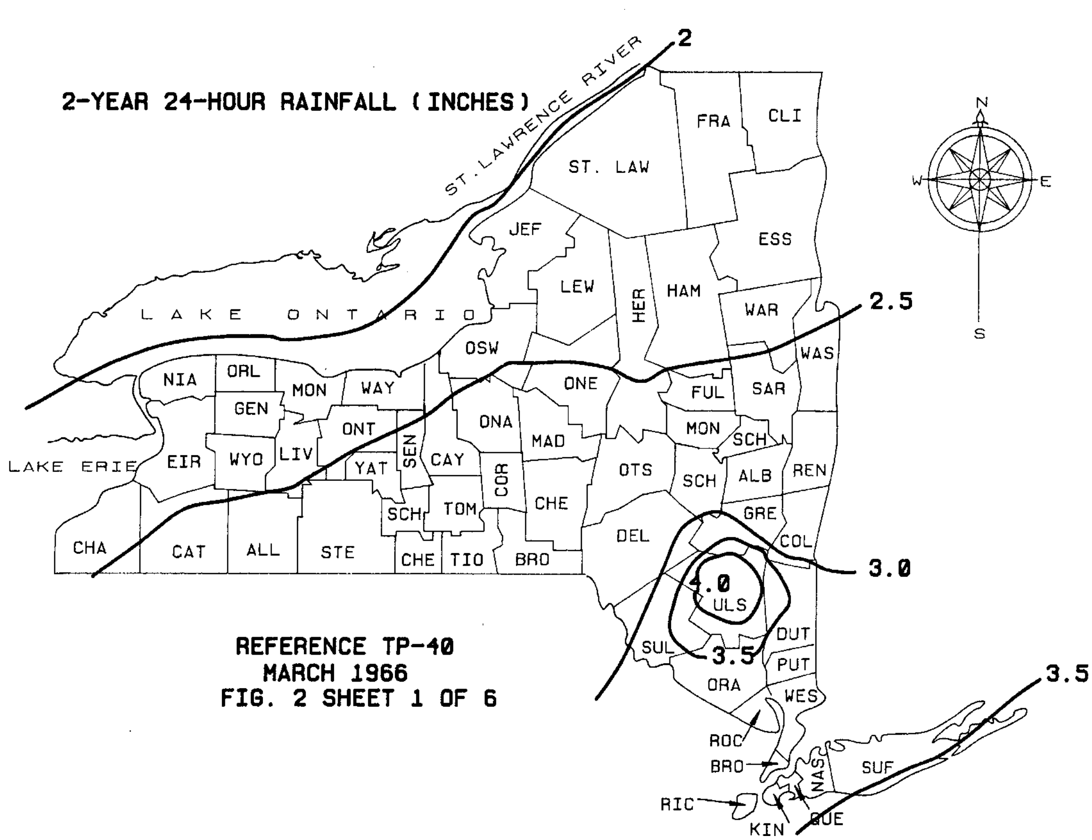
The analysis should include the following:

- Computation of flows and velocities for channel protection, overbank, and flood control storms at 200-foot intervals, at the point where the 10% rule is met, and at all confluences along the downstream channel with first order or higher streams.
- Hydrologic and hydraulic effects of all culverts and/or obstructions within the downstream channel.
- An assessment of water surface elevations to determine if an increase in water surface elevations will impact existing buildings and other structures.

The design, or waiver, at a site level can be approved if the following criteria are met:

- Flow rates and velocities increase by less than 5% of the pre-developed condition for all flow conditions analyzed.
- No downstream structures or buildings are impacted.
- The site as designed is not expected to exacerbate downstream channel erosion.

Figure 4.7. Two-Year Design Storm



Section 4.8 Stormwater Hotspots

A stormwater hotspot is defined as a land use or activity that generates higher concentrations of hydrocarbons, trace metals or toxicants than are found in typical stormwater runoff, based on monitoring studies. If a site is designated as a hotspot, it has important implications for how stormwater is managed. First and foremost, stormwater runoff from hotspots cannot be allowed to infiltrate into groundwater, where it may contaminate water supplies. Second, a greater level of stormwater treatment is needed at hotspot sites to prevent pollutant washoff after construction. This treatment plan typically involves preparing and implementing *a stormwater pollution prevention plan* that involves a series of operational practices at the site that reduce the generation of pollutants from a site or prevent contact of rainfall with the pollutants. Table 4.3 provides a list of designated hotspots for the State of New York

Under EPA's stormwater NPDES program, some industrial sites are required to prepare and implement a stormwater pollution prevention plan. A list of industrial categories that are subject to the pollution prevention requirement can be found in the State of New York SPDES. In addition, New York's requirements for preparing and implementing a stormwater pollution prevention plan are described in the SPDES general discharge permit. The stormwater pollution prevention plan requirement applies to both existing and new industrial sites.

Table 4.3 Classification of Stormwater Hotspots

The following land uses and activities are deemed *stormwater hotspots:*

- Vehicle salvage yards and recycling facilities #
- Vehicle fueling stations
- Vehicle service and maintenance facilities
- Vehicle and equipment cleaning facilities #
- Fleet storage areas (bus, truck, etc.) #
- Industrial sites (based on SIC codes outlined in the SPDES)
- Marinas (service and maintenance) #
- Outdoor liquid container storage
- Outdoor loading/unloading facilities
- Public works storage areas
- Facilities that generate or store hazardous materials #
- Commercial container nursery
- Other land uses and activities as designated by an appropriate review authority

 # indicates that the land use or activity is required to prepare a stormwater pollution prevention plan under the SPDES stormwater program.

The following land uses and activities are not normally considered hotspots:

- Residential streets and rural highways
- Residential development
- Institutional development
- Office developments
- Non-industrial rooftops
- Pervious areas, except golf courses and nurseries (which may need an Integrated Pest Management (IPM) Plan).

While large highways (average daily traffic volume (ADT) greater than 30,000) are not designated as a stormwater hotspot, it is important to ensure that highway stormwater management plans adequately protect groundwater.

Chapter 5

List of Acceptable Stormwater Management Practices

Chapter 5: Acceptable Stormwater Management Practices (SMPs)

This section presents a list of practices that are acceptable for water quality treatment. The practices on this list are selected based on the following criteria:

1. Can capture and treat the full water quality volume (WQ_v)
2. Are capable of 80% TSS removal and 40% TP removal.
3. Have acceptable longevity in the field.
4. Have a pretreatment mechanism.

It also provides data justifying the use of these practices, and minimum criteria for the addition of new practices to the list.

Section 5.1 Practice List

Practices on the following list will be presumed to meet water quality requirements set forth in this manual if designed in accordance with the sizing criteria presented in Chapter 4 and constructed in accordance with the performance criteria in Chapter 6. The practices must also be maintained properly in accordance with the prescribed maintenance criteria also presented in Chapter 6. Acceptable practices are divided into five broad groups, including:

I. **Stormwater Ponds** — Practices that have either a permanent pool of water or a combination of permanent pool and extended detention capable of treating the WQ_v

II. **Stormwater Wetlands** — Practices that include significant shallow marsh areas, and may also incorporate small permanent pools and extended detention storage to achieve the full WQ_v

III. **Infiltration Practices** — Practices that capture and temporarily store the WQ_v before allowing it to infiltrate into the soil.

IV. **Filtering Practices** — Practices that capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil, or other acceptable treatment media.

V. **Open Channel Practices** — Practices explicitly designed to capture and treat the full WQ_v within dry or wet cells formed by check dams or other means.

Within each of these broad categories, select practices are presumed to meet the established water quality goals (see Table 5.1). It is important to note that several practices that are not on the list may be of value as pretreatment, or to meet water quantity requirements (see Section 5.2). Guidance on the performance criteria for each practice type and matrices for selecting practices are provided in Chapters 6 and 7.

Table 5.1 Stormwater Management Practices Acceptable for Water Quality		
Group	**Practice**	**Description**
Pond	Micropool Extended Detention Pond (P-1)	Pond that treats the majority of the water quality volume through extended detention, and incorporates a micropool at the outlet of the pond to prevent sediment resuspension.
	Wet Pond (P-2)	Pond that provides storage for the entire water quality volume in the permanent pool.
	Wet Extended Detention Pond (P-3)	Pond that treats a portion of the water quality volume by detaining storm flows above a permanent pool for a specified minimum detention time.
	Multiple Pond System (P-4)	A group of ponds that collectively treat the water quality volume.
	Pocket Pond (P-5)	A stormwater wetland design adapted for the treatment of runoff from small drainage areas that has little or no baseflow available to maintain water elevations and relies on ground water to maintain a permanent pool.
Wetland	Shallow Wetland (W-1)	A wetland that provides water quality treatment entirely in a wet shallow marsh.
	Extended Detention Wetland (W-2)	A wetland system that provides some fraction of the water quality volume by detaining storm flows above the marsh surface.
	Pond/ Wetland System (W-3)	A wetland system that provides a portion of the water quality volume in the permanent pool of a wet pond that precedes the marsh for a specified minimum detention time.
	Pocket Wetland (W-4)	A shallow wetland design adapted for the treatment of runoff from small drainage areas that has variable water levels and relies on groundwater for its permanent pool.
Infiltration	Infiltration Trench (I-1)	An infiltration practice that stores the water quality volume in the void spaces of a gravel trench before it is infiltrated into the ground.
	Infiltration Basin (I-2)	An infiltration practice that stores the water quality volume in a shallow depression, before it is infiltrated it into the ground.
	Dry Well (I-3)	An infiltration practice similar in design to the infiltration trench, and best suited for treatment of rooftop runoff.
Filtering Practices	Surface Sand Filter (F-1)	A filtering practice that treats stormwater by settling out larger particles in a sediment chamber, and then filtering stormwater through a sand matrix.
	Underground Sand Filter (F-2)	A filtering practice that treats stormwater as it flows through underground settling and filtering chambers.
	Perimeter Sand Filter (F-3)	A filter that incorporates a sediment chamber and filer bed as parallel vaults adjacent to a parking lot.
	Organic Filter (F-4)	A filtering practice that uses an organic medium such as compost in the filter, in the place of sand.
	Bioretention (F-5)	A shallow depression that treats stormwater as it flows through a soil matrix, and is returned to the storm drain system.
Open Channels	Dry Swale (O-1)	An open drainage channel or depression explicitly designed to detain and promote the filtration of stormwater runoff into the soil media.
	Wet Swale (O-2)	An open drainage channel or depression designed to retain water or intercept groundwater for water quality treatment.

Section 5.2 Structural Practices Suitable for Pretreatment or as Supplemental Practices Only

Several practices that are not capable of providing water quality treatment can nonetheless function in a pretreatment role or as a supplemental practice to the recommended practices in Table 5.1. These practices can often be incorporated into SMP design as pretreatment devices, to treat a small portion of a site, or in retrofit or redevelopment applications. Some of these practices, including dry ponds and underground storage vaults, can be used to meet water quantity goals such as channel protection and flood control requirements. In addition, some of these practices may be helpful to reduce the total volume of runoff from a site or to disconnect impervious surfaces, as indicated on the Fact Sheets presented in this chapter. Some practices not currently deemed effective for stand-alone water quality treatment include:

- Catch basin inserts
- Dry ponds
- Underground vaults (designed for flood control)
- Oil/grit separators and hydrodynamic structures
- Filter strips
- Grass channels (includes ditches designed primarily for conveyance as well as modified practices that can achieve some pollutant removal)
- Deep sump catch basins
- On-line storage in the storm drain network
- Porous pavement

Fact sheets for some of these practices (dry ponds, filter strips, porous pavement, and grass channels) have been provided following section 5.3.

Section 5.3 Criteria for Practice Addition

The stormwater field is always evolving, and new technologies constantly emerge. New practices can be included in future revisions to the stormwater design manual, provided they can prove that they meet the water quality goals established in the manual. These goals include the 80% TSS (defined as suspended organic and inorganic material) and 40% TP removal target and a proven record of longevity in the field. For a practice to receive consideration for addition to the manual, the following monitoring criteria must be met by supporting studies:

- Must be monitored in at least two locations.
- At least five storm events must be sampled at each site.
- Concentrations reported in the studies must be flow-weighted.
- The studies must be independent (i.e., may not be conducted by the vendor or designer).
- The studies must be conducted in the field, as opposed to laboratory testing.

- The practice must have been in the ground for at least one year at the time of monitoring (to assume the practice will be tested after a minimum amount of "in-service" time).
- At least one storm event in each study must be greater than the 90% storm event for the location.

Additional testing for new technologies based on the performance of practices with a similar design may be required before consideration. For example, if a practice has a very similar design to an oil/grit separator, which has consistently poor removal, then additional studies may be required to justify incorporation of that practice into the manual. The long-term performance of a practice based on field applications in New York or other regions with a similar climate or conditions may also determine if that practice will receive consideration for inclusion in the manual. A poor maintenance record is a valid justification for not including a practice in the manual.

Dry Ponds

Description: Dry extended detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins designed to temporarily detain runoff for some minimum time. Dry detention ponds are used for water quantity control only, and can also be used to provide flood control by including additional flood detention storage.

REASONS FOR LIMITED USE

- Controls stormwater quantity – not intended to provide water quality treatment

KEY CONSIDERATIONS

- Applicable for drainage areas up to 75 acres
- Typically less costly than stormwater (wet) ponds for equivalent flood storage, as less excavation is required
- May provide recreational and open space opportunities between storm runoff events

STORMWATER MANAGEMENT SUITABILITY

[ ] **Water Quality**

[X] **Channel/Flood Protection**

SPECIAL APPLICATIONS

[ ] **Pretreatment**

[ ] **High Density/Ultra-Urban**

[ ] **Runoff Reduction/Impervious Cover Disconnection**

Residential Subdivision Use: *Yes*

Filter Strip

Description: Grassed filter strips (a.k.a., vegetated filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces and remove pollutants through filtration and infiltration.

REASONS FOR LIMITED USE

- Cannot alone achieve the 80% TSS removal target

KEY CONSIDERATIONS

- Runoff from an adjacent impervious area must be evenly distributed across the filter strip (i.e., sheet flow)
- Can be used as part of the runoff conveyance system to provide pretreatment
- Can provide groundwater recharge
- Reasonably low construction cost
- Large land requirement
- Requires periodic repair, regrading, and sediment removal to prevent channelization
- To size this practice, design a berm at the base of the filter strip. The volume to be treated should be captured behind the berm.

STORMWATER MANAGEMENT SUITABILITY

- [ ] **Water Quality**
- [ ] **Channel/Flood Protection**

SPECIAL APPLICATIONS

- [X] **Pretreatment**
- [ ] **High Density/Ultra-Urban**
- [X] **Runoff Reduction / Impervious Cover Disconnection**
- [X] **Other:** Use in buffer system; treating runoff from pervious areas

Residential Subdivision Use: *Yes*

Modular Block Porous Pavement

Description: Modular block porous pavement is a permeable pavement surface with an underlying stone reservoir designed to temporarily store surface runoff before it infiltrates into the subsoil. Porous pavement options are primarily intended for low vehicle traffic areas such as spillover parking or simply the parking aisle portion of a parking lot.

REASONS FOR LIMITED USE

- Maintenance record is unclear, and pretreatment cannot be provided.
- Should not be applied on parking lots that are sanded or salted for snow control.

DESIGN CONSIDERATIONS

- Soil permeability between 0.5 and 3.0 inches per hour
- Do not locate on slopes > 15% or within fill soils
- Site at least 3 feet above the seasonally high groundwater table, and at least 100 feet away from drinking water wells
- Direct runoff from pervious or exposed areas away from pavement
- Size the gravel trench using the same equation provided in Section 6.3 for infiltration trenches.
- Provide conveyance for larger storms with raised inlet or perimeter gravel trench
- Sediment-laden runoff must be directed away from the porous pavement
- Maximum depth should not exceed 4 feet
- Ensure that the upland drainage is fully stabilized after construction;.
- Use permanent sign(s) containing a short list of maintenance requirements
- Do not use excavated stone reservoir as a sediment control device
- Avoid compacting subsoils during construction
- Ensure that paving dewaters between storms
- Periodically inspect the surface for deterioration or spalling

STORMWATER MANAGEMENT SUITABILITY

- [ ] **Water Quality**
- [ ] **Channel/Flood Protection**

SPECIAL APPLICATIONS

- [ ] **Pretreatment**
- [X] **High Density/Ultra-Urban**
- [X] **Runoff Reduction / Impervious Cover Disconnection**
- [X] **Other:** Overflow Parking

Grass Channel

Description: Vegetated channels designed to filter stormwater runoff and meet velocity targets for the water quality design storm and the two-year storm event.

REASONS FOR LIMITED USE • Cannot alone achieve the 80% TSS removal target **KEY CONSIDERATIONS** • Can be used as part of the runoff conveyance system to provide pretreatment • Grass channels can act to partially infiltrate runoff from small storm events if underlying soils are pervious • Less expensive than curb and gutter systems • Should not be used on slopes greater than 4%; slopes between 1% and 2% recommended • Design as a parabola, or as a trapezoid with a bottom width of between 2' and 8', with 3:1 or flatter side slopes. • Provide sufficient length to retain the treatment volume in the system for 10 minutes, to flow at no greater than 1.0 fps, and at a depth of no greater than 4". • Design to maintain between 4.0 and 5.0 fps for the 2-year storm, and no greater than 7.0 fps for the 10-year storm event. • Size the channel to safely convey the 10-year storm event. • Size using Manning's Equation (US DOT, 1990). Us an "n" value of 0.15 for flow depths of 4" or smaller, and linearly increase to 0.03 for a depth of 12".	**STORMWATER MANAGEMENT SUITABILITY** ☐ **Water Quality** ☐ **Channel/Flood Protection** **SPECIAL APPLICATIONS** X **Pretreatment** ☐ **High Density/Ultra-Urban** X **Runoff Reduction / Impervious Cover Disconnection** X **Other:** Curb and gutter replacement **Residential Subdivision Use**: *Yes*

Chapter 6

Performance Criteria

Chapter 6: Performance Criteria

This chapter outlines performance criteria for five groups of structural stormwater management practices (SMPs) to meet water quality treatment goals. These include ponds, wetlands, infiltration practices, filtering systems and open channels. Each set of SMP performance criteria, in turn, is based on six performance goals:

Feasibility

Identify site considerations that may restrict the use of a practice.

Conveyance

Convey runoff to the practice in a manner that is safe, minimizes erosion and disruption to natural channels, and promotes filtering and infiltration.

Pretreatment

Trap coarse elements before they enter the facility, thus reducing the maintenance burden and ensuring a long-lived practice.

Treatment Geometry

Provide water quality treatment, through design elements that provide the maximum pollutant removal as water flows through the practice.

Environmental/Landscaping

Reduce secondary environmental impacts of facilities through features that minimize disturbance of natural stream systems and comply with environmental regulations. Provide landscaping that enhances the pollutant removal and aesthetic value of the practice.

Maintenance

Maintain the long-term performance of the practice through regular maintenance activities, and through design elements that ease the maintenance burden.

Cold climate regions of New York State may present special design considerations. Each section includes a summary of possible design modifications that address the primary concerns associated with the use of that SMP in cold climates. A more detailed discussion of cold climate modifications can be found in the publication *Stormwater BMP Design Supplement for Cold Climates* (Caraco & Claytor, 1997). In addition, Appendix I of this manual provides some sizing examples that incorporate cold climate design.

IMPORTANT NOTES:

ANY PRACTICE THAT CREATES A DAM IS REQUIRED TO FOLLOW THE GUIDANCE PRESENTED IN THE *GUIDELINES FOR DESIGN OF DAMS* AND MAY REQUIRE A PERMIT FROM THE NYSDEC. FOR THE MOST RECENT COPY OF THIS DOCUMENT, CONTACT THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, DAM SAFETY DIVISION, AT: 518-402-8151. AN EVALUATION OF HAZARD CLASSIFICATION MUST BE INCLUDED IN THE DESIGN REPORT FOR STORMWATER PONDS OR WETLANDS CREATED BY A DAM.

THIS CHAPTER FOLLOWING TEXT PRESENTS CRITERIA IN TWO PARTS. DESIGN GUIDELINES ARE FEATURES THAT ENHANCE PRACTICE PERFORMANCE, BUT MAY NOT BE NECESSARY FOR ALL APPLICATIONS. REQUIRED ELEMENTS ARE FEATURES THAT SHOULD BE USED IN ALL APPLICATIONS. A FACT SHEET AT THE BACK OF EACH SECTION HIGHLIGHTS THE REQUIRED ELEMENTS.

APPENDICES F AND G PROVIDE EXAMPLE CHECKLISTS FOR THE CONSTRUCTION AND OPERATION&MAINTENANCE OF EACH OF THE PRACTICE TYPES.

Section 6.1 Stormwater Ponds

Stormwater ponds are practices that have either a permanent pool of water, or a combination of a permanent pool and extended detention, and some elements of a shallow marsh equivalent to the entire WQ_v. Five design variants include:

- P-1 Micropool Extended Detention Pond (Figure 6.1)
- P-2 Wet Pond (Figure 6.2)
- P-3 Wet Extended Detention Pond (Figure 6.3)
- P-4 Multiple Pond System (Figure 6.4)
- P-5 Pocket Pond (Figure 6.5)

Treatment Suitability:

Dry extended detention ponds without a permanent pool are not considered an acceptable option for meeting water quality treatment goals. Each of the five stormwater pond designs can be used to provide channel protection volume as well as overbank and extreme flood attenuation. The term "pocket" refers to a pond or wetland that has such a small contributing drainage area that little or no baseflow is available to sustain water elevations during dry weather. Instead, water elevations are heavily influenced, and in some cases maintained, by a locally high water table.

IMPORTANT NOTES:

ANY PRACTICE THAT CREATES A DAM IS REQUIRED TO FOLLOW THE GUIDANCE PRESENTED IN THE *GUIDELINES FOR DESIGN OF DAMS* AND MAY REQUIRE A PERMIT FROM THE NYSDEC. FOR THE MOST RECENT COPY OF THIS DOCUMENT, CONTACT THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, DAM SAFETY DIVISION, AT: 518-402-8151. AN EVALUATION OF HAZARD CLASSIFICATION MUST BE INCLUDED IN THE DESIGN REPORT FOR STORMWATER PONDS CREATED BY A DAM.

WHILE THE STORMWATER PONDS DESIGNED ACCORDING TO THIS GUIDANCE MAY ACT AS A COMMUNITY AMMENITY, AND MAY PROVIDE SOME HABITAT VALUE, THEY CANNOT BE ANTICIPATED TO FUNCTION AS NATURAL LAKES OR PONDS.

Figure 6.1 Micropool Extended Detention Pond (P-1)

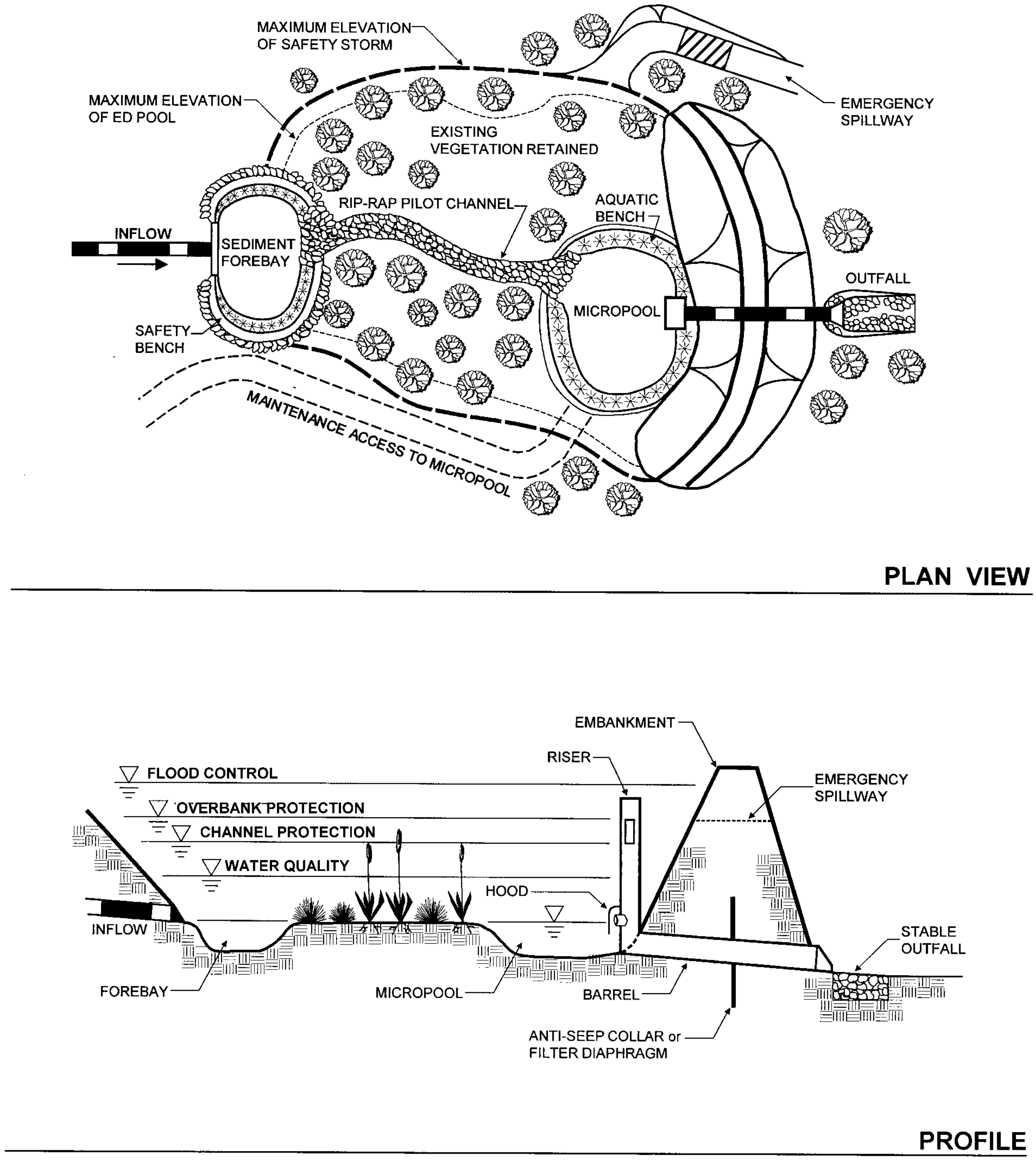


Figure 6.2 Wet Pond (P-2)

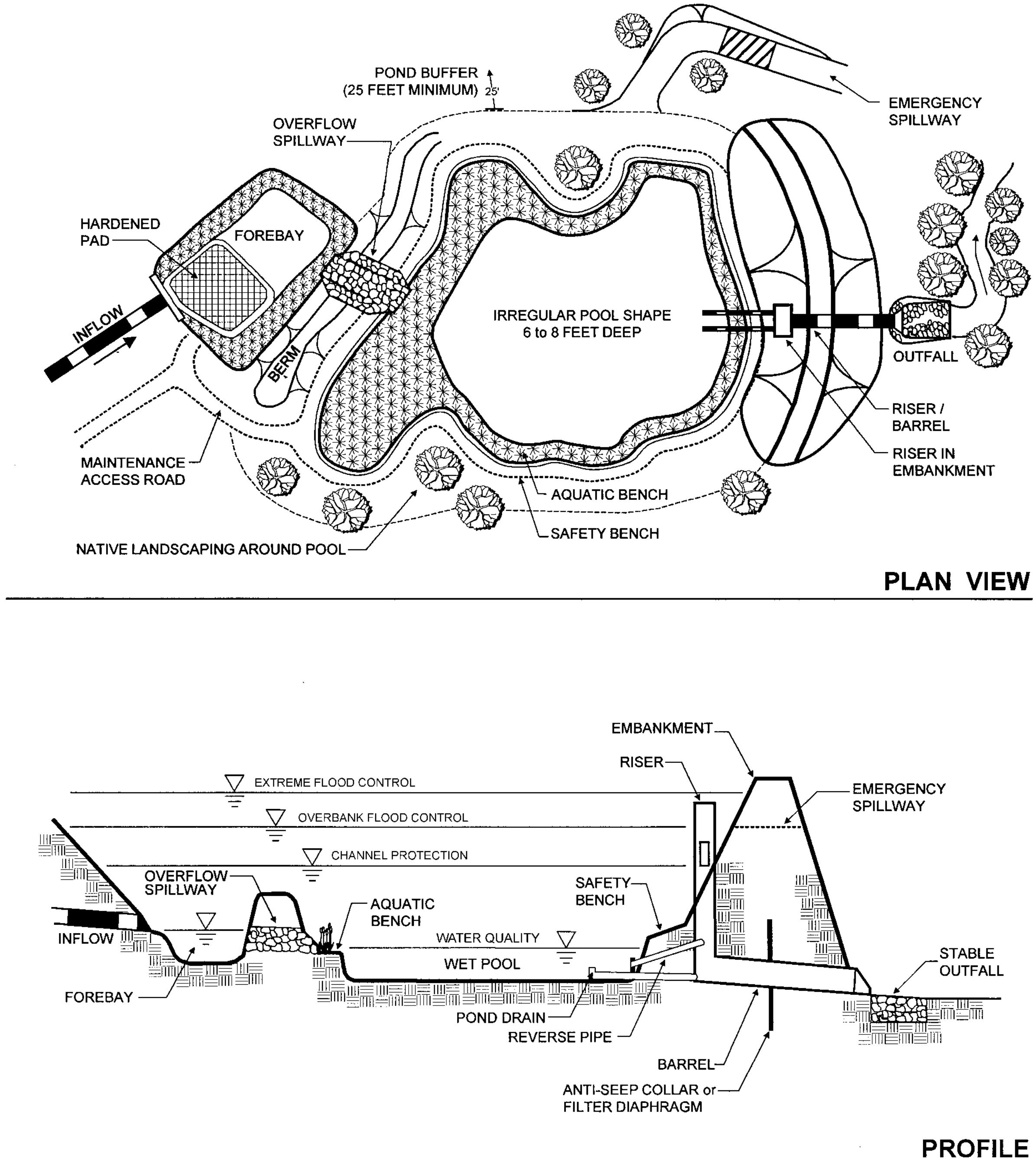
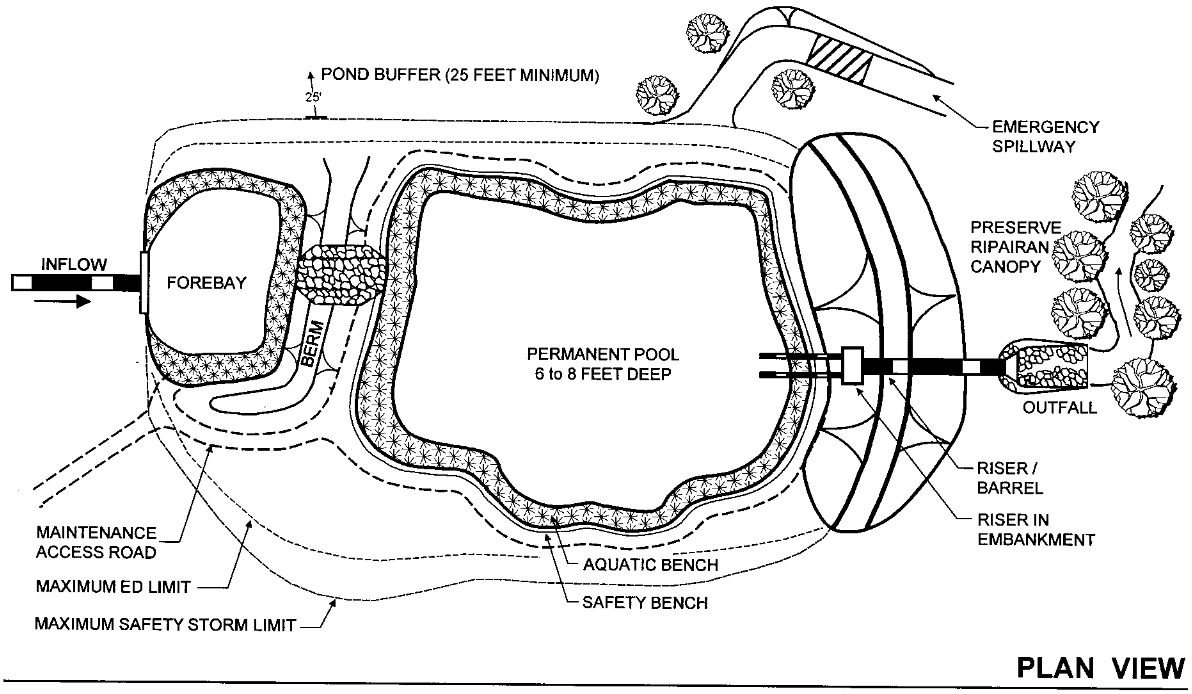


Figure 6.3 Wet Extended Detention Pond (P-3)



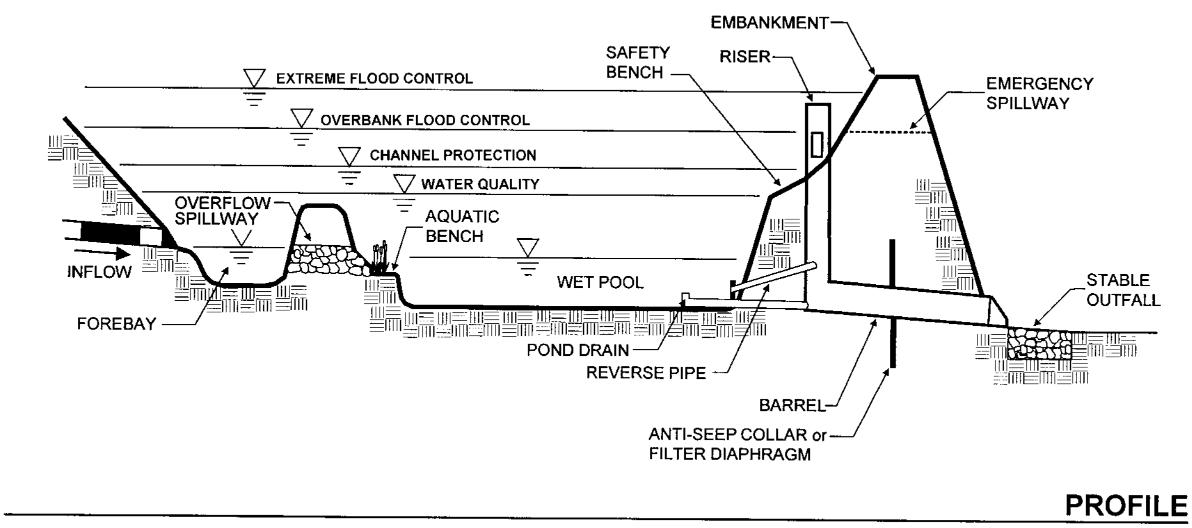


Figure 6.4 Multiple Pond System (P-4)

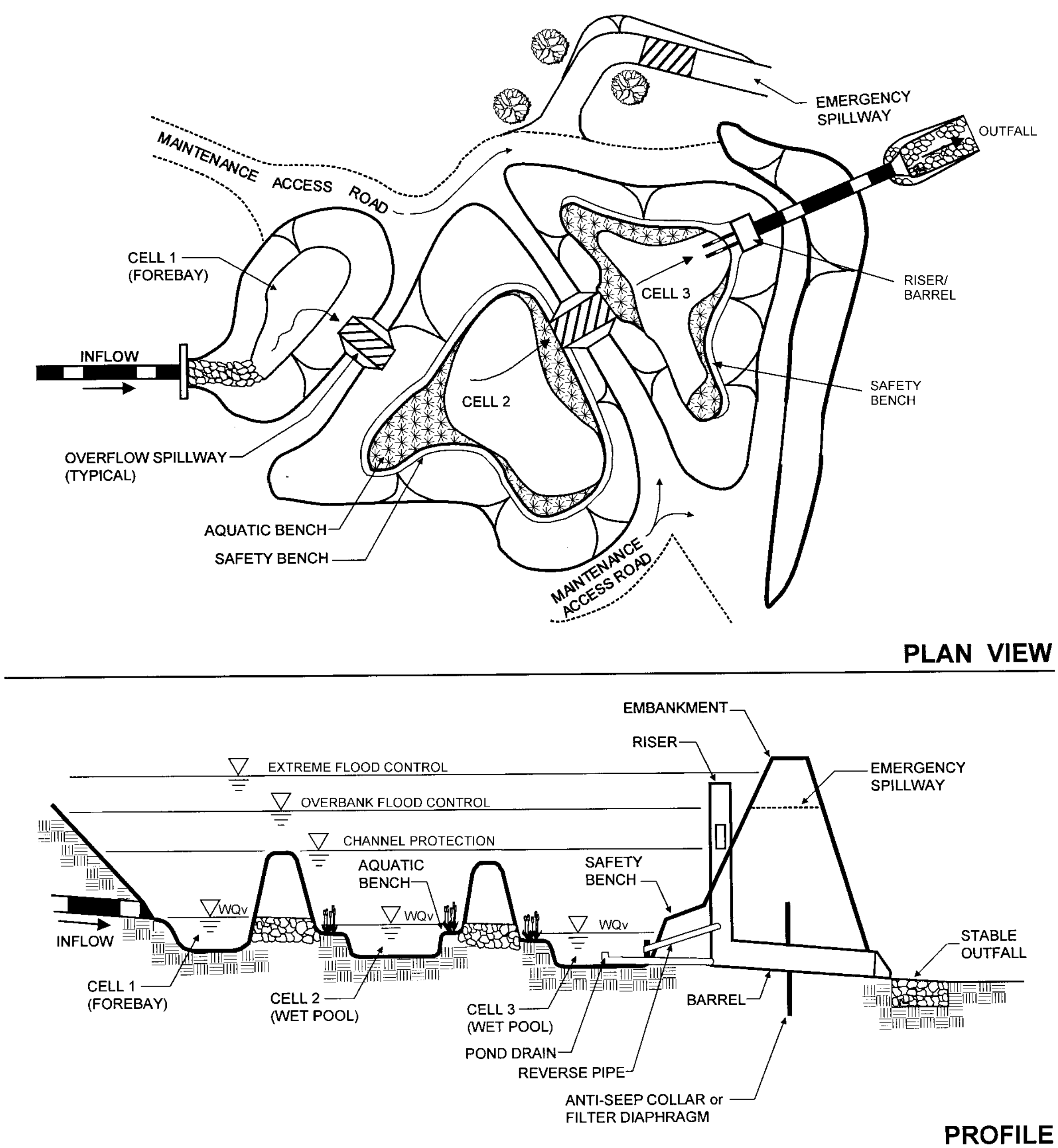
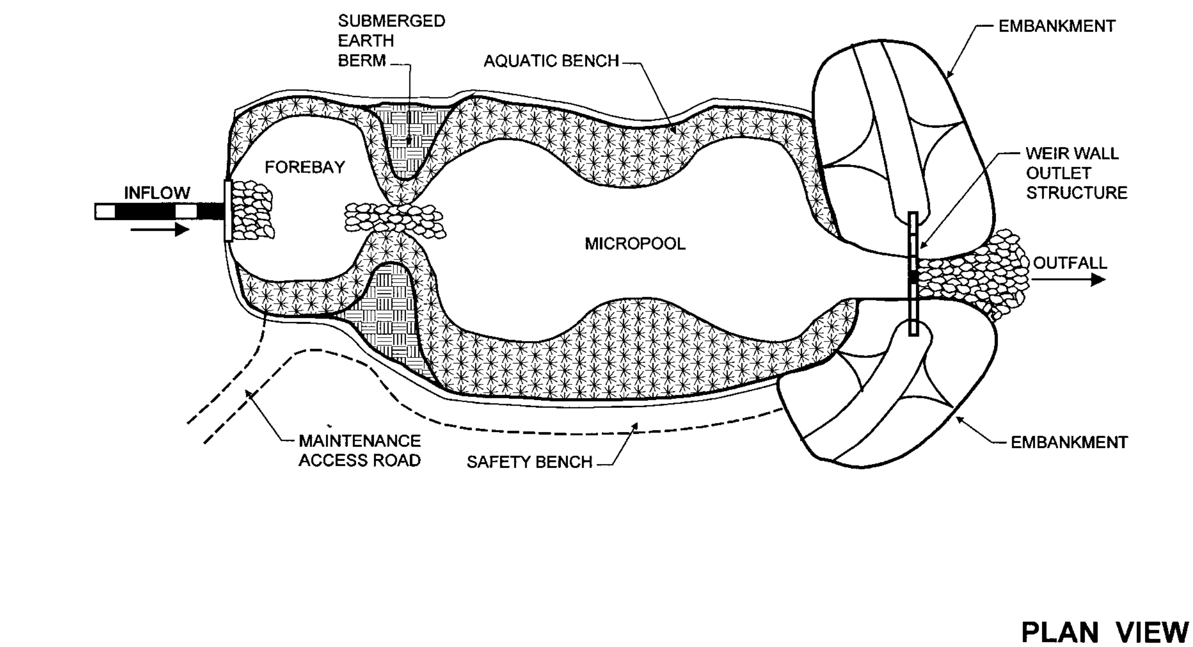
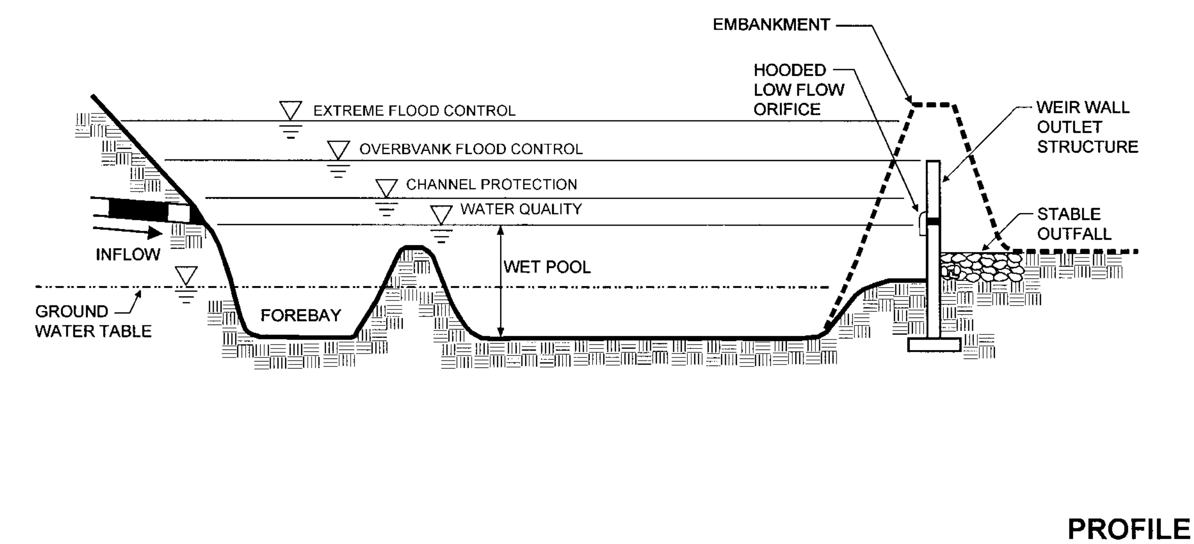


Figure 6.5 Pocket Pond (P-5)





6.1.1 Feasibility

<u>Required Elements</u>

- Designs P-2, P-3, and P-4 shall have a minimum contributing drainage area of 25 acres. A 10-acre drainage is required for design P-1.
- Stormwater ponds shall not be located within jurisdictional waters, including wetlands.
- Evaluate the site to determine the Hazard Class, and to determine what design elements are required to ensure dam safety (see *Guidelines for Design of Dams)*. For the most recent copy of this document, contact the New York State Department of Environmental Conservation, Dam Safety Division, at: 518-402-8151.
- Avoid direction of hotspot runoff to design P-5.
- Provide a 2' minimum separation between the pond bottom and groundwater in sole source aquifer recharge areas.

<u>Design Guidance</u>

- The use of stormwater ponds (with the exception of design P-1, Micropool Extended Detention Pond) on trout waters is strongly discouraged, as available evidence suggests that these practices can increase stream temperatures.
- Avoid location of pond designs within the stream channel, to prevent habitat degradation caused by these structures.
- A maximum drainage area of five acres is suggested for design P-5.

6.1.2 Conveyance

Inlet Protection

<u>Required Elements</u>

- A forebay shall be provided at each pond inflow point, unless an inflow point provides less than 10% of the total design storm flow to the pond.

<u>Design Guidance</u>

- Inlet areas should be stabilized to ensure that non-erosive conditions exist for at least the 2-year frequency storm event.

- Except in cold regions of the State, the ideal inlet configuration is a partially submerged (i.e., ½ full) pipe.

Adequate Outfall Protection

Required Elements

- The channel immediately below a pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, typically by use of appropriately-sized riprap placed over filter cloth. Typical examples include submerged earthen berms, concrete weirs, and gabion baskets.
- A stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities (3.5 to 5.0 fps). (See Appendix L for a table of erosive velocities for grass and soil).

Design Guidance

- Outfalls should be constructed such that they do not increase erosion or have undue influence on the downstream geomorphology of the stream.
- Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement should be used at the spillway outlet.
- If a pond 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. Excessive use of riprap should be avoided to reduce stream warming.

Pond Liners

Design Guidance

- When a pond is located in gravelly sands or fractured bedrock, a liner may be needed to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner, acceptable options include: (a) six to 12 inches of clay soil (minimum 15% passing the #200 sieve and a minimum permeability of 1 x 10^{-5} cm/sec), (b) a 30 ml poly-liner (c) bentonite, (d) use of chemical additives (*see NRCS Agricultural Handbook No. 386*, dated 1961, or *Engineering Field Manual*) or (e) a design prepared by a Professional Engineer registered in the State of New York.

6.1.3 Pretreatment

Required Elements

- A sediment forebay is important for maintenance and longevity of a stormwater treatment pond. Each pond shall have a sediment forebay or equivalent upstream pretreatment. The forebay shall consist of a separate cell, formed by an acceptable barrier. Typical examples include earthen berms, concrete weirs, and gabion baskets.
- The forebay shall be sized to contain 10% of the water quality volume (WQ_v), and shall be four to six feet deep. The forebay storage volume counts toward the total WQ_v requirement.
- The forebay shall be designed with non-erosive outlet conditions, given design exit velocities.
- Direct access for appropriate maintenance equipment shall be provided to the forebay.
- In sole source aquifers, 100% of the WQ_v for stormwater runoff from designated hotspots shall be provided in pretreatment.

Design Guidance

- A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.
- The bottom of the forebay may be hardened to ease sediment removal

6.1.4 Treatment

Minimum Water Quality Volume (WQ_v)

Required Elements

- Provide water quality treatment storage to capture the computed WQ_v from the contributing drainage area through a combination of permanent pool, extended detention (WQ_v-ED) and marsh. The division of storage into permanent pool and extended detention is outlined in Table 6.1.

Table 6.1 Water Quality Volume Distribution in Pond Designs

Design Variation	%WQ_v Permanent Pool	%WQ_v Extended Detention
P-1	20% min.	80% max.
P-2	100%	0%
P-3	50% min.	50% max.
P-4	50% min.	50% max.
P-5	50% min.	50% max.

- Although both CP_v and WQ_v-ED storage can be provided in the same practice, WQ_v cannot be met by simply providing Cp_v storage for the one-year storm.

Design Guidance

- It is generally desirable to provide water quality treatment off-line when topography, hydraulic head and space permit (i.e., apart from stormwater quantity storage; see Appendix K for a schematic).
- Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, ED, and marsh).

Minimum Pond Geometry

Required Elements

- The minimum length to width ratio for the pond is 1.5:1 (i.e., length relative to width).
- Provide a minimum Surface Area:Drainage Area of 1:100.

Design Guidance

- To the greatest extent possible, maintain a long flow path through the system, and design ponds with irregular shapes.

6.1.5 Landscaping

Pond Benches

Required Elements

- The perimeter of all deep pool areas (four feet or greater in depth) shall be surrounded by two benches:
  - Except when pond side slopes are 4:1 (h:v) or flatter, provide a safety bench that generally extends 15 feet outward (10' to 12' allowable on sites with extreme space limitations) from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench shall be 6%; *and*

- Incorporate an aquatic bench that generally extends up to 15 feet inward from the normal shoreline, has an irregular configuration, and a maximum depth of 18 inches below the normal pool water surface elevation.

Landscaping Plan

Required Elements

- A landscaping plan for a stormwater pond and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be vegetatively stabilized and established.

Design Guidance

- Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED wetlands) or within shallow areas of the pool itself.
- The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.
- The soils of a 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 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.
  - As a rule of thumb, planting holes should be three times deeper and wider than the diameter of the rootball (of balled and burlap stock), and five times deeper and wider for container grown stock. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade, are susceptible to winterkill, or are prone to wind damage. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

Pond Buffers and Setbacks

Required Elements

- A pond buffer shall be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer shall be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers). An additional setback may be provided to permanent structures.
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.

Design Guidance

- Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To help discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.
- Annual mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

6.1.6 Maintenance

Required Elements

- Maintenance responsibility for a pond and its buffer shall be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.
- The principal spillway shall be equipped with a removable trash rack, and generally accessible from dry land.
- Sediment removal in the forebay shall occur every five to six years or after 50% of total forebay capacity has been lost.

Design Guidance

- Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are generally not considered toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present (see Section 4.8 for a list of potential hotspots).

- Sediment removed from stormwater ponds should be disposed of according to an approved comprehensive operation and maintenance plan.

Maintenance Access

Required Elements

- A maintenance right of way or easement shall extend to the pond from a public or private road.

Design Guidance

- Maintenance access should be at least 12 feet wide, have a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access should extend to the forebay, safety bench, riser, and outlet and be designed to allow vehicles to turn around.

Non-clogging Low Flow Orifice

Required Elements

- A low flow orifice shall be provided, with the size for the orifice sufficient to ensure that no clogging shall occur. (See Appendix K for details of a low flow orifice and trash rack options).

Design Guidance

- The low flow orifice should be adequately protected from clogging by either an acceptable external trash rack (recommended minimum orifice of 3") or by internal orifice protection that may allow for smaller diameters (recommended minimum orifice of 1").
- The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation.
- Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round CMP that extends at least 12 inches below the normal pool.
- The use of horizontally extended perforated pipe protected by geotextile fabric and gravel is not recommended. Vertical pipes may be used as an alternative if a permanent pool is present.

Riser in Embankment

Required Elements

- The riser shall be located within the embankment for maintenance access, safety and aesthetics.

Design Guidance

- Access to the riser should be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls. The principal spillway opening should be "fenced" with pipe or rebar at 8-inch intervals (for safety purposes).

Pond Drain

Required Elements

- Except where local slopes prohibit this design, each pond shall have a drain pipe that can completely or partially drain the pond. The drain pipe shall have an elbow or protected intake within the pond to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours.

Design Guidance

- Care should be exercised during pond drawdowns to prevent rapid drawdown and minimize downstream discharge of sediments or anoxic water. The approving jurisdiction should be notified before draining a pond.

Adjustable Gate Valve

Required Elements

- Both the WQ_v-ED pipe and the pond drain shall be equipped with an adjustable gate valve (typically a handwheel activated knife gate valve).
- Valves shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

Design Guidance

- Both the WQ_v-ED pipe and the pond drain should be sized one pipe size greater than the calculated design diameter.

- To prevent vandalism, the handwheel should be chained to a ringbolt, manhole step or other fixed object.

Safety Features

Required Elements

- Side slopes to the pond shall not exceed 3:1 (h:v), and shall terminate at a safety bench.
- The principal spillway opening shall not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter shall be fenced to prevent a hazard.

Design Guidance

- Both the safety bench and the aquatic bench may be landscaped to prevent access to the pool.
- Warning signs prohibiting swimming and skating may be posted.
- Pond fencing is generally not encouraged, but may be required by some municipalities. A preferred method is to manage the contours of the pond to eliminate dropoffs or other safety hazards.

6.1.7 Cold Climate Pond Design Considerations

Inlets, outlet structures and outfall protection for pond systems require modifications to function well in cold climates. Among the problems those wishing to use stormwater ponds in cold climates may encounter are:

- Higher runoff volumes and increased pollutant loads during the spring melt
- Pipe freezing and clogging
- Ice formation on the permanent pool
- Road sand build-up

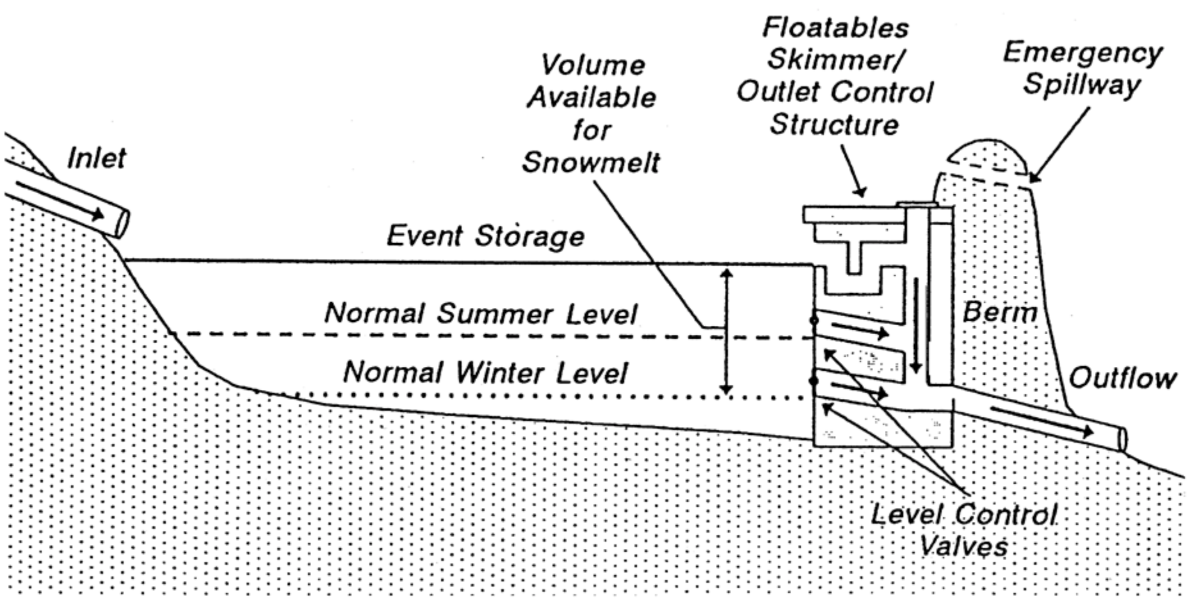
Higher runoff volumes and increased pollutant loads during the spring melt

- Operate the pond based on seasonal inputs by adjusting dual water quality outlets to provide additional storage (see Figure 6.6).
- Adapt sizing based on snowmelt characteristics (see Appendix I).
- Do not drain ponds during the spring season. Due to temperature stratification and high chloride concentrations at the bottom, the water may become highly acidic and anoxic and may cause negative downstream effects.

<u>Pipe Freezing and Clogging</u>

- Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.
- Bury all pipes below the frost line to prevent frost heave and pipe freezing. Bury pipes at the point furthest from the pond deeper than the frost line to minimize the length of pipe exposed.
- Increase the slope of inlet pipes to a minimum of 1% to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum orifice diameter should be ½". In addition, the pipe should have a minimum 6" diameter.
- When a standard weir is used, the minimum slot width should be 3", especially when the slot is tall.
- Baffle weirs can prevent ice formation near the outlet by preventing surface ice from blocking the inlet, encouraging the movement of baseflow through the system (see Appendix K).
- In cold climates, riser hoods and reverse slope pipes should draw from at least 6" below the typical ice layer. This design encourages circulation in the pond, preventing stratification and formation of ice at the outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation (see Appendix K).

Figure 6.6 Seasonal Operation Pond



Ice Formation on the Permanent Pool

- In cold climates, the treatment volume of a pond system should be adjusted to account for ice build-up on the permanent pool by providing one foot of elevation above the WQ_v. The total depth of the pond, including this additional elevation, should not exceed eight feet.
- Using pumps or bubbling systems can reduce ice build-up and prevent the formation of an anaerobic zone in pond bottoms.
- Provide some storage as extended detention. This recommendation is made for very cold climates to provide detention while the permanent pond is iced over. In effect, it discourages the use of wet ponds (P-2), replacing them with wet extended detention ponds (P-3).
- Multiple pond systems are recommended regardless of climate because they provide redundant treatment options. In cold climates, a berm or simple weir should be used instead of pipes to separate multiple ponds, due to their higher freezing potential.

Road Sand Build-up

- In areas where road sand is used, an inspection of the forebay and pond should be scheduled after the spring melt to determine if dredging is necessary. For forebays, dredging is needed if one half of the capacity of the forebay is full.

Stormwater Ponds

Description:
Constructed stormwater retention basin that has a permanent pool (or micropool). Runoff from each rain event is detained and treated in the pool through settling and biological uptake mechanisms.

Design Options:
Micropool Extended Detention (P-1), Wet Pond (P-2), Wet Extended Detention (P-3), Multiple Pond (P-4), Pocket Pond (P-5)

KEY CONSIDERATIONS

FEASIBILITY
- Contributing drainage area greater than 10 acres for P-1, 25 acres for P-2 to P-4.
- Follow DEC Guidelines for Design of Dams.
- Provide a minimum 2' separation from the groundwater in sole source aquifers.
- Do not locate ponds in jurisdictional wetlands.
- Avoid directing hotspot runoff to design P-5.

CONVEYANCE
- Forebay at each inlet, unless the inlet contributes less than 10% of the total inflow, 4' to 6' deep.
- Stabilize the channel below the pond to prevent erosion.
- Stilling basin at the outlet to reduce velocities.

PREATREATMENT
- Forebay volume at least 10% of the WQ_v
- Forebay shall be designed with non-erosive outlet conditions.
- Provide direct access to the forebay for maintenance equipment
- In sole source aquifers, provide 100% pretreatment for hotspot runoff.

TREATMENT
- Provide the water quality volume in a combination of permanent pool and extended detention (Table 6.1 in manual provides limitations on storage breakdown)
- Minimum length to width ratio of 1.5:1
- Minimum surface area to drainage area ratio of 1:100

LANDSCAPING
- Provide a minimum 10' and preferably 15' safety bench extending from the high water mark, with a maximum slope of 6%.
- Provide an aquatic bench extending 15 feet outward from the shoreline, and a maximum depth of 18" below normal water elevation.
- Develop a landscaping plan.
- Provide a 25'pond buffer.
- No woody vegetation within 15 feet of the toe of the embankment, or 25 feet from the principal spillway.

STORMWATER MANAGEMENT SUITABILITY

[X] **Water Quality**

[X] **Channel Protection**

[X] **Overbank Flood Protection**

[X] **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes*
(2 feet minimum separation distance required to water table)

FEASIBILITY CONSIDERATIONS

[L] **Cost**

[L] **Maintenance Burden**

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

Residential Subdivision Use: Yes
High Density/Ultra-Urban: *No*

Soils: *Hydrologic group 'A' soils may require pond liner*

Hydrologic group 'D' soils may have compaction constraints

Other Considerations:
- *Thermal effects*
- *Outlet clogging*
- *Safety bench*

MAINTENANCE REQUIREMENTS	POLLUTANT REMOVAL
• Legally binding maintenance agreement • Sediment removal from forebay every five to six years or when 50% full. • Provide a maintenance easement and right-of-way. • Removable trash rack on the principal spillway. • Non-clogging low flow orifice • Riser in the embankment. • Pond drain required, capable of drawing down the pond in 24 hours. • Notification required for pond drainage. • Provide an adjustable gate valve on both the WQ_v-ED pipe, and the pond drain. • Side Slopes less than 3:1, and terminate at a safety bench. • Principal spillway shall not permit access by small children, and endwalls above pipes greater than 48” in diameter shall be fenced.	G **Phosphorus** G **Nitrogen** G **Metals** - Cadmium, Copper, Lead, and Zinc removal G **Pathogens** Coliform, E.Coli, Streptococci removal **Key:** **G**=Good **F**=Fair **P**=Poor

Section 6.2 Stormwater Wetlands

Stormwater wetlands are practices that create shallow marsh areas to treat urban stormwater and often incorporate small permanent pools and/or extended detention storage to achieve the full WQv. Design variants include:

- W-1 Shallow Wetland (Figure 6.7)
- W-2 ED Shallow Wetland (Figure 6.8)
- W-3 Pond/Wetland System (Figure 6.9)
- W-4 Pocket Wetland (Figure 6.10)

Wetland designs W-1 through W-4 can be used to provide Channel Protection volume as well as Overbank and Extreme Flood attenuation. In these design variations, the permanent pool is stored in a depression excavated into the ground surface. Wetland plants are planted at the wetland bottom, particularly in the shallow regions.

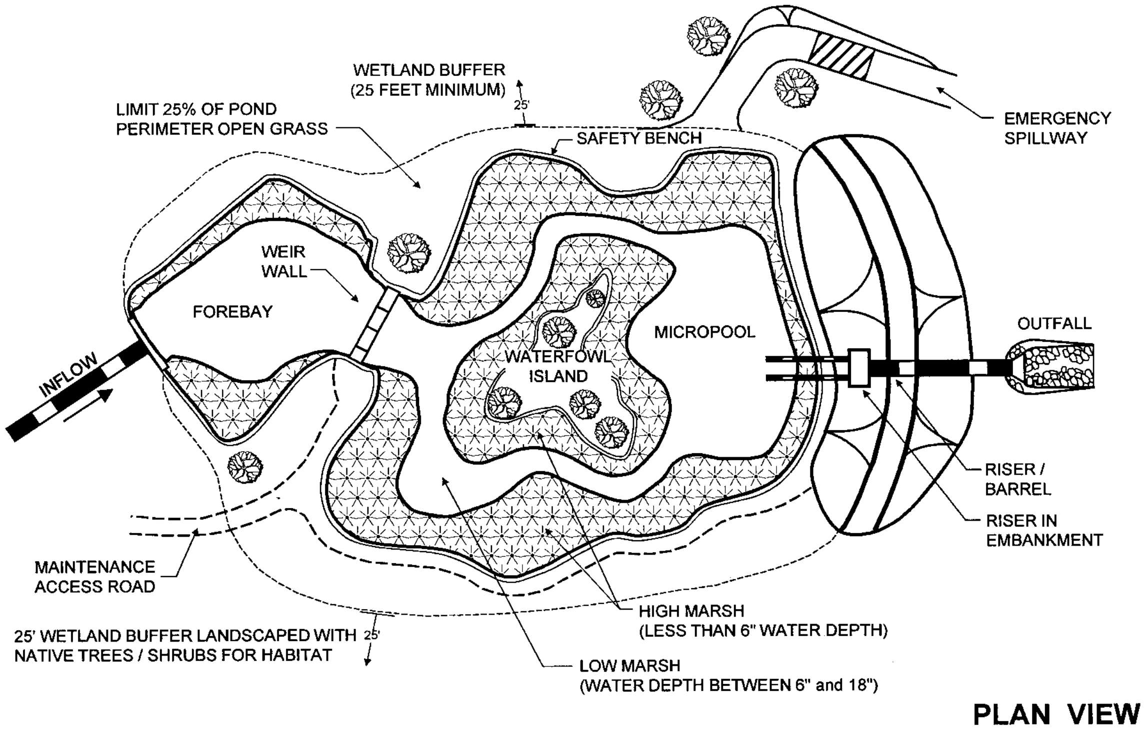
IMPORTANT NOTES

ALL OF THE POND CRITERIA PRESENTED IN PERFORMANCE CRITERIA – PONDS (CHAPTER 6.1) ALSO APPLY TO THE DESIGN OF STORMWATER WETLANDS. ADDITIONAL CRITERIA THAT GOVERN THE GEOMETRY AND ESTABLISHMENT OF CREATED WETLANDS ARE PRESENTED IN THIS SECTION.

ANY PRACTICE THAT CREATES A DAM IS REQUIRED TO FOLLOW THE GUIDANCE PRESENTED IN THE *GUIDELINES FOR DESIGN OF DAMS* AND MAY REQUIRE A PERMIT FROM THE NYSDEC. FOR THE MOST RECENT COPY OF THIS DOCUMENT, CONTACT THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, DAM SAFETY DIVISION, AT: 518-402-8151. AN EVALUATION OF HAZARD CLASSIFICATION MUST BE INCLUDED IN THE DESIGN REPORT FOR STORMWATER WETLANDS CREATED BY A DAM.

