COLUMBUS

City of Columbus, Indiana

Stormwater Design Manual

Effective July 1st 2008

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It was adopted by the Board of Public Works and Safety this 24th Day of June 2008.

Fred L. Armstrong, Mayor	6-24-08 Date
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DLZ

TABLE OF CONTENTS

1.0 INTRODUCTION

The City of Columbus Stormwater Design Manual sets forth minimum standards for development activities, which require a permit. The City of Columbus finds that:

1. Land development alters the hydrologic response of watersheds and can result in increased stormwater runoff rates and volumes, flooding, stream channel erosion, and sediment transport and deposition;

2. Stormwater runoff produced after land development can contribute to increased quantities of water-borne pollutants;

3. Increased runoff rates and volumes of stormwater runoff and the sediments and pollutants associated with stormwater runoff from development projects with the City of Columbus may, absent of reasonable regulation and control, adversely affect the City of Columbus's water bodies and water resources, and those of downstream municipalities;

4. Stormwater runoff, soil erosion, and nonpoint source pollution can be controlled and minimized by the regulation of stormwater runoff from development;

5. Adopting the standards, criteria and procedures contained in the Stormwater Design Manual and implementing the same will address many of the deleterious effects of stormwater runoff;

6. Adopting these standards is beneficial for the preservation of the public health, safety and welfare.

The purpose of this Design Manual is to present recommended design and review procedures and guidelines for use in complying with the City's requirements. The Stormwater Design Manual establishes minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public. The Stormwater Design Manual seeks to accomplish, among others, the following objectives:

1. To reduce flood damage;

2. To minimize increased stormwater runoff rates and volumes from identified new land development;

3. To minimize the deterioration of existing watercourses, culverts and bridges, and other structures associated with stormwater conveyance;

4. To encourage water recharge into the ground where geologically favorable conditions exist;

5. To prevent an increase in nonpoint source pollution;

6. To maintain the integrity of stream channels for biological and drainage functions as well as aesthetics and other purposes;

7. To minimize the impact of development upon stream bank and streambed stability;

8. To reduce erosion from development or construction projects;

9. To preserve and protect water supply facilities and water resources by means of controlling increased flood discharges, stream erosion, and runoff pollution;

10. To reduce stormwater runoff rates and volumes, soil erosion, and nonpoint source pollution, wherever practicable, from lands that were developed without stormwater management controls meeting the purposes and standards of the Stormwater Management Ordinance as well as future developments; and,

11. To implement the minimum standards established in the Stormwater Management Ordinance to protect water bodies from degradation resulting from land use where there are insufficient stormwater management controls.

Definitions, formulas, criteria procedures and data are presented here in the Stormwater Design Manual to provide guidance to developers and consultants in project planning and design, and to City enforcement staff in permit application and plan review. The intended use of the Manual is a guidance document to assist in achieving compliance with the Stormwater Management Ordinance.

The Stormwater Design Manual presents minimum design requirements. When unusual or complex problems are encountered during the design process, it is the responsibility of the designer to identify such conditions and notify the City Engineer. In such cases, the designer shall propose an alternative higher standard, criteria, solution or methodology consistent with good planning and engineering practice and shall receive approval of the change prior to finalizing the design. Use of this Manual or the issuance of a permit does not release the designer of the design responsibility.

This Manual includes a list of acceptable Stormwater Quality Practices (SQP's), including the specific design criteria for each stormwater practice. The Manual may be updated and expanded from time to time, at the discretion of the local review authority, based on improvements in engineering, science, monitoring, and local maintenance experience. It is the responsibility of the designer to use the most current Manual (http://www.columbus.in.gov/engineers-index.html). SQP's that are designed and constructed in accordance with these design and sizing criteria will be presumed to meet the minimum water quality performance standards.

The material contained here is intended to provide guidance to engineers and designers in developing solutions to stormwater management problems. This Guide is not intended to specify limitations on the creative design process. Within the requirements of the City of Columbus Stormwater Management Ordinance and this Stormwater Design Manual, a designer has flexibility in developing solutions. In the event of a disagreement between this Manual and the Stormwater Quantity and Quality Management Ordinance, the Stormwater Management Ordinance shall govern. In the event of disagreement with other requirements such as county or state regulations, the more stringent shall apply.

2.0 DEFINITIONS

Accelerated Erosion: The erosion caused by development activities that exceeds the natural processes by which the land is worn away by the action of water, wind or chemical action.

ACOE: The Army Corps of Engineers

Base Flood: The flooding having a one percent probability of being equaled or exceeded in a given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE): The height of the base floods of 100-year flood in relation to the National Geodetic Vertical Datum (NGVD) of 1929.

BMP: Best Management Practices can refer to structural measures (ponds, swales, etc.) and non-structural measures (restrictive zoning, reduced impervious area, etc.) utilized for the benefit of water quality and, as appropriate, to reduce the stormwater runoff rate. A subset of BMPs is stormwater quality units (SQUs). These are engineered systems or practices designed to improve stormwater quality. Each unit is either singularly or is a combination of systems / practices used to achieve a water quality goal at an outfall or release point. For the purposes of this technical guide, SQUs refer to structural water quality SQUs that comply with this Manual.

BMP / SQU Owner: The owner of the BMP / SQU, typically the property owner. The BMP / SQU owner may also be the lessee of the property in the case of a long-term lease. The lessee is considered the BMP / SQU owner only if the lease specifically states that construction by the lessee must meet applicable local codes and regulations.

Board: The City of Columbus Board of Public Works and Safety

Building: An enclosed structure constructed or erected partially or wholly above ground. The term "building" includes both the above ground and below ground portions of the structure.

Certify: A statement that a proposed development meets the requirements of the Stormwater Management Ordinance.

Channel: A natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically the flow of water.

Clean Water Act: The Federal Water Pollution Control Act, 33 USC Sec 1251 et seq., as amended, and the applicable regulations promulgated there under.

CLOMR: A Conditional Letter of Map Revision. A letter that indicates that FEMA will revise base flood elevations, flood insurance rate zones, flood boundaries, or floodways as shown on an effective FIRM or FBFM, after the as-built or record drawings confirming the proposed conditions are submitted and approved.

CLOMR-F: A Conditional Letter of Map Revision Based on Fill. This letter indicates that FEMA will revise the base flood boundaries as shown on an effective FIRM. This letter does not apply to map revisions involving BFE or floodway delineation changes.

Conveyance: Any pipe, swale, ditch, etc. intended to carry stormwater from one point to another.

Culvert: A closed conduit such as a pipe designed for the conveyance of surface drainage water under a roadway, railroad, embankment or other impediment.

Detention: The temporary storage of storm runoff in a stormwater management practice with the goals of controlling peak discharge rates and / or providing gravity settling of pollutants.

Detention Facility: A manmade structure for the temporary storage of stormwater runoff with a controlled release during or immediately following a storm.

Developed or Development: A land alteration that requires, pursuant to state law or local ordinance, the approval of a site plan, plat, special land use, planned unit development, rezoning of land, land division approval, private road approval or other approvals required for the construction of land or the erection of buildings or structures; provided, however, that for purposes of this Guide only, developed or development shall not include the actual construction of, or an addition, extension or modification to, an individual single-family or a two-family detached dwelling.

Developer: A person who undertakes land disturbing activities as result of development.

Development Site: Any land that is being or has been developed, or that a developer proposes for development.

Ditch: An earthen conveyance with side slopes steeper than 5:1 or carrying stormwater at a rate greater than 10 cubic feet per second.

Drainage: The collection, conveyance, or discharge of ground water and/or surface water.

Drainage Easement: The legal right granted by a landowner to a grantee allowing the use of private land for stormwater management purposes and granting ingress and egress for the purpose of viewing the condition of the stormwater management facility and maintaining the same if necessary in an emergency situation.

Drainage and Stormwater Management Facilities: All ditches, channels, conduits, retention-detention systems, tiles, swales, sewers, SQUs and other natural or artificial means of draining and treating stormwater runoff from land.

Drainage Facility: All ditches, channels, conduits, levees, ponds, natural and manmade impoundments, tile, swales, sewers, and other natural or artificial means of draining surface and subsurface water from land.

Drainage and Stormwater Management Requirements: Includes the following:

1. Commitments relating to drainage made pursuant to Chapter 185 of the Indiana Acts of 1973.
2. Commitments relating to stormwater quality treatment made pursuant to 327 IAC 15-5 and 327 IAC 15-13.
3. This Stormwater Design Manual

Engineer: The City Engineer of the City of Columbus and any subordinate employee to whom he shall specifically delegate a responsibility authorized by the Stormwater Management Ordinance.

EPA: Environmental Protection Agency

Erosion: The process by which the ground surface is worn away by action of wind, water, gravity or a combination thereof.

Erosion and Sediment Control Plan: A plan that is designed to minimize the accelerated erosion and sediment runoff at a site during construction activities and fulfills the requirements of 327 IAC 15-5 and 327 IAC 15-13.

FBFM: A Flood Boundary and Floodway Map. A floodplain management map issued by FEMA that depicts, based on detailed engineering analyses, the boundaries of the base or 100-year flood, the 500-year flood, and the floodway.

FEMA: The Federal Emergency Management Agency.

FIRM: A Flood Insurance Rate Map. A map issued by FEMA that is an official community map, on which FEMA has delineated both the special flood hazard areas and the insurance risk premium zones applicable to the community. This map may or may not include floodways.

Flood or Flooding: A general and temporary condition of partial or complete inundation of normally dry land areas resulting from the overflow of water bodies or the unusual and rapid accumulation or runoff of surface waters from any source.

Floodplain: The area adjacent to and including a body of water with ground surface elevations at or below a specified flood elevation. Generally, for the Stormwater Management Ordinance this refers to the area inundated by the base or 100-year flood.

Floodway: The channel and that portion of the floodplain adjacent to a stream or watercourse that is reserved to convey the base flood flow as indicated on the FIRM.

IDEM: The Indiana Department of Environmental Management.

Impacted Drainage Areas: Areas defined and mapped by the Board, which are unlikely to be easily drained because of one or more factors such as topography, soil type or distance from adequate drainage and stormwater management facilities.

Impervious Cover: Those surfaces that do not allow stormwater runoff to percolate into the ground such as asphalt, concrete, roofs, and compacted stone aggregate.

Infiltration: The process of percolating stormwater into the subsoil.

Infiltration Facility: Any structure or device designed to infiltrate retained water to the subsurface. These structures may be above or below grade.

Landowner: The legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.

Land Alteration: Any action taken relative to land which either:

1. Removes the natural ground cover; or
2. Changes the contour; or
3. Changes the runoff rate and / or volume; or
4. Changes the elevation; or
5. Decreases the rate at which water is absorbed; or

6. Changes the drainage pattern; or

7. Creates or changes a drainage and stormwater management facility; or

8. Involves construction, enlargement or location of any building on a permanent foundation; or

9. Creates an impoundment.

Land alteration includes (by way of example and not of limitation) terracing, grading, excavating, constructing earthwork, draining, installing drainage tile, filling and paving.

Land Surveyor: A person licensed under the laws of the State of Indiana to practice land surveying.

LOMA: A Letter of Map Amendment. The official determination by FEMA that a specific structure or lot is not within a regulatory floodplain due to naturally high ground (i.e. without fill). A LOMA amends the effective FIRM.

LOMR: A Letter of Map Revision. This is a letter from FEMA that revises base flood elevations; flood insurance rate zones, flood boundaries, or floodways as shown on an effective FBFM or FIRM.

LOMR-F: A Letter of Map Revision Based on Fill. A letter that provides formal recognition by FEMA that either a parcel of property or a structure has been removed from the base or 100-year floodplain due to elevation based on the placement of fill. This letter does not apply to map revisions involving BFE or floodway delineation changes.

Maintenance: Cleaning, removing obstructions from and making minor repairs to a drainage and stormwater management facility so that it will perform the function for which it was designed and constructed.

Maintenance Plan: A drawn and written document that illustrates the procedures and processes necessary for long-term maintenance of a drainage and stormwater management facility or SQU.

NFIP: The National Flood Insurance Program. The requirements of the NFIP are codified in Title 44 of the Code of Federal Regulations.

Non-structural Stormwater Quality Practice (SQP): A SQP that is not constructed by physical means of land disturbance, such as education, public information handouts, street sweeping, etc.

Nonpoint Source Pollution: Pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.

NPDES: National Pollution Discharge Elimination System.

Off-line structure: SQUs that treat only the water quality volume (WQv) or water the water quality treatment rate (WQr). Flows exceeding the WQv or WQr bypass the structure and re-enter the watercourse below the SQU.

Off-Site Facility: A stormwater management measure located outside the subject property boundary described in the permit application for land development activity.

On-Site Facility: A stormwater management measure located within the subject property boundary described in the permit application for land development activity.

Pollutant: A substance which causes or contributes to pollution which includes, but is not limited to the following: any dredged spoil, solid waste, vehicle fluids, yard wastes, animal wastes, agricultural waste products, sediment, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological wastes, radioactive materials, heat, wrecked or discharged equipment, rock, sand, cellar dirt, and industrial, municipal, commercial and agricultural waste, or any other contaminant or other substance defined as a pollutant under the Clean Water Act.

Pollution: The alteration of the quality of waters by introduction of a material to a degree which unreasonably affects, or has the potential to unreasonably affect, either the waters for beneficial uses or the facilities which serve these beneficial uses.

Professional Engineer: A person licensed under the laws of the State of Indiana to practice engineering.

Proprietary System: A structural BMP designed for stormwater quality treatment and/or quantity control constructed of a combination of manmade materials at an off-site facility.

Record Drawings: Drawings prepared, signed and sealed by a professional engineer or land surveyor representing the final "as-built" record of the actual in-place elevations, location of structures, and topography.

Redevelopment: Any construction, alteration or improvement where existing land use is high density commercial, industrial, institutional or multi-family residential.

Regulated Drain: A drain, either open channel or closed tile/sewer, subject to the provisions of the Indiana Drainage Code, I.C.-36-9-27.

Retention Facility: A facility designed to completely retain a specified amount of stormwater runoff without release except by means of evaporation or infiltration.

Runoff: The waters derived from melting snow or rain falling within a tributary drainage basin that exceeds the infiltration capacity of the soils of that basin.

Storm Drain / Sewer: A system of open or enclosed conduits and appurtenant structures intended to convey or manage stormwater runoff, ground water, and drainage.

Stormwater: Any surface flow, runoff, and drainage consisting entirely of water from rainstorm events.

Stormwater Management: The use of structural or non-structural practices that are designed to reduce stormwater runoff, pollutant loads, discharge volumes, and/or peak flow discharge rates.

Stormwater Runoff: The runoff and drainage of precipitation resulting from rainfall or snowmelt or other natural events or processes.

Stormwater Treatment: The implementation of measures designed to prevent or reduce point source or nonpoint source pollution inputs to stormwater runoff and water bodies.

Structural SQU: A structure designed and constructed for the purpose of stormwater quality treatment.

Swale: A depressed earthen conveyance designed to convey stormwater runoff with side slopes 5:1 or shallower and conveying no more than 10 cfs.

TSS: Total suspended solids.

Water Body: A river, lake, stream, creek or other watercourse or wetlands.

Water Quality Rate (WQr): Minimum flow rate that must be treated to effectively treat the runoff from 90% of the runoff from a watershed annually.

Water Quality Volume (WQ_v): The storage needed to capture and treat the volume of rainfall for 90% of the storm events, which produce runoff in the watershed annually.

Watercourse: A permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

Watershed: The total drainage area contributing runoff to a single point.

Wetland: An area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

3.0 DRAINAGE AND STORMWATER MANAGEMENT PERMITS

All land alterations accomplished in the City of Columbus shall adhere to and be in compliance with the minimum drainage and stormwater management standards of the City of Columbus unless a variance from the minimum drainage and erosion control standards or regulations has been granted by the Board of Public Works.

A variance can be considered where standards of engineering practice cannot be substantially met. The following reasons shall be presented to the Board of Public Works:

1. The practice in this manual cannot be implemented because the site constrains make it physically impossible.
2. A variance must propose an alternative that meets or exceeds these standards.

Land alteration shall be carried out in conformity with all existing covenants, variance conditions, plat restrictions and building code standards of the City Code

3.1 Drainage and Stormwater Management Plans

A drainage and stormwater management plan fulfilling the requirements of the Stormwater Management Ordinance shall be submitted to the City Engineer for approval before a permit can be obtained for a proposed land alteration. The drainage and stormwater management plan shall be submitted in duplicate and shall contain complete, accurate and specific information regarding the proposed land alteration and impact upon adjacent properties. The following information shall demonstrate and describe surface and subsurface drainage and stormwater management strategy and shall accompany the drainage and stormwater management plan submitted for approval:

3.1.1 Construction Features

- Scale: Standard scale such 1" = 10', 20', 30', 50', 100', etc., as appropriate shall be used. Scale shall be indicated graphically on each sheet.

- North arrow on each sheet.

- Existing contours:

  A. 1-foot contour intervals for land slopes less than 10%.

  B. 2-foot contour intervals for land slopes equal to or greater that 10%, but less than 20%. NAVD

  C. 5-foot contour intervals for land slopes equal to or greater than 20%.

- Benchmarks (minimum 2) based on NGVD 29, which are easily accessible and re-locatable (a benchmark not based on these datum may be assumed for areas less that three acres in size).

- Location and vicinity map for the proposed land alteration.

- Existing and proposed drainage and stormwater management facilities, including storm drains, manholes, inlets, swales, ditches, natural or manmade drainage ways, stormwater outlets and Stormwater Quality Units (SQUs). The plans shall identify:

  A. Location of the drainage and stormwater management facility by planimetric distances, referenced from traverse lines, USGS section lines, property markers or road centerlines. In areas where such physical features are unavailable, the State of Indiana coordinate system or other acceptable horizontal and vertical datum may be used.

  B. Direction of flow.

  C. Elevation of storm drain and SQU inverts.

  C. Gradient of storm drain and SQU's.

  D. Size of storm drain and SQU's.

  E. Capacity of storm drain and SQU's.

  F. A sequence describing when each post construction stormwater quality treatment SQU will be installed.

  G Overland overflow route

- Plan (top portion) and profile (bottom portion) shall be shown on the same sheet. The plans shall include:

    D. Scale: Horizontal and vertical as appropriate.

    E. Right-of-way and easement limits.

    F. Sufficient information downstream to show effect of the drainage and management facility on the outfall channel.

    G. Existing grade above existing storm drains and pipes.

    H. Proposed grade above proposed storm drains and pipes.

    I. Profile of undisturbed earth for storm drains and BMP's constructed on fill.

    J. Buffer Zones

    K. Pipe size and material(s)

8. An Erosion Control Plan (ECP) pursuant to 327 IAC 15-5, which includes but is not limited to treatment controls, temporary and permanent seeding schedule, construction schedule, and maintenance schedule.

The above items are contained in the "Stormwater Management Plan Technical Review Checklist" found in Appendix 15 of this Manual.

3.1.2 Design Calculations / Report

Design calculations shall be provided in a separate report and are required as part of the drainage and stormwater management plan. These calculations shall be in accordance with engineering standards of good practice, the recommendations of the City Engineer and all regulations of the City. The design calculations / report shall specifically include:

- Natural Resources Assessment

    B. A site layout and narrative indicating the conservation and preservation of significant natural features.

- Estimation of stormwater runoff.

    A. Drainage area map with standard scale and the 100-year FEMA floodplain where applicable. The BFE must be provided on the plans if the scaled floodplain touches or crosses the project property.

    B. Weighted runoff coefficient and / or curve number computations.

    C. Time of concentration (Tc) computations.

- Closed conduit and open channel design computations.

  A. Size of pipe or channel cross-section.

  B. Pipe or channel invert.

  C. Roughness coefficients.

  D. Flow velocities (in feet per second).

  E. Design capacities (in cubic feet per second).

  F. Energy dissipation computations[1]

- Head loss computations in manholes and junction chambers.
- Hydraulic gradient computations.
- Gutter spread calculations / inlet grate capacity calculations
- Erosion control methods.
- Water Quality Volume (WQv) or water quality treatment rate (WQr) calculations.
- SQU computations.
- A drainage narrative describing the existing conditions and flow patterns, the proposed conditions and flow patterns, summarizing the pre- and post-developed runoff calculations, indicating if any off-site flow is entering the site, and discussing any special considerations / assumptions, etc.

The above items are contained in the "Stormwater Management Plan Technical Review Checklist" found in Appendix 15 of this Manual.

3.1.3 Operation and Maintenance Manual

An operations and maintenance (O&M) manual is required for each SQU as part of the drainage and stormwater maintenance plan. The O&M manual will include the following:

- SQU owner name, address, business phone number, home phone number, email address, cellular phone number, pager number;
- Site drawings (8 ½" by 11"), both plan and cross-section views, showing the SQU and applicable features, including dimensions, maintenance easements, outlet works, forebays, signage, connecting structures, weirs, invert elevations, etc.;
- Guidance on owner-required routine inspections;

[1] Energy Dissipater (Outlet Protection) page 121 Indiana Storm Water Quality Manual

- Requirement of owner to perform maintenance;

- Guidance on routine maintenance, including mowing, litter removal, woody growth removal, signage, etc.;

- Guidance on remedial maintenance; such as inlet replacement, outlet works maintenance, etc.;

- Guidance on sediment removal, both narrative and graphical, describing when sediment removal should occur in order to insure that the SQU remains effective as a water quality control device;

- A statement that the City's representatives have the right to enter the property to inspect or in an emergency and, at the owners cost, maintain the SQU;

- An inspection checklist

- A tabular schedule showing inspection and maintenance requirements; and

- Identification of the property / SQU owner as the party responsible for maintenance, including cost.

3.1.4 Additional Requirements

The City Engineer may request additional data and information to be included in the plans, specifications and design calculations in order to evaluate the adequacy of the proposed design plans. A registered professional engineer, land surveyor or architect, engaged in storm drainage and stormwater management design must sign a certificate of sufficiency of plan (Appendix 11) and a certificate of obligation to observe (Appendix 13).

3.2 Revised Plans

The applicant is expected to provide the City Engineer with detailed and accurate plans and specifications, which fully consider the site conditions. However, the City Engineer will consider deviations from approved plans if revisions reflect the City Engineer's review comments or are required due to field changes during construction, provided they are filed in duplicate, prior to the revised plan being implemented. If approved by the City Engineer, a copy of the revised plans and specifications shall be attached to the original permit and plans at the site.

3.3 Impacted Drainage Areas

Geographic areas, which are defined and mapped by the City Engineer and approved by the Board of Public Works as impacted drainage areas, are considered difficult to drain because of one or more factors such as topography, soil type or distance from an adequate drainage and stormwater management facilities. The City Engineer will evaluate the following, among others, in determining the impacted drainage areas.

- A floodway or floodplain designated in the Zoning Ordinance of the City of Columbus, Indiana;

- Land within 75 feet of each bank of any legal drain;

- Land within 50 feet of each bank of a natural drainage way, including a river, stream, gully, ditch or other definite natural watercourse;

- Land where there is not an adequate outlet, taking into consideration the capacity and depth of the outlet.

3.4 Covenants and Easements

The City Engineer may require the execution of covenants or easements to achieve satisfactory present and future drainage and stormwater management of a parcel for which a drainage and stormwater management permit is requested and the area surrounding that parcel.

As a minimum, the City Engineer shall require that the following covenant be executed by the owner or owners of such land which will be included in a recorded plat:

> "It shall be the responsibility of the owner of any lot or parcel of land within the area of this plat to comply at all times with the provisions of the drainage and stormwater management plan as approved for this plat by the Board of Public Works and Safety of the City of Columbus and the requirements of all permits for this plat issued by the City". (See Appendix 15)

The drainage and stormwater management plans submitted in support of a permit application shall provide sufficient detail to identify existing or proposed covenants or easements. Applicants are encouraged to identify the planimetric dimensions and location of these and to initiate contact with affected property owners prior to the submittal of the permit application.