WHILE THE STORMWATER WETLANDS DESIGNED ACCORDING TO THIS GUIDANCE MAY ACT AS A COMMUNITY AMMENITY, AND MAY PROVIDE SOME HABITAT VALUE, THEY CANNOT BE ANTICIPATED TO FUNCTION AS NATURAL WETLANDS

Figure 6.7 Shallow Wetland (W-1)



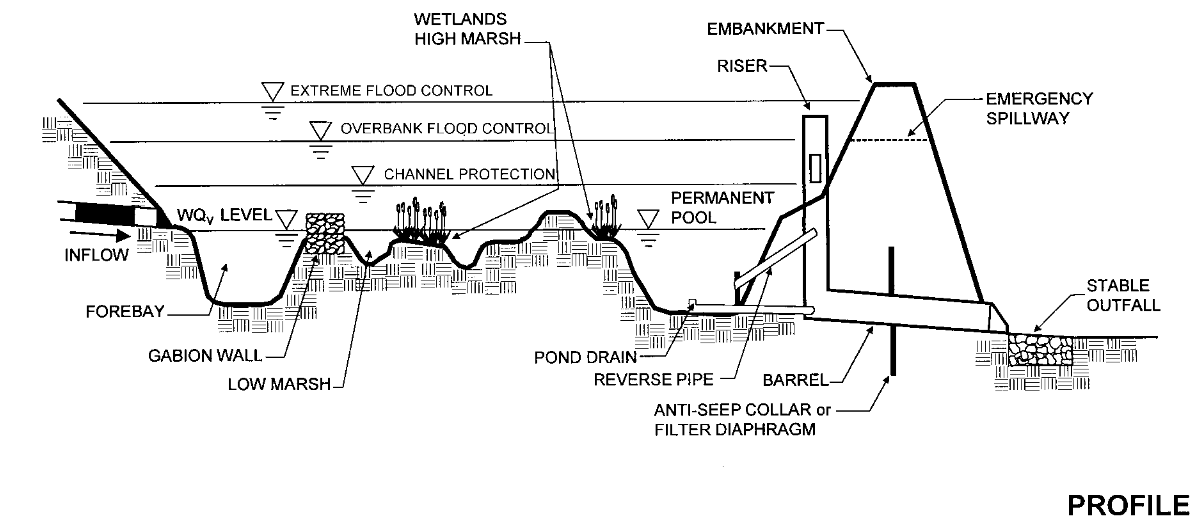


Figure 6.8 Extended Detention Shallow Wetland (W-2)

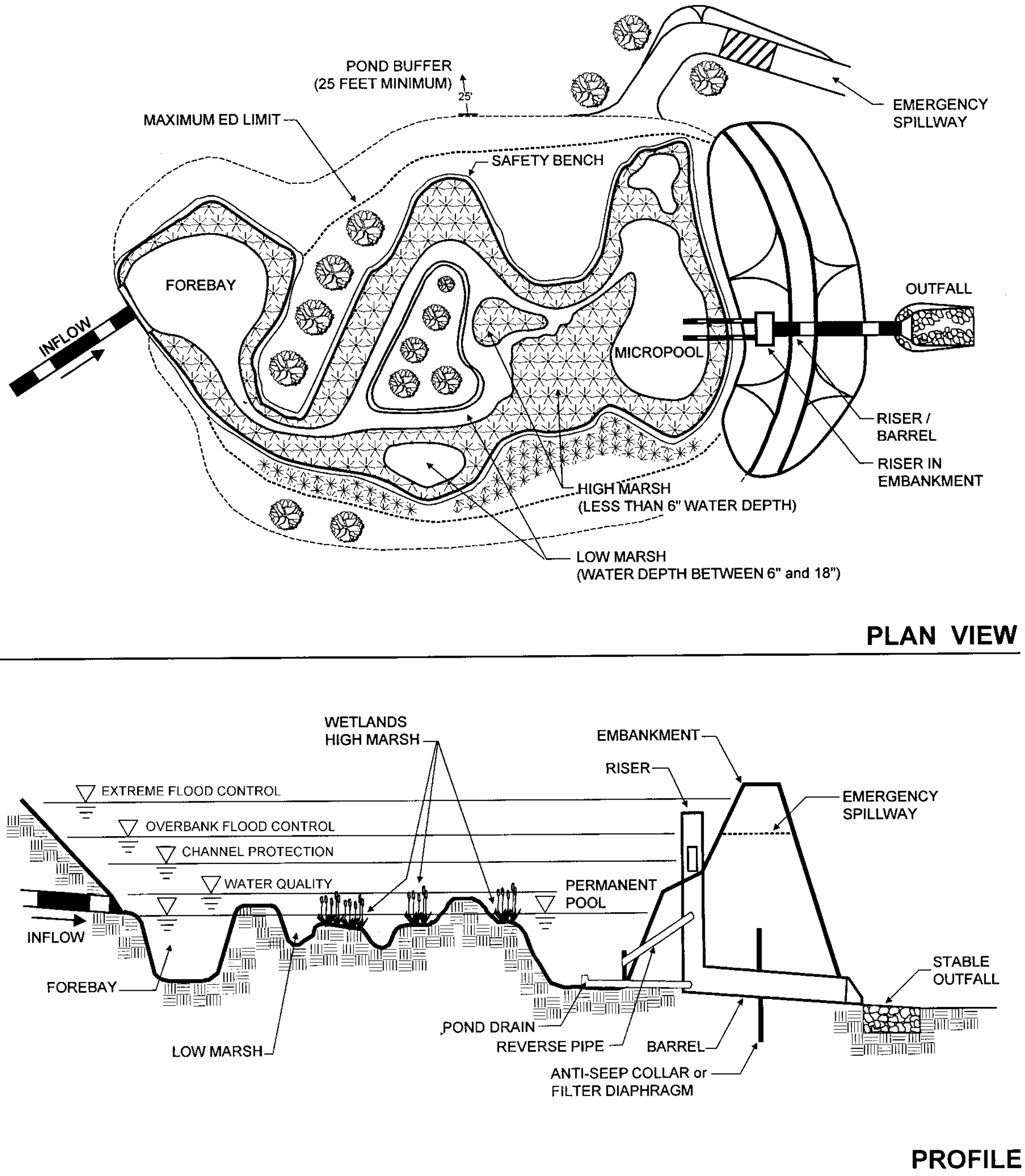
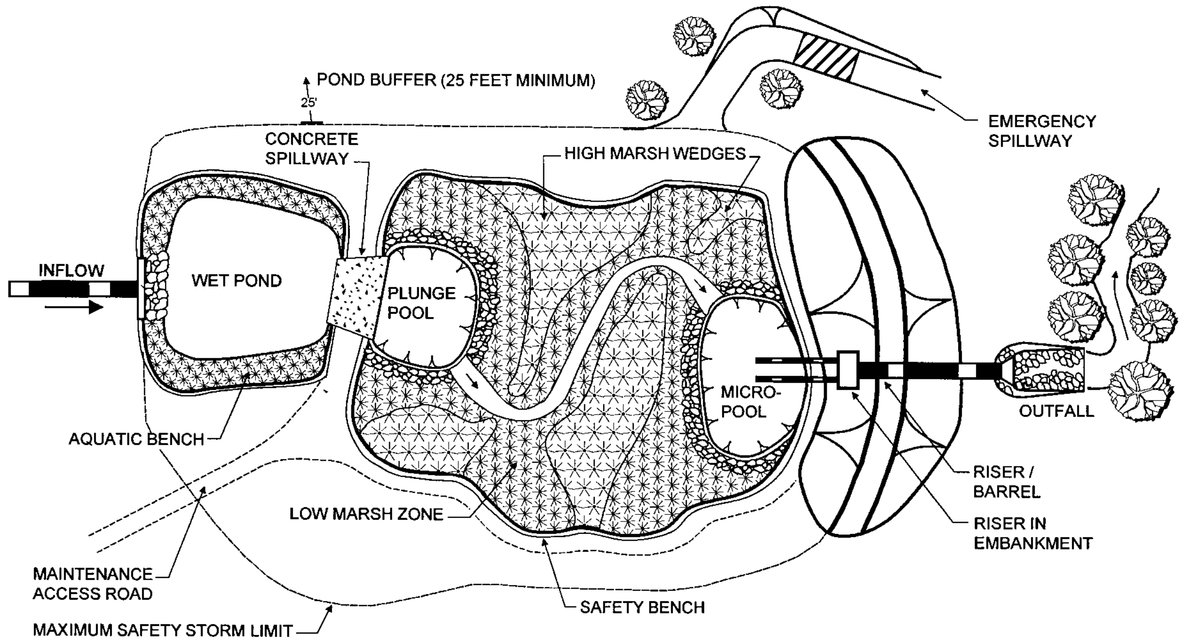
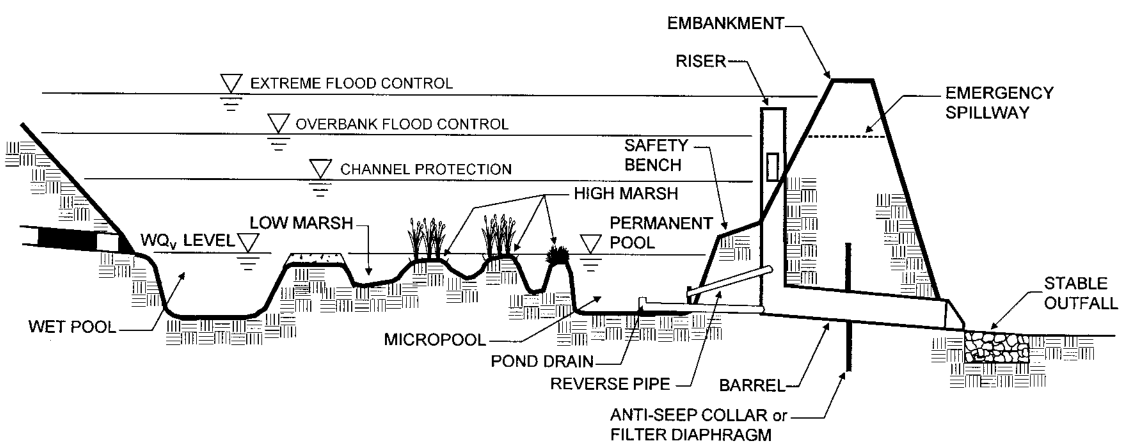


Figure 6.9 Pond/Wetland System (W-3)

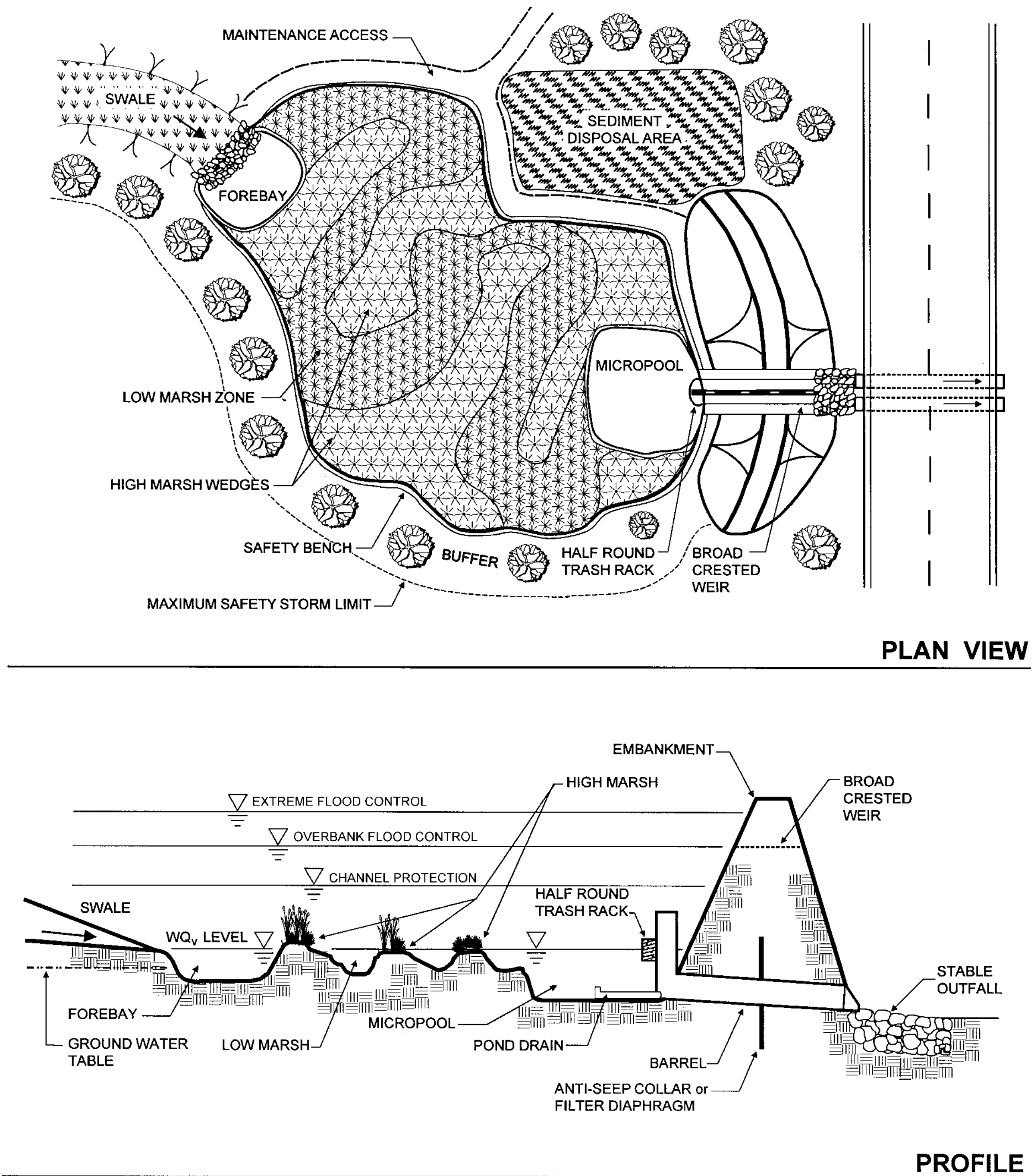


PLAN VIEW



PROFILE

Figure 6.10 Pocket Wetland (W-4)



6.2.1 *Feasibility*

Design Guidance

- *Stormwater wetlands should not be located within existing jurisdictional wetlands.* In some isolated cases, a permit may be granted to convert an existing degraded wetland in the context of local watershed restoration efforts.
- The use of stormwater wetlands on trout waters is strongly discouraged, as available evidence suggests that these practices can increase stream temperatures.

6.2.2 Conveyance

Required Elements

- Flowpaths from the inflow points to the outflow points of stormwater wetlands shall be maximized.
- A minimum flowpath of 2:1 (length to relative width) shall be provided across the stormwater wetland. This path may be achieved by constructing internal berms (e.g., high marsh wedges or rock filter cells).

Design Guidance

- Microtopography is encouraged to enhance wetland diversity.

6.2.3 Pretreatment

Required Elements

- A forebay shall be located at the inlet, and a four to six foot deep micropool that stores approximately 10% of the WQ_v shall be located at the outlet to protect the low flow pipe from clogging and prevent sediment resuspension.

6.2.4 Treatment

Required Elements

- The surface area of the entire stormwater wetland shall be at least one percent of the contributing drainage area (1.5% for shallow marsh design).
- At least 25% of the WQ_v shall be in deepwater zones with a depth greater than four feet.

- A minimum of 35% of the total surface of area can have a depth of six inches or less, and at least 65% of the total surface area shall be shallower than 18 inches.
- If extended detention is used in a stormwater wetland, provide a minimum of 50% of the WQ_v in permanent pool; the maximum water surface elevation of WQ_v-ED shall not extend more than three feet above the permanent pool.

Design Guidance

- The bed of stormwater wetlands should be graded to create maximum internal flow path and microtopography.
- To promote greater nitrogen removal, rock beds may be used a medium for growth of wetland plants. The rock should be one to three inches in diameter, placed up to the normal pool elevation, and open to flow-through from either direction.

6.2.5 Landscaping

Required Elements

- A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.
- A wetland plant buffer must extend 25 feet outward from the maximum water surface elevation, with an additional 15-foot setback to structures.
- Donor soils for wetland mulch shall not be removed from natural wetlands.

Design Guidance

- Structures such as fascines, coconut rolls, straw bales, or carefully designed stone weirs can be used to create shallow marsh cells in high-energy areas of the stormwater wetland.
- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
- Follow wetland establishment guidelines (see Appendix H).

6.2.6 Maintenance

Required Elements

- If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting is required.

Design Guidance

- Stormwater wetlands that are separated from jurisdictional wetlands and regularly maintained are not typically regulated under State and Federal laws.

6.2.7 Cold Climate Design Considerations

Many of the cold climate concerns for wetlands are very similar to the ones for ponds. Two additional concerns with regards to stormwater wetlands focus on cold climate impacts to wetland plants:

- Short Growing Season
- Chlorides

Short Growing Season

- Planting schedule should reflect the short growing season, perhaps incorporating relatively mature plants, or planting rhizomes during the winter.

Chlorides

- Use in combination with a grassed infiltration area prior to the wetland to provide some infiltration of chlorides to dampen the shock to wetland plants
- Emphasize the pond/wetland design option to dilute chlorides prior to the wetland area. If this option is used, the pond should use the modifications described in Section 6.1.7. The pond system dilutes chlorides before they enter the marsh, protecting wetland plants.
- Consider salt-tolerant plants if wetland treats runoff from roads or parking lots where salt is used as a deicer.

Stormwater Wetlands

Description: Stormwater wetlands (a.k.a. constructed wetlands) are structural practices that incorporate wetland plants into the design to both store and treat runoff. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice

Design Options:
Shallow wetland (W-1), Extended Detention Wetland (W-2), Pond/Wetland (W-3), Pocket Wetland (W-4)

KEY CONSIDERATIONS

MUST MEET ALL OF THE REQUIREMENTS OF STORMWATER PONDS.

CONVEYANCE

- Minimum flowpath of 2:1 (length to width)
- Flowpath maximized

PREATREATMENT

- Micropool at outlet, capturing 10% of the WQ_v

TREATMENT

- Minimum drainage area to surface ratio of 1:100
- ED no greater than 50% of entire WQ_v (permanent pool at least 50% of the volume)25% of the WQ_v in deepwater zones.
- 35% of the total surface area in depths six inches or less, and 65% shallower than 18”

LANDSCAPING

- Landscaping plan that indicates methods to establish and maintain wetland coverage. Minimum elements include: delineation of pondscaping zones, selection of species, planting plan, and sequence for bed preparation.
- Wetland buffer 25 feet from maximum surface elevation, with 15 foot additional setback for structures.
- Donor plant material must not be from natural wetlands

MAINTENANCE REQUIREMENTS

- Reinforcement plantings after second season if 50% coverage not achieved

POLLUTANT REMOVAL

G	**Phosphorus**
G	**Nitrogen**
F	**Metals** - Cadmium, Copper, Lead, and Zinc removal
G	**Pathogens** - Coliform, Streptococci, E.Coli removal

Key: G=Good **F**=Fair **P**=Poor

STORMWATER MANAGEMENT SUITABILITY

X	**Water Quality**
X	**Channel Protection**
X	**Overbank Flood Protection**
X	**Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes*
(2 feet minimum separation distance required to water table)

IMPLEMENTATION CONSIDERATIONS

M	**Capital Cost**

Maintenance Burden:

M	Shallow Wetland
M	ED Shallow Wetland
H	Pocket Wetland
M	Pond/Wetland

Residential Subdivision Use: Yes
High-Density/Ultra-Urban: *No*

Soils: *Hydrologic group ‘A’ and ‘B’ soils may require liner*

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

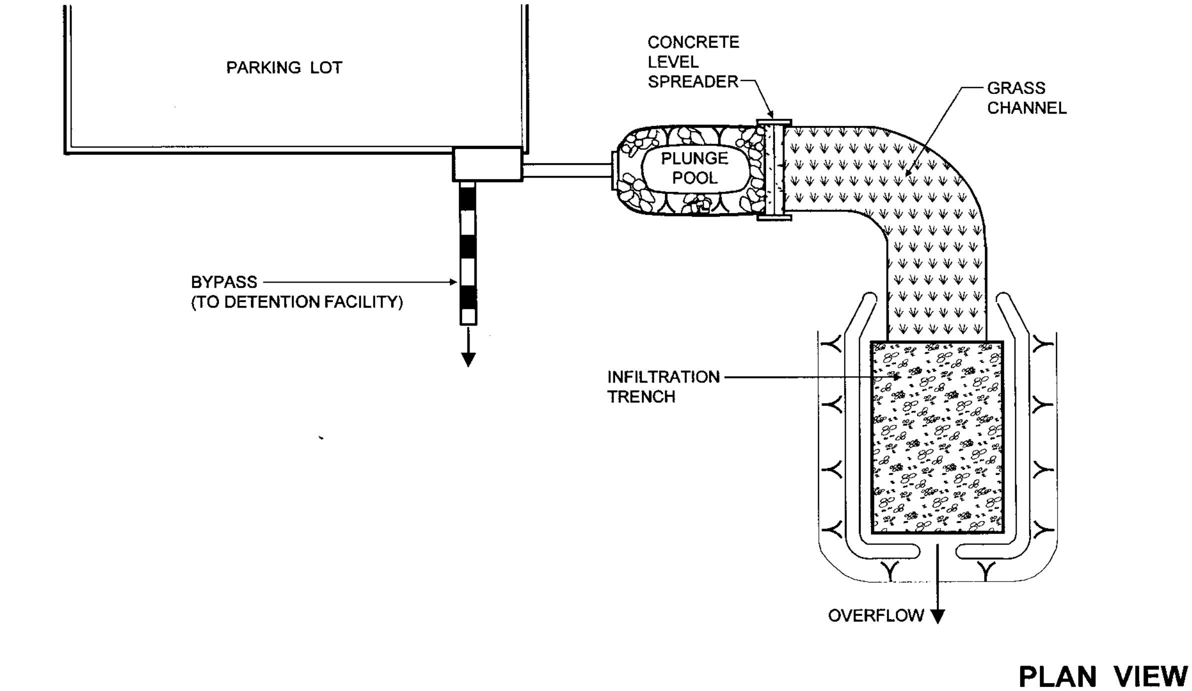
Section 6.3 Stormwater Infiltration

Stormwater infiltration practices capture and temporarily store the WQ_v before allowing it to infiltrate into the soil over a two-day period. Design variants include the following:

- I-1 Infiltration Trench (Figure 6.11)
- I-2 Infiltration Basin (Figure 6.12)
- I-3 Dry Well (Figure 6.13)

Treatment Suitability: Infiltration practices alone typically cannot meet detention (Q_p) and channel protection (Cp_v) requirements, except on sites where the soil infiltration rate is greater than 5.0 in/hr. However, extended detention storage may be provided above an infiltration basin. Extraordinary care should be taken to assure that long-term infiltration rates are achieved through the use of performance bonds, post construction inspection and long-term maintenance.

Figure 6.11 Infiltration Trench (I-1)



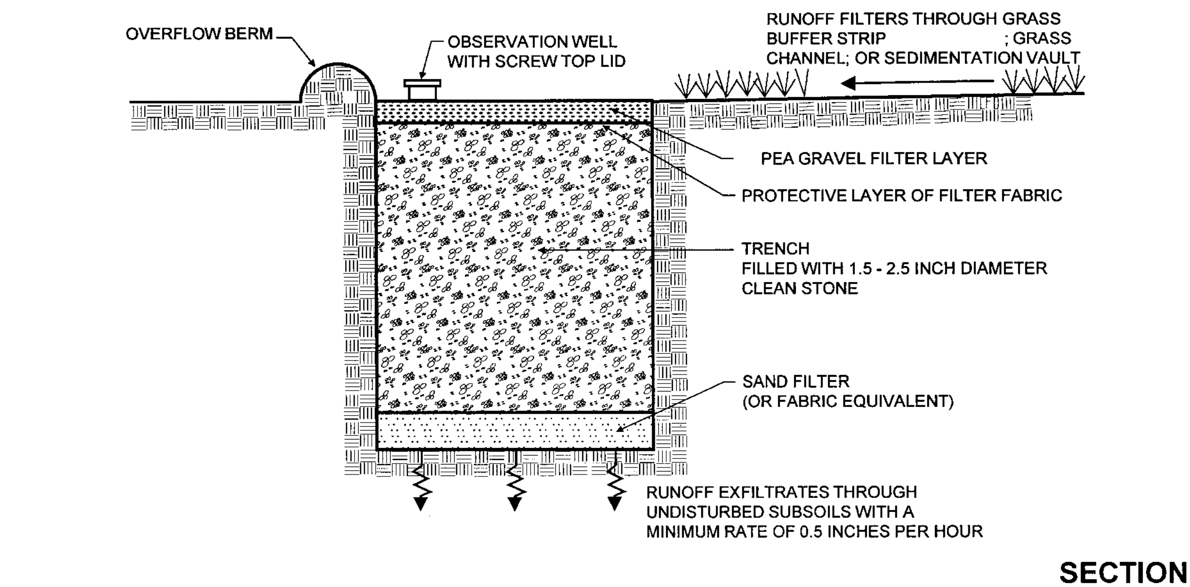
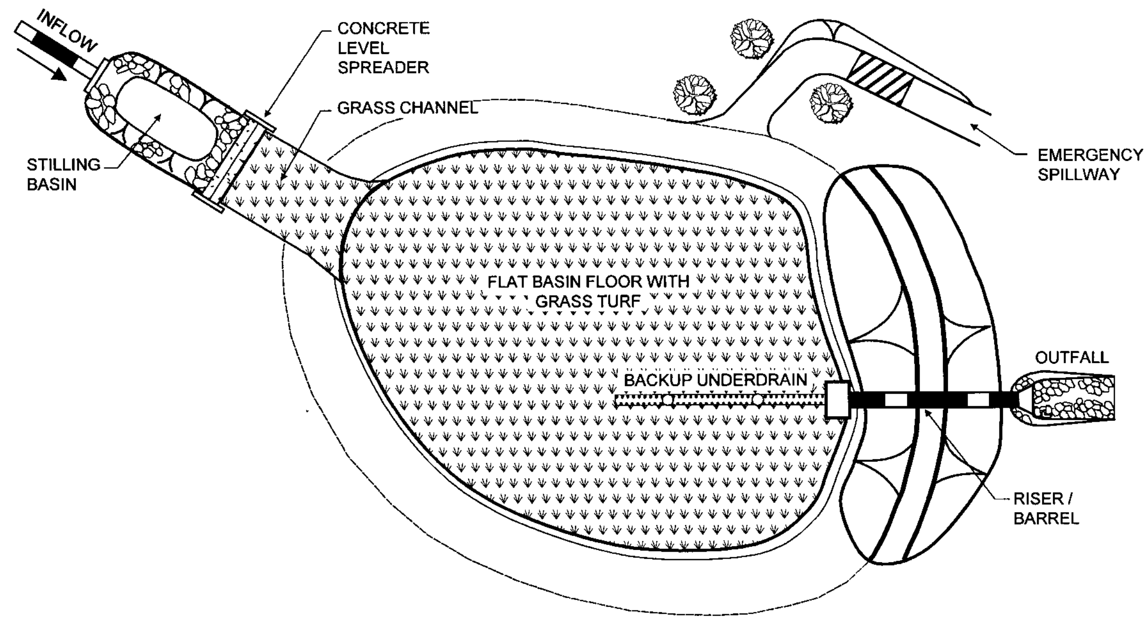
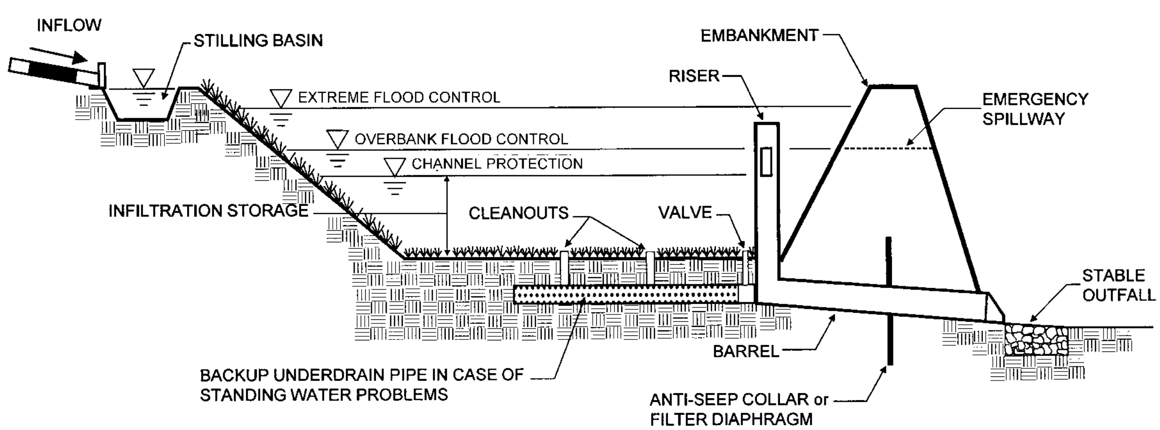


Figure 6.12 Infiltration Basin (I-2)

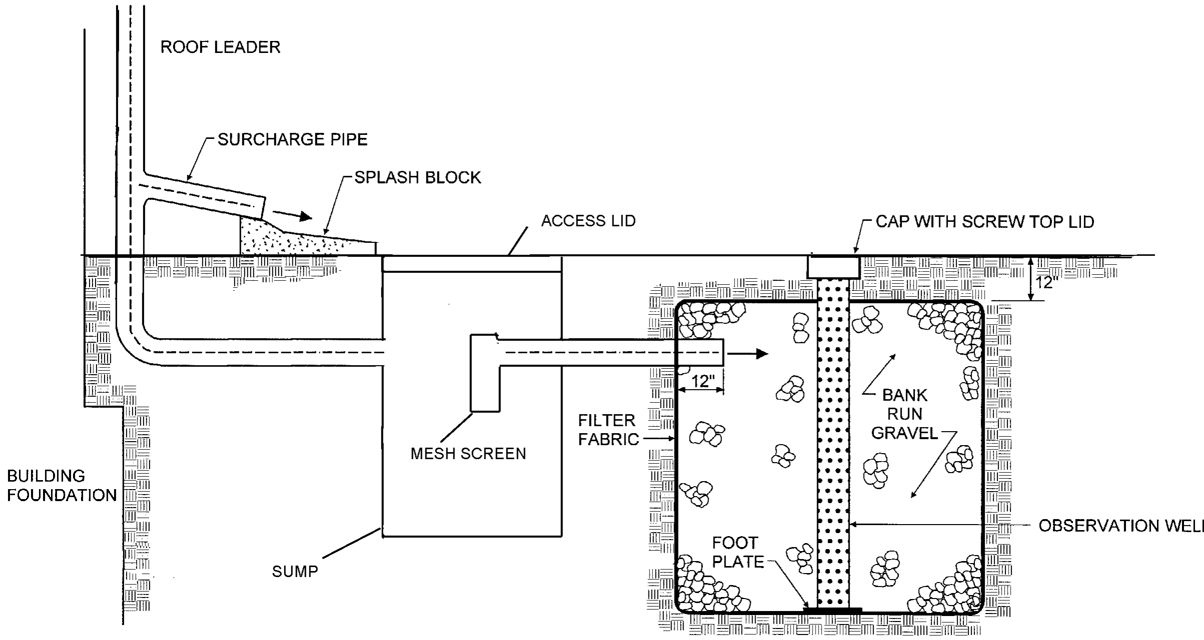


PLAN VIEW



PROFILE

Figure 6.13 Dry Well (I-3)



6.3.1 Feasibility

Required Elements

- To be suitable for infiltration, underlying soils shall have an infiltration rate (fc) of at least 0.5 inches per hour, as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests (see Appendix D). The minimum geotechnical testing is one test hole per 5000 sf, with a minimum of two borings per facility (taken within the proposed limits of the facility).
- Soils shall also have a clay content of less than 20% and a silt/clay content of less than 40%.
- Infiltration practices cannot be located on areas with natural slopes greater than 15%.
- Infiltration practices cannot be located in fill soils, except the top quarter of an infiltration trench or dry well.
- To protect groundwater from possible contamination, runoff from designated hotspot land uses or activities must not be directed to a formal infiltration facility. In cases where this goal is impossible (e.g., where the storm drain system leads to a large recharge facility designed for flood control), redundant pretreatment must be provided by applying two of the practices listed in Table 5.1 in series, both of which are sized to treat the entire WQ_v.
- The bottom of the infiltration facility shall be separated by at least three feet vertically from the seasonally high water table or bedrock layer, as documented by on-site soil testing. (Four feet in sole source aquifers).
- Infiltration facilities shall be located at least 100 feet horizontally from any water supply well.
- Infiltration practices cannot be placed in locations that cause water problems to downgradient properties. Infiltration trenches and basins shall be setback 25 feet downgradient from structures and septic systems. Dry wells shall be separated a minimum of 10 feet from structures.

Design Guidance

- The maximum contributing area to infiltration basins or trenches should generally be less than five acres. The infiltration basin can theoretically receive runoff from larger areas, provided that the soil is highly permeable (i.e., greater than 5.0 inches per hour). (See Appendix L for erosive velocities of grass and soil).
- The maximum drainage area to dry wells should generally be smaller than one acre, and should include rooftop runoff only.

6.3.2 Conveyance

Required Elements

- The overland flow path of surface runoff exceeding the capacity of the infiltration system shall be evaluated to preclude erosive concentrated flow during the overbank events. If computed flow velocities exceed erosive velocities (3.5 to 5.0 fps), an overflow channel shall be provided to a stabilized watercourse. (See Appendix L for erosive velocities of grass and soil).
- All infiltration systems shall be designed to fully de-water the entire WQ_v within 48 hours after the storm event.
- If runoff is delivered by a storm drain pipe or along the main conveyance system, the infiltration practice must be designed as an off-line practice (see Appendix K for a detail), except when used as a regional flood control practice.

Design Guidance

- For infiltration basins and trenches, adequate stormwater outfalls should be provided for the overflow associated with the 10-year design storm event (non-erosive velocities on the down-slope
- For dry wells, all flows that exceed the capacity of the dry well should be passed through the surcharge pipe.

6.3.3 Pretreatment

Required Elements

- A minimum pretreatment volume of 25% of the WQ_v must be provided prior to entry to an infiltration facility, and can be provided in the form of a sedimentation basin, sump pit, grass channel, plunge pool or other measure.
- If the f_c for the underlying soils is greater than 2.00 inches per hour, a minimum pretreatment volume of 50% of the WQ_v must be provided.
- If the f_c for the underlying soils is greater than 5.00 inches per hour, 100% of the WQ_v shall be pre-treated prior to entry into an infiltration facility.
- Exit velocities from pretreatment chambers shall be non-erosive (3.5 to 5.0 fps) during the two-year design storm). (See Appendix L for erosive velocities of grass and soil).

Pretreatment Techniques to Prevent Clogging

Infiltration basins or trenches can have redundant methods to ensure the long-term integrity of the infiltration rate. The following techniques are pretreatment options for infiltration practices:

- Grass channel (Maximum velocity of 1 fps for water quality flow. See the Fact Sheet on page 5-10 for more detailed design information.)
- Grass filter strip (minimum 20 feet and only if sheet flow is established and maintained)
- Bottom sand layer (for I-1)
- Upper sand layer (for I-1; 6" minimum with filter fabric at sand/gravel interface)
- Use of washed bank run gravel as aggregate
- Alternatively, a pre-treatment settling chamber may be provided and sized to capture the pretreatment volume. Use the method prescribed in section 6.4.3 (i.e., the Camp-Hazen equation) to size the chamber.
- Plunge Pool
- An underground trap with a permanent pool between the downspout and the dry well (I-3)

Design Guidance

- The sides of infiltration trenches and dry wells should be lined with an acceptable filter fabric that prevents soil piping.
- In infiltration trench designs, incorporate a fine gravel or sand layer above the coarse gravel treatment reservoir to serve as a filter layer.

6.3.4 Treatment

Required Elements

- Infiltration practices shall be designed to exfiltrate the entire WQ_v through the floor of each practice (sides are not considered in sizing).
- The construction sequence and specifications for each infiltration practice shall be precisely followed. Experience has shown that the longevity of infiltration practices is strongly influenced by the care taken during construction
- Calculate the surface area of infiltration trenches as:

$$A_p = V_w / (nd_t)$$

Where:

A_p = surface area (sf)
V_W = design volume (e.g., WQ_V) (ft^3)
n = porosity (assume 0.4)
d_t = trench depth (maximum of four feet, and separated at least three feet from seasonally high groundwater) (ft)

- Calculate the approximate bottom area of infiltration basins using the following equation:

$$A = V_w/d_b$$

Where:

A = surface area of the basin (ft^2)
d_b = depth of the basin (ft)

Note that in trapezoidal basins, this area should first be used to approximate the area at the bottom of the basin, but can later be modified to account for additional storage provided above side slopes.

Design Guidance

- Infiltration practices are best used in conjunction with other practices, and downstream detention is often needed to meet the Cp_v and Q_p sizing criteria.
- A porosity value (V_v/V_t) of 0.4 can be used to design stone reservoirs for infiltration practices.

The bottom of the stone reservoir should be completely flat so that infiltrated runoff will be able to infiltrate through the entire surface.

6.3.5 Landscaping

Required Elements

- Upstream construction shall be completed and stabilized before connection to a downstream infiltration facility. A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility.
- Infiltration trenches shall not be constructed until all of the contributing drainage area has been completely stabilized.

Design Guidance

- Mow upland and adjacent areas, and seed bare areas.

6.3.6 Maintenance

Required Elements

- Infiltration practices shall never serve as a sediment control device during site construction phase. In addition, the Erosion and Sediment Control plan for the site shall clearly indicate how sediment will be prevented from entering an infiltration facility. Normally, the use of diversion berms around the perimeter of the infiltration practice, along with immediate vegetative stabilization and/or mulching can achieve this goal.
- An observation well shall be installed in every infiltration trench and dry well, consisting of an anchored six- inch diameter perforated PVC pipe with a lockable cap installed flush with the ground surface.
- Direct access shall be provided to infiltration practices for maintenance and rehabilitation. If a stone reservoir or perforated pipe is used to temporarily store runoff prior to infiltration, the practice shall not be covered by an impermeable surface.

Design Guidance

- OSHA trench safety standards should be consulted if the infiltration trench will be excavated more than five feet.
- Infiltration designs should include dewatering methods in the event of failure. Dewatering can be accomplished with underdrain pipe systems that accommodate drawdown.

6.3.7 Cold Climate Design Considerations

Because of additional challenges in cold climates, infiltration SMPs need design modifications to function properly. These modifications address the following problems:

- Reduced infiltration into frozen soils
- Chlorides

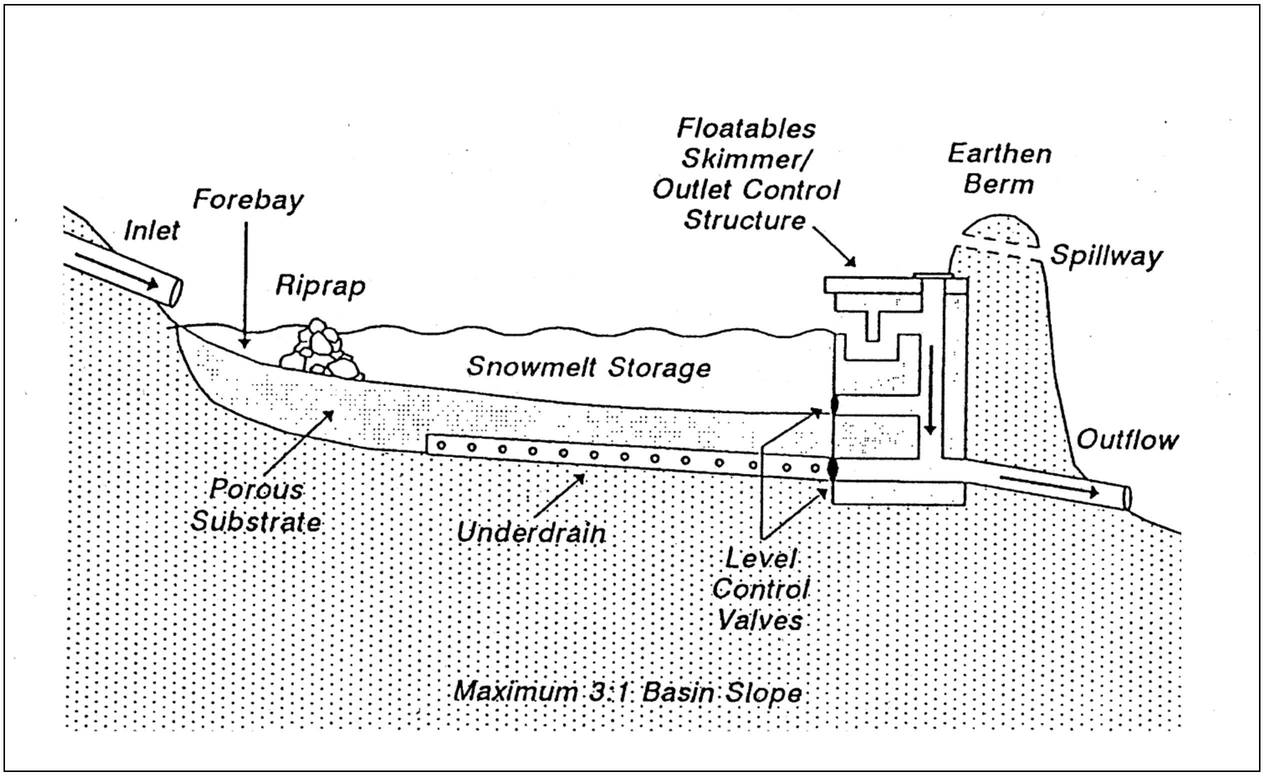
Reduced Infiltration

- Draining the ground beneath an infiltration system with an underdrain can increase cold weather soil infiltration.
- Another alternative is to divide the treatment volume between an infiltration SMP and another SMP to provide some treatment during the winter months.
- A seasonally operated infiltration/detention facility combines several techniques to improve the performance of infiltration SMPs in cold climates. Two features, the underdrain system and level control valves, are useful in cold climates. The level control and valves are opened at the beginning of the winter season and the soil is allowed to drain. As the snow begins to melt in the spring, the valves are closed, and the snowmelt is infiltrated until the capacity of the soil is reached. After this point, the facility acts as a detention facility, providing storage for particles to settle (Figure 6.14)

Chlorides

- Consider diverting snowmelt runoff past infiltration devices, especially in regions where chloride concentration in groundwater is a concern.
- Incorporate mulch into infiltration basin soil to mitigate problems with soil fertility.
- The selection of upland landscaping materials should include salt-tolerant grasses where appropriate.

Figure 6.14 Seasonal Operation Infiltration Facility



Infiltration Practices

Description: Excavated trench or basin used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the basin or trench.

Design Options:
Infiltration Trench (**I**-1), Shallow **I**nfiltration Basin (**I**-2), Dry Well (**I**-3)

KEY CONSIDERATIONS

FEASIBILITY

- Minimum soil infiltration rate of 0.5 inches per hour
- Soils less than 20% clay, and 40% silt/clay, and no fill soils.
- Natural slope less than 15%
- Cannot accept hotpot runoff, except under the conditions outlined in Section 6.3.1.
- Separation from groundwater table of at least three feet (four feet in sole source aquifers).
- 25' separation from structures for **I**-1 and **I**-2; 10' for **I**-3.

CONVEYANCE

- Flows exiting the practice must be non-erosive (3.5 to 5.0 fps)
- Maximum dewatering time of 48 hours.
- Design off-line if stormwater is conveyed to the practice by a storm drain pipe.

PRETREATMENT

- Pretreatment of 25% of the WQv at all sites.
- 50% pretreatment if fc >2.0 inches/hour.
- 100% pretreatment in areas with fc >5.0 inches/hour.
- Exit velocities from pretreatment must be non-erosive for the 2-year storm.

TREATMENT

- Water quality volume designed to exfiltrate through the floor of the practice.
- Construction sequence to maximize practice life.
- Trench depth shall be less than four feet (**I**-2 and **I**-3).
- Follow the methodologies in Chapter 6 to size practices.

LANDSCAPING

- Upstream area shall be completely stabilized before flow is directed to the practice.

MAINTENANCE REQUIREMENTS

- Never serves as a sediment control device
- Observation well shall be installed in every trench, (6" PVC pipe, with a lockable cap)
- Provide direct maintenance access.

STORMWATER MANAGEMENT SUITABILITY

- [X] **Water Quality**
- [ ] **Channel Protection**
- [ ] **Overbank Flood Protection**
- [ ] **Extreme Flood Protection**

Accepts Hotspot Runoff: *No*

IMPLEMENTATION CONSIDERATIONS

H **Capital Cost**

H **Maintenance Burden**

Residential Subdivision Use: Yes

High Density/Ultra-Urban: *Yes*

Drainage Area: *10 acres max.*

Soils: *Pervious soils required (0.5 in/hr or greater)*

Other Considerations:

- *Must not be placed under pavement or concrete*

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

POLLUTANT REMOVAL		
G	**Phosphorus**	
G	**Nitrogen**	
G	**Metals** - Cadmium, Copper, Lead, and Zinc removal	
G	**Pathogens** - Coliform, Streptococci, E.Coli removal	
	Key: G=Good **F**=Fair **P**=Poor	

Section 6.4 Stormwater Filtering Systems

Stormwater filtering systems capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, or soil. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Design variants include:

F-1	Surface Sand Filter	(Figure 6.15)
F-2	Underground Sand Filter	(Figure 6.16)
F-3	Perimeter Sand Filter	(Figure 6.17)
F-4	Organic Filter	(Figure 6.18)
F-5	Bioretention	(Figure 6.19)

Treatment Suitability: Filtering systems should not be designed to provide stormwater detention (Q_p) or channel protection (Cp_v) except under extremely unusual conditions. Filtering practices shall generally be combined with a separate facility to provide those controls.

Figure 6.15 Surface Sand Filter (F-1)

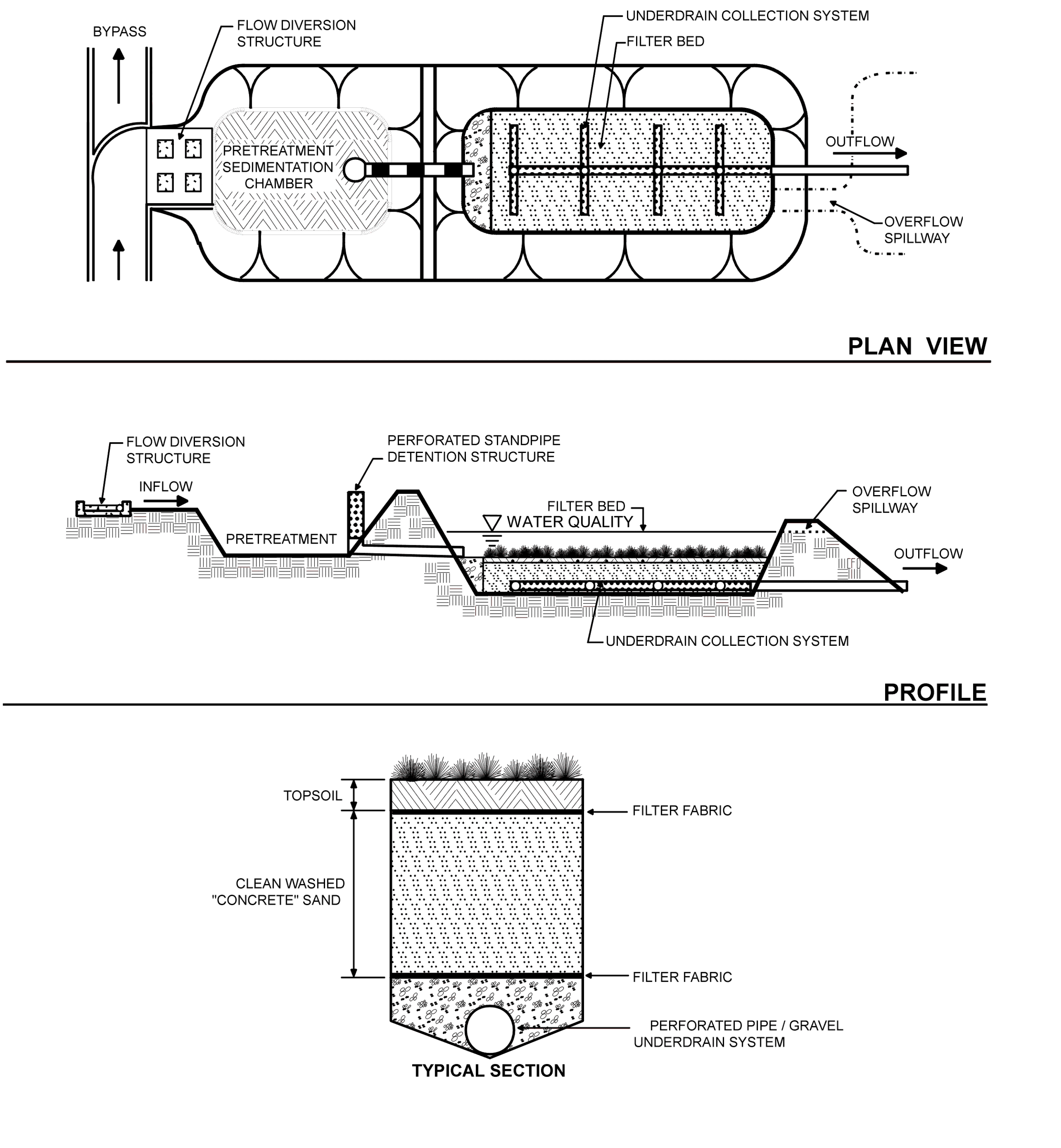


Figure 6.16 Underground Sand Filter (F-2)

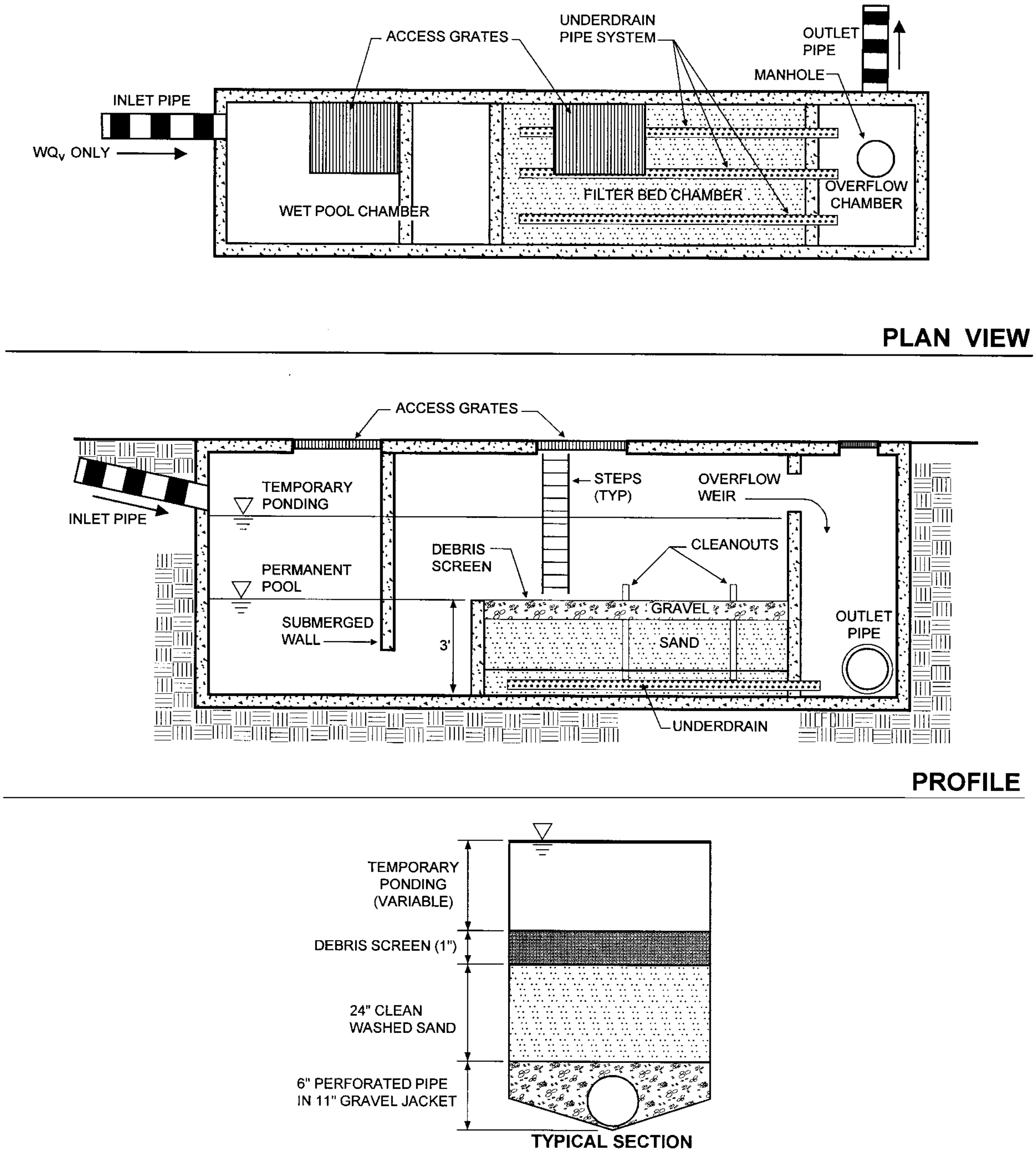


Figure 6.17 Perimeter Sand Filter (F-3)

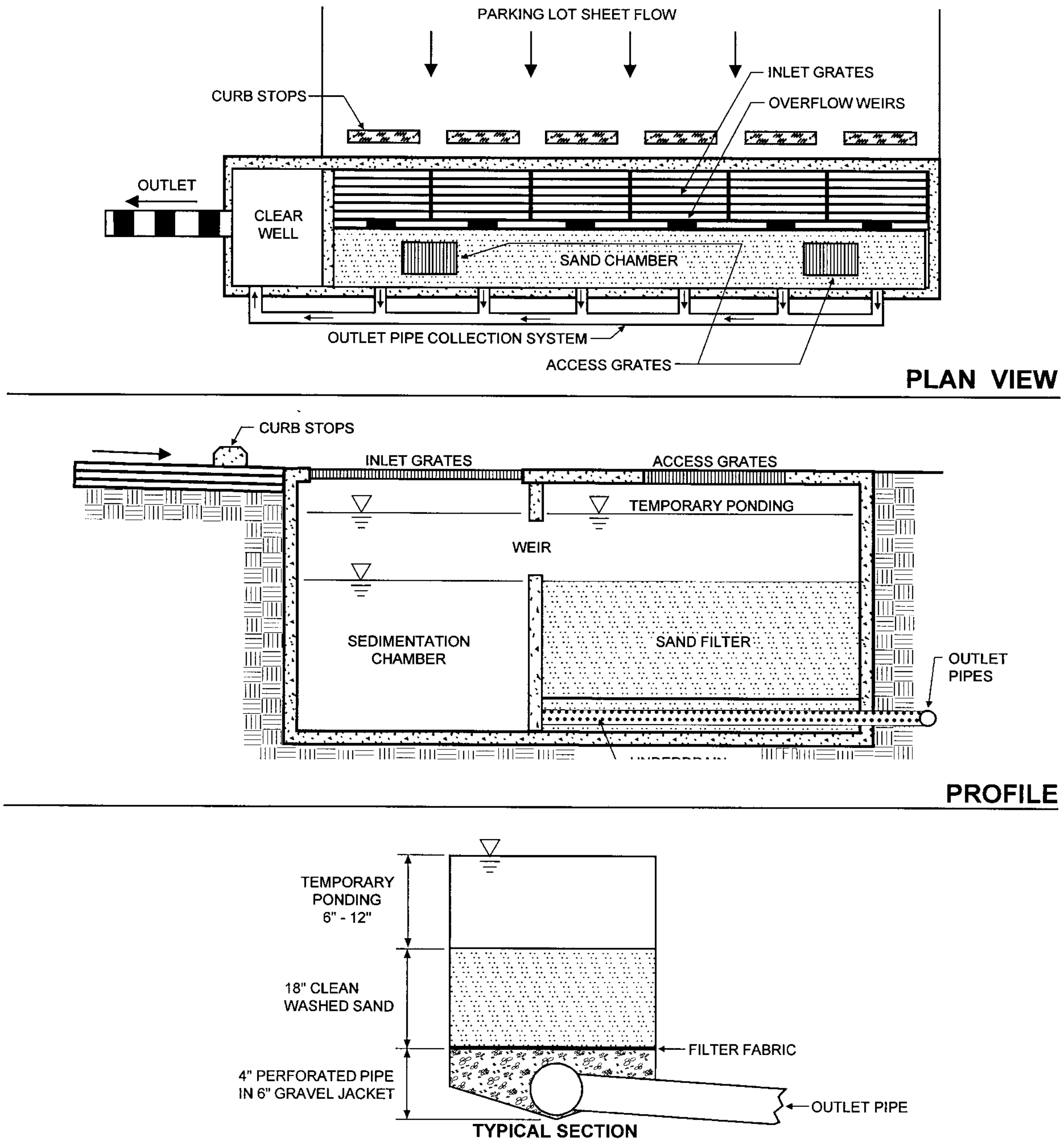


Figure 6.18 Organic Filter (F- 4)

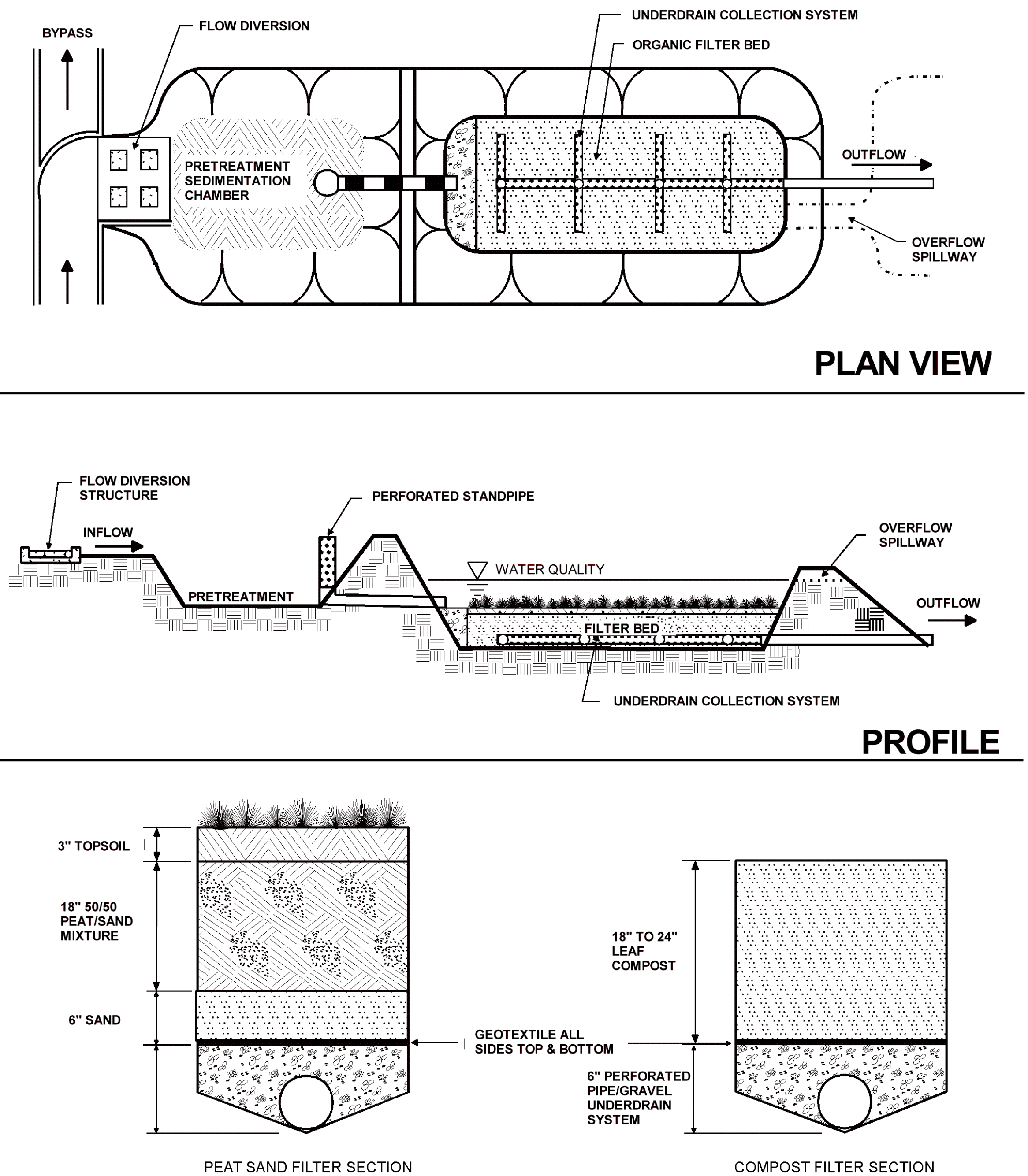
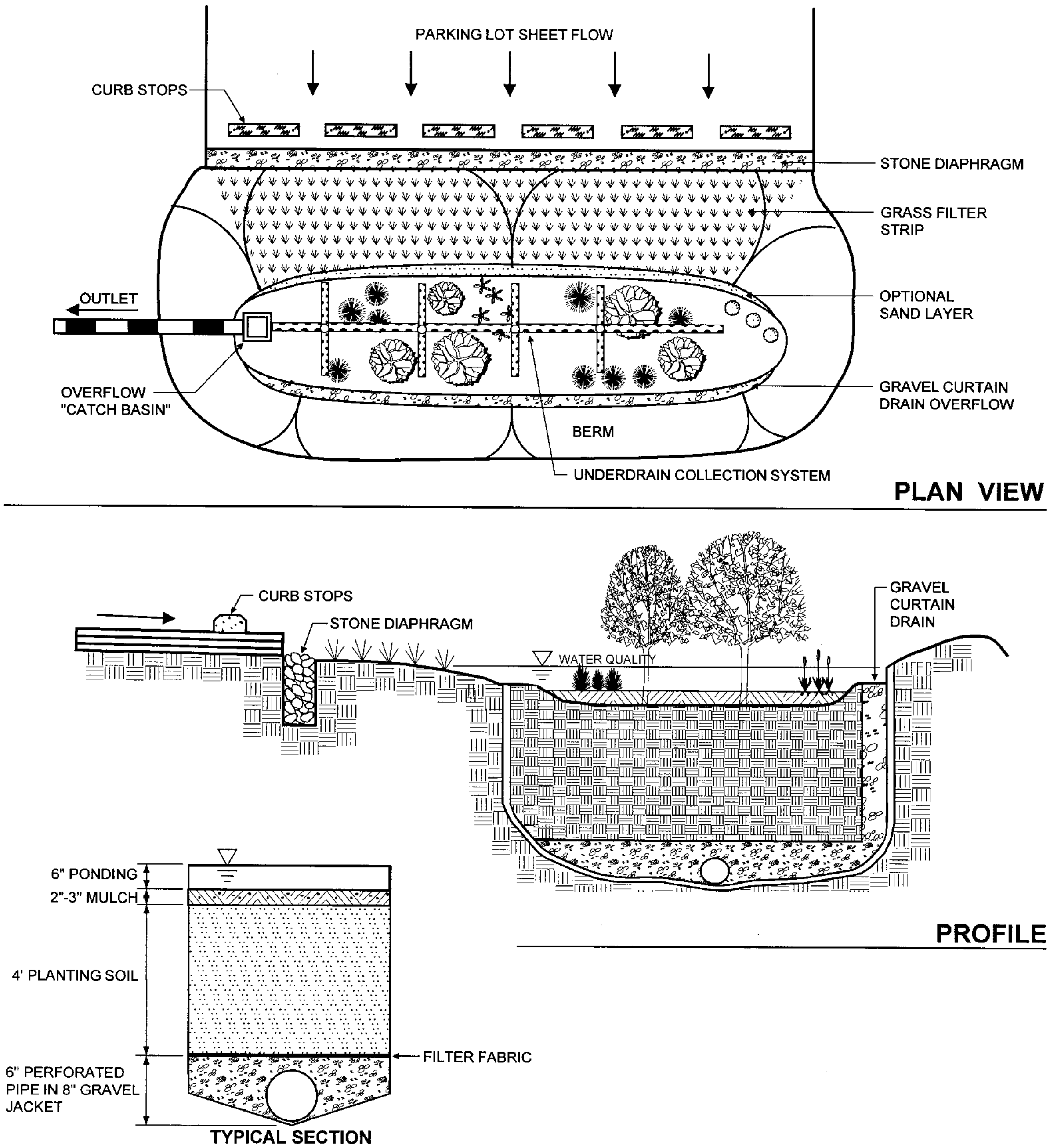


Figure 6.19 Bioretention (F-5)



6.4.1 Feasibility

Design Guidance

- Most stormwater filters require four to six feet of head, depending on site configuration and land area available. The perimeter sand filter (F-3), however, can be designed to function with as little as 18” to 24” of head.
- The recommended maximum contributing area to an individual stormwater filtering system is usually less than 10 acres. In some situations, larger areas may be acceptable.
- Sand and organic filtering systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with imperviousness less than 75% will require full sedimentation pretreatment techniques.

6.4.2 Conveyance

Required Elements

- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line (see Appendix K).
- An overflow shall be provided within the practice to pass a percentage of the WQ_v to a stabilized water course. In addition, overflow for the ten-year storm shall be provided to a non-erosive outlet point (i.e., prevent downstream slope erosion).
- A flow regulator (or flow splitter diversion structure) shall be supplied to divert the WQ_v to the filtering practice, and allow larger flows to bypass the practice.
- Stormwater filters shall be equipped with a minimum 4" perforated pipe underdrain (6" is preferred) in a gravel layer. A permeable filter fabric shall be placed between the gravel layer and the filter media.
- Require a minimum 2’ separation between the filter bottom and groundwater.