Emergency access easements (easement) shall be provided for all stormwater conveyances and facilities to be maintained or inspected by the City of Columbus. In addition, easements shall be provided for all conveyances, including ponds, carrying or receiving runoff from off-site drainage basins and for any pond serving greater than 5 acres. Regulated Drains (proposed and existing) may have additional easement requirements to ensure the provisions of this Manual and the City Ordinances are met. The City Engineer shall be contacted to determine any special requirements prior to design. All stormwater conveyances must be centered within the required easement.

Stormwater quality units must be included in easements. Stormwater ponds shall maintain the same easement as required for a detention facility. Off-line manufactured BMP structures shall maintain an easement that includes the connecting manholes and the weir structure. All easements shall be clearly delineated and labeled on the plans. Water quality easements shall be included in the O&M manual as outlined in Section 3.1.3 of this Manual. On a case-by-case basis the Board may determine additional easements are required. The Board of Public Works may require additional easement requirements such as are necessary to ensure the provisions of the Stormwater Management Ordinance and this Stormwater Design Manual are met. The following table summarizes the easement widths required:

Table 3.1 Easement Requirements

Stormwater Facility Description	**Minimum Easement (ft)**
Detention Pond/Facility (Serving > 5.0 ac and / or all stormwater ponds used for stormwater quality)	20 horizontally from the 100-year elevation of the pond or maintenance road, whichever is more restrictive – Detention facilities shall not be constructed within the public right-of-way.
Storm sewer pipe and structures < 2 feet in diameter and < 6 feet to invert	15 feet (7.5 feet from centerline of pipe)
Storm sewer pipe and structures (> 2 feet in diameter and < 6 feet deep to invert)	20 (10' from center of pipe/structure)
Storm sewer pipe and structures (> 6 feet deep to invert)	25 (12.5' from center of pipe/structure)
Drainage Ditch	15 feet minimum from top of bank
Drainage Swale	10 feet minimum from top of bank
Structural and Manufactured SQU's	20 from the outside of SQU – Manufactured SQUs must maintain 20 from the center of the unit or 10 from the outside of the unit (whichever is greater) and include the connecting manholes when in an off-line configuration

4.0 PERFORMANCE CRITERIA FOR DRAINAGE FACILTIES

A drainage and stormwater management facility for a parcel shall be provided which allows drainage and treatment of stormwater runoff from each portion of the parcel as well as the upstream area, which drains through the parcel or treatment unit. The drainage and stormwater management facility shall:

- Accommodate the stormwater runoff for the required rainfall event or greater without endangering public safety and health or causing significant damage to the property;
- Be designed to treat the Water Quality Volume (WQ_v) or the water quality treatment rate (WQr) as appropriate.
- Be durable;
- Be easily maintained;
- Be safe to persons;
- Minimize off-site sedimentation to the maximum extent practicable; and
- Minimize erosion to the maximum extent practicable.

Additionally, the drainage and stormwater management facility should be designed to operate in accordance with the provisions of the Stormwater Management Ordinance.

4.1 Runoff Within the Parcel

Runoff quantities shall be computed for the area of the parcel under development plus the area of the watershed flowing into the parcel under existing or future development conditions. At least one waterway opening shall be provided for each existing watershed at the upstream edge of the parcel to accept upstream drainage.

Reasonable future development for the area upstream of the parcel should be considered. The nature of future development shall be that projected by the Comprehensive Land Use Plan for the City of Columbus adopted by the Plan Commission or that allowed by current zoning districts, whichever reflects the more intense use. The amount of runoff not accommodated in connection with such future development shall be determined by good engineering practice and may assume use of retention-detention systems except for:

- Land alteration not requiring a permit; and
- Parcels too small for a retention-detention facility; and
- Parcels where it is technically unfeasible to use a retention-detention facility; and
- Parcels where the cost of a retention-detention facility is substantially higher than the cost of providing for increase runoff capacity through the parcel.

Improvements such as retention-detention facilities may be included when the conditions of the land makes use of such improvements feasible and appropriate.

4.1.1 Calculations of Runoff

The quantity of runoff which is generated as the result of a given rainfall intensity may be calculated as follows:

For areas up to and including five (5) acres, the Rational Method may be used. In the Rational Method, the peak rate of runoff, Q, in cubic feet per second is computed as:

$$Q=CiA$$

where:

C = runoff coefficient, representing the characteristics of the drainage area and defined as the ratio of runoff to rainfall.
i = average intensity of rainfall in inches per hour for a duration equal to the time of concentration (T_c) for a selected rainfall frequency.
A = tributary drainage area in acres.

Tables 4.1 and 4.2 provide guidance in selecting the runoff coefficient “C”. Various “C” values are provided for different types of surface and local soil characteristics. The composite “C” value used for a given drainage area with various surface types should be the weighted average value for the total area calculated from a breakdown of individual areas having different surface types. Table 4.3 provides runoff coefficients for different land use classifications. In the instance of undeveloped land situated in an upstream area, a coefficient or coefficients should be used for this area in its present or existing state of development.

Rainfall intensity should be determined from the data shown in Table 4.4. The time of concentration (T_c) to be used should be the sum of the inlet time and flow time in the drainage facility from the most remote part of the drainage area to the point under consideration. The flow time in the storm sewers may be estimated by the distance in feet divided by velocity of full flow in feet per second. The Manning Equation should determine the velocity. All times-of-concentration calculations shall be done using the methodology outlined in NRCS TR-55.

Inlet time is the combined time required for the runoff to reach the inlet of the storm sewer. It includes overland flow time and flow time through established surface drainage channels such as swales, ditches and sheet flow across such areas as lawns, fields, and other graded surfaces.

The runoff rate for areas in excess of five (5) acres should be determined by SCS (NRCS) hydrograph methods.

Table 4.1 Urban Runoff Coefficients

Type of Surface	Runoff Coefficient "C"
Asphalt	0.82
Concrete	0.85
Roof	0.85
Gravel	0.82
Lawns (Sandy)	
Flat (0-2% Slope)	0.07
Rolling (2-7% Slope)	0.12
Steep (>7% Slope)	0.17
Lawns (Clay)	
Flat (0-2% Slope)	0.16
Rolling (2-7% Slope)	0.21
Steep (>7% Slope)	0.30

Table 4.2 Rural Runoff Coefficients

Type of Surface	Runoff Coefficient "C"
Woodland (Sandy)	
Flat (0-5% Slope)	0.10
Rolling (5-10% Slope)	0.25
Steep (> 10% Slope)	0.30
Woodland (Clay)	
Flat (0-5% Slope)	0.30
Rolling (5-10% Slope)	0.35
Steep (> 10% Slope)	0.50
Pasture (Sandy)	
Flat (0-5% Slope)	0.10
Rolling (5-10% Slope)	0.16
Steep (> 10% Slope)	0.22
Pasture (Clay)	
Flat (0-5% Slope)	0.30
Rolling (5-10% Slope)	0.36
Steep (> 10% Slope)	0.42
Cultivated (Sandy)	
Flat (0-5% Slope)	0.30
Rolling (5-10% Slope)	0.40
Steep (> 10% Slope)	0.52
Cultivated (Clay)	
Flat (0-5% Slope)	0.50
Rolling (5-10% Slope)	0.60
Steep (> 10% Slope)	0.72

Table 4.3 Runoff Coefficients by Land Use

Land Use	Runoff Coefficients "C"		
	Flat (1)	Rolling (2)	Steep (3)
Commercial (CBD)	0.75	0.83	0.91
Commercial (Neighborhood)	0.54	0.60	0.66
Industrial	0.63	0.70	0.77
Garden Apartments	0.54	0.60	0.66
Churches	0.54	0.60	0.66
Schools	0.31	0.35	0.39
Semi-Detached Residential	0.45	0.50	0.55
Detached Residential	0.40	0.45	0.50
Quarter Acre Lots	0.36	0.40	0.44
Half Acres Lots	0.31	0.35	0.39
Parkland	0.18	0.20	0.22

1. Flat terrain - 0-2% slopes
2. Rolling terrain – 2-7% slopes.
3. Steep terrain - - > 7% slopes

Table 4.4 Rainfall Intensities for Various Return Period and Storm Durations[2]

Duration	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
5 Min	4.20	5.28	6.12	7.44	8.52	9.84
10 Min	3.66	4.56	5.34	6.48	7.50	8.64
15 Min	3.16	3.92	4.60	5.56	6.44	7.40
20 Min	2.67[3]	3.30	3.87	4.68	5.43	6.24
30 Min	2.16	2.70	3.14	3.82	4.40	5.06
40 Min	1.77	2.21	2.57	3.12	3.60	4.14
50 Min	1.52	1.91	2.22	2.71	3.12	3.58
1 Hr	1.37	1.71	2.00	2.43	2.80	3.21
2 Hr	0.85	1.06	1.23	1.50	1.73	1.99
3 Hr	0.62	0.78	0.91	1.10	1.27	1.46
6 hr	0.37	0.46	0.53	0.65	0.74	0.86
12 hr	0.21	0.26	0.31	0.37	0.43	0.50
24 hr	0.12	0.15	0.18	0.22	0.25	0.29

4.1.2 Amount of Runoff to be Accommodated by Various Parts of the Drainage and Stormwater Management Facility

Various parts of a drainage and stormwater management facility should accommodate stormwater runoff as follows:

- The minor drainage and stormwater management system such as inlets, catch basins, street gutter, swales, sewers and small channels, which collect stormwater, should convey peak runoff from a 10-year return period storm with the free surface (hydraulic gradeline

[2] The above information is taken directly from Bulletin 71 "Rainfall Frequency Atlas of the Midwest" (by Floyd A. Huff and James R. Angel) funded by a grant from the Midwestern Climate Center (MCC).
[3] Areas shaded in gray are linear interpolations from the above-mentioned Bulletin 71.

or HGL) below the crown of the pipe at or below the top of bank. Rainfall duration should be equal to the time of concentration for the rational method. The appropriate Huff rainfall distribution should be used to determine the peak runoff for hydrograph / computer modeling methods. These minimum requirements should be satisfied:

A. The allowable spread of water on collector streets is limited to maintaining two clear 10-foot moving lanes of traffic. One 10-foot lane is to be maintained for local roads.

B. Open channels carrying peak flows greater than 30 cubic feet per second should be capable of conveying peak runoff for a 50-year return period storm within the drainage easement.

C. Culverts should be capable of conveying peak runoff from a 50-year return period storm when crossing under a road that is part of the Indiana Department of Transportation functional classification system and are classified as arterial or collector roads. Culverts under local roads which provide the only method of ingress / egress to a development should convey the 100-year storm without inundating the roadway.

- Major drainage and stormwater management systems are those carrying runoff from an area of one or more square miles, and should be designed in accordance with Indiana Department of Natural Resources Standards.

4.1.3 Water Quality Volume/Rate Calculations

In order to protect and maintain water quality, a portion of the stormwater runoff created by the development project must be treated. SQUs may be designed to treat on a volumetric basis or flow rate basis. Water quality volume or rate should be determined in accordance with Section 6.0 of this Manual

4.2 Runoff Downstream of the Parcel

The drainage and stormwater management facility within the parcel shall be designed with detention as required by the Stormwater Management Ordinance and such that there will be no increase in peak discharge, pollutant loads, or runoff rates as a result of the development. The downstream facilities must be sufficient to accept:

- The post development runoff from the parcel; plus
- The present runoff from developed areas upstream; plus
- The present runoff from undeveloped areas upstream; plus
- The present runoff from those areas through which the drainage and stormwater management facility passes.

Where downstream facilities are determined to be less than adequate to accommodate the proposed runoff from both the upstream and the proposed development areas, additional the City Engineer may require restrictions on the release rate above those required by the Stormwater Management Ordinance.

4.3 Storm Sewer Design Criteria

All storm sewers, whether private or public, and whether constructed on private or public property should conform to the design standards and other requirements contained herein. The minor drainage and stormwater management system such as inlets, catch basins and sewers which collect stormwater, should convey peak runoff from a 10-year return period storm with the free surface (hydraulic gradeline or HGL) below the crown of the pipe. Rainfall duration should be equal to the time of concentration for the rational method. The appropriate Huff rainfall distribution should be used to determine the peak runoff for hydrograph / computer modeling methods. .

4.3.1 Manning's Equation

The hydraulic capacity of storm sewers should be determined using the Manning's Equation:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

V = mean velocity of flow in feet per second

R = the hydraulic radius in feet

S = the slope of the energy grade line in feet per foot

n = Manning's roughness coefficient

Typical "n" values and desirable velocities for storm sewer materials are listed in Table 4.5.

4.3.2 Minimum Size

The minimum size of all storm sewers shall be 12 inches. An orifice plate or other devices, subject to approval of the City Engineer where the 12-inch pipe will not limit the rate or release as required, should control the rate of release for detention storage.

Table 4.5 Typical Values of Manning's "n"

Material	Manning's n	Desirable Maximum Velocities
Closed Conduits		
Concrete	0.013	15 f.p.s.
Vitrified Clay	0.013	15 f.p.s.
Brick	0.015	15 f.p.s.
Cast Iron	0.013	15 f.p.s.
Circular Corrugated Metal Pipe, Annular Corrugations – 2 2/3 x ½ in.		
Unpaved	0.024	7 f.p.s.
25% Paved	0.021	7 f.p.s
50% Paved	0.018	7 f.p.s
100% Paved	0.013	7 f.p.s
Circular Corrugated Metal Pipe, Helical – 2 2/3 x ½ in., Unpaved Corrugations		
12"	0.011	
18"	0.013	
24"	0.015	
36"	0.018	
48"	0.020	
60" or Larger	0.021	
Corrugated Polyethylene, Smooth Interior Pipe	0.012	15 f.p.s.
Concrete Culverts	0.013	
Open Channels		
Concrete, Trowel Finish	0.013	
Concrete, Broom or Float Finish	0.015	
Gunite	0.018	
Riprap Placed	0.030	
Riprap Dumped	0.035	
Gabion	0.028	
New Earth (Uniform, Sodded, Clay)	0.025	
Existing earth (Faintly Uniform, with some Weeds)	0.030	
Dense Growth of Weeds	0.040	
Dense Weeds and Brush	0.040	
Swale with Grass	0.035	

4.3.3 Grade

Sewer grade should be such that a minimum of two feet of cover is maintained over the top of the pipe. Pipe cover less than the minimum may be used only upon approval of the Engineer. Uniform slopes shall be maintained between inlets, manholes and inlets to manholes. Final grade should be set with full consideration of the capacity required, sedimentation problems and other design parameters. Minimum and maximum allowable slopes should be those capable of producing velocities of two and one-half (2.5) and 15 feet per second, minimum and maximum, respectively, when the sewer is flowing full.

4.3.4 Alignment

Storm sewers should be straight between manholes whenever possible. Smaller sewer diameters (less than 42 inch) shall require structures for turning. Where larger sewer long sweep radius curves are necessary to conform to street layout, the minimum radius of curvature should be no less than 100 feet for sewers 42 inches and larger in diameter. Deflection of pipe sections should not exceed the maximum deflection recommended by the pipe manufacturer. The deflection should be uniform and finished installation shall follow a smooth curve.

4.3.5 Manholes

Manholes should be installed to provide access to continuous underground storm sewers for the purpose of inspection and maintenance. Manholes should be provided at the following locations:

- Where two or more storm sewers converge.
- At the point of beginning or at the end of a curve, and at the point of reverse curvature (PC, PT, PRC).
- Where pipe size changes.
- Where a change in horizontal or vertical alignment occurs.
- Where a change occurs in grade (slope) of the pipe.
- At suitable intervals in straight sections of sewer.

The maximum distance between storm sewer manholes should be 300 feet unless the City Engineer grants special exception.

4.3.6 Inlets

Inlets or drainage structures shall be utilized to collect surface water through grated openings and convey it to storm sewers, channels or culverts. Inlet design and spacing shall be in accordance with the design procedure below. The inlet grate opening provided must be adequate to pass the design 10-year flow with 50% of the sag inlet areas clogged.

Inlets shall be spaced to limit the allowable spread of water on collector streets so that two clear 10-foot moving lanes of traffic are maintained. One 10-foot lane is to be maintained for local roads.

Inlet spacing shall be determined using the equation:

$$Q = \frac{0.56}{n} * S_x^{1.67} * S^{0.5} * T^{2.67}$$

where:

Q = discharge (cfs) (Including any carryover as appropriate).

S_x = cross slope of the pavement (ft/ft) (= 0.02, the typical street cross-slope).

T = top width of water from vertical face of gutter into roadway (ft).

S = longitudinal grade of street (ft/ft).

n = Manning's roughness coefficient (= 0.016 for street gutters).

Inlets shall be placed, at a minimum, where T equals the maximum allowable spread.

An overland flow route from sag inlets to an overflow channel or basin shall be provided at sag inlets, so that the maximum depth of water that might be ponded during extreme storm events (>10-year) in the street sag does not exceed 12 inches. All overflow channels shall direct the runoff to the detention facility. Overload storage basins shall be modeled using the 100-year storm to demonstrate the peak elevation will not flood adjoining structures. Alternatively, if an overload channel or storage basin is not feasible, the design engineer may submit hydraulic gradeline calculations showing the 100-yr storm hydraulic gradeline does not exceed the elevation of the casting.

4.4 Open Channel / Swale Design Criteria

All open channels and swales, whether private or public, and whether constructed on private or public land, should conform to the design standards and other design requirements contained herein. The minor drainage and stormwater management system such as swales and small channels, which collect stormwater, should convey peak runoff from a 10-year return period storm with the free surface (hydraulic gradeline or HGL) below the top of bank. Open channels carrying peak flows greater than 30 cubic feet per second should be capable of conveying peak runoff for a 50-year return period storm within the drainage easement.

4.4.1 Manning's Equation

The capacity of open channels / swales shall be determined using Manning's Equation.

$$Q = AV = A \frac{1.486}{n} R^{2/3} S^{1/2}$$

where:
- A = Waterway area of channel (sft)
- Q = Discharge in cubic feet per second (cfs)
- V, R, S & n are explained in Section 4.3.1

4.4.2 Cross-Section and Grade

The design capacity, the material in which the channel or swale is to be constructed, and the requirements for maintenance determine the required cross-section and grade. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. The grade should be such that the velocity in the channel or swale is high enough to prevent siltation but low enough to prevent erosion. Velocities less than 1.5 feet per second for the design storm event[4] should be avoided because siltation will take place and ultimately reduce the cross-section. The maximum permissible velocities in vegetated channels and swales are shown in Table 4.6.

4.4.3 Side Slopes

Earthen channel side slopes shall be no steeper than 3 (horizontal) to 1 (vertical). Flatter slopes may be required to prevent erosion and for ease of maintenance. Where channels will be lined, side slopes should be no steeper than 1.5 to 1 with adequate provisions made for weep holes.

Side slopes steeper than 1.5 to 1 may be used for lined channels provided that the side lining and structural retaining wall are designed and constructed with provisions for live and dead load surcharge.

4.4.4 Stability

- Characteristics of a stable channel / swale are:

  A. The banks do not erode to the extent that the cross-section is changed appreciably.

  B. Excessive sediment bars do not develop.

  C. Excessive erosion does not occur around culverts, bridges or elsewhere.

  D. Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

- Stability should be determined for an aged condition and the velocity should be based on the design flow or the bank full flow, whichever is greater, using “n” values for various channel linings as shown in Table 4.5. In no case is it necessary to check stability for discharges greater than that from a 100-year return period storm.

[4] The design storm event depends on the application for example detaining the 100 year storm post development and releasing at the 10 year pre development would require the engineer to limit velocities to that recommended above unless soil or other conditions override.

Table 4.6 Maximum Permissible Velocities in Vegetated Channels / Swales[5*]

Cover	Slope Range[2] (%)	Permissible Velocity[1]	
		Erosion Resistant Soils (fps)	Easily Eroded Soils (fps)[6]
Bermuda Grass	0-5 5-10 >10	8 7 8	6 5 4
Bahia Buffalo Grass Kentucky Bluegrass Smooth Brome Blue Grama	0-5 5-10 >10	7 6 5	5 4 3
Grass Mixture[7] Reed Canary Grass	[2]0-5 5-10	5 4	4 3
Lespediza Sericea Weeping Lovegrass Yellow Bluestem Redtop Alfalfa Red Fescue	[3]0-5 5-10	3.4	2.5
Common Lespedeza[4] Sundangrass	[5]0-5	3.5	2.5

1. Use velocities exceeding 5 feet per second (fps) only where good cover and proper maintenance can be obtained
2. Do not use on slopes steeper than 10 % except for vegetated side slopes in combination with stone, concrete, or highly resistant vegetative channel bottom.
3. Do not use on slopes steeper than 5% except for vegetated side slopes in combination with stone, concrete, or highly resistant vegetative channel bottom.
4. Annuals – use on mild slopes or as temporary protection until permanent covers are established.
5. Use on slopes steeper than 5% is not recommended

- Stability should be checked immediately after construction. For this stability analysis, the velocity should be calculated for the expected flow from a ten-year return period storm on the watershed, or the bank full flow, whichever is smaller. The "n" value for newly constructed channels and swales in fine-grained soils and sands may be determined in accordance with the National Engineering Handbook 5, Supplement B, Natural Resources Conservation Service and should not exceed 0.025. The allowable velocity in the newly constructed channel or swale may be increased by a maximum of 20 percent to reflect the effects of vegetation to be established under the following conditions:

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[5] From Natural Resources Conservation Service, NRCS-TP-61, Handbook of Channel Design for Soil and Water Conservation.
[6] See United States Geological Survey: Soil Survey Soil Description.
[7] See Chapter 7 of the Indiana Storm Water Quality Manual.

A. The soil and site in which the channel or swale is to be constructed are suitable for rapid establishment and support of erosion controlling vegetation.

B. The species of erosion controlling vegetation specified is acceptable for the area, and proven methods of establishment are shown.

C. The channel or swale design includes detailed plans for establishment of vegetation on the side slopes.

- The design of energy dissipaters shall be in conformance with the methods and procedures outlined in HEC-14, "Hydraulic Design of Energy Dissipaters for Culverts and Channels" as published by the Federal Highway Administration.

4.4.5 Drainage of Waterways

Vegetated waterways that are subject to low flows of long duration or where wet conditions prevail shall be drained with a tile system or by other means such as paved gutters. Tile lines may be outletted through a drop structure at the end of the waterway or through a standard tile outlet.

4.4.6 Appurtenant Structures

The design plans for channels/ swales will contain all structures required for the proper functioning of the channel or swale and associated drainage ways and account for operation and maintenance. Recessed inlets and structures needed for entry of surface and subsurface flow into channels or swales without significant erosion or degradation shall be included in the design of improvements. The design shall also provide the necessary floodgates, water level control devices, and any other appurtenant structures affecting the function of the channels or swales and the attainment of the purpose for which they are built.

The effect of channel / swale improvements on existing culverts, bridges, buried cables, pipelines and inlet structures for surface and subsurface drainage on the channel / swale being improved shall be evaluated to determine the need for modification or replacement. Culverts and bridges which are modified or added as part of channel improvement projects shall meet reasonable standards for the type of structure, and shall have a minimum capacity equal to the design discharge or governmental agency design requirements, whichever is greater.

4.5 Stormwater Detention

All developments that will increase the rate of stormwater runoff when compared to the pre-developed conditions will require detention meeting the requirements below.

4.5.1 Acceptable Detention Methods

The stormwater runoff resulting from a proposed development shall be detained on-site by the provisions of appropriate wet or dry bottom reservoir, by storage on parking lots, streets, lawns, or other acceptable techniques. Measures, which retard the rate of overland flow and the velocity in runoff channels, should also be used to control the runoff rate. Control devices shall limit the discharge to a rate no greater than that prescribed below.

4.5.2 Design Storm

Design of stormwater detention facilities should be based on a return period of once in 100 years. The storage volume and outflow rate should be sufficient to handle stormwater runoff from a critical duration storm, as defined in Sections 4.5.5 and 4.5.6 of this Guide. Rainfall intensity-duration-frequency relationships and depth-duration-frequency relationships should be those given in Tables 4.4 and 4.7, respectively.