6.4.3 Pretreatment

Required Elements

- Dry or wet pretreatment shall be provided prior to filter media equivalent to at least 25% of the computed WQ_v. The typical method is a sedimentation basin that has a length to width ratio of 1.5:1. The Camp-Hazen equation is used to compute the required surface area for sand and organic filters requiring full sedimentation for pretreatment (WSDE, 1992) as follows:

- The required sedimentation basin area is computed using the following equation:

$$A_s = -(Qo/W) \cdot Ln\ (1\text{-}E)$$

where:

A_s = Sedimentation basin surface area (ft^2)
E = sediment trap efficiency (use 90%)
W = particle settling velocity (ft/sec)
use 0.0004 ft/sec for imperviousness (I) $\leq$75%
use 0.0033 ft/sec for I > 75%
Qo = Discharge rate from basin = (WQ_v/24 hr)

This equation reduces to:

A_s = (0.066) (WQ_v) ft^2 for I $\leq$75%
A_s = (0.0081) (WQ_v) ft^2 for I > 75%

Design Guidance

- Adequate pretreatment for bioretention systems should incorporate all of the following: (a) grass filter strip below a level spreader or grass channel, (b) gravel diaphragm and (c) a mulch layer.
- The grass filter strip should be sized using the guidelines in Table 6.2.

Table 6.2 Guidelines for Filter Strip Pretreatment Sizing

Parameter	Impervious Parking Lots				Residential Lawns			
Maximum Inflow Approach Length (ft.)	35		75		75		150	
Filter Strip Slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%
Filter Strip Minimum Length	10’	15’	20’	25’	10’	12’	15’	18’

- The grass channel should be sized using the following procedure:
  1- Determine the channel length needed to treat the WQ_v, using sizing techniques described in the Grass Channel Fact Sheet (Chapter 5).
  2- Determine the volume directed to the channel for pretreatment
  3- Determine the channel length by multiplying the length determined in step 1 above by the ratio of the volume in step 2 to the WQ_v.

6.4.4 Treatment

Required Elements

- The entire treatment system (including pretreatment) shall be sized to temporarily hold at least 75% of the WQ_v prior to filtration.
- The filter media shall consist of a medium sand (meeting ASTM C-33 concrete sand). Media used for organic filters may consist of peat/sand mix or leaf compost. Peat shall be a reed-sedge hemic peat.
- Bioretention systems shall consist of the following treatment components: A four foot deep planting soil bed, a surface mulch layer, and a six inch deep surface ponding area. Soils shall meet the design criteria outlined in Appendix H.

Design Guidance

- The filter bed typically has a minimum depth of 18". The perimeter filter may have a minimum filter bed depth of 12".
- The filter area for sand and organic filters should be sized based on the principles of Darcy's Law. A coefficient of permeability (k) should be used as follows:

Sand:	3.5 ft/day (City of Austin 1988)
Peat:	2.0 ft/day (Galli 1990)
Leaf compost:	8.7 ft/day (Claytor and Schueler, 1996)
Bioretention Soil:	0.5 ft/day (Claytor and Schueler, 1996)

The required filter bed area is computed using the following equation

$$A_f = (WQ_v)\,(d_f) \,/\, [\,(k)\,(h_f + d_f)\,(t_f)]$$

Where:

A_f = Surface area of filter bed (ft^2)
d_f = Filter bed depth (ft)
k = Coefficient of permeability of filter media (ft/day)
h_f = Average height of water above filter bed (ft)
t_f = Design filter bed drain time (days)
(1.67 days or 40 hours is recommended maximum t_f for sand filters, two days for bioretention)

6.4.5 Landscaping

Required Elements

- A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility.
- Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas.

Design Guidance

- Surface filters can have a grass cover to aid in pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought.

- Planting recommendations for bioretention facilities are as follows:
  - Native plant species should be specified over non-native species.
  - Vegetation should be selected based on a specified zone of hydric tolerance.
  - A selection of trees with an understory of shrubs and herbaceous materials should be provided.
  - Woody vegetation should not be specified at inflow locations.
  - Trees should be planted primarily along the perimeter of the facility.
  - A tree density of approximately one tree per 100 square feet (i.e., 10 feet on-center) is recommended. Shrubs and herbaceous vegetation should generally be planted at higher densities (five feet on-center and 2.5 feet on center, respectively).

6.4.6 Maintenance

Required Elements

- A legally binding and enforceable maintenance agreement shall be executed between the facility owner and the local review authority to ensure the following:

  - Sediment shall be cleaned out of the sedimentation chamber when it accumulates to a depth of more than six inches. Vegetation within the sedimentation chamber shall be limited to a height of 18 inches. The sediment chamber outlet devices shall be cleaned/repaired when drawdown times exceed 36 hours. Trash and debris shall be removed as necessary.

  - Silt/sediment shall be removed from the filter bed when the accumulation exceeds one inch. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), the top few inches of discolored material shall be removed and shall be replaced with fresh material. The removed sediments shall be disposed in an acceptable manner (i.e., landfill).
- A stone drop of at least six inches shall be provided at the inlet of bioretention facilities (F-6) (pea gravel diaphragm). Areas devoid of mulch shall be re-mulched on an annual basis. Dead or diseased plant material shall be replaced.

Design Guidance

- Organic filters or surface sand filters that have a grass cover should be mowed a minimum of three times per growing season to maintain maximum grass heights less than 12 inches.

6.4.7 Cold Climate Design Considerations

In cold climates, stormwater filtering systems need to be modified to protect the systems from freezing and frost heaving. The primary cold climate concerns to address with regards to filtering systems are:

- Freezing of the filter bed
- Pipe freezing
- Clogging of filter

NOTE

ALTHOUGH FILTERING SYSTEMS ARE NOT AS EFFECTIVE DURING THE WINTER, THEY ARE OFTEN EFFECTIVE AT TREATING STORM EVENTS IN AREAS WHERE OTHER SMPS ARE NOT PRACTICAL, SUCH AS IN HIGHLY URBANIZED REGIONS. THUS, THEY MAY BE A GOOD DESIGN OPTION, EVEN IF WINTER FLOWS CANNOT BE TREATED. IT IS ALSO IMPORTANT TO REMEMBER THAT THESE SMPS ARE DESIGNED FOR HIGHLY IMPERVIOUS AREAS. IF THE SNOW FROM THEIR CONTRIBUTING AREAS IS TRANSPORTED TO ANOTHER AREA, SUCH AS A PERVIOUS INFILTRATION AREA, A PRACTICE'S PERFORMANCE DURING THE WINTER SEASON MAY BE LESS CRITICAL TO OBTAIN WATER QUALITY GOALS.

Freezing of the Filter Bed

- Place filter beds for underground filter below the frost line to prevent the filtering medium from freezing during the winter.
- Discourage organic filters using peat and compost media, which are ineffective during the winter in cold climates. These organic filters retain water, and consequently can freeze solid and become completely impervious during the winter.
- Combine treatment with another SMP option that can be used as a backup to the filtering system to provide treatment during the winter when the filter is ineffective

Pipe Freezing

- Use a minimum 8" underdrain diameter in a 1' gravel bed. Increasing the diameter of the underdrain makes freezing less likely, and provides a greater capacity to drain standing water from the filter. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media.
- Replace standpipes with weirs, which can be “frost free.” Although weir structures will not always provide detention, they can provide retention storage (i.e., storage with a permanent pool) in the pretreatment chamber.

Clogging of Filter with Excess Sand from Runoff

- If a filter is used to treat runoff from a parking lot or roadway that is frequently sanded during snow events, there is a high potential for clogging from sand in runoff. In these cases, the size of the pretreatment chamber should be increased to 40% of the treatment volume. For bioretention systems, a grass strip, such as a swale, of at least twenty-five feet in length should convey flow to the system.
- Filters should always be inspected for sand build-up in the filter chamber following the spring melt event.

Sand/ Organic Filters

Description: Multi-chamber structure designed to treat stormwater runoff through filtration, using a sediment forebay, a primary filter media and, typically, an underdrain collection system.

Design Variations:
Surface Sand Filter (F-1), Underground Sand Filter (F-2), Perimeter Sand Filter (F-3), Organic Sand Filter (F-4)

KEY CONSIDERATIONS

CONVEYANCE

- If stormwater is delivered by stormdrain, design off-line.
- Overflow shall be provided to pass a fraction of the WQ_v to a stabilized watercourse.
- Overflow for the ten-year storm to a non-erosive point.
- Flow regulator needed to divert WQ_v to the practice, and bypass larger flows.
- Underdrain (4” perforated pipe minimum; 6” preferred)

PRETREATMENT

- Pretreatment volume of 25% of WQ_v.
- Typically a sediment basin with a 1.5:1 L:W ratio, sized with the Camp-Hazen equation (See Section 6.4.3)

TREATMENT

- System must hold 75% of the WQ_v
- Filter media shall be ASTM C-33 sand for sand filters
- Organic filters shall be a peat/sand mix, or leaf compost.
- Peat shall be reed-sedge hemic peat

LANDSCAPING

- Contributing area stabilized before runoff is directed to the facility

MAINTENANCE REQUIREMENTS:

- Legally binding maintenance agreement.
- Sediment cleaned out of sedimentation chamber when it reaches more than 6” in depth.
- Vegetation height limited to 18”
- Sediment chamber cleaned if drawdowns exceed 36 hours.
- Trash and debris removal
- Silt/sediment removed from filter bed after it reaches one inch.
- If water ponds on the filter bed for greater than 48 hours, remove material, and replace.

STORMWATER MANAGEMENT SUITABILITY

- [X] **Water Quality**
- [ ] **Channel Protection**
- [ ] **Overbank Flood Protection**
- [ ] **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes (requires impermeable liner)*

IMPLEMENTATION CONSIDERATIONS

H **Capital Cost**

H **Maintenance Burden**

Residential Subdivision Use: No

High Density/Ultra-Urban: *Yes*

Drainage Area: *2-10 acres max.*

Soils: *No restrictions*

Other Considerations:
Typically needs to be combined with other controls to provide water quantity control

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

POLLUTANT REMOVAL	
G	**Phosphorus**
G	**Nitrogen**
G	**Metals** - Cadmium, Copper, Lead, and Zinc removal
F	**Pathogens** - Coliform, Streptococci, E.Coli removal

Key: **G**=Good **F**=Fair **P**=Poor

Bioretention Areas (F-5)

Description: Shallow stormwater basin or landscaped area which utilizes engineered soils and vegetation to capture and treat runoff. The practice is often located in parking lot islands, and can also be used to treat residential areas.

KEY CONSIDERATIONS

CONVEYANCE

- Provide overflow for the 10-year storm to the conveyance system.
- Conveyance to the system is typically overland flow delivered to the surface of the system, typically through curb cuts or over a concrete lip.

PRETREATMENT

- Pretreatment consists of a grass channel or grass filter strip, a gravel diaphragm, and a mulch layer, sized based on the methodologies described in Section 6.4.2.

TREATMENT

- Treatment area should have a four foot deep planting soil bed, a surface mulch layer, and a 6" ponding layer.
- Size the treatment area using equations provided in Chapter 6.

LANDSCAPING

- Detailed landscaping plan required.

MAINTENANCE

- Inspect and repair/replace treatment area components
- Stone drop (at least 6") provided at the inlet
- Remulch annually

POLLUTANT REMOVAL

G	**Phosphorus**
G	**Nitrogen**
G	**Metals** - Cadmium, Copper, Lead, and Zinc removal
F	**Pathogens** – Coliform, Streptococci, E.Coli removal

Key: **G**=Good **F**=Fair **P**=Poor

STORMWATER MANAGEMENT SUITABILITY

X	**Water Quality**
	Channel Protection
	Overbank Flood Protection
	Extreme Flood Protection

Accepts Hotspot Runoff: *Yes (requires impermeable liner)*

IMPLEMENTATION CONSIDERATIONS

M	**Capital Cost**
M	**Maintenance Burden**

Residential Subdivision Use: Yes

High Density/Ultra-Urban: *Yes*

Drainage Area: *5 acres max.*

Soils: *Planting soils must meet specified criteria; No restrictions on surrounding soils*

Other Considerations:

- *Use of native plants is recommended*

Key: L=Low **M**=Medium **H**=High

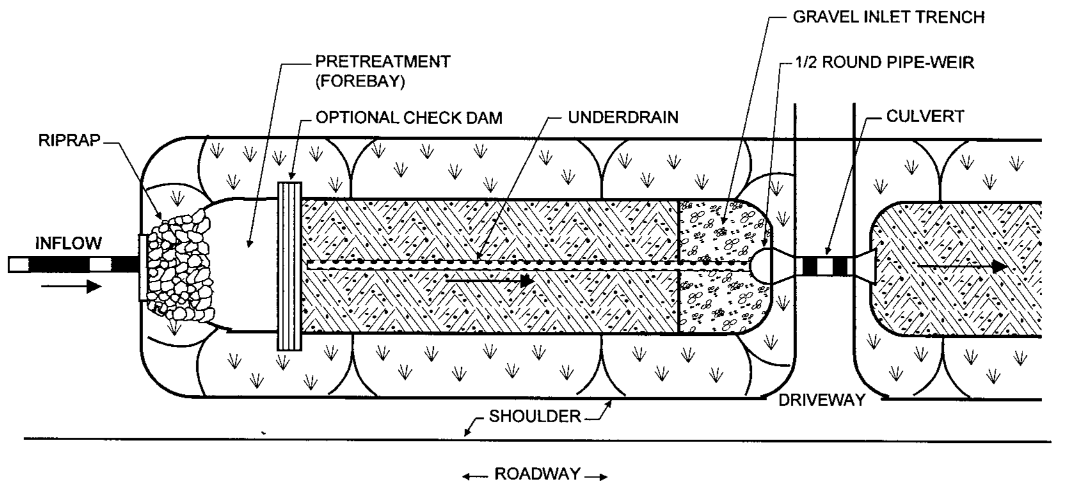
Section 6.5 Open Channel Systems

Open channel systems are vegetated open channels that are explicitly designed to capture and treat the full WQ_v within dry or wet cells formed by check dams or other means. Design variants include:

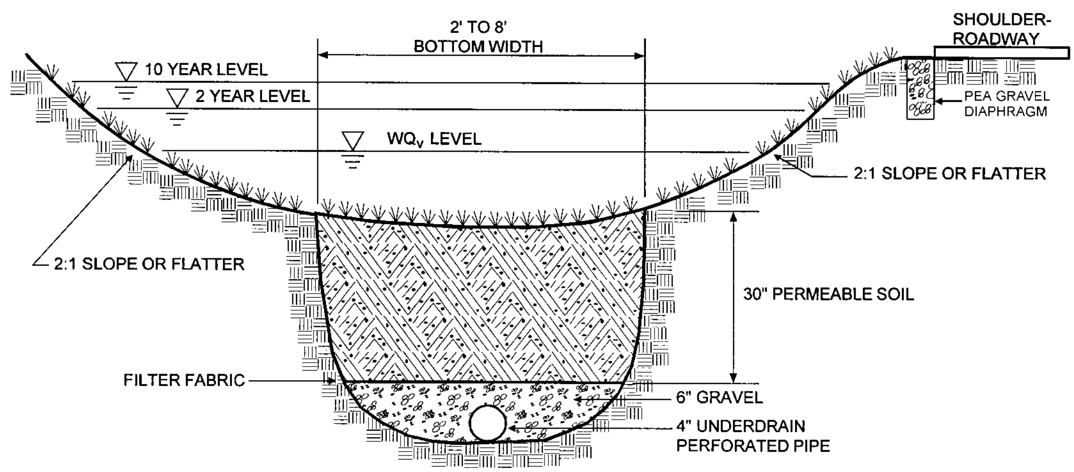
- O-1 Dry Swale (Figure 6.20)
- O-2 Wet Swale (Figure 6.21)

Treatment Suitability: Open Channel Systems can meet water quality treatment goals only, and are not appropriate for Cp_v or Q_p.

Figure 6.20 Dry Swale (O-1)

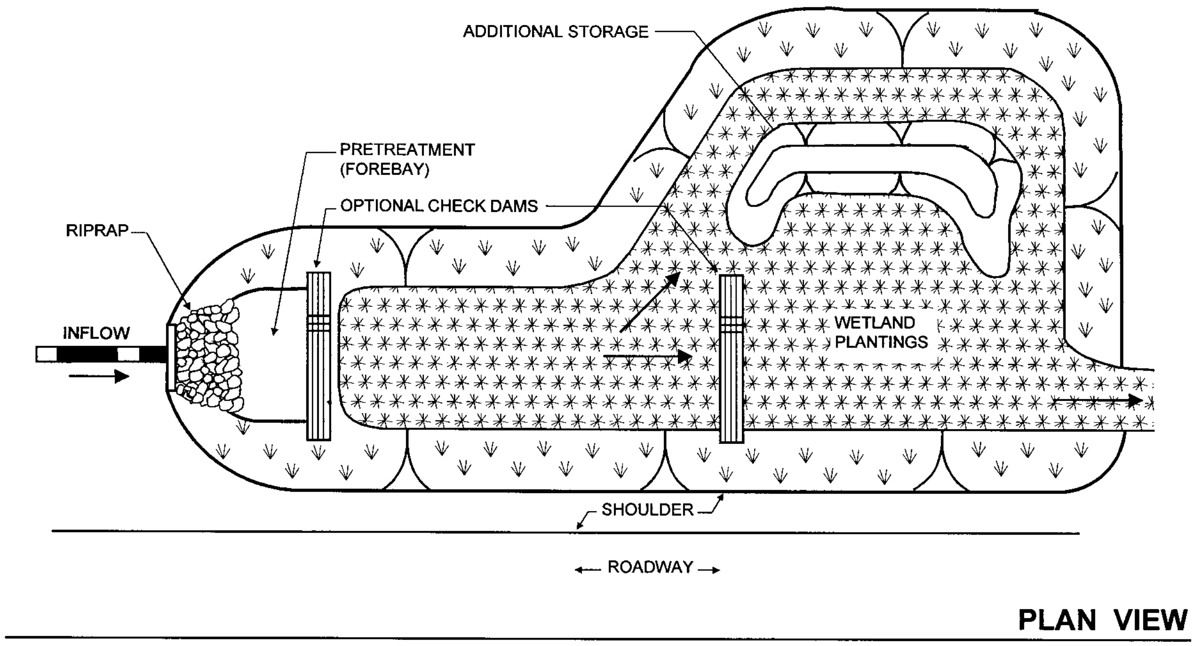


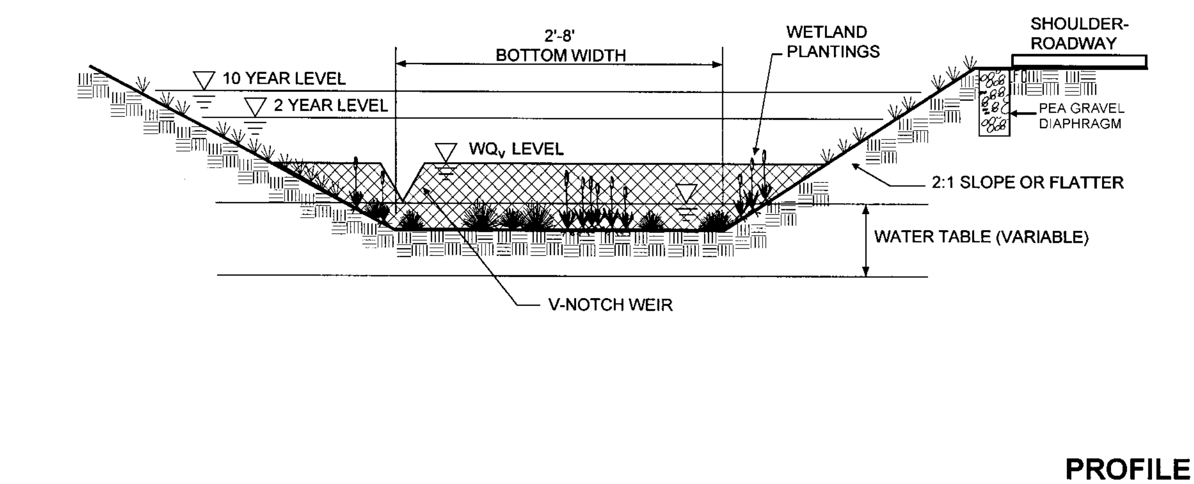
PLAN VIEW



SECTION

Figure 6.21 Wet Swale (O-2)





6.5.1 Feasibility

Required Elements

- The system shall have a maximum longitudinal slope of 4.0%

Design Guidance

- Dry Swales (O-1) are primarily applicable for land uses such as roads, highways, residential development, and pervious areas.
- Wet Swales (O-2) should be restricted in residential areas because of the potential for stagnant water and other nuisance ponding.
- Provide a 2' separation distance from groundwater for O-2.

6.5.2 Conveyance

Required Elements

- The peak velocity for the two-year storm must be non-erosive (i.e., 3.5-5.0 fps). (See Appendix L for a table of erosive velocities for grass and soil).
- Open channels shall be designed to safely convey the ten-year storm with a minimum of 6 inches of freeboard. Note that some agencies or local municipalities may design channel to convey a different design storm.
- The maximum allowable temporary ponding time within a channel shall be less than 48 hours. An underdrain system shall be used in the dry swale to ensure this ponding time.
- Channels shall be designed with moderate side slopes (flatter than 3:1) for most conditions. 2:1 is the absolute maximum side slope.

Design Guidance

- Open channel systems which directly receive runoff from impervious surfaces may have a 6 inch (maximum) drop onto a protected shelf (pea gravel diaphragm) to minimize the clogging potential of the inlet.
- The underdrain system should be composed of a 6" gravel bed with a 4" PVC pipe.
- If the site slope is greater than 2%, check dams may be needed to retain the water quality volume within the swale system.

6.5.3 Pretreatment

Required Elements

- Provide 10% of the WQ_v in pretreatment. This storage is usually obtained by providing checkdams at pipe inlets and/or driveway crossings.

Design Guidance

- Utilize a pea gravel diaphragm and gentle side slopes along the top of channels to provide pretreatment for lateral sheet flows.

6.5.4 Treatment

Required Elements

- Temporarily store the WQ_v within the facility to be released over a minimum 30 minute duration.
- Design with a bottom width no greater than eight feet to avoid potential gullying and channel braiding, but no less than two feet.
- Soil media for the dry swale shall meet the specifications outlined in Appendix H.

Design Guidance

- Open channels should maintain a maximum ponding depth of one foot at the mid-point of the channel, and a maximum depth of 18" at the end point of the channel (for storage of the WQ_v).

6.5.5 Landscaping

Design Guidance

- Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel (see Appendix H for landscaping guidance for New York).

6.5.6 Maintenance

Required Elements

- A legally binding and enforceable maintenance agreement shall be executed between the facility owner and the local review authority to ensure the following:

- Sediment build-up within the bottom of the channel or filter strip is removed when 25% of the original WQ_v volume has been exceeded.
- Vegetation in dry swales is mowed as required during the growing season to maintain grass heights in the 4 to 6 inch range.

6.5.7 Cold Climate Design Considerations

For open channel systems, the primary cold climate design challenges that need to be addressed are:

- Snowmelt infiltration on frozen ground
- Culvert freezing
- The impacts of deicers on channel vegetation.

<u>Snowmelt Infiltration on Frozen Ground</u>

- In order to ensure that the filter bed remains dry between storm events, increase the size of the underdrain pipe to a minimum diameter of 6” with a minimum 1’ filter bed.
- The soil bed permeability of the dry swale should be NRCS class SM (NRCS, 1984), which is slightly higher than in the base criteria. This increased permeability will encourage snowmelt infiltration.

<u>Culvert Freezing</u>

- Use culvert pipes with a minimum diameter of 18".
- Design culverts with a minimum 1% slope where possible.

<u>The Impacts of De-icers on Channel Vegetation</u>

- Inspect open channel systems after the spring melt. At this time, residual sand should be removed and any damaged vegetation should be replaced.
- If roadside or parking lot runoff is directed to the practice, mulching may be required in the spring to restore soil structure and moisture capacity to reduce the impacts of deicing agents.
- Use salt-tolerant plant species in vegetated swales.

Open Channels

Description: Vegetated channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.

Design Options:
Dry Swale (O-1), Wet Swale (O-2)

KEY CONSIDERATIONS

FEASIBILITY

- Maximum longitudinal slope of 4%

CONVEYANCE

- Non-erosive (3.5 to 5.0 fps) peak velocity for the 2-year storm
- Safe conveyance of the ten-year storm with a minimum of 6 inches of freeboard.
- Side slopes gentler than 2:1 (3:1 preferred).
- The maximum allowable temporary ponding time of 48 hours

PRETREATMENT

- 10% of the WQ_v in pretreatment, usually provided using check dams at culverts or driveway crossings.

TREATMENT

- Temporary storage the WQ_v within the facility to be released over a minimum 30 minute duration.
- Bottom width no greater than 8 feet, but no less than two feet.
- Soil media as detailed in Appendix H.

MAINTENANCE

- Removal of sediment build-up within the bottom of the channel or filter strip when 25% of the original WQ_v volume has been exceeded.
- Maintain a grass height of 4" to 6" in dry swales.

MANAGEMENT CAPABILITY

- [G] **Phosphorus**
- [F] **Nitrogen**
- [G] **Metals** - Cadmium, Copper, Lead, and Zinc removal
- [P] **Pathogens** - Coliform, Streptococci, E.Coli removal

Key: **G**=Good **F**=Fair **P**=Poor

STORMWATER MANAGEMENT SUITABILITY

- [X] **Water Quality**
- [ ] **Channel Protection**
- [ ] **Overbank Flood Protection**
- [ ] **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes (requires impermeable liner)*

IMPLEMENTATION CONSIDERATIONS

- [L] **Capital Cost**
- [L] **Maintenance Burden**

Residential Subdivision Use: Yes

High Density/Ultra-Urban: *No*

Drainage Area: *5 acres max.*

Soils: *No restrictions*

Other Considerations:

- *Permeable soil layer (dry swale)*
- *Wetland plants (wet swale)*

Key: **H**=High **M**=Medium **L**=Low

Chapter 7

SMP Selection Matrices

This chapter presents a series of matrices that can be used as a screening process to select the best SMP or group of SMPs for a development site. It also provides guidance for best locating practices on the site. The matrices presented can be used to screen practices in a step-wise fashion. The screening factors include:

1. Land Use
2. Physical Feasibility
3. Watershed/ Regional Factors
4. Stormwater Management Capability
5. Community and Environmental Factors

The five matrices presented here are not exhaustive. Specific additional criteria may be incorporated depending on local design knowledge and resource protection goals. Furthermore, many communities may wish to eliminate some of the selection factors presented in this section. Caveats for the application of each matrix are included in the detailed description of each.

More detail on the proposed step-wise screening process is provided below:

Step 1 Land Use

Which practices are best suited for the proposed land use at this site? In this step, the designer makes an initial screen to select practices that are best suited to a particular land use.

Step 2 Physical Feasibility Factors

Are there any physical constraints at the project site that may restrict or preclude the use of a particular SMP? In this step, the designer screens the SMP list using Matrix No. 2 to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of a SMP.

Step 3 Watershed Factors

What watershed protection goals need to be met in the resource my site drains to? Matrix No.3 outlines SMP goals and restrictions based on the resource being protected.

Step 4 Stormwater Management Capability

Can one SMP meet all design criteria, or is a combination of practices needed? In this step, designers can screen the SMP list using Matrix No. 4 to determine if a particular SMP can meet water quality, channel protection, and flood control storage requirements. At the end of this step, the designer can screen the SMP options down to a manageable number and determine if a single SMP or a group of SMPs is needed to meet stormwater sizing criteria at the site.

Step 5 Community and Environmental Factors

Do the remaining SMPs have any important community or environmental benefits or drawbacks that might influence the selection process? In this step, a matrix is used to compare the SMP options with regard to cold climate restrictions, maintenance, habitat, community acceptance, cost and other environmental factors.

Section 7.1 Land Use

This matrix allows the designer to make an initial screen of practices most appropriate for a given land use (Table 7.1).

Rural. This column identifies SMPs that are best suited to treat runoff in rural or very low density areas (e.g., typically at a density of less than ½ dwelling unit per acre).

Residential. This column identifies the best treatment options in medium to high density residential developments.

Roads and Highways. This column identifies the best practices to treat runoff from major roadways and highway systems.

Commercial Development. This column identifies practices that are suitable for new commercial development

Hotspot Land Uses. This last column examines the capability of an SMP to treat runoff from designated hotspots (see Appendix A). An SMP that receives hotspot runoff may have design restrictions, as noted.

Ultra-Urban Sites. This column identifies SMPs that work well in the ultra-urban environment, where space is limited and original soils have been disturbed. These SMPs are frequently used at redevelopment sites.

Table 7.1 Land Use Selection Matrix							
SMP Group	**SMP Design**	**Rural**	**Residential**	**Roads and Highways**	**Commercial/ High Density**	**Hotspots**	**Ultra Urban**
Pond	Micropool ED	❍	❍	❍	◗	①	●
	Wet Pond	❍	❍	❍	◗	①	●
	Wet ED Pond	❍	❍	❍	◗	①	●
	Multiple Pond	❍	❍	◗	◗	①	●
	Pocket Pond	❍	◗	❍	◗	●	●
Wetland	Shallow Wetland	❍	❍	◗	◗	①	●
	ED Wetland	❍	❍	◗	◗	①	●
	Pond/Wetland	❍	❍	●	◗	①	●
	Pocket Wetland	❍	◗	❍	◗	●	●
Infiltration	Infiltration Trench	◗	◗	❍	❍	●	◗
	Shallow I-Basin	◗	◗	◗	◗	●	◗
	Dry Well[1]	◗	❍	●	◗	●	◗
Filters	Surface Sand Filter	●	◗	❍	❍	②	❍
	Underground SF	●	●	◗	❍	❍	❍
	Perimeter SF	●	●	◗	❍	❍	❍
	Organic SF	●	◗	❍	❍	②	❍
	Bioretention	◗	◗	❍	❍	②	❍
Open Channels	Dry Swale	❍	◗	❍	◗	②	◗
	Wet Swale	❍	●	❍	●	●	●

❍: Yes. Good option in most cases.
◗: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
●: No. Seldom or never suitable.
①: Acceptable option, but may require a pond liner to reduce risk of groundwater contamination.
②: Acceptable option, if not designed as an exfilter.
1: The dry well can only be used to treat rooftop runoff

Section 7.2 Physical Feasibility Factors

This matrix allows the designer to evaluate possible options based on physical conditions at the site (Table 7.2). More detailed testing protocols are often needed to confirm physical conditions at the site. Five primary factors are:

Soils. The key evaluation factors are based on an initial investigation of the NRCS hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors. Appendix H describes geotechnical testing requirements for New York State.

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom elevation, or floor, of an SMP.

Drainage Area. This column indicates the minimum or maximum drainage area that is considered optimal for a practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is warranted where a practice meets other management objectives. Likewise, the minimum drainage areas indicated for ponds and wetlands should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), mechanisms employed to prevent clogging, or the ability to assume an increased maintenance burden.

Slope. This column evaluates the effect of slope on the practice. Specifically, the slope guidance refers to how flat the area where the practice is installed must be and/or how steep the contributing drainage area or flow length can be.

Head. This column provides an estimate of the elevation difference needed for a practice (from the inflow to the outflow) to allow for gravity operation.

Table 7.2 Physical Feasibility Matrix

SMP Group	SMP Design	Soils	Water Table	Drainage Area (acres)	Site Slope	Head (ft)
Pond	Micropool ED	HSG A soils may require pond liner.	2 foot separation if hotspot or aquifer	10 min[1]	No more than 15%	6 to 8 ft
	Wet Pond			25 min[1]		
	Wet ED Pond					
	Multiple Pond					
	Pocket Pond	OK	below WT	5 max[2]		4 ft
Wetland	Shallow Wetland	HSG A soils may require liner	2 foot separation if hotspot or aquifer	25 min	No more than 8%	3 to 5 ft
	ED Wetland					
	Pond/Wetland					
	Pocket Wetland	OK	below WT	5 max		2 to 3 ft
Infiltration	Infiltration Trench	$f_c > 0.5$ inch/hr; additional pretreatment required over 2.0 in/hr (See Section 6.3.3)	3 feet, 4 feet if sole source aquifer.	5 max	No more than 15%	1 ft[6]
	Shallow I-Basin			10 max[3]		3 ft
	Dry Well			1 max[4]		1 ft
Filters	Surface SF	OK	2 feet[5]	10 max[2]	No more than 6%	5 ft
	Underground SF			2 max[2]		5 to 7ft
	Perimeter SF			2 max[2]		2 to 3 ft
	Organic SF			5 max[2]		2 to 4 ft
	Bioretention			5 max[2]		5 ft
	Dry Swale	Made Soil				3 to 5 ft
Open Channels	Wet Swale	Made Soil	2 feet	5 max	No more than 4%	1 ft
	Wet Swale	OK	below WT	5 max		1 ft

Notes:
1: Unless adequate water balance and anti-clogging device installed
2: Drainage area can be larger in some instances
3: May be larger in areas where the soil percolation rate is greater than 5.0 in/hr
4: Designed to treat rooftop runoff only
5: If designed with a permeable bottom, must meet the depth requirements for infiltration practices.
6: Required ponding depth above geotextile layer.

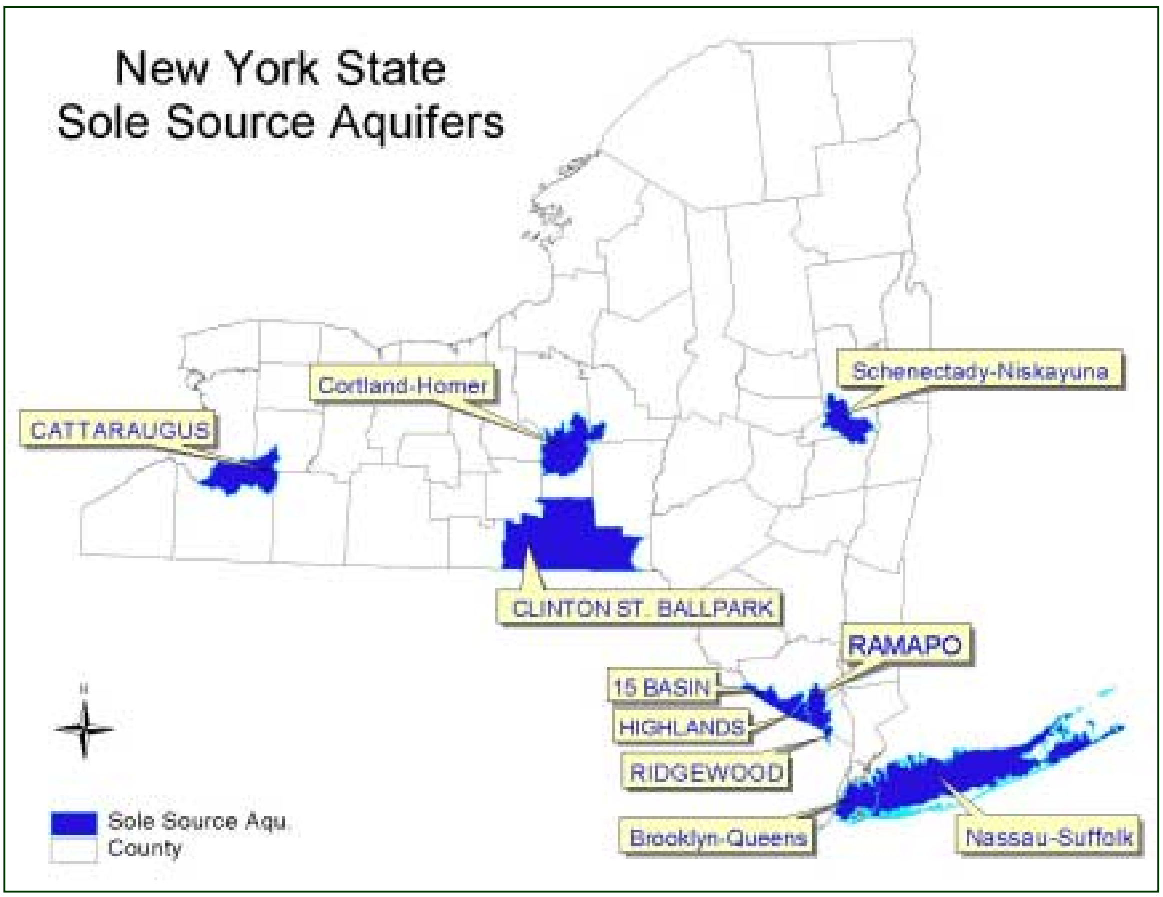
Section 7.3 Watershed/Regional Factors

The choices made by the designer should be influenced to some extent by the resource being protected, and the region of New York State where the site is located. The following matrices (Tables 7.3a and 7.3b) present some design considerations for six watershed or regional factors in New York:

Sensitive Streams. The guidance presented here should apply to all trout waters and Class N waters, and any streams that support high biodiversity and water quality, and have a low density of development.

Aquifers. In sole source aquifers, special care should be taken to select practices and incorporate design considerations that protect the groundwater quality. Figure 7.1 depicts sole source aquifers in the State of New York.

Figure 7.1 Sole Source Aquifers in New York State



Lakes. Lakes are of particular concern in New York, which has many natural lake systems and borders on two Great Lakes. The information in this matrix focuses on phosphorous removal, which is an important concern in most lake systems. It is important to note, however, that many lakes in New York State have other important issues to address. Some lakes, such as Lake Onondoga, have other specific concerns, such as toxics and metals. Each community should also take these goals into consideration when reviewing site plans.

Table 7.3a Watershed/ Regional Selection Matrix-1

<table>
<tr><th>SMP Group</th><th>Sensitive Stream</th><th>Aquifer</th><th>Lakes</th></tr>
<tr><td>Ponds</td><td>Emphasize channel protection.

Restrict in-stream practices.

In trout waters, minimize permanent pool area, and encourage shading.</td><td rowspan="2">May require liner if HSG A soils are present.

Pretreat 100% of WQ_v from hotspots.

Provide a 2’ separation distance to water table.</td><td rowspan="2">Encourage the use of a large permanent pool to improve phosphorus removal.</td></tr>
<tr><td>Wetlands</td><td>Require channel protection.

Restrict in-stream practices.

Restrict use in trout waters.</td></tr>
<tr><td>Infiltration</td><td>Strongly encourage use for groundwater recharge.

Combine with a detention facility to provide channel protection.</td><td>Provide 100' horizontal separation distance from wells and 4' vertical distance from the water table.</td><td>OK. Provides high phosphorus removal.</td></tr>
<tr><td>Filtering Systems</td><td>Combine with a detention facility to provide channel protection.</td><td>Excellent pretreatment for infiltration or open channel practices.</td><td>OK, but designs with a submerged filter may result in phosphorus release.</td></tr>
<tr><td>Open Channels</td><td>Combine with a detention facility to provide channel protection.</td><td>OK, but hotspot runoff must be adequately pretreated</td><td>OK. Moderate P removal.</td></tr>
</table>

Reservoirs. For drinking water reservoirs, and in particular for unfiltered water supplies such as the New York City Reservoir system, turbidity, phosphorous removal, and bacteria are of particular concern. A particular reservoir may have other specific concerns, which should be identified as part of a Source Water Assessment.

Estuary/Coastal. In New York State, coastal or estuary areas include the South Shore Estuary Reserve, Peconic Estuary, NY/NJ Harbor, and Hudson River Estuary. In these areas, nitrogen is typically a concern due to potential eutrophication. In addition, bacteria control is important to protect shellfish beds.

Cold Climates. Many portions of New York State experience cold or very snowy winters. This matrix summarizes some of the design considerations in these cold climate areas. For more detailed information, consult Chapter 6, which provides cold climate design guidance for each group of SMPs.

<table>
<tr><th colspan="4">Table 7.3b Watershed/Regional Selection Matrix-2</th></tr>
<tr><th>SMP Group</th><th>Reservoir</th><th>Estuary/Coastal</th><th>Cold Climates</th></tr>
<tr><td>Ponds</td><td rowspan="2">Encourage the use of a large permanent pool to improve sediment and phosphorous removal.

Promote long detention times to encourage bacteria removal.</td><td rowspan="2">Encourage long detention times to promote bacteria removal.

Provides high nitrogen removal.

In flat coastal areas, a pond drain may not be feasible.</td><td>Incorporate design features to improve winter performance.</td></tr>
<tr><td>Wetlands</td><td>Encourage the use of salt-tolerant vegetation.</td></tr>
<tr><td>Infiltration</td><td>Provide a separation distance from bedrock and water table

Pretreat runoff prior to infiltration practices.</td><td>OK, but provide a separation distance to seasonally high groundwater.

In the sandy soils typical of coastal areas, additional pretreatment may be required (See Section 6.3.3)</td><td>Incorporate features to minimize the risk of frost heave.

Discourage infiltration of chlorides.</td></tr>
<tr><td>Filtering Systems</td><td>Excellent pretreatment for infiltration or open channel practices.

Moderate to high coliform removal</td><td>Moderate to high coliform removal

Designs with a submerged filter bed appear to have very high nitrogen removal</td><td>Incorporate design features to improve winter performance.</td></tr>
<tr><td>Open Channels</td><td>Poor coliform removal for wet swales.</td><td>Poor coliform removal for grass wet swales.</td><td>Encourage the use of salt-tolerant vegetation.</td></tr>
</table>

Section 7.4 Stormwater Management Capability

This matrix examines the capability of each SMP option to meet stormwater management criteria (Table 7.4). It shows whether an SMP can meet requirements for:

Water Quality. The matrix summarizes the relative pollutant removal of each practice for nitrogen, metals, and bacteria. All of the practices approved for water quality achieve at least 80% TSS and 40% TP removal. For more detailed information, consult Appendix A, which describes the application of the Simple Method in New York State. Pollutant removals are based a comprehensive pollutant removal database produced by the Center for Watershed Protection (Winer, 2000).

Channel Protection. The matrix indicates whether the SMP can typically provide channel protection storage. The finding that a particular SMP cannot meet the channel protection requirement does not necessarily imply that the SMP should be eliminated from consideration, but is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream ED pond).

Flood Control The matrix shows whether an SMP can typically meet the overbank flooding criteria for the site. Again, the finding that a particular SMP cannot meet the requirement does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream stormwater detention pond).

Table 7.4 Stormwater Management Capability Matrix

SMP Group	SMP Design	Water Quality			Channel Protection	Flood Control
		Nitrogen	Metals	Bacteria		
Pond	Micropool ED	❍	❍	❍	❍	❍
	Wet Pond				❍	❍
	Wet ED Pond				❍	❍
	Multiple Pond				❍	❍
	Pocket Pond				❍	❍
Wetland	Shallow Wetland	❍	◗	❍	❍	❍
	ED Wetland				❍	❍
	Pond/Wetland				❍	❍
	Pocket Wetland				❍	❶
Infiltration	Infiltration Trench	❍	❍	❍	●	●
	Shallow I-Basin				❷	❷
	Dry Well				●	●
Filters	Surface Sand Filter	❍	❍	◗	❶	●
	Underground SF				●	●
	Perimeter SF				●	●
	Organic SF				●	●
	Bioretention				❶	●
	Dry Swale				●	●
Open Channels	Wet Swale	◗	❍	●	●	●
	Wet Swale				●	●

❍: Good option for meeting management goal
Good pollutant removal (>30% TN, >60% Metals, >70% Bacteria)
◗: Fair pollutant removal (15-30% TN, 30-60% Metals, 35-70% Bacteria)
●: Cannot meet management goal.
Poor pollutant removal (<15% TN, <30 Metals, <35% Bacteria)
❶: In most cases, cannot meet this goal, but the design may be adapted to add storage.
❷: Generally cannot meet this goal, except in areas with soil percolation rates greater than 5.0 in/hr

Section 7.5 Community and Environmental Factors

The last step assesses community and environmental factors involved in SMP selection. This matrix employs a comparative index approach (Table 7.5.). An open circle indicates that the SMP has a high benefit and a dark circle indicates that the particular SMP has a low benefit.

Ease of Maintenance. This column assesses the relative maintenance effort needed for an SMP, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that **all SMPs** require routine inspection and maintenance.

Community Acceptance. This column assesses community acceptance, as measured by three factors: market and preference surveys, reported nuisance problems, and visual orientation (i.e., is it prominently located or is it in a discrete underground location). It should be noted that a low rank can often be improved by a better landscaping plan.

Affordability. The SMPs are ranked according to their relative construction cost per impervious acre treated.

Safety. A comparative index that expresses the relative safety of an SMP. An open circle indicates a safe SMP, while a darkened circle indicates deep pools may create potential safety risks. The safety factor is included at this stage of the screening process because liability and safety are of paramount concern in many residential settings.

Habitat. SMPs are evaluated on their ability to provide wildlife or wetland habitat, assuming that an effort is made to landscape them appropriately. Objective criteria include size, water features, wetland features and vegetative cover of the SMP and its buffer.

Table 7.5 Community and Environmental Factors Matrix

SMP Group	SMP List	Ease of Maintenance	Community Acceptance	Affordability	Safety	Habitat
Ponds	Micropool ED	◗	◗	❍	❍	◗
	Wet Pond	❍	❍	❍	●	❍
	Wet ED Pond	❍	❍	❍	●	❍
	Multiple Pond	❍	❍	◗	●	❍
	Pocket Pond	●	◗	❍	◗	●
Wetlands	Shallow Wetland	◗	❍	◗	❍	❍
	ED Wetland	◗	◗	◗	◗	❍
	Pond/Wetland	❍	❍	◗	●	❍
	Pocket Wetland	●	●	❍	❍	◗
Infiltration	Infiltration Trench	●	❍	◗	❍	●
	Shallow I-Basin	●	●	◗	❍	●
	Dry Well	●	◗	◗	❍	●
Filters	Surface SF	◗	◗	●	❍	●
	Underground SF	●	❍	●	◗	●
	Perimeter SF	●	❍	●	❍	●
	Organic SF	◗	❍	●	❍	●
	Bioretention	◗	◗	◗	❍	◗
Open Channels	Dry Swale	❍	❍	◗	❍	●
	Wet Swale	❍	◗	❍	❍	◗

Chapter 8

Stormwater Management Design Examples

Chapter 8: Stormwater Management Design Examples

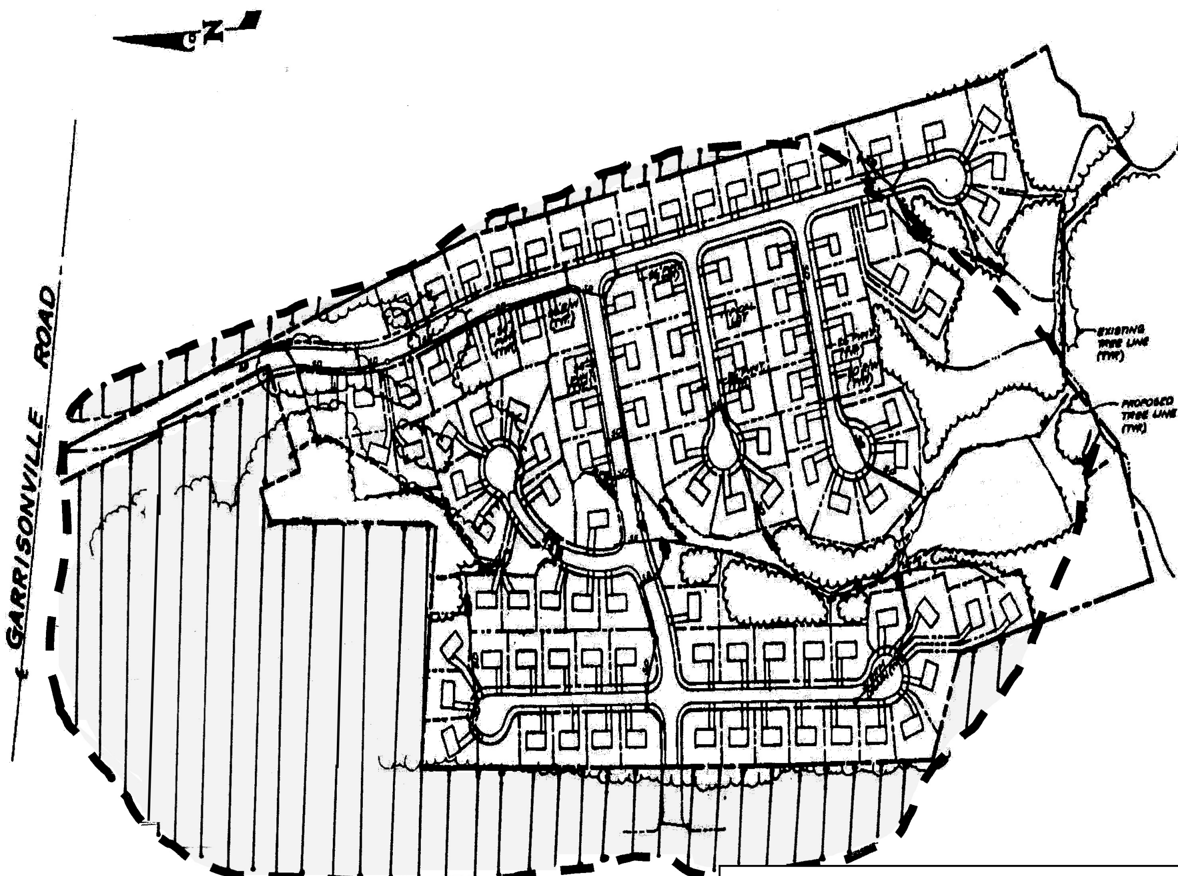
This chapter presents design examples for two hypothetical development sites in the State of New York. The first site, "Stone Hill Estates," is a residential development near Ithaca. The second is a commercial site in Albany. The chapter is divided into five sections, each of which focuses on a particular element of stormwater management design.

- Section 8.1 provides an example of detailed hydrology calculations at the residential site.
- Section 8.2 presents a pond design example based on the hydrology calculated in Section 8.1. This design example demonstrates the hydrologic and hydraulic computations to achieve water quality and water quantity control for stormwater management. Other specific dam design criteria such as soil compaction, structural appurtenances, embankment drainage, outlet design, gates, reservoir drawdown requirements, etc. are stated in Guidelines For Design of Dams.
- This design example in Section 8.2 requires an Article 15 Permit from NYS-DEC since the dam is 15 feet high measured from the top of dam to the low elevation at the downstream outlet, and the storage measured behind the structure to the top of the dam is 2.2 MG.
- Sections 8.3 through 8.5 present design examples for three practices on the commercial site: a sand filter, infiltration trench, and bioretention practice.

Section 8.1 Sizing Example - Stone Hill Estates

Following is a sizing example for the hypothetical "Stone Hill Estates," a 45-acre residential development in Ithaca, New York (Figure 8.1). The site also drains approximately 20 acres of off-site drainage, which is currently in a meadow condition. The site is on mostly C soils with some D soils.

Figure 8.1 Stone Hill Site Plan



Drainage Area = ▬ ▬ ▬ ▬
Offsite Drainage = Light Gray Fill/ Hatch

<u>Base Data</u>
Location: Ithaca, NY
Site Area = 45.1 ac; Offsite Area = 20.0 ac (meadow)
Total Drainage Area (A) = 65.1
Measured Impervious Area=12.0 ac;
Site Soils Types: 78% "C", 22% "D"
Offsite Soil Type: 100% "C"
Zoning: Residential (½ acre lots)

<u>Hydrologic Data</u>

	Pre	Post	Ult.
CN	72	78	82
t_c (hr)	.46	.35	.35

Computation of Preliminary Stormwater Storage Volumes and Peak Discharges

The layout of the Stone Hill subdivision is shown on the previous page.

Water Quality Volume, WQ_v

- Compute Impervious Cover

  Use both on-site and off-site drainage:

$$I = 12.0 \text{ acres}/65.1 \text{ acres}$$
$$= 18.4\%$$

- Compute Runoff Coefficient, R_v

$$R_v = 0.05 + (I)(0.009)$$
$$= 0.05 + (18.4)(0.009) = 0.22$$

- Compute WQ_v (Includes both on-site and off-site drainage)

Use the 90% capture rule with 0.9" of rainfall. (From Figure 4.1)

$$WQ_v = (0.9")(R_v)(A)$$
$$= (0.9")(0.22)(65.1 \text{ ac})(1\text{ft}/12\text{in})$$
$$= \underline{1.07 \text{ ac-ft}}$$

Establish Hydrologic Input Parameters and Develop Site Hydrology (see Figures 8.2, 8.3, and 8.4)

Condition	**Area**	**CN**	**Tc**
	Ac		*hrs*
Pre-developed	65.1	72	0.46
Post-developed	65.1	78	0.35
Ultimate buildout*	65.1	82	0.35

*Zoned land use in the drainage area.

Hydrologic Calculations

Condition	**$Q_{1\text{-yr}}$**	**$Q_{1\text{-yr}}$**	**$Q_{10\text{-yr}}$**	$Q_{100\text{-yr}}$
Runoff	*inches*	*cfs*	*cfs*	*cfs*
Pre-developed	0.4	19	72	141
Post-developed	0.7	38	112	202
Ultimate buildout	NA	NA	NA	227

PEAK DISCHARGE SUMMARY				
JOB:	STONE HILL			EWB
DRAINAGE AREA NAME:	PRE DEVELOPMENT			21-Jan-97
COVER DESCRIPTION	**SOIL NAME**	**GROUP A,B,C,D?**	**Curve Number**	**AREA (In acres)**
MEADOW		C	71	20.25 Ac.
MEADOW		D	78	7.95 Ac.
WOOD		C	70	15.09 Ac.
WOOD		D	77	1.81 Ac.
OFF-SITE MEADOW		C	71	20.00 Ac.
			AREA SUBTOTALS:	**65.10 Ac.**
Time of Concentration 2-Yr 24 Hr Rainfall = 2.7 In	Surface Cover / **Cross Section**	Manning 'n' / **Wetted Per**	Flow Length / **Avg Velocity**	Slope / **Tt (Hrs)**
Sheet Flow	dense grass	'n'=0.24	150 Ft.	3.80% / **0.28 Hrs**
Shallow Flow	UNPAVED		1300 Ft. / **2.65 F.P.S.**	2.70% / **0.14 Hrs.**
Channel Flow Hydraulic Radius =1.26	22.0 SqFt	'n'=0.040 / 17.5 Ft.	1100 Ft. / **7.14 F.P.S.**	2.70% / **0.04 Hrs.**
Total Area in Acres =	**65.10 Ac.**	**Total Sheet Flow= 0.28 Hrs.**	**Total Shallow Flow= 0.14 Hrs.**	**Total Channel Flow = 0.04 Hrs.**
Weighted CN =	**72**			
Time Of Concentration =	**0.46 Hrs.**			
Pond Factor =	**1**	**RAINFALL TYPE II**		
STORM	***Precipitation* (P) inches**	***Runoff* (Q)**	**Qp, PEAK DISCHARGE**	**TOTAL STORM Volumes**
1 Year	**2.3 In.**	**0.4 In.**	**18.6 CFS**	101,195 Cu. Ft.
2 Year	**2.7 In.**	**0.6 In.**	**30.2 CFS**	150,257 Cu. Ft.
10 Year	**3.9 In.**	**1.4 In.**	**72 CFS**	328,570 Cu. Ft.
100 Year	**5.5 In.**	**2.6 In.**	**141 CFS**	611,958 Cu. Ft.

Figure 8.2 Stone Hill Pre-Development Conditions

PEAK DISCHARGE SUMMARY				
JOB:	STONE HILL			EWB
DRAINAGE AREA NAME:	POST DEVELOPMENT			21-Jan-97
COVER DESCRIPTION	SOIL NAME	GROUP A,B,C,D?	Curve	AREA (In acres)
MEADOW		C	71	0.16 Ac.
MEADOW		D	78	0.14 Ac.
WOOD		C	70	3.09 Ac.
WOOD		D	77	1.81 Ac.
IMPERVIOUS			98	12.00 Ac.
GRASS		C	74	20.09 Ac.
GRASS		D	80	7.81 Ac.
OFFSITE MEADOW		C	71	20.00 Ac.
			AREA SUBTOTALS:	65.10 Ac.

Time of Concentration 2-Yr 24 Hr Rainfall = 2.7 In	Surface Cover Cross Section	Manning 'n' Wetted Per	Flow Length Avg Velocity	Slope Tt (Hrs)
Sheet Flow	dense grass	'n'=0.24	100 Ft.	3.80% 0.20 Hrs
Shallow Flow (a)	UNPAVED		100 Ft. 1.98 F.P.S.	1.50% 0.01 Hrs.
(b)	PAVED		400 Ft. 2.03 F.P.S.	1.00% 0.05 Hrs.
Channel Flow (a) Hydraulic Radius =0.50	1.6 SqFt	'n'=0.013 3.2 Ft.	1550 Ft. 7.22 F.P.S.	1.00% 0.06 Hrs.
(b) Hydraulic Radius =1.42	12.0 SqFt	'n'=0.030 8.5 Ft.	350 Ft. 13.01 F.P.S.	4.30% 0.01 Hrs.
(c) Hydraulic Radius =1.26	22.0 SqFt	'n'=0.040 8.5 Ft.	300 Ft. 7.89 F.P.S.	3.30% 0.01 Hrs.
Total Area in Acres =	65.10 Ac.	Total Sheet Flow= 0.20 Hrs.	Total Shallow Flow= 0.07 Hrs.	Total Channel Flow = 0.08 Hrs.
Weighted CN =	78			
Time Of Concentration =	0.35 Hrs.			
Pond Factor =	1	RAINFALL TYPE II		
STORM	Precipitation (P) inches	Runoff (Q)	Qp, PEAK DISCHARGE	TOTAL STORM Volumes
1 Year	2.3 In.	0.7 In.	37.6 CFS	156,283 Cu. Ft.
2 Year	2.7 In.	0.9 In.	54.0 CFS	217,511 Cu. Ft.
10 Year	3.9 In.	1.8 In.	112 CFS	427,155 Cu. Ft.
100 Year	5.5 In.	3.1 In.	202 CFS	742,265 Cu. Ft.

Figure 8.3 Stone Hill Post-Development Conditions

PEAK DISCHARGE SUMMARY				
JOB:	STONE HILL			EWB
DRAINAGE AREA NAME:	ULTIMATE BUILDOUT			21-Jan-97
COVER DESCRIPTION	SOIL NAME	GROUP A,B,C,D?	Curve	AREA (In acres)
MEADOW		C	71	0.16 Ac.
MEADOW		D	78	0.14 Ac.
WOOD		C	70	3.09 Ac.
WOOD		D	77	1.81 Ac.
IMPERVIOUS			98	12.00 Ac.
GRASS		C	74	20.09 Ac.
GRASS		D	80	7.81 Ac.
OFFSITE ULTIMATE				
SF RES (0.25 AC LOTS)		C	83	20.00 Ac.
		AREA SUBTOTALS:		65.10 Ac.
Time of Concentration 2-Yr 24 Hr Rainfall = 2.7 In	Surface Cover Cross Section	Manning 'n' Wetted Per	Flow Length Avg Velocity	Slope Tt (Hrs)
Sheet Flow	dense grass	'n'=0.24	100 Ft.	3.80% 0.20 Hrs
Shallow Flow (a)	UNPAVED		100 Ft. 1.98 F.P.S.	1.50% 0.01 Hrs.
(b)	PAVED		400 Ft. 2.03 F.P.S.	1.00% 0.05 Hrs.
Channel Flow (a) Hydraulic Radius =0.50	1.6 SqFt	'n'=0.013 3.2 Ft.	1550 Ft. 7.22 F.P.S.	1.00% 0.06 Hrs.
(b) Hydraulic Radius =1.42	12.0 SqFt	'n'=0.030 8.5 Ft.	350 Ft. 13.01 F.P.S.	4.30% 0.01 Hrs.
(c) Hydraulic Radius =1.26	22.0 SqFt	'n'=0.040 8.5 Ft.	300 Ft. 7.89 F.P.S.	3.30% 0.01 Hrs.
Total Area in Acres =	65.10 Ac.	Total Sheet	Total Shallow	Total Channel
Weighted CN =	82	Flow=	Flow=	Flow =
Time Of Concentration =	0.35 Hrs.	0.20 Hrs.	0.07 Hrs.	0.08 Hrs.
Pond Factor =	1	RAINFALL TYPE II		
STORM	Precipitation (P) inches	Runoff (Q)	Qp, PEAK DISCHARGE	TOTAL STORM Volumes
1 Year	2.3 In.	0.9 In.	50.9 CFS	201,772 Cu. Ft.
2 Year	2.7 In.	1.1 In.	70.0 CFS	271,097 Cu. Ft.
10 Year	3.9 In.	2.1 In.	135 CFS	500,458 Cu. Ft.
100 Year	5.5 In.	3.5 In.	227 CFS	834,167 Cu. Ft.

Figure 8.4 Stone Hill Ultimate Buildout Conditions

Compute Stream Channel Protection Volume, (Cp_v) (see Section 4.3 and Appendix B)

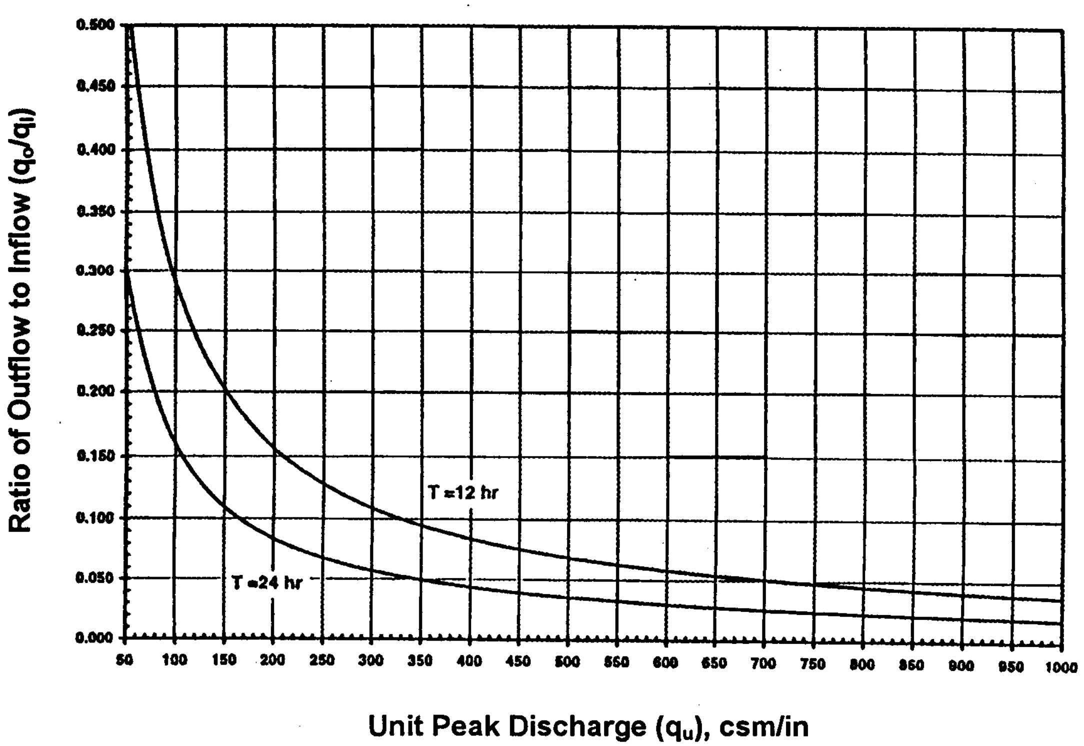
For stream channel protection, provide 24 hours of extended detention (T) for the one-year event.