4.5.3 Allowable Release Rate

In general, the allowable release rate of stormwater originating from a proposed development should not exceed the amounts defined in Sections 4.5.5 and 4.5.6 of this Guide. In general, the post-developed 100-year release rate should be reduced to the existing 10-year release rate.

In the event the natural downstream channel or storm sewer system is inadequate to accommodate the release rate provided above, then the allowable release rate should be reduced to that rate permitted by the capacity of the receiving downstream channel or storm sewer system. Additional detention, as approved by the Board, shall be required to store that portion of the runoff exceeding the capacity of the receiving sewers or waterways.

If more than one detention basin is involved in the development of the area upstream of the limiting restriction, the allowable release rate from any one-detention basin should be in direct proportion to the ratio of its drainage area to the drainage area of the entire watershed upstream of the restriction.

If off-site runoff enters the detention facility, the allowable release rate should be determined by using the existing on-site 10-year runoff. The detention volume should then be determined by routing the proposed on-site 100-yr runoff hydrograph through the storage facility. The additional off-site runoff shall be conveyed by a structure such as weir set at or above the peak elevation resulting from the previous hydrograph routing through the proposed detention facility. This weir shall be in addition to the emergency overflow structure.

Table 4.7 Rainfall Depths for Various Return Periods and Storm Durations (inches)[8]

Duration		2	5	10	25	50	100
5	min	.35	.44	.51	.62	.71	.82
10	min	.61	.76	.89	1.08	1.25	1.44
15	min	.79	.98	1.15	1.39	1.61	1.85
20	min	.89[9]	1.10	1.29	1.56	1.81	2.08
30	min	1.08	1.35	1.57	1.91	2.20	2.53
40	min	1.18	1.47	1.71	2.08	2.40	2.76
50	min	1.27	1.59	1.85	2.26	2.60	2.98
1	hr	1.37	1.71	2.00	2.43	2.80	3.21
2	hr	1.69	2.11	2.46	2.99	3.45	3.97
3	hr	1.87	2.33	2.72	3.30	3.81	4.38
6	hr	2.19	2.73	3.19	3.87	4.46	5.13
12	hr	2.54	3.17	3.70	4.49	5.18	5.95
24	hr	2.92	3.64	4.25	5.16	5.95	6.84

4.5.4 Drainage and Stormwater Management Facilities Overflow Design

Drainage and stormwater management facilities should have adequate capacity to convey the stormwater runoff from all upstream tributary areas through the development under consideration for a storm of a 100-year design return period calculated on the basis of the upstream land in its present state of development. An allowance, equivalent to the reduction in flow rate provided, should be made for upstream detention when such upstream detention and release rate have previously been approved by the City Engineer and evidence of its construction can be shown. The overflow shall be designed to accommodate the peak 100-year inflow to the detention facility with 1' of freeboard.

4.5.5 Determination of Storage Volume – Rational Method

For drainage areas of five (5) acres or less, the Rational Method may be used to determine the required volume of stormwater storage. The following eleven-step procedure may be used to determine the required volume of storage using this methodology. Other design methods may also be used, subject to approval of the City Engineer, and as described in Section 4.5.6.

Steps Procedure

1. Determine the total site drainage area in acres "A".

2. Determine composite runoff coefficient "C_u" based on existing land use (undeveloped).

3. Determine time of concentration "Tc" in minutes based on existing conditions.

4. Determine rainfall intensity "i_u" in inches per hour, based on time of concentration and using the data given in Table 5 for the 10-year return period.

[8] The above information is taken directly from Bulletin 71 "Rainfall Frequency Atlas of the Midwest" (by Floyd A. Huff and James R. Angel) funded by a grant from the Midwestern Climate Center (MCC).

[9] Areas shaded in gray are linear interpolations from the above-mentioned Bulletin 71.

5. Compute runoff based on existing land use (undeveloped), and 10-year return period:

$$Q_u = C_u i_u A$$

6. Determine composite runoff coefficient "C_d" based on developed conditions and a 100-year return period.

7. Determine the 100-year return period rainfall intensity "i_d" for various storm durations "T_d" for the developed area using Table 4.4.

8. Determine developed inflow rates "Q_d" for various storm durations "t_d", measured in hours.

$$Q_d = C_d i_d A$$

9. Compute a storage rate "S_{td}" for various storm durations "t_d" up through the time of concentration of the developed area.

$$S_{td} = Q_d - Q_u$$

10. Compute required storage volume "S_R" in acre-feet for each storm duration "t_d". This assumes a triangular hydrograph of duration ($2^* t_d$) hours with peak flow of S_{td} at t_d hours.

$$S_R = S_{td}\,(t_d/12)$$

11. Select the largest storage volume computed in Step 10 for detention basin design.

4.5.6 Determination of Storage Volume – Hydrograph Methods

Hydrograph methods for determining runoff and routing of stormwater must be used to determine the storage volume required to control stormwater runoff for drainage areas greater than five (5) acres. The procedures or methods used must receive the prior approval of the City Engineer. The TR-20 computer model is accepted for use in analysis of the runoff and routing of stormwater. The use of models or other approved procedures can be defined in a four-step procedure to determine the required storage volume of the detention basin.[10]

<u>Step</u> <u>Procedure</u>

1. Determine the drainage area, the composite curve number and the time-of-concentration for both the undeveloped and the developed conditions of the basin or basins tributary to the proposed storage facility. Complete documentation shall be provided in the report for all input parameters (i.e. drainage basin map with delineation of the time-of-concentration path, copies of time-of-concentration and curve number calculations, etc).

2. If TR-20 is selected, determine the 10-year, undeveloped peak flow using the appropriate Huff rainfall distribution (see Table 4.8 for the Huff ordinates) for each storm duration listed in Table 4.7. Denote this flow by Q_u^{10}.

[10] Rational method is not acceptable for areas over 5 acres.

3. Determine the allowable release rate using the peak 10-year flow determined in step 2.

4. If TR-20 is used, determine the 100-year peak outflow and elevation of the proposed stormwater facility for developed conditions by routing hydrographs for each storm duration listed in Table 4.7 directly to the pond. Copies of outlet sizing calculations and stage-storage tables shall be provided in the report.

5. If off-site runoff enters the detention facility, the allowable release rate should be determined by using the existing on-site 10-year runoff. The detention volume should then be determined by routing the proposed on-site 100-yr runoff hydrograph through the storage facility. The additional off-site runoff shall be conveyed by a structure such as weir set at or above the peak elevation resulting from the previous hydrograph routing through the proposed detention facility.

Table 4.8 Huff Rainfall Distribution Ordinates

Cumulative Storm Rainfall (Percent) for Given Storm Type				
Cumulative Storm Time (%)	1st Quartile (Rainfall Duration 6 hours or less)	2nd Quartile (Rainfall Duration 6.1 to 12 hours)	3rd Quartile (Rainfall Duration 12.1 to 24 hours)	4th Quartile (Rainfall Duration > 24 hours)
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92
100	100	100	100	100

4.5.7 General Detention Basin Design Requirements

Basins should be constructed to temporarily detain the stormwater runoff, which exceeds the maximum peak flow rate authorized by the Stormwater Design Manual. The volume of storage provided in these basins, together with such storage as may be authorized in other on-site facilities should be sufficient to control runoff release rate from the 100-year storm and not exceed the existing 10-year release rate at the point of discharge.

The following design principals should be used:

1. The maximum planned depth of stormwater stored (without a permanent pool) should not exceed 4 feet.

2. All detention facilities should be separated by not less than 50 feet from any building or structure to be occupied.

3. Screens having a maximum opening of 4 inches should be provided for any pipe or opening to prevent children or large animals from crawling into the structures.

4. “Danger – Deep Water” signs should be mounted at appropriate locations to warn of deep water, possible flooding conditions during storm periods and other dangers that exist.

Signs should be placed at locations and sufficient frequency to be visible from all directions including all corners.[11]

5. Outlet control structures should be designed to operate as simply as possible and shall require little or no maintenance or attention for proper operation. They should limit discharges into existing or planned downstream channels or conduits so as to not exceed the maximum permitted peak flow rate. Outlet structures shall be constructed of pre-cast concrete. CMP will not be considered acceptable.

6. Emergency overflow facilities such as a weir or spillway should be provided for the release of exceptional stormwater runoff or in emergency conditions should the normal discharge devices become totally or partially inoperative. The overflow facility should be of such design that its operation is automatic and does not require manual attention. The overflow shall be designed to accommodate the peak 100-year inflow to the detention facility with 1' of freeboard.

7. Grass or other suitable vegetative cover should be provided throughout the entire basin area. Grass should be cut regularly at approximately monthly intervals during the growing season or as required.

8. Debris and trash removal and other necessary maintenance should be performed on a regular basis to assure continued operation in conformance to design.

9. A ledge a minimum of 4 feet minimum wide is required and should be installed in all ponds 30 inches below the permanent water level. In addition, a similar maintenance ledge 12 inches above the permanent water line should be provided. The slope between the two ledges should be stable and of a material such as stone or riprap which will prevent erosion due to wave action.

4.5.8 Dry Bottom Basin Design Requirements

Detention basins that will not contain a permanent pool of water should follow the criteria listed below:

1. The bottom slopes of the basin shall drain to the outlet drain and must contain either minimum grades of 2% or underdrains leading to the outlet drain.

2. Provisions should be incorporated to facilitate complete interior drainage of dry bottom basins, to include the provision of natural grades to outlet structures, longitudinal and transverse grades to perimeter drainage facilities, paved gutters, or the installation of subsurface drains.

3. The detention basin should, whenever possible, be designed to serve a secondary or multipurpose function. Recreational facilities, aesthetic qualities (open spaces) or other types of use should be considered in planning the detention facility.

4.5.9 Wet Bottom Basin Design Requirements

[11] Signs should be on all sides of the pond and should have 6 inch lettering stating "Danger Deep Water". Signs should also be placed at locations where side walks are near or play grounds are within view.

Where part of a detention basin will contain a permanent pool of water, all of the items required for detention storage should apply except that the system of drains with a positive gravity outlet required to maintain a dry bottom basin will not be required. A controlled positive outlet will be required to maintain the design water level in the wet bottom basin and provide required detention storage above the design water level. However, the following additional requirements apply:

1. Basins designed with permanent pools or containing permanent ponds should have a water area of at lease one-half acre. If fish are to be maintained in the pond, a minimum depth of approximately 10 feet should be maintained over at least 25 percent of the pond area. The remaining pond area should have no extensive shallow areas, except as required by subsection (3) below. Ponds not intended to maintain fish shall have a minimum depth of 8 feet.

2. In excavated ponds, the underwater side slopes in the pond should be stable. Earthen side slopes shall be no steeper than 3 (horizontal) to 1 (vertical) for the bottommost 4 feet of the pond. Side slopes above 4 feet from the bottom shall be no steeper than 5 (horizontal) to 1 (vertical). In the case of valley storage, natural slopes may be considered to be stable.

3. A safety ramp from the pond is required in all cases and should have a minimum width of 20 feet and exit slope of 6 (horizontal) to 1 (vertical). The ramp should be of a material that will prevent its deterioration due to vehicle use and/or wave action.

4. Periodic maintenance is required in ponds to control weed and larval growth. The pond should also be designed to provide for the easy removal of sediment, which will accumulate during periods of pond operation. A means of maintaining the designed water level of the pond during prolonged periods of dry weather is also required.

5. For emergency use, basin cleaning or shoreline maintenance, facilities shall be provided or plans prepared for auxiliary equipment to permit emptying and drainage.

4.5.10 Parking Lot Storage

Paved parking lots may be designed to provide temporary detention storage of accumulated stormwater on all or a portion of their surfaces. Outlets will be designed so as to empty the stored waters slowly. Depths of storage must be limited to a maximum depth of 6 inches so as to prevent damage to parked vehicles and so that access to parked vehicles is not impaired. Ponding should, in general, be confined to those positions of the parking lots farthest from the area served and should not be provided in the natural path of pedestrians. An emergency overflow limiting the depth of water stored must be provided.

4.5.11 Facility Maintenance Responsibility

Maintenance of detention-retention facilities during construction and thereafter, shall be the responsibility of the landowner. Assignment of responsibility for maintaining facilities serving more than one lot or holding shall be documented by appropriate covenants to property deeds, unless responsibility is formally accepted by a public body, and shall be determined before the final drainage and stormwater management plans are approved.

4.5.12 Installation of Control Systems

Runoff and erosion control systems shall be installed as soon as possible during the course of site development and in accordance with Rule 5 (327 IAC 15-5). Detention-retention basins should be designed with an additional 6 percent of available capacity to allow for sediment accumulation resulting from development and to permit the pond to function for reasonable periods between cleanings. Basins should be designed to collect sediment and debris in specific locations so that removal costs are kept to a minimum. During and at the close of construction activities the basins shall be maintained pursuant to Rule 5 (327 IAC 15-5).

4.5.13 Detention Facilities in Floodplains

If detention storage is provided within a floodplain, only the net increase in storage volume above that which naturally existed on the floodplain will be credited to the development. No credit will be granted for volumes below the elevation of the regulatory flood at the location unless compensatory storage is also provided.

4.5.14 Downstream Receiving Facility Provisions

When the allowable runoff is released in an area that is susceptible to flooding, the developer may be required to construct appropriate storm drains through the area to avert increased flood hazards caused by the concentration of allowable runoff at one point instead of the natural overland distribution. The requirement for downstream receiving facility provisions will be at the discretion of the Board.

4.6 Structures

The drainage stormwater management facility shall be such that all habitable structures are 2 feet above the 100-year flood elevation as stated on the Flood Insurance Rate Map (FIRM) and stormwater shall be directed away from structures.

New structures built on natural high ground and involving no fill must have the lowest adjacent grade to the structures at or above the 100-year flood elevation. New structures built on fill must have both the lowest adjacent grade of the structure at or above the 100-year flood elevation and the lowest finished floor 2 feet above the 100-year flood elevation (including basement). The regulations for new structures to be at or above the 100-year flood are the requirements of the National Flood Insurance Program (NFIP) and apply to all habitable and non-habitable structures. Through its participation in the NFIP, the City of Columbus has agreed that new construction in and near designated 100-year floodplains will be compliant with the Federal regulations.

4.7 Additional Considerations

Land alterations shall be accomplished so as to prevent damage to adjacent property. The maximum vertical fall of earth on the parcel shall be 6” per foot (2’ horizontal to 1’ vertical). Slopes of materials other than earth shall be at the safe angle of repose for the respective materials.

Land alterations shall be accomplished in such a way that the post-development grades are permanent and stable. Vegetative cover or landscaping may be buried in the ground only if the activity will not interfere with the stability of fill or cause settlement or erosion. Subsurface drainage should be sufficient to intercept seepage that would affect earth slope stability of a building foundation or create undesirable wetness.

5.0 SEDIMENT AND EROSION CONTROL

All persons who cause, in whole or in part, any earth change to occur shall provide soil erosion and sedimentation control so as to adequately prevent soils from being eroded and discharged or deposited onto adjacent properties or into a stormwater drainage system, a public street or right of way, wetland, creek, stream, water body, or floodplain.

All development shall be in accordance with all applicable federal, state and local ordinances, rules and regulations.

Prior to making any earth change on a qualifying development site, the developer shall first obtain Site Development Approval from the City Engineer's Office. The developer shall install stormwater runoff facilities and shall phase the development activities so as to prevent construction site stormwater runoff and off-site sedimentation.

Land alterations, including regrading, which strip the land of vegetation, shall be accomplished in a manner, which minimizes erosion or the addition of sediment to natural and manmade drainage ways. This will reduce the impact on adjacent properties and water quality of receiving waters. Whenever feasible, natural vegetation shall be retained, protected and supplemented.

Cut and fill operations shall be kept to a minimum to ensure conformity with existing topography to reduce the potential erosion. Applicants shall follow the procedures and comply with the requirements of "Rule 5" (327 IAC 15-5), regarding sediment and erosion control during construction. Indiana Department of Environmental Management (IDEM) administers this rule. The regulation applies to all sites where construction activity disturbs one (1) acre or more or disturbances of less than one (1) acre of land that are part of a larger common plan of development or sale if the larger common plan will ultimately disturb one (1) or more acres of land. Applicants are required per Rule 5 to have an approved erosion control plan and approved sediment and erosion control devices in place prior to the beginning of land disturbances.

Sediment controls should be installed whenever runoff from disturbed portions of the parcel will leave the parcel. Sediment controls may include vegetative buffer strips, filter barriers, sediment basins, debris basins or silt traps. Vegetative buffer strips should only be used where runoff is dispersed and exits the parcel as sheet flow. Filter barriers should not be used in areas of concentrated flow. Synthetic filter fences are more effective than straw bales and should be used in series. Straw bales should also be anchored with stakes and grounded to reduce unfiltered underflow by burying the lower three (3) inches of each bale.

Any flow from a disturbed parcel should pass through a vegetative filter barrier or sediment basin before entering a storm drain inlet. Existing inlets or those being constructed in a disturbed area should have all flow diverted away from them, be plugged or protected by a filter. Downstream development parcels should be protected from increases in volume, velocity, and sediment load or peak flow rates.

5.1 Stabilization

The duration of time, which an area remains exposed, shall be kept to a practical minimum. And the area shall be stabilized as quickly as possible. Applicants are encouraged to implement sediment and erosion control for stockpiles exposed longer than three (3) days and the remainder of the property within 15 days. Temporary vegetation or mulch shall be used to protect exposed areas during development.[12] For areas subject to daily disturbance, a weighted cover of impermeable material may be used, if approved by the City Engineer.

Stockpiles should be located outside of drainage ways and the 100-year floodplain if possible. It may be necessary to divert drainage around a stockpile that must be located in a drainage way.

Soil stabilization should be maintained in an effective condition throughout construction until permanent vegetation stabilization is achieved.

5.2 Permanent Stabilization

Permanent vegetation or structural erosion control devices shall be installed as soon as practical after as-built topographic conditions are finalized. Permanent stabilization requires permanent structures, pavement or vegetation sufficiently mature to withstand annual climate cycle or permanent mulch.

6.0 BEST MANAGEMENT PRACTICES AND STORMWATER QUALITY

6.1 INTRODUCTION

Stormwater runoff contains many types and forms of pollutants that lead to impairments in our nation's waterways. Best management practices (BMPs) or stormwater controls are an effective method of reducing the amount of pollutants in stormwater. A subset of BMPs is stormwater quality units (SQUs); stormwater design practices implemented to improve runoff water quality and meet regulatory requirements. This Section of the Manual describes the most common SQUs applicable to the Columbus area. This Section is divided into two parts. The first part describes the stormwater SQUs in detail. The information provided for each SQU includes a description of the SQU and its purpose along with design criteria and guidelines, performance standards, and maintenance requirements. The second part describes the stormwater SQU selection process with the usage of matrices to simplify the decision process. The matrices investigate land use settings, site considerations, and social factors for the SQUs.

The SQUs described in this Manual are pre-approved SQUs that can be used in Columbus for stormwater quality management if designed according to the criteria set forth in the Manual. A key component to designing structural stormwater controls is adequate sizing for water quality treatment. SQUs can be classified into two categories with respect to performance, volume based SQUs and rate-limited SQUs. It is required that SQU's shall be placed upstream of stormwater quantity control structures. This will mediate sedimentation and provide water quality for the aesthetic aspects of retention and detention controls. The minimum requirements for each are addressed below.

Volume Based Treatment
The water volume quality sizing criterion, denoted WQ_v, is the storage volume needed to capture and treat the runoff from the first one-inch of rainfall. The WQ_v is equivalent to an inch of rainfall multiplied by the volumetric runoff coefficient (R_v) and the site area. The following equation is used to calculate WQ_v:

[12] See Chapter 7 of the Indiana Storm Water Quality Manual

$$WQv = \frac{(P)(Rv)(A)}{12}$$

where:

WQ_v = water quality volume (acre-feet)
P = 1 inch of rainfall
R_v = 0.05 + 0.009(I), where I is the percent of impervious cover
A = area in acres

Rate-Limited Treatment
The design flow rate for rate-limited SQUs (e.g. manufactured stormwater quality units) shall be determined using the following Soil Conservation Service (SCS) runoff methodology as outlined below.

1. Delineate the watershed basins. Tabulate the total impervious and pervious areas. *Please note impervious and pervious area runoff rates MUST be calculated as separate basins. The sizing calculation assumes the impervious area is connected directly to the SQU and the Tc calculation must be adjusted for this assumption (i.e. no flow over grass).*

2. Determine the time of concentration using the TR-55 methodology (Worksheet 3 – See Appendix 14) for each basin.

3. Calculate the curve numbers (CN) for each basin, using CN=98 for the impervious basin.

Determine the peak discharge from the 0.3 inch storm using the appropriate Huff, 50% rainfall distribution (Storm duration 0 up to and including 6 hrs – 1st Quartile, 6.1 to 12 hrs – 2nd Quartile, 12.1 to 24 hrs – 3rd Quartile. See Table 4.8 for Huff ordinates.). A single hydrograph for each basin should be determined and all basin hydrographs added to determine the peak flow. Storm durations of 15-, 30- and 45 minutes as well as 1-, 2-, 3- 6- 12- and 24- hours should be checked to determine the peak SQU flow.

This Manual follows the thinking of removing pollutants to the "maximum extent practicable" through the use of a percentage removal performance goal. The approach taken in this Manual is to require treatment of the first flush of runoff or WQ_v from a site to reduce post-development total suspended solids (TSS) loadings by 80%, as measured on an average annual basis and remove floatable material such as trash to the maximum extent practicable. This performance goal is based upon U.S. EPA guidance and has been adopted nationwide by many local and statewide agencies.

TSS was chosen as the representative stormwater pollutant for measuring treatment effectiveness for several reasons:

1. The use of TSS as an "indicator" pollutant is well established.
2. Sediment and turbidity, as well as other pollutants of concern that adhere to suspended solids, are a major source of water quality impairment due to urban development in Columbus watersheds.
3. A large fraction of many other pollutants of concern are either removed along with TSS, or at rates proportional to the TSS removal.
4. The 80% TSS removal level is reasonably attainable using well-designed structural stormwater controls (for typical ranges of TSS concentration found in stormwater runoff).

TSS is a good indicator for many stormwater pollutants. However, the removal process for pollutants that are soluble or that cannot be removed by settling will vary depending on the structural control practice. For pollutants of specific concern, individual analyses of specific pollutant sources and the appropriate removal mechanisms should be performed.

There are two primary approaches for managing stormwater runoff and addressing the stormwater structural sizing criteria requirements on a development site:

- The use of better site design practices to reduce the amount of stormwater runoff and pollutants generated and/or provide for natural treatment and control of runoff; and
- The use of structural stormwater controls to provide treatment and control of stormwater runoff.

The first step in addressing stormwater management begins with the site planning and design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to conserve natural areas, reduce impervious cover and better integrate stormwater treatment. By implementing a combination of these nonstructural approaches, collectively known as stormwater better site design practices, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff. The goals of better site design include:

- Managing stormwater (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing stormwater impacts rather than mitigating them
- Utilizing simple, nonstructural methods for stormwater management that are lower cost and lower maintenance than structural controls
- Creating a multifunctional landscape
- Using hydrology as a framework for site design

Better site design for stormwater management includes a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site for stormwater management. The aim is to reduce the environmental impact "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the better site design concepts can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

Reduction of adverse stormwater runoff impacts through the use of better site design practices should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of better site design practices offers significant benefits over treating and controlling runoff downstream. Therefore, all opportunities for using these methods should be explored and all options exhausted before considering structural stormwater controls.

The reduction in runoff and pollutants realized from using better site design practices can reduce the required runoff peak volumes that need to be conveyed and controlled on a site and, therefore, reduce the size and cost of necessary drainage infrastructure and structural stormwater controls. In some cases, the use of better site design practices may eliminate the need for structural controls entirely. Hence, better site design concepts practices can be viewed as both a water quantity and water quality management tool.
The use of stormwater better site design practices can also have a number of other ancillary benefits including:

- Reduced construction costs
- Increased property values

- More open space for recreation
- More pedestrian friendly neighborhoods
- Protection of sensitive forests, wetlands and habitats
- More aesthetically pleasing and naturally attractive landscape
- Easier compliance with wetland and other resource protection regulations

Site design should be done in unison with the design and layout of stormwater infrastructure in attaining stormwater management goals. The first step in stormwater better site design involves identifying significant natural features and resources on a site such as undisturbed forest areas, stream buffers and steep slopes that should be preserved to retain some of the original hydrologic function of the site. Next, the site layout is designed such that these conservation areas are preserved and the impact of the development is minimized. A number of techniques can then be used to reduce the overall imperviousness of the development site. Finally, natural features and conservation areas can be utilized to serve Soil Erosion and Sedimentation Control and Post Construction Stormwater Runoff purposes.

Examples of stormwater better site design practices and techniques are listed below in four categories:

<u>Conservation of Natural Features and Resources</u>
- Preserve Undisturbed Natural Areas
- Preserve Riparian Buffers
- Avoid Floodplains
- Avoid Steep Slopes
- Minimize Sitting on Porous or Erodible Soils

<u>Lower Impact Site Design Techniques</u>
- Fit Design to the Terrain
- Locate Development in Less Sensitive Areas
- Reduce Limits of Clearing and Grading
- Utilize Open Space Development
- Consider Creative Development Design

<u>Reduction of Impervious Cover</u>
- Reduce Roadway Lengths and Widths
- Reduce Building and Parking Footprints
- Reduce Setbacks and Frontages
- Use Fewer Cul-de-Sacs
- Create Parking Lot Stormwater "Islands"

<u>Utilization of Natural Features for Stormwater Management</u>
- Use Buffers and Undisturbed Areas
- Use Natural Drainage ways Instead of Storm Sewers
- Use Vegetated Swale Instead of Curb and Gutter
- Drain Rooftop Runoff to Pervious Areas

Structural stormwater controls, or structural SQUs, are constructed stormwater management facilities designed to treat stormwater runoff and/or mitigate the effects of increased stormwater runoff peak rate, volume, and velocity due to urbanization.

This Manual recommends a number of structural stormwater controls for meeting the stormwater sizing criteria. The recommended controls are divided into three categories: general application, limited application, and detention structural controls.

General Application Controls

General application structural controls are recommended for use with a wide variety of land uses and development types. These structural controls have a demonstrated ability to effectively treat the Water Quality Volume (WQ_v) and are presumed to be able to remove 80% of the annual average TSS load in typical post-development urban runoff when designed, constructed, and maintained in accordance with recommended specifications. Several of the general application structural controls can also be designed to provide water quantity control. General application controls are the most often recommended stormwater management facilities for a site wherever feasible or practical.

There are three types of general application controls, which are summarized below. Detailed descriptions of each structural control along with design criteria are provided in Section 6.3.

Stormwater Ponds

Stormwater ponds are constructed stormwater retention basins that have a permanent pool or micropool of water. Runoff from each rain event is detained and treated in the pool. Pond design variants include:

- Wet Pond
- Wet Extended Detention Pond
- Micropool Extended Detention Pond
- Multiple Pond Systems
- Pocket Pond

Bioretention Areas

Bioretention areas are shallow stormwater basins or landscaped areas that utilize engineered soils and vegetation to capture and treat stormwater runoff. Runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.

Water Quality Swales

Dry water quality swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff volume within dry cells formed by check dams or other means.

Limited Application Controls

Limited application structural controls are those that are recommended only for limited use or for special site or design conditions. Generally, these practices cannot or may not alone achieve the 80% TSS removal target. They are intended to address hotspot or specific land use constraints or conditions, and/or may have high or special maintenance requirements that may preclude their use. Limited application controls are typically used for water quality treatment only. Some of these controls can be used as a pretreatment measure or in series with other structural controls to meet pollutant removal goals. Limited application structural controls should be considered primarily for commercial, industrial, or institutional developments and / or limited area developments.

The following limited application controls are provided for consideration in this Manual. Each is discussed in detail with appropriate application guidance in Section 6.6.

Biofilters

- Filter Strip
- Riparian buffer

Porous Surfaces

- Modular Porous Paver Systems
- Porous Concrete (or Asphalt)

Proprietary Systems

- Commercial or Manufactured Stormwater Controls

Limited Detention Controls

Limited detention controls provide only water quantity control and are typically used downstream of a general application or limited application stormwater quality structural control. Types of detention controls include:

- Dry Detention and Dry Extended Detention Basins
- Multi-purpose Detention Areas
- Underground Detention

A detailed discussion of each of the limited detention controls, as well as design criteria and procedures can be found in Section 6.9 to 6.11.

6.2 STORMWATER SQUs

SQU inspections/fees (per SQU):

Inspections for first 3 years	$85 per hour per SQU
Annual SQU inspection after year 3	$85 per hour
Additional inspections for maintenance	$85 per hour

Routine inspections and maintenance are the responsibility of the SQU owner. SQU owners can be the property owners, or lessee of the property in the case of long-term leases of commercial or industrial property. The lessee is considered the SQU owner only if the lease specifies that construction by the lessee must meet applicable local codes and regulations. The approved maintenance plan and inspection forms provided for each SQU should be used as guidance for performing maintenance activities. Completed inspection forms must be maintained by the SQU owner and produced upon request by the City. The City must be notified of any changes in SQU ownership, major repairs, or SQU failure in writing within 30 days. The letter should be addressed to:

City of Columbus
Office of the City Engineer
123 Washington Street
Columbus, IN 47201

If the City determines a SQU is in need of maintenance or repair, the City will notify the SQU owner and provide a timeframe for completing the maintenance and repairs. If the maintenance or repairs are not completed within the designated timeframe, the City shall perform the repairs or maintenance and bill the landowner for the actual costs for the work.

6.3 GENERAL APPLICATION CONTROLS

6.3.1 Ponds

6.3.1.1 General Description

Stormwater ponds are small man-made surface waters designed to treat stormwater runoff and the pond's natural physical, biological, and chemical processes work together to remove the pollutants. In a stormwater pond, runoff from each rain event is detained and treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool serves to protect deposited sediments from resuspension. Sedimentation processes remove particulates, organic matter, and metals, while dissolved metals and nutrients are removed through biological uptake. Above the permanent pool level, additional temporary storage is provided for runoff quantity control.

Multiple variations of stormwater ponds exist to control both stormwater quantity and quality by capturing and detaining runoff during storm events. The ponds can be wet detention ponds, wet extended detention ponds, micropool extended detention ponds, multiple pond systems, and pocket ponds.

- **Wet Detention Ponds:** A wet detention pond provides all of the water quality volume (WQv) storage and includes a permanent pool. The permanent pool of water is equal to, at a minimum, the water quality volume requirement. Figure 6.1 illustrates wet detention ponds.

- **Wet Extended Detention (ED) Ponds:** A wet extended detention (ED) pond is a wet pond where the water quality volume is split evenly between the permanent pool and the extended detention storage provided above the permanent pool. These ponds are suitable for any size tributary area from an individual commercial development to a large residential area. During storm events, water is detained above the permanent pool and released over 12 - 48 hours. This design has similar pollutant removal to a traditional wet pond, but consumes less space. Refer to Figure 6.2 for an example illustration of wet ED ponds.

- **Micropool Extended Detention (ED) Pond:** The micropool extended detention pond is a variation of the wet ED pond where only a small micropool is maintained at the outlet to the pond. A low flow channel with a minimum grade of 0.50% generally characterizes these basins. The remainder of the basin should drain towards this channel at a minimum 1% slope. This low flow channel should end at the lip of the lower stage, where riprap or gabion baffles will be placed to prevent scour and resuspension. The outlet is sized to detain the water quality volume for 24 hours. The micropool prevents resuspension of previously settled sediments and helps prevent clogging of the low flow orifice. Figure 6.3 illustrates a micropool extended detention pond.

- **Multiple Pond Systems:** Multiple pond systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection. Figure 6.4 illustrates a multiple pond system.

- **Pocket Pond:** A pocket pond drains a smaller area than a traditional wet pond and the permanent pool is maintained by intercepting the groundwater. Excavation to groundwater interception should be avoided where the land uses draining to the pond may contaminate drinking water supplies such as well-field protection zones. Figure 6.5 illustrates a pocket pond.

> ⚠ Conventional dry detention basins do not provide a permanent pool and are not recommended for general application use to meet water quality criteria, as they fail to demonstrate an ability to meet the majority of the water quality goals. In addition, dry detention basins are prone to clogging and resuspension of previously settled solids and require a higher frequency of maintenance than wet ponds if used for untreated stormwater flows. These facilities can be used in combination with appropriate water quality controls upstream of the dry pond to provide channel protection, and overbank and extreme flood storage. Please see a further discussion in subsection 6.9.1.