<u>Compute Channel Protection Storage Volume</u>

First, determine the value of the unit peak discharge (q_u) using TR-55 and Type II Rainfall Distribution

- Initial abstraction (Ia) for CN of 78 is 0.564: [Ia = (200/CN - 2)]
- Ia/P = (0.564)/ 2.3 inches = 0.245
- T_c = 0.35 hours
- Using the above data, q_u = 570 csm/in (cubic feet per second per square mile per year)

Figure 8.5 Detention Time vs. Discharge Ratios (Source: MDE, 2000)



- Knowing q_u and T = 24 hours, find q_o/q_i using Figure 8.5 (also see methodology in Appendix B)
- Peak outflow discharge/peak inflow discharge $(q_o/q_i) = 0.035$
- $Vs/Vr = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3$ (from Appendix B)

  Where Vs equals channel protection storage (Cp_v) and Vr equals the volume of runoff in inches.
- Vs/Vr = 0.63 and, from figure 8.3, Q = 0.7"
- Solving for V_s

  $Vs = Cp_v = 0.63(0.7")(1/12)(65.1\text{ ac}) = 2.4$ ac-ft (104,214 cubic feet)

Define the Average Release Rate

- The above volume, 2.4 ac-ft, is to be released over 24 hours
- $(2.4\text{ ac-ft} \times 43{,}560\text{ ft}^2/\text{ac}) / (24\text{ hrs} \times 3{,}600\text{ sec/hr}) = 1.2$ cfs

Compute Overbank Flood Protection Volume, (Qp_{10}) (see Section 4.4)

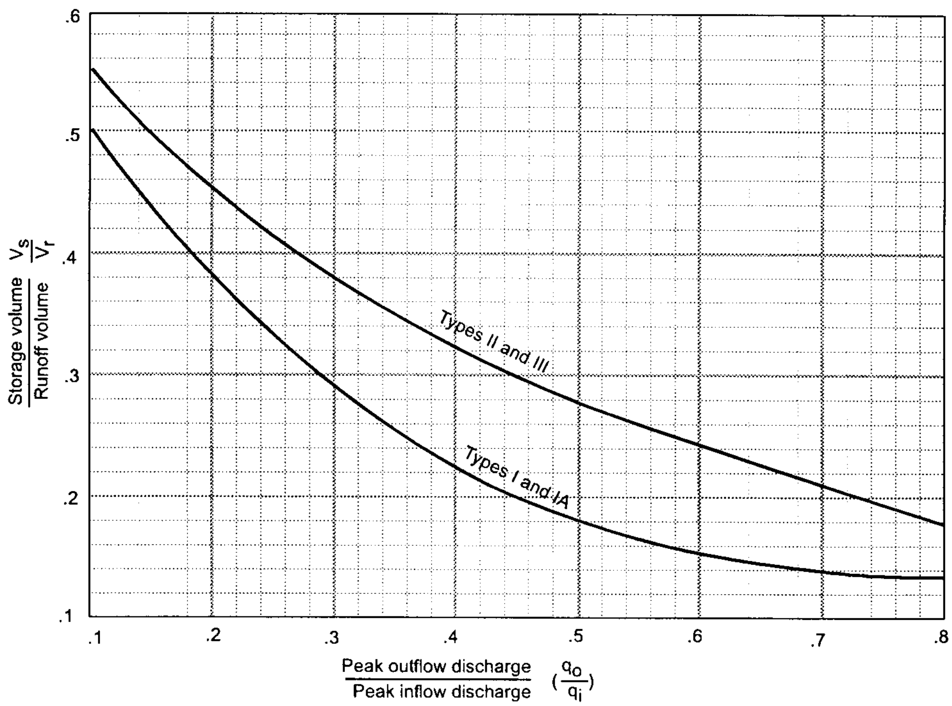
For both the overbank flood protection volume and the extreme flood protection volume, size is determined using the TR-55 "Short-Cut Method," which relates the storage volume to the required reduction in peak flow and storm inflow volume (Figure 8.6).

- For a q_i of of 112 cfs (post-developed), and an allowable q_o of 72 cfs (pre-developed), the value of $(q_o)/(q_i)$ is 0.64
- Using figure 8.6, and a post-developed curve number of 78, Vs/Vr = 0.23
- Using a total storm runoff volume of 427,155 cubic feet (9.8 acre-feet), the required storage (Vs) is:

  $V_s = Qp_v = 0.23(427{,}155)/43{,}560 = 2.26$ acre-feet

Figure 8.6 Approximate Detention Basin Routing for Rainfall Types I, IA, II, and III

Source: TR-55, 1986



While the TR-55 short-cut method reports to incorporate multiple stage structures, experience has shown that an additional 10-15% storage is required when multiple levels of extended detention are provided inclusive with the 10-year storm. So, for preliminary sizing purposes, add 15% to the required volume for the 10-year storm. $Q_{p\text{-}10} = 2.23 \times 1.15 = 2.59$ ac-ft.

Compute Extreme Flood Protection Volume, (Q_f)

Extreme flood protection is calculated using the same methodology as overbank protection.

- For a Q_{in} of, and an allowable Q_{out} of, and a runoff volume of the Vs necessary for 100-year control is, under a developed CN of 78. Note that 5.5 inches of rain fall during this event, with approximately 3.1 inches of runoff.
- While the TR-55 short-cut method reports to incorporate multiple stage structures, experience has shown that an additional 10-15% storage is required when multiple levels of extended detention are provided inclusive with the 100-year storm. So, for preliminary sizing purposes add 15% to the required volume for the 100-year storm. $Q_{f\text{-}100} = 3.53 \times 1.15 = 4.06$ ac-ft.

Analyze Safe Passage of 100-Year Design Storm (Qf)

If peak discharge control of the 100-year storm is not required, it is still necessary to provide safe passage for the 100-year event under ultimate buildout conditions (Q_{ult} = 227 cfs).

Section 8.2 Pond Design Example

Following is a step-by-step design example for an extended detention pond (P-3) applied to Stone Hill Estates, which is described in detail in Section 8.1 along with design treatment volumes. This example continues with the design to develop actual design parameters for the constructed facility.

Step 1. Compute preliminary runoff control volumes.

The volume requirements were determined in Section 8.1. Table 8.1 provides a summary of the storage requirements.

Table 8.1. Summary of General Storage Requirements for Stone Hill Estates

Symbol	*Category*	Volume Required (ac- ft)	*Notes*
WQ_v	Water Quality Volume	1.07	
Cp_v	Stream Protection	2.4	Average ED release rate is 1.2 cfs over 24 hours
Q_p	Peak Control	2.6	10-year, in this case
Q_f	Flood Control	4.1	

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater pond.

The drainage area to the pond is 65.1 acres. Existing ground at the proposed pond outlet is 619 MSL. Soil boring observations reveal that the seasonally high water table is at elevation 618. The underlying soils are SC (sandy clay) and are suitable for earthen embankments and to support a wet pond without a liner. The stream invert at the adjacent stream is at elevation 616.

Step 3. Confirm local design criteria and applicability.

There are no additional requirements for this site.

Step 4. Determine pretreatment volume.

Size wet forebay to treat 10% of the WQ_v. (10%)(1.07 ac-ft) = **0.1 ac-ft**
(forebay volume is included in WQ_v as part of permanent pool volume)

Step 5. Determine permanent pool volume and ED volume.

Size permanent pool volume to contain 50% of WQ_v:
$0.5 \times (1.07$ ac-ft$)$ = **0.54 ac-ft**. (includes 0.1 ac-ft of forebay volume)

Size ED volume to contain 50% of WQ_v: $0.5 \times (1.07$ ac-ft$)$ = **0.54 ac-ft**

NOTE

THIS DESIGN APPROACH ASSUMES THAT ALL OF THE ED VOLUME 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 ED CONTROL OVER A WIDER RANGE OF STORMS, NOT JUST THE TARGET RAINFALL.

Step 6. Determine pond location and preliminary geometry. Conduct pond grading and determine storage available for WQv permanent pool and WQv-ED if applicable.

This step involves initially grading the pond (establishing contours) and determining the elevation-storage relationship for the pond. Storage must be provided for the permanent pool (including sediment forebay), extended detention (WQ_v-ED), Cp_v-ED, 10-year storm, 100-year storm, plus sufficient additional storage to pass the ultimate condition 100-year storm with required freeboard. An elevation-storage table and curve is prepared using the average area method for computing volumes. See Figure 8.7 for pond location on site, Figure 8.8 for grading and Figure 8.9 for Elevation-Storage Data.

Figure 8.7 Pond Location on Site

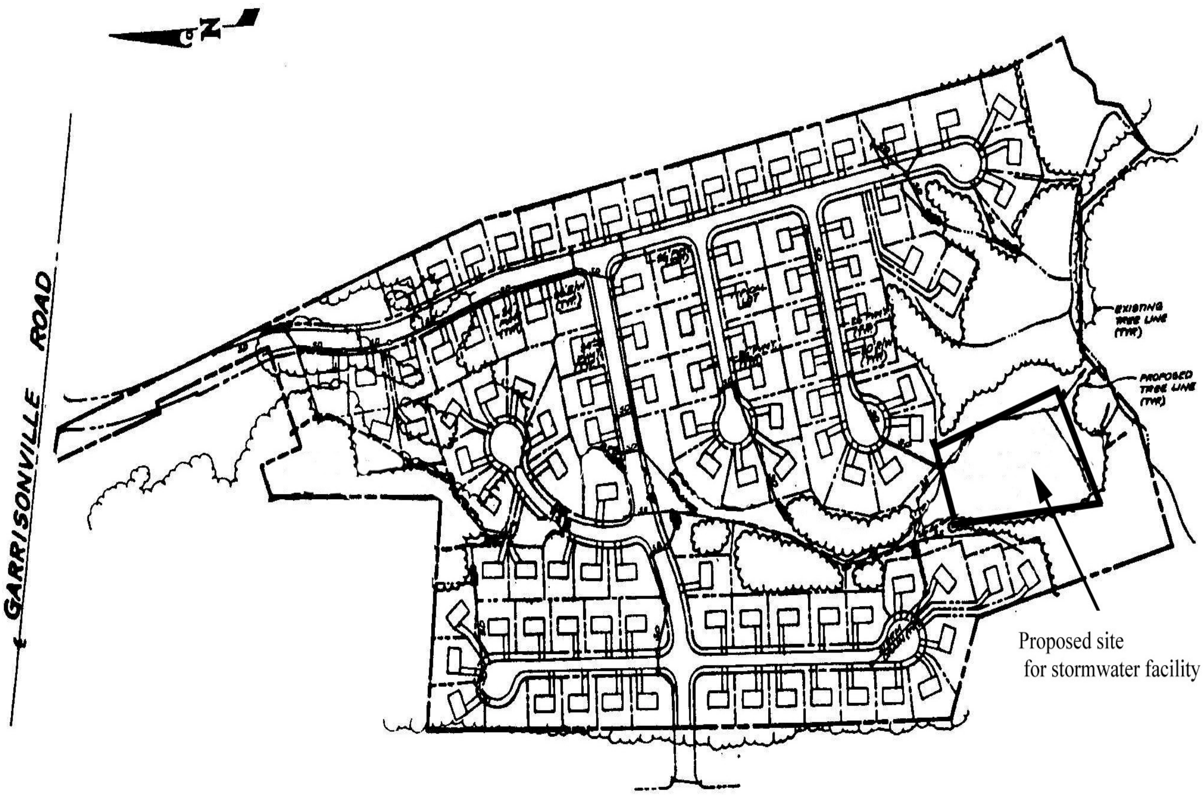


Figure 8.8 Plan View of Pond Grading (Not to Scale)

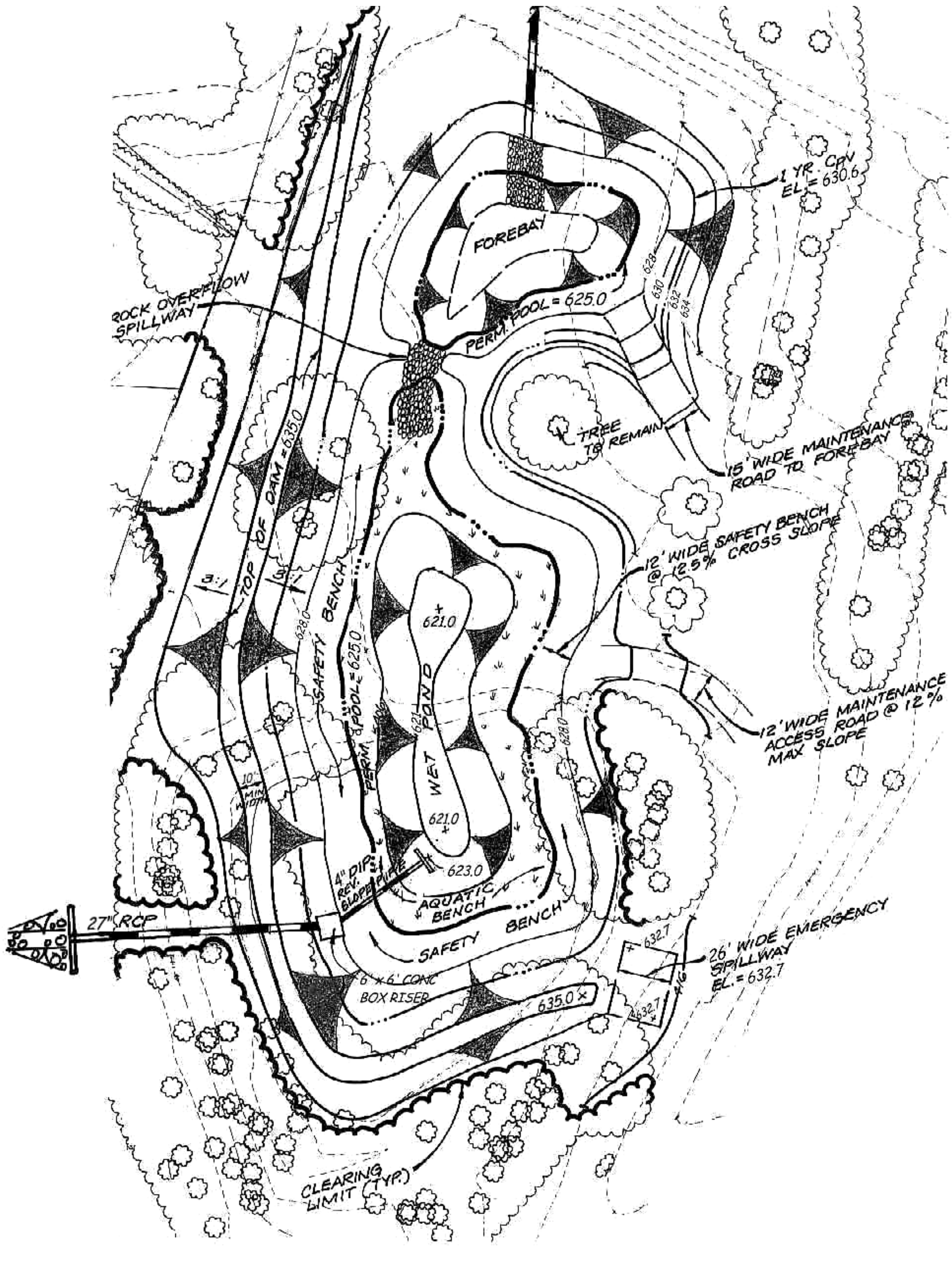
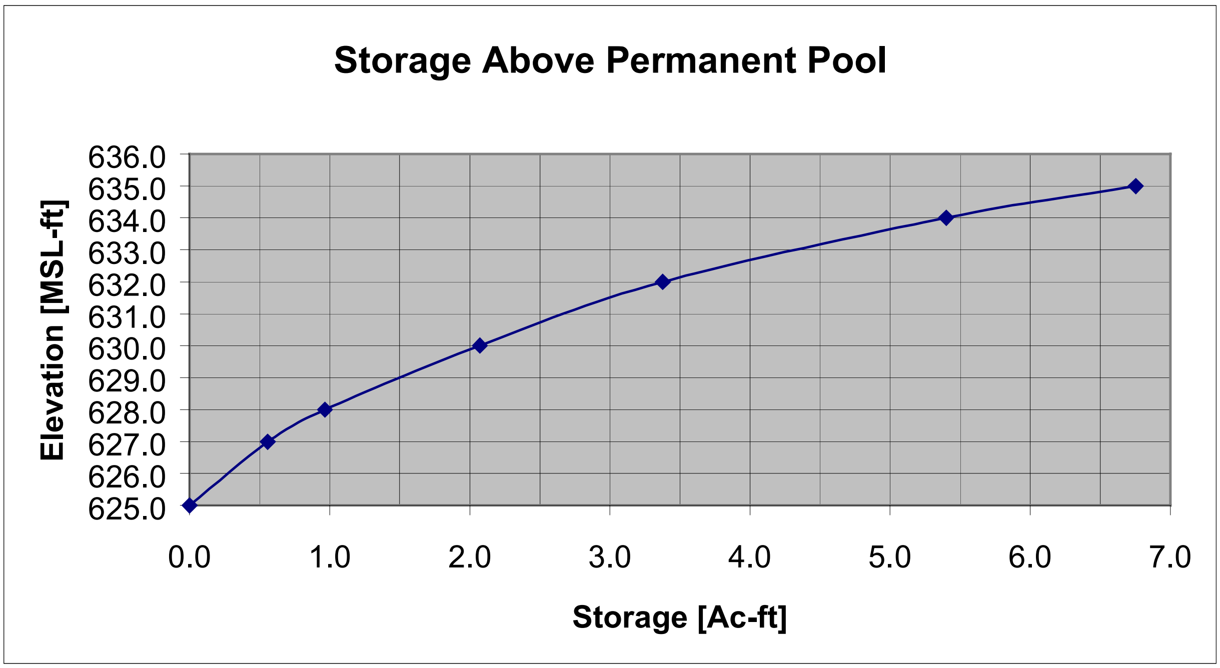


Figure 8.9 Storage-Elevation Table/Curve

Elevation MSL	Area ft^2	Average Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume ac-ft	Volume Above Permanent Pool ac-ft
621.0	3150						
624.0	8325	5738	3	17213	17213	0.40	
625.0	10400	9363	1	9363	26575	0.61	0
627.0	13850	12125	2	24250	50825	1.17	0.56
628.0	21850	17850	1	17850	68675	1.58	0.97
630.0	26350	24100	2	48200	116875	2.68	2.07
632.0	30475	28413	2	56825	173700	3.99	3.38
634.0	57685	44080	2	88160	261860	6.01	5.40
635.0	60125	58905	1	58905	320765	7.36	6.75



Set basic elevations for pond structures

- The pond bottom is set at elevation 621.0
- Provide gravity flow to allow for pond drain, set riser invert at 620.5
- Set barrel outlet elevation at 620.0

Set water surface and other elevations

- Required permanent pool volume = 50% of WQv = 0.54 ac-ft. From the elevation-storage table, read elevation 625.0 (0.61 ac-ft > 0.54 ac-ft) site can accommodate it and it allows a small safety factor for fine sediment accumulation – OK

Set permanent pool wsel = 625.0

- Forebay volume provided in single pool with volume = 0.1 ac-ft - OK
- Required extended detention volume (WQ_v-ED)= 0.54 ac-ft. From the elevation-storage table (volume above permanent pool), read elevation 627.0 (0.56 ac-ft > 0.54 ac-ft) OK. Set ED wsel = 627.0

Note: Total storage at elevation 627.0 = 1.17 ac-ft (greater than required WQ_v of 1.07 ac-ft)

Compute the required WQ_v-ED orifice diameter to release 0.54 ac-ft over 24 hours

- Avg. ED release rate = (0.54 ac-ft)(43,560 ft^2/ac)/(24 hr)(3600 sec/hr) = 0.27 cfs
- Invert of orifice set at wsel = 625.0
- Average head = (627.0 - 625.0)/ 2 = 1.0'
- Use orifice equation to compute cross-sectional area and diameter

  $Q = CA(2gh)^{0.5}$, for Q=0.27 cfs h = 1.0 ft; C = 0.6 = discharge coefficient. Solve for A

  $A = 0.27 \text{ cfs} / [(0.6)((2)32.2 \text{ ft/s}^2)(1.0 \text{ ft}))^{0.5}]$ $A = 0.057 \text{ ft}^2$, $A = \pi d^2 / 4$;

  dia. = 0.26 ft = 3.2", say 3.0 inches

  <u>Use 4" pipe with 4" gate valve to achieve equivalent diameter</u>

Compute the stage-discharge equation for the 3.0" dia. WQv orifice

- $Q_{WQv\text{-}ED} = CA(2gh)^{0.5} = (0.6)(0.052 \text{ ft}^2)[((2)(32.2 \text{ ft/s}^2))^{0.5}](h^{0.5})$,
- <u>$Q_{WQv\text{-}ED} = (0.25)\, h^{0.5}$, where: h = wsel - 625.125</u>

  (Note: Account for one half of orifice diameter when calculating head)

Step 7. Compute ED orifice size, and compute release rate for Cpv-ED control and establish Cpv elevation.

Set the Cp_v pool elevation

- Required Cp_v storage = 2.4 ac-ft (see Table 1).
- From the elevation-storage table, read elevation 630.6 (this includes the WQ_v).
- Set Cp_v wsel = 630.6

Size Cp_v orifice

- Size to release average of 1.2 cfs.
- Set invert of orifice at wsel = 627.0
- Average WQ_v-ED orifice release rate is 0.41 cfs, based on average head of 2.74' ((630.6 – 625.125)/2)
- Cp_v-ED orifice release = 1.2 -0.41 = 0.79 cfs
- Head = (630.6 - 627.0)/2 = 1.8'

Use orifice equation to compute cross-sectional area and diameter

- $Q = CA(2gh)^{0.5}$, for h = 1.8'
  - $A = 0.79 \text{ cfs} / [(0.6)((2)(32.2'/s^2)(1.8'))^{0.5}]$
  - $A = 0.12 \text{ ft}^2$, $A = \pi d^2 / 4$;
  - dia. = 0.39 ft = 4.7"
  - Use 6" pipe with 6" gate valve to achieve equivalent diameter

Compute the stage-discharge equation for the 4.7" dia. Cp_v orifice

- $Q_{Cpv\text{-}ED} = CA(2gh)^{0.5} = (0.6)\ (0.12 \text{ ft}^2)\ [((2)\ (32.2'/s^2))^{0.5}]\ (h^{0.5})$,
- $Q_{Cpv\text{-}ED} = (0.58)\ (h^{0.5})$, where: h = wsel – 627.2

(Note: Account for one half of orifice diameter when calculating head)

Step 8. Calculate Qp_{10} (10 year storm) release rate and water surface elevation.

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

Develop basic data and information

- The 10 year pre-developed peak discharge = 72 cfs,
- The post developed inflow = 112 cfs, from Table 1,
- From previous estimate Q_{p-10} = 2.26 ac-ft. Adding 15% to account for ED storage yields a preliminary volume of 2.56 ac-ft.
- From elevation-storage table (Figure 8.9), read elevation 631.0.
- Size 10 year slot to release 72 cfs at elevation 631.0.

@ wsel 631.0:

- WQ_v-ED orifice releases 0.61 cfs,
- Cp_v-ED orifice releases 1.13 cfs, therefore;
- Allowable Q_{p-10} = 72 cfs - (.61 + 1.13) = 70.26 cfs, say 70.3 cfs.
- Set weir crest elevation at wsel = 630.6
- Max head = (631.0 – 630.6) = 0.4'

Use weir equation to compute slot length

- $Q = CLh^{3/2}$
- $L = 70.3 \text{ cfs} / (3.1)(0.4^{3/2}) = 89.6 \text{ ft}$
- This weir length is impractical, so adjust max head (and therefore slot height) to 1.5' and recalculate weir length.
- $L = 70.3 \text{ cfs} / (3.1)(1.5^{3/2}) = 12.3 \text{ ft}$
- <u>Use three 5ft x 1.5 ft slots for 10-year release</u> (opening should be slightly larger than needed so as to have the barrel control before slot goes from weir flow to orifice flow).
- Maximum $Q = (3.1)(15)(1.5)^{3/2} = 85.4$ cfs

Check orifice equation using cross-sectional area of opening

- $Q = CA(2gh)^{0.5}$, for h = 0.75' (For orifice equation, h is from midpoint of slot)
- $A = 3\,(5.0')\,(1.5') = 22.5\text{ft}^2$
- $Q = 0.6\,(22.5\text{ft}^2)\,[(64.4)(0.75)]^{0.5} = 93.8$ cfs > 85.4 cfs, so use weir equation

$$Q_{10} = (3.1)\,(15')\,h^{3/2}\ ,\ \underline{Q_{10} = (46.5)\,h^{3/2},\text{ where } h = \text{wsel} - 630.6}$$

- Size barrel to release approximately 70.3 cfs at elevation 632.1 (630.6 + 1.5)
- Check inlet condition: (use FHWA culvert charts)

H_w = 632.1-620.5 = 11.6 ft

- Try 27" diameter RCP, Using FHWA Chart ("Headwater Depth for Concrete Pipe Culverts with Inlet Control") with entrance condition 1
- H_w / D = 11.6/2.25 = 5.15, Discharge = 69 cfs
- Check outlet condition (use NRCS pipe flow equation from NEH Section 5 ES-42):
- $Q = a [(2gh)/(1+k_m+k_pL)]^{0.5}$

where:
- Q = discharge in cfs
- a = pipe cross sectional area in ft^2
- g = acceleration of gravity in ft/sec^2
- h = head differential (wsel - downstream centerline of pipe or tailwater elev.)
- k_m = coefficient of minor losses (use 1.0)
- k_p = pipe friction loss coef. (= $5087n^2/d^{4/3}$, d in inches, n is Manning's n)
- L = pipe length in ft

h = 632.1 - (620.0 + 1.125) = 10.98'
for 27" RCP, approximately 70 feet long:
$Q = 4.0 [(64.4) (10.98) / (1+1+(0.0106) (70))]^{0.5} = 64.2$ cfs
64.2 cfs < 69 cfs, so barrel is outlet controlled and use outlet equation
$Q = 19.4 (h)^{0.5}$, where h = wsel – 621.125

Note: pipe will control flow before high stage inlet reaches max head.

Complete stage-storage-discharge summary (Figure 8.10) up to preliminary 10-year wsel (632.1) and route 10 year post-developed condition inflow using computer software (e.g., TR-20). Pond routing computes 10-year wsel at 632.5 with discharge = 65.4 cfs < 72 cfs, OK (see Figure 8.11).

Figure 8.10 Stage-Storage-Discharge Summary

Elevation MSL	Storage ac-ft	Low Flow WQv-ED 3.0" eq dia		Riser: Cpv-ED 4.7" eq. dia		Riser: High Stage Slot Orifice		Riser: High Stage Slot Weir		27" Barrel: Inlet		27" Barrel: Pipe		Emergency Spillway 26' earthen 3:1		Total Discharge
		H ft	Q cfs	H ft	Q cfs	H ft	Q cfs	H ft	Q cfs	H ft	Q cfs	H ft	Q cfs	H ft	Q cfs	Q cfs
625.0	0.00	0	0													0.00
625.5	0.14	0.4	0.15													0.15
626.0	0.28	0.9	0.23													0.23
626.5	0.42	1.4	0.29													0.29
627.0	0.56	1.9	0.34	0.0	0.00											0.34
627.5	0.77	2.4	0.39	0.3	0.32											0.70
628.0	0.97	2.9	0.42	0.8	0.52											0.94
629.0	1.52	3.9	0.49	1.8	0.78											1.27
629.5	1.80	4.4	0.52	2.3	0.88											1.40
630.0	2.07	4.9	0.55	2.8	0.97											1.52
630.6	2.40	5.5	0.58	3.4	1.07	-	-	0.0	0.0							1.65
631.0	2.73	5.9	0.61	3.8	1.13	-	-	0.4	11.8							13.5
632.1	3.45	7.0	0.66	4.9	1.28	0.75	94	1.5	85.4	11.6	69.0	11.0	64.2			64.2
632.5	3.80	7.4	0.68	5.3	1.34	0.95	106	-	-	12.0	70.0	11.4	65.4			65.4
632.7	4.10	7.6	0.69	5.5	1.36	1.05	111	-	-	12.2	71.0	11.6	66.0	0.0	0.0	66.0
633.3	4.70	-	-	-	-	-	-	-	-	12.8	72.0	12.2	67.6	0.6	26.0	93.6
634.0	5.40	-	-	-	-	-	-	-	-	13.5	73.0	12.9	69.6	1.3	95.0	164.6
635.0	6.75	-	-	-	-	-	-	-	-	14.5	86.0	13.9	72.2	2.3	251.0	323.2

Note: Adequate outfall protection must be provided in the form of a riprap channel, plunge pool, or combination to ensure non-erosive velocities.

Step 9. Calculate Qp_{100} (100-year storm) release rate and water surface elevation, size emergency spillway, calculate 100-year water surface elevation.

In order to calculate the 100-year release rate and water surface elevation, the designer must continue with the stage-storage-discharge relationship (Figure 8.10) for the control riser and emergency spillway.

Develop basic data and information

- The 100 year pre-developed peak discharge = 141 cfs,
- The post developed inflow = 202 cfs, from Table 1,
- From previous estimate $Q_{p\text{-}100}$ = 3.53 ac-ft. Adding 15% to account for ED storage yields a preliminary volume of 4.06 ac-ft.
- From elevation-storage table (Figure 8.10), read elevation 632.8, say 633.0.

The 10-year wsel is at 632.5. Set the emergency spillway at elevation at 632.7 (this allows for some additional storage above the 10-yr wsel) and use design information and criteria for Earth Spillways (not included in this manual).

- Size 100 year spillway to release 141 cfs at elevation 633.0.
- @ wsel 633.0:

- Outflow from riser structure is controlled by barrel (under outlet control), from Figure 8.11, read Q = 67.6 cfs at wsel = 633.3. Assume Q = 67 cfs at wsel = 633.0.
- Set spillway invert at wsel = 632.7
- Try 26' wide vegetated emergency spillway with 3:1 side slopes.
- Finalize stage-storage-discharge relationships and perform pond routing

Pond routing (TR-20) computes 100-year wsel at 633.76 with discharge = 140.95 cfs < 141 cfs, OK (see Figure 8.11).

Note: this process of sizing the emergency spillway and storage volume determination is usually iterative. This example reflects previous iterations at arriving at an acceptable design solution.

Step 10. Check for safe passage of Qp_{100} under ultimate buildout conditions and set top of embankment elevation.

The safety design of the pond embankment requires that the 100-year discharge, based on ultimate buildout conditions be able to pass safely through the emergency spillway with sufficient freeboard (one foot). This criteria does not mean that the ultimate buildout peak discharge be attenuated to pre-development rates.

From previous hydrologic modeling we know that:

- The 100 year ultimate buildout peak discharge = 227 cfs,
- The ultimate buildout composite curve number is 82.

Using TR-20 or equivalent routing model, determine peak wsel. Pond routing computes 100-year wsel at 634.0 with discharge = 192 cfs (Figure 8.12).

Therefore, with one foot of freeboard, the minimum embankment elevation is 635.0. Table 8.2 provides a summary of the storage, stage, and discharge relationships determined for this design example. See Figure 8.13 for a schematic of the riser.

Table 8.2 Summary of Controls Provided					
Control Element	**Type/Size of Control**	**Storage Provided**	**Elevation**	**Discharge**	**Remarks**
Units		Acre-feet	MSL	cfs	
Permanent Pool		0.61	625.0	0	part of WQ_v
Forebay	submerged berm	0.1	625.0	0	included in permanent pool vol.
Extended Detention (WQ_v-ED)	4" pipe, sized to 3.0" equivalent diameter	0.56	627.0	0.25	part of $WQ_{V.}$, vol. above perm. pool, discharge is average release rate over 24 hours
Channel Protection (Cp_v-ED)	6" pipe sized to 4.7" equivalent diameter	2.4	630.6	1.2	volume above perm. pool, discharge is average release rate over 24 hours
Overbank Protection (Q_{p-10})	Three 5' x 1.5' slots on a 6' x 6' riser, 30"barrel.	2.5	632.5	65.4	volume above perm. pool
Extreme Storm (Q_{f-100})	26' wide earth spillway	4.0	633.8	140.9	volume above perm. pool
Extreme Storm Ultimate Buildout	26' wide earth spillway	NA	634	192.0	Set minimum embankment height at 635.0

Figure 8.11 TR-20 Model Input and Output

```
*****************80-80 LIST OF INPUT DATA FOR TR-20 HYDROLOGY******************

JOB TR-20                    FULLPRINT                        NOPLOTS
TITLE      New York Manual Wet ED Example 1/01          EWB
TITLE      Post Developed Conditions Routing for 1, 10, and 100
 3 STRUCT       1
 8                    625.0       0.0         0.0
 8                    625.5       0.15        0.14
 8                    626.0       0.23        0.28
 8                    626.5       0.29        0.42
 8                    627.0       0.34        0.56
 8                    627.5       0.70        0.77
 8                    628.0       0.94        0.97
 8                    629.0       1.27        1.52
 8                    629.5       1.40        1.80
 8                    630.0       1.52        2.07
 8                    630.6       1.65        2.40
 8                    631.0       13.50       2.73
 8                    632.1       64.20       3.45
 8                    632.7       66.00       4.10
 8                    633.3       93.60       4.70
 8                    634.0       165.0       5.40
 8                    635.0       35230       6.75
 9 ENDTBL
 6 RUNOFF 1     1     2 0.102       78.0        0.35        1 1   0 0 1
 6 RESVOR 2     1 2   3 625.0                               1 1       1
   ENDATA
 7 INCREM 6           0.1
 7 COMPUT 7     1     1 0.0         2.3         1.0         2 2   1  01
   ENDCMP 1
 7 COMPUT 7     1     1 0.0         3.9         1.0         2 2   1  10
   ENDCMP 1
 7 COMPUT 7     1     1 0.0         5.5         1.0         2 2   1  99
   ENDCMP 1
   ENDJOB 2

*******************************END OF 80-80 LIST********************************
```

```
TR20 XEQ  1/22/**              New York Manual Wet ED Example 1/01         EWB                                  JOB  1   SUMMARY
     REV 09/01/83              Post Developed Conditions Routing for 1, 10, and 100                                      PAGE   8
```

SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
(A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH
A QUESTION MARK(?) INDICATES A HYDROGRAPH WITH PEAK AS LAST POINT.)

SECTION/ STRUCTURE ID	STANDARD CONTROL OPERATION	DRAINAGE AREA (SQ MI)	RAIN TABLE #	ANTEC MOIST COND	MAIN TIME INCREM (HR)	PRECIPITATION BEGIN (HR)	AMOUNT (IN)	DURATION (HR)	RUNOFF AMOUNT (IN)	PEAK DISCHARGE ELEVATION (FT)	TIME (HR)	RATE (CFS)	RATE CSM)
ALTERNATE 1 STORM 1													
STRUCTURE 1	RUNOFF	.10	2	2	.10	.0	2.30	24.00	.66	---	12.13	40.62	398.2
STRUCTURE 1	RESVOR	.10	2	2	.10	.0	2.30	24.00	.40	630.31	18.00?	1.59?	15.6
ALTERNATE 1 STORM 10													
STRUCTURE 1	RUNOFF	.10	2	2	.10	.0	3.90	24.00	1.81	---	12.11	118.47	161.5
STRUCTURE 1	RESVOR	.10	2	2	.10	.0	3.90	24.00	1.49	632.51	12.34	65.43	41.5
ALTERNATE 1 STORM 99													
STRUCTURE 1	RUNOFF	.10	2	2	.10	.0	5.50	24.00	3.14	---	12.11	206.59	025.4
STRUCTURE 1	RESVOR	.10	2	2	.10	.0	5.50	24.00	2.80	633.76	12.29	140.95	381.9

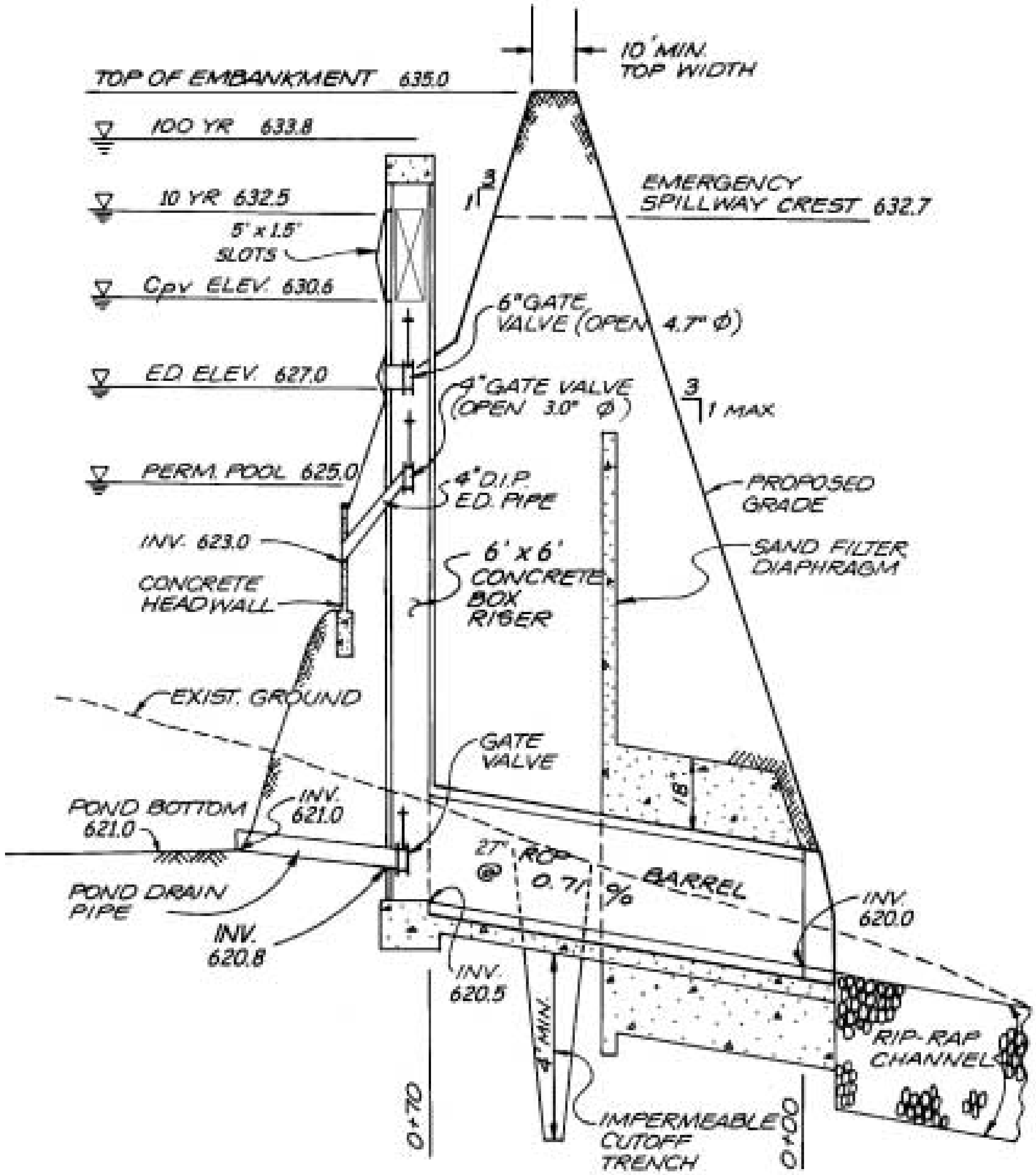
Figure 8.12 TR-20 Model Input and Output for Ultimate Buildout Conditions

```
TR20 XEQ  1/22/**              New York Manual Wet ED Example 1/01          EWB                                  JOB  1   SUMMARY
     REV 09/01/83              Ultimate Buildout Conditions for 100-yr                                                   PAGE   4


SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
                  (A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH
                   A QUESTION MARK(?) INDICATES A HYDROGRAPH WITH PEAK AS LAST POINT.)
```

SECTION/ STRUCTURE ID	STANDARD CONTROL OPERATION	DRAINAGE AREA (SQ MI)	RAIN TABLE #	ANTEC MOIST COND	MAIN TIME INCREM (HR)	PRECIPITATION BEGIN (HR)	PRECIPITATION AMOUNT (IN)	PRECIPITATION DURATION (HR)	RUNOFF AMOUNT (IN)	PEAK DISCHARGE ELEVATION (FT)	PEAK DISCHARGE TIME (HR)	PEAK DISCHARGE RATE (CFS)	PEAK DISCHARGE RATE (CSM)
ALTERNATE 1	STORM 99												
STRUCTURE 1	RUNOFF	.10	2	2	.10	.0	5.50	24.00	3.53	---	12.10	230.71	2261.9
STRUCTURE 1	RESVOR	.10	2	2	.10	.0	5.50	24.00	3.19	634.00	12.22	191.83	1880.7

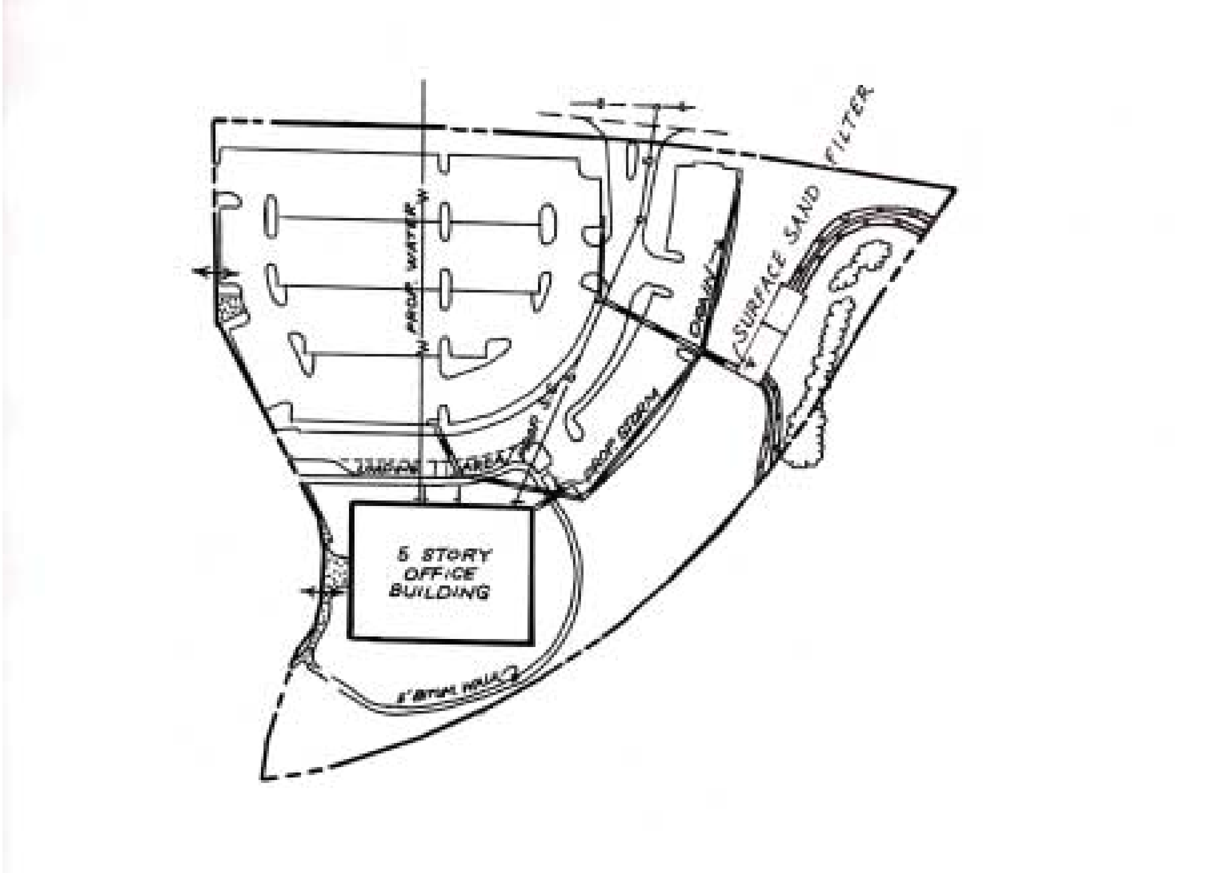
Figure 8.13 Profile of Principle Spillway



Section 8.3 Sand Filter Design Example

This design example focuses on the design of a sand filter for a 4.5-acre catchment of Lake Center, a hypothetical commercial site located in Albany, NY. A five-story office building and associated parking are proposed within the catchment. The layout is shown in Figure 8.14. The catchment has 3.05 acres of impervious cover, resulting in 68% impervious cover. The pre-developed site is a mixture of forest and meadow. On-site soils are predominantly HSG "B" soils.

Figure 8.14 Lake Center Site Plan



Base Data	Hydrologic Data		
Location: Albany, NY		**Pre**	**Post**
Site Area = Total Drainage Area (A) = 4.50 ac	CN	58	83
Impervious Area = 3.05 ac; or I =3.05/4.50 = 68%	t_c (hr)	.44	.10
Soils Type "B"			

This step-by-step example will focus on meeting the water quality requirements. Channel protection control, overbank flood control, and extreme flood control are not addressed in this example. Therefore, a detailed hydrologic analysis is not presented. For an example of detailed sizing calculations, consult section 8.1. In general, the primary function of sand filters is to provide water quality treatment and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility. For this example, the post-development 10-yr peak discharge is provided to appropriately size the necessary by-pass flow splitter. Where quantity control is required, bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults).

Step 1.	**Compute design volumes using the Unified Stormwater Sizing Criteria.**

Water Quality Volume, WQ_v

Select the Design Storm

Consulting Figure 4.1 of this document, use 1.0" as the 90% rainfall event for Albany.

<u>Compute Runoff Coefficient, R_v</u>

$R_v = 0.05 + (68)(0.009) = 0.66$

<u>Compute WQ_v</u>

$$\begin{aligned} WQ_v &= (1.0")(R_v)(A) / 12 \\ &= (1.0")(0.66)(4.5\text{ ac})(43{,}560\text{ft}^2/\text{ac})(1\text{ft}/12\text{in}) \\ &= \underline{10{,}781}\text{ ft}^3 = \underline{0.25\text{ ac-ft}} \end{aligned}$$

Develop Site Hydrologic Input Parameters and Perform Preliminary Hydrologic Calculations (see Table 8.3)

Note: For this design example, the 10-year peak discharge is given and will be used to size the bypass flow splitter. Any hydrologic models using SCS procedures, such as TR-20, HEC-HMS, or HEC-1, can be used to perform preliminary hydrologic calculations.

Table 8.3 Site Hydrology					
Condition	**CN**	**Q_1**	**Q_2**	**Q_{10}**	**Q_{100}**
		cfs	*cfs*	*cfs*	*cfs*
Pre-developed	58	0.2	0.4	3	9
Post-Developed	83	7	10	19	36

Step 2. Determine if the development site and conditions are appropriate for the use of a surface sand filter.

Site Specific Data:

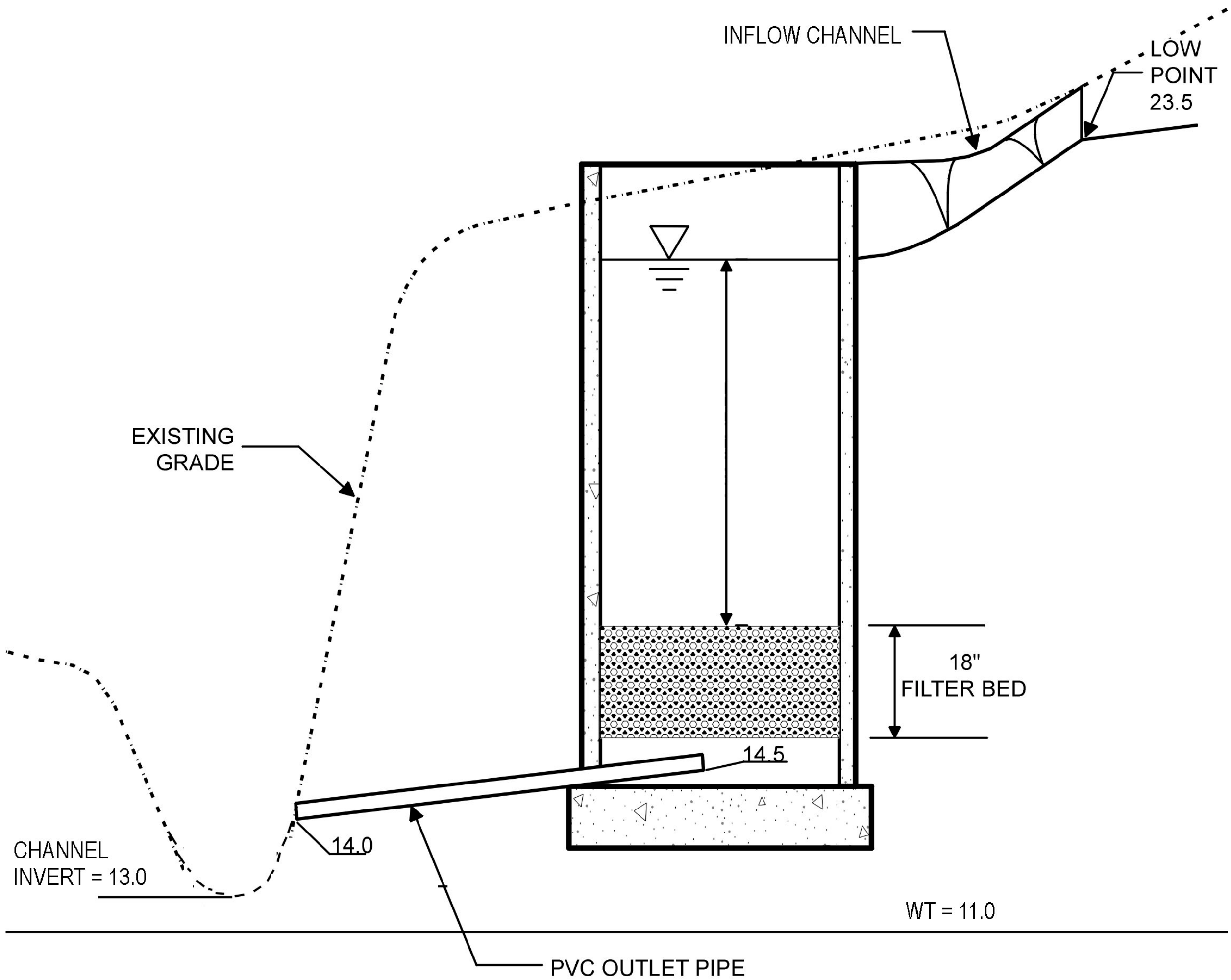
Existing ground elevation at practice location is 222.0 feet, mean sea level. Soil boring observations reveal that the seasonally high water table is at 211.0 feet. Adjacent drainage channel invert is at 213.0 feet.

Step 3. Compute available head, & peak discharge (Q_{wq}).

- Determine available head (See Figure 8.15)

The low point at the parking lot is 223.5. Subtract 2' to pass the Q_{10} discharge (221.5) and a half foot for the inflow channel to the facility (221.0). The low point at the channel invert is 213.0. Set the outfall underdrain pipe 1.0’ above the drainage channel invert and add 0.5’ to this value for the drain slope (214.5). Add to this value 8" for the gravel blanket over the underdrains, and 18" for the sand bed (216.67). The total available head is 221.0 - 216.67 or 4.33 feet. Therefore, the available average depth (h_f) = 4.33' / 2 = 2.17'.

Figure 8.15 Available Head Diagram



- <u>Compute Peak Water Quality Discharge:</u>

The peak rate of discharge for the water quality design storm is needed for the sizing of off-line diversion structures, such as sand filters and grass channels. The Small Storm Hydrology Method presented in Appendix B was followed to calculate a modified curve number and subsequent peak discharge associated with the 1.0-inch rainfall. Calculation steps are provided below.

Compute modified CN for 1.0" rainfall

P = 1.0"

$Q_a = WQ_v \div \text{area} = (10{,}781\ ft^3 \div 4.5\ ac \div 43{,}560\ ft^2/ac \times 12\ in/ft) = 0.66"$

$CN = 1000/[10+5P+10Q_a-10(Q_a^2+1.25*Q_a*P)^{1/2}]$

$= 1000/[10+5*1.0+10*0.66-10(0.66^2+1.25*0.66*1.0)^{½}]$

$= 96.4$

Use CN = 96

For CN = 96 and the t_c = 0.1 hours, compute the Q_{wq} for a 1.0" storm. With the CN = 96, a 1.0" storm will produce 0.6" of runoff. From TR-55 Chapter 2, Hydrology, I_a = 0.083, therefore:

$I_a/P = 0.083/1.0 = 0.083$.

From TR-55 Chapter 4 q_u = 1000 csm/in, and

Q_{wq} = (1000 csm/in) (4.5 ac/640ac/sq mi.) (0.66") = 4.6 cfs.

Step 4. Size the flow diversion structure.

Assume that flows are diverted to a diversion structure (Figure 8.16). First, size a low-flow orifice to pass the water quality storm (Q_p = 4.6 cfs).

$Q = CA(2gh)^{1/2}$; 4.6 cfs = (0.6) (A) $[(2)\ (32.2\ ft/s^2)\ (1.5')]^{1/2}$

A = 0.77 sq ft = $\pi d^2/4$: d = 0.99' or 12"

Size the 10-year overflow as follows:
The 10-year wsel is initially set at 223.0. Use a concrete weir to pass the 10-year flow (19.0 cfs), minus the flow carried by the low flow orifice, into a grassed overflow channel using the Weir equation. Assume 2' of head to pass this event. Overflow channel should be designed to provide sufficient energy dissipation (e.g., riprap, plunge pool, etc.) so that there will be non-erosive velocities.

Determine the flow from the low-flow orifice (Q_{lf}). Assume 3.5' of head (1.5' plus 2' for the 10-year head):

Q_{lf}=(0.6) (A) $[(2)\ (32.2\ ft/s^2)\ (3.5')]^{1/2}$

$A = \pi (1')^2/4$

$= 0.78$ sf

So,

Q_{lf} = (0.6) (0.78) [(2) (32.2 ft/s^2) (3.5')]$^{1/2}$

= 7.0 cfs

Thus, determine the flow passed to the through the channel as:

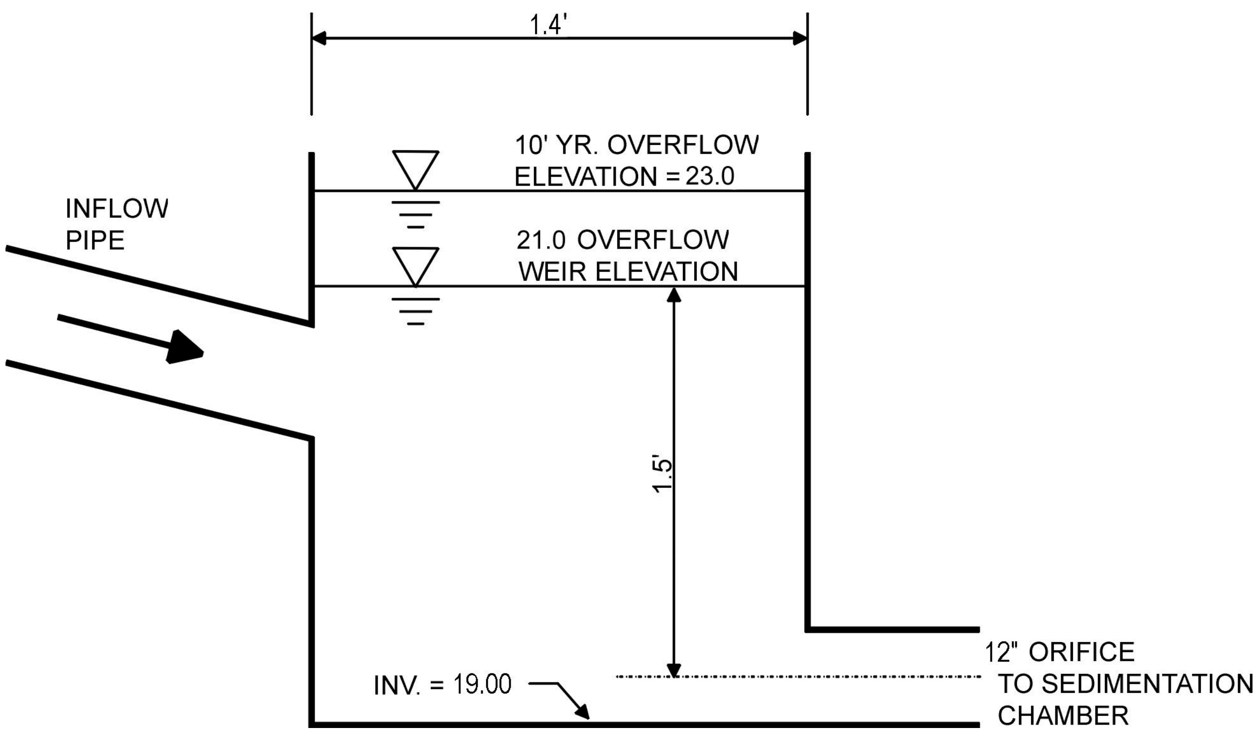
$Q = CLH^{3/2}$

(19-7) = 3.1 (L) (2')$^{1.5}$

<u>L = 1.4'</u> which sets the minimum length of the flow diversion overflow weir.

Weir wall elev. = 21.0. Set low flow invert at 21.0 - [1.5' + (0.5*12"*1ft/12")] = 19.00.

Figure 8.16 Flow Diversion Structure



Step 5. Size filtration bed chamber (see Figure 8.17).

From Darcy's Law: $A_f = WQ_v\ (d_f)\ /\ [k\ (h_f + d_f)\ (t_f)]$

where d_f = 18" or 1.5’ (Filter thickness)

k = 3.5 ft/day (Flow-through rate)

h_f = 2.17' (Average head on filter)

t_f = 40 hours (Drain time)

A_f = (10,781 cubic feet) (1.5') / [3.5 (2.17' + 1.5') (40hr/24hr/day)]

A_f = 755 sq ft; filter is 20' by 40' (= 800 sq ft)

Step 6. Size sedimentation chamber.

Size the sedimentation chamber as wet storage with a 2.5' depth. Determine the pretreatment volume as:

P_v = (0.25) (10,781 cf)

= 2,695 cf

Therefore,

A_s = (2,695 cf)/(2.5')

= 1,078 sf (Use 20'X55' or 1,100 sf)

Step 7. Compute V_{min}.

V_{min} = ¾(WQ_v) or 0.75 (10,781 cubic feet) = 8,086 cubic feet

Step 8. Compute volume within practice.

Volume within filter bed (V_f): $V_f = A_f (d_f) (n)$; n = 0.4 for sand

V_f = (800 sq ft) (1.5') (0.4) = 480 cf

temporary storage above filter bed ($V_{f\text{-temp}}$): $V_{f\text{-temp}} = 2h_fA_f$

$V_{f\text{-temp}}$ = 2 (2.17') (800 sq ft) = 3,472 cf

Compute storage in the sedimentation chamber (V_s):

V_s = (2.5')(1,100 sf)+4.33'(1,100 sf) = 7,513 cf

$V_f + V_{f\text{-temp}} + V_s$ = 480 cf + 3,472 cf + 7,513 cf = 11,465 cf

11,465 > 8,086 OK.

Pass flow through to the distribution chamber using a 12" orifice with an inverted elbow (see Figure 8.17).

Step 9. Compute sedimentation chamber and filter bed overflow weir sizes.

Assume overflow that needs to be handled is equivalent to the 12” orifice discharge under a head of 3.5 ft (i.e., the head in the diversion chamber associated with the 10-year peak discharge).

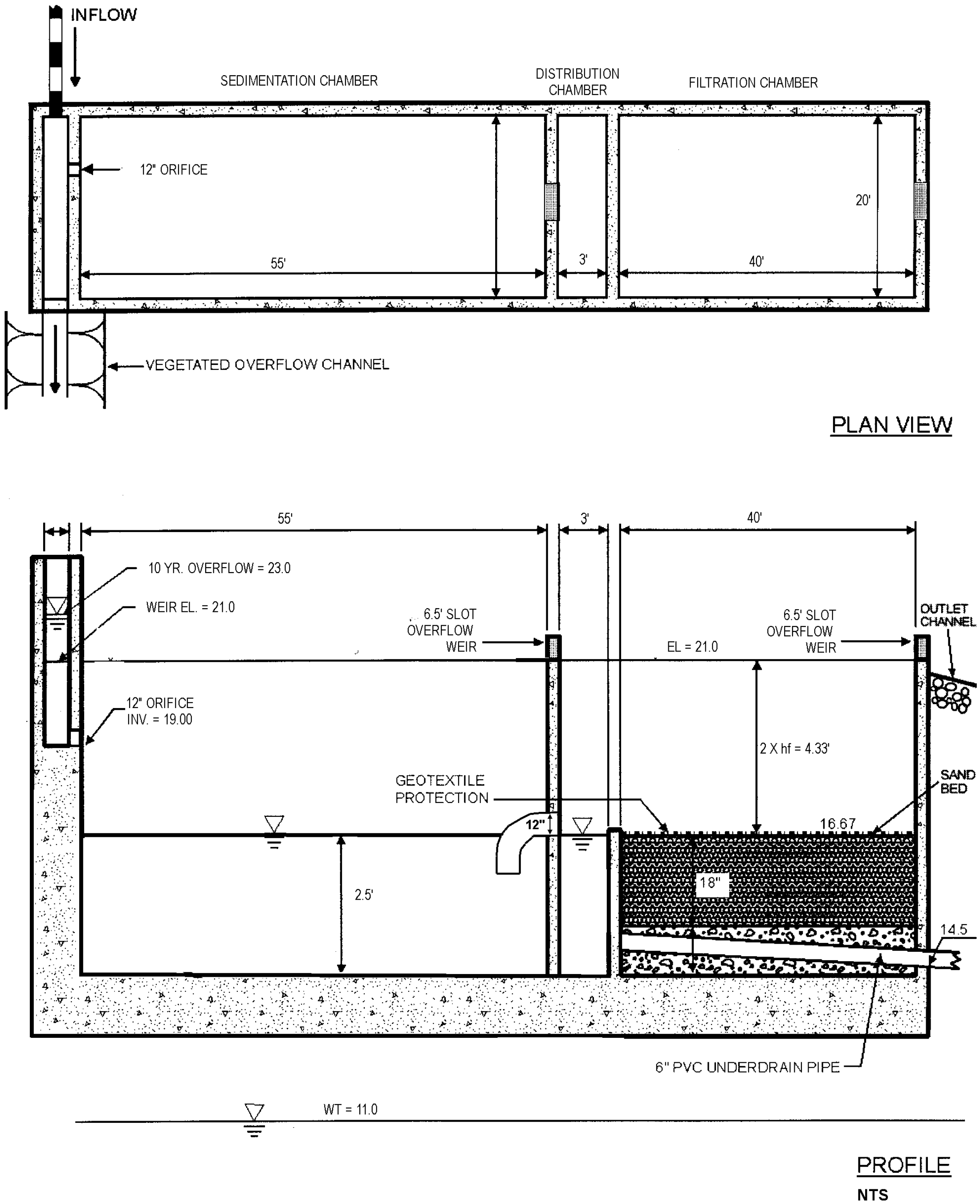
$Q = CA(2gh)^{½}$
$Q = 0.6(0.79\ ft^2)[(2)(32.2\ ft/s^2)(3.5\ ft)]^{½}$
$Q = 7.1cfs$

Size the overflow weir from the sediment chamber and the filtration chamber to pass 7.1 cfs (this assumes no attenuation within the practice).

Weir equation: $Q = CLh^{3/2}$, assume a maximum allowable head of 0.5’
$7.1 = 3.1 * L * (0.5\ ft)^{3/2}$
<u>L = 6.5 ft.</u>

Adequate outlet protection and energy dissipation (e.g., riprap, plunge pool, etc.) should be provided for the downstream overflow channel.

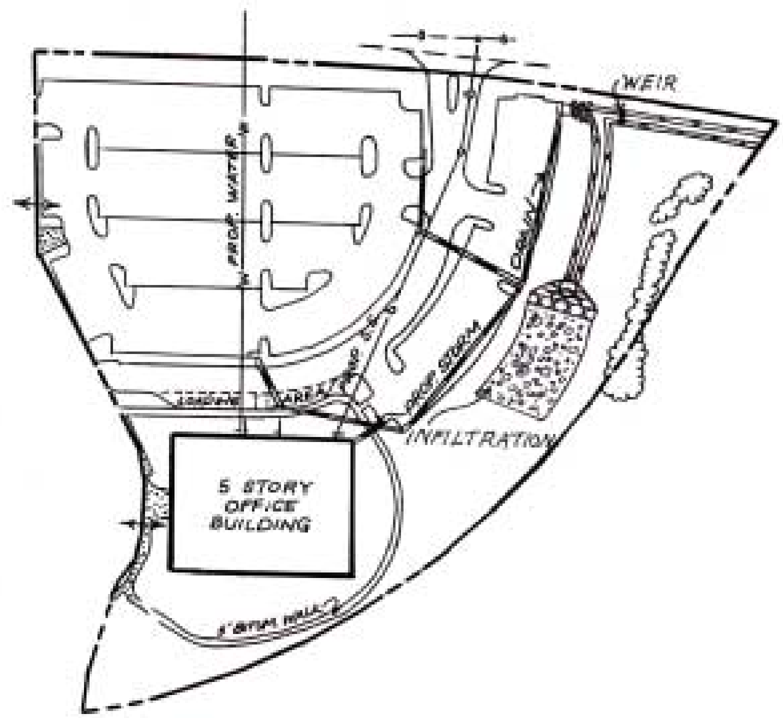
Figure 8.17 Plan and Profile of Surface Sand Filter



Section 8.4 Infiltration Trench Design Example

This design example focuses on the design of an infiltration trench for a 4.5-acre catchment of the Lake Center, a hypothetical commercial site located in Albany, NY. A five-story office building and associated parking are proposed within this catchment. The layout is shown in Figure 8.18. The catchment has 3.05 acres of impervious cover, resulting in a site impervious cover of 68%. The pre-developed site is a mixture of forest and meadow. On-site soils are predominantly HSG "B" soils.

Figure 8.18 Lake Center Site Plan



Base Data	Hydrologic Data		
Location: Albany, NY		Pre	Post
Site Area = Total Drainage Area (A) = 4.5 ac	CN	58	83
Impervious Area = 3.05 ac; or I =3.05/4.50 = 68%	t_c (hrs)	.44	.10
Soils Type "B"			

This step-by-step example will focus on meeting the water quality requirements. Channel protection control, overbank flood control, and extreme flood control are not addressed in this example. Therefore, a detailed hydrologic analysis is not presented. For an example of detailed sizing calculations, consult section 8.1. In general, the primary function of infiltration practices is to provide water quality treatment and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility. For this example, the post-development 10-yr peak discharge is provided to appropriately size the necessary by-pass flow splitter. Where quantity control is required, bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults).