Figure 6.1Wet Detention Pond

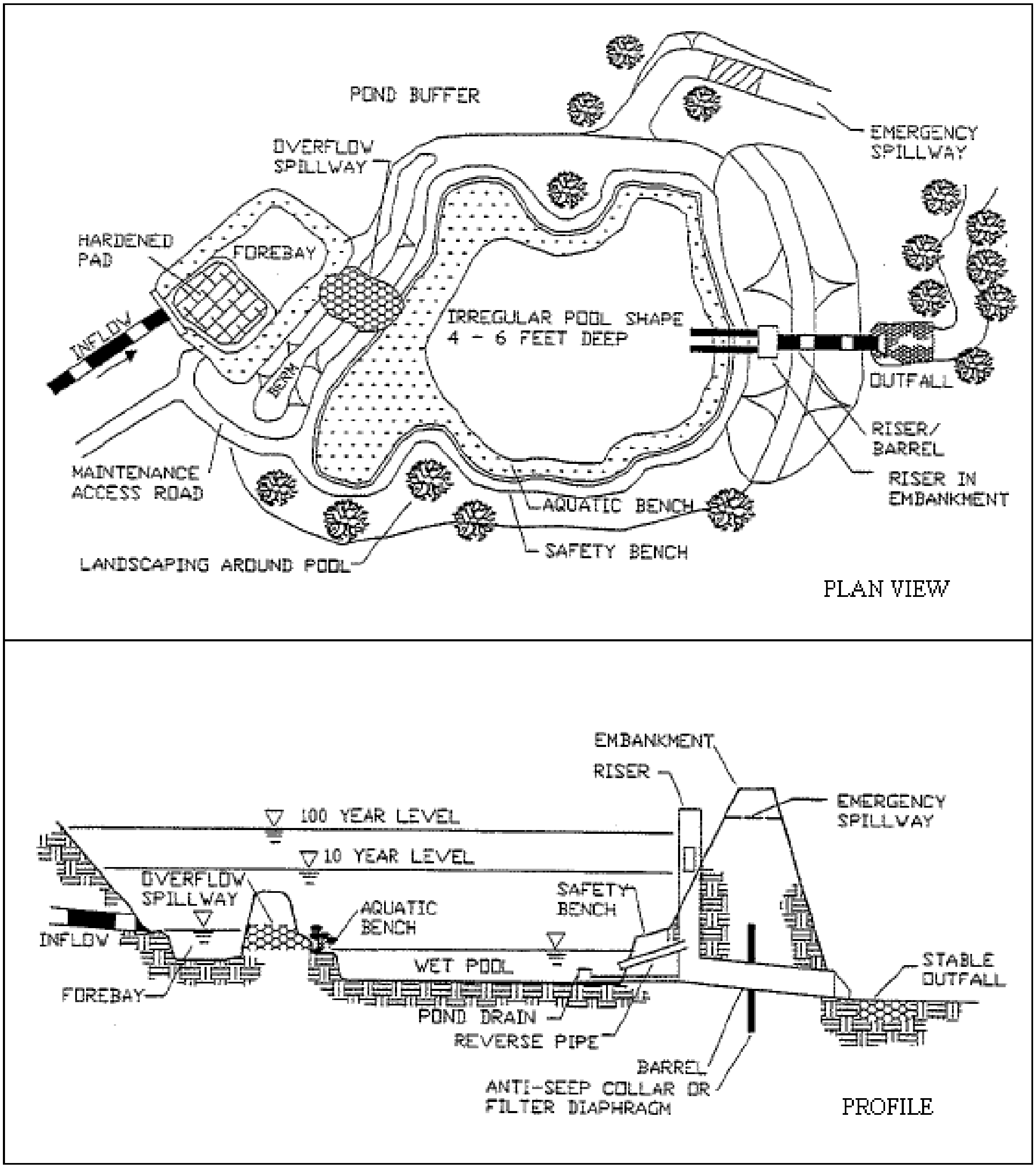


Figure 6.2 Wet Extended Detention Pond

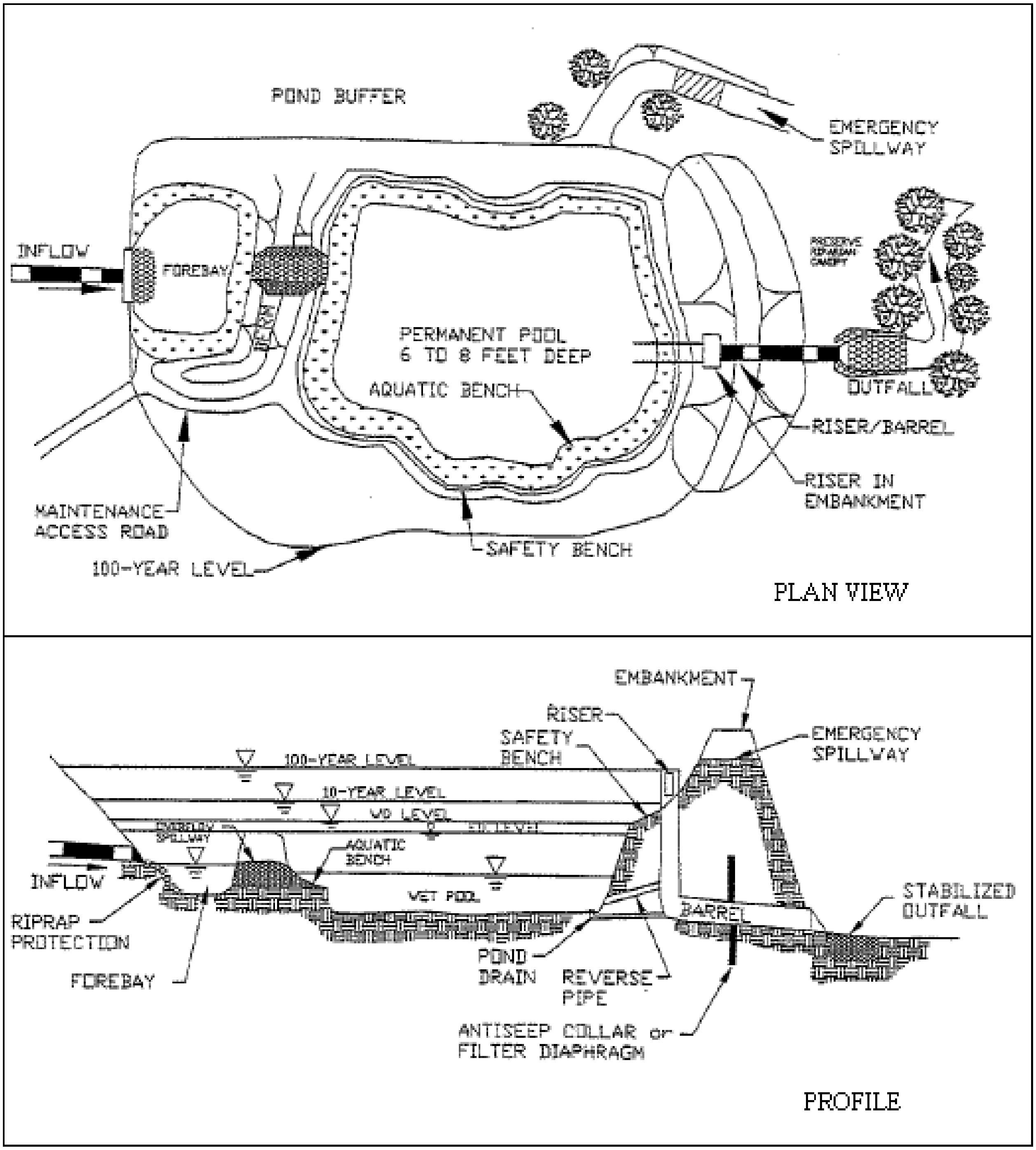


Figure 6.3 Micropool Extended Detention Pond

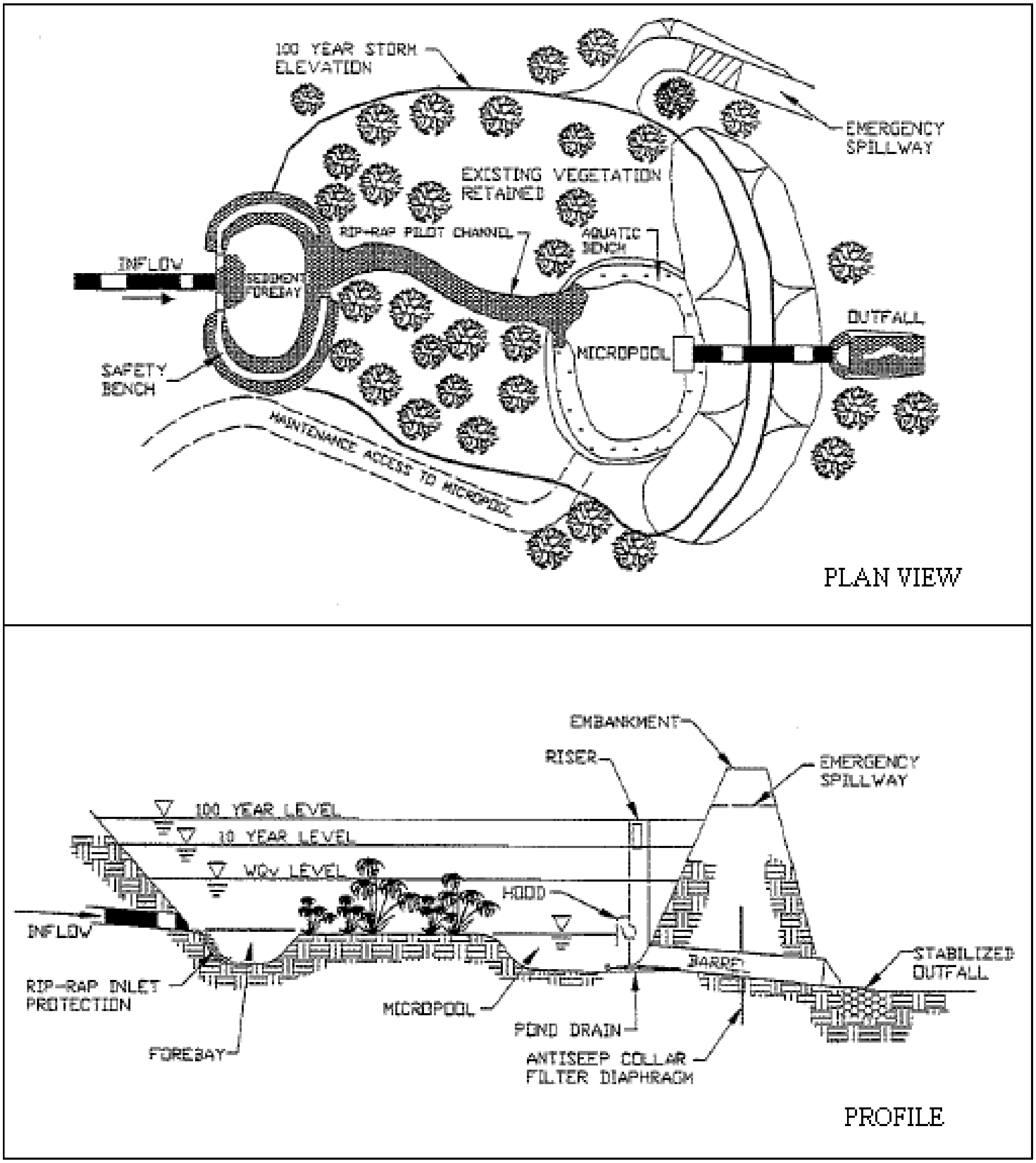


Figure 6.4 Multiple Pond System

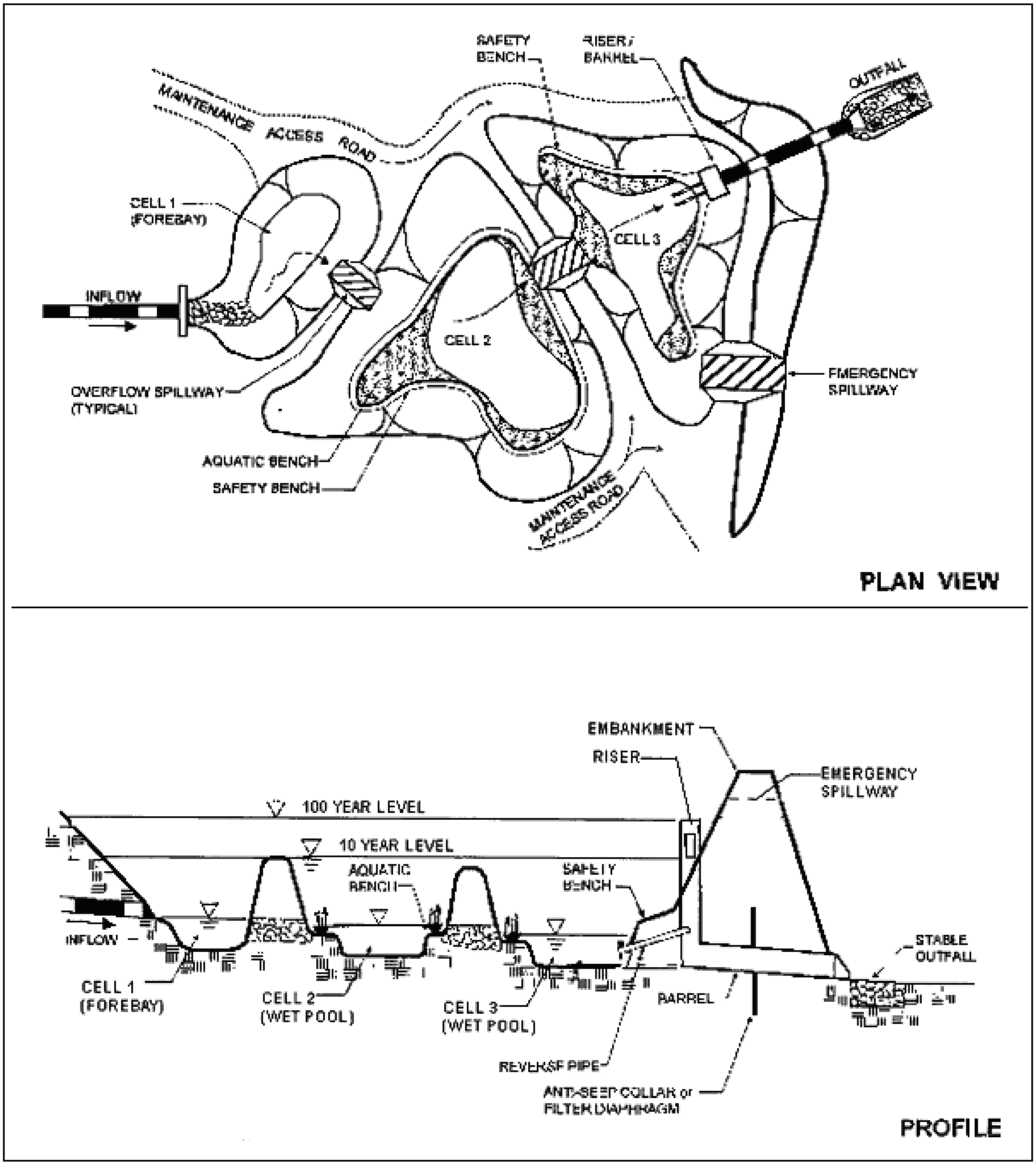
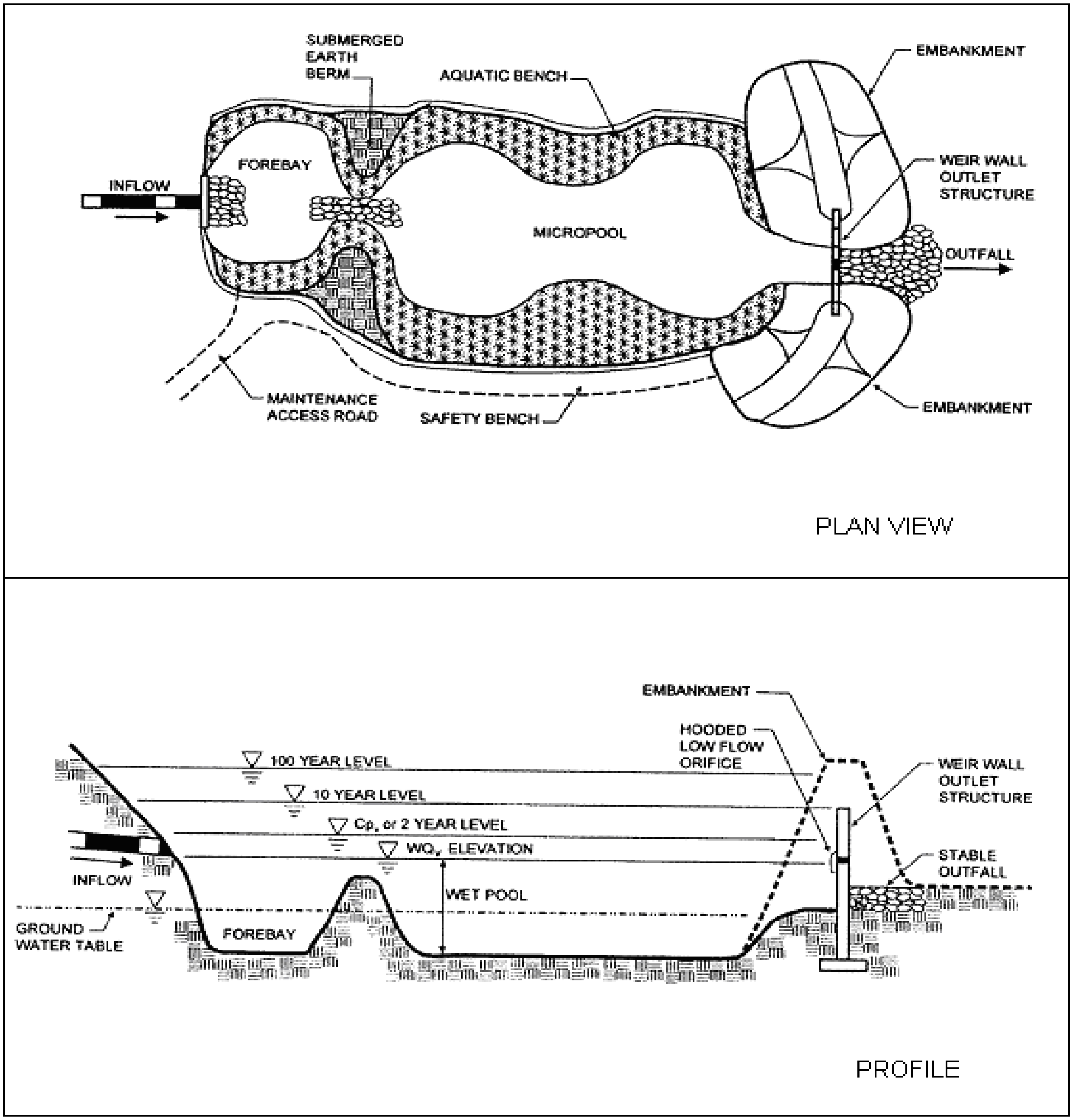


Figure 6.5 Pocket Pond



6.3.2 Site and Design Considerations

The following design and site considerations must be followed when designing a stormwater pond:

1. Design the pond with a minimum length to width ratio of 3:1 (preferably expanding outward toward the outlet). The length shall be considered along the flow path from the inlet (forebay outlet) to the pond outlet. Irregular shorelines for larger ponds also provide visual variety.
2. Maximize flow length between the inlet and outlet structure. Use baffles if short-circuiting cannot be prevented with inlet-outlet placement. Long flow paths and irregular shapes are recommended.
3. When designing the SQU for the contributing drainage area, assume that the entire upstream watershed is fully developed. When designing the SQU for the effective drainage area where offsite areas bypass the SQU, the design shall only consider the drainage from the site.
4. Provide a sediment forebay or other pretreatment upstream from the SQU inlet of the water quality structure.
    a. The forebay must be sized to contain 0.1 inches of runoff per impervious acre of contributing drainage. The forebay storage volume counts toward the total water quality storage requirements.
    b. Exit velocities from the forebay must be non-erosive.
    c. Direct maintenance access for appropriate equipment must be provided to the forebay.
    d. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
    e. A fixed vertical sediment depth marker must be installed in the forebay to measure sediment deposition over time. The marker must be constructed of materials to last the design life of the SQU.
    f. Sediment removal in the forebay shall occur when 50% of the total capacity has been lost.
5. Side slopes shall be no greater than 3:1 if vegetation is to be mowed.
6. Riprap protection must be provided (or other suitable erosion control means) for the outlet and all inlet structures into the pond.
7. The minimum drainage area (contributing or effective) for stormwater ponds is 25 acres. The minimum drainage area (contributing or effective) for a micro-pool extended detention facility is 10 acres. Wet extended detention ponds may be used for smaller drainage areas (<10 acres).
8. Anti-seep collars or filter diaphragms must be provided for the barrel of the principal spillway outlet.
9. If reinforced concrete pipe is used for the principal spillway outlet, O-ring gaskets (ASTM C361) shall be used to create watertight joints.
10. Provide a one (1) foot minimum freeboard above the maximum anticipated flow depth through the emergency spillway.
11. Design and install an emergency drain (i.e. sluice gate or drawdown pipe) capable of draining within 24 hours. When a physical drawdown method is not possible, a stormwater pump with a specific pumping rate to meet the drawdown time must be noted on the plans and in the O & M Manual.
12. The emergency spillway must be designed to pass 1.25 times the peak discharge runoff and peak flow velocity from the 100-year storm event for the entire contributing drainage area (unless bypassed), assuming post-development conditions.
13. Regional facilities must be constructed within a stormwater easement either platted or legally described and recorded as a perpetual stormwater easement a minimum of 20 feet horizontally outside of the design 100-year flood water elevation of the basin. Provide a 10-foot wide permanent access easement for all local ponds for long-term maintenance.
14. Provide a permanent benchmark applicable to the within the permanent pool and a sediment marker in the forebay for sediment removal.

15. The principal spillway/riser system must incorporate anti-floatation, anti-vortex, and trash-rack designs.
16. To prevent drawdown of the permanent pool, an impervious soil boundary may be needed.
17. Orifice-type outlets are not allowed below the permanent pool elevation of wet ponds and micropools.
18. Construction debris cannot be disposed of within the facility or used as fill in the embankment.
19. The SQU must be located within an easement. The easement must include access to the SQU for maintenance. A copy of the easement should be included in the digital copy of the SQU operations and maintenance manual.
20. If the pond is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the pond and elevations and grades have been reestablished as noted in the approved stormwater management plan for post-construction runoff control.
21. The final outfall design must include a means to capture floatable material and must include measures to prevent blockage / obstruction by debris such as trash racks, filters and , hoods.

6.3.3 Performance Standards

Wet ponds and variations designed, constructed and maintained as noted above can provide the following pollutant reductions:

Table 6.1 Performance Standards for Wet Ponds

Pollutant	Percent Reduction
BOD	30%
TSS	85%
Total P	50%
Total N	30%
Metals	30%

6.3.4 Advantages

1. High pollutant removal.
2. High community acceptance, if designed and maintained correctly.
3. Opportunity for wildlife habitat.
4. Multi-objective use for water quality and quantity control.
5. Decreased potential for downstream flooding and stream bank erosion.

6.3.5 Disadvantages

1. Potential for thermal impacts downstream.
2. Dam height restrictions.
3. Must evaluate potential for groundwater contamination.

6.3.6 Maintenance

Refer to the checklist provided in Appendix 1 for operation, maintenance and inspection of stormwater ponds. The checklist is for the use of the owner in performing routine inspections. The City will perform annual inspections of SQUs, using a similar checklist. The developer/owner is responsible for the cost of maintenance and annual inspections. See Section 6.2 for a schedule of fees. The SQU owner must maintain and update the SQU operations and maintenance plan. At a minimum, the operations and maintenance plan must include, but is not limited to:

1. Removal of debris from inlet and outlet structures.
2. Removal of invasive vegetation from all side slopes.
3. Removal of sediment accumulation from forebay and permanent pool area when it is 50% full.
4. Removal of woody vegetation from the embankment.

Regular maintenance is critical to the effective operation of stormwater ponds as designed. Maintenance responsibility for a pond and its buffer should 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 following table further describes the typical maintenance requirements associated with wet ponds.

Table 6.2 Typical Maintenance Activities for Wet Ponds (Source: WMI, 1997)

Activity	Schedule
• Clean and remove debris form inlet and outlet structures. • Mow side slopes.	Monthly and After Large Rainfall Events (>1 inch)
• If wetland components are included, inspect for invasive vegetation.	Semiannual Inspection
• Inspect for damage, paying particular attention to the control structure. • Check for signs of eutrophic conditions. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational. • Check all control gates, valves, or other mechanical devices.	Annual Inspection
• Repair undercut or eroded areas.	As Needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Removal of sediment from the forebay.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	10 to 20 years or after 25% of the permanent pool volume has been lost

Watershed Management Institute (WMI). 1997. Operation, Maintenance, and Management of Stormwater Management Systems. Prepared for the US EPA Office of Water. Washington, DC.

6.3.7 Landscaping

Aquatic vegetation can play an important role in pollutant removal in a stormwater pond. In addition, vegetation can enhance the appearance of the pond, stabilize side slopes and serve as wildlife habitat. Therefore, wetland plants should be encouraged in a pond design, along the aquatic bench, the safety bench and side slopes (ED ponds), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches of the normal pool elevation.

The following items should be considered when dealing with wetland plans:

1. Woody vegetation may not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
2. A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond.
3. Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs, and native ground covers.
4. 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 high that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. It is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.

6.4.1 Bioretention

6.4.1.1 General Description

Bioretention areas, or rain gardens, are structural stormwater controls developed in the early 1990's that capture and temporarily store the water quality volume using soils and vegetation in landscaped areas to remove pollutants from stormwater runoff. Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," consisting of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can be exfiltrated into the surrounding soil in areas with porous soils though exfiltration. This may not be permitted in a wellhead protection zoning district.

There are numerous design applications, both on- and off-line, for bioretention areas. These include use on single-family residential lots, as well as off-line facilities adjacent to parking lots, along highways and road drainage swales, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments. However, the structures are not suitable for regional stormwater quality or quantity control.

Bioretention facilities can provide a limited amount of water quantity control, with the storage provided by the facility included in the design of any downstream detention structures. Bioretention areas are designed for intermittent flow and to drain and aerate between rainfall events. Sites with continuous flow from groundwater, sump pumps or other areas must be avoided.

Bioretention areas consist of:

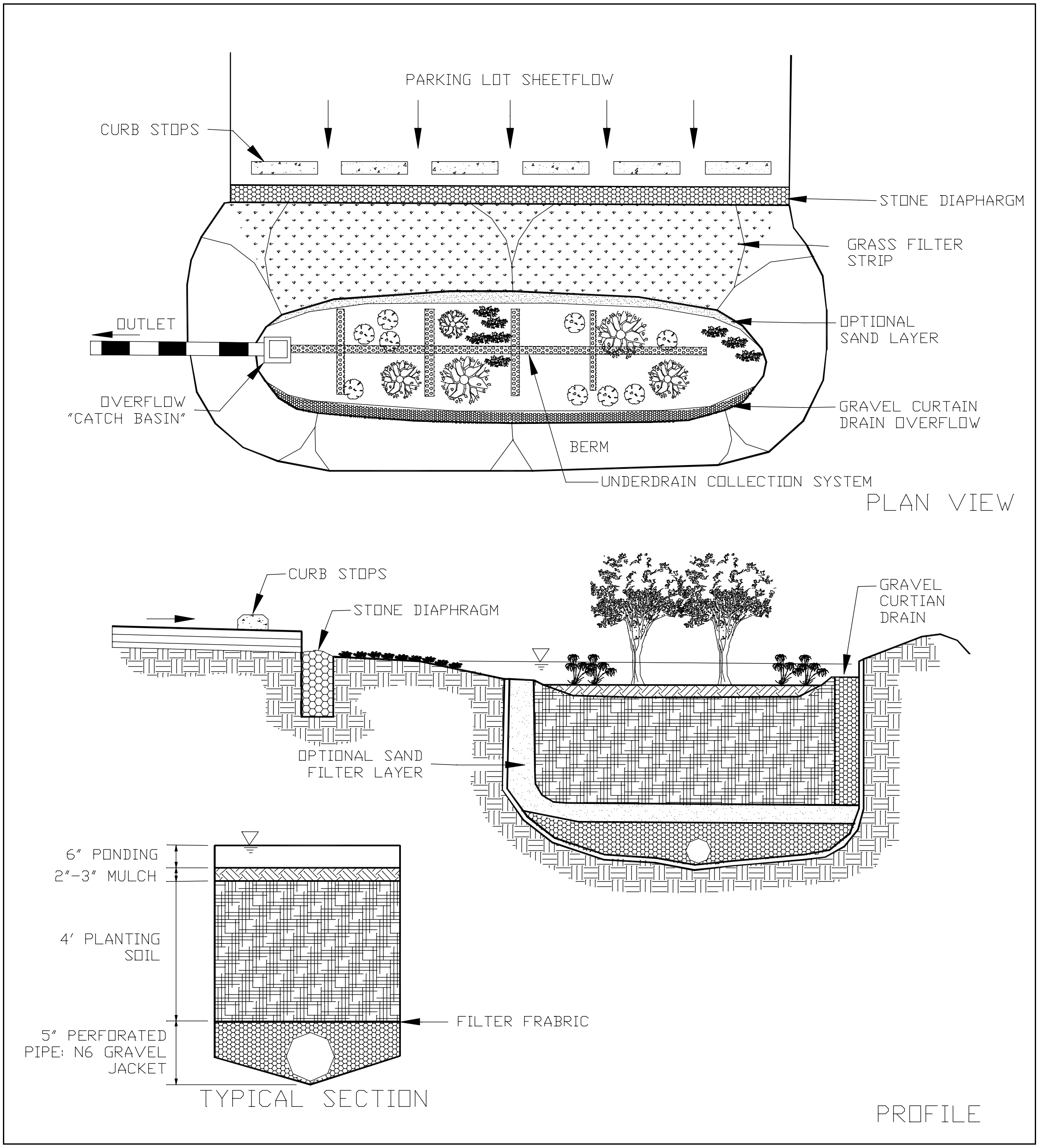
1. Grass filter strip between the contributing drainage area and the ponding area;
2. Ponding areas containing vegetation with a planting soil bed,
3. Organic/mulch layer, and
4. Gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil when a suitable evaluation of the site soil has been performed by a soil scientist).

Optional design components include:

1. Sand filter layer to spread flow, filter runoff and aid in aeration and drainage of the planting soil;
2. Stone diaphragm at the beginning of the grass filter strip to reduce velocities and spread flow into the grass filter;
3. Inflow diversion or an overflow structure.

Figure 6.6 provides an example of a bioretention area.

Figure 6.6 Bioretention Area



6.4.2 Site and Design Considerations

The following design and site considerations must be incorporated into the SQU plan including bioretention areas:

1. The drainage area (contributing or effective) must be 2 acres or less.

2. The minimum size for the facility is 200 ft^2, with a length to width ratio of 2:1. The slope of the site can be no more than 6%.
3. Planting soil filter bed is sized using a Darcy's Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day. The planting soil bed must be at least 4 feet deep. Planting soils must be sandy loam, loamy sand or loam texture with a clay content rating from 10 to 25 percent. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil should have a 1.5 to 3 percent organic content and a maximum 500-ppm concentration of soluble salts.
4. The maximum ponding depth in bioretention areas is 6 inches.
5. Filter strip design for pre-treatment must follow the requirements outlined in Section 6.6.1.1.
6. The mulch layer must consist of 2-4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.
7. The sand bed must be 12-18 inches thick. Sand must be clean and have less than 15% silt or clay content.
8. Pea gravel for the diaphragm and curtain, where used, must be ASTM D 448 size No. 6 (1/8" to 1/4").
9. The underdrain collection system must be equipped with a 6 inch perforated PVC pipe in an 8-inch gravel layer. The pipe must have 3/8-inch perforations, spaced on 6-inch centers with a minimum of 4 holes per row. The pipe is spaced at a maximum of 10 feet on center, and a minimum grade of 0.5% must be maintained. A permeable filter fabric is placed between the gravel layer and the planting soil bed. (See Figure 6.6 Bioretention Area)
10. The required elevation difference needed from the inflow to the outflow is 5 feet.
11. The depth from the bottom of the bioretention facility to the seasonally high water table must be a minimum of 2 feet. Boring or inspection by a soil scientist must document this.
12. Runoff captured by facility must be sheet flow to prevent erosion of the organic or mulch layer. Velocities entering the mulch layer must be between 1-2 fps.
13. Continuous flow from groundwater, sump pumps or other areas to the bioretention area is prohibited.
14. An overflow structure and a non-erosive overflow channel must be provided to safely pass the flow from the bioretention area that exceeds the storage capacity to a stabilized downstream area. The high flow structure within the bioretention area can consist of a yard drain catch basin, with the throat of the catch basin inlet typically 6 inches above the elevation of the shallow ponding area.
15. All components of the SQU must be located within an easement. Access to the SQU must be located within the SQU, if needed.
16. If the bioretention area is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the bioretention area and elevations and grades have been reestablished as noted in the approved stormwater management plan for post-construction runoff control Stormwater Management Ordinance.
17. The final outfall design must include a means to capture floatable material.

6.4.3 Performance Standards

Bioretention areas designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Table 6.3 Performance Standards for Bioretention Areas

Pollutant	Percent Reduction
TSS	81%
Total P	29%
Total N	49%
Metals	61%

6.4.4 Advantages

1. Applicable to small drainage areas.
2. Often located in landscape islands.
3. High pollutant removal.
4. High community acceptance, if designed and maintained correctly.
5. Able to provide shade, wind break, absorb noise, and improve landscape.

6.4.5 Disadvantages

1. Requires extensive landscaping.
2. Not recommended for areas with steep slopes.
3. Not appropriate for areas where water table is within 6 feet of the ground surface.
4. Potential for freezing can prevent runoff from infiltrating into the planting soil.

6.4.6 Maintenance

A SQU operations and maintenance plan is required for bioretention facilities. The plan must be approved by the City and maintained and updated by the SQU owner. Refer to Appendix 1 for a checklist for SQU owners for the routine operation, maintenance and inspection of bioretention areas. The City will perform annual SQU inspections, using a similar checklist. The SQU owner is responsible for maintenance costs and inspection fees. See Section 6.2 for the schedule of fees.

When bioretention basins are first placed into use they should be inspected on a monthly basis, and more frequently if a large storm occurs in between that schedule. Once it is determined that the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semi-annual basis with additional inspections following the occurrence of a large storm.

The facility should be observed after storms to ensure adequate drainage and water standing longer than 4 days will severely limit the growth of most plants and requires maintenance of the planting soils. Mosquitoes and other insects may start to breed as well. The microbial processes of the planting soil that remove nutrients will not work as well if the facility becomes waterlogged and anaerobic.

Trees and shrubs should be inspected twice per year. Any dead or severely diseased vegetation should be removed and replaced. Prune and weed to maintain the bioretention area’s appearance. Spot mulch when bare spots appear. Every two to three years the entire area should be remulched. One to two times a year, lime should be applied to counteract soil acidity resulting from the treated runoff.

Soil should be tested annually to detect toxic concentrations of pollutants. As toxins accumulate, they may impair plant growth and bioretention effectiveness, and soil replacement may be required.

6.4.7 Landscaping

Landscaping is critical to the performance and function of the bioretention area. A dense and vigorous groundcover must be established over the contributing pervious drainage area before runoff can be diverted into the facility.

1. The bioretention area should be vegetated like a terrestrial forest ecosystem, with a mature tree canopy, sub-canopy of understory trees, scrub layer and herbaceous ground cover. Three species of each tree and shrub type should be planted.
2. The tree-to-shrub ratio should be 2:1 to 3:1. On average, trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be planted at inflow locations.
3. After the trees and shrubs are established, the ground cover and mulch should be established.
4. Use native plants, selected based upon hardiness and hydric tolerance.

6.5.1 Water Quality Swales

6.5.1.1 General Description

Dry water quality swales are channels designed and constructed to capture and treat stormwater runoff within dry cells formed by check dams or other means. Dry water quality swales are also described as biofiltration swales. These swales are designed with a limited slope for slow, shallow flow to allow particulates to settle out and to promote infiltration. Water quality swales are limited to areas with low impervious acreage, such as residential and industrial developments.

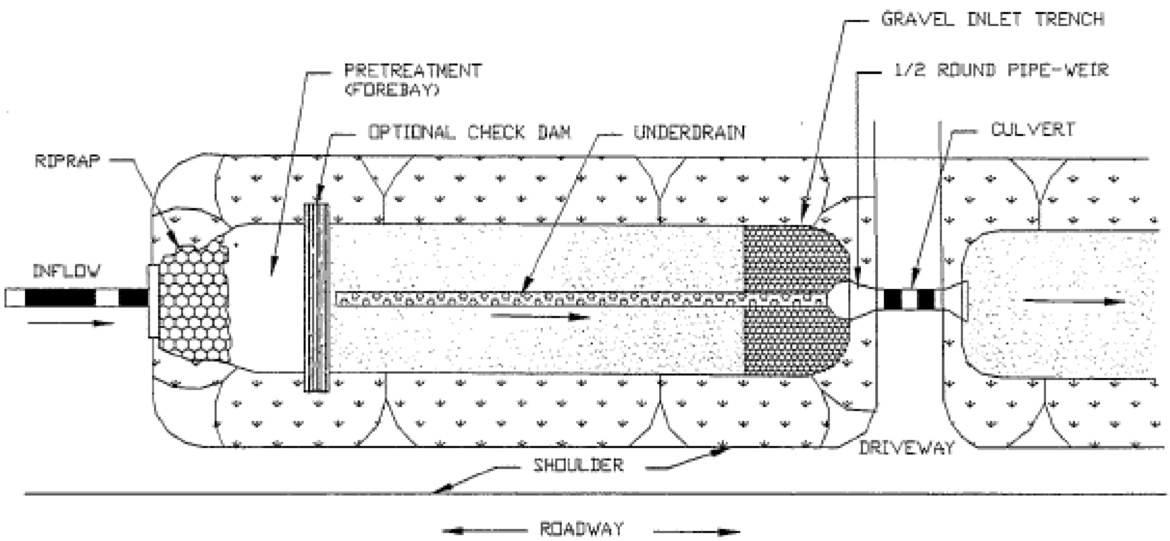
Dry water quality swales are channels designed with a filter bed and underdrain system. They are designed to filter and infiltrate the entire WQv through the bottom of the swale. Runoff is collected by a perforated pipe and discharged at the outlet. Water quality swales are dry most of the time and are therefore well suited for residential areas. Refer to Figure 6.7 for a schematic of a dry swale.

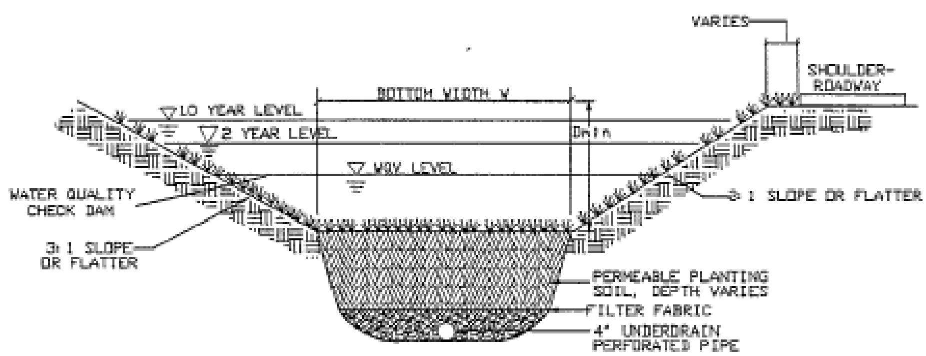
6.5.2 Site and Design Considerations

The following site and design criteria must be followed:

1. Water quality swales treat only the water quality volume. An additional measure is needed to provide detention in conjunction with the water quality swale. The swales can be designed as on-line or off-line structures. Larger storms must pass non-erosive through the channels.
2. Water quality swales are limited to peak discharges generally less than 5 to 10 cfs and runoff velocities less than 2.5 ft/sec for all storm events. The maximum drainage area is 5 acres. The maximum ponding time must be less than 48 hours, and a minimum ponding time of 30 minutes is recommended. Ponding greater than 38 hours requires maintenance of the planting soil.
3. The maximum design flow depth is 1 foot, with a ponding depth of 18 inches at the end of the channel.
4. The swale cross-section must have side slopes of 3:1 (h:v) or flatter. Bottom widths must be between 2-8 feet wide.
5. Underlying soils shall have a high permeability ($fc > 0.5$ inches per hour). Seasonally high water table must be greater than 2 feet below the bottom of the swale.
6. Water quality swales must have a minimum length of 100 feet.
7. Provide a sediment forebay must be provided at the inlet to the swales. The forebay should meet the requirements of Section 6.3.2 (item 4).
8. Locate the swale and all of its components within a drainage easement. The easement should include access to the SQU.
9. The maximum allowable length of a swale within a residential subdivision is 300 feet.
10. Swales must be completely sodded, well vegetated, and follow the natural, pre-development drainage path when possible.
11. Vegetation should be uniform with fine, turf-forming water-resistant grasses. Wetland vegetation should be used in areas with high groundwater and/or little slope. Vegetation examples include Sweet Flag, Iris, White Water Lily, Pickeral Weed and Arrowhead for wetland vegetation and/or Kentucky Blue Grass, or Bermuda Grass for sod.
12. Check dams may be used to enhance water quality and reduce velocities.
13. The final outfall design must include a means to capture floatable material.
14. A minimum of 18 inches of cover above the underdrain must be provided.

Figure 6.7 Dry Swale





6.5.3 Performance Standards

Water quality swales designed, constructed and maintained (on a 4% or flatter slope) as noted in this manual provide the following pollutant reductions:

Table 6.4 Performance Standards for Water Quality Swales

Pollutant	Percent Reduction
BOD	10%
TSS	80%
Total P	83%
Total N	92%
Metals	75%

6.5.4 Advantages

1. Typically well accepted in residential settings.
2. Inexpensive.
3. Combines water quality treatment with runoff conveyance.
4. Reduces runoff velocities.
5. Low maintenance.

6.5.5 Disadvantages

1. Cannot be used on steep slopes.
2. Can only provide a limited amount of stormwater quantity control.

6.5.6 Maintenance

Each SQU must have an operations and maintenance plan submitted to the City for approval and maintained and updated by the SQU owner. Refer to Appendix 1 for a checklist for SQU owner routine operation, inspection and maintenance of water quality swales. The City will perform annual inspections. The SQU owner shall be responsible for maintenance costs and the annual inspection fee.

1. A stormwater management easement and maintenance agreement is required for each facility. The maintenance covenant must require the owner of the grassed swale to periodically clean the structure. A copy of the easement should be included in the digital copy of the SQU operations and maintenance manual.
2. Provide adequate access for inspection and maintenance.
3. Dry swales shall be maintained to keep grass cover dense and vigorous.
4. At a minimum, maintenance shall include periodic mowing, occasional spot reseeding, and weed control. Swale grasses must never be mowed close to the ground. Grass heights in the 4 to 6 inch range are recommended.
5. Fertilization of grass swale shall be done when needed to maintain the health of the grass, with care not to over-apply the fertilizer.
6. Remove sediment accumulated in forebay when it is 50% full.
7. Water standing greater than 48 hours within the swale will require maintenance of the planting soils.

6.6 LIMITED APPLICATION CONTROLS

6.6.1 Biofilters

6.6.1.1 General Description

Biofilters are densely vegetated sections of land designed to treat runoff from and remove pollutants through vegetative filtering and infiltration. Biofilters must receive runoff from adjacent areas as sheet flow. The vegetation slows the runoff and filters out sediment and other pollutants. However, the TSS removal provided is less than 80 percent. Therefore, biofilters must be used in a treatment train in conjunction with other management practices to provide the 80 percent TSS removal performance goal and floatable debris removal requirements.

Biofilters are best suited to treating sheet flow runoff from roadways, rooftops, small parking areas and pervious areas. They can be easily incorporated into residential development as land-use buffers and setbacks. Biofilters should not be utilized in areas of concentrated flow.

Allowable Biofilter variations are filter strips and riparian buffers.

- **Filter strip**: A filter strip is a uniformly graded and densely vegetated strip of land. The vegetation can be grasses or a combination of grass and woody plants. Pollutant removal efficiencies are based upon a 50-foot wide strip. Refer to Figure 6.1.2.1-1 for a schematic of a filter strip. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion.

- **Riparian buffer**: A riparian buffer is a strip of land with natural, woody vegetation along a stream or other watercourse. Besides the undergrowth of grasses and herbaceous vegetation, the riparian buffer includes deep rooted trees. The 20- foot zone closest to the stream or watercourse (Zone 1) contains the trees, while the outer 30 feet of the riparian buffer contains a dense stand of grasses. The overall width of the riparian buffer is 50 feet. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion. Refer to Figure 6.8 for a schematic of a riparian buffer.

Figure 6.8 Filter Strip

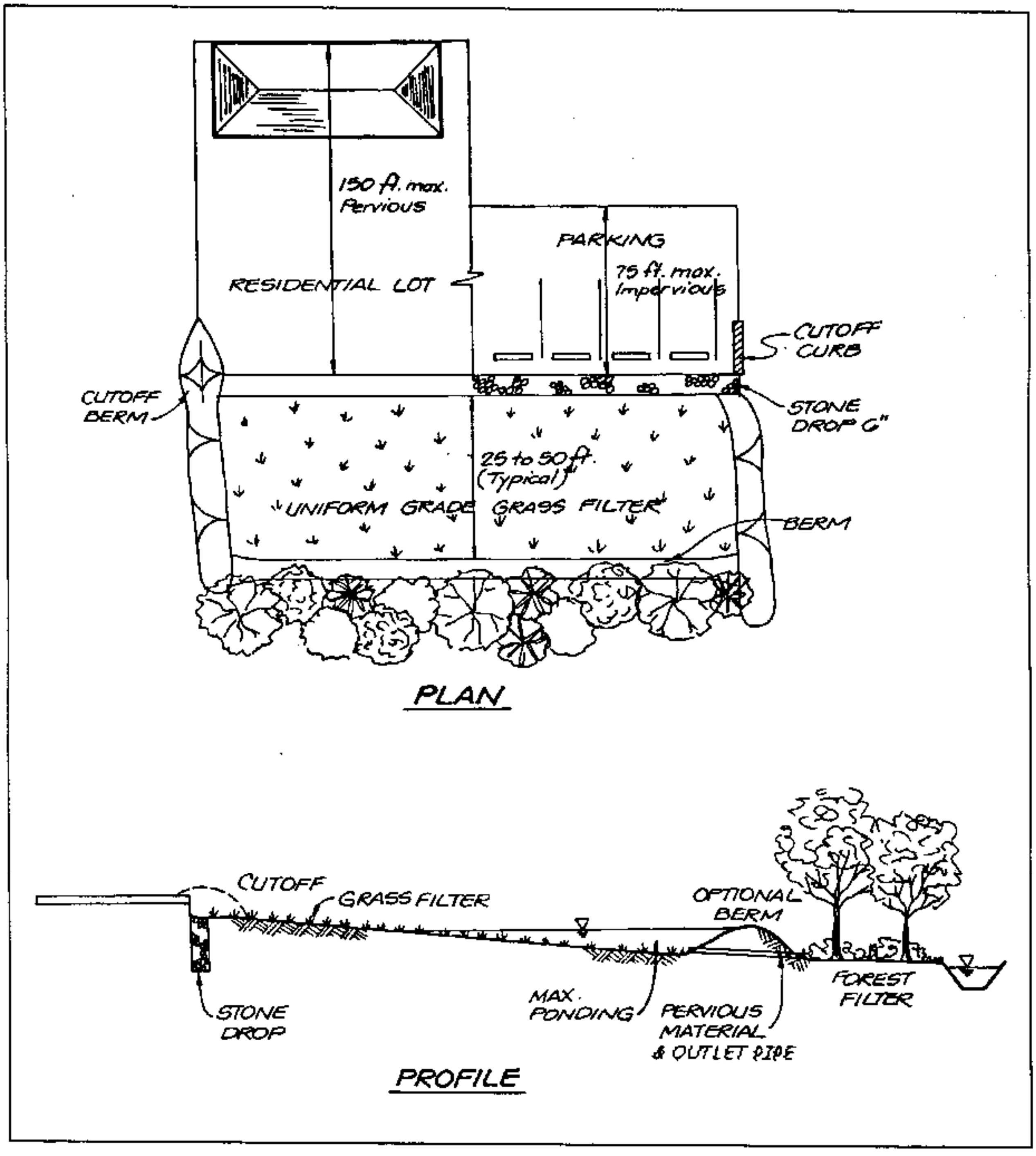
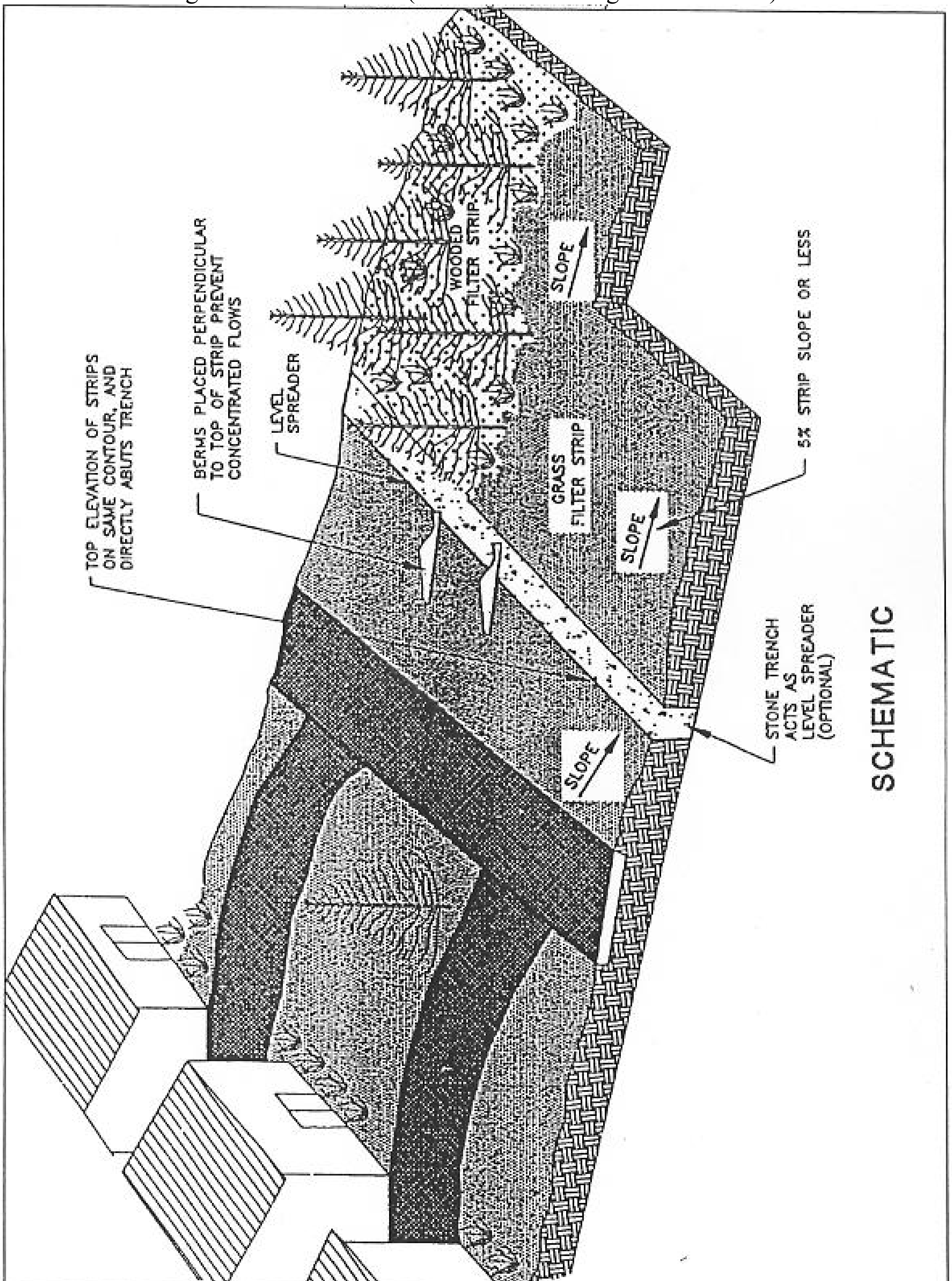


Figure 6.9 Buffer Area (Source: Controlling Urban Runoff)



6.6.2 Site and Drainage Considerations

The following site and drainage considerations must be included in the SQU plan for Biofilters:

1. To ensure sheet flow into the filter strips and riparian buffers, flow spreaders or level spreaders must be designed and installed where concentrated runoff flows into filter strips or riparian buffers.
2. Level Spreader: The grade of a level spreader shall be 0%. The channel grade for the last 20 feet of the dike or diversion entering the level spreader must be less than or equal to 1% and designed to provide a smooth transition into spreader. The depth of a level spreader as measured from the lip must be at least 6 inches. The level spreader lip must be constructed on undisturbed soil (not fill material) to uniform height and zero grade over length of the spreader. The maximum drainage area to the level spreader shall be 10 acres or less with the optimal size being less than 5 acres. The maximum flow into the level spreader must be 30 cfs or less.
3. Appropriate length, width, and depth of level spreaders shall be selected from the following table.

Design Flow (cfs)	Entrance Width (ft)	Depth (ft)	End Width (ft)	Length (ft)
0-10	10	0.5	3	10
10-20	16	0.6	3	20
20-30	14	0.7	3	30

4. Capacity of the spreader, filter strip and riparian buffer length (perpendicular to flow) must be determined by estimating the volume of flow that is diverted to the spreader for water quality control.
5. The released runoff to the outlet must be on undisturbed stabilized areas in sheet flow and not allowed to re-concentrate below the structure.
6. All disturbed areas must be vegetated immediately after construction.
7. The minimum filter strip width is 20 feet.
8. Filter strips must be designed for slopes between 2 percent and 6 percent.
9. Ensure that flows in excess of design flow move across and around the filter strip without damaging it.
10. Filter strips can be used effectively as pretreatment measures. The minimum sizing criteria are as follows:

Source: Claytor and Schueler, 1996

Parameters	Impervious Area				Pervious Area (lawns, etc.)			
Maximum Inflow Approach Length (ft)	35		75		75		100	
Filter Strip Slope (max = 6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter Strip Minimum Length	10	15	20	25	10	12	15	18

12. Riparian buffers: The use of buffers is limited to drainage areas of 10 acres or less with the optimal size being less than 5 acres.
13. Slope of the buffer from a level spreader cannot exceed 6 percent.
14. Top edge of buffer must directly abut the contributing impervious area and follow the same elevation contour line.
15. Biofilters and level spreaders must be located within a drainage easement. A copy of the easement should be included in the digital copy of the SQU operations and maintenance manual.
16. The final design must include a means to capture floatable material.

6.6.3 Performance Standards

Biofilters designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Table 6.5 Performance Standards for Biofilters

Pollutant	**Percent Reduction (riparian buffer in feet/filter strip)**
BOD	40/10%
TSS	60/30%
Total P	35/10%
Total N	25/10%
Metals	70/30%

6.6.4 Advantages

1. Filter strips and riparian buffers can easily be incorporated into new development design.
2. Low maintenance once a dense ground cover is established in filter strips and level spreaders and once trees and other woody vegetation are established in riparian buffers.
3. Riparian buffers provide wildlife habitat.

6.6.5 Disadvantages

1. Filter strips, riparian buffers and level spreaders have limited drainage areas.
2. Constructing a level lip on a level spreader can be difficult. Failure to construct a level lip makes the level spreader ineffective.
3. Capturing of floatable material in sheet flow requires additional design effort.

6.6.6 Maintenance

A SQU operations and maintenance plan is required for each SQU. The plan must be submitted to the City for approval and maintained and updated by the SQU owner. Refer to Appendix 1 for a SQU owner's routine checklist for inspection and maintenance of filter strips and riparian buffers. The City shall perform annual inspections, using a similar checklist. The SQU owner is responsible for maintenance costs and the annual inspection fee.

6.7 Porous Surfaces

6.7.1 General Description

Porous surfaces such as modular porous paver systems and porous concrete systems are permeable pavement surfaces with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil or is collected by an underdrain system. Porous concrete is a mixture of course aggregate, portland cement and water that allows for rapid infiltration of water. Modular porous paver systems consist of open void paver units laid on a gravel subgrade. The void spaces between the aggregates act as a storage reservoir for runoff. This reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system. Both porous concrete and porous paver systems provide water quality and quantity benefits, but has high workmanship and maintenance requirements, as well as high failure rates.

Modifications or additions to the standard porous concrete design have been used to pass flows and volumes in excess of the water quality volume, or to increase storage capacity or treatment. These include:

- Placing a perforated pipe near the top of the crushed stone reservoir to pass excess flows after the reservoir is filled.
- Providing surface detention storage in a parking lot, adjacent swale, or detention pond with suitable overflow conveyance.
- Connecting the stone reservoir layer to a stone filled trench.
- Adding a sand layer and perforated pipe beneath the stone layer for filtration of the water quality volume.
- Placing an underground detention tank or vault system beneath the layers.

Modular porous paver systems are structural units, such as concrete blocks, bricks, or reinforced plastic mats, with regularly interdispersed void spaces to create a load-bearing pavement surface. The void areas are filled with pervious materials, such as gravel, sand, or grass turf, to create a system that allows for the infiltration of stormwater runoff.

Porous surfaces such as porous concrete and porous pavers are typically used in low-traffic areas such as the following types of applications:

- Parking pads in parking lots
- Overflow parking areas
- Residential street parking lanes
- Recreational trails
- Golf cart and pedestrian paths
- Emergency vehicle and fire access lanes

6.7.2 Site and Design Considerations

The following site and drainage conditions must be considered when designing porous pavement:

1. Porous paver systems can include infiltration in the design where the underlying in-situ subsoils have an infiltration rate of between 0.5 and 3.0 inches per hour. Porous concrete systems can be used where the underlying in-situ subsoils have an infiltration rate greater

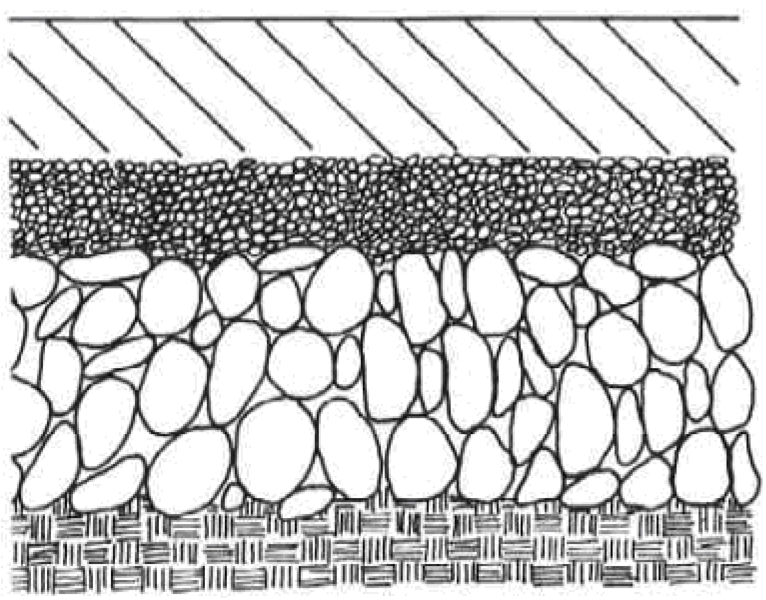
than 0.5 inches per hour. Therefore, porous surfaces are not suitable on sites with hydrologic group D or most group C soils, or soils with a high (>30%) clay content. During construction and preparation of the subgrade, special care must be taken to avoid compaction of the soils.

2. An underdrain should be provided where the soil frost zone includes the reservoir zone. When underdrains are required, the porous concrete / pavers and the underlying gravel storage should be designed as a detention structure.
3. Porous surfaces should typically be used in applications where the pavement receives tributary runoff only from impervious areas. Actual pervious surface area sizing will depend on achieving a 24 hour minimum and 48 hour maximum draw down time for the design storm volume. The ratio of the contributing impervious area to the porous paver surface area should be no greater than 3:1.
4. If runoff is coming from adjacent pervious areas, it is important that those areas be fully stabilized to reduce sediment loads and prevent clogging of the porous surface.
5. Pretreatment using filter strips or vegetated swales for removal of course sediments is recommended. (see subsection 6.6.1)
6. Porous concrete systems should not be used on slopes greater than 5% with slopes of no greater than 2% recommended. For slopes greater than 1%, barriers perpendicular to the direction of drainage should be installed in sub-grade material to keep it from washing away, or filter fabric should be placed at the bottom and sides of the aggregate to keep soil from migrating into the aggregate and reducing porosity.
7. Porous paver systems are not recommended on sites with a slope greater than 2%.
8. A minimum of four feet of clearance for porous concrete and two feet of clearance for porous pavers is recommended between the bottom of the gravel base course and underlying bedrock or the seasonally high groundwater table as determined by a geological boring or inspection by a soil scientist
9. Porous surfaces should be sited at least 10 feet down-gradient from buildings and 100 feet away from drinking water wells.
10. To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities must not be infiltrated. Porous concrete should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals. In addition, porous concrete should not be considered for areas with a high pesticide concentration. Porous concrete is also not suitable in areas with karst geology without adequate geotechnical testing by qualified individuals and in accordance with local requirements.
11. Porous surface designs must use some method to convey larger storm event flows to the conveyance system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface, but would accept bypass flows that are too large to be infiltrated by the porous surface, or if the surface clogs.
12. For the purpose of sizing downstream conveyance and structural control system, porous surfaces can be assumed to be 35% impervious.
13. For treatment control, the design volume should be, at a minimum, equal to the water quality volume. The water storage volume for porous concrete is contained in the surface layer, the aggregate reservoir, and the sub-grade above the seasonal high water table – if the sub-grade is sandy.
14. The storm duration (fill time) is normally short compared to the infiltration rate of the sub-grade. Critical storm duration should be used for design purposes. The total storage

volume in a layer is equal to the percent of voids times the volume of the layer. Alternately storage may be created on the surface through temporary ponding, though this would tend to accelerate clogging if course sediment or mud settles out on the surface.

15. The cross-section of porous concrete typically consists of four layers, as shown in Figure 6.10. The aggregate reservoir can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without bypassing the water quality volume. Descriptions of each of the layers is presented below:

Figure 6.5 Porous Concrete Pavement Section



<u>*Porous Concrete Layer*</u> – The porous concrete layer consists of an open-graded concrete mixture usually ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous concrete can be assumed to contain 18 percent voids (porosity = 0.18) for design purposes. Thus, for example, a 4 inches thick porous concrete layer would hold 0.72 inches of rainfall. The omission of the fine aggregate provides the porosity of the porous pavement. To provide a smooth riding surface and to enhance handling and placement, a coarse aggregate of 3/8 inches maximum size is normally used.