Step 1. Compute design volumes and flows using the Unified Stormwater Sizing Criteria.

Design values are presented in Table 8.4 below.

Table 8.4 Site Design Hydrology

Condition	CN	WQ_v	Q_1	Q_2	Q_{10}
		ft^3	*cfs*	*cfs*	*cfs*
Pre-Developed	58		0.2	0.4	3
Post-Developed	83	10,781	7	10	19

Step 2. Determine if the development site and conditions are appropriate for the use of an infiltration trench.

Site Specific Data:

Table 8.5 presents site-specific data, such as soil type, percolation rate, and slope, for consideration in the design of the infiltration trench. See Appendix D for infiltration testing requirements and Appendix C for infiltration practice construction specifications.

Table 8.5 Site Specific Data	
Criteria	**Value**
Soil	Silt Loam
Percolation Rate	0.5"/hour
Ground Elevation at BMP	219'
Seasonally High Water Table	211'
Local Ground Slope	<1%

Step 3. Confirm local design criteria and applicability.

Table 8.6, below, summarizes the requirements that need to be met to successfully implement infiltration practices. On this site, infiltration is feasible, with restrictions on the depth and width of the trench.

Table 8.6 Infiltration Feasibility	
Criteria	**Status**
Infiltration rate (f_c) greater than or equal to 0.5 inches/hour.	• Infiltration rate is 0.5 inches/hour. OK.
Soils have a clay content of less than 20% and a silt/clay content of less than 40%.	• Silt Loam meets both criteria.
Infiltration cannot be located on slopes greater than 6% or in fill soils.	• Slope is <1%; not fill soils. OK.
Hotspot runoff should not be infiltrated.	• Not a hotspot land use. OK.
The bottom of the infiltration facility must be separated by at least two feet vertically from the seasonally high water table.	• Elevation of seasonally high water table: 11' • Elevation of BMP location: 19'. • The difference is 8'. • Thus, the trench can be up to 5' deep. OK.
Infiltration facilities must be located 100 feet horizontally from any water supply well.	• No water supply wells nearby. OK.
Maximum contributing area generally less than 5 acres.	• Area draining to facility is approximately 4.5 acres.
Setback 25 feet down-gradient from structures.	• Trench edge is > 25' from all structures. OK.

Step 4. Size overflow channel.

Water flows from the edge of the parking lot to a 4' wide, flat bottom channel with 3:1 side slopes and a 2% slope. This channel also provides pretreatment (See Step 6). Use a weir to divert the water quality volume to the infiltration trench, while allowing the 10-year event to an adjacent drainage channel and the water quality storm to flow to the infiltration trench. The peak flow for the water quality storm is 4.6 cfs (see Section 8.3 for an example calculation).

Determine the depth of flow for the water quality storm using Manning's equation. (Several software packages can be used). The following assumptions are made:

Trapezoidal channel with 3:1 side slopes

4' bottom width.

S = 1%

n varies between 0.03 at 1' depth to 0.15 at 4" depth (See Appendix L and Grass Channel Fact Sheet in Chapter 5).

Determine that the water quality storm passes at d = 0.64'.

Size a weir to pass the 10-year peak event, less the water quality peak flow, so that:

Q = 19cfs – 4.6 cfs = 14.4 cfs.

Use a weir length, L, of 4.0'.

By rearranging the weir equation:

$H = (Q/CL)^{2/3} = (14.4/3.1(4))^{2/3} = 1.1'$

Size the channel to pass the 10-year event with 6" of freeboard.

Step 5. Size the infiltration trench.

The area of the trench can be determined by the following equation:

A = WQv/(nd)

Where:

A = Surface Area

WQ_v = Water Quality volume (ft^3)

n = Porosity

d = Trench depth (feet)

Assume that:

$n = 0.4$

$d = 4$ feet

Therefore:

$$A = 10{,}781\ ft^3 / (0.4 \times 4)ft$$

$$A = 6{,}738 ft^2$$

The proposed location for the infiltration trench will accommodate a trench width of up to 65 feet. Therefore, the minimum length required would be:

$$L = 6{,}738\ ft^2 / 65\ ft$$

L = 104 feet, <u>say 105 feet</u>

Step 6. Size pretreatment.

Pass the 10-year flow event through an overflow channel.

Size pretreatment to treat ¼ of the WQ_v. Therefore, treat $10{,}781 \times 0.25 = 2{,}695\ ft^3$.

For pretreatment, use a pea gravel filter layer with filter fabric, a plunge pool, and a grass channel.

Pea Gravel Filter

The pea gravel filter layer covers the entire trench with 2" (see Figure 8.19). Assuming a porosity of 0.32, the pretreatment volume (Pv) provided in the pea gravel filter layer is:

$$Pv_{filter} = (0.32)(2'')(1\ ft/12\ inches)(125')(50') = 333\ ft^3$$

*Plunge Pool*s

Use a 65 'X20' triangular plunge pool with a two foot depth as flow is diverted to the infiltration trench.

Pv_{pool} = (65 x 20 ft)/2 ∗ (2 ft) = 1,300 ft^3

Grass Channel

Accounting for the pretreatment volumes provided by the pea gravel filter and plunge pool, the grass channel then needs to treat at least (2,695 - 333 – 1,300)ft^3 = 1,062 ft^3

Currently stormwater flows through a 150' long channel, with parameters described under step 4. For this channel, the flow velocity of the peak flow from the water quality storm (4.6 cfs) is approximately 1.2 fps.

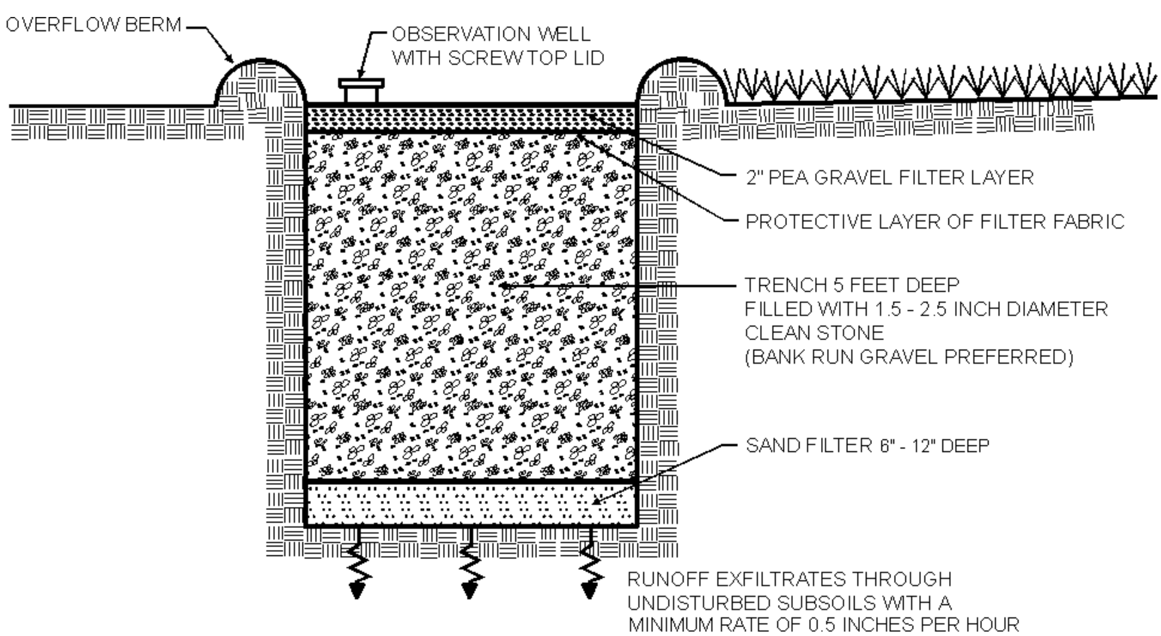
Using a required residence time of 10 minutes (600 seconds), the required length of channel for 100% of the WQ_v (10,781 ft^3) would be 1.2 fps x 600 sec = 720ft.

Adjust the length to account for the volume that must be provided, or:

(720ft) (1,062 ft^3)/(10,781 ft^3) = 71 ft

Therefore, for this example, a grass channel length of at least 71 feet is required. 150' is OK.

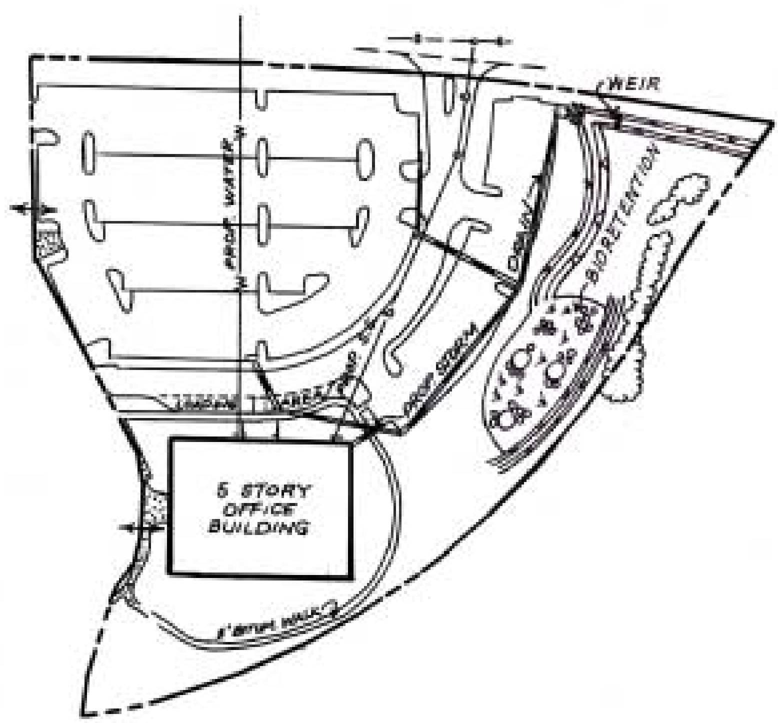
Figure 8.19 Schematic Infiltration Trench Cross Section



Section 8.5 Bioretention Design Example

This design example focuses on the design of a Bioretention area for a 4.5-acre catchment of Lake Center, a hypothetical commercial site located in Albany, NY. A five-story office building and associated parking are proposed within this catchment. The layout is shown in Figure 8.20. The catchment has 3.05 acres of impervious cover, resulting in 68% impervious cover. The pre-developed site is a mixture of forest and meadow. On-site soils are predominantly HSG "B" soils.

Figure 8.20 Lake Center Site Plan



<u>Base Data</u>
Location: Albany, NY
Site Area = Total Drainage Area (A) = 4.5 ac
Impervious Area = 3.05 ac; or I =3.05/4.50 = 68%
Soils Type "B"

Hydrologic Data

	Pre	**Post**
CN	58	83
t_c	.44	.10

This step-by-step example will focus on meeting the water quality requirements. Channel protection control, overbank flood control, and extreme flood control are not addressed in this example. Therefore, a detailed hydrologic analysis is not presented. For an example of detailed sizing calculations, consult section 8.1. In general, the primary function of bioretention is to provide water quality treatment and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility. For this example, the post-development 2-year and 10-year peaks are used to appropriately size the grass channel leading to the facility.

Step 1. Compute design volumes using the Unified Stormwater Sizing Criteria.

Design volumes are presented in Table 8.7 below.

Table 8.7 Design Hydrology

Condition	CN	WQ_v	Q_1	Q_2	Q_{10}
		ft^3	*cfs*	*cfs*	*cfs*
Pre-developed	58		0.3	0.6	4
Post-Developed	83	10,781	9	13	26

Step 2. Determine if the development site and conditions are appropriate for the use of a bioretention area.

Site Specific Data:

Existing ground elevation at practice location is 222.0 feet, mean sea level. Soil boring observations reveal that the seasonally high water table is at 211.0 feet and underlying soil is silt loam (ML). Adjacent channel invert is at 213 feet.

Step 3. Determine size of bioretention filter area.

$A_f = (WQ_v)\ (d_f) / [\ (k)\ (h_f + d_f)\ (t_f)]$

Where:

A_f = surface area of filter bed (ft^2)

d_f = filter bed depth (ft)

k = coefficient of permeability of filter media (ft/day)

h_f = average height of water above filter bed (ft)

t_f = design filter bed drain time (days) (2 days is recommended)

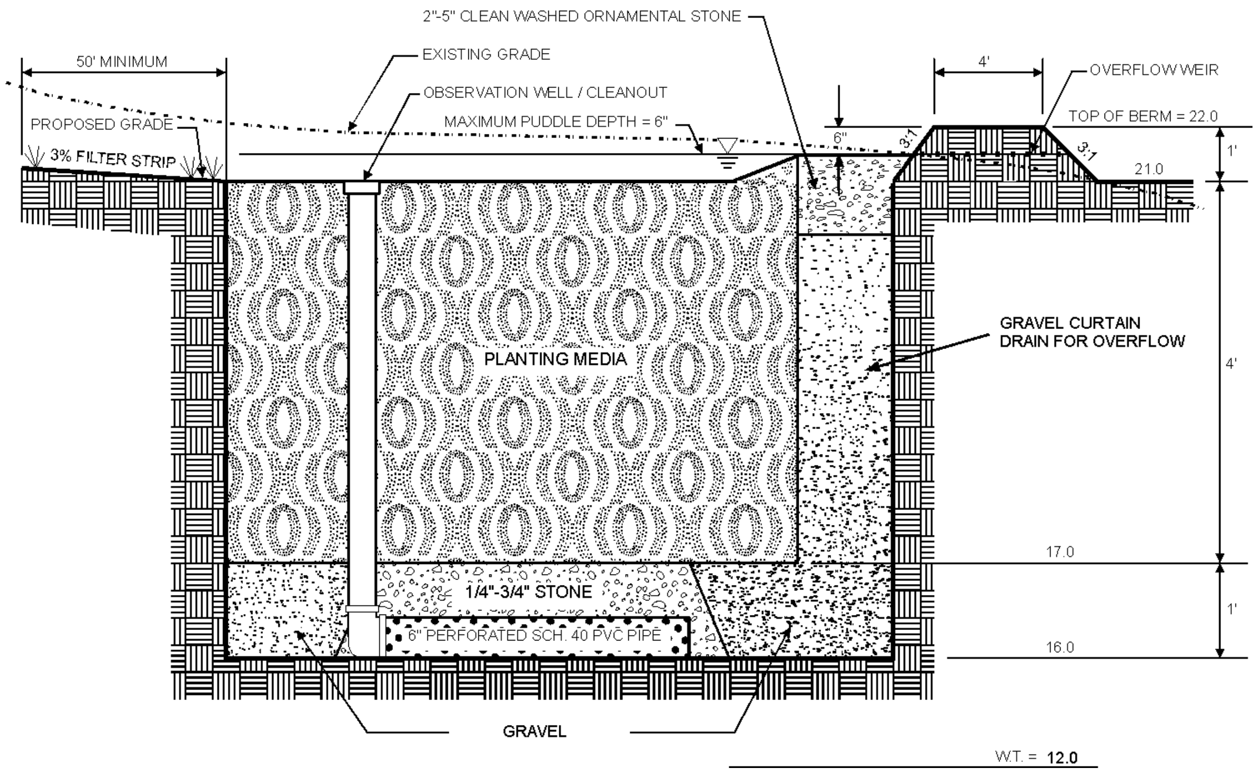
A_f = (10,781 ft^3)(5') / [(0.5'/day) (0.25' + 5') (2 days)] (With k = 0.5'/day, h_f = 0.25', t_f = 2 days)

A_f = <u>10,267 sq ft</u>

Step 4. Set design elevations and dimensions.

Assume a roughly 2 to 1 rectangular shape. Given a filter area requirement of 10,267 sq ft, <u>say facility is roughly 70' by 150'</u>. Set top of facility at 219.0 feet, with the berm at 220.0 feet. The facility is 5' deep, which will allow 3' of separation distance over the seasonally high water table. See Figure 8.21 for a typical section of the facility.

Figure 8.21 Typical Section of Bioretention Facility



Step 5. Size overflow channel.

Assuming the same channel configuration as in Section 8.3, use a 4’ weir set 0.63’ above the base of the overflow channel. The overflow channel will flow to the adjacent drainage channel, while the water quality storm will be diverted to the bioretention cell.

Step 6. Design Pretreatment

Size pretreatment to treat ¼ of the WQ_v. Therefore, treat $10,781 \times 0.25 = 2,695$ ft^3.

For pretreatment, a grass channel is used. This channel has a 4’ width and 3:1 side slopes.

Using the methodologies described in Section 6.3, determine that the length of channel required to treat the entire water quality volume is 720 ft. Adjust the length to correspond to the pretreatment volume, or L = (720 ft)(2,695/10,781) = 180ft.

Step 7. Size underdrain area.

As a rule of thumb, the length of underdrain should be based on 10% of the A_f or 1,027 sq ft and a three-foot wide zone of influence. Using 8" perforated plastic pipes surrounded by a three-foot wide gravel bed, 10' on center (o.c.), yields the following length of pipe:

(1,027 sq ft)/3' per foot of underdrain = 342' of perforated underdrain

Step 8. Create overdrain design.

To ensure against the planting media clogging, design a small ornamental stone window of 2" to 5" stone connected directly to the gravel curtain drain. This area is based on 5% of the A_f or 514 sq ft. Say 15' by 35' (see Figure 8.23).

Step 9. Choose plants for planting area.

Choose plants based on factors such as whether native or not, resistance to drought and inundation, cost, aesthetics, maintenance, etc. Select species locations (i.e., on center planting distances) so species will not "shade out" one another. Do not plant trees and shrubs with extensive root systems (e.g., willows) near pipe work. A potential plant list for this site is presented in Appendix H.

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Glossary

ANTI-SEEP COLLAR - An impermeable diaphragm usually of sheet metal or concrete constructed at intervals within the zone of saturation along the conduit of a principal spillway to increase the seepage length along the conduit and thereby prevent piping or seepage along the conduit.

ANTI-VORTEX DEVICE - A device designed and placed on the top of a riser or at the entrance of a pipe to prevent the formation of a vortex in the water at the entrance.

AQUATIC BENCH - A ten to fifteen foot wide bench which is located around the inside perimeter of a permanent pool and is normally vegetated with aquatic plants; the goal is to provide pollutant removal and enhance safety in areas using stormwater pond SMP's.

AQUIFER - A geological formation which contains and transports groundwater.

"AS-BUILT" - Drawing or certification of conditions as they were actually constructed.

BAFFLES - Guides, grids, grating or similar devices placed in a pond to deflect or regulate flow and create a longer flow path.

BANKFULL FLOW - The condition where streamflow just fills a stream channel up to the top of the bank and at a point where the water begins to overflow onto a floodplain.

BARREL - The closed conduit used to convey water under or through an embankment: part of the principal spillway.

BASE FLOW - The stream discharge from ground water.

BERM - A shelf that breaks the continuity of a slope; a linear embankment or dike.

BIORETENTION - A water quality practice that utilizes landscaping and soils to treat urban stormwater runoff by collecting it in shallow depressions, before filtering through a fabricated planting soil media.

CHANNEL - A natural stream that conveys water; a ditch or channel excavated for the flow of water.

CHANNEL STABILIZATION - Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

CHECK DAM - A small dam constructed in a gully or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour, and promote deposition of sediment.

CHUTE - A high velocity, open channel for conveying water to a lower level without erosion.

CLAY (SOILS) - 1. A mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter. 2. A soil texture class. 3. (Engineering) A fine grained soil (more than 50 percent passing the No. 200 sieve) that has a high plasticity index in relation to the liquid limit. (Unified Soil Classification System)

COCONUT ROLLS - Also known as coir rolls, these are rolls of natural coconut fiber designed to be used for streambank stabilization.

COMPACTION (SOILS) - Any process by which the soil grains are rearranged to decrease void space and bring them in closer contact with one another, thereby increasing the weight of solid material per unit of volume, increasing the shear and bearing strength and reducing permeability.

CONDUIT - Any channel intended for the conveyance of water, whether open or closed.

CONTOUR - 1. An imaginary line on the surface of the earth connecting points of the same elevation. 2. A line drawn on a map connecting points of the same elevation.

CORE TRENCH - A trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

CRADLE - A structure usually of concrete shaped to fit around the bottom and sides of a conduit to support the conduit, increase its strength and in dams, to fill all voids between the underside of the conduit and the soil.

CREST - 1. The top of a dam, dike, spillway or weir, frequently restricted to the overflow portion. 2. The summit of a wave or peak of a flood.

CRUSHED STONE - Aggregate consisting of angular particles produced by mechanically crushing rock.

CURVE NUMBER (CN) - A numerical representation of a given area's hydrologic soil group, plant cover, impervious cover, interception and surface storage derived in accordance with Natural Resources Conservation Service methods. This number is used to convert rainfall volume into runoff volume.

CUT - Portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

CUT-AND-FILL - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

CUTOFF - A wall or other structure, such as a trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

CZARA - Acronym used for the Coastal Zone Act Reauthorization Amendments of 1990. These amendments sought to address the issue of nonpoint source pollution issue by requiring states to develop Coastal Nonpoint Pollution Control Programs in order to receive federal funds.

DAM - A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, sediment or other debris.

DETENTION - The temporary storage of storm runoff in a SMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

DETENTION STRUCTURE - A structure constructed for the purpose of temporary storage of stream flow or surface runoff and gradual release of stored water at controlled rates.

DIKE - An embankment to confine or control water, for example, one built along the banks of a river to prevent overflow or lowlands; a levee.

DISTRIBUTED RUNOFF CONTROL (DRC) - A stream channel protection criteria which utilizes a non-uniform distribution of the storage stage-discharge relationship within a SMP to minimize the change in channel erosion potential from predeveloped to developed conditions.

DISTURBED AREA - An area in which the natural vegetative soil cover has been removed or altered and, therefore, is susceptible to erosion.

DIVERSION - A channel with a supporting ridge on the lower side constructed across the slope to divert water from areas where it is in excess to sites where it can be used or disposed of safely. Diversions differ from terraces in that they are individually designed.

DRAINAGE - 1. The removal of excess surface water or ground water from land by means of surface or subsurface drains. 2. Soils characteristics that affect natural drainage.

DRAINAGE AREA (WATERSHED) - All land and water area from which runoff may run to a common (design) point.

DROP STRUCTURE - A structure for dropping water to a lower level and dissipating surplus energy; a fall. The drop may be vertical or inclined.

DRY SWALE - An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media.

EMERGENCY SPILLWAY - A dam spillway designed and constructed to discharge flow in excess of the principal spillway design discharge.

ENERGY DISSIPATOR - A designed device such as an apron of rip-rap or a concrete structure placed at the end of a water transmitting apparatus such as pipe, paved ditch or paved chute for the purpose of reducing the velocity, energy and turbulence of the discharged water.

EROSION - 1. The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. 2. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:

Accelerated erosion - Erosion much more rapid than normal, natural or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose base surfaces, for example, fires.

Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 or 2 feet to as much as 75 to 100 feet.

Rill erosion - An erosion process in which numerous small channels only several inches deep are formed. See rill.

Sheet erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not subsequently be removed by surface runoff.

EROSIVE VELOCITIES - Velocities of water that are high enough to wear away the land surface. Exposed soil will generally erode faster than stabilized soils. Erosive velocities will vary according to the soil type, slope, structural, or vegetative stabilization used to protect the soil.

EXFILTRATION - The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration SMP into the soil.

EXTENDED DETENTION (ED) - A stormwater design feature that provides for the gradual release of a volume of water over a 12 to 48 hour interval in order to increase settling of urban pollutants and protect downstream channels from frequent storm events.

EXTREME FLOOD (Q_f) - The storage volume required to control those infrequent but large storm events in which overbank flows approach the floodplain boundaries of the 100-year flood.

FILTER BED - The section of a constructed filtration device that houses the filter media and the outflow piping.

FILTER FENCE - A geotextile fabric designed to trap sediment and filter runoff.

FILTER MEDIA - The sand, soil, or other organic material in a filtration device used to provide a permeable surface for pollutant and sediment removal.

FILTER STRIP - A strip of permanent vegetation above ponds, diversions and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

FINES (SOIL) - Generally refers to the silt and clay size particles in soil.

FLOODPLAIN - Areas adjacent to a stream or river that are subject to flooding or inundation during a storm event that occurs, on average, once every 100 years (or has a likelihood of occurrence of 1/100 in any given year).

FLOW SPLITTER - An engineered, hydraulic structure designed to divert a percentage of storm flow to a SMP located out of the primary channel, or to direct stormwater to a parallel pipe system, or to bypass a portion of baseflow around a SMP.

FOREBAY - Storage space located near a stormwater SMP inlet that serves to trap incoming coarse sediments before they accumulate in the main treatment area.

FREEBOARD (HYDRAULICS) - The distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.

FOURTH ORDER STREAM - Designation of stream size where many water quantity requirements may not be needed. A first order stream is identified by "blue lines" on USGS quad sheets. A second order stream is the confluence of two first order streams, and so on.

FRENCH DRAIN - A type of drain consisting of an excavated trench refilled with pervious material, such as coarse sand, gravel or crushed stone, through whose voids water percolates and flows to an outlet.

GABION - A flexible woven-wire basket composed of two to six rectangular cells filled with small stones. Gabions may be assembled into many types of structures such as revetments, retaining walls, channel liners, drop structures and groins.

GABION MATTRESS - A thin gabion, usually six or nine inches thick, used to line channels for erosion control.

GRADE - 1. The slope of a road, channel or natural ground. 2. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, like paving or laying a conduit. 3. To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

GRASS CHANNEL - A open vegetated channel used to convey runoff and to provide treatment by filtering out pollutants and sediments.

GRAVEL - 1. Aggregate consisting of mixed sizes of 1/4 inch to 3 inch particles which normally occur in or near old streambeds and have been worn smooth by the action of water. 2. A soil having particle sizes, according to the Unified Soil Classification System, ranging from the No. 4 sieve size angular in shape as produced by mechanical crushing.

GRAVEL DIAPHRAGM - A stone trench filled with small, river-run gravel used as pretreatment and inflow regulation in stormwater filtering systems.

GRAVEL FILTER - Washed and graded sand and gravel aggregate placed around a drain or well screen to prevent the movement of fine materials from the aquifer into the drain or well.

GRAVEL TRENCH - A shallow excavated channel backfilled with gravel and designed to provide temporary storage and permit percolation of runoff into the soil substrate.

GROUND COVER - Plants which are low-growing and provide a thick growth which protects the soil as well as providing some beautification of the area occupied.

GULLY - A channel or miniature valley cut by concentrated runoff through which water commonly flows only during and immediately after heavy rains or during the melting of snow. The distinction between gully and rill is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lessor depth and would be smoothed by ordinary farm tillage.

HEAD (HYDRAULICS) - 1. The height of water above any plane of reference. 2. The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head, and head loss.

HERBACEOUS PERENNIAL (PLANTS) - A plant whose stems die back to the ground each year.

HI MARSH - A pondscaping zone within a stormwater wetland which exists from the surface of the normal pool to a six inch depth and typically contains the greatest density and diversity of emergent wetland plants.

HI MARSH WEDGES - Slices of shallow wetland (less than or equal to 6 inches) dividing a stormwater wetland.

HOT SPOT - Area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

HYDRAULIC GRADIENT - The slope of the hydraulic grade line. The slope of the free surface of water flowing in an open channel.

HYPOXIA - Lack of oxygen in a waterbody resulting from eutrophication.

HYDROGRAPH - A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

HYDROLOGIC SOIL GROUP (HSG) - A Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff.

HYDROSEED - Seed or other material applied to areas in order to revegetate after a disturbance.

IMPERVIOUS COVER (I) - Those surfaces in the urban landscape that cannot effectively infiltrate rainfall consisting of building rooftops, pavement, sidewalks, driveways, etc.

INDUSTRIAL STORMWATER PERMIT - An NPDES permit issued to a commercial industry or group of industries which regulates the pollutant levels associated with industrial storm water discharges or specifies on-site pollution control strategies.

INFILTRATION RATE (F_c) - The rate at which stormwater percolates into the subsoil measured in inches per hour.

INFLOW PROTECTION - A water handling device used to protect the transition area between any water conveyance (dike, swale, or swale dike) and a sediment trapping device.

LEVEL SPREADER - A device for distributing stormwater uniformly over the ground surface as sheet flow to prevent concentrated, erosive flows and promote infiltration.

MANNING'S FORMULA (HYDRAULICS) - A formula used to predict the velocity of water flow in an open channel or pipeline:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

Where V is the mean velocity of flow in feet per second; R is the hydraulic radius; S is the slope of the energy gradient or for assumed uniform flow the slope of the channel, in feet per foot; and n is the roughness coefficient or retardance factor of the channel lining.

MICROPOOL - A smaller permanent pool which is incorporated into the design of larger stormwater ponds to avoid resuspension or settling of particles and minimize impacts to adjacent natural features.

MICROTOPOGRAPHY - The complex contours along the bottom of a shallow marsh system, providing greater depth variation which increases the wetland plant diversity and increases the surface area to volume ratio of a stormwater wetland.

MULCH - Covering on surface of soil to protect and enhance certain characteristics, such as water retention qualities.

MUNICIPAL STORMWATER PERMIT - A SPDES permit issued to municipalities to regulate discharges from municipal separate storm sewers for compliance with EPA established water quality standards and/or to specify stormwater control strategies.

NPDES - Acronym for the National Pollutant Discharge Elimination System, which regulates point source and non-point source discharge.

NITROGEN-FIXING (BACTERIA) - Bacteria having the ability to fix atmospheric nitrogen, making it available for use by plants. Inoculation of legume seeds is one way to insure a source of these bacteria for specified legumes.

NORMAL DEPTH - Depth of flow in an open conduit during uniform flow for the given conditions.

OUTFALL - The point where water flows from a conduit, stream, or drain.

OFF-LINE - A stormwater management system designed to manage a storm event by diverting a percentage of stormwater events from a stream or storm drainage system.

ON-LINE - A stormwater management system designed to manage stormwater in its original stream or drainage channel.

ONE YEAR STORM ($Q_{P\,1}$) - A stormwater event which occurs on average once every year or statistically has a 100% chance on average of occurring in a given year.

ONE HUNDRED YEAR STORM ($Q_{P\,100}$) A extreme flood event which occurs on average once every 100 years or statistically has a 1% chance on average of occurring in a given year.

OPEN CHANNELS - Also known as swales, grass channels, and biofilters. These systems are used for the conveyance, retention, infiltration and filtration of stormwater runoff.

OUTLET - The point at which water discharges from such things as a stream, river, lake, tidal basin, pipe, channel or drainage area.

OUTLET CHANNEL - A waterway constructed or altered primarily to carry water from man-made structures such as terraces, subsurface drains, diversions and impoundments.

PEAK DISCHARGE RATE - The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

PERMANENT SEEDING - Results in establishing perennial vegetation which may remain on the area for many years.

PERMEABILITY - The rate of water movement through the soil column under saturated conditions

PERMISSIBLE VELOCITY (HYDRAULICS) - The highest average velocity at which water may be carried safely in a channel or other conduit. The highest velocity that can exist through a substantial length of a conduit and not cause scour of the channel. A safe, non-eroding or allowable velocity

pH - A number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denotes neutrality, higher values indicate alkalinity, and lower values indicate acidity.

PIPING - Removal of soil material through subsurface flow channels or "pipes" developed by seepage water.

PLUGS - Pieces of turf or sod, usually cut with a round tube, which can be used to propagate the turf or sod by vegetative means.

POCKET POND - A stormwater pond designed for treatment of small drainage area (< 5 acres) runoff and which has little or no baseflow available to maintain water elevations and relies on ground water to maintain a permanent pool.

POCKET WETLAND - A stormwater wetland design adapted for the treatment of runoff from small drainage areas (< 5 acres) and which has little or no baseflow available to maintain water elevations and relies on ground water to maintain a permanent pool.

POND BUFFER - The area immediately surrounding a pond which acts as filter to remove pollutants and provide infiltration of stormwater prior to reaching the pond. Provides a separation barrier to adjacent development.

POND DRAIN - A pipe or other structure used to drain a permanent pool within a specified time period.

PONDSCAPING - Landscaping around stormwater ponds which emphasizes native vegetative species to meet specific design intentions. Species are selected for up to six zones in the pond and its surrounding buffer, based on their ability to tolerate inundation and/ or soil saturation.

POROSITY - Ratio of pore volume to total solids volume.

PRETREATMENT - Techniques employed in stormwater SMPs to provide storage or filtering to help trap coarse materials before they enter the system.

PRINCIPAL SPILLWAY - The primary pipe or weir which carries baseflow and storm flow through the embankment.

REDEVELOPMENT - New development activities on previously developed land.

RETENTION - The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

REVERSE-SLOPE PIPE - A pipe which draws from below a permanent pool extending in a reverse angle up to the riser and which determines the water elevation of the permanent pool.

RIGHT-OF-WAY - Right of passage, as over another's property. A route that is lawful to use. A strip of land acquired for transport or utility construction.

RIP-RAP - Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applies to brush or pole mattresses, or brush and stone, or similar materials used for soil erosion control.

RISER - A vertical pipe or structure extending from the bottom of a pond SMP and houses the control devices (weirs/orifices) to achieve the discharge rates for specified designs.

ROUGHNESS COEFFICIENT (HYDRAULICS) - A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.

RUNOFF (HYDRAULICS) - That portion of the precipitation on a drainage area that is discharged from the area in the stream channels. Types include surface runoff, ground water runoff or seepage.

RUNOFF COEFFICIENT (R_V) - A value derived from a site impervious cover value that is applied to a given rainfall volume to yield a corresponding runoff volume.

SAFETY BENCH - A flat area above the permanent pool and surrounding a stormwater pond designed to provide a separation from the pond pool and adjacent slopes.

SAND - 1. (Agronomy) A soil particle between 0.05 and 2.0 millimeters in diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System, a soil particle larger than the No. 200 sieve (0.074mm) and passing the No. 4 sieve (approximately 1/4 inch).

SEDIMENT - Solid material, both mineral and organic, that is in suspension, being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

SEEPAGE - 1. Water escaping through or emerging from the ground.2. The process by which water percolates through the soil.

SEEPAGE LENGTH - In sediment basins or ponds, the length along the pipe and around the anti-seep collars that is within the seepage zone through an embankment.

SETBACKS - The minimum distance requirements for location of a structural SMP in relation to roads, wells, septic fields, other structures.

SHEET FLOW - Water, usually storm runoff, flowing in a thin layer over the ground surface.

SIDE SLOPES (ENGINEERING) - The slope of the sides of a channel, dam or embankment. It is customary to name the horizontal distance first, as 1.5 to 1, or frequently, 1 ½: 1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

SILT - 1. (Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System a fine grained soil (more than 50 percent passing the No. 200 sieve) that has a low plasticity index in relation to the liquid limit.

SOIL TEST - Chemical analysis of soil to determine needs for fertilizers or amendments for species of plant being grown.

SPILLWAY - An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.

STABILIZATION - Providing adequate measures, vegetative and/or structural that will prevent erosion from occurring.

STAGE (HYDRAULICS) - The variable water surface or the water surface elevation above any chosen datum.

STILLING BASIN - An open structure or excavation at the foot of an outfall, conduit, chute, drop, or spillway to reduce the energy of the descending stream of water.

STORMWATER FILTERING - Stormwater treatment methods which utilize an artificial media to filter out pollutants entrained in urban runoff.

STORMWATER PONDS - A land depression or impoundment created for the detention or retention of stormwater runoff.

STORMWATER WETLANDS - Shallow, constructed pools that capture stormwater and allow for the growth of characteristic wetland vegetation.

STREAM BUFFERS - Zones of variable width which are located along both sides of a stream and are designed to provided a protective natural area along a stream corridor.

STREAM CHANNEL PROTECTION (Cp_V) - A design criteria which requires 24 hour detention of the one year postdeveloped, 24 hour storm event for the control of stream channel erosion.

STRUCTURAL SMPs - Devices which are constructed to provide temporary storage and treatment of stormwater runoff.

SUBGRADE - The soil prepared and compacted to support a structure or a pavement system.

TAILWATER - Water, in a river or channel, immediately downstream from a structure.

TECHNICAL RELEASE No. 20 (TR-20) - A Soil Conservation Service (now NRCS) watershed hydrology computer model that is used to compute runoff volumes and route storm events through a stream valley and/or ponds.

TECHNICAL RELEASE No. 55 (TR-55) - A watershed hydrology model developed by the Soil Conservation Service (now NRCS) used to calculate runoff volumes and provide a simplified routing for storm events through ponds.

TEMPORARY SEEDING - A seeding which is made to provide temporary cover for the soil while waiting for further construction or other activity to take place.

TEN YEAR STORM ($Q_{P\ 10}$) - The peak discharge rate associated with a 24 hour storm event that occurs on average once every ten years (or has a likelihood of occurrance of 1/10 in a given year).

TIME OF CONCENTRATION - Time required for water to flow from the most remote point of a watershed, in a hydraulic sense, to the outlet.

TOE (OF SLOPE) - Where the slope stops or levels out. Bottom of the slope.

TOE WALL - Downstream wall of a structure, usually to prevent flowing water from eroding under the structure.

TOPSOIL - Fertile or desirable soil material used to top dress roadbanks, subsoils, parent material, etc.

TOTAL SUSPENDED SOLIDS - The total amount of soil particulate matter, including both organic and inorganic material, suspended in the water column.

TRASH RACK - Grill, grate or other device at the intake of a channel, pipe, drain or spillway for the purpose of preventing oversized debris from entering the structure.

TROUT WATERS - Waters classified as (T) or (TS) by the New York State DEC.

TWO YEAR STORM ($Q_{P\ 2}$) - The peak discharge rate associated with a 24 hour storm event that occurs on average once every two years (or has a likelihood of occurrance of 1/2 in a given year).

ULTIMATE CONDITION - Full watershed build-out based on existing zoning.

ULTRA-URBAN - Densely developed urban areas in which little pervious surface exists.

VELOCITY HEAD - Head due to the velocity of a moving fluid, equal to the square of the mean velocity divided by twice the acceleration due to gravity (32.16 feet per second per second).

VOLUMETRIC RUNOFF COEFFICIENT (R_v) - The value that is applied to a given rainfall volume to yield a corresponding runoff volume based on the percent impervious cover in a drainage basin.

WATER QUALITY VOLUME (WQ_V) - The storage needed to capture and treat 90% of the average annual stormwater runoff volume.

WATER SURFACE PROFILE - The longitudinal profile assumed by the surface of a stream flowing in an open channel; the hydraulic grade line.

WEDGES - Design feature in stormwater wetlands which increases flow path length to provide for extended detention and treatment of runoff.

WET SWALE - An open drainage channel or depression, explicitly designed to retain water or intercept groundwater for water quality treatment.

WETTED PERIMETER - The length of the line of intersection of the plane or the hydraulic cross-section with the wetted surface of the channel.

WING WALL - Side wall extensions of a structure used to prevent sloughing of banks or channels and to direct and confine overfall.

Appendix A

Appendix A: The Simple Method to Calculate Urban Stormwater Loads

This appendix presents data and methodologies for using the Simple Method (Schueler, 1987) to estimate pollutant load from a site or drainage area. This appendix is meant for planning purposes only, and should not be used for SMP design.

The Simple Method estimates stormwater runoff pollutant loads for urban areas. The technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. With the Simple Method, the investigator can either break up land use into specific areas, such as residential, commercial, industrial, and roadway and calculate annual pollutant loads for each type of land, or utilize more generalized pollutant values for urban runoff. It is also important to note that these values may vary depending on other variables such as the age of development.

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$\mathbf{L = 0.226 * R * C * A}$$

Where:

	L	=	Annual load (lbs)
	R	=	Annual runoff (inches)
	C	=	Pollutant concentration (mg/l)
	A	=	Area (acres)
	0.226	=	Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$\mathbf{L = 103 * R * C * A}$$

Where:

	L	=	Annual load (Billion Colonies)
	R	=	Annual runoff (inches)
	C	=	Bacteria concentration (1,000/ ml)
	A	=	Area (acres)
	103	=	Unit conversion factor

A.1 Pollutant Concentrations

Stormwater pollutant concentrations can be estimated from local or regional data, or from national data sources. Table A.1 presents typical concentration data for pollutants in urban stormwater.

Table A.1 National Median Concentrations for Chemical Constituents in Stormwater

Constituent	Units	Urban Runoff
TSS	mg/l	54.5[1]
TP	mg/l	0.26[1]
TN	mg/l	2.00[1]
Cu	ug/l	11.1[1]
Pb	ug/l	50.7[1]
Zn	ug/l	129[1]
F Coli	1,000 col/ ml	1.5[2]

Source:
1: Pooled NURP/USGS (Smullen and Cave, 1998)
2: Schueler (1999)

In addition, some source areas appear to be particularly important for some pollutants. Table A.2 summarizes these data for several key source areas. It is important to note that, because the Simple Method computes runoff based on an impervious area fraction, it cannot be easily used to isolate pervious sources, such as lawns. However, a user can evaluate particular hotspots, such as auto recyclers, separately. In addition, a composite runoff concentration can be developed based on the fraction of lawn, driveway, and roof on a residential site, for example.

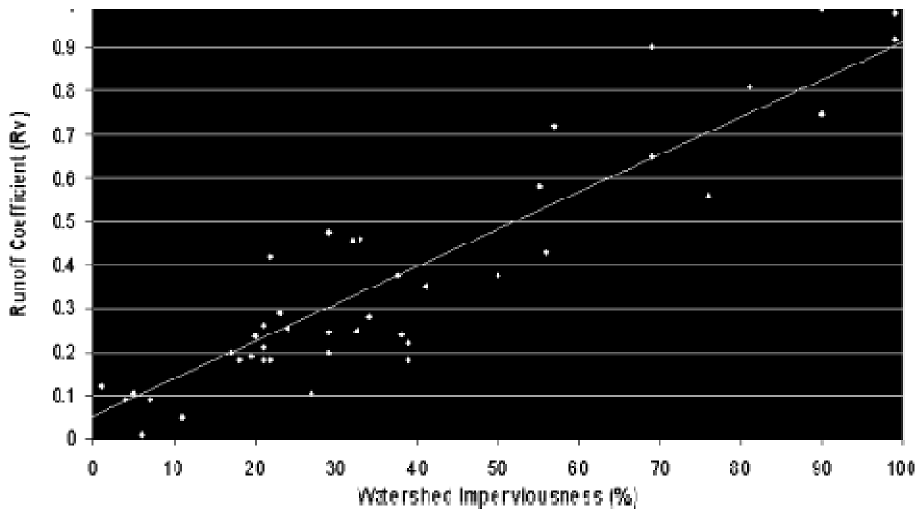
Table A.2 Pollutant Concentrations from Source Areas							
Constituent	**TSS[1]**	**TP[2]**	**TN[3]**	**F Coli[1]**	**Cu[1]**	**Pb[1]**	**Zn[1]**
	mg/l	mg/L	mg/l	1,000 col/ ml	ug/l	ug/l	ug/l
Resid Roof	19	0.11	1.5	0.26	20	21	312
Comm Roof	9	0.14	2.1	1.1	7	17	256
Indust Roof	17	-	-	5.8	62	43	1,390
C/R Parking	27	0.15	1.9	1.8	51	28	139
Indust Parking	228	-	-	2.7	34	85	224
Res Street	172	0.55	1.4	37	25	51	173
Comm Street	468	-	-	12	73	170	450
Rural Highway	51	-	22	-	22	80	80
Urban Highway	142	0.32	3.0	-	54	400	329
Lawns	602	2.1	9.1	24	17	17	50
Landscaping	37	-	-	94	94	29	263
Driveway	173	0.56	2.1	17	17	-	107
Gas Station	31	-	-	-	88	80	290
Auto Recycler	335	-	-	-	103	182	520
Heavy Industrial	124	-	-	-	148	290	1600

1: Claytor and Schueler (1996)

2: Average of Steuer et al. (1997),Bannerman (1993) and Waschbusch (2000)

3: Steuer et al. (1997)

Figure A.1 Relationship Between Watershed Imperviousness and the Stormwater Runoff Coefficient



A.2 Annual Runoff

The Simple Method calculates annual runoff as a product of annual runoff volume, and a runoff coefficient (Rv). Runoff volume is calculated as:

$$\mathbf{R = P * P_j * Rv}$$

Where:	R	=	Annual runoff (inches)
	P	=	Annual rainfall (inches)
	P_j	=	Fraction of annual rainfall events that produce runoff (usually 0.9)
	Rv	=	Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on impervious cover in the subwatershed. This relationship is shown in Figure A.1. Although there is some scatter in the data, watershed imperviousness does appear to be a reasonable predictor of Rv.

The following equation represents the best fit line the dataset (N=47, R^2=0.71).

$$\mathbf{Rv=0.05+0.9Ia}$$

Where: Ia = Impervious fraction

A.3 Impervious Cover Data

The Simple Method uses different impervious cover values for separate land uses within a subwatershed. Representative impervious cover data, are presented in Table A.3. These numbers are derived from a recent study conducted by the Center for Watershed Protection under a grant from the U.S. Environmental Protection Agency to update impervious cover estimates for a variety of land uses. (Cappiella and Brown, 2001). In addition, some jurisdictions may have detailed impervious cover information if they maintain a detailed land use/land cover GIS database.

Table A.3 Land Use and Impervious Cover Estimates

Land Use Category	Mean Impervious Cover
Agriculture	**2**
Open Urban Land*	**9**
2 Acre Lot Residential	**11**
1 Acre Lot Residential	**14**
1/2 Acre Lot Residential	**21**
1/4Acre Lot Residential	**28**
1/8 Acre Lot Residential	**33**
Townhome Residential	**41**
Multifamily Residential	**44**
Institutional**	**31-38%**
Light Industrial	**50-56%**
Commercial	**70-74%**

* Open urban land includes developed park land, recreation areas, golf courses, and cemeteries.

** Institutional is defined as places of worship, schools, hospitals, government offices, and police and fire stations

A.4 Limitations of the Simple Method

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method.

The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land use and stormwater management scenarios. The Simple Method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to over emphasis the precision of the results obtained. For example, it would be inappropriate to use the Simple Method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% Impervious cover). The simple method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling may be needed to analyze larger and more complex drainages.

In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow volume. Typically, baseflow is negligible or non-existent at the scale of a single development site, and can be safely neglected, unless wastewater sources such as illicit connections and wastewater treatment plans are significant. However, catchments and subwatersheds do generate baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels (NVPDC, 1980). Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low. For example, in a large low density residential subwatershed (Imp. Cover < 5%), as much as 75% of the annual runoff volume may occur as baseflow. In such a case, the annual baseflow nutrient load may be equivalent to the annual stormflow nutrient load.

A.5 SMP Pollutant Removal

The removal efficiencies of various SMP practices also help determine final annual pollutant loads. Table A.4 provides estimates of the average pollutant removal efficiency of the five SMP categories.

Table A.4. Suggested Removal Rates for SMPs

	TSS	TP	TN	Metals[1]	Bacteria
Wet Ponds	80	50 (51)	35 (33)	60 (62)	70
Stormwater Wetlands	80[2] (76)	50 (49)	30	40 (42)	80 (78)
Filtering Practices	85 (86)	60 (59)	40 (38)	70 (69)	35 (37)
Infiltration Practices [4]	90[3] (95)	70	50 (51)	90[3] (99)	90[4]
Water Quality Swales	85 (84)	40 (39)	50[5] (84)	70	0 (-25)[6]

1. Average of zinc and copper. Only zinc for infiltration
2. Many wetland practices in the database were poorly designed, and we consequently adjusted sediment removal upward.
3. It is assumed that no practice is greater than 90% efficient.
4. Data inferred from sediment removal.
5. Actual data is based on only two highly performing practices.
6. Assume 0 rather than a negative removal.

Note: Data in parentheses represent median pollutant removal data reported in the *National Pollutant Removal Database - Revised Edition* (Winer, 2000). These data were adjusted for convenience and to reflect biases in the data.

These efficiencies represent ideal pollutant removal rates that cannot be achieved at all sites, or at a watershed level. Typically, they need to be "discounted" to account for site constraints, and other factors that reduce practice efficiency. For example, the removal rate should be adjusted to reflect the fraction of runoff captured by a practice on an annual basis (90% if this guidance is followed). For more detail on how to apply these discounts, consult Caraco (2001).

One particularly important consideration is how to account for practices applied in series (e.g., two ponds applied in sequence). If the volume within the practices adds up to the total water quality volume, they are assumed to act as a single practice with that volume. Otherwise, total pollutant removal should be determined by the following equation:

$$R = L\,[(E_1)+(1-E_1)E_2+(1-((E_1)+(1-E_1)E_2)E_3+\ldots]$$

Where:

R = Pollutant Removal (lbs)

L = Annual Load from Simple Method (lbs.)

E_i = Efficiency of the ith practice in a series

Another adjustment can be made to these removals to account for loss of effectiveness and "irreducible concentrations." Evidence suggests that, at low concentrations, SMPs can no longer remove pollutants.

Table A.5 depicts typical outflow concentrations for various SMPs. Another simplified way to account for this phenomenon is to reduce the efficiency of a second or third practice in a series. For example, the removal efficiency could be cut in half to reflect inability to remove fine particles.

Table A.5. Typical SMP Effluent Concentrations					
	TSS	**TP**	**TN**	**Cu**	**Zn**
Wet Ponds	17	0.11	1.3	5.0	30
Wetlands	22	0.20	1.7	7.0	31
Filtering Practices	11	0.10	1.12	10	21
Infiltration Practices	17[2]	0.05[2]	3.8[2]	4.8[2]	39[2]
Open Channel Practices	14	0.19	1.12	10	53

1. Units for Zn and Cu are micrograms per liter
2. Data based on fewer than five data points

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Appendix B

This Appendix presents two hydrologic and hydraulic analysis tools that can be used to size stormwater management practices (SMPs). The first is the TR-55 (NRCS, 1986) "short-cut" sizing technique, used to size practices designed for extended detention, slightly modified to incorporate the small flows necessary to provide channel protection. The second is a method used to determine the peak flow from water quality storm events. (This is often important when the water quality storm is diverted to a water quality practice, with other larger events bypassed).

B.1 Storage Volume Estimation

This section presents a modified version of the TR-55 short cut sizing approach. The method was modified by Harrington (1987), for applications where the peak discharge is very small compared with the uncontrolled discharge. This often occurs in the 1-year, 24-hour detention sizing.

Using TR-55 guidance (NRCS, 1986), the unit peak discharge (qu) can be determined based on the the Curve Number and Time of Concentration. Knowing q_U and T (extended detention time), q_O/q_I (peak outflow discharge/peak inflow discharge) can be estimated from Figure B.1.

Figure B.2 can also be used to estimate V_S/V_r. For a Type II or Type III rainfall distribution, V_S/V_r can also be calculated using the following equation:

$$V_S/V_r = 0.682 - 1.43\,(q_O/q_I) + 1.64\,(q_O/q_I)^2 - 0.804\,(q_O/q_I)^3 \qquad (2.1.16)$$

Where: V_S = required storage volume (acre-feet)

V_r = runoff volume (acre-feet)

q_O = peak outflow discharge (cfs)

q_I = peak inflow discharge (cfs)

The required storage volume can then be calculated by:

$$V_S = \frac{(V_S/V_r)(Q_d)(A)}{12} \qquad (2.1.17)$$

Where: V_S and V_r are defined above

Q_d = the post-developed runoff for the design storm (inches)

A = total drainage area (acres)

While the TR-55 short-cut method reports to incorporate multiple stage structures, experience has shown that an additional 10-15% storage is required when multiple levels of extended detention are provided.

Figure B.1 Detention Time vs. Discharge Ratios (Source: MDE, 2000)

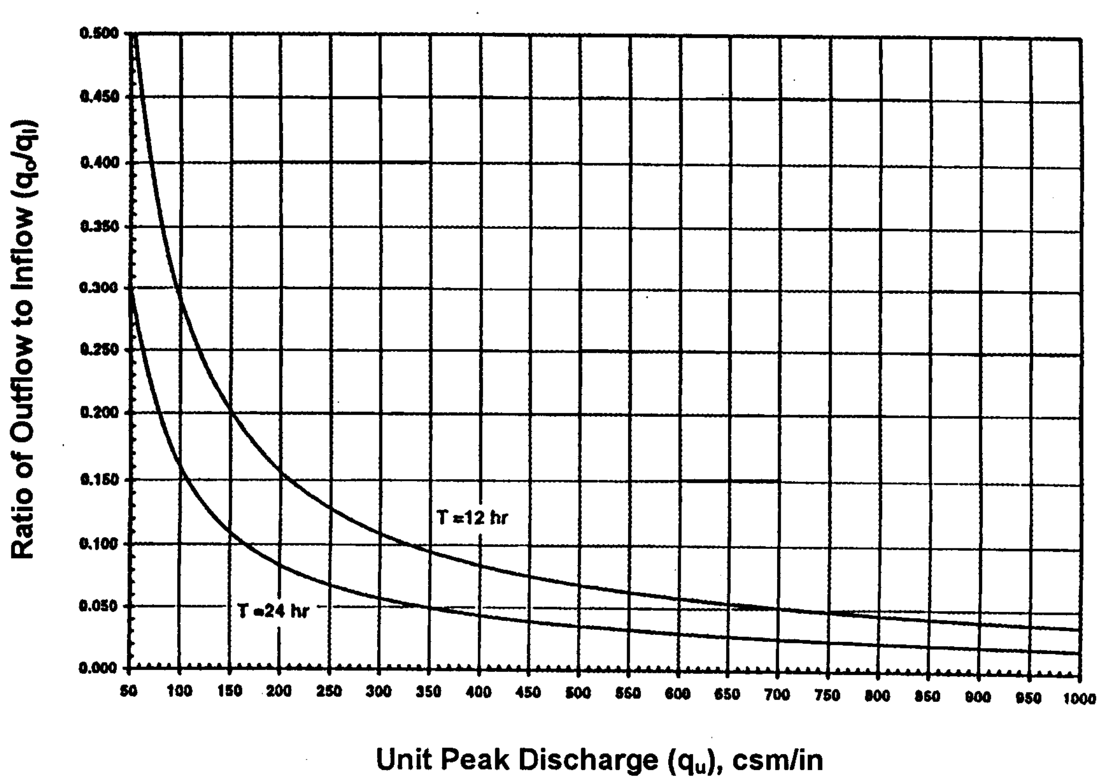
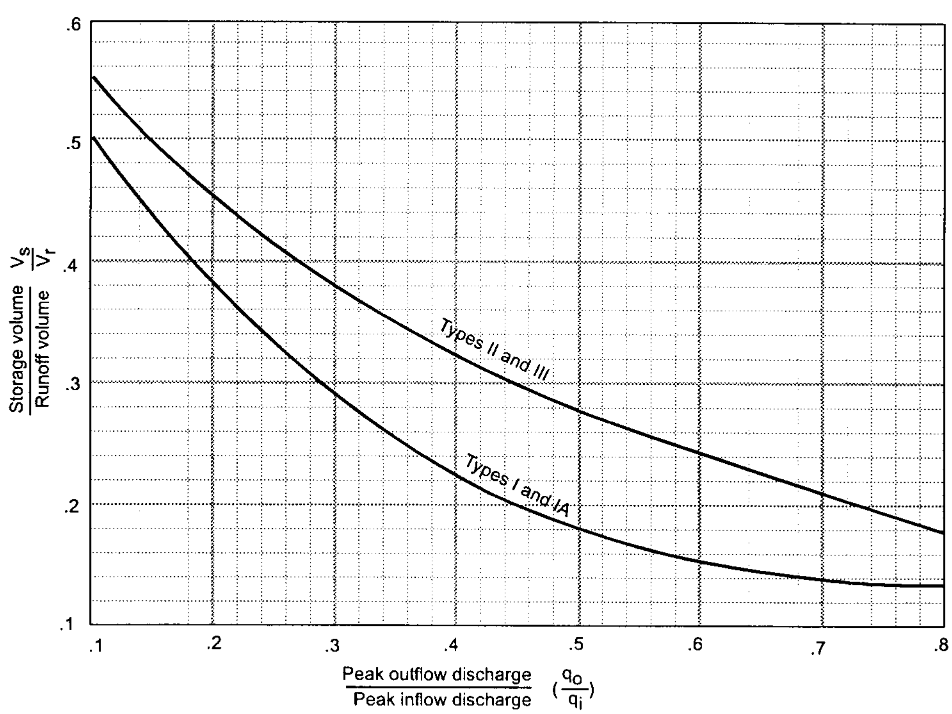


Figure B.2 Approximate Detention Basin Routing For Rainfall Types I, IA, II, and III (Source: NRCS, 1986)



B.2 Water Quality Peak Flow Calculation

The peak rate of discharge for the water quality design storm is needed for the sizing of diversion structures for off-line practices such as sand filters. An arbitrary storm would need to be chosen using the Rational method, and conventional SCS methods have been found to underestimate the volume and rate of runoff for rainfall events less than 2". This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff by-passes the filtering treatment practice due to an inadequately sized diversion structure and leads to the design of undersized bypass channels.

The following procedure can be used to estimate peak discharges for small storm events. It relies on the Water Quality Volume and the simplified peak flow estimating method above. A brief description of the calculation procedure is presented below.

Using the water quality volume (WQ_V), a corresponding Curve Number (CN) is computed utilizing the following equation:

$$\mathbf{CN = 1000/[10 + 5P + 10Q - 10(Q^2 + 1.25\,QP)^{1/2}]}$$

Where

P = rainfall, in inches (use the 90% rainfall event from Figure 4.1 for the Water Quality Storm)

Q = runoff volume, in inches

Once a CN is computed, the time of concentration (t_c) is computed using guidance provided in TR-55.

Using the computed CN, t_c and drainage area (A), in acres; the peak discharge (Q_p) for the water quality storm event is computed (either Type II or Type III in the State of New York).

Read initial abstraction (Ia), compute Ia/P

Read the unit peak discharge (qu) for appropriate t_c

Using the water quality volume (WQ_V), compute the peak discharge (Q_p)

$$\mathbf{Q_p = q_u * A * WQ_V}$$

where Q_p = the peak discharge, in cfs

q_u = the unit peak discharge, in cfs/mi²/inch

A = drainage area, in square miles

WQ_V = Water Quality Volume, in watershed inches

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Appendix C

C.1 Pond Construction Standards/Specifications

These specifications are generally appropriate to all earthen ponds, and are adapted from NRCS Pond Code 378. Practitioners should always consult the New York State Department of Environmental Conservation – Dam Safety Division for the most recent guidance. All references to ASTM and AASHTO specifications apply to the most recent version.

Site Preparation

Areas designated for borrow areas, embankment, and structural works shall be cleared, grubbed and stripped of topsoil. All trees, vegetation, roots and other objectionable material shall be removed. Channel banks and sharp breaks shall be sloped to no steeper than 1:1. All trees shall be cleared and grubbed within 15 feet of the toe of the embankment.

Areas to be covered by the reservoir will be cleared of all trees, brush, logs, fences, rubbish and other objectionable material unless otherwise designated on the plans. Trees, brush, and stumps shall be cut approximately level with the ground surface. For dry stormwater management ponds, a minimum of a 25-foot radius around the outlet structure shall be cleared.

All cleared and grubbed material shall be disposed of outside and below the limits of the dam and reservoir as directed by the owner or his representative. When specified, a sufficient quantity of topsoil will be stockpiled in a suitable location for use on the embankment and other designated areas.

Earth Fill

Material - The fill material shall be taken from approved designated borrow areas. It shall be free of roots, stumps, wood, rubbish, stones greater than 6”, frozen or other objectionable materials. Fill material for the center of the embankment, and cut off trench shall conform to Unified Soil Classification GC, SC, CH, or CL and must have at least 30% passing the #200 sieve. Consideration may be given to the use of other materials in the embankment if designed by a geotechnical engineer. Such special designs must have construction supervised by a geotechnical engineer.

Materials used in the outer shell of the embankment must have the capability to support vegetation of the quality required to prevent erosion of the embankment.

Placement - Areas on which fill is to be placed shall be scarified prior to placement of fill. Fill materials shall be placed in maximum 8 inch thick (before compaction) layers which are to be continuous over the entire length of the fill. The most permeable borrow material shall be placed in the downstream portions of the embankment. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.

Compaction - The movement of the hauling and spreading equipment over the fill shall be controlled so that the entire surface of each lift shall be traversed by not less than one tread track of heavy equipment or compaction shall be achieved by a minimum of four complete passes of a sheepsfoot, rubber tired or vibratory roller. Fill material shall contain sufficient moisture such that the required degree of compaction will be obtained with the equipment used. The fill material shall contain sufficient moisture so that if formed into a ball it will not crumble, yet not be so wet that water can be squeezed out.

When required by the reviewing agency the minimum required density shall not be less than 95% of maximum dry density with a moisture content within 2% of the optimum. Each layer of fill shall be compacted as necessary to obtain that density, and is to be certified by the Engineer at the time of construction. All compaction is to be determined by AASHTO Method T-99 (Standard Proctor).

Cut Off Trench - The cutoff trench shall be excavated into impervious material along or parallel to the centerline of the embankment as shown on the plans. The bottom width of the trench shall be governed by the equipment used for excavation, with the minimum width being four feet. The depth shall be at least four feet below existing grade or as shown on the plans. The side slopes of the trench shall be 1 to 1 or flatter. The backfill shall be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability.

Embankment Core - The core shall be parallel to the centerline of the embankment as shown on the plans. The top width of the core shall be a minimum of four feet. The height shall extend up to at least the 10 year water elevation or as shown on the plans. The side slopes shall be 1 to 1 or flatter. The core shall be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. In addition, the core shall be placed concurrently with the outer shell of the embankment.

Structure Backfill

Backfill adjacent to pipes or structures shall be of the type and quality conforming to that specified for the adjoining fill material. The fill shall be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material needs to fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure. Under no circumstances shall equipment be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24” or greater over the structure or pipe.

Structure backfill may be flowable fill meeting the requirements of the New York State Department of Transportation. The mixture shall have a 100-200 psi; 28 day unconfined compressive strength. The flowable fill shall have a minimum pH of 4.0 and a minimum resistivity of 2,000 ohm-cm. Material shall be placed such that a minimum of 6” (measured perpendicular to the outside of the pipe) of flowable fill shall be under (bedding), over and, on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits. Average slump of the fill shall be 7” to assure flowability of the material. Adequate measures shall be taken (sand bags, etc.) to prevent floating the pipe. When using flowable fill, all metal pipe shall be bituminous coated. Any adjoining soil fill shall be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material shall completely fill all voids adjacent to the flowable fill zone. At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure. Under no circumstances shall equipment be driven over any part of a structure or pipe unless there is a compacted fill of 24” or greater over the structure or pipe. Backfill material outside the structural backfill (flowable fill) zone shall be of the type and quality conforming to that specified for the core of the embankment or other embankment materials.

Pipe Conduits

All pipes shall be circular in cross section.

Corrugated Metal Pipe - All of the following criteria shall apply for corrugated metal pipe:

Materials - (Polymer Coated steel pipe) - Steel pipes with polymeric coatings shall have a minimum coating thickness of 0.01 inch (10 mil) on both sides of the pipe. This pipe and its appurtenances shall conform to the requirements of AASHTO Specifications M-245 & M-246 with watertight coupling bands or flanges.

Materials - (Aluminum Coated Steel Pipe) - This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-274 with watertight coupling bands or flanges. Aluminum Coated Steel Pipe, when used with flowable fill or when soil and/or water conditions warrant the need for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Any aluminum coating damaged or otherwise removed shall be replaced with cold applied bituminous coating compound. Aluminum surfaces that are to be in contact with concrete shall be painted with one coat of zinc chromate primer or two coats of asphalt.

Materials - (Aluminum Pipe) - This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-196 or M-211 with watertight coupling bands or flanges. Aluminum Pipe, when used with flowable fill or when soil and/or water conditions warrant for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Aluminum surfaces that are to be in contact with concrete shall be painted with one coat of zinc chromate primer or two coats of asphalt. Hot dip galvanized bolts may be used for connections. The pH of the surrounding soils shall be between 4 and 9.

Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.

Connections - All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser shall be welded all around when the pipe and riser are metal. Anti-seep collars shall be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.All connections shall use a rubber or neoprene gasket when joining pipe sections. The end of each pipe shall be re-rolled an adequate number of corrugations to accommodate the bandwidth. The following type connections are acceptable for pipes less than 24 inches in diameter: flanges on both ends of the pipe with a circular 3/8 inch closed cell neoprene gasket, pre-punched to the flange bolt circle, sandwiched between adjacent flanges; a 12-inch wide standard lap type band with 12-inch wide by 3/8-inch thick closed cell circular neoprene gasket; and a 12-inch wide hugger type band with o-ring gaskets having a minimum diameter of 1/2 inch greater than the corrugation depth. Pipes 24 inches in diameter and larger shall be connected by a 24 inch long annular corrugated band using a minimum of 4 (four) rods and lugs, 2 on each connecting pipe end. A 24-inch wide by 3/8-inch thick closed cell circular neoprene gasket will be installed with 12 inches on the end of each pipe. Flanged joints with 3/8 inch closed cell gaskets the full width of the flange is also acceptable.

Helically corrugated pipe shall have either continuously welded seams or have lock seams with internal caulking or a neoprene bead.

Bedding - The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support.

Backfilling shall conform to Structure Backfill requirements.

Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

Reinforced Concrete Pipe - All of the following criteria shall apply for reinforced concrete pipe:

Materials - Reinforced concrete pipe shall have bell and spigot joints with rubber gaskets and shall equal or exceed ASTM C-361.

Bedding - Reinforced concrete pipe conduits shall be laid in a concrete bedding / cradle for their entire length. This bedding / cradle shall consist of high slump concrete placed under the pipe and up the sides of the pipe at least 50% of its outside diameter with a minimum thickness of 6 inches. Where a concrete cradle is not needed for structural reasons, flowable fill may be used as described in the Structure Backfill section of this standard. Gravel bedding is not permitted.

Laying pipe - Bell and spigot pipe shall be placed with the bell end upstream. Joints shall be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding shall be placed so that all spaces under the pipe are filled. Care shall be exercised to prevent any deviation from the original line and grade of the pipe. The first joint must be located within 4 feet from the riser.

Backfilling shall conform to **Structure Backfill** requirements.

Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

Plastic Pipe - The following criteria shall apply for plastic pipe:

1. Materials - PVC pipe shall be PVC-1120 or PVC-1220 conforming to ASTM D-1785 or ASTM D-2241. Corrugated High Density Polyethylene (HDPE) pipe, couplings and fittings shall conform to the following: 4” through 10” pipe shall meet the requirements of AASHTO M252 Type S, and 12” through 24” pipe shall meet the requirements of AASHTO M294 Type S.
2. Joints and connections to anti-seep collars shall be completely watertight.
3. Bedding -The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support.
4. Backfilling shall conform to **Structure Backfill** requirements.
5. Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

Drainage Diaphragms - When a drainage diaphragm is used, a registered professional engineer will supervise the design and construction inspection.

Concrete

Concrete shall meet the requirements of the New York State Department of Transportation.

Rock Riprap

Rock riprap shall meet the requirements of the New York State Department of Transportation.

Geotextile shall be placed under all riprap and shall meet the requirements of the New York State Department of Transportation.

Care of Water During Construction

All work on permanent structures shall be carried out in areas free from water. The Contractor shall construct and maintain all temporary dikes, levees, cofferdams, drainage channels, and stream diversions necessary to protect the areas to be occupied by the permanent works. The contractor shall also furnish, install, operate, and maintain all necessary pumping and other equipment required for removal of water from various parts of the work and for maintaining the excavations, foundation, and other parts of the work free from water as required or directed by the engineer for constructing each part of the work. After having served their purpose, all temporary protective works shall be removed or leveled and graded to the extent required to prevent obstruction in any degree whatsoever of the flow of water to the spillway or outlet works and so as not to interfere in any way with the operation or maintenance of the structure. Stream diversions shall be maintained until the full flow can be passed through the permanent works. The removal of water from the required excavation and the foundation shall be accomplished in a manner and to the extent that will maintain stability of the excavated slopes and bottom required excavations and will allow satisfactory performance of all construction operations. During the placing and compacting of material in required excavations, the water level at the locations being refilled shall be maintained below the bottom of the excavation.

Stabilization

All borrow areas shall be graded to provide proper drainage and left in a sightly condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms shall be stabilized by seeding, liming, fertilizing and mulching in accordance with local Natural Resources Conservation Service Standards and Specifications.

Erosion and Sediment Control

Construction operations will be carried out in such a manner that erosion will be controlled and water and air pollution minimized. Federal, State and local laws concerning pollution abatement will be followed. Construction plans shall detail erosion and sediment control measures.

Operation and Maintenance

An operation and maintenance plan in accordance with Local or State Regulations will be prepared for all ponds. As a minimum, a dam inspection checklist shall be included as part of the operation and maintenance plan and performed at least annually. Written records of maintenance and major repairs need to be retained in a file.

Supplemental Stormwater Pond and Wetland Specifications

1. It is preferred to use the same material in the embankment as is being installed for the core trench. If this is not possible, a dam core with a shell may be used. The cross-section of the stormwater facility should show the limits of the dam core (up to the 10-year water surface elevation) as well as the acceptable materials for the shell. The shape of the dam core and the material to be used in the shell should be provided by the geotechnical engineer.

2. If the compaction tests for the remainder of the site improvements is using Modified Proctor (AASHTO T-180), then to maintain consistency on-site, modified proctor may be used in lieu of standard proctor (AASHTO T-99) for checking embankment compaction. The minimum required density using the modified proctor test method shall be at least 92% of maximum dry density with a moisture content of 2% of the optimum.

3. For all stormwater management facilities, a geotechnical engineer must be present to verify compaction in accordance with the selected test method. This information needs to be provided in a report to the design engineer, so that as-built certification of the facility can be made.

4. A 4-inch layer of topsoil shall be placed on all disturbed areas of the dam embankment. Seeding, liming, fertilizing, mulching, etc. shall be in accordance with NRCS Soil Standards and Specifications or New York State Standards and Specifications for Soil Erosion and Sediment Control. The purpose of the topsoil is to establish a good growth of grass which is not always possible with some of the materials that may be placed for the embankment fill.

5. Filter fabric placed beneath the rip-rap shall meet state or local department of transportation requirements for a Class "C" filter fabric. Some acceptable filter fabrics that meet the Class "C" criteria include:

   Mirafi 180-N

   Amoco 4552

   Webtec N07

   Geolon N70

   Carthage FX-70S

   This is only a partial listing of available filter fabrics based on information provided by the manufacturers to the 1997 Specifier's Guide dated December 1996. It is the responsibility of the engineer to verify the adequacy of the material, as there are changes in the manufacturing process and the type of fabric used, which may affect the continued acceptance.

6. The design engineer and geotechnical engineer should make the determination that the settlement of the pond will not cause excessive joint extension. For further information on joint extension analysis, see NRCS Publication TR-18.

7. Fill placement shall not exceed a maximum of 8-inch lift thickness. Each lift shall be continuous for the entire length of the embankment.

8. The embankment fill **shall not** be placed higher than the centerline of the principle spillway until after the principle spillway has been installed.

9. The side slopes of a cut to repair a dam, install a principle spillway for an excavated pond, or other repair work, shall be stepped and on an average slope of 2:1 or flatter.

C.2 Construction Specifications for Infiltration Practices

Infiltration Trench General Notes and Specifications

The infiltration trench systems may not receive run-off until the entire contributing drainage area to the infiltration system has received final stabilization.

1. Heavy equipment and traffic shall be restricted from traveling over the infiltration trench to minimize compaction of the soil.

2. Excavate the infiltration trench to the design dimensions. Excavated materials shall be placed away from the trench sides to enhance trench wall stability. Large tree roots must be trimmed flush with the trench sides in order to prevent fabric puncturing or tearing of the filter fabric during subsequent installation procedures. The side walls of the trench shall be roughened where sheared and sealed by heavy equipment.

3. A Class "C" geotextile or better shall interface between the trench side walls and between the stone reservoir and gravel filter layers. A partial list of non-woven filter fabrics that meet the Class "C" criteria is contained below. Any alternative filter fabric must be approved by the local municipality prior to installation.

   Mirafi 180-N
   Amoco 4552
   WEBTEC N70
   GEOLON N70
   Carthage FX-80S

   The width of the geotextile must include sufficient material to conform to trench perimeter irregularities and for a 6-inch minimum top overlap. The filter fabric shall be tucked under the sand layer on the bottom of the infiltration trench for a distance of 6 to 12 inches. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the trench open during windy periods. When overlaps are required between rolls, the uphill roll should lap a minimum of 2 feet over the downhill roll in order to provide a shingled effect.

4. A 6 inch sand layer may be placed on the bottom of the infiltration trench in lieu of filter fabric, and shall be compacted using plate compactors. The sand for the infiltration trench shall be washed and meet AASHTO Std. M-43, Size No. 9 or No. 10. Any alternative sand gradation must be approved by the Engineer or the local municipality.

5. The stone aggregate should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. Gravel filling (rounded bank run gravel is preferred) for the infiltration trench shall be washed and meet one of the following: AASHTO Std. M-43; Size No. 2 or No. 3.

6. Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 6-inch minimum longitudinal lap. The desired fill soil or stone aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

7. Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

8. Voids can be created between the fabric and the excavation sides and shall be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids, therefore, natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides.

9. Vertically excavated walls may be difficult to maintain in areas where soil moisture is high or where soft cohesive or cohesionless soils are predominate. These conditions may require laying back of the side slopes to maintain stability.

10. PVC distribution pipes shall be Schedule 40 and meet ASTM Std. D 1784. All fittings and perforations (1/2 inch in diameter) shall meet ASTM Std. D 2729. A perforated pipe shall be provided only within the infiltration trench and shall terminate 1 foot short of the infiltration trench wall. The end of the PVC pipe shall be capped.

11. Corrugated metal distribution pipes shall conform to AASHTO Std. M-36, and shall be aluminized in accordance with AASHTO Std. M-274. Coat aluminized pipe in contact with concrete with an inert compound capable of effecting isolation of the deleterious effect of the aluminum on the concrete. Perforated distribution pipe shall be provided only within the infiltration trench and shall terminate 1 foot short of the infiltration trench wall. An aluminized metal plate shall be welded to the end of the pipe.

12. The observation well is to consist of 6-inch diameter PVC Schedule 40 pipe (ASTM Std. D 1784) with a cap set 6 inches above ground level and is to be located near the longitudinal center of the infiltration trench. Preferably the observation well will not be located in vehicular traffic areas. The pipe shall have a plastic collar with ribs to prevent rotation when removing cap. The screw top lid shall be a "Panella" type cleanout with a locking mechanism or special bolt to discourage vandalism. A perforated (1/2 inch in diameter) PVC Schedule 40 pipe shall be provided and placed vertically within the gravel portion of the infiltration trench and a cap provided at the bottom of the pipe. The bottom of the cap shall rest on the infiltration trench bottom.

13. If a distribution structure with a wet well is used, a 4-inch PVC drain pipe shall be provided at opposite ends of the infiltration trench distribution structure. Two (2) cubic feet of porous backfill meeting AASHTO Std. M-43 Size No. 57 shall be provided at each drain.

14. If a distribution structure is used, the manhole cover shall be bolted to the frame.

NOTE: PVC pipe with a wall thickness classification of SDR-35 meeting ASTM standard D3034 is an acceptable substitution for PVC Schedule 40 pipe.

Infiltration Basins Notes and Specifications

1. The sequence of various phases of basin construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin (to not less than 2' from final grade) with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin, however, **cannot** serve as a sedimentation basin.

   Specifications for basin construction should state: (1) the earliest point in progress when storm drainage may be directed to the basin, and (2) the means by which this delay in use is to be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.

2. Initial basin excavation should be carried to within 2 feet of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas on the watershed have been stabilized or protected. The final phase excavation should remove all accumulated sediment. Relatively light tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin should retain a highly porous surface texture.

3. Infiltration basins may be lined with a 6- to 12-inch layer of filter material such as coarse sand (AASHTO Std. M-43, Sizes 9 or 10) to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when it becomes clogged. When a 6-inch layer of coarse organic material is specified for discing (such as hulls, leaves, stems, etc.) or spading into the basin floor to increase the permeability of the soils, the basin floor should be soaked or inundated for a brief period, then allowed to dry subsequent to this operation. This induces the organic material to decay rapidly, loosening the upper soil layer.

4. Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative stand will not only prevent erosion and sloughing, but will also provide a natural means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin shall also be provided.

5. Selection of suitable vegetative materials for the side slope and all other areas to be stabilized with vegetation and application of required lime, fertilizer, etc. shall be done in accordance with the NRCS Standards and Specifications or your local Standards and Specifications for Soil Erosion and Sediment Control.

6. Grasses of the fescue family are recommended for seeding primarily due to their adaptability to dry sandy soils, drought resistance, hardiness, and ability to withstand brief inundations. The use of fescues will also permit long intervals between mowings. This is important due to the relatively steep slopes which make mowing difficult. Mowing twice a year, once in June and again in September, is generally satisfactory.

C.3 Construction Specifications for Bioretention, Sand Filters and Open Channels

Sand Filter Specifications

Material Specifications for Sand Filters

The allowable materials for sand filter construction are detailed in Table 1.

Sand Filter Testing Specifications

Underground sand filters, facilities within sensitive groundwater aquifers, and filters designed to serve urban hot spots are to be tested for water tightness prior to placement of filter layers. Entrances and exits should be plugged and the system completely filled with water to demonstrate water tightness.

All overflow weirs, multiple orifices and flow distribution slots to be field-tested as to verify adequate distribution of flows.

Sand Filter Construction Specifications

Provide sufficient maintenance access; 12-foot-wide road with legally recorded easement. Vegetated access slopes to be a maximum of 10%; gravel slopes to 15%; paved slopes to 25%.

Absolutely no runoff is to enter the filter until all contributing drainage areas have been stabilized.

Surface of filter bed to be *completely level*.

All sand filters should be clearly delineated with signs so that they may be located when maintenance is due.

Surface sand filters shall be planted with appropriate grasses as specified in your local NRCS Standards and Specifications guidance.

Pocket sand filters (and residential bioretention facilities treating areas larger than an acre) shall be sized with an ornamental stone window covering approximately 10% of the filter area. This surface shall be 2” to 5” size stone on top of a pea gravel layer (3/4 inch stone) approximately 4 to 6” of pea gravel.

Specifications Pertaining to Underground Sand Filters

Provide manhole and/or grates to all underground and below grade structures. Manholes shall be in compliance with standard specifications for each jurisdiction but diameters should be 30” minimum (to comply with OSHA confined space requirements) but not too heavy to lift. Aluminum and steel louvered doors are also acceptable. Ten-inch long (minimum) manhole steps (12” o.c.) shall be cast in place or drilled and mortared into the wall below each manhole. A 5= minimum height clearance (from the top of the sand layer to the bottom of the slab) is required for all permanent underground structures. Lift rings are to be supplied to remove/replace top slabs. Manholes may need to be grated to allow for proper ventilation; if required, place manholes *away* from areas of heavy pedestrian traffic.

Underground sand filters shall be constructed with a dewatering gate valve located just above the top of the filter bed should the bed clog.

Underground sand beds shall be protected from trash accumulation by a wide mesh geotextile screen to be placed on the surface of the sand bed; screen is to be rolled up, removed, cleaned and re-installed during maintenance operations.

Table C-1 Sand Filter Material Specifications

Parameter	Specification	Size	Notes
Sand	Clean AASHTO M-6 or ASTM C-33 concrete sand	0.02” to 0.04”	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. “Rock dust” cannot be substituted for sand.
Peat	Ash content: < 15% PH range: 5.2 to 4.9 Loose bulk density 0.12 to 0.15 g/cc	n/a	The material must be Reed-Sedge Hemic Peat, shredded, uncompacted, uniform, and clean.
Underdrain Gravel	AASHTO M-43 No. 67	0.25” to 0.75”	
Geotextile Fabric (if required)	ASTM D-751 (puncture strength - 125 lb.) ASTM D-1117 (Mullen Burst Strength - 400 psi) ASTM D-1682 (Tensile Strength - 300 lb.)	0.08” thick equivalent opening size of #80 sieve	Must maintain 125 gpm per sq. ft. flow rate. Note: a 4” pea gravel layer may be substituted for geotextiles meant to separate sand filter layers.
Impermeable Liner (if required)	ASTM D 751 (thickness) ASTM D 412 (tensile strength 1,100 lb., elongation 200%) ASTM D 624 (Tear resistance - 150 lb./in) ASTM D 471 (water adsorption: +8 to -2% mass)	30mil thickness	Liner to be ultraviolet resistant. A geotextile fabric should be used to protect the liner from puncture.
Underdrain Piping	ASTM D-1785 or AASHTO M-278	6” rigid schedule 40 PVC	3/8” perf. 6” on center, 4 holes per row; minimum of 3” of gravel over pipes; not necessary underneath pipes
Concrete (Cast-in-place)	See local DOT Standards and Specs. f=c = 3500 psi, normal weight, air-entrained; re-inforcing to meet ASTM 615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a licensed professional structural engineer.
Concrete (pre-cast)	per pre-cast manufacturer	n/a	SEE ABOVE NOTE
Non-rebar steel	ASTM A-36	n/a	structural steel to be hot-dipped galvanized ASTM A123

Specifications for Bioretention

Material Specifications

The allowable materials to be used in bioretention area are detailed in Table G.2.

Planting Soil

The soil shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches. No other materials or substances shall be mixed or dumped within the bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The planting soil shall be free of noxious weeds.

The planting soil shall be tested and shall meet the following criteria:

pH range	5.2 - 7.0
organic matter	1.5 - 4%
magnesium	35 lb./ac
phosphorus P_2O_5	75 lb./ac
potassium K_2O	85 lb./ac
soluble salts	not to exceed 500 ppm

All bioretention areas shall have a minimum of one test. Each test shall consist of both the standard soil test for pH, phosphorus, and potassium and additional tests of organic matter, and soluble salts. A textural analysis is required from the site stockpiled topsoil. If topsoil is imported, then a texture analysis shall be performed for each location where the top soil was excavated.

Since different labs calibrate their testing equipment differently, all testing results shall come from the same testing facility.

Should the pH fall out of the acceptable range, it may be modified (higher) with lime or (lower) with iron sulfate plus sulfur.

Compaction

It is very important to minimize compaction of both the base of the bioretention area and the required backfill. When possible, use excavation hoes to remove original soil. If bioretention areas are excavated using a loader, the contractor should use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reduced infiltration rates and storage volumes and is not acceptable. Compaction will significantly contribute to design failure.

Compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12 inch compaction zone. Substitute methods must be approved by the engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

Rototill 2 to 3 inches of sand into the base of the bioretention facility before back filling the required sand layer. Pump any ponded water before preparing (rototilling) base.

When back filling the topsoil over the sand layer, first place 3 to 4 inches of topsoil over the sand, then rototill the sand/topsoil to create a gradation zone. Backfill the remainder of the topsoil to final grade.

When back filling the bioretention facility, place soil in lifts 12” or greater. Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand. Grade bioretention materials by hand or with light equipment such as a compact loader or a dozer/loader with marsh tracks.

Plant Installation

Mulch around individual plants only. Shredded hardwood mulch is the only accepted mulch. Pine mulch and wood chips will float and move to the perimeter of the bioretention area during a storm event and are not acceptable. Shredded mulch must be well aged (6 to 12 months) for acceptance.

The plant root ball should be planted so 1/8th of the ball is above final grade surface.

Root stock of the plant material shall be kept moist during transport and on-site storage. The diameter of the planting pit shall be at least six inches larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.

Trees shall be braced using 2" X 2" stakes only as necessary and for the first growing season only. Stakes are to be equally spaced on the outside of the tree ball.

Grasses and legume seed shall be tilled into the soil to a depth of at least one inch. Grass and legume plugs shall be planted following the non-grass ground cover planting specifications.

The topsoil specifications provide enough organic material to adequately supply nutrients from natural cycling. The primary function of the bioretention structure is to improve water quality. Adding fertilizers defeats, or at a minimum, impedes this goal. Only add fertilizer if wood chips or mulch is used to amend the soil. Rototill urea fertilizer at a rate of 2 pounds per 1000 square feet.

Underdrains

Under drains to be placed on a 3’-0” wide section of filter cloth. Pipe is placed next, followed by the gravel bedding. The ends of under drain pipes not terminating in an observation well shall be capped.

The main collector pipe for underdrain systems shall be constructed at a minimum slope of 0.5%. Observation wells and/or clean-out pipes must be provided (one minimum per every 1000 square feet of surface area).

Miscellaneous

The bioretention facility may not be constructed until all contributing drainage area has been stabilized.

Table C.2 Materials Specifications for Bioretention

Parameter	Specification	Size	Notes
Plantings	see your local NRCS Standards and Specifications guidance.	n/a	plantings are site-specific
Planting Soil [4= deep]	sand 35 - 60% silt 30 - 55% clay 10 - 25%	n/a	USDA soil types loamy sand, sandy loam or loam
Mulch	shredded hardwood		aged 6 months, minimum
pea gravel diaphragm and curtain drain	pea gravel: ASTM D 448 ornamental stone: washed cobbles	pea gravel: No. 6 stone: 2" to 5"	
Geotextile	Class "C" apparent opening size (ASTM-D-4751) grab tensile strength (ASTM-D-4632) burst strength (ASTM-D-4833)	n/a	for use as necessary beneath underdrains only
underdrain gravel	AASHTO M-43. No. 67.	0.25" to 0.75"	
underdrain piping	ASTM D 1785 or AASHTO M-278	6" rigid schedule 40 PVC	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
poured in place concrete (if required)	See local DOT Standards and Specs.; f=c = 3500 psi. @ 28 days, normal weight, air-entrained; re-inforcing to meet ASTM 615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a licensed professional structural engineer.
sand [1= deep]	AASHTO M-6 or ASTM C-33	0.02" to 0.04"	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. No "rock dust" can be used for sand.

Specifications for Open Channels and Filter Strips

Material Specifications
The recommended construction materials for open channels and filter strips are detailed in Table G.3.

Dry Swales

Roto-till soil/gravel interface approximately 6” to avoid a sharp soil/gravel interface.

Permeable soil mixture (20" to 30" deep) should meet the bioretention planting soil specifications.

Check dams, if required, shall be placed as specified.

System to have 6” of freeboard, minimum.

Side slopes to be 3:1 minimum; (4:1 or greater preferred).

No gravel or perforated pipe is to be placed under driveways.

Bottom of facility to be above the seasonably high water table.

Seed with flood/drought resistant grasses; see your local NRCS Standards and Specifications guidance.

Longitudinal slope to be 1 to 2%, maximum [up to 5% with check dams].

Bottom width to be 8’= maximum to avoid braiding; larger widths may be used if proper berming is supplied. Width to be 2’= minimum.

Wet Swales
Follow above information for dry swales, with the following exceptions: the seasonally high water table may inundate the swale; but not above the design bottom of the channel [NOTE: if the water table is stable within the channel; the WQv storage may start at this point]

Excavate into undisturbed soils; do not use an underdrain system.

Filter Strips

Construct pea gravel diaphragms 12” wide, minimum, and 24” deep minimum.

Pervious berms to be a sand/gravel mix (35-60% sand, 30-55% silt, and 10-25% gravel). Berms to have overflow weirs with 6 inch minimum avilable head.

Slope range to be 2% minimum to 6% maximum.

Table C.3 Open Vegetated Swale and Filter Strip Materials Specifications

Parameter	Specification	Size	Notes
Dry swale soil	USCS; ML, SM, SC	n/a	soil with a higher percent organic content is preferred
Dry Swale sand	ASTM C-33 fine aggregate concrete sand	0.02” to 0.04”	
Check Dam (pressure treated)	AWPA Standard C6	6” by 6” or 8” by 8”	*do not* coat with creosote; embed at least 3= into side slopes
Check Dam (natural wood)	Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut	6” to 12” diameter; notch as necessary	*do not* use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow
Filter Strip sand/gravel pervious berm	sand: per dry swale sand gravel; AASHTO M-43 No. 57	sand: 0.02” to 0.04” gravel: 2” to 1”	mix with approximately 25% loan soil to support grass cover crop; see Bioretention planting soil notes for more detail.
pea gravel diaphragm and curtain drain	ASTM D 448	varies (No. 6) or (1/8” to 3/8”)	use clean bank-run gravel
under drain gravel	AASHTO M-43 No. 67	0.25” to 0.75”	
under drain	ASTM D -1785 or AASHTO M-278	6” rigid Schedule 40 PVC	3/8” perf. @ 6” o.c.; 4 holes per row
Geotextile	See local DOT Standards and Specs	n/a	
rip rap	per local DOT criteria	size per New York State DOT requirements based on 10-year design flows	

Appendix D

General Notes Pertinent to All Testing

1. For infiltration practices, a minimum field infiltration rate (f_c) of 0.5 inches per hour is required; areas yielding a lower rate preclude these practices. If the minimum f_c exceeds two inches per hour, half of the WQ_v must be treated by an upstream SMP that does allow infiltration. For F-1 and F-6 practices, no minimum infiltration rate is required if these facilities are designed with a "day-lighting" underdrain system; otherwise these facilities require a 0.5 inch per hour rate.

2. Number of required borings is based on the size of the proposed facility. Testing is done in two phases, (1) Initial Feasibility, and (2) Concept Design Testing.

3. Testing is to be conducted by a qualified professional. This professional shall either be a registered professional engineer in the State of New York, a soils scientist or geologist also licensed in the State of New York.

Initial Feasibility Testing

Feasibility testing is conducted to determine whether full-scale testing is necessary, and is meant to screen unsuitable sites, and reduce testing costs. A soil boring is not required at this stage. However, a designer or landowner may opt to engage Concept Design Borings per Table H-1 at his or her discretion, without feasibility testing.

Initial testing involves either one field test per facility, regardless of type or size, or previous testing data, such as the following:

* septic percolation testing on-site, within 200 feet of the proposed SMP location, and on the same contour [can establish initial rate, water table and/or depth to bedrock]
* previous written geotechnical reporting on the site location as prepared by a qualified geotechnical consultant
* NRCS County Soil Mapping *showing an unsuitable soil group* such as a hydrologic group "D" soil in a low-lying area, or a Marlboro Clay

If the results of initial feasibility testing as determined by a qualified professional show that an infiltration rate of greater than 0.5 inches per hour is probable, then the number of *concept design test* pits shall be per the following table. An encased soil boring may be substituted for a test pit, if desired.

Table D-1 Infiltration Testing Summary Table

Type of Facility	Initial Feasibility Testing	Concept Design Testing (initial testing yields a rate greater than 0.5"/hr)	Concept Design Testing (initial testing yields a rate lower than 0.5"/hr)
I-1 (trench)	1 field percolation test, test pit not required	1infiltration test and 1 test pit per 50' of trench	not acceptable practice
I-2 (basin)	1 field percolation test, test pit not required	1 infiltration test* and 1 test pit per 200 sf of basin area	not acceptable practice
F-1(sand filter)	1 field percolation test, test pit not required	1 infiltration test and 1 test pit per 200 sf of filter area (no underdrains required**)	underdrains required
F-6 (bioretention)	1 field percolation test, test pit not required	1 infiltration test and 1 test pit per 200 sf of filter area (no underdrains required**)	underdrains required

*feasibility test information already counts for one test location
** underdrain installation still strongly suggested

Documentation

Infiltration testing data shall be documented, which shall also include a description of the infiltration testing method, if completed. This is to ensure that the tester understands the procedure.

Test Pit/Boring Requirements

a. excavate a test pit or dig a standard soil boring to a minimum depth of 4 feet below the proposed facility bottom elevation

b. determine depth to groundwater table (if within 4 feet of proposed bottom) upon initial digging or drilling, and again 24 hours later

c. conduct Standard Penetration Testing (SPT) every 2' to a depth of 4 feet below the facility bottom

d. determine USDA or Unified Soil Classification System textures at the proposed bottom and 4 feet below the bottom of the SMP

e. determine depth to bedrock (if within 4 feet of proposed bottom)

f. The soil description should include all soil horizons.
g. The location of the test pit or boring shall correspond to the SMP location; test pit/soil boring stakes are to be left in the field for inspection purposes and shall be clearly labeled as such.

Infiltration Testing Requirements

a. Install casing (solid 5 inch diameter, 30" length) to 24" below proposed SMP bottom (see Figure D-1).

b. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a two (2) inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with *clean* water to a depth of 24" and allow to pre-soak for twenty-four hours

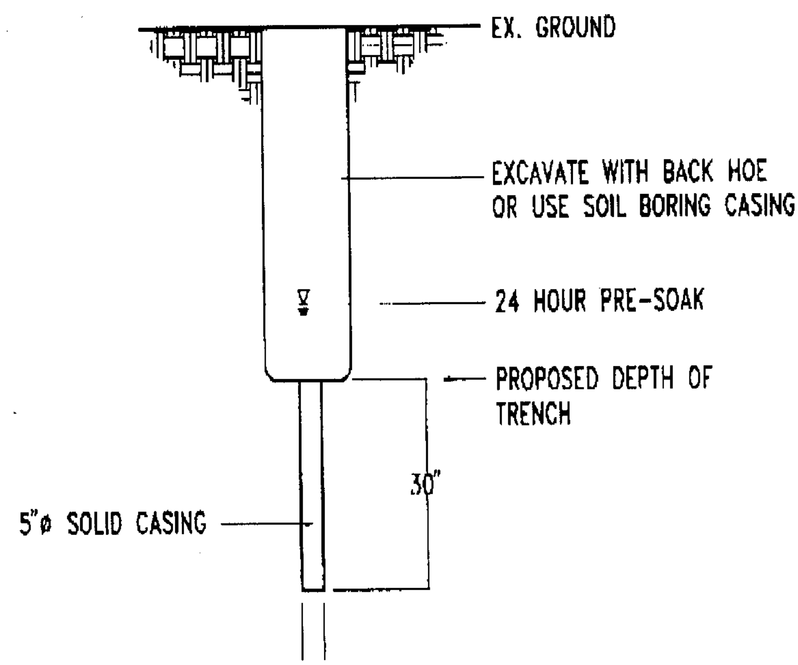
c. Twenty-four hours later, refill casing with another 24" of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate shall be reported in *inches per hour*.

d. May be done though a boring or open excavation.

e. The location of the test shall correspond to the SMP location.

f. Upon completion of the testing, the casings shall be immediately pulled, and the test pit shall be back-filled.

Figure D.1 Infiltration Testing Requirements



Laboratory Testing

a. Grain-size sieve analysis and hydrometer tests where appropriate may be used to determine USDA soils classification and textural analysis. Visual field inspection by a qualified professional may also be used, provided it is documented. *The use of lab testing to establish infiltration rates is prohibited.*

Bioretention Testing

All areas to be used as bioretention facilities shall be back-filled with a suitable sandy loam planting media. The borrow source of this media, which may be the same or different location from the bioretention area itself, must be tested as follows:

If the borrow area is virgin, undisturbed soil, one test is required per 200 sf of borrow area; the test consists of "grab" samples at one foot depth intervals to the bottom of the borrow area. All samples at the testing location are then mixed, and the resulting sample is then lab-tested to meet the following criteria:

a) USDA minimum textural analysis requirements: A textural analysis is required from the site stockpiled topsoil. If topsoil is imported, then a texture analysis shall be performed for each location where the top soil was excavated.

Minimum requirements:

sand	35 - 60%
silt	30 - 55%
clay	10 - 25%

b) The soil shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches.

c) Consult the bioretention construction specifications (Appendix J) for further guidance on preparing the soil for a bioretention area.

Appendix E

Example Checklist for Preliminary/Concept Stormwater Management Plan Preparation and Review

☐ Applicant information
☐ Name, legal address, and telephone number
☐ Common address and legal description of site
☐ Vicinity map
☐ Existing and proposed mapping and plans (recommended scale of 1” = 50’.) which illustrate at a minimum:
- Existing and proposed topography (minimum of 2-foot contours recommended)
- Perennial and intermittent streams
- Mapping of predominant soils from USDA soil surveys
- Boundaries of existing predominant vegetation and proposed limits of clearing
- Location and boundaries of resource protection areas such as wetlands, lakes, ponds, and other setbacks (e.g., stream buffers, drinking water well setbacks, septic setbacks)
- Location of existing and proposed roads, buildings, and other structures
- Existing and proposed utilities (e.g., water, sewer, gas, electric) and easements
- Location of existing and proposed conveyance systems such as grass channels, swales, and storm drains
- Flow paths
- Location of floodplain/floodway limits and relationship of site to upstream and downstream properties and drainages
- Preliminary location and dimensions of proposed channel modifications, such as bridge or culvert crossings
- Preliminary location, size, and limits of disturbance of proposed stormwater treatment practices

☐ Hydrologic and hydraulic analysis including:
- Existing condition analysis for runoff rates, volumes, and velocities presented showing methodologies used and supporting calculations
- Proposed condition analysis for runoff rates, volumes, and velocities showing the methodologies used and supporting calculations
- Preliminary analysis of potential downstream impact/effects of project, where necessary
- Preliminary selection and rationale for structural stormwater management practices
- Preliminary sizing calculations for stormwater treatment practices including contributing drainage area, storage, and outlet configuration

☐ Preliminary landscaping plans for stormwater treatment practices and any site reforestation or revegetation
☐ Preliminary erosion and sediment control plan that at a minimum meets the requirements outlined in local Erosion and Sediment Control guidelines
☐ Identification of preliminary waiver requests

Example Checklist for Final Stormwater Management Plan Preparation and Review

- ☐ Applicant information
  - Name, legal address, and telephone number
- ☐ Common address and legal description of site
- ☐ Signature and stamp of registered engineer/surveyor and design/owner certification
- ☐ Vicinity map
- ☐ Existing and proposed mapping and plans (recommended scale of 1" = 50' or greater detail) which illustrate at a minimum:
  - ▸ Existing and proposed topography (minimum of 2-foot contours recommended)
  - ▸ Perennial and intermittent streams
  - ▸ Mapping of predominant soils from USDA soil surveys as well as location of any site-specific borehole investigations that may have been performed.
  - ▸ Boundaries of existing predominant vegetation and proposed limits of clearing
  - ▸ Location and boundaries of resource protection areas such as wetlands, lakes, ponds, and other setbacks (e.g., stream buffers, drinking water well setbacks, septic setbacks)
  - ▸ Location of existing and proposed roads, buildings, and other structures
  - ▸ Location of existing and proposed utilities (e.g., water, sewer, gas, electric) and easements
  - ▸ Location of existing and proposed conveyance systems such as grass channels, swales, and storm drains
  - ▸ Flow paths
  - ▸ Location of floodplain/floodway limits and relationship of site to upstream and downstream properties and drainages
  - ▸ Location and dimensions of proposed channel modifications, such as bridge or culvert crossings
  - ▸ Location, size, maintenance access, and limits of disturbance of proposed structural stormwater Management practices
- ☐ Representative cross-section and profile drawings and details of structural stormwater Management practices and conveyances (i.e., storm drains, open channels, swales, etc.) which include:
  - ▸ Existing and proposed structural elevations (e.g., invert of pipes, manholes, etc.)
  - ▸ Design water surface elevations
  - ▸ Structural details of outlet structures, embankments, spillways, stilling basins, grade control structures, conveyance channels, etc.
  - ▸ Logs of borehole investigations that may have been performed along with supporting geotechnical report.

☐ Hydrologic and hydraulic analysis for all structural components of stormwater system (e.g., storm drains, open channels, swales, Management practices, etc.) for applicable design storms including:
  - Existing condition analysis for time of concentrations, runoff rates, volumes, velocities, and water surface elevations showing methodologies used and supporting calculations
  - Proposed condition analysis for time of concentrations, runoff rates, volumes, velocities, water surface elevations, and routing showing the methodologies used and supporting calculations
  - Final sizing calculations for structural stormwater Management practices including, contributing drainage area, storage, and outlet configuration
  - Stage-discharge or outlet rating curves and inflow and outflow hydrographs for storage facilities (e.g., stormwater ponds and wetlands)
  - Final analysis of potential downstream impact/effects of project, where necessary
  - Dam breach analysis, where necessary

☐ Final landscaping plans for structural stormwater Management practices and any site reforestation or revegetation
☐ Structural calculations, where necessary
☐ Applicable construction specifications
☐ Erosion and sediment control plan that at a minimum meets the requirements of the local Erosion and Sediment Control Guidelines
☐ Sequence of construction
☐ Maintenance plan which will include:
  - Name, address, and phone number of responsible parties for maintenance.
  - Description of annual maintenance tasks
  - Description of applicable easements
  - Description of funding source
  - Minimum vegetative cover requirements
  - Access and safety issues
  - Testing and disposal of sediments that will likely be necessary

☐ Evidence of acquisition of all applicable local and non-local permits
☐ Evidence of acquisition of all necessary legal agreements (e.g., easements, covenants, land trusts)
☐ Waiver requests
☐ Review agency should have inspector's checklist identifying potential features to be inspected on site visits

Appendix F

Stormwater/Wetland Pond Construction Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
Pre-Construction/Materials and Equipment		
Pre-construction meeting		
Pipe and appurtenances on-site prior to construction and dimensions checked		
1. Material (including protective coating, if specified)		
2. Diameter		
3. Dimensions of metal riser or pre-cast concrete outlet structure		
4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans		
5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope		
6. Number and dimensions of prefabricated anti-seep collars		
7. Watertight connectors and gaskets		
8. Outlet drain valve		
Project benchmark near pond site		
Equipment for temporary de-watering		

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
2. Subgrade Preparation		
Area beneath embankment stripped of all vegetation, topsoil, and organic matter		
3. Pipe Spillway Installation		
Method of installation detailed on plans		
A. Bed preparation		
Installation trench excavated with specified side slopes		
Stable, uniform, dry subgrade of relatively impervious material (If subgrade is wet, contractor shall have defined steps before proceeding with installation)		
Invert at proper elevation and grade		
B. Pipe placement		
Metal / plastic pipe		
1. Watertight connectors and gaskets properly installed		
2. Anti-seep collars properly spaced and having watertight connections to pipe		
3. Backfill placed and tamped by hand under “haunches” of pipe		
4. Remaining backfill placed in max. 8 inch lifts using small power tamping equipment until 2 feet cover over pipe is reached		

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
3. Pipe Spillway Installation		
Concrete pipe		
1. Pipe set on blocks or concrete slab for pouring of low cradle		
2. Pipe installed with rubber gasket joints with no spalling in gasket interface area		
3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set		
4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant		
5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix		
6. Upper half of anti-seep collar(s) formed with reinforcing steel set		
7. Concrete for collar of an approved mix and vibrated into place (protected from freezing while curing, if necessary)		
8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary.		
C. Backfilling		
Fill placed in maximum 8 inch lifts		
Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment		

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
4. Riser / Outlet Structure Installation		
Riser located within embankment		
A. Metal riser		
Riser base excavated or formed on stable subgrade to design dimensions		
Set on blocks to design elevations and plumbed		
Reinforcing bars placed at right angles and projecting into sides of riser		
Concrete poured so as to fill inside of riser to invert of barrel		
B. Pre-cast concrete structure		
Dry and stable subgrade		
Riser base set to design elevation		
If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely		
Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway		
C. Poured concrete structure		
Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set		
Structure formed to design dimensions, with reinforcing steel set as per plan		
Concrete of an approved mix and vibrated into place (protected from freezing while curing, if necessary)		
Forms stripped & inspected for “honeycomb” prior to backfilling; parge if necessary		

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
5. Embankment Construction		
Fill material		
Compaction		
Embankment		
1. Fill placed in specified lifts and compacted with appropriate equipment		
2. Constructed to design cross-section, side slopes and top width		
3. Constructed to design elevation plus allowance for settlement		
6. Impounded Area Construction		
Excavated / graded to design contours and side slopes		
Inlet pipes have adequate outfall protection		
Forebay(s)		
Pond benches		
7. Earth Emergency Spillway Construction		
Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.		
Excavated to proper cross-section, side slopes and bottom width		
Entrance channel, crest, and exit channel constructed to design grades and elevations		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
8. Outlet Protection		
A. End section		
Securely in place and properly backfilled		
B. Endwall		
Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified		
Endwall formed to design dimensions with reinforcing steel set as per plan		
Concrete of an approved mix and vibrated into place (protected from freezing, if necessary)		
Forms stripped and structure inspected for “honeycomb” prior to backfilling; parge if necessary		
C. Riprap apron / channel		
Apron / channel excavated to design cross-section with proper transition to existing ground		
Filter fabric in place		
Stone sized as per plan and uniformly place at the thickness specified		
9. Vegetative Stabilization		
Approved seed mixture or sod		
Proper surface preparation and required soil amendments		
Excelsior mat or other stabilization, as per plan		

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
10. Miscellaneous		
Drain for ponds having a permanent pool		
Trash rack / anti-vortex device secured to outlet structure		
Trash protection for low flow pipes, orifices, etc.		
Fencing (when required)		
Access road		
Set aside for clean-out maintenance		
11. Stormwater Wetlands		
Adequate water balance		
Variety of depth zones present		
Approved pondscaping plan in place Reinforcement budget for additional plantings		
Plants and materials ordered 6 months prior to construction		
Construction planned to allow for adequate planting and establishment of plant community (April-June planting window)		
Wetland buffer area preserved to maximum extent possible		

Comments:

Actions to be Taken:

Infiltration Trench Construction Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Soil permeability tested		
Groundwater / bedrock sufficient at depth		
2. Excavation		
Size and location		
Side slopes stable		
Excavation does not compact subsoils		
3. Filter Fabric Placement		
Fabric specifications		
Placed on bottom, sides, and top		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Aggregate Material		
Size as specified		
Clean / washed material		
Placed properly		
5. Observation Well		
Pipe size		
Removable cap / footplate		
Initial depth =______feet		
6. Final Inspection		
Pretreatment facility in place		
Contributing watershed stabilized prior to flow diversion		
Outlet		

Comments:

Actions to be Taken:

Infiltration Basin Construction Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
1. Pre-Construction		
Runoff diverted		
Soil permeability tested		
Groundwater / bedrock depth		
2. Excavation		
Size and location		
Side slopes stable		
Excavation does not compact subsoils		
3. Embankment		
Barrel		
Anti-seep collar or Filter diaphragm		
Fill material		

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
4. Final Excavation		
Drainage area stabilized		
Sediment removed from facility		
Basin floor tilled		
Facility stabilized		
5. Final Inspection		
Pretreatment facility in place		
Inlets / outlets		
Contributing watershed stabilized before flow is routed to the factility		

Comments:

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Actions to be Taken:

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Sand/Organic Filter System Construction Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Pre-construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
Facility location staked out		
2. Excavation		
Size and location		
Side slopes stable		
Foundation cleared of debris		
If designed as exfilter, excavation does not compact subsoils		
Foundation area compacted		
3. Structural Components		
Dimensions and materials		
Forms adequately sized		
Concrete meets standards		
Prefabricated joints sealed		
Underdrains (size, materials)		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Completed Facility Components		
24 hour water filled test		
Contributing area stabilized		
Filter material per specification		
Underdrains installed to grade		
Flow diversion structure properly installed		
Pretreatment devices properly installed		
Level overflow weirs, multiple orifices, distribution slots		
5. Final Inspection		
Dimensions		
Surface completely level		
Structural components		
Proper outlet		
Ensure that site is properly stabilized before flow is directed to the structure.		

Comments:

Actions to be Taken:

Bioretention Construction Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

CONSTRUCTION SEQUENCE	SATISFACTORY/ UNSATISFACTORY	COMMENTS
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
If designed as exfilter, soil testing for permeability		
Facility location staked out		
2. Excavation		
Size and location		
Lateral slopes completely level		
If designed as exfilter, ensure that excavation does not compact susoils.		
Longitudinal slopes within design range		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
3. Structural Components		
Stone diaphragm installed correctly		
Outlets installed correctly		
Underdrain		
Pretreatment devices installed		
Soil bed composition and texture		
4. Vegetation		
Complies with planting specs		
Topsoil adequate in composition and placement		
Adequate erosion control measures in place		
5. Final Inspection		
Dimensions		
Proper stone diaphragm		
Proper outlet		
Soil/ filter bed permeability testing		
Effective stand of vegetation and stabilization		
Construction generated sediments removed		
Contributing watershed stabilized before flow is diverted to the practice		

Comments:

Actions to be Taken:

Open Channel System Construction Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility location staked out		
2. Excavation		
Size and location		
Side slope stable		
Soil permeability		
Groundwater / bedrock		
Lateral slopes completely level		
Longitudinal slopes within design range		
Excavation does not compact subsoils		
3. Check dams		
Dimensions		
Spacing		
Materials		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Structural Components		
Underdrain installed correctly		
Inflow installed correctly		
Pretreatment devices installed		
5. Vegetation		
Complies with planting specifications		
Topsoil adequate in composition and placement		
Adequate erosion control measures in place		
6. Final inspection		
Dimensions		
Check dams		
Proper outlet		
Effective stand of vegetation and stabilization		
Contributing watershed stabilized before flow is routed to the factility		

Comments:

Actions to be Taken:

Appendix G

Stormwater Pond/Wetland Operation, Maintenance and Management Inspection Checklist

Project ______________________________
Location: ______________________________
Site Status: ______________________________

Date: ______________________________
Time: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Embankment and emergency spillway (Annual, After Major Storms)		
1. Vegetation and ground cover adequate		
2. Embankment erosion		
3. Animal burrows		
4. Unauthorized planting		
5. Cracking, bulging, or sliding of dam		
a. Upstream face		
b. Downstream face		
c. At or beyond toe		
downstream		
upstream		
d. Emergency spillway		
6.Pond, toe & chimney drains clear and functioning		
7.Seeps/leaks on downstream face		
8.Slope protection or riprap failure		
9. Vertical/horizontal alignment of top of dam “As-Built”		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
10. Emergency spillway clear of obstructions and debris		
11. Other (specify)		
2. Riser and principal spillway (Annual)		
Type: Reinforced concrete _______ Corrugated pipe _______ Masonry _______ 1. Low flow orifice obstructed		
2. Low flow trash rack. a. Debris removal necessary		
b. Corrosion control		
3. Weir trash rack maintenance a. Debris removal necessary		
b. corrosion control		
4. Excessive sediment accumulation insider riser		
5. Concrete/masonry condition riser and barrels a. cracks or displacement		
b. Minor spalling (<1")		
c. Major spalling (rebars exposed)		
d. Joint failures		
e. Water tightness		
6. Metal pipe condition		
7. Control valve a. Operational/exercised		
b. Chained and locked		
8. Pond drain valve a. Operational/exercised		
b. Chained and locked		
9. Outfall channels functioning		
10. Other (specify)		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
3. Permanent Pool (Wet Ponds) (monthly)		
1. Undesirable vegetative growth		
2. Floating or floatable debris removal required		
3. Visible pollution		
4. Shoreline problem		
5. Other (specify)		
4. Sediment Forebays		
1.Sedimentation noted		
2. Sediment cleanout when depth < 50% design depth		
5. Dry Pond Areas		
1. Vegetation adequate		
2. Undesirable vegetative growth		
3. Undesirable woody vegetation		
4. Low flow channels clear of obstructions		
5. Standing water or wet spots		
6. Sediment and / or trash accumulation		
7. Other (specify)		
6. Condition of Outfalls (Annual , After Major Storms)		
1. Riprap failures		
2. Slope erosion		
3. Storm drain pipes		
4.Endwalls / Headwalls		
5. Other (specify)		
7. Other (Monthly)		
1. Encroachment on pond, wetland or easement area		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
2. Complaints from residents		
3.Aesthetics a. Grass growing required		
b. Graffiti removal needed		
c. Other (specify)		
4. Conditions of maintenance access routes.		
5. Signs of hydrocarbon build-up		
6. Any public hazards (specify)		
8. Wetland Vegetation (Annual)		
1. Vegetation healthy and growing Wetland maintaining 50% surface area coverage of wetland plants after the second growing season. (If unsatisfactory, reinforcement plantings needed)		
2. Dominant wetland plants: Survival of desired wetland plant species Distribution according to landscaping plan?		
3. Evidence of invasive species		
4. Maintenance of adequate water depths for desired wetland plant species		
5. Harvesting of emergent plantings needed		
6. Have sediment accumulations reduced pool volume significantly or are plants “choked” with sediment		
7. Eutrophication level of the wetland.		
8. Other (specify)		

Comments:

Actions to be Taken:

Infiltration Trench Operation, Maintenance, and Management Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Trench surface clear of debris		
Inflow pipes clear of debris		
Overflow spillway clear of debris		
Inlet area clear of debris		
2. Sediment Traps or Forebays (Annual)		
Obviously trapping sediment		
Greater than 50% of storage volume remaining		
3. Dewatering (Monthly)		
Trench dewaters between storms		
4. Sediment Cleanout of Trench (Annual)		
No evidence of sedimentation in trench		
Sediment accumulation doesn't yet require cleanout		
5. Inlets (Annual)		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
Good condition		
No evidence of erosion		
6. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repair		
No evidence of erosion		
7. Aggregate Repairs (Annual)		
Surface of aggregate clean		
Top layer of stone does not need replacement		
Trench does not need rehabilitation		

Comments:

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Actions to be Taken:

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Sand/Organic Filter Operation, Maintenance and Management Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Contributing areas clean of debris		
Filtration facility clean of debris		
Inlet and outlets clear of debris		
2. Oil and Grease (Monthly)		
No evidence of filter surface clogging		
Activities in drainage area minimize oil and grease entry		
3. Vegetation (Monthly)		
Contributing drainage area stabilized		
No evidence of erosion		
Area mowed and clipping removed		
4. Water Retention Where Required (Monthly)		
Water holding chambers at normal pool		
No evidence of leakage		
5. Sediment Deposition (Annual)		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
Filter chamber free of sediments		
Sedimentation chamber not more than half full of sediments		
6. Structural Components (Annual)		
No evidence of structural deterioration		
Any grates are in good condition		
No evidence of spalling or cracking of structural parts		
7. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repairs		
No evidence of erosion (if draining into a natural channel)		
8. Overall Function of Facility (Annual)		
Evidence of flow bypassing facility		
No noticeable odors outside of facility		

Comments:

Actions to be Taken:

Bioretention Operation, Maintenance and Management Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Bioretention and contributing areas clean of debris		
No dumping of yard wastes into practice		
Litter (branches, etc.) have been removed		
2. Vegetation (Monthly)		
Plant height not less than design water depth		
Fertilized per specifications		
Plant composition according to approved plans		
No placement of inappropriate plants		
Grass height not greater than 6 inches		
No evidence of erosion		
3. Check Dams/Energy Dissipaters/Sumps (Annual, After Major Storms)		
No evidence of sediment buildup		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
Sumps should not be more than 50% full of sediment		
No evidence of erosion at downstream toe of drop structure		
4. Dewatering (Monthly)		
Dewaters between storms		
No evidence of standing water		
5. Sediment Deposition (Annual)		
Swale clean of sediments		
Sediments should not be > 20% of swale design depth		
6. Outlet/Overflow Spillway (Annual, After Major Storms)		
Good condition, no need for repair		
No evidence of erosion		
No evidence of any blockages		
7. Integrity of Filter Bed (Annual)		
Filter bed has not been blocked or filled inappropriately		

Comments:

Actions to be Taken:

Open Channel Operation, Maintenance, and Management Inspection Checklist

Project:
Location:
Site Status:

Date:

Time:

Inspector:

MAINTENANCE ITEM	SATISFACTORY/ UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Contributing areas clean of debris		
2. Check Dams or Energy Dissipators (Annual, After Major Storms)		
No evidence of flow going around structures		
No evidence of erosion at downstream toe		
Soil permeability		
Groundwater / bedrock		
3. Vegetation (Monthly)		
Mowing done when needed		
Minimum mowing depth not exceeded		
No evidence of erosion		
Fertilized per specification		
4. Dewatering (Monthly)		
Dewaters between storms		

MAINTENANCE ITEM	SATISFACTORY/ UNSATISFACTORY	COMMENTS
5. Sediment deposition (Annual)		
Clean of sediment		
6. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repairs		
No evidence of erosion		

Comments:

Actions to be Taken:

Appendix H

H.1 Ponds and Wetlands

For areas that are to be planted within a stormwater pond, it is necessary to determine what type of hydrologic zones will be created within the pond. The following six zones describe the different conditions encountered in stormwater management facilities. Every facility does not necessarily reflect all of these zones. The hydrologic zones designate the degree of tolerance the plant exhibits to differing degrees of inundation by water.

Table H.5 at the end of this appendix designates appropriate zones for each plant. There may be other zones listed outside of these brackets. The plant materials may occur within these zones, but are not typically found in them. Plants suited for specific hydrologic conditions may perish when those conditions change, exposing the soil, and therefore, increasing the chance for erosion.

Each zone has its own set of plant selection criteria based on the hydrology of the zone, the stormwater functions required of the plant and the desired landscape effect. The hydrologic zones are as follows:

Table H.1 Hydrologic Zones

Zone #	Zone Description	Hydrologic Conditions
Zone 1	Deep Water Pool	1-6 feet deep Permanent Pool
Zone 2	Shallow Water Bench	6 inches to 1 foot deep
Zone 3	Shoreline Fringe	Regularly inundated
Zone 4	Riparian Fringe	Periodically inundated
Zone 5	Floodplain Terrace	Infrequently inundated
Zone 6	Upland Slopes	Seldom or never inundated

Zone 1: Deep Water Area *(1- 6 Feet)*

Ponds and wetlands both have deep pool areas that comprise Zone 1. These pools range from one to six feet in depth, and are best colonized by submergent plants, if at all.

This pondscaping zone has not been routinely planted for several reasons. First, the availability of plant materials that can survive and grow in this zone is limited, and it is also feared that plants could clog the stormwater facility outlet structure. In many cases, these plants will gradually become established through natural recolonization (e.g., transport of plant fragments from other ponds via the feet and legs of waterfowl). If submerged plant material becomes more commercially available and clogging concerns are addressed, this area can be planted. The function of the planting is to reduce resedimentation and improve oxidation while creating a greater aquatic habitat.

- Plant material must be able to withstand constant inundation of water of one foot or greater in depth.
- Plants may be submerged partially or entirely.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects, and other aquatic life.

Zone 2: Shallow Water Bench ***(Normal Pool To 1 Foot)***

Zone 2 includes all areas that are inundated below the normal pool to a depth of one foot, and is the primary area where emergent plants will grow in a stormwater wetlands. Zone 2 also coincides with the aquatic bench found in stormwater ponds. This zone offers ideal conditions for the growth of many emergent wetland species. These areas may be located at the edge of the pond or on low mounds of earth located below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and nonaquatic animals, creating a diverse food chain. This food chain includes predators, allowing a natural regulation of mosquito populations, thereby reducing the need for insecticidal applications.

- Plant material must be able to withstand constant inundation of water to depths between six inches and one foot deep.
- Plants will be partially submerged.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects and other aquatic life.

Plants will stabilize the bottom of the pond, as well as the edge of the pond, absorbing wave impacts and reducing erosion, when water level fluctuates. Plant also slow water velocities and increase sediment deposition rates. Plants can reduce resuspension of sediments caused by the wind. Plants can also soften the engineered contours of the pond, and can conceal drawdowns during dry weather.

Zone 3: Shoreline Fringe ***(Regularly Inundated)***

Zone 3 encompasses the shoreline of a pond or wetland, and extends vertically about one foot in elevation from the normal pool. This zone includes the safety bench of a pond, and may also be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh and can be the most difficult to establish since plants must be able to withstand inundation of water during storms, when wind might blow water into the area, or the occasional drought during the summer. In order to stabilize the soil in this zone, Zone 3 must have a vigorous cover.

- Plants should stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation.
- Plant material must be able to withstand occasional inundation of water. Plants will be partially submerged at this time.
- Plant material should, whenever possible, shade the shoreline, especially the southern exposure. This will help to reduce the water temperature.

- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife. Plants could also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce human access, where there are potential hazards, but should not block the maintenance access.
- Plants should have very low maintenance requirements, since they may be difficult or impossible to reach.
- Plants should be resistant to disease and other problems which require chemical applications (since chemical application is not advised in stormwater ponds).

Zone 4: Riparian Fringe ***(Periodically Inundated)***

Zone 4 extends from one to four feet in elevation above the normal pool. Plants in this zone are subject to periodic inundation after storms, and may experience saturated or partly saturated soil conditions. Nearly all of the temporary ED area is included within this zone.

- Plants must be able to withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months.
- Plants should stabilize the ground from erosion caused by run-off.
- Plants should shade the low flow channel to reduce the pool warming whenever possible.
- Plants should be able to enhance pollutant uptake.
- Plant material should have very low maintenance, since they may be difficult or impossible to access.
- Plants may provide food and cover for waterfowl, songbirds and wildlife. Plants may also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce pedestrian access to the deeper pools.

Zone 5: Floodplain Terrace ***(Infrequently Inundated)***

Zone 5 is periodically inundated by flood waters that quickly recedes in a day or less. Operationally, Zone 5 extends from the maximum two year or Cpv water surface elevation up to the 10 or 100 year maximum water surface elevation. Key landscaping objectives for Zone 5 are to stabilize the steep slopes characteristic of this zone, and establish a low maintenance, natural vegetation.

- Plant material should be able to withstand occasional but brief inundation during storms, although typical moisture conditions may be moist, slightly wet, or even swing entirely to drought conditions during the dry weather periods.
- Plants should stabilize the basin slopes from erosion.
- Ground cover should be very low maintenance, since they may be difficult to access on steep slopes or if frequency of mowing is limited. A dense tree cover may help reduce maintenance and discourage resident geese.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife.

- Placement of plant material in Zone 5 is often critical, as it often creates a visual focal point and provides structure and shade for a greater variety of plants.

Zone 6: Upland Slopes *(Seldom or Never Inundated)*

The last zone extends above the maximum 100 year water surface elevation, and often includes the outer buffer of a pond or wetland. Unlike other zones, this upland area may have sidewalks, bike paths, retaining walls, and maintenance access roads. Care should be taken to locate plants so they will not overgrow these routes or create hiding places that might make the area unsafe.

- Plant material is capable of surviving the particular conditions of the site. Thus, it is not necessary to select plant material that will tolerate any inundation. Rather, plant selections should be made based on soil condition, light, and function within the landscape.
- Ground covers should emphasize infrequent mowing to reduce the cost of maintaining this landscape.
- Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, serve as a buffer, or provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

H.2 Bioretention

Planting Soil Bed Characteristics

The characteristics of the soil for the bioretention facility are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

The planting soil should be a sandy loam, loamy sand, loam (USDA), or a loam/sand mix (should contain a minimum 35 to 60% sand, by volume). The clay content for these soils should by less than 25% by volume. Soils should fall within the SM, or ML classifications of the Unified Soil Classification System (USCS). A permeability of at least 1.0 feet per day (0.5"/hr) is required (a conservative value of 0.5 feet per day is used for design). The soil should be free of stones, stumps, roots, or other woody material over 1" in diameter. Brush or seeds from noxious weeds. Placement of the planting soil should be in lifts of 12 to 18", loosely compacted (tamped lightly with a dozer or backhoe bucket). The specific characteristics are presented in Table H.2.

Table H.2 Planting Soil Characteristics

Parameter	Value
PH range	5.2 to 7.00
Organic matter	1.5 to 4.0%
Magnesium	35 lbs. per acre, minimum
Phosphorus (P_2O_5)	75 lbs. per acre, minimum
Potassium (K_2O)	85 lbs. per acre, minimum
Soluble salts	≤ 500 ppm
Clay	10 to 25%
Silt	30 to 55%
Sand	35 to 60%

Mulch Layer

The mulch layer plays an important role in the performance of the bioretention system. The mulch layer helps maintain soil moisture and avoid surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment.

The mulch layer should be standard landscape style, single or double, shredded hardwood mulch or chips. The mulch layer should be well aged (stockpiled or stored for at least 12 months), uniform in color, and free of other materials, such as weed seeds, soil, roots, etc. The mulch should be applied to a maximum depth of three inches. Grass clippings should not be used as a mulch material.

Planting Plan Guidance

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure H.1). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. When using Table A.5 to identify species, use the following guideline:

Lowest Zone: Zones 2-3

Middle Zone: Zones 3-4

Outer Zone: Zones 5-6

The layout of plant material should be flexible, but should follow the general principals described in Table H.3. The objective is to have a system which resembles a random and natural plant layout, while maintaining optimal conditions for plant establishment and growth.

Figure H.1 Planting Zones for Bioretention Facilities

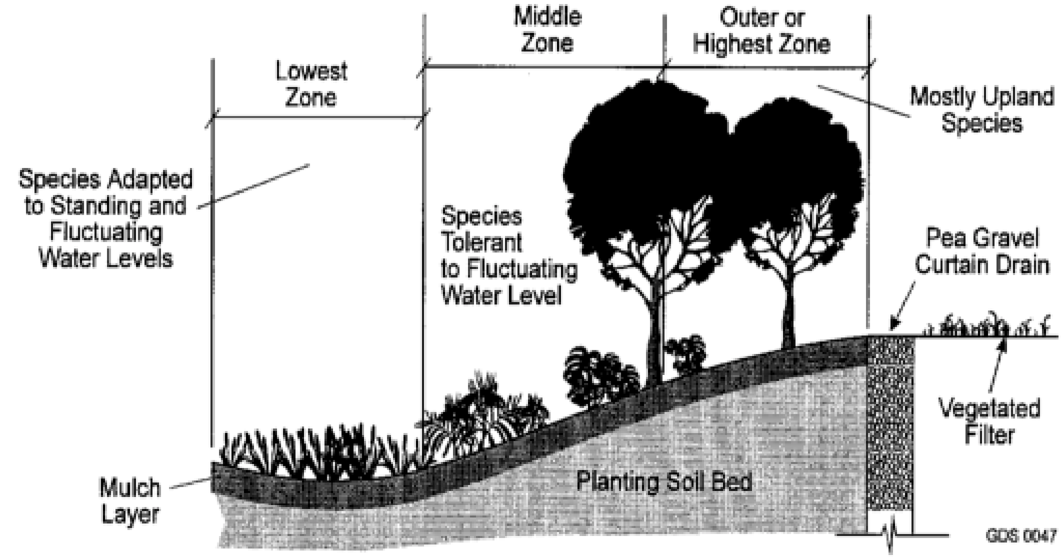


Table H.3 Planting Plan Design Considerations
Native plant species should be specified over exotic or foreign species.
Appropriate vegetation should be selected based on the zone of hydric tolerance (see Figure H.1).
Species layout should generally be random and natural.
A canopy should be established with an understory of shrubs and herbaceous materials.
Woody vegetation should not be specified in the vicinity of inflow locations.
Trees should be planted primarily along the perimeter of the bioretention area.
Urban stressors (e.g., wind, sun, exposure, insect and disease infestation, drought) should be considered when laying out the planting plan.
Noxious weeds should not be specified.
Aesthetics and visual characteristics should be a prime consideration.
Traffic and safety issues must be considered.
Existing and proposed utilities must be identified and considered.

Plant Material Guidance

Plant materials should conform to the American Standard Nursery Stock, published by the American Association of Nurserymen, and should be selected from certified, reputable nurseries. Planting specifications should be prepared by the designer and should include a sequence of construction, a description of the contractor's responsibilities, a planting schedule and installation specifications, initial maintenance, and a warranty period and expectations of plant survival. Table H.4 presents some typical issues for planting specifications.

Table H.4 Planting Specification Issues for Bioretention Areas	
Specification Element	**Elements**
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean-up.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	Specify the warranty period, the required survival rate, and expected condition of plant species at the end of the warranty period.