Details of construction of the concrete layer are beyond the scope of this manual. However, construction of porous concrete is exacting, and requires special handling, timing, and placement to perform adequately.

Top Filter Layer – Consists of a 0.5-inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt concrete layer. The top filter layer can be combined with reservoir layer using suitable stone.

Reservoir Layer – The reservoir gravel base course consists of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from 2 to 4 feet. The layer must have a minimum depth of 9 inches; it should be designed to drain completely in 48 hours, and should be designed to store at a minimum the water quality volume (WQv). Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations unless aggregate specific data exist.

Bottom Filter Layer – The surface of the subgrade should be a 6-inch layer of sand or a 2-inch layer of 0.5 inch crushed stone, and is completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and acts as the interface between the reservoir layer and the filter fabric covering the underlying soil.

Filter Fabric – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity.

Underlying Soil – The underlying soil should have an infiltration capacity of at least 0.5 in/hr, but preferably greater than 0.50 in/hr. as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils. Soils at the lower end of this range may not be suited for a full infiltration system.

Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, impervious substrata, and an initial estimate of permeability. Often a double-ring infiltrometer test is done at subgrade elevation to determine the impermeable layer, and, for safety, one-half the measured value is allowed for infiltration calculations.

The pit excavation should be limited to the width and depth specified in the design. Excavated material should be placed away from the open trench as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench should not be loaded so as to cause compaction, and should be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities should be protected during site construction, and should be constructed after upstream areas have been stabilized.

An observation well consisting of perforated PVC pipe 4 to 6 inches in diameter should be placed at the downstream end of the facility and protected. The well should be used to determine actual infiltration rates.

A warning sign should be placed at porous concrete facilities that states, "Porous Paving used on this site to reduce pollution. Do not resurface with non-porous material. Call (812) 376-2540 for more information."

14. A minimum of 40% of the porous paver surface area should consist of open void spaces. If it is a load-bearing surface, then the pavers should be able to support the maximum load.

15. The different layers for porous pavers should meet the following requirements:

    Porous Paver Infill – The porous paver infill is selected based upon the intended application and required infiltration rate. Masonry sand has a high infiltration rate and should be used in applications where no vegetation is desired. A sandy loam soil has a substantially lower infiltration rate, but will provide for growth of a grass ground cover.

    Top Filter Layer – A 1-inch top course (filter layer) of sand underlain by filter fabric is placed under the porous pavers and above the gravel base course.

    Reservoir Layer – The gravel base course should be designed to store at a minimum the WQv. The stone aggregate should be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations unless aggregate specific data exist.

    The gravel base course must have a minimum depth of 9 inches. The following equation can be used to determine if the depth of the storage layer (gravel base course) needs to be greater than the minimum depth:

    $$D = V / A * n$$

    Where:

    D = Gravel Layer Depth (feet)
    V = Water Quality Volume or Total Volume to be Infiltrated
    A = Surface Area (square feet)
    N = Porosity (use n=0.32)

    Bottom Filter Layer – The surface of the subgrade should be lined with filter fabric or an 8-inch layer of sand and be completely flat to promote infiltration across the entire surface. Floatable material capture must be incorporated into the overflow structure(s). In addition, regular removal of floatable / trash (e.g. weekly) from the porous surface must be addressed in the O & M Manual.

6.7.3 Performance Standards

Porous surfaces have a high removal of both soluble and particulate pollutants, where they become trapped, absorbed, or broken down in the underlying soil layers. Due to the potential for clogging, porous surfaces should not be used for the removal of sediment or other coarse particulate pollutants. Porous surfaces can provide the following pollutant reductions:

Table 6.6 Performance Standards for Porous Concrete Systems

Pollutant	**Percent Reduction (porous concrete, / porous paver)**
TSS	Not applicable
Total P	50/80%
Total N	65/80%
Metals	60/90%

6.7.4 Advantages

1. Volume reduction due to infiltration and groundwater recharge.
2. Blends into the normal urban landscape.
3. Allows a reduction in the cost of other stormwater infrastructure.

6.7.5 Disadvantages

1. Cost and complexity of porous concrete systems compared to conventional pavements.
2. High level of construction workmanship to ensure they function as designed.
3. High failure rate if not designed, constructed, and maintained properly.
4. Frequent, routine removal of floatable material / trash must be performed.

6.7.6 Maintenance

Table 6.7 Typical Maintenance Activities for Porous Concrete Systems

Activity	Schedule
• Initial inspection.	Monthly for three months after installation
• Ensure that the porous paver surface is free of sediment.	Monthly
• Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous concrete surface followed by high pressure hosing to keep pores free of sediment	Four times a year
• Inspect the surface for deterioration or spalling. • Check to make sure that the system dewaters between storms.	Annually
• Spot clogging can be handled by drilling half-inch holes through the pavement every few feet. • Rehabilitation of the porous concrete system, including the top and base course as needed.	Upon failure

Table 6.8 Typical Maintenance Activities for Porous Paver Systems

Activity	Schedule
• Ensure that the porous paver surface is free of sediment. • Check to make sure that the system dewaters between storms.	Monthly
• Ensure that contributing area and porous paver surface are clear of debris. • Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous paver surface to keep free of sediment.	Typically three to four times a year
• Inspect the surface for deterioration or spalling.	Annually
• Spot clogging can be handled by drilling half-inch holes through the pavement every few feet. • Totally rehabilitate the porous paver system, including the top and base course, as needed. .	Upon failure

6.8 Proprietary Systems

6.8.1 General Description

There are many types of commercially available proprietary stormwater structural controls available for both water quality treatment and quantity control. These systems include:

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures

Many proprietary systems are useful on small sites and space-limited areas where there is not enough land or room for other structural control alternatives. Proprietary systems can often be used in pretreatment applications in a treatment train. However, proprietary systems are often more costly than other alternatives and, may have high maintenance requirements and are rate limited. Perhaps the largest difficulty in using a proprietary system is the lack of adequate independent performance data, particularly for use in Indiana conditions. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

6.8.2 Guidelines for Using Proprietary Systems

Proprietary systems must be professionally certified and approved by the City Engineer prior to any construction or installation. The City ASTM standard methods must be followed when verifying performance of new measures. New BMPs should have low to medium maintenance requirements as directed by the City Engineer. In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the stormwater management goals for which it is being intended. This means that the system must provide:

1. Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection)
2. Proven record of longevity in the field
3. Results of Laboratory testing as described below.:

The City has adopted laboratory testing requirements for approval of rate limited SQUs. Manufacturers must submit laboratory results based on these requirements prior to approval for use. During the approval process, the accepted treatment rate is established for the unit(s) and well as specific design requirements. The current approved list and specific requirements can be found on the City website, http://www.columbus.in.gov/engineers-index.html. The design engineer must then determine the treatment flow rate required by the specific site conditions as described previously in this manual and choose an SQU with an approved flow rate less than or equal to the calculated rate from the approved list.

Field data should also be provided as available. Although local data is preferred, field data from other regions can be accepted as long as the design accounts for the local conditions. A poor performance record or high failure rate in the field is valid justification for not allowing the use of a proprietary system or device.

6.8.3 Infiltration Trench

6.8.3.1 General Description

Infiltration trenches, if installed properly, can remove suspended solids, particulate pollutants, coli form bacteria, organics, and some soluble forms of metals and nutrients from stormwater runoff. Infiltration trenches are excavated trenches, usually 3 to 12 feet deep, backfilled with a stone aggregate, and lined with filter fabric. A small portion of the runoff, usually the first flush, is diverted to the infiltration trench, which is located either underground or at grade. Pollutants are filtered out of the runoff as it infiltrates the surrounding soils. Infiltration trenches also provide groundwater recharge and preserve base flow in nearby streams.

6.8.3.2 Site and Design Considerations

1. Infiltration trenches should not be used in wellfield protection areas.
2. Infiltration trenches are often used in place of other SQUs where limited land is available.
3. Prior to trench construction, the City shall require design plan review. The design plans should include a geotechnical evaluation that determines the feasibility of using an infiltration trench at the site.
4. Soils should have a low silt and clay content and have infiltration rates greater than 0.5 inches per hour. Acceptable soil texture classes include sand, loamy sand, sandy loam and loam. These soils are within the A or B hydrologic group. Soils in the C or D hydrologic groups should be avoided. Soil survey reports published by the Soil Conservation Service can be used to identify soil types and infiltration rates. However, sufficient soil borings should always be taken to verify site conditions.
5. Feasible sites should have a minimum soil depth of 4 feet to bedrock in order to reduce excavation costs.
6. There should also be at least 4 feet below the trench to the water table to prevent potential ground water problems.
7. Trenches should also be located at least 100 feet upgradient from water supply wells and 100 feet from building foundations.
8. Land availability, the depth to bedrock, and the depth to the water table will determine whether the infiltration trench is located underground or at grade. Underground trenches receive runoff through pipes or channels, whereas surface trenches collect sheet flow from the drainage area. In general, infiltration trenches are suitable for drainage areas up to 10 acres (SEWRPC, 1991, Harrington, 1989). However, when the drainage area exceeds 5 acres, other SQUs should be carefully considered.
9. The drainage area must be fully developed and stabilized with vegetation before constructing an infiltration trench. High sediment loads from unstabilized areas will quickly clog the infiltration trench. Runoff from unstabilized areas should be diverted away from the trench into a construction SQU until vegetation is established.
10. The final design must include a means to capture floatable material and routine removal of the debris must be addressed in the O & M Manual.

6.8.3.3 Performance Standards

Infiltration trenches function similarly to rapid infiltration systems that are used in wastewater treatment. Estimated pollutant removal efficiencies from wastewater treatment performance and modeling studies are shown in Table 6.9. Based on this data, infiltration trenches can be expected to remove up to 90 percent of sediments, metals, coli form bacteria and organic matter, and up to 60 percent of phosphorus and nitrogen in the runoff (Schueler, 1992). Biochemical oxygen demand (BOD) removal is estimated to be between 70 to 80 percent. Lower removal rates for nitrate, chlorides and soluble metals should be expected. Using washed aggregate and adding organic matter and loam to the subsoil may improve pollutant removal efficiencies. The stone aggregate should be washed to remove dirt and fines before placement in the trench. The addition of organic material and loam to the trench subsoil will enhance metals and nutrient removal through adsorption.

Table 6.9 Performance Standards for Infiltration Trench

Pollutant	**Percent Reduction (Infiltration trench)**
TSS	90%
Total P	60%
Total N	60%
Metals	90%
BOD	70-80%
Bacteria	90%
Organics	90%

6.8.3.4 Advantages

1. Provides efficient removal of suspended solids, particulate pollutants, coli form bacteria, organics and some soluble forms of metals and nutrients from stormwater runoff.
2. The captured runoff infiltrates the surrounding soils and increases groundwater recharge and base flow in nearby streams.

6.8.3.5 Disadvantages

1. Potential for groundwater contamination.
2. High likelihood of early failure if not properly maintained.
3. Frequent removal of floatable / trash must be performed.

6.8.3.6 Maintenance

Infiltration trenches, as with all SQUs, must have routine inspection and maintenance designed into the life performance of the facility. Maintenance should be performed as indicated by these routine inspections. The principal maintenance objective is to prevent clogging, which may lead to trench failure. Infiltration trenches and any pretreatment SQUs should be inspected after large storm events and any accumulated debris or material should be removed. A more thorough inspection of the trench should be conducted at least annually. Annual inspection should include monitoring of the observation well to confirm that the trench is draining within the specified time. Trenches with filter fabric should be inspected for sediment deposits by removing a small section of the top layer. If inspection indicates that the trench is partially or completely clogged, it should be restored to its design condition. When vegetated buffer strips are used, they should be inspected for erosion or other damage after each major storm event. The vegetated buffer strip should have healthy grass that is routinely mowed. Trash, grass clippings and other debris should be removed from the trench perimeter and should be disposed properly. Trees and other large vegetation adjacent to the trench should also be removed to prevent damage to the trench.

6.8.4 Modular Treatment Systems

6.8.4.1 General Description

The StormTreat^{TM} System (STS) is a primary modular water treatment systems. STS consists of a series of sedimentation chambers and constructed wetlands. The STS is a 9.5 feet diameter recycled-polyethylene tank. As the influent enters the system it enters the sedimentation chambers where pollutants are removed via sedimentation and filtration. From the sedimentation chambers, the stormwater is conveyed to the subsurface of the constructed wetland and through the root zone where the pollutants are then removed through filtration, adsorption, and biochemical reactions. Stormwater is retained in the wetland for five to ten days prior to discharge.

The STS is appropriate for residential areas and most industrial parks but is not designed to be used directly in wastewater streams.

6.8.4.2 Site and Design Considerations

1. The wetland has an approximate storage capacity of 760 gallons. The entire system has a static holding volume of 1,390 gallons. However, the system is sized based upon this volume plus associated detention structures.
2. Vegetation within the wetland will vary depending on the local conditions. Bulrush and burreeds are two species typically used in the constructed wetland and they typically have maximum root depths of 2.6 and 2 feet, respectively (U.S. EPA, 1993).
3. Mature vegetation in the outer ring should have roots that extend into the permanent 6 inches of water in the bottom of the tank. Insufficient root depth may result in a lack of water supply to the plants during the periods between storm events. Effluent from the wetland is discharged through a 2-inch diameter pipe that is controlled by a valve.
4. Flow rates and holding times are controlled by manipulating the outlet control valve. The valve has an added benefit that in the event of an upstream toxic spill; it can be closed, trapping the pollutants in the STS. Tanks are available in one size, but several tanks can be installed at a site to capture the projected volume of runoff. The determination of the number of tanks needed for a site is based on three factors:

    - Area of impervious drainage surfaces.
    - Design storm to be treated.
    - Detention storage prior to the STS tanks.

    Generally 1-2 units are required for each acre of impervious surface. The system is sized based upon the design storm, which is determined by state regulations. This first flush storage volume is stored in preliminary storage structures such as underground tanks and large diameter pipes (which can be placed under parking areas).

6.8.4.3 Performance Standards

Analyzes of the runoff has shown that pollutant removal efficiencies in Table 6.10 may be expected.

Table 6.10 Performance Standards for Modular Treatment Systems

Pollutant	Percent Reduction
TSS	99%
Total P	90%
Total N	77%
Metals	90%
COD	82%
Bacteria	97%
Metals	70-90%

6.8.4.4 Advantages

1. Protects groundwater by removing pollutants prior to infiltration.
2. Spill containment feature can capture upstream releases.
3. High pollutant removals.

6.8.4.5 Disadvantages

There may be possible limitations in different areas, although soil types and high water tables surrounding the modular unit will not limit the system's effectiveness.

6.8.4.6 Maintenance

The system should be observed at least once a year to be sure that it is operating effectively. At that time, the burlap sack that covers the influent line should be replaced. If the installed system uses filters, these should be removed, cleaned, and reinstalled. Sediment should be removed from the system once every three to five years, more often if the system has higher than normal sediment loads. The sediment level may be measured with a probeIt is recommended that the sediment be removed when 1 foot of sediment has accumulated. The sediment can be pumped from the tank by septic haulers or by maintenance personnel responsible for sediment removal from catch basins. Sediment needs to be disposed of properly.

6.9 DETENTION ONLY CONTROLS

6.9.1 Dry Detention Basins

6.9.1.1 General Description

Dry detention and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events.

Dry detention basins are intended to provide overbank flood protection, designed to control the extreme flood (100-year, Qf) storm event. Dry ED basins provide downstream channel protection through extended detention. Both dry detention and dry ED basins provide limited pollutant removal benefits and are not intended for water quality treatment. Detention-only facilities must be used in a treatment train approach with other structural controls that provide treatment of the WQv. Additional water quality measures should be provided upstream of a dry detention facility or downstream if the dry-detention facility is designed to function as a forebay.

6.9.1.2 Site and Design Considerations

1. Dry detention basins are sized to temporarily store the volume of runoff required to provide overbank flood protection controlling the 100-year storm.
2. Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 2:1 (horizontal to vertical) although 3:1 is preferred. Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Indiana guidelines for dam safety.
3. The maximum depth of the basin should not exceed 10 feet.
4. Areas above the normal high water elevations of the detention facility should be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The bottom area of storage facilities should be graded toward the outlet to prevent standing water conditions. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.
5. Adequate maintenance access must be provided for all dry detention and dry ED basins.
6. Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. A sediment forebay sized to 0.1 inches per impervious acre of contributing drainage should be provided for dry detention and dry ED basins to prevent loss of volume from sedimentation.
7. Seepage control or anti-seep collars should be provided for all outlet pipes.
8. Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion. If the basin discharges 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.
9. An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the

embankment and causing structural damage. The emergency spillway must be designed to State of Indiana guidelines for dam safety and must be located so that downstream structures will not be impacted by spillway discharges.

10. A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood, to the lowest point of the dam embankment not counting the emergency spillway.

6.9.1.3 Advantages

1. Typically less costly than stormwater wet ponds for equivalent storage.
2. Recreational and other open space opportunities between storm runoff events.

6.9.1.4 Disadvantages

1. Not intended to provide water quality treatment

6.9.1.5 Maintenance

Table 6.11 Typical Maintenance Activities for Dry Detention and Extended Detention Basins

Activity	Schedule
• Remove debris from basin surface to minimize outlet clogging and improve aesthetics.	Annually and following significant storm events
• Remove sediment buildup. • Repair and revegetate eroded areas. • Perform structural repairs to inlet and outlets.	As needed, based on inspection
• Mow to limit unwanted vegetation.	Routine

6.10 Multi-purpose Detention Areas

6.10.1 General Description

Multi-purpose detention areas are site areas primarily used for one or more specific activities that are also designed to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. Example of multi-purpose detention areas include:

- Parking Lots
- Rooftops
- Sports Fields
- Recessed Plazas

Multi-purpose detention areas are normally dry between rain events, and by their very nature must be usable for their primary function the majority of the time. As such, multi-purpose detention areas should not be used for extended detention. Multi-purpose detention areas are not intended for water quality treatment and must be used in a treatment train approach with other structural controls that provide treatment of the WQv. Additional water quality measures should be provided upstream of a multi-purpose detention facility.

6.10.2 Site and Design Considerations

1. Location

   Multi-purpose detention areas can be located upstream or downstream of other structural stormwater controls providing treatment of the water quality volume (WQv).

2. General Design
   - Multi-purpose detention areas are sized to temporarily store a portion or all of the volume of runoff required to provide flood protection controlling the 100-year storm release. Routing calculations must be used to demonstrate that the storage volume is adequate.
   - All multi-purpose detention facilities must be designed to minimize potential safety risks, potential property damage, and inconvenience to the facility's primary purposes. Emergency overflows are to be provided for storm events larger than the design storm. The overflow must not create a significant adverse impact to downstream properties or the conveyance system.

3. Parking Lot Storage
   - Parking lot detention can be implemented in areas where portions of large, paved lots can be temporarily used for runoff storage without significantly interfering with normal vehicle and pedestrian traffic. Parking lot detention can be created in two ways: by using ponding areas along sections of raised curbing, or through depressed areas of pavement at drop inlet locations.
   - The maximum depth of detention ponding in a parking lot, except at a flow control structure, should be 6 inches for a 10-year storm, and 9 inches for a 100-year storm. The maximum depth of ponding at a flow control structure is 12 inches for a 100-year storm.
   - The storage area (portion of the parking lot subject to ponding) must have a minimum slope of 0.5% towards the outlet to ensure complete drainage following. A slope of 1% or greater is recommended.

- Fire lanes used for emergency equipment must be free of ponding water for runoff events up to the storm (100-year) event.
- Flows are typically backed up in the parking lot using a raised inlet.

4. Rooftop Storage
   - Rooftops can be used for detention storage as long as the roof support structure is designed to address the weight of ponded water and is sufficiently waterproofed to achieve a minimum service life of 30 years. All rooftop detention designs must meet Indiana State Building Code and local building code requirements. Certification by a licensed structural engineer for the design should be provided with all rooftop storage plans.
   - The minimum pitch of the roof area subject to ponding is 0.25 inches per foot.
   - The rooftop storage system must include another mechanism for draining the ponding area in the event that the primary outlet is clogged.

5. Sports Fields
   Athletic facilities such as football and soccer fields and tracks can be used to provide stormwater detention. Constructing berms around the facilities accomplish this, which in essence creates very large detention basins. Outflow can be controlled through the use of an overflow weir or other appropriate control structure. Proper grading must be performed to ensure complete drainage of the facility.

6. Public Plazas
   In high-density areas, recessed public common areas such as plazas and pavilions can be utilized for stormwater detention. These areas can be designed to flood no more than once or twice annually, and provide important open recreation space during the rest of the year.

6.10.3 Performance Standards
The performance standards will vary with the system used. The designing engineer will provide guidelines and performance standards with references to other facilities used in other areas. The City Engineer/MS4 Operator shall approve these methods in the agreement.

6.10.4 Advantages
- Good in densely populated urban areas.
- Provides channel and flood protection.
- Allows for multiple uses of site areas and reduces the need for downstream detention facilities.

6.10.5 Disadvantages
- Controls for stormwater only-not intended to provide water quality treatment. Will need additional structures for water quality.
- Adequate grading and drainage must be provided to allow full use of facility’s primary purposes following a storm event
- Used in conjunction with water quality structural control.

6.10.6 Maintenance

Maintenance will vary with the application used. An operation and maintenance plan shall be supplied by the licensed engineer/architect that is approved by the City Engineer/MS4 Operator.

Table 6.12 Typical Maintenance Activities for Multi-Purpose Systems

Activity	Schedule
• Remove debris from ponding area to minimize outlet clogging and improve aesthetics.	Annually and following significant storm events
• Remove sediment buildup. • Repair and revegetate eroded areas. • Perform structural repairs to inlet and outlets.	As needed based on inspection
• Perform additional maintenance activities specific to the type of facility.	As required

6.11 Underground Detention

6.11.1 General Description

Detention tanks and vaults are underground structures used to attenuate peak stormwater flows. They are usually constructed out of either concrete vaults or various pipe materials and must consider the potential loading from vehicles on the vault or pipe. Pretreatment structures must be used at the inlet of an underground detention facility to treat stormwater runoff and remove trash and debris prior to storage.

6.11.2 Site and Design Considerations

i. The systems used for large storage volumes are usually a series of pipes interconnected by a junction box or main pipe with an outfall structure. There should be a sufficient number of access holes and access points in the system to efficiently inspect and maintain both the outfall structure and the storage area. Each pipe run should have access at each end for maintenance and inspection. Whenever possible, the system should be located in an area where maintenance and potential repairs can be conducted with minimal disturbance to surrounding uses.

ii. Water quality controls, such as water quality inlets and sand filters, are often used to pretreat the stormwater before it enters the system. This is done to remove sediment and pollutants, which might clog the system. The systems can work in conjunction with infiltration to provide additional stormwater treatment.

iii. When infiltration is used, perforations may be added to the pipe to allow the pipe to store the water until it can be exfiltrated into the soils below the pipe. In critical areas, such as under roads and parking lots, pipe joints may require gaskets and watertight seals to protect the integrity of the pipe. Most systems have pipes or vaults inverts that are 1.8 to

3 m (6 to 10 ft) underground. Therefore, it may be difficult to obtain an adequate outfall for the system.

iv. Another type of underground detention is the retrofitting of overcapacity storm drain pipes with baffles. The baffles cause the water to be stored in the pipes and to be released to the outfall at a slower rate (ASCE, 1992).