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)						
Plant Name	**Zone**	**Form**	**Available**	**Inundation Tolerance**	**Wildlife Value**	**Notes**
Trees and Shrubs						
American Elm *(Ulmus americana)*	4,5,6	Dec. Tree	yes	Irregular-seasonal saturation	High. Food (seeds,browsing), cover, nesting for birds & mammals	Susceptible to diesease (short-lived). Sun to full shade, tolerates drought and wind/ice damage.
Arrowwood Viburrium *(Viburrium dentatum)*	3,4	Dec. Shrub	yes	yes	High. Songbirds and mammals	Grows best in sun to partial shade
Bald Cypress *(Taxodium distichum)*	3,4	Dec. Tree	yes	yes	Little food value, but good perching site for waterfowl	Forested Coastal Plain. North of normal range. Tolerates drought.
Bayberry *(Myrica pensylvanica)*	4,5,6	Dec. Shrub	yes	yes	High. Nesting, food, cover. Berries last into winter	Coastal Plain only. Roots fix N_2 Tolerates slightly acidic soils.
Black Ash *(Fraxinus nigra)*	3,4,5	Dec. Tree	yes	Irregular-seasonal saturation	High. Food (seeds, sap), cover, nesting for birds & mammals. Fruit persists in winter	Rapid growth. Requires full sun. Susceptible to wind/ice damage & disease. Tolerates drought and infrequent flooding by salt water.
Black Cherry *(Prunus serotina)*	5,6	Dec. Tree	yes	no	High. Food	Moist soils or wet bottomland areas
Blackgum or Sourgum *(Nyssa sylvatica)*	4,5,6	Dec. Tree	yes	yes	High. Songbirds, egrets, herons, raccoons, owls	Can be difficult to transplant. Prefers sun to partial shade
Black Willow *(Salix nigra)*	3,4,5	Dec. Tree	yes	yes	High. Browsing and cavity nesters.	Rapid growth, stabilizes stream-banks. Full sun
Buttonbush *(Cepahlanthus occidentalis)*	2,3,4,5	Dec. Shrub	yes	yes	High. Ducks and shorebirds. Seeds, nectar and nesting.	Full sun to partial shade. Will grow in dry areas.
Common Spice Bush *(Lindera benzoin)*	3,4,5	Dec. Shrub	yes	yes	Very high. Songbirds	Shade and rich soils. Tolerates acidic soils. Good understory species

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)

Plant Name	Zone	Form	Available	Inundation Tolerance	Wildlife Value	Notes
Eastern Cottonwood *(Populus deltoides)*	4,5	Dec. Tree	yes	yes	Moderate. Cover, food.	Shallow rooted, subject to windthrow. Invasive roots. Rapid growth.
Eastern Hemlock *(Tsuga canadensis)*	5,6	Conif. Tree	yes	yes	Moderate. Mostly cover and some food	Tolerates all sun/shade conditions. Tolerates acidic soil.
Eastern Red Cedar *(Juniperus virginiana)*	4,5,6	Conif. Tree	yes	no	High. Fruit for birds. Some cover.	Full sun to partial shade. Common in wetlands, shrub bogs and edge of stream
Elderberry *(Sambucus canadensis)*	3,4,5,6	Dec. Shrub	yes	yes	Extremely high. Food and cover, birds and mammals.	Full sun to partial shade.
Green Ash, Red Ash *(Fraxinus pennsylvania)*	4,5	Dec. Tree	yes	yes	Moderate. Songbirds.	Rapid growing streambank stabilizer. Full sun to partial shade.
Hackenberry *(Celtis occidentalis)*	5,6	Dec. Tree	yes	some	High. Food and cover	Full sun to partial shade.
Larch, Tamarack *(Larix latricina)*	3,4	Conif. Tree	no	yes	Low. Nest tree and seeds.	Rapid initial growth. Full sun, acidic boggy soil.
Pin Oak *(Quercus palustris)*	3,4,5,6	Dec. Tree	yes	yes	High. Tolerates acidic soil	Gypsy moth target. Prefers well drained, sandy soils.
Red Choke Berry *(Pyrus arbutifolia)*	3,4,5	Dec. Shrub	no	yes	Moderate. Songbirds.	Bank stabilizer. Partial sun.
Red Maple *(Acer rubrum)*	3,4,5,6	Dec. Tree	yes	yes	High seeds and browse. Tolerates acidic soil.	Rapid growth.
River Birch *(Betula nigra)*	3,4,5	Dec. Tree	yes	yes	Low. Good for cavity nesters.	Bank erosion control. Full sun.
Shadowbush, Serviceberry *(Amelanchier*	4,5,6	Dec. Shrub	yes	yes	High. Nesting, cover, food. Birds and	Prefers partial shade. Common in forested

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)						
Plant Name	**Zone**	**Form**	**Available**	**Inundation Tolerance**	**Wildlife Value**	**Notes**
canadensis)					mammals.	wetlands and upland woods.
Silky Dogwood *(Cornus amomium)*	3,4,5	Dec. Shrub	yes	yes	High. Songbirds, mammals.	Shade and drought tolerant. Good bank stabilizer.
Slippery Elm *(Ulnus rubra)*	3,4,5	Dec. Tree	rare	yes	High. Food (seeds, buds) for birds & mammals (browse). Nesting	Rapid growth, no salinity tolerance. Tolerant to shade and drought.
Smooth Alder *(Alnus serrulata)*	3,4,5	Dec. Tree	no	yes	High. Food, cover.	Rapid growth. Stabilizes streambanks.
Speckled Alder *(Alnus rugosa)*	3,4	Dec. Shrub	yes	yes	High. Cover, browse for deer, seeds for bird.	
Swamp White Oak *(Quercus bicolor)*	3,4,5	Dec. Tree	yes	yes	High. Mast	Full sun to partial shade. Good bottomland tree.
Swamp Rose *(Rosa Palustrus)*	3,4	Dec. Shrub		Irregular, seasonal, or regularly saturated	High. Food (hips) for birds including turkey, ruffed grouse and mammals. Fox cover.	Prefers full sun. Easy to establish. Low salt tolerance.
Sweetgum *(Liquidambar styraciflua)*	4,5,6	Dec. Tree	yes	yes	Moderate. Songbirds	Tolerates acid or clay soils. Sun to partial shade.
Sycamore *(Platanus occidentalis)*	4,5,6,	Dec. Tree	yes	yes	Low. Food, cavities for nesting.	Rapid growth. Common in floodplains and alluvial woodlands.
Tulip Tree *(Liriodendron tulipifera)*	5,6	Dec. Tree	yes	no	Moderate. Seeds and nest sites	Full sun to partial shade. Well drained soils. Rapid growth.
Tupelo *(Nyssa sylvatica vari biflora)*	3,4,5	Dec. Tree	yes	yes	High. Seeds and nest sites	Ornamental

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)

Plant Name	Zone	Form	Available	Inundation Tolerance	Wildlife Value	Notes
White Ash *(Fraxinus americana)*	5,6	Dec. Tree	yes	no	High. Food	All sunlight conditions. Well drained soils.
Winterberry *(Ilex verticillata)*	3,4,5	Dec. Shrub	yes	yes	High. Cover and fruit for birds. Holds berries into winter.	Full sun to partial shade. Seasonally flooded areas.
Witch Hazel *(Hamamelis virginiana)*	4,5	Dec. Shrub	yes	no	Low. Food for squirrels, deer, and ruffed grouse.	Prefers shade. Ornamental.
Herbaceous Plants						
Arrow arum *(Peltandra virginica)*	2,3	Emergent	yes	up to 1 ft.	High. Berries are eaten by wood ducks.	Full sun to partial shade.
Arrowhead, Duck Potato *(Saggitaria latifolia)*	2,3	Emergent	yes	up to 1 ft.	Moderate. Tubers and seeds eaten by ducks.	Aggressive colonizer.
Big Bluestem (*Andropogon gerardi*)	4,5	Perimeter	yes	Irregular or seasonal inundation.	High. Seeds for songbirds. Food for deer	Requires full sun.
Birdfoot deervetch (*Lotus Corniculatus*)	4,5,6	Perimeter	yes	Infrequent inundation	High. Food for birds.	Full sun. Nitrogen fixer.
Blue Flag Iris *(Iris versicolor)*	2,3	Emergent	yes	Regular or permanently, up to ½ ft or saturated	Moderate. Food muskrat and wildfowl. Cover, marshbirds	Slow growth. Full sun to partial shade. Tolerates clay. Fresh to moderately brackish water.
Blue Joint (*Calamagrotis canadensis*)	2,3,4	Emergent	yes	Regular or permanent inundation up to 0.5 ft.	Moderate. Food for game birds and moose.	Tolerates partial shade
Broomsedge *(Andropogon virginicus)*	2,3	Perimeter	yes	up to 3 in.	High. Songbirds and browsers. Winter food and cover.	Tolerant of fluctuation water levels & partial shade.
Bushy Beardgrass *(Andropogon glomeratus)*	2,3	Emergent	yes	up to 1 ft.		Requires full sun.
Cardinal flower (*Lobelia cardinalis*)	4,5,6	Perimeter	yes	Some. Tolerates saturation up to 100% of season.	High. Nectar for hummingbird, oriole, butterflies.	Tolerates partial shade

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)						
Plant Name	**Zone**	**Form**	**Available**	**Inundation Tolerance**	**Wildlife Value**	**Notes**
Cattail *(Typha sp.)*	2,3	Emergent	yes	up to 1 ft.	Low. Except as cover	Aggressive. May eliminate other species. Volunteer. High pollutant treatment
Coontail *(Ceratophyllum demersum)*	1	Submergent	no	yes	Low food value. Good habitat and shelter for fish and invertebrates.	Free floating SAV. Shade tolerant. Rapid growth.
Common Three-Square *(Scirpus pungens)*	2	Emergent	yes	up to 6 in.	High. Seeds, cover. Waterfowl and fish.	High metal removal.
Duckweed *(Lemma sp.)*	1,2	Submergent/ Emergent	yes	yes	High. Food for waterfowl and fish.	High metal removal.
Fowl mannagrass (*Glyceria striata*)	4,5	Perimeter	yes	Irregular or seasonal inundation	High. Food for waterfowl, muskrat, and deer.	Partial to full shade.
Hardstem Bulrush *(Scirpus acutus)*	2	Emergent	yes	up to 3 ft.	High. Cover, food (achenes, rhizomes) ducks, geese, muskrat, fish. Nesting for bluegill and bass.	Quick to establish, fresh to brackish. Good for sediment stabilization and erosion control.
Giant Burreed *(Sparganium eurycarpum)*	2,3	Emergent	rare	Regular to permanently inundated. up to 1 ft.	High. Food (seeds, plant) waterfowl, beaver & other mammals. Cover for marshbirds, waterfowl.	Rapid spreading . Tolerates partial sun. Good for shoreline stabilization.. Salinity <0.5 ppt
Lizard's Tail *(Saururus cernuus)*	2	Emergent	yes	up to 1 ft.	Low, except wood ducks.	Rapid growth. Shade tolerant
Long-leaved Pond Weed *(Potamogeton nodosus)*	1,2	Rooted submerged aquatic	yes	up to 1-6 ft. depending on turbidity	High. Food (seeds, roots) waterfowl, aquatic fur-bearers, deer, moose. Habitat for fish	Rapid spread. Salinity <0.5 ppt. Flowers float on surface, Aug.-Sept.

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)						
Plant Name	**Zone**	**Form**	**Available**	**Inundation Tolerance**	**Wildlife Value**	**Notes**
Marsh Hibiscus *(Hibiscus moscheutos)*	2,3	Emergent	yes	up to 3 in.	Low. Nectar.	Full sun. Can tolerate periodic dryness.
Pickerelweed *(Pontederia cordata)*	2,3	Emergent	yes	up to 1 ft.	Moderate. Ducks. Nectar for butterflies.	Full sun to partial shade.
Pond Weed, Sago *(Potamogeton pectinatus*	1	Submergent	yes	yes	Extremely high. Waterfowl, marsh and shorebirds.	Removes heavy metals.
Redtop (*Agrostis alba*)	3,4,5	Perimeter	yes	Up to 25% of season	Moderate. Rabbits and some birds.	Quickly established but not highly competitive.
Rice Cutgrass *(Leersia oryzoides)*	2,3	Emergent	yes	up to 3 in.	High. Food and cover.	Full sun although tolerant of shade. Shoreline stabilization.
Sedges *(Carex spp.)*	2,3	Emergent	yes	up to 3 in.	High waterfowl, songbirds.	Many wetland and upland species.
Tufted Hairgrass (*Deschampsia caespitosa*)	3,4,5	Perimeter	yes	Regular to irregular inundation.	High.	Full sun. May become invasive.
Soft-stem Bulrush *(Scirpus validus)*	2,3	Emergent	yes	up to 1 ft.	Moderate. Good cover and food.	Full sun. Aggressive colonizer. High pollutant removal.
Smartweed *(Polygonum spp.)*	2,3,4	Emergent	yes	up to 1 ft.	High. Waterfowl, songbirds. Seeds and cover.	Fast colonizer. Avoid weedy aliens such as *P. perfoliatum.*
Soft Rush *(Juncus effusus)*	2,3,4	Emergent	yes	up to 3 in.	Moderate.	Tolerates wet or dry conditions.
Spatterdock *(Nuphar luteum)*	2	Emergent	yes	up to 3 ft.	Moderate for food but high for cover.	Fast colonizer. Tolerant of fluctuating water levels.
Switchgrass *(Panicum virgatum)*	2,3,4,5,6	Perimeter	yes	up to 3 in.	High. Seeds, cover for waterfowl, songbirds.	Tolerates wet/dry conditions.

Table H.5 Native Plant Guide for Stormwater Management Areas (NY)						
Plant Name	**Zone**	**Form**	**Available**	**Inundation Tolerance**	**Wildlife Value**	**Notes**
Sweet Flag *(Acorus calamus)*	2,3	Herbaceous	yes	up to 3 in.	Low.	Tolerant of dry periods. Not a rapid colonizer. Tolerates acidic conditions.
Waterweed *(Elodea canadensis)*	1	Submergent	yes	yes	Low.	Good water oxygenator. High nutrient, copper, manganese and chromium removal.
Wild Celery *(Valisneria americana)*	1	Submergent	yes	yes	High. Food for waterfowl. Habitat for fish and invertebrates.	Tolerant of murkey water and high nutrient loads.
Wild Rice *(Zizania aquatica)*	2	Emergent	yes	up to 1 ft.	High. Food for birds.	Prefers full sun
Wool Grass *(Scirpus cyperinus)*	2,3	Emergent	yes	Irregularly to seasonally indundated	Moderate. Cover, Food.	Requires full sun. Can tolerate acidic soils, drought. Colonizes disturbed areas, moderate growth.

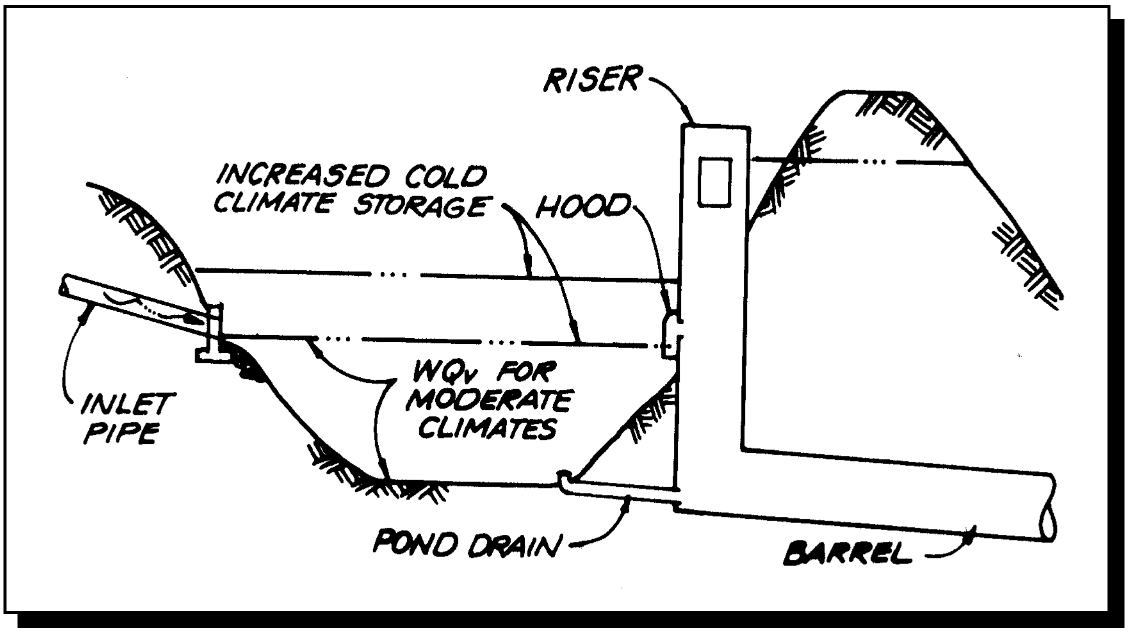
Appendix I

Traditional SMP sizing criteria are based on the hydrology and climatic conditions of moderate climates. These criteria are not always applicable to cold climate regions due to snowmelt, rain-on-snow and frozen soils. This chapter identifies methods to adjust both water quality (Section I.1) and water quantity (Section I.2) sizing criteria for cold climates.

I.1 Water Quality Sizing Criteria

The water quality volume is the portion of the SMP reserved to treat stormwater either through detention, filtration, infiltration or biological activity. Base criteria developed for SMP sizing nationwide are based on rainfall events in moderate climates (e.g., Schueler, 1992). Designers may wish to increase the water quality volume of SMPs to account for the unique conditions in colder climates, particularly when the spring snowfall represents a significant portion of the total rainfall. Spring snowmelt, rain-on-snow and rain-on-frozen ground may warrant higher treatment volumes. It is important to note that **the base criteria required by a region must always be met**, regardless of calculations made for cold climate conditions.

Figure I.1 Increased Water Quality Volume in Cold Climates



The goal of treating 90% of the annual pollutant load (Schueler, 1992), can be applied to snowmelt runoff and rain-on snow events. In the following conditions, cold climate sizing may be greater than base criteria sizing:

- Snowfall represents more than 10% of total annual precipitation. This value is chosen because, at least some portion of the spring snowmelt needs to be treated in order to treat 90% of annual runoff in these conditions. Using the rule of thumb that the moisture content of snowfall has about 10% moisture content, this rule can be simplified as:

  Oversize when average annual snowfall depth is greater than or equal to annual precipitation depth.

- The area is in a coastal or Great Lakes region with more than 3' of snow annually. In these regions, rain-on-snow events occur frequently enough to justify oversizing stormwater SMPs for water quality.

The following caveats apply to the sizing criteria presented in this section:

- These criteria are not appropriate for very deep snowpacks (i.e., greater than 4') because the volume to be treated would be infeasible, and often unnecessary.
- Sizing for snow storage areas is described in Appendix C.
- Snowmelt is a complicated process, with large annual variations. While the criteria presented here address the

affects of snowmelt and rain-on-snow, several simplifying assumptions are made. Where local data or experience are available, more sophisticated methods should be substituted.

I.1.1 Water Quality Volume for Snowmelt

In order to treat 90% of annual runoff volume, sizing for snowmelt events needs to be completed in the context of the precipitation for the entire year. In relatively dry regions that receive much of their precipitation as snowfall, the sizing is heavily influenced by the snowmelt event. On the other hand, in regions with high annual rainfall, storm events are more likely to carry the majority of pollutants annually. The sizing criteria for this section are based on three assumptions: 1) SMPs should be sized to treat the spring snowmelt event 2)Snowmelt runoff is influenced by the moisture content of the spring snowpack and soil moisture 3) No more than five percent of the annual runoff volume should bypass treatment during the spring snowmelt event and 4) SMPs can treat a snowmelt volume greater than their size.

- *SMPs should be sized to treat the spring snowmelt runoff event*

  Snowmelt occurs throughout the winter in small, low-flow events. These events have high concentrations of soluble pollutants such as chlorides and metals, because of "preferential elution" from the snowpack (Jeffries, 1988). Although these events have significant pollutant loads, the flows are very low intensity, and generally will not affect SMP sizing decisions.

  The spring snowmelt, on the other hand, is higher in suspended solids and hydrophobic elements, such as hydrocarbons, which can remain in the snowpack until the last five to ten percent of water leaves the snowpack (Marsalek, 1991). In addition, a large volume of runoff occurs over a comparatively short period of time (i.e., approximately two weeks). Most SMPs rely on settling to treat pollutants, and the pollutants carried in the spring snowmelt are more easily treated by these mechanisms. In addition, the large flow volume during this event may be the critical water quality design event in many cold regions.

- *Snowmelt runoff is influenced by the moisture content of the spring snowpack and soil moisture*

  Because of small snowmelt events that occur throughout the winter, losses through sublimation, and management practices such as hauling snow to other locations, the snowpack only contains a fraction of the moisture from the winter snowfall. Thus, the remaining moisture in the snowpack can be estimated by:

$$M=0.1\cdot S-L_1-L_2-L_3 \qquad \text{Equation I.1}$$

Where:

M=Moisture in the Spring Snowpack (inches)
S=Annual Snowfall (inches)
L_1, L_2 and L_3 = Losses to Hauling, Sublimation and Winter Melt, respectively.

The volume of snow hauled off site can be determined based on available information on current plowing practices. In New York, sublimation to the atmosphere is not very important

The design examples in this section use a simple "rule of thumb" approach, to estimate winter snowmelt for simplicity (Table I.1). The method assumes that winter snowmelt is influenced primarily by temperature, as represented by the average daily temperature for January. One half of the snow (adjusted for plowing and sublimation) is assumed to melt during the winter in very cold regions (Average T_{max} <25°F) and two thirds is assumed to melt during the winter in moderately cold regions (Average T_{max} <35°F). Winter snowmelt can be estimated using several methods, such as the simple degree-day method, or through more complex continuous modeling efforts.

Table I.1 Winter Snowmelt*

Adjusted Snowfall Moisture Equivalent	Winter Snowmelt (January T_{max}<25°F)	Winter Snowmelt (January T_{max}<35°F)
2"	1.0"	1.3"
4"	2.0"	2.7"
6"	3.0"	4.0"
8"	4.0"	5.3"
10"	5.0"	6.7"
12"	6.0"	8.0"

* Snowmelt occuring before the spring snowmelt event, based on the moisture content in the annual snowfall. The value in the first column is adjusted for losses due to sublimation and plowing off site.

Snowmelt is converted to runoff when the snowmelt rate exceeds the infiltration capacity of the soil. Although the rate of snowmelt is slow compared with rainfall events, snowmelt can cause significant runoff because of frozen soil conditions. The most important factors governing the volume of snowmelt runoff are the water content of the snowpack and the soil moisture content at the time the soil freezes (Granger et al., 1984). If the soil is relatively dry when it freezes, its permeability is retained. If, on the other hand, the soil is moist or saturated, the ice formed within the soil matrix acts as an impermeable layer, reducing infiltration. Section I.1.3 outlines a methodology for computing snowmelt runoff based on this principle.

- *No more than 5% of the* ***annual runoff volume*** *should bypass treatment during spring snowmelt* In order to treat 90% of the annual runoff volume, at least some of the spring snowmelt, on average, will go un-treated. In addition, large storm events will bypass treatment during warmer months. Limiting the volume that bypasses treatment during the spring snowmelt to 5% of the annual runoff volume allows for these large storm events to pass through the facility untreated, while retaining the 90% treatment goal.

The resulting equation is:

$T=(R_s-0.05R)A/12$ (Equation I.2)

Where:

T = Volume Treated (acre-feet)
R_s = Snowmelt Runoff [See Section I.1.3]
R = Annual Runoff Volume (inches) [See Section I.1.2]
A = Area (acres)

- *SMPs can treat a volume greater than their normal size.*

Snowmelt occurs over a long period of time, compared to storm events. Thus, the SMP does not have to treat the entire water quality treatment volume computed over twenty four hours, but over a week or more. As a result, the necessary water quality volume in the structure will be lower than the treatment volume. For this manual, we have assumed a volume of ½ of the value of the computed treatment volume (T) calculated in equation I.2.
Thus,

$WQ_v = ½ T$ (Equation I.3)

I.1.2 Base Criteria/ Annual Runoff

The base criterion is the widely-used, traditional water quality sizing rule. This criterion, originally developed for moderate climates, represents the minimum recommended water quality treatment volume. In this manual, the runoff from a one inch rainfall event is used as the base criteria. The basis behind this sizing criteria is that approximately 90% of the storms are treated using this event. This value may vary nationwide, depending on local historical rainfall frequency distribution data. However, the one inch storm is used as a simplifying assumption. The base criteria included in this manual is chosen because it incorporates impervious area in the sizing of urban SMPs, and modifications are used nationwide. The cold climate sizing modifications used in this manual may be applied to any base criteria, however.

Runoff for rain events can be determined based on the Simple Method (Schueler, 1987).

$r = p(.05+.9I)$ (Equation I.4)

Where: r = Event Rainfall Runoff (inches)
p = Event Precipitation (inches)
I = Impervious Area Fraction

Thus, the water quality volume for the base criteria can be determined by:

$WQ_v = (0.05+.9I)\ A/12$ (Equation I.5)

Where: WQ_v =Water Quality Volume (acre-feet)
I= Impervious Fraction
A=Area (acres)

The Simple Method can also be used to determine the annual runoff volume. An additional factor, P_j, is added because some storms do not cause runoff. Assume $P_j = 0.9$ (Schueler, 1987). Therefore, annual runoff volume from rain can be determined by:

$R = 0.9\ P\ (0.05+.9I)$ (Equation I.6)

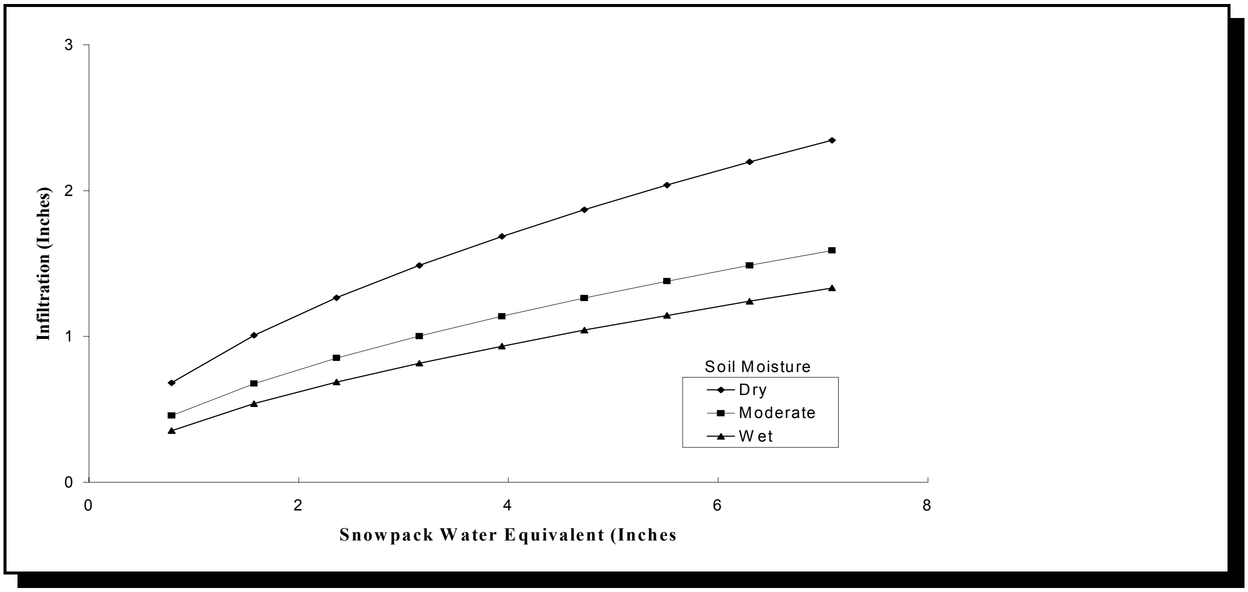
Where: R = Annual Runoff (inches)
P = Annual Rainfall (inches)

I.1.3 Calculating the Snowmelt Runoff

To complete water quality sizing, it is necessary to calculate the snowmelt runoff. Several methods are available, including complex modeling measures. For the water quality volume, however, simpler sizing methods can be used since the total water quality volume, not peak flow, is critical. One method, modified from Granger et al. (1984) is proposed here. Other methods can be used, particularly those adjusted to local conditions.

According to Granger et al. (1984) the infiltration into pervious soils is primarily based on the saturation of the soils prior to freezing. While saturated soils allow relatively little snowmelt to infiltrate, dry soils have a high capacity for infiltration. Thus, infiltration volumes vary between wet, moderate and dry soil conditions (Figure I.2).

Figure I.2 Snowmelt Infiltration Based on Soil Moisture



Assume also that impervious area produces 100% runoff. The actual percent of snowmelt converted to runoff from impervious areas such as roads and sidewalks may be less than 100% due to snow removal, deposition storage and sublimation. However, stockpiled areas adjacent to paved surfaces often exhibit increased runoff rates because of the high moisture content in the stockpiled snow (Buttle and Xu, 1988). This increased contribution from pervious areas off-sets the reduced runoff rates from cleared roads and sidewalks.

The resulting equation to calculate snowmelt runoff volume based on these assumptions is:

R_S = [runoff generated from the pervious areas] + [runoff from the impervious areas]

R_s = [(1 - I)(M-Inf)] + [(I)(1)(M)] (Equation I.7)

where:

R_S = Snowmelt Runoff
I = Impervious Fraction
M = Snowmelt (inches)
Inf = Infiltration (inches)

Sizing Example 1: Snowpack Treatment	
Scenario:	50 Acre Watershed 40% Impervious Area Average Annual Snowfall= 5'=60" Average Daily Maximum January Temperature= 20° Average Annual Precipitation = 30" 20% of snowfall is hauled off site Sublimation is not significant Prewinter soil conditions: moderate moisture.

Sizing Example 1: Snowpack Treatment

Step 1: Determine if oversizing is necessary
Since the average annual precipitaiton is only ½ of average annual snowfall depth, oversizing is needed.

Step 2: Determine the annual losses from sublimation and snow plowing.
Since snow hauled off site is about 20% of annual snowfall, the loss from snow hauling, L_1, can be estimated by:

$L_1 = (0.2)(0.1)S$

Where: L_1 = Water equivalent lost to hauling snow off site (inches)
S = Annual snowfall (inches)
0.1 = Factor to convert snowfall to water equivalent

Therefore, the loss to snow hauling is equal to:
$L_1 = (0.2)(0.1)(60")$
$L_1 = 1.2"$

Since sublimation is negligible, $L_2 = 0$

Step 3: Determine the annual water equivalent loss from winter snowmelt events
Using the information in Step 2, the moisture equivalent in the snowpack remaining after hauling is equal to:

$60"\cdot 0.1-1.2" = 4.8"$

Substituting this value into Table I.1, and interpolating, find the volume lost to winter melt, L_3.
$L_3 = 2.4"$

Step 4: Calculate the final snowpack water equivalent, M
$M = 0.1\cdot S-L_1-L_2-L_3$ (Equation I.1)
S = 60"
$L_1 = 1.2"$
$L_1 = 0"$
$L_3 = 2.4"$

Therefore, M = 2.4"

Step 5: Calculate the snowmelt runoff volume, R_s
$R_s = (1-I)(M-Inf)+ I\cdot M$ Equation I.7
M =2.4"
I =0.4
Inf =0.8" (From figure I.2; assume average moisture)
Therefore, $R_S = 1.9"$

Step 6: Determine the annual runoff volume, R
Use the Simple Method to calculate rainfall runoff:
$R=0.9(0.05+0.9*I)P$ (Equation I.6)
I=0.4
P=30"
Therefore, R=11"

Sizing Example 1: Snowpack Treatment

Step 7: Determine the runoff to be treated
Treatment, T should equal:
$T= (R_s-0.05*R)\ A/12$ (Equation I.2)
R_s=1.9"
R =11"
A = 50 Acres
Therefore, T=5.6 acre-feet

Step 8: Size the SMP
The volume treated by the base criteria would be:
WQ_v=(.05+.9*.4)(1'/12")(50 acres) = 1.7 acre-feet (Equation I.5)

For cold climates:
WQ_v=1/2(T) = 2.8 acre-feet (Equation I.3)
The cold climate sizing criteria is larger, and should be used to size the SMP.

I.1.4 Rain-on-Snow Events

For water quality volume, an analysis of rain-on-snow events is important in coastal regions. In non-coastal regions, rain-on-snow events may occur annually but are not statistically of sufficient volume to affect water quality sizing, especially after snowpack size is considered. In coastal regions, on the other hand, flooding and annual snowmelt are often driven by rain-on-snow events (Zuzel et al., 1983). Nearly 100% of the rain from rain-on-snow events and rain immediately following the spring melt is converted to runoff (Bengtsson, 1990). Although the small rainfall events typically used for SMP water quality do not produce a significant amount of snowmelt (ACOE, 1956), runoff produced by these events is high because of frozen and saturated ground under snow cover.

Many water quality volume sizing rules are based on treating a certain frequency rainfall event, such as treating the 1-year, 24-hour rainfall event. The rationale for treating 90% of the pollutant load (Schueler, 1992) can also be applied to rain-on-snow events, as shown in the following example.

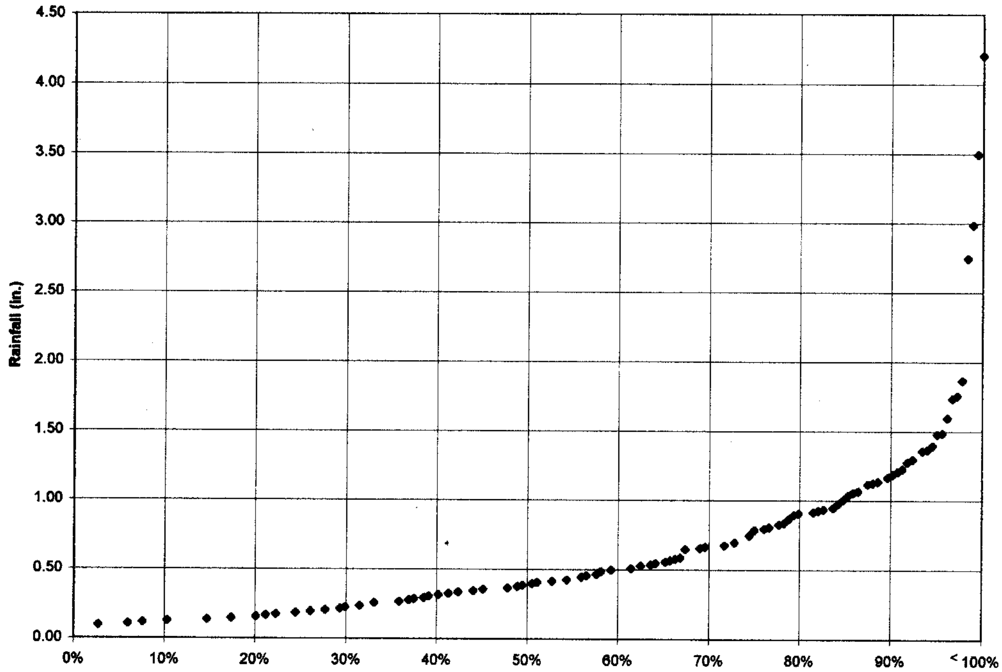
Sizing Example 2: Rain-on-Snow

Step 1: Develop a rain-on-snow data set.
Find all the rainfall events that occur during snowy months. Rainfall from December through April were included. Please note that precipitation data includes both rainfall and snowfall, and only data from days without snowfall should be included. Exclude non-runoff-producing events (less than 0.1"). Some of these events may not actually occur while snow is on the ground, but they represent a fairly accurate estimate of these events.

Step 2: Calculate a runoff distribution for rain-on-snow events
Since rain-on-snow events contribute directly to runoff, the runoff distribution is the same as the precipitation distribution in Figure I.3.

Sizing Example 2: Rain-on-Snow

Figure I.3 Rainfall Distribution for Snowy Months



Step 3: Calculate a rainfall distribution for non-snow months.
Develop a distribution of rainfall for months where snow is not normally on the ground. The rainfall distribution for May through November is included in Figure I.4.

Sizing Example 2: Rain-on-Snow

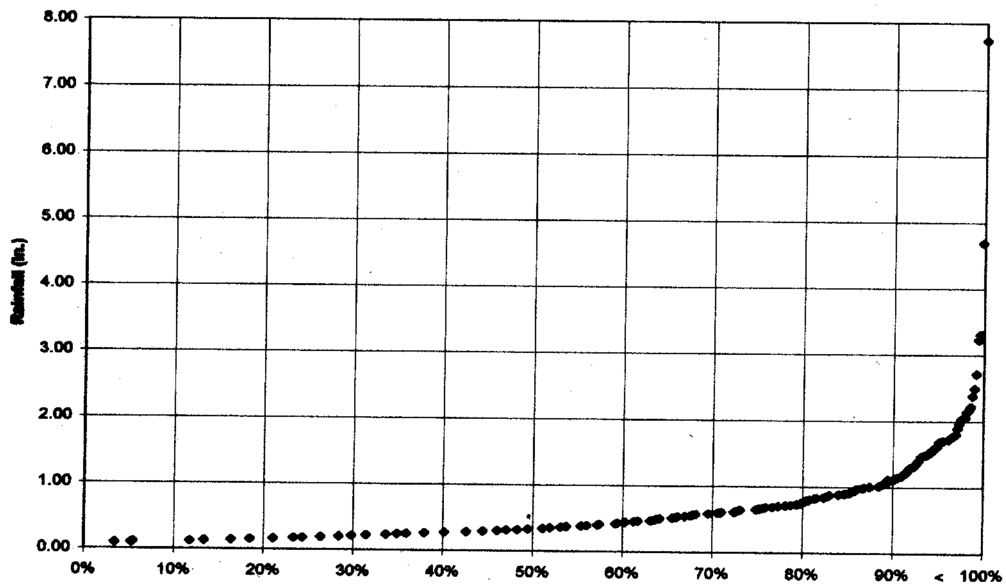


Figure I.4
Rainfall Distribution for Non-Snowy Months

Step 4: Calculate the runoff distribution for non-snow months.
Use a standard method to convert rainfall to runoff, particularly methods that are calibrated to local conditions. For this example, use the Simple Method. Runoff is calculated as:

$r=(0.05+0.9\ I)p$ (Equation I.4)

For this example, I=0.3 (30% impervious area), so:

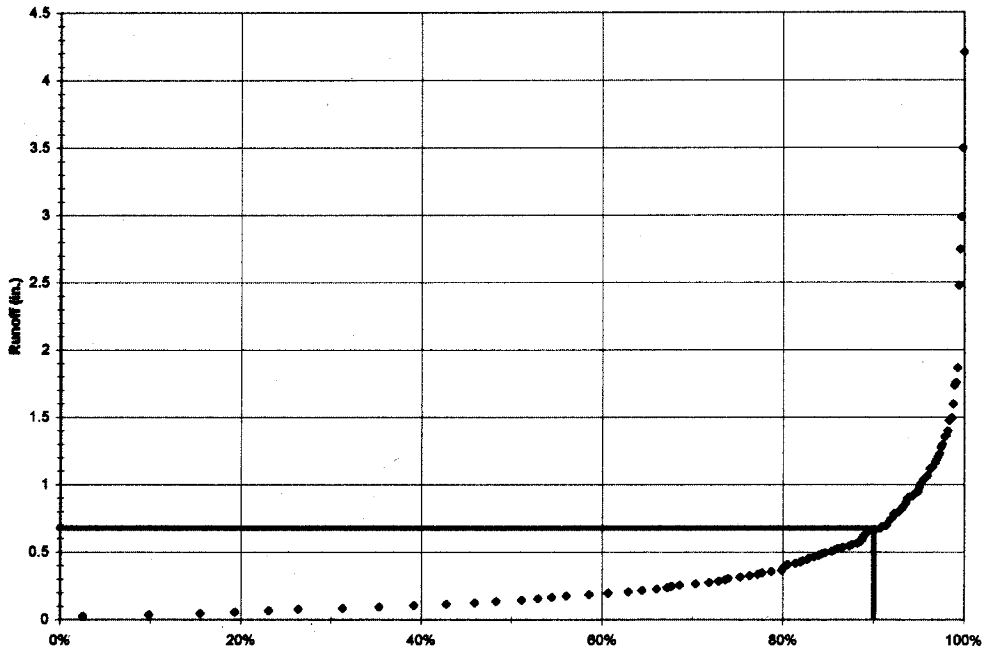
$r=0.32\ p$

The runoff distribution for non-snow months is calculated by multiplying the rainfall in Figure I.4 by 0.32.

Step 5: Combine the runoff distributions calculated in Steps 2 and 4 to produce an annual runoff distribution. The resulting runoff distribution (Figure I.5) will be used to calculate the water quality volume.

Sizing Example 2: Rain-on-Snow

Figure I.5 Annual Runoff Distribution



Step 6: Size the SMP.

In this case, use the 90% frequency runoff event (Figure I.4), or 0.65 watershed inches. This value is greater than the base criteria of 0.32 watershed inches (1" storm runoff). Therefore, the greater value is used.

WQ_v=(0.65 inches) (1 foot/12 inches) (50 acres) = 2.7 acre-feet

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Appendix J

Distributed Runoff Control Methodology
Pond Outlet Structure Design Example

The following design example illustrates a step-by-step methodology for the design of a weir for the control of instream erosion potential using a Stormwater Management (SWM) wet pond design based on the Distributed Runoff Control (DRC) approach. The DRC approach incorporates boundary material composition and its sensitivity to erosion (entrainment and transport) into the design protocol. The boundary materials are characterized at the point of maximum boundary shear stress on the bed and the point of secondary maximum boundary shear stress on the bank. By examining the channel at selected sites downstream of the SWM facility the DRC protocol provides a pseudo 3-dimensional assessment of the impact of development and the SWM facility on the receiving channel.

This design example involves 5 Steps as listed in Table J.1.

Table J.1 Overview of Key Steps in the DRC Design Approach
1) Determine the "stability" and "mode-of-adjustment" of the receiving channel
2) Complete a Diagnostic Geomorphic Survey of the receiving channel
3) Determine channel sensitivity to an alteration in the sediment-flow regime
4) Approximate the elevation-discharge curve for the pond.
5) Size the DRC weir

Step 1. Determine Channel "Stability" and "Mode-of-Adjustment"

Channel stability is determined using a Rapid Geomorphic Assessment (RGA) of the channel downstream of the outlet of the proposed Stormwater Management (SWM) pond. The RGA protocol involves the identification of the presence of in-stream features resulting from a variety of geomorphic processes to provide a semi-quantitative assessment of a stream's stability and mode-of-adjustment. The processes are represented by four Factors: aggradation (AF), widening (WF), downcutting (DF), and planimetric form adjustment (PF)). Each Factor is composed of 7 to 10 indices for which a "present" or "absent" response is required. The total number of "present" or "yes" responses is summed and divided by the total number of responses (both "yes" and "no") to derive a value for each Factor. An index that is not relevant is not assigned a response. An example of an RGA Form is provided in Table J.2.

A Stability Index (SI) value is determined from the Factor values using the following equation:

$$SI = \frac{\{AF + DF + WF + PF\}}{m}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [J.1]$$

where 'm' is the number of Factors (typically 4 for alluvial streams).

Table J.2 Rapid Geomorphic Assessment Form

FORM/ PROCESS	GEOMORPHIC INDICATOR No.	Description	PRESENT No	Yes	FACTOR VALUE
Evidence of Aggradation (AI)	1	Lobate bar	1		1/7=0.143
	2	Coarse material in riffles embedded		1	
	3	Siltation in pools	1		
	4	Medial bars	1		
	5	Accretion on point bars	1		
	6	Poor longitudinal sorting of bed materials	1		
	7	Deposition in the overbank zone	1		
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	-	-	2/6=0.333
	2	Exposed sanitary/storm sewer/pipeline/etc.	-	-	
	3	Elevated stormsewer outfall(s)	-	-	
	4	Undermined gabion baskets/concrete aprons/etc.	-	-	
	5	Scour pools d/s of culverts/stormsewer outlets	1		
	6	Cut face on bar forms	1		
	7	Head cutting due to knick point migration	1		
	8	Terrace cut through older bar material		1	
	9	Suspended armor layer visible in bank		1	
	10	Channel worn into undisturbed overburden/bedrock	1		
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.		1	3/10=0.30
	2	Occurrence of Large Organic Debris		1	
	3	Exposed tree roots		1	
	4	Basal scour on inside meander bends	1		
	5	Basal scour on both sides of channel through riffle	1		
	6	Gabion baskets/concrete walls/armor stone/etc. out flanked	1		
	7	Length of basal scour >50% through subject reach	1		
	8	Exposed length of previously buried pipe/cable/etc.	1		
	9	Fracture lines along top of bank	1		
	10	Exposed building foundation	1		
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cute(s)	1		0/7=0
	2	Evolution of single thread channel to multiple channel	1		
	3	Evolution of pool-riffle form to low bed relief form	1		
	4	Cutoff channel(s)	1		
	5	Formation of island(s)	1		
	6	Thalweg alignment out of phase with meander geometry	1		
	7	Bar forms poorly formed/reworked/removed	1		
STABILITY INDEX (SI) = (AI+DI+WI+PI)/m				SI=	0.19

The Stability Index (SI) provides an indication of the stability of the creek channel at a given time based on the guidelines provided in Table J.3. The SI Value, however, does not differentiate between current and past disturbances.

Table J.3 Interpretation of the RGA Stability Index Value		
Stability Index Value	**Stability Class**	**Description**
0.0<SI<0.25	Stable	Metrics describing channel form are within the expected range of variance (typically accepted as one standard deviation from the mean) for stable channels of similar type
0.25<SI<0.4	Transitional	Metrics are within the expected range of variance as defined above but with evidence of stress
0.4<SI<1.0	In Adjustment	Metrics are outside of the expected range of variance for channels of similar type.

The guidelines presented in Table J.3 for the interpretation of the SI Value will vary with the field experience and the bias of the observer. The SI Values however, have been shown to be consistent between observers indicating that the protocol, once calibrated to the observer provides a reliable means of screening the channel for stability and mode-of-adjustment.

The RGA protocol is applied to channel segments of two meanders in length or the equivalent of 20 bankfull channel widths (the width of the channel at the geomorphically dominant discharge, recurrence interval of between 1 and 2 years or 1.5 years on average).

The segment chosen for application of the RGA assessment is selected to be representative of the morphology of the channel for some distance up and downstream of the surveyed segment. That is, the parameters defining channel cross-section and plan form (e.g. width, depth, meander wavelength, etc.) are within a consensual level of variance for this reach of channel. An acceptable level of variance is typically defined as within one standard deviation of the mean. These reaches are referred to as being of "like" morphology. Since the morphology of the channel will vary in the longitudinal direction with changes in flow, slope, physiography, etc., it will be necessary to re-apply the RGA protocol where the parameters characterizing the morphology of the channel have changed beyond the consensual level of variance from the previous survey reach. In this manner the channel is divided into a series of reaches of "like" morphology.

Having determined the length of the survey reach, the longitudinal profile can be plotted from topographic mapping as illustrated in Figure J.1 (Topo). Examination of Figure J.1 (topographic map data) suggests that the channel can be differentiated into three distinct reaches. In the first reach (length L=146 ft, the channel has an average slope of S=0.00385 ft/ft and a meander-pool-riffle morphology. In the middle reach (L≈356 ft; S≈0.0142 ft/ft) the channel has cascade morphology. The third reach (L≈258 ft; S≈0.00794 ft/ft) returns to the meander-pool-riffle form.

Land use through the study reach is homogeneous (forest) and there are no other features (e.g. bridges, dams, weirs, instream works, etc.) that would affect the hydraulic characteristics of the active channel. Consequently, a preliminary definition of "like" reaches includes the three morphologies described above.

A synoptic geomorphic survey was conducted through the subject reach with an RGA assessment completed for each of the three reaches of "like" morphology. The results of the RGA assessment for the first reach (Reach 1) are reported in Tables J.2 and J.4. Referring to Table J.2, the Stability Index (SI) value was found to be SI=0.19, which is less than 0.25, therefore the channel is considered to be "stable" (Table J.3).

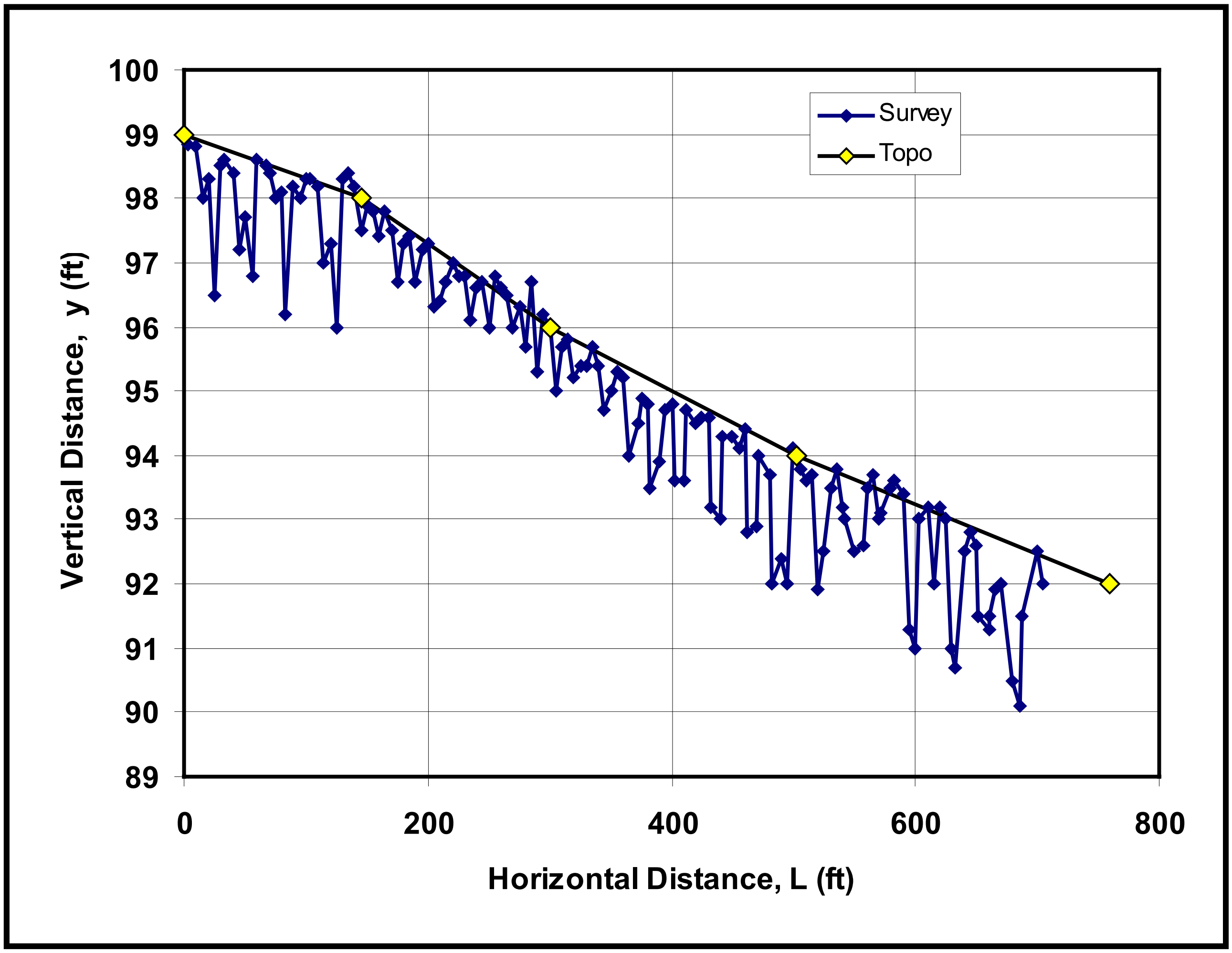


Figure J.1 Longitudinal Profile from Topographic Mapping and Field Survey of Channel Thalweg

Table J.4 Summary of Average Longitudinal Slope and Pool-Riffle Dimensions

Parameter	Reach 1	Reach 2	Reach 3
Longitudinal Gradient, S (ft/ft)	0.00385	0.0142	0.00794
Riffle Length, LRIF (ft)	16	34	27
Pool Length, LPOL (ft)	37	10	18
Total Pool-Riffle Length, LTOT (ft)	53	44	45

Step 2. Diagnostic Geomorphic Survey

Following completion of the identification of reaches of "like" morphology and the synoptic survey to finalize the delineation of the "like" reaches, a diagnostic geomorphic survey is undertaken to characterize the morphological attributes of the channel. This information has two primary functions.

1. The optimization of the erosion control benefit of the pond; and,
2. The provision for establishing a baseline condition from which it is possible to assess the performance of the SWM measures.

A detailed diagnostic survey includes a collection of a comprehensive set of parameters to assess and evaluate stream geomorphic conditions. A complete survey is typically required when:

a) A post-construction monitoring program is mandated; and,
b) Data are required for the design and construction of instream works.

Only a partial diagnostic survey is needed where the above issues are not relevant to the project. The following lists those parameters required for the partial diagnostic survey:

1. In the absence of flow measurements, a field estimate of Manning's 'n' value is obtained for comparison with sediment computed estimates.
2. Detailed survey of the channel cross-section, including the floodplain, to determine hydraulic geometry metrics at a so called "Master cross-section" and the relative location of bank material strata.
3. The longitudinal profile of the bed along the channel thalweg and the water surface at the time of survey over a distance of one meander wavelength or 10 bankfull widths. These data are used to determine the longitudinal gradient of the channel from riffle crest to riffle crest and to determine the dimensions of the pool-riffle complex.
4. At least one estimate of bankfull depth (the depth of flow at the dominate discharge) at the Master cross-section and all ancillary cross-sections (3 alternative methods are described in this example for illustrative purposes).
5. Bed material characteristics based on pebble counts of the bed material at a riffle crossover. These data are collected to help assess roughness coefficients, bed material resistance, and provide an alternate method for the estimation of bankfull depth.
6. Soil pits in the banks to map bank stratigraphy and to determine bank material composition using soil consistency tests (stickiness, plasticity and firmness) or particle size analysis (percent silt clay) with Atterberg Limits (Plasticity Index) for each stratigraphic unit. These data are required to help assess historic degradation or aggradation patterns and determine bank material resistance.
7. Map riparian vegetation and root zone characteristics in the soil pits for assessment of the affect of root binding on bank material resistance.

The cross-section data and bank material characterization is completed at a Master cross-section within the representative segment of each "like" reach. The Master cross-section is typically located at a riffle crossover on a straight reach between meander bends. Ancillary cross-sections are located in the lower one third of the meander bends and riffle crossover points up and downstream of the Master cross-section. Data collected at the ancillary cross-sections includes a cross-section profile (typically 7 to 9 ordinates) and estimates of bankfull stage. The longitudinal profile is collected throughout the survey segment along with characterization of plan form geometry.

Design Case: Diagnostic Geomorphic Survey

The longitudinal survey of the channel along the thalweg is presented in Figure J.1 ("Survey" data points). This profile more clearly demonstrates the differences between the three reaches as represented by slope and pool-riffle dimensions (Table J.4). Other parameter values derived from the geomorphic survey are summarized in Table J.5. These data are combined with the cross-section, soils and sediment data to generate values for key parameters as described in the following series of calculations.

The following calculations are required to determine the 3 different estimates of the dominant discharge.

Estimate of Geomorphic Referenced Dominant Discharge

1. The longitudinal data are plotted to generate estimates of the channel gradient in order of priority as follows:
   (1) Water surface profile based on estimates of bankfull stage from the Master and ancillary cross-sections.
   (2) Bed slope (riffle crest to riffle crest), and
   (3) Water surface profile (dry weather flow at the time of the survey).
2. The pebble count data (length, width and breadth) are transformed into an equivalent diameter and used to generate a mass curve wherein cumulative percent finer by mass is plotted as a function of particle diameter;
3. The $\square_{50}$ and $\square_{84}$ particle size values (the particle diameter below which 50 and 84% of the particles are finer by mass, respectively) are determined from the mass curve;
4. Manning's roughness coefficient is estimated at bankfull stage using:
   (1) Standard field guides, and
   (2) Empirical relations such as: the Strickler (1923) and Limerinos (1970) equations.
5. The cross-section ordinates collected at the Master cross-section are plotted to produce a cross-section profile and a stage-area curve;
6. The stage-area curve is combined with the longitudinal gradient (S) and the estimate of Manning's roughness coefficient (n) to generate the stage-discharge curve for the cross-section using Manning's equation,

$$Q = \frac{1.49}{n} A R^{(\frac{2}{3})} S^{\frac{1}{2}}, \qquad \text{[J.2]}$$

   in which Q represents the flow rate (cfs) at depth 'y' above the thalweg, 'A' is the cross-section area of the channel at depth 'y', 'R' represents the hydraulic radius at depth 'y' and 'S' is the longitudinal gradient of the channel (ft/ft). An example of a stage-discharge curve is provided in Figure J.2;

Table J.5 Summary of Hydraulic and Sediment Parameters

Reach No.	Rosgen Stream Type	2 Year Flow Q_{2YR} (cfs)	W/d Ratio	Width W_{BFL} (ft)	Depth d_{BFL} (ft)	Flow Q_{BFL} (cfs)	Base B (ft)	Wetted Perimeter P (ft)
1	C3	8.9	3.00	3.00	1.00	4.76	2.00	4.24
2	B3	9.54	3.23	2.75	0.85	5.10	1.90	3.80
3	C3	10.1	2.87	2.83	0.99	5.40	1.85	4.06

Reach No.	Bed Material Mean Particle Size □50 (in)	Bed Material Mean Particle Size □84 (in)	Area A_{BFL} (ft^2)	Hydraulic Radius R (ft)	Slope S (ft/ft)	Velocity v (fps)	Riparian Vegetation Type
1	2.8	3.3	2.50	0.590	.00385	1.90	Woody
2	5.1	7.5	1.99	0.521	.0142	2.57	Woody
3	3.7	5.2	2.32	0.570	.00794	2.35	Woody

Reach No.	Bank Material Composition: Soil Class: Class	Unit No.	Soil Consistence Test: X1	X2	X3	SCORE	Critical Shear Stress: Bank (*) □CRT (lbs/ft^2)	Critical Shear Stress: Bed □CRT (lbs/ft^2)	Depth of Stratigraphic Unit h (ft)	Excess Boundary Shear Stress □CRT (lbs/ft^2): Bank	Excess Boundary Shear Stress: Bed
1	SiLm	1	1	2	1	4			0.36<h≤1.00		
	SiSa	2	0	0	1	1	0.120	0.548	0.10<h≤0.36	0.057	-0.334
	CoGr	3	N/a	N/a	N/a	N/a			0.0<h≤0.10		
2	CoBo	1	N/a	N/a	N/a	N/a	0.573	1.206	0.39<h≤0.85	-0.016	-0.526
	GrCo	2	N/a	N/a	N/a	N/a			0.0<h≤0.39		
3	SiLm	1	2	1	3	6			0.32<h≤0.99		
	SiCl	2	2	2	2	6	0.329	0.878	0.12<h≤0.32	0.03	-0.446
	SiCl	3	2	3	2	7			0.0<h≤0.12		

(*) Least resistant lower bank stratigraphic unit corresponding to the zone of secondary maximum boundary shear stress.

7. The dominant discharge (Q_{GEO}) is determined from the stage-discharge curve and field estimate of bankfull stage (d_{BFL}). For Reach 1 in this example, d_{BFL}=1.0 ft, consequently Q_{GEO}=4.76 cfs (Figure J.2). This procedure is repeated for each cross-section within the reach and the flow rate most common to all cross-sections is adopted as the geomorphic referenced estimate of the dominant discharge. If a wide disparity exists between estimates of (Q_{GEO}) than the determination of slope, Manning's 'n' value and the geomorphic indicators of bankfull stage are revisited to determine if a miss-interpretation of the data or an error in calculations has occurred.

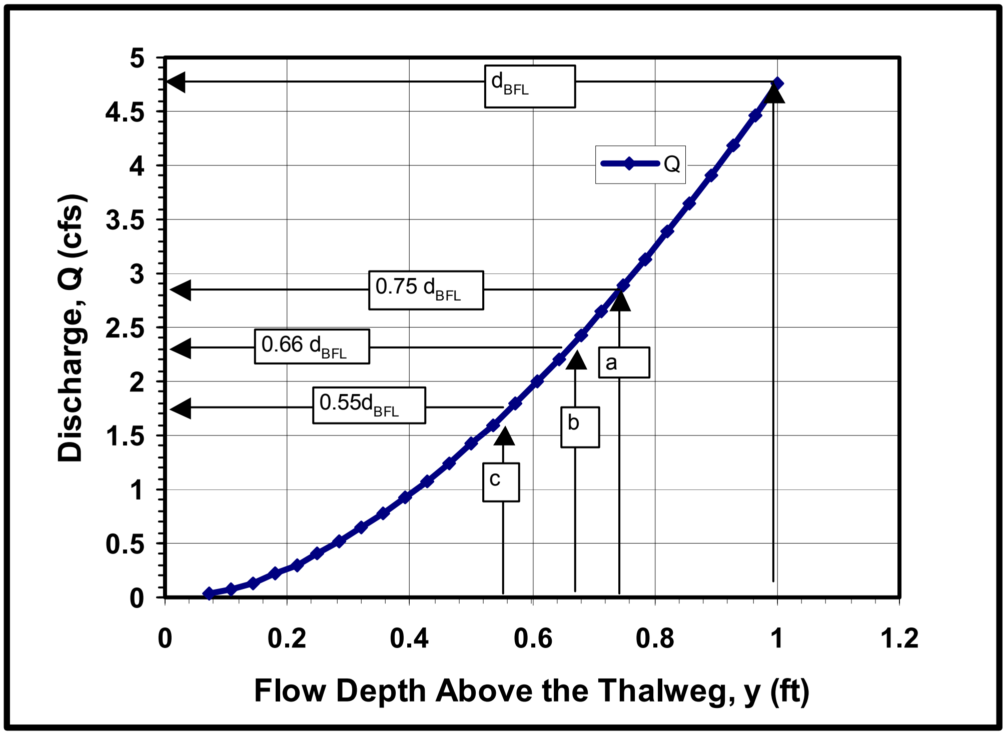


Figure J.2 Stage-Discharge Curve for Reach 1 Downstream of the Proposed Development

Estimate of Bed Material Critical Shear Stress

8. Critical shear stress is estimated for the ϕ_{84} particle size value of the bed material using procedures such as:
   (1) The modified Shield's equation (Vanoni, 1977), or
   (2) Various empirical relations (from the literature) that express critical shear stress as a function of particle size, one such is Eqn J.3 proposed by Lane (1955)

$$(\tau_{CRT})_{BED} = 0.164\phi_{84}, \qquad \text{[J.3]}$$

in which ϕ_{84} is the particle size for which 84% of the materials are finer (inches) and τ_{CRT} represents the critical shear stress (lbs/ft^2). Applying Eqn, [J.3] :

$(\tau_{CRT})_{BED} = 0.164\phi_{84} = 0.164\ (3.34\ \text{in}) = 0.548\ \text{lbs/ft}^2$

at the Master cross-section (Reach 1);

Estimate of Instantaneous Bed Shear Stress

9. A stage-shear stress curve is generated for the Master cross-section using DuBoy's relation for average shear stress and a channel shape adjustment factor proposed by Lane (1955) as follows:

$$\tau_0 = k_b \rho g (d - d_P) S, \qquad \text{[J.4]}$$

and,

$$k_b = 0.000547\left(\frac{B}{d}\right)^3 - 0.0121\left(\frac{B}{d}\right)^2 + 0.092\left(\frac{B}{d}\right) + 0.75, \ldots\ldots\ldots\ldots\ldots\ldots[J.5]$$

in which τ_0 represents the instantaneous boundary shear stress at point 'P' on the bed (lbs/ft s^2), k_b is a channel shape adjustment factor (dimensionless; Fig. J.3), ρ is the density of the sediment-water mixture being conveyed by the channel (62.4 lbs/ft^3), 'g' is acceleration due to gravity (32.2 ft/s^2), 'd' is the depth of the flow above the thalweg (ft), d_P is the depth of flow above the thalweg at point 'P' (ft), 'S' represents the longitudinal gradient of the flow at depth 'd' and 'B' is the bottom width of the channel (assuming a trapezoidal configuration). In this design case, a mapping of the isovels through the Master cross-section indicates that the point of maximum boundary shear stress occurs at the thalweg. Since the thalweg is the deepest part of the channel, the term d_P=0 in Eqn. J.4. A stage-shear stress curve for Reach 1 is illustrated in Figure J.4. Note that the units for τ_0 are reported in lbs/ft^2 to be consistent with the estimate of critical shear stress reported in Task 8. To obtain units of lbs/ft^2 remove 'g' from Eqn. J.4.

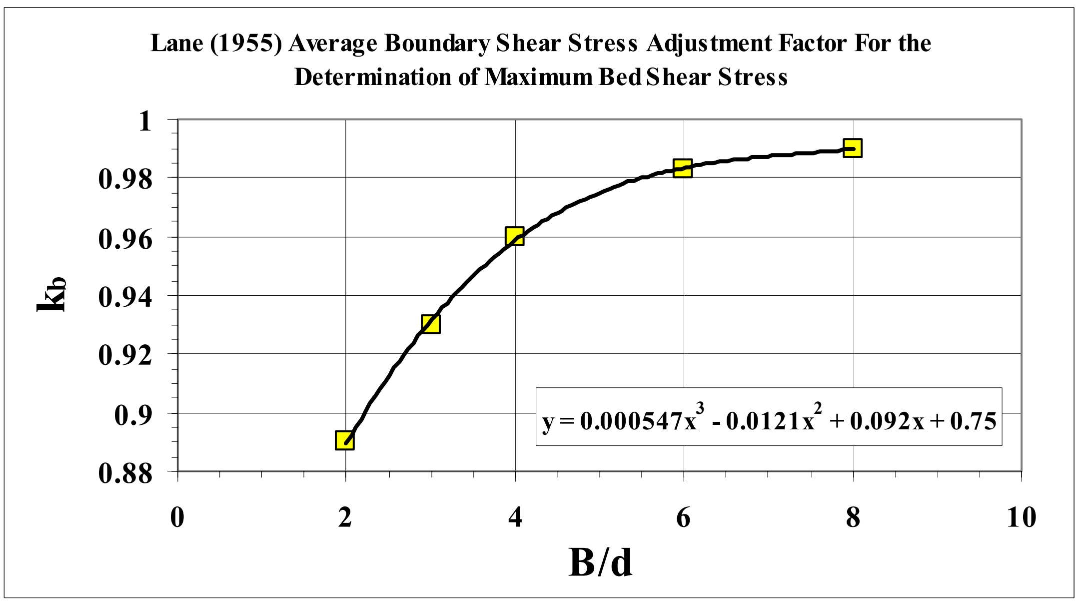


Figure J.3 Determination of k_B for the Adjustment of Average Boundary Shear Stress For Variations in Channel Shape Assuming A Trapezoidal Channel Cross-Section Configuration

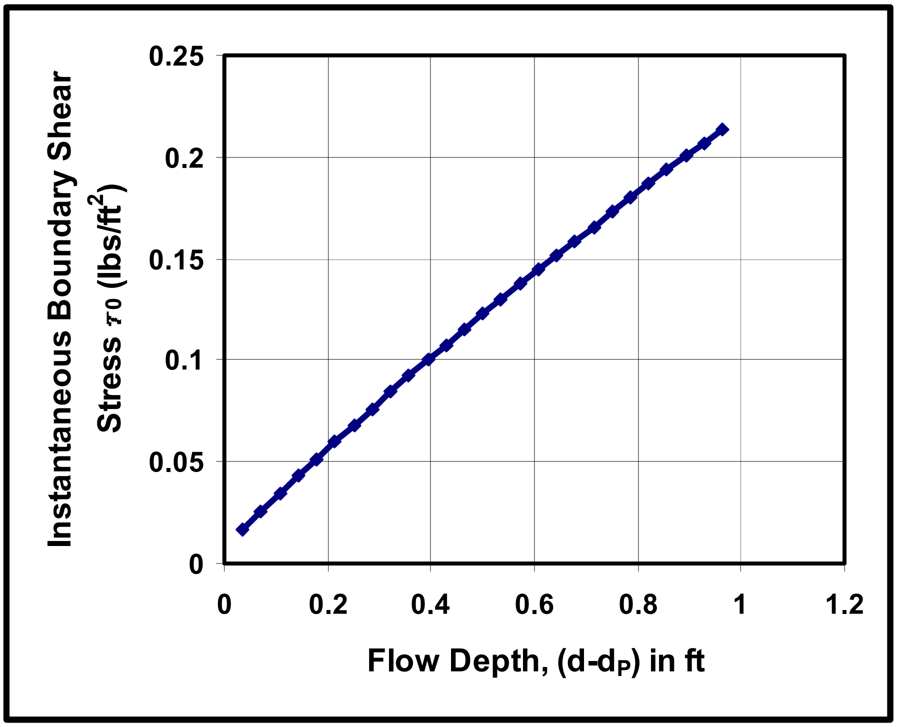


Figure J.4. Stage-Shear Stress Curve for Reach 1 (Master Cross-section): Bed Station.

Estimate the Sediment Referenced Dominant Discharge

10. The stage-shear stress curve is used to determine the depth of flow at which the boundary shear stress on the bed is equal to the critical shear stress of the ϕ_{84} particle size fraction. This depth is transformed into an estimate of flow rate from the stage-discharge curve (Task 5 above), providing a second, independent estimate of the dominant discharge (Q_{SED}). This calculation also provides a basis for determination of the sensitivity of the bed material to an alteration in the sediment-flow regime. This assessment is described in Task 21 below;

Estimate The Flow Recurrence Interval of the Referenced Dominant Discharge

11. A flow time series is generated using:
    (1) Flow gauge data if available, or
    (2) A continuous hydrologic model to generate a synthetic flow time series of 6 to 13 years in length.
12. The flow time series is used to derive a flood frequency curve from which a third independent estimate of the dominant discharge (Q_{RI}) is determined as the flow having a recurrence interval between 1 and 2 years (average RI=1.5 years);

Finalize the Estimate of Dominant Discharge

13. The three estimates of dominant discharge are compared for consistency. If consistent (e.g. the range is equal to or less than 20% of the mean), then the mean value of the dominant discharge can be accepted with a higher degree of confidence

Step 3. Determine the Sensitivity of the Boundary Materials

A) Sensitivity of the Bed Material

14. Using the stage-shear stress relationship developed in Task 9 and the estimate of flow depth (d_{BFL}, Task 10) from the dominant discharge (Task 13), determine the boundary shear stress $(\tau_0)_{BED}$ being applied to the bed at point 'P' at the dominant discharge. Point 'P' is located on the bed within the zone of maximum boundary shear stress. In this example the value of maximum instantaneous boundary shear stress at a depth of d_{BFL}= 1.0 ft was found to be $(\tau_0)_{BED}$ = 0.214 lbs/ft^2 at the Master cross-section in Reach 1 (Figure J.4). Similarly, for Reaches 2 and 3 the maximum value of instantaneous boundary shear stress was found to be $(\tau_0)_{BED}$ = 0.680 and 0.432 lbs/ft^2 respectively.
15. Compute the value of $(\tau_e)_{BED}$ for the Master cross-section knowing $(\tau_0)_{BED}$ and $(\tau_{CRT})_{BED}$ as,

$$(\tau_e)_{BED} = (\tau_0 - \tau_{CRT})_{BED}, \ldots\ldots [J.6]$$

in which $(\tau_e)_{BED}$ represents the effective boundary shears stress, τ_0 is the instantaneous boundary shear stress at the dominant discharge and τ_{CRT} is the critical shear stress of the bed material at point 'P'.

16. Repeat the bed shear stress analysis for all Master cross-sections in all reaches of "like" morphology.
17. Compare the value of $(\tau_e)_{BED}$ for all Master cross-sections through the study reach and select the Master cross-section for which the value of $(\tau_e)_{BED}$ is greatest. The reach represented by the Master cross-section having the highest value of $(\tau_e)_{BED}$ is referred to as the "Control Reach".

In this example, effective boundary shear stress on the bed was found to range from between -0.526 and -0.334 (Table J.5). The negative values infer that the channel bed is armored and the bed material is mobile under flood flow events in excess of the dominant discharge. However, of the three Master cross-sections the value of $(\tau_e)_{BED}$ was greatest for Reach 1, consequently, Reach 1 was identified as the "Control Reach".

B) Sensitivity of the Bank Material

18. The bank material for the "Control Reach" is classified according to soil type for each stratigraphic unit using:
    (1) Soil consistency tests; or
    (2) Particle size analysis and Atterberg Limits.

    In this example the bank materials were mapped and differentiated into stratigraphic units as summarized for the three reaches in Table J.5. The soil consistency test results determined using standard soil classification guidelines (as quantified by MacRae, 1991)), are summarized below and reported in Table J.5.

    i) Assign a value for the stickiness of the material, e.g. not sticky, (X1=0) to extremely sticky (X1=4),
    ii) Assign a value for the plasticity of the material, e.g. not plastic (X2=0) to extremely plastic (X2=4),
    iii) Assign a value for the firmness of the material, e.g. loose, no structure (X3=0) to

stiff (X4=4).

(3) Sum the consistency test values,

$$SCORE = \sum_{i=1}^{3} x_i \text{ ,..[J.7]}$$

in which SCORE represents the sum of the values assigned for stickiness, plasticity and firmness.

19. Construct stage-shear stress curves for selected bank stations approximated by $0.25d_{BFL}$, $0.33d_{BFL}$, $0.4d_{BFL}$. More than one bank station may be required in a stratigraphic unit depending upon the thickness of the unit. The curves may be approximated as follows:

$$\tau_0 = k_S(\rho g(d - d_P)S) \text{ ,..[J.8]}$$

in which k_S is a correction factor for points on the channel bank determined as a function of channel shape (see Eqn. J.9, Figure J.5), 'd' is the depth of flow (ft), ρ is the density of water (62.4 lbs/ft^3), 'g' is acceleration due to gravity (32.2 ft/s^2) and d_P is the depth of flow at the elevation of the boundary station (ft).

$$k_S = 0.7236\left(\frac{B}{d}\right)^{0.0241} \text{ ,.......................................[J.9]}$$

in which B is the channel bottom (ft) width and 'd' is the depth of flow (ft). Note, to obtain units of lbs/ft^2 remove the constant 'g' from Eqn. J.8.

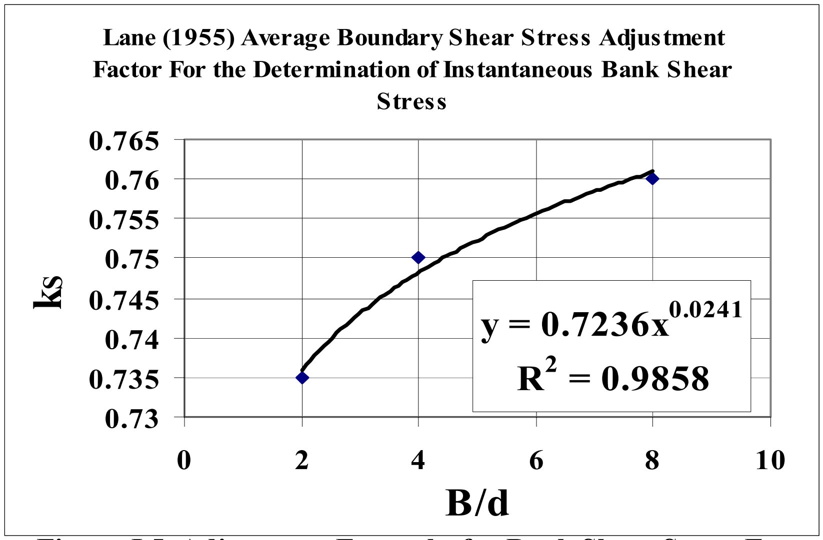


Figure J.5 Adjustment Factor k_S for Bank Shear Stress For Channels Approximating a Trapezoidal Shape

20. Estimate the critical shear stress (τ_{CRT}) within each stratigraphic unit using available empirical relationships. These relations are typically based on percent silt and clay content, degree of compaction, particle size (Vanoni, 1977) or the SCORE value (MacRae, 1991);
21. Compute the excess boundary shear stress for each bank station at a flow depth of between 0.6 and 0.75 feet by reading the boundary shear stress off the stage-shear stress curve for each boundary station and subtracting the critical shear stress as described in DuBoy's relation,

$$(\tau_e)_{BNK} = (\tau_0 - \tau_{CRT})_{BNK}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [J.10]$$

in which $(\tau_e)_{BNK}$ represents the excess boundary shear stress (lbs/ft^2) at the selected boundary station (P), τ_0 is the instantaneous boundary shear stress (lbs/ft^2) at any specified depth of flow at point P and τ_{CRT} represent the critical shear stress (lbs/ft^2) of the boundary material at point P.

22. Compare the estimates of excess boundary shear stress $(\tau_e)_{BNK}$ at each bank station and select that station having the highest value of $(\tau_e)_{BNK}$ as the bank station controlling bank response (controlling stratigraphic unit) to a change in the flow regime. Using the guidelines presented in Table J.6 determine channel sensitivity to an alteration in the sediment-flow regime and the corresponding Over Control (OC) curve and Inflection Point

Table J.6 General Guidelines for the Application of the DRC Approach Based on Bank Material Sensitivity Using SCORE Values							
BANK SENSITIVITY		**BED SENSITIVITY**				**DRC PARAMETERS**	
Excess Shear Stress $(\tau_e)_{BED}$	Sensitivity Class	Excess Shear Stress $(\tau_e)_{BNK}$	Bank Resistance: Soil Class	Bank Resistance: SCORE	Sensitivity Class	Over Control Multiplier R_{OC}	Inflection Point
<0	**L**	<0	Very Stiff	N/a	L	1.0 –0.9	a
		≈0	Stiff	10-12	ML	0.9 - 0.7	a
			Firm	7-9	M	0.7 - 0.5	b
			Soft	≤6	H	0.5 - 0.2	c
		>0	**N/a**			**0.5 - 0.2**	**c**
≈0	ML	<0	N/a			0.9 - 0.7	a
		≈0	Stiff	10-12	ML	0.9 - 0.7	a
			Firm	7-9	M	0.7 - 0.5	b
			Soft	≤6	H	0.5 - 0.2	c
		>0	N/a			0.5 - 0.2	c
	M	<0	N/a			0.7 - 0.5	b
		≈0	Stiff	N/a		0.7 - 0.5	b
			Firm	7-9	M	0.7 - 0.5	b
			Soft	≤6	H	0.5 - 0.2	c
		>0	N/a			0.5 - 0.2	c
	H	N/a				0.5 - 0.2	c
>0	H	N/a				0.5 - 0.2	c

The multiplier (R_{OC}) in Table J.6 is used in the following manner:

a) The 2 year peak flow attenuation technique is used to derive the stage-discharge curve for the erosion control component of the SWM pond.

b) A multiplier of unity is equivalent to the traditional 2-year peak flow attenuation approach.

c) The multiplier is used to adjust the 2-year stage-discharge curve to account for differences in the erodability of the boundary materials. The adjustment is performed by multiplying each ordinate of the stage-discharge curve by R_{OC}. For stiff materials, the multiplier approaches unity ($R_{OC} \rightarrow 1.0$). For very sensitive materials, the multiplier is between 0.2 and 0.3, which is equivalent to 80%OC to 70%OC respectively.

Bank materials may be grouped according to the SCORE value if the soil consistency tests apply (i.e. fine-grained material with few stones). For coarse-grained materials, resistance can be determined from observation of bank erosion following a high flow event. As an alternative the resistance of the coarse-grained stratigraphic unit can be inferred from bank form and shear stress distribution through comparison with adjoining strata of fine-grained material.

Finally, relations expressing critical shear stress as a function of particle size are available in the literature. Many of these relations were derived from flume experiments using disturbed material that has been re-compacted. These relations tend to underestimate the resistance of the material as it is observed in the field. Consequently, these relations should be employed with caution or corrected to account for root binding, imbrication, compaction and structurization.

Step 4. Approximate the Elevation-Discharge Curve For the DRC Pond.

The DRC outflow control structure can be constructed as set of pipes or nested weirs. This design example is for a nested, sharp crested weir.

Determine the stage-discharge curve for the flow rate having a recurrence interval of 2 years for the baseline land use condition. For this example, the baseline condition is the reforested land use scenario. The flow having a recurrence interval 2 years was determined previously as between 8.9 and 10.1 cfs for Reaches 1 through 3 respectively (Table J.5).

Construct the 2 year stage-discharge curve using an equation for sharp crested weirs with end contractions:

$$Q = C_e L_e h_e^{\left(\frac{3}{2}\right)} ,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[J.11]$$

in which, 'Q' represents the rate of flow (cfs), 'C_e' is the effective weir coefficient (C=3.19, Brater and King, 1982), L_e is the effective length of the weir (ft) and 'h_e' is the effective depth of flow above the weir crest (ft). Set the invert of the weir at 628.0 ft. The terms L_e, C_e and h_e are adjusted to account for losses due to end contractions (Brater and King, 1982). In this illustration it is assumed that the stage-volume curve has already been derived and that the approximate head at Q_{BFL}=8.9 cfs is h=2.25 ft.

Re-arranging Eqn. J.11 and solving for 'L_e' at Q=$(Q_{2YR})_{PRE}$=8.9 cfs yields,

$$L_e = \frac{Q}{C_e h_e^{\left(\frac{3}{2}\right)}} = \frac{8.9}{3.19(2.25)^{\left(\frac{3}{2}\right)}} = 0.83\text{ft} ,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[J.12]$$

Compute the stage-discharge curve for the 2-year weir using Eqn. J.11 as illustrated in Figure J.6 (Q_{2YR}, curve AB. This stage-discharge curve represents the rating curve for the 2-year post- to pre-development peak flow attenuation approach.

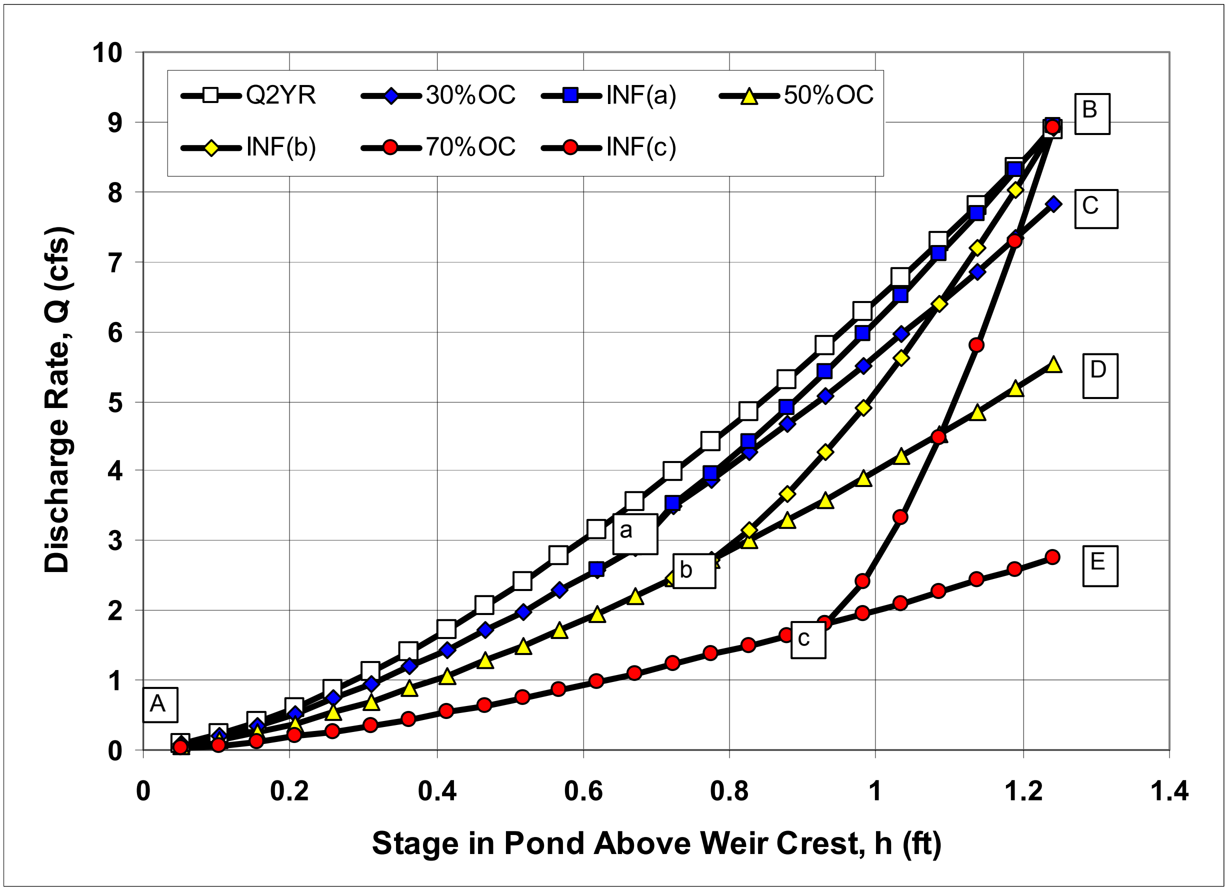


Figure J.6. The 2 Year Peak Flow Attenuation and DRC Rating Curves for 30%OC, 50%OC and 70%OC

Construct the DRC stage-discharge curve as follows:

- Determine the level of OC control and the inflection point from Table J.6.
  - Since $(\tau_e)_{BED}<0$ (Table J.5) then the bed is classified as "Low" sensitivity (shaded boxes in the first two columns of Table J.6);
  - The value of $(\tau_e)_{BNK}>0$ consequently, Row 3 of Column 3 (shaded box in Table J.6) was selected;
  - The bank material was classified as soft (SCORE=1), consequently, the 4th Row of Column 4 was chosen providing a range of R_{OC} between 0.5 and 0.2 with an inflection point at "c". In this case R_{OC}=0.3 was selected in accordance with the guidelines in Table J.6. Note: 70%OC means that the multiplier for the 2 year curve is R_{OC}=0.3
  - The 70%OC curve (designated as curve AE in Figure J.6) is created by multiplying the ordinance of the 2 year stage-discharge curve (Q_{2YR} in Figure J.6) by the multiplier R_{OC}=0.3.
  - The inflection point (c) is determined using the guidelines provided in Table J.7.

Table J.7 Guidelines For Determination of the Flow Rate for the DRC Curve Inflection Point (Reach 1)					
Inflection Point	Ratio of Inflection Point Depth to Bankfull Depth d_i/d_{BFL} (dim)	Bankfull Depth d_{BFL} (ft)	Inflection Point Depth d_i (ft)	Dominant Discharge Q_{BFL} (cfs)	Flow Rate at Inflection Point Q_i (cfs)
a	.75	1.0	.75	4.76	2.88
b	.67		.67		2.30
c	.55		.55		1.74

The point d_c=0.55 ft, d_{BFL}=1.0 ft, characterize the Control Reach, consequently the ratio,

$$\frac{d_c}{d_{BFL}} = \frac{0.55\,ft}{1.0\,ft} = 0.55\,,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[J.12]}$$

- The flow rate at d_c/d_{BFL}=0.55 was estimated from Figure J.6 to be Q_c=1.74 cfs.
- Point (c) can be located on curve AE at a flow corresponding to Q_c=1.74 cfs.

- The DRC stage-discharge curve follows the curve A(c)B in Figure J.6. For the purpose of illustration, the stage-discharge curves for 30%OC (inflection point (a)) and 50%OC (inflection point (b)) are also provided in Figure J.6.

Step 5. Sizing the DRC Weir

After establishing the DRC stage-discharge curve the next step is to size the DRC weir. This is done using a nested weir configuration as illustrated in Figure J.7. The equation for the nested weir can be approximated from Eqn. J.14 for sharp crested weirs as,

$$Q = \left(C_e L_e h_e^{\left(\frac{3}{2}\right)} \right)_{INSET} + \left(C_e (L_e^* - L_e)(h_e^* - h_e)^{\left(\frac{3}{2}\right)} \right),\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[J.14]}$$

in which Q represents the discharge from the nested weir, 'C_e' is a coefficient (3.19) adjusted to account for end contractions, L_e is the length of the inset weir, h_e represents the height of the inset weir where $0 \le h_e \le h_2$ (h_2 represents the total height of the nested weir) and h_e^* is the depth of flow through the nested weir above the inset weir ($h_e \le h_e^* \le h_2$).

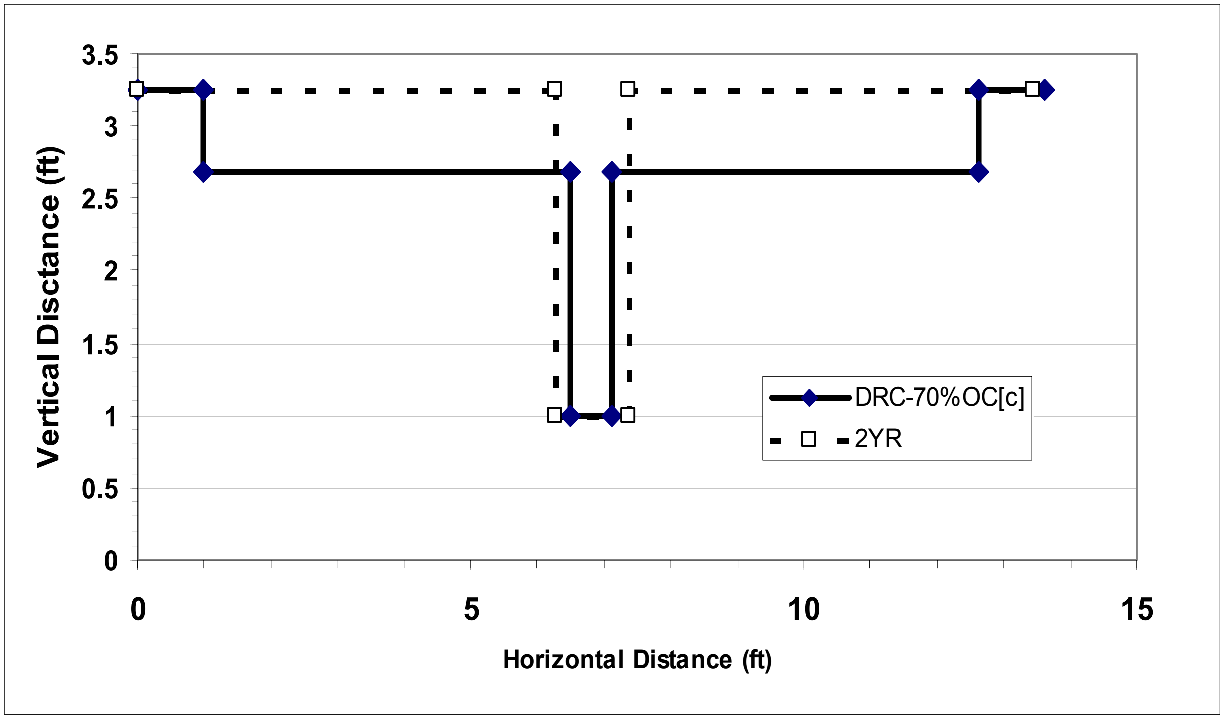


Figure J.7 Comparison of the 70% OC DRC Weir with Inflection Point at [c] and the Traditional 2-year Peak Flow Attenuation Weir

Solving Eqn. D.14 for results in the dimensions and flow values reported in Table J.8.

Table J.8. Summary of Dimensions and Flow Characteristics For a Nested DRC Weir: Reach 1

Parameter	DRC Weir			2 Year Weir
	Inflection Point (a)	Inflection Point (b)	Inflection Point (c)	
L_e (ft)	1.77	1.00	0.62	N/A
h_e (ft)	0.67	0.78	0.93	
Q_i at h_e (cfs)	2.89	2.21	1.74	
L_e^* (ft)	0.80	4.32	11.0	0.83
h_2 (ft)	2.25			
Q at h_2 (cfs)	8.94			

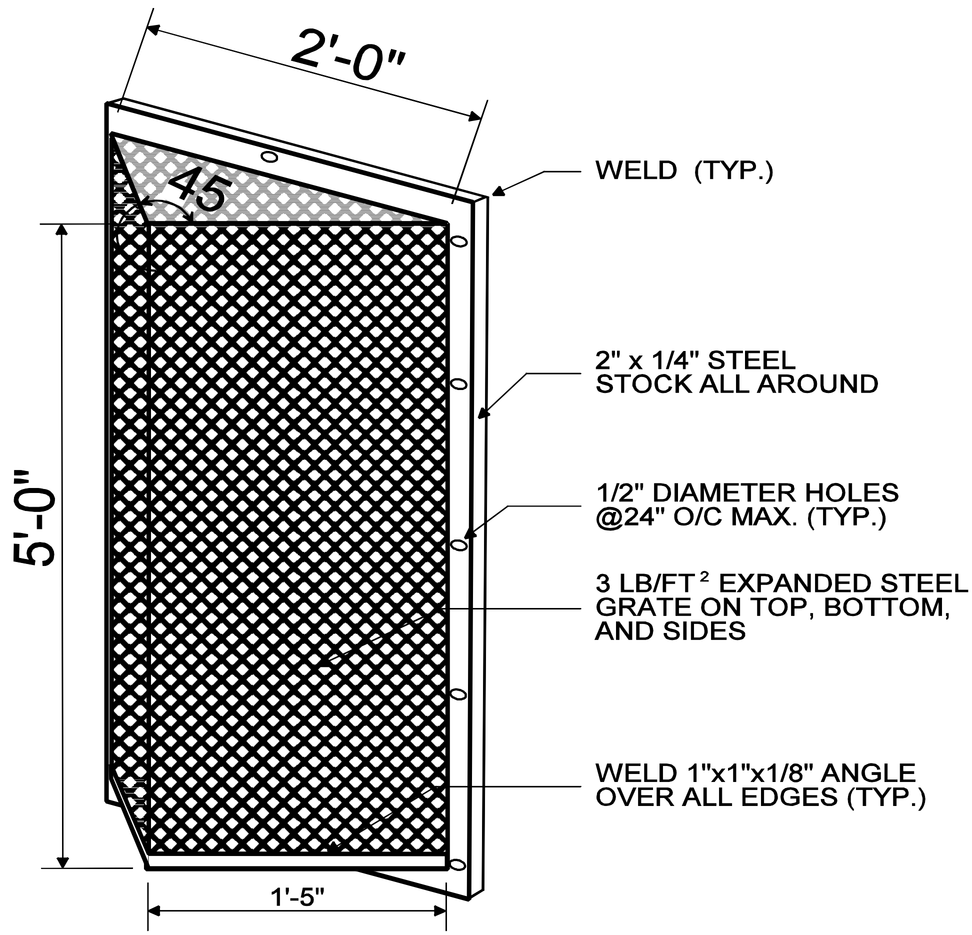
Parameters in Table J.8 are defined in the preceding text.
Note: the weir dimensions for DRC stage discharge curves 30%OC (inflection point 'a') and 50%OC (inflection point 'b') are provided for comparison with the selected option (inflection point 'c').

Appendix K

Appendix K. Miscellaneous Details

Miscellaneous Design Schematics for Compliance with Performance Criteria

Figure K.1 Trash Rack Protection for Low Flow Orifice



NOTES FOR TRASH RACK

1. TRASH RACK TO BE CENTERED OVER OPENING.
2. STEEL TO CONFORM TO ASTM A-36.
3. ALL SURFACES TO BE COATED WITH ZRC COLD GALVANIZING COMPOUND AFTER WELDING.

Figure K.2 Expanded Trash Rack Protection for Low Flow Orifice

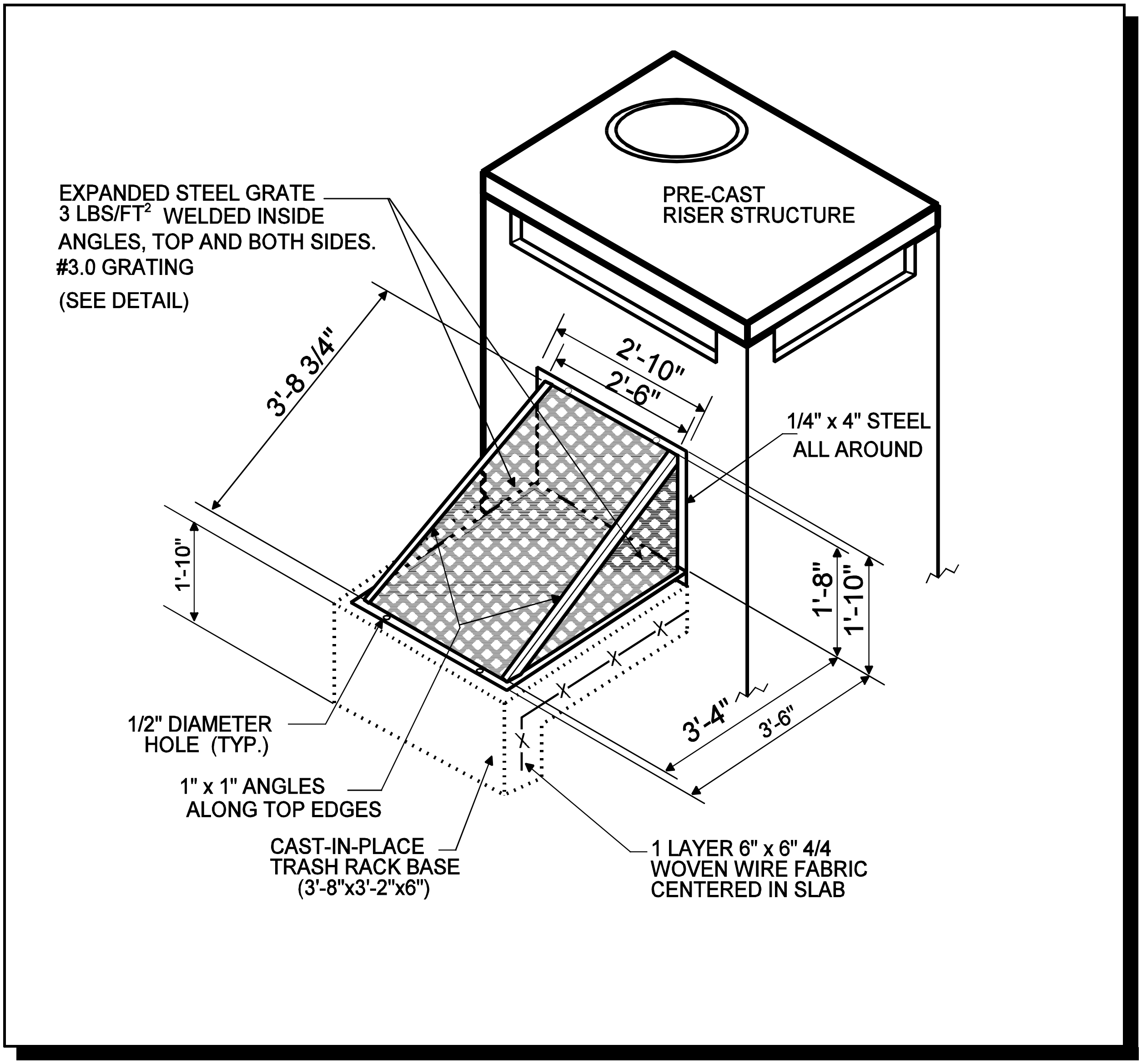


Figure K.3 Internal Control for Orifice Protection

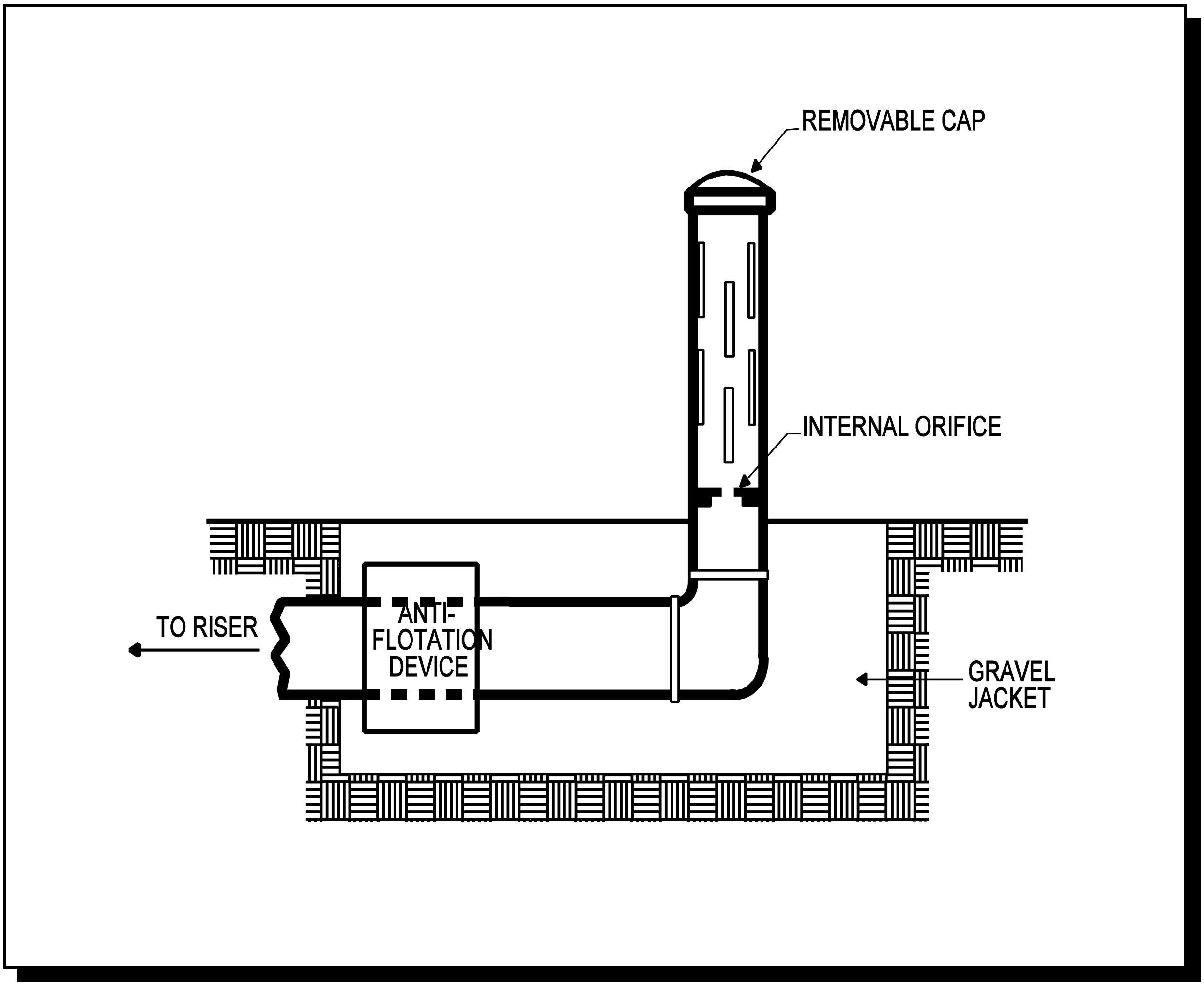
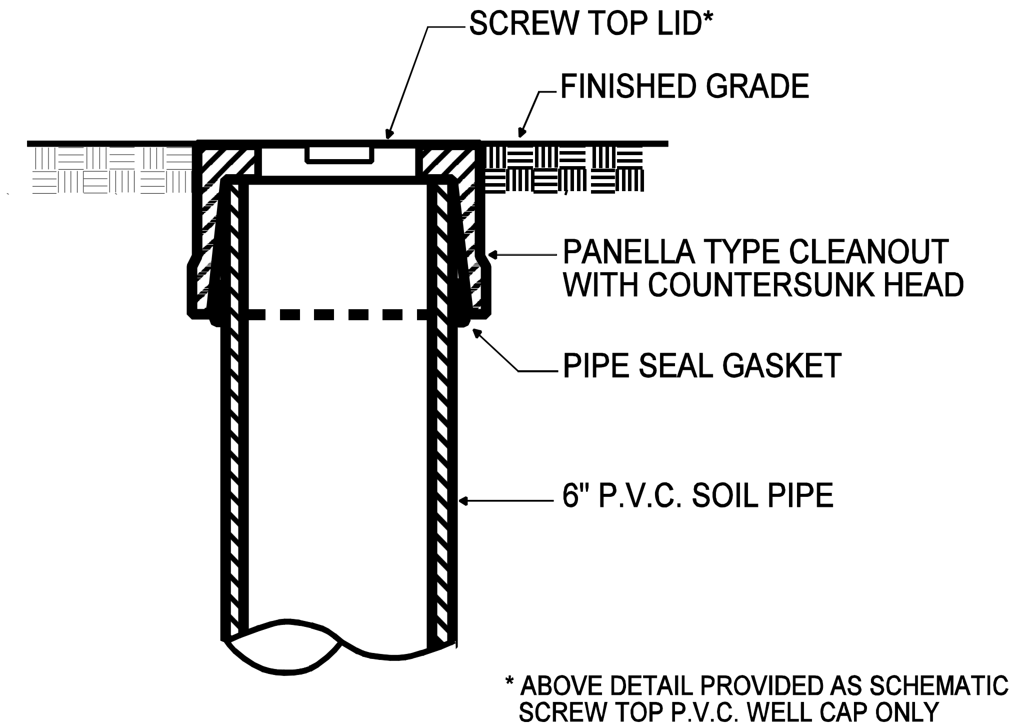


Figure K.4 Observation Well for Infiltration Practices



EACH OBSERVATION WELL / CLEANOUT SHALL INCLUDE THE FOLLOWING:

1. FOR AN UNDERGROUND FLUSH MOUNTED OBSERVATION WELL / CLEANOUT, PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST THREE FEET LONG WITH AN INSIDE DIAMETER OF AT LEAST 6 INCHES.

2. THE TUBE SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH OMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

Figure K.5 On-Line Versus Off-Line Schematic

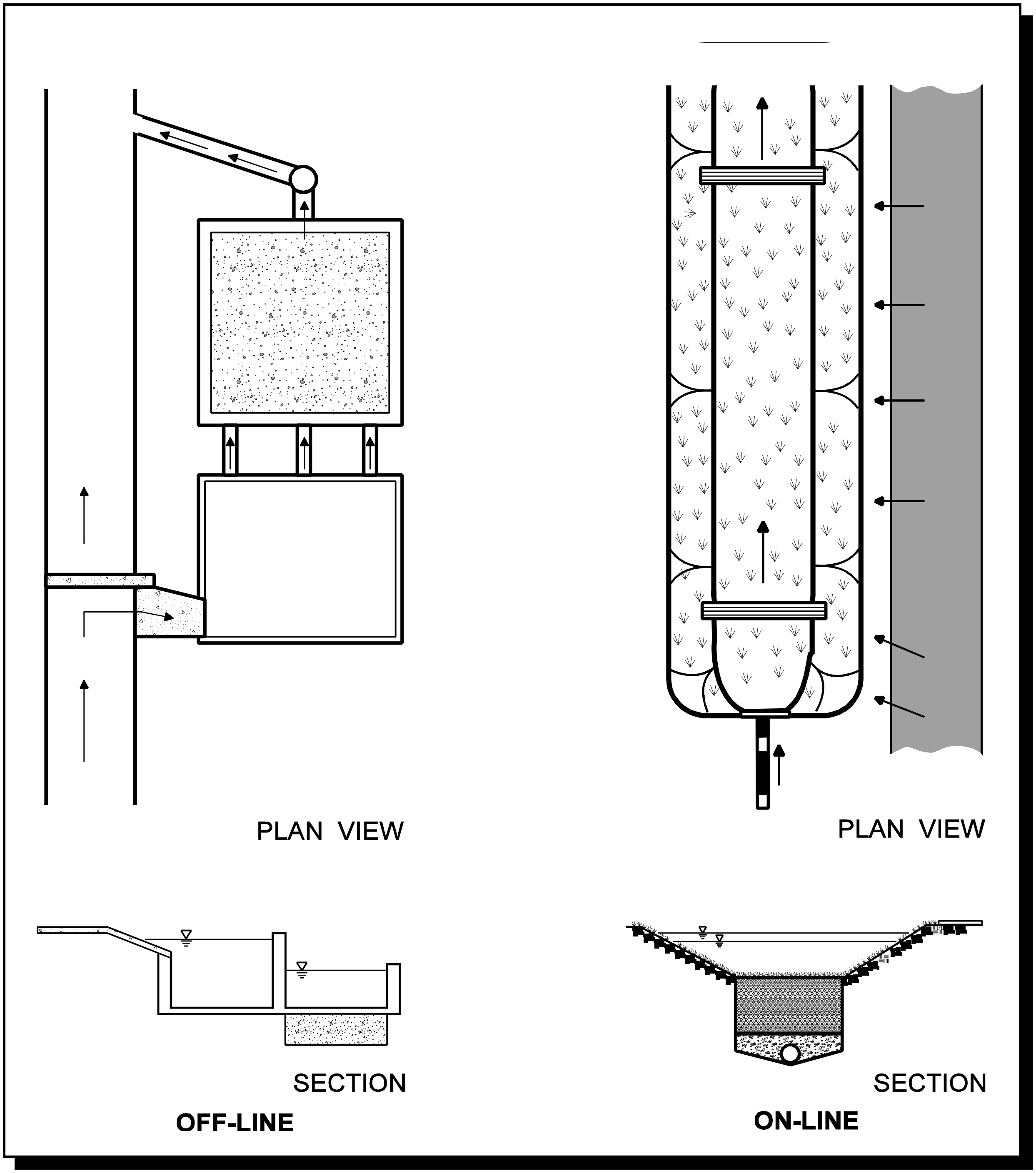


Figure K. 6 Isolation Diversion Structure

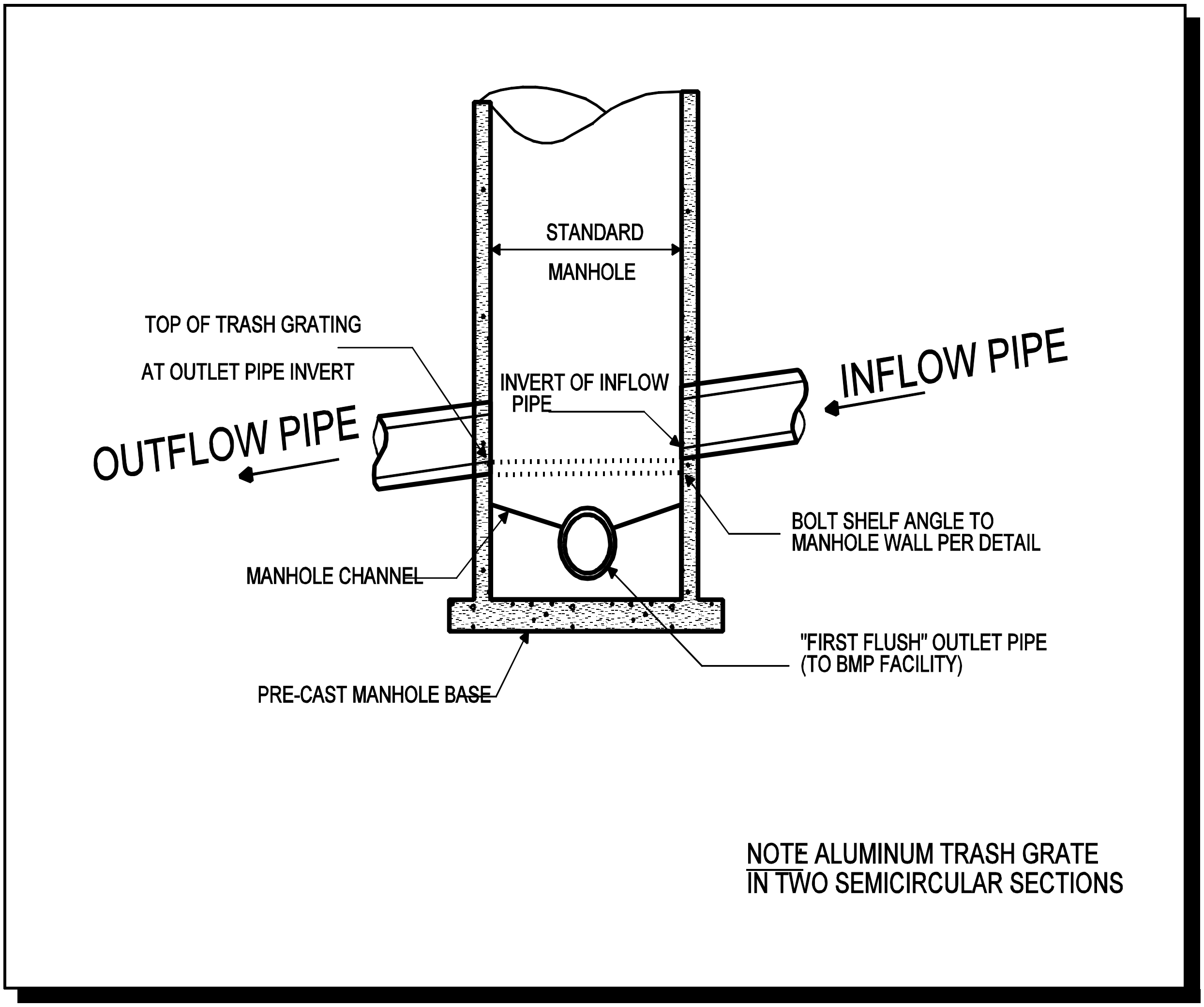


Figure K.7 Half Round CMP Hood

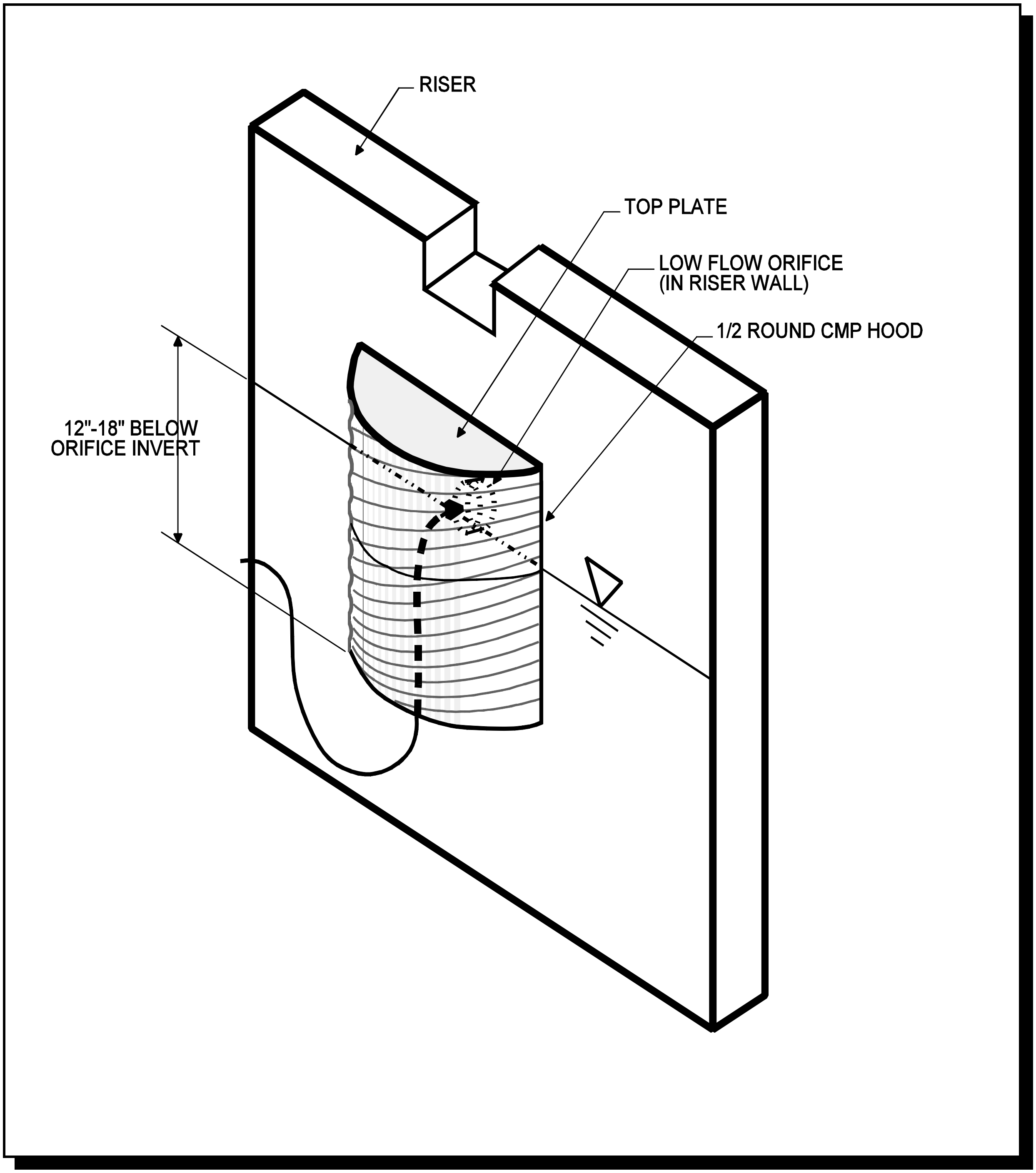


Figure K.8 Half Round CMP Weir

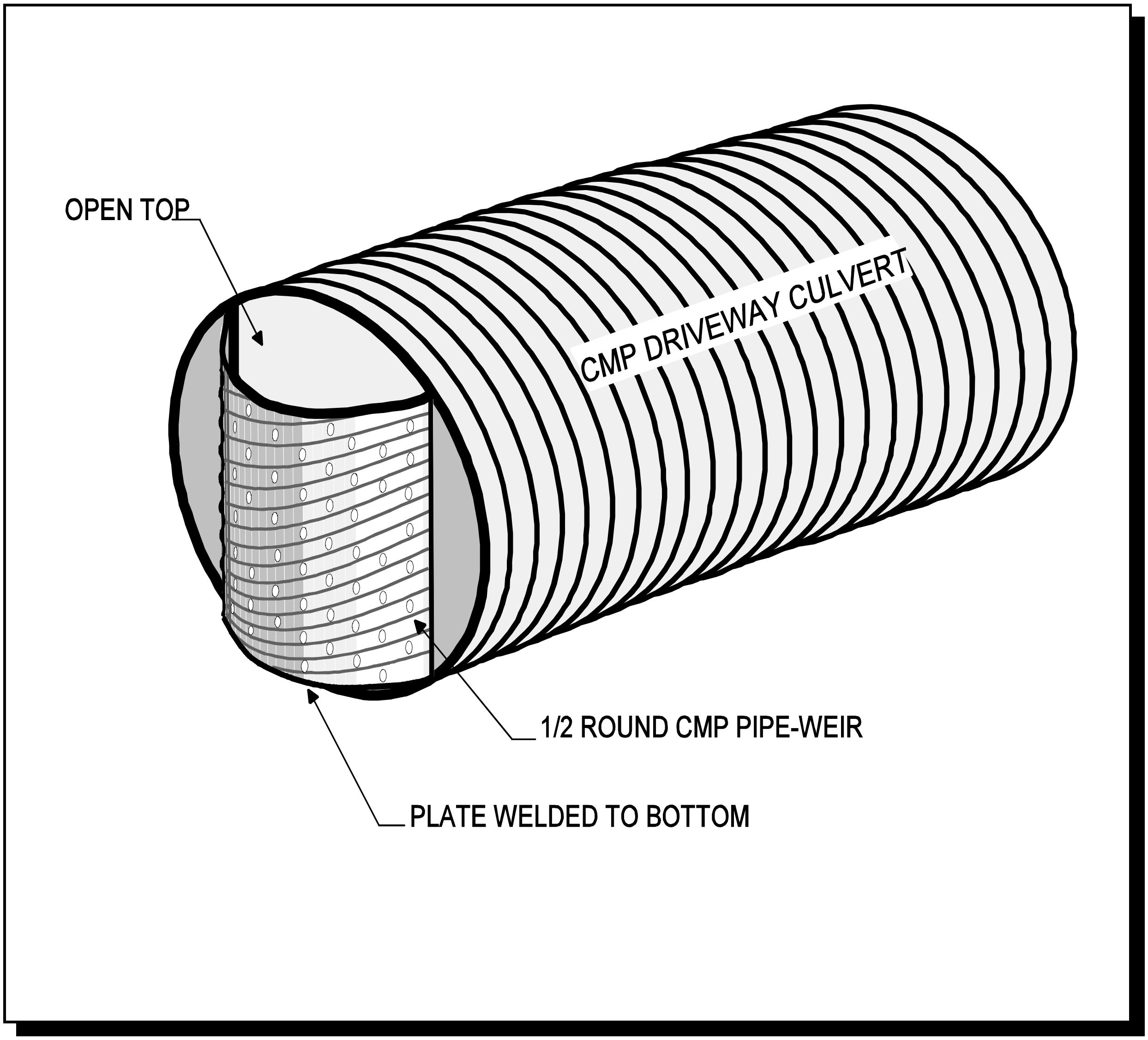


Figure K.9 Concrete Level Spreader

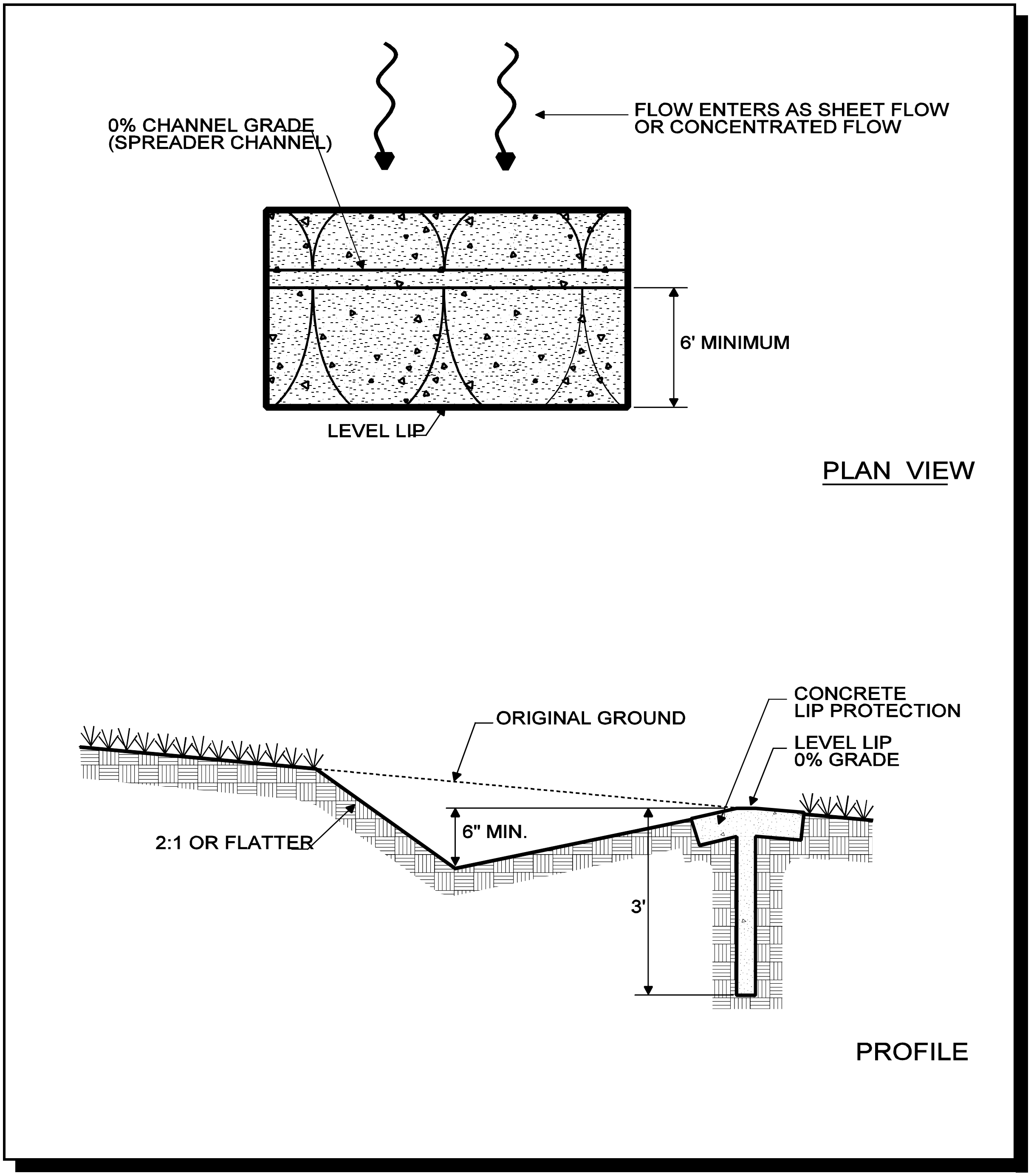


Figure K.10 Baffle Weir for Cold Climates

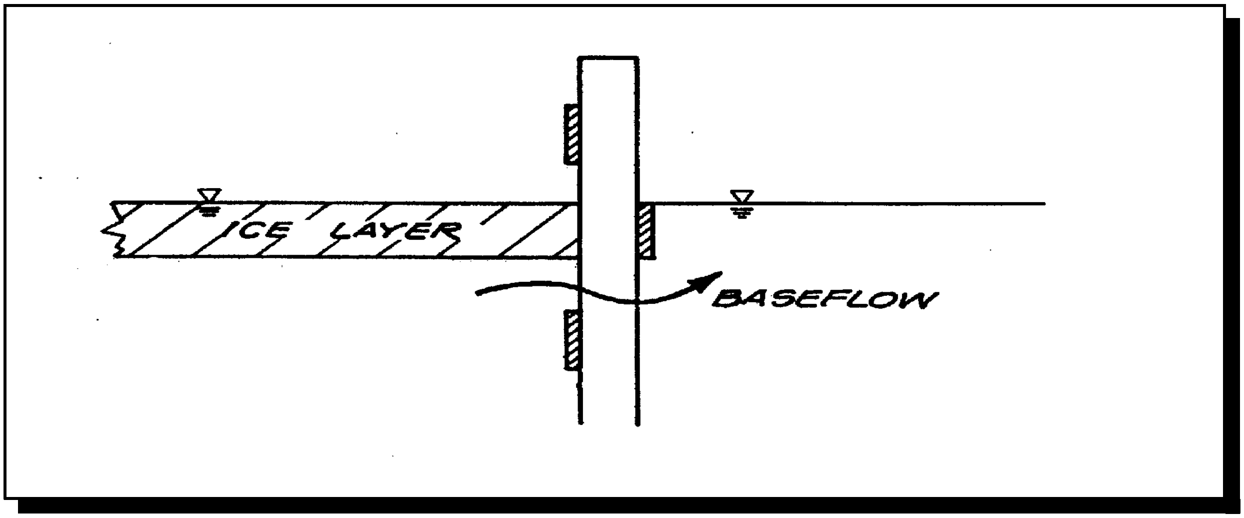


Figure K.11 Hooded Outlet with Hood Below Ice Layer

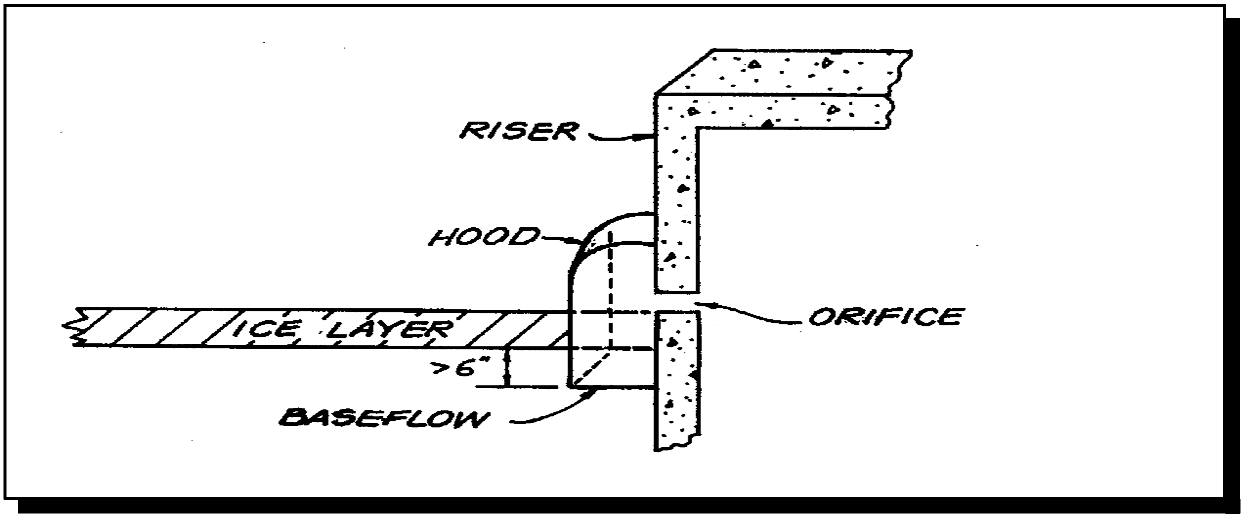
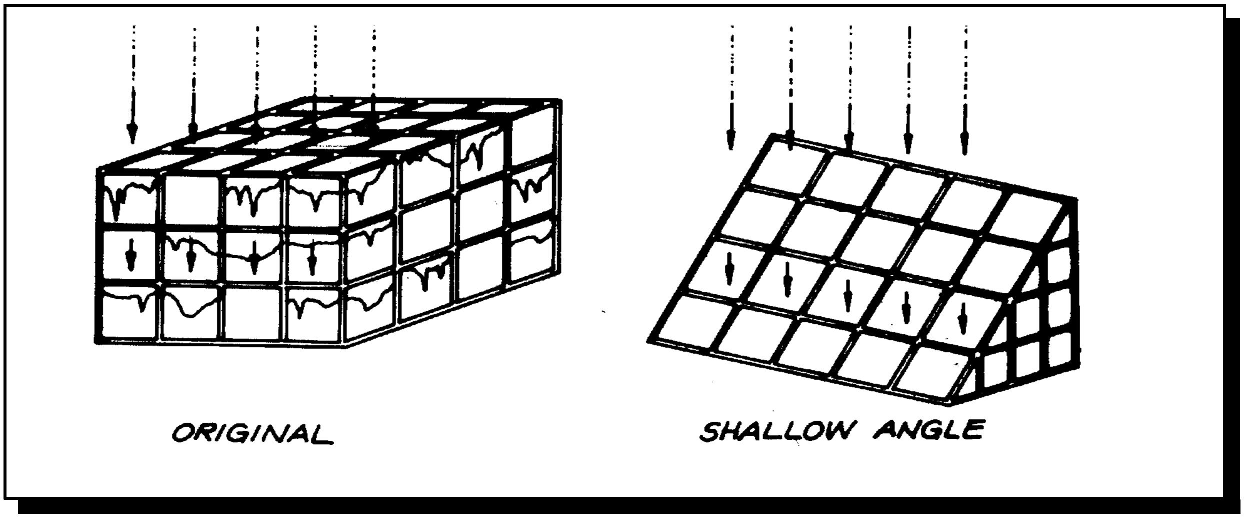


Figure K.12 Shallow Angle Trash Rack to Prevent Icing



Appendix L

Velocity

Maximum permissible velocities of flow in vegetated channels absent of permanent turf reinforcement matting shall not exceed the values shown in the following table:

Table L.1 Permissible Velocities for Channels Lined with Vegetation

Channel Slope	Lining	Permissible Velocity[1] (ft/sec)
0-5%	Reed canarygrass Tall fescue Kentucky bluegrass	5
		4
	Grass-legume mixture	
	Red fescue Redtop Serices lespedeza Annual lespedeza Small grains	2.5
5-10%	Reed canarygrass Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater than 10%	Reed canarygrass Tall fescue Kentucky bluegrass	3

Source: Soil and Water Conservation Engineering, Schwab, *et al.*

For vegetated earth channels having permanent turf reinforcement matting, the permissible flow velocity shall not exceed 8 ft/sec. Turf reinforcement matting shall be a machine produced mat of nondegradable fibers or elements having a uniform thickness and distribution of weave throughout. Matting shall be installed per manufacturer's recommendations with appropriate fasteners as required. Examples of acceptable products include but are not limited to:

- North American Green "C350" or "P300"
- Greenstreak "PEC-MAT"
- Tensar "Erosion Mat"

1 For highly erodible soils, permissible velocities should be decreased 25%. An erodibility factor (K) greater than 0.35 would indicate a highly erodible soil. Erodibility factors (K-factors) can be obtained from local NRCS offices.

<u>Manning's n value</u>

The roughness coefficient, n, varies with the type of vegetative cover and flow depth. At very shallow depths, where the vegetation height is equal to or greater than the flow depth, the n value should be approximately 0.15. This value is appropriate for flow depths up to 4 inches typically. For higher flow rates and flow depths, the n value decreases to a minimum of 0.03 for grass channels at a depth of approximately 12 inches. The n value must be adjusted for varying flow depths between 4" and 12" (see Figure L.1).

Figure L.1 Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)