6.11.3 Performance Standards

Underground detention structures are effective measures for stormwater runoff quantity control; however, these facilities do not provide significant water quality control or primary stormwater treatment, without extensive modifications. Consequently, they are more frequently used to attenuate and store peak flows. In addition to providing insignificant stormwater treatment without modifications, receiving waters can be very sensitive to releases of the stored volume from these underground detention systems. Preliminary results of water quality monitoring of modified underground detention structures are shown in Table 6.13 below

Table 6.13 Performance Standards for Underground Detention

Pollutant	**Percent Reduction**
TSS	60-80%
Total P	20-40%

6.11.4 Advantages

1. Supply a large storage volume for stormwater runoff.

6.11.5 Disadvantages

1. Structures must be able to withstand big large loads, or it is subject to load failure.
2. Facility requires weekly maintenance and cleaning out of the structure to maintain its efficiency.
3. High cost of construction and maintenance.

6.11.6 Maintenance

The cost and maintenance of these systems are major considerations. The systems must be designed so that they can have easy access for inspection and maintenance. Maintenance is usually conducted by periodically pumping out sediments and debris. In areas of high sediment flows, pretreatment is required to minimize the inflow of particulates so that the need to clean the system is reduced. An analysis of other management measures in the watershed is required to ensure that peak release rates are coordinated so that peak flows are reduced to predevelopment rates.

With the facilities located underground, inspection and maintenance are important issues because of the relatively high costs. In the ultra-urban environment, the facilities may require location under structures, such as buildings, parking lots, and roadways. Frequent maintenance is required to remove sediment and debris and to ensure that the outlet structure is functioning properly. Large-scale removal of accumulated sediment in the system may be difficult due to limited access. In addition, underground systems will be considered confined spaces that require additional safety requirements for inspection and maintenance.

6.12 STORMWATER SQU SELECTION

The City of Columbus offers this section to assist in the selection of stormwater quality SQUs for use within its corporate boundaries. This section presents matrices that can be used as a screening process to select the best SQU or group of SQUs for a development or redevelopment site. The SQUs listed in the matrices have been determined to be widely accepted by the City Engineer and should be considered to be pre-approved for use within the City of Columbus if all necessary and appropriate design criteria and guidelines are met.

The matrices presented below can be used to screen practices in a step-wise fashion. The screening factors include:

1. Land Use
2. Physical Feasibility
3. Community and Environmental Factors

The three matrices presented here are not exhaustive. Specific additional criteria may be incorporated or considered depending on enhanced local design knowledge, experience and resource protection goals. 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

In this step, the designer/engineer makes an initial screen of practices most appropriate for a given land use. The different types of land use are described as follows:

Rural. This column identifies SQUs 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.

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

Downtown Sites. This column identifies SQUs that work well in an ultra-urban environment, where space is limited and original soils have been disturbed. These SQUs are also frequently used at redevelopment sites.

Table 6.14 Land Use Selection Matrix

SQU Group	SQU Design	Rural	Residential	Commercial/ High Density	Downtown
Pond	Micropool ED	**1**	**1**	**2**	**3**
	Wet Pond	**1**	**1**	**2**	**3**
	Wet Pond ED	**1**	**1**	**2**	**3**
	Multiple Pond	**1**	**1**	**2**	**3**
	Pocket Pond	**1**	**2**	**2**	**3**
Filtration	Bioretention	**2**	**2**	**1**	**1**
	Filter Strip	**2**	**2**	**2**	**3**
	Riparian Buffer	**1**	**1**	**1**	**1**
	Porous Surface	**1**	**1**	**2**	**2**
Open Channels	Dry Swale	**1**	**2**	**1**	**2**
	Structural Interceptors	**2**	**2**	**1**	**1**

1: Yes. Good option in most cases.
2: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
3: No. Seldom or never suitable.

Step 2-Physical Feasibility Factors

In this step, the designer/engineer screens the SQU list to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of the SQU. The five primary physical conditions are described as follows:

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.

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

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 (base flow 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 6.15 Physical Feasibility Matrix

SQU Group	**SQU Design**	**Soils**	**Water Table**	**Drainage Area (acres)**	**Site Slope**	**Head (ft)**
Pond	Micropool ED	May require a 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
Filters	Bioretention	OK	2 feet[3]	5 max[2]	No more than 6%	5 ft
	Filter Strip	OK	Above WT	5max	2% – 6%	Concentrated Depth no more than 2.5 in
	Riparian Buffer	OK	Above WT	10 max	No more than 10% from level spreader	Sheet flow
	Porous Surface	OK	Above WT	5 max	2%-5%	Site specific
Open Channels	Dry Swale	Manufactured Soil	Above WT	5 max[2]	No more than 6%	3 to 5 ft
Proprietary System		OK	Structure specific	Structure specific	Structure specific	Structure specific

Notes:
1: Unless adequate water balance and anti-clogging device installed.
2: Drainage area can be larger in some instances.
3: If designed with a permeable bottom, must meet the depth requirements for infiltration practices.

Step 3 Community and Environmental Factors

In this step, a matrix is used to compare the SQU options with regard to maintenance, community acceptance, safety and habitat considerations. These community and environmental factors are described as follows:

Ease of Maintenance. This column assesses the relative maintenance effort needed for an SQU, 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 SQUs require routine inspection and maintenance.

*Community Acceptanc*e. 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 could often be improved by a better landscaping plan.

Safety. A comparative index that expresses the relative safety of an SQU. An open circle indicates a safe SQU, while a circle with and "x" 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. SQUs 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 SQU and its buffer.

Table 6.16 Community and Environmental Factors

SQU Group	SQU List	Ease of Maintenance	Community Acceptance	Safety	Habitat
Ponds	Micropool ED	**2**	**2**	**1**	**2**
	Wet Pond	**1**	**1**	**3**	**1**
	Wet ED Pond	**1**	**1**	**3**	**1**
	Multiple Pond	**1**	**1**	**3**	**1**
	Pocket Pond	**3**	**2**	**2**	**3**
Filters	Bioretention	**2**	**2**	**1**	**2**
	Filter Strip	**2**	**1**	**1**	**2**
	Riparian Buffer	**2**	**1**	**1**	**1**
	Porous Surface	**2**	**1**	**1**	**3**
Open Channels	Dry Swale	**1**	**1**	**1**	**2**
Structural Interceptors		**1**	**1**	**1**	**3**

1: Yes. Good option in most cases.
2: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
3: No. It is seldom or never suitable.

6.13 LANDSCAPING GUIDANCE

6.13.1 GENERAL

Below are general guidelines that should be followed in the landscaping of any stormwater control or conveyance facility.

DO NOT:

- Plant trees, shrubs or any type of woody vegetation on an embankment
- Plant trees and shrubs within 15 feet of the toe of slope of a dam.
- Plant trees or shrubs known to have long tap roots within the vicinity of the earthen dam or embankment, or subsurface drainage facilities.
- Plant trees and shrubs within 25 feet of a principal spillway structure (e.g., riser)
- Plant trees and shrubs within 25 feet of perforated pipes.
- Block maintenance access to structures with trees or shrubs.

DO:

- Take into account site characteristics and plant selection guidelines when selecting plants for stormwater facilities.
- Consider how plant characteristics will affect the landscape and the performance of a structural stormwater control or conveyance.
- Carefully consider the long-term vegetation management strategy for the structural control, keeping in mind the maintenance legacy for the future owners.
- Preserve existing natural vegetation when possible.
- Avoid the overuse of any plant materials.
- Have soils tested to determine if there is a need for amendments.
- Select plants that can thrive in on-site soils with no additional amendments or a minimum of amendments.
- Consider water availability, particularly for wetland and water-intensive plantings.
- Decrease the areas where turf is used. Use low maintenance ground cover to absorb run-off.
- Plant stream and edge of water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade.
- Provide slope stabilization methods for slopes steeper than 2:1, such as planted erosion control mats. Also, use seed mixes with quick germination rates in this area. Augment temporary seeding measures with container crowns or root mats of more permanent plant material.
- Utilize erosion control mats and fabrics to protect in channels that are subject to frequent washouts.
- Stabilize all water overflows with plant material that can withstand strong current flows. Root material should be fibrous and substantial but lacking a taproot.
- Sod area channels that are not stabilized using erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Check water tolerances of existing plant materials prior to inundation of area.
- Stabilize aquatic and safety benches with emergent wetland plants and wet seed mixes.
- Provide a 15-foot clearance from a non-clogging, low flow orifice.

- Limit herbaceous embankment plantings to 10 inches in height, to allow visibility for the inspector who is looking for burrowing rodents that may compromise the integrity of the embankment.
- Shade inflow and outflow channels, as well as the southern exposures of pond, to reduce thermal warming
- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area).
- Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen or buffer unattractive views into the site.
- Use plants to prohibit pedestrian access to pools or slopes that may be unsafe.
- Keep maintenance area open to allow future access for pond maintenance.
- Provide a planting surface that can withstand the compaction of vehicles using maintenance access roads.
- Make sure the facility maintenance agreement includes a maintenance requirement of designated plant material.
- Provide signage for:
  - Stormwater management facilities to help educate the public
  - Wildflower areas to designate limits of mowing
  - Preserving existing natural vegetation

6.13.2 SITE CONSIDERATIONS

A development site's characteristics often will help to determine which plant materials and planting methods the site designer should select and will help improve plant establishment.

Primary site considerations include:

1. Soil Characteristics
2. Drainage
3. Slope
4. Orientation

Soil Characteristics
Plant establishment and growth can be limited by a number of different soil characteristics including:

- Soil texture
- PH -- whether acid, neutral, or alkali
- Nutrient levels -- nitrogen, phosphorus, potassium
- Minerals -- such as chelated iron, lime
- Salinity
- Toxicity

Soils are made up of four basic ingredients: mineral elements, pore space, organic matter and other items consisting mainly of living organisms including fungi, bacteria, and nematodes. One classification of soils is based upon the mineral part of soil and consists of four sizes of particles.

Clay particles are the smallest, followed by silt, sand, and gravel. The USDA has devised another system of classifying soil particles. In this system soil is divided into seven categories: clay, silt, and five sizes of sand.

Soil texture is determined by the percentage of sand, silt, and clay in the soil. The structure of a soil is influenced by soil texture and also by the aggregation of small soil particles into larger particles. The amount of aggregation in a soil is strongly influenced by the amount of organic matter present.

Experienced and qualified individuals who can explain the results and provide information on any soil amendments that are required should analyze soil samples. Soil fertility can often be corrected by applying fertilizer or by increasing the level of organic matter in the soil. Soil pH can be corrected with applications of lime. Where poor soils can't be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

Areas that have recently been involved in construction can become compacted so that plant roots cannot penetrate the soil. Seeds lying on the surface of compacted soils can be washed away or be eaten by birds. Soils should be loosened to a minimum depth of two inches, preferably to a four-inch depth. Hard soils may require discing to a deeper depth. Loosening soils will improve seed contact with the soil, provide greater germination rates, and allow the roots to penetrate into the soil. If the area is to be sodded, discing will allow the roots to penetrate into the soil.

Whenever possible, topsoil should be spread to a depth of four inches (two inch minimum) over the entire area to be planted. This provides organic matter and important nutrients for the plant material. This also allows the stabilizing materials to become established faster, while the roots are able to penetrate deeper and stabilize the soil, making it less likely that the plants will wash out during a heavy storm. If topsoil has been stockpiled in deep mounds for a long period of time, it is desirable to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, it may be necessary to inoculate the soil after application.

Drainage

Soil moisture and drainage have a direct bearing on the plant species and communities that can be supported on a site. Factors such as soil texture, topography, groundwater levels and climatic patterns all influence soil drainage and the amount of water in the soil. Identifying the topography and drainage of the site will help determine potential moisture gradients. The following categories can be used to describe the drainage properties of soils on a site:

Flooded - Areas where standing water is present most of the growing season.

Wet - Areas where standing water is present most of the growing season, except during times of drought. Wet areas are found at the edges of ponds, rivers, streams, ditches, and low spots. Wet conditions exist on poorly drained soils, often with high clay content.

Moist - Areas where the soil is damp. Occasionally, the soil is saturated and drains slowly. These areas usually are at slightly higher elevations than wet sites. Moist conditions may exist in sheltered areas protected from sun and wind.

Well-drained - Areas where rainwater drains readily, and puddles do not last long. Moisture is available to plants most of the growing season. Soils usually are medium textures with enough sand and silt particles to allow water to drain through the soil.

Dry - Areas where water drains rapidly through the soil. Soils are usually coarse, sandy, rocky or shallow. Slopes are often steep and exposed to sun and wind. Water runs off quickly and does not remain in the soil.

Slope

The degree of slope can also limit its suitability for certain types of plants. Plant establishment and growth requires stable substrates for anchoring root systems and preserving propagules such as seeds and plant fragments, and slope is a primary factor in determining substrate stability. Establishing plants directly on or below eroding slopes is not possible for most species. In such instances, plant species capable of rapid spread and anchoring soils should be selected or bioengineering techniques should be used to aid the establishment of a plant cover.

In addition, soils on steep slopes generally drain more rapidly than those on gradual slopes. This means that the soils may remain saturated longer on gradual slopes. If soils on gradual slopes are classified as poorly drained, care should be taken those plants species are selected that are tolerant of saturation.

Site topography also affects maintenance of plant species diversity. Small irregularities in the ground surface (e.g., depressions, etc.) are common in natural systems. More species are found in areas with many micro-topographic features than in areas without such features. Raised sites are particularly important in wetlands because they allow plants that would otherwise die while flooded to escape inundation.

In wetland plant establishment, ground surface slope interacts with the site hydrology to determine water depths for specific areas within the site. Depth and duration of inundation are principal factors in the zonation of wetland plant species. A given change in water levels will expose a relatively small area on a steep slope in comparison with a much larger area exposed on a gradual or flat slope. Narrow planting zones will be delineated on steep slopes for species tolerant of specific hydrologic conditions, whereas gradual slopes enable the use of wider planting zones.

Orientation

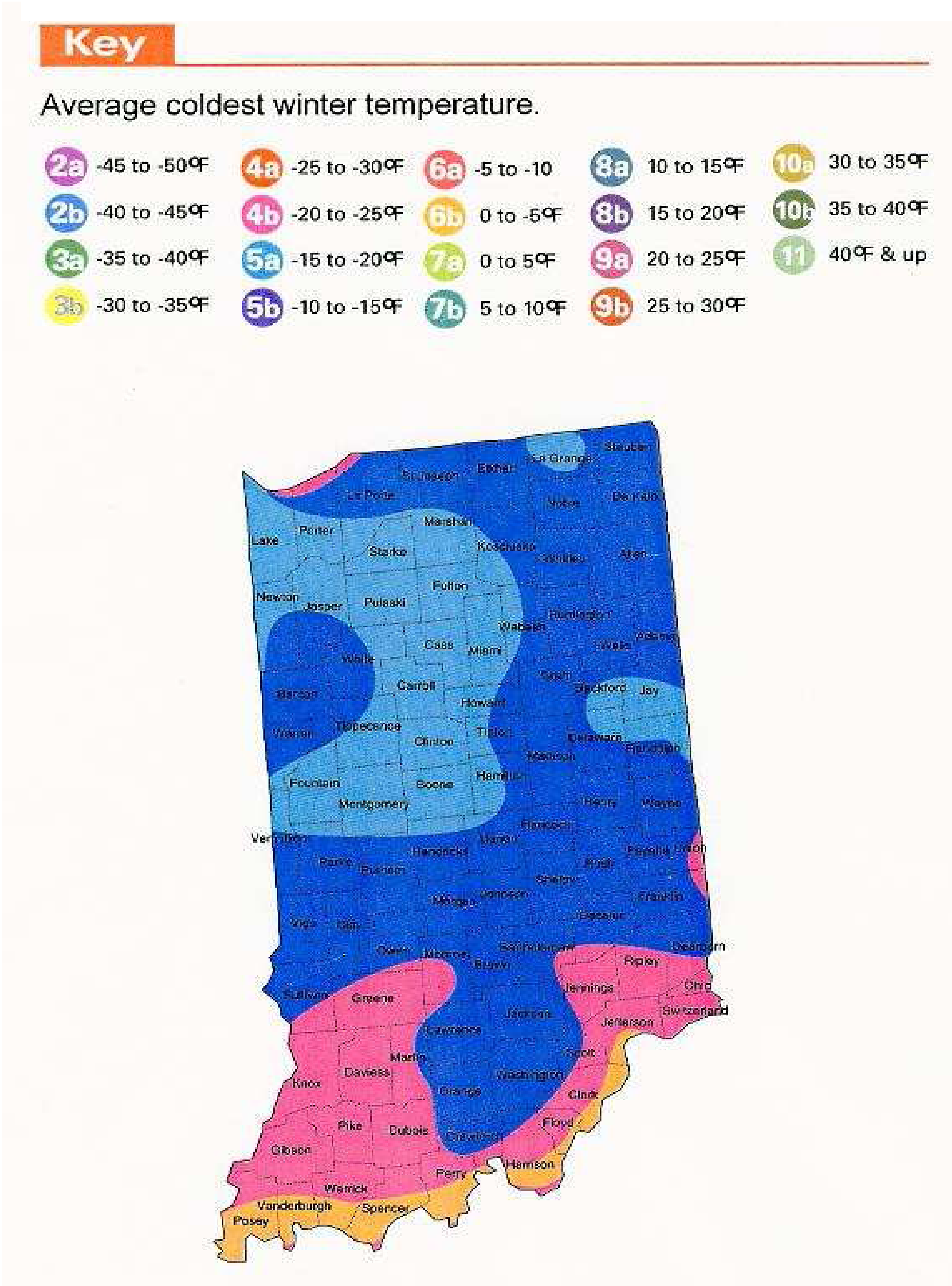
Slope exposure should be considered for its effect on plants. A southern-facing slope receives more sun and is warmer and drier, while the opposite is true of a northern slope. Eastern- and western-facing slopes are intermediate, receiving morning and afternoon sun, respectively. Western-facing slopes also tend to receive more wind.

6.13.4 PLANT SELECTION FOR STORMWATER FACILITIES

6.13.4.1 Plant Hardiness Map

Hardiness zones are based on historical annual minimum temperatures recorded in an area. The 1990 USDA Plant Hardiness Zones divide the United States and southern Canada into 11 areas based on a 10 degree Fahrenheit difference in the average annual minimum temperature. A site's location in relation to plant hardiness zones is important to consider first because plants differ in their ability to withstand very cold winters. It is best to recommend plants known to thrive in specific hardiness zones. It should be noted, however, that certain site factors could create microclimates or environmental conditions which permit the growth of plants not listed as hardy for that zone. By investigating numerous references and based on personal experience, a designer should be able to confidently recommend plants that will survive in microclimates. According to Figure 6.11, it appears that Bartholomew County is contained within area 5b.

Figure 6.11 Coldest Temperature Map



6.13.4.2 Other Considerations

Use or Function
In selecting plants, consideration must be given to their desired function in the stormwater management facility. Is the plant needed as ground cover, soil stabilizer, biofilter or source of shade? Will the plant be placed for functional or aesthetic purposes? Does the adjacent use provide conflicts or potential problems and require a barrier, screen, or buffer? Nearly every plant and plant location should be provided to serve some function in addition to any aesthetic appeal.

Plant Characteristics
Certain plant characteristics are so obvious they may actually be overlooked in the plant selection. These are size and shape. For example, tree limbs, after several years, can grow into power lines. A wide growing shrub may block maintenance access to a stormwater facility. Consider how these characteristics can work for you or against you, today and in the future.

Other plant characteristics must be considered to determine how the plant grows and functions seasonally, and whether the plant will meet the needs of the facility today and in the future. Some of these characteristics are:

- Growth Rate
- Regeneration Capacity
- Maintenance Requirements (e.g. mowing, harvesting, leaf collection, etc.)
- Aesthetics

In urban or suburban settings, a plant's aesthetic interest may be of greater importance. Residents living next to a stormwater system may desire that the facility be appealing or interesting to look at throughout the year. Aesthetics is an important factor to consider in the design of these systems. Failure to consider the aesthetic appeal of a facility to the surrounding residents may result in reduced value to nearby lots. Careful attention to the design and planting of a facility can result in maintained or increased values of a property.

Native versus Nonnative Species
This Manual encourages the use of native plants in stormwater management facilities, since they are best suited to thrive under the physiographic and hardiness conditions encountered at a site. Unfortunately, not all native plants provide the desired landscape or appearance, and may not always be available in quantity from local nurseries. Therefore, naturalized plants that are not native species, but can thrive and reproduce in the new area may be a useful alternative.

Because native or naturalized plants may not meet all landscaping needs, some ornamental and exotic species are provided in this guide that can survive under difficult conditions encountered in a stormwater management facility. Since many stormwater facilities are adjacent to residential areas, the objectives of the stormwater planting plan may shift to resemble the more controlled appearance of nearby yards, or to provide a pleasing view. Great care should be taken; however, when introducing plant species so as not to create a situation where they may become invasive and take over adjacent natural plant communities.

Moisture Status

In landscaping stormwater management facilities, hydrology plays a large role in determining which species will survive in a given location. For areas that are to be planted within a stormwater management facility it is necessary to determine what type of hydrologic zones will be created within the facility.

The six zones shown in Table 6.17 in the next section 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. 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.

6.13.5 SPECIFIC LANDSCAPING CRITERIA FOR STRUCTURAL STORMWATER CONTROLS

6.13.5.1 Stormwater Ponds and Wetlands

Stormwater ponds and wetlands are engineered basins and wetland areas designed to control and treat stormwater runoff. Aquatic vegetation plays an important role in pollutant removal in both stormwater ponds and wetlands. In addition, vegetation can enhance the appearance of a pond or wetland, stabilize side slopes, and serve as wildlife habitat, and can temporarily conceal unsightly trash and debris.

Within a stormwater pond or wetland, there are various hydrologic zones as shown in Table 6.17 that must be considered in plant selection. These hydrologic zones designate the degree of tolerance a plant must have to differing degrees of inundation by water. Hydrologic conditions in an area may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases the successful establishment of a planting. Plants suited for specific hydrologic conditions may perish when those conditions change, exposing the soil, and therefore, increasing the chance for erosion. Each of the hydrologic zones is described in more detail below along with examples of appropriate plant species.

Table 6.17 Hydrologic Zones

Zone #	**Zone Description Hydrologic Conditions**
Zone 1	Deep Water Pool 1-6 feet depth (permanent pool)
Zone 2	Shallow Water Bench Normal pool elevation to 1 foot depth
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 is *not* 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 is 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.

Some suggested emergent or submergent species include, but are not limited to: Water Lily, Deepwater Duck Potato, Spatterdock, Wild Celery and Redhead Grass.

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 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.

Common emergent wetland plant species used for stormwater wetlands and on the aquatic benches of stormwater ponds include, but are not limited to: Arrowhead/Duck Potato, Soft Rush, various Sedges, Softstem Bulrush, Cattail, Switchgrass, Southern Blue-Flag Iris, Swamp Hibiscus, Swamp Lily, Pickerelweed, Pond Cypress and various Asters.

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 partially 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).

Many of the emergent wetland plants that perform well in Zone 2 also thrive in Zone 3. Some other species that do well include: Broom Grass, Upland Sea-Oats, Dwarf Tickseed, various Ferns, and Hawthorns. If shading is needed along the shoreline, the following tree species are suggested: Boxelder, Ash, Willow, Red Maples and Willow Oak.

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 inundation. Nearly all of the temporary extended detention (ED) storage 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.

Some frequently used plant species in Zone 4 include Broom Grass, Yellow Indian Grass, Ironweed, Joe Pye Weed, Lilies, Flatsedge, Hollies, Forsythia, Lovegrass, Hawthorn and Sugar Maples.

Zone 5: Floodplain Terrace *(Infrequently Inundated)*
Zone 5 is periodically inundated by floodwaters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum two year or Cpv water surface elevation up to the 25 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 the 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.

Some commonly planted species in Zone 5 include many wildflowers or native grasses, many Fescues, many Viburnums, Witch Hazel, Blueberry, American Holly, American Elderberry and Red Oak.

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 should be 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.

Some frequently used plant species in Zone 6 include most ornamentals (as long as soils drain well), many wildflowers or native grasses, Linden, False Cypress, Magnolia, most Spruce, Mountain Ash and most Pine.

Table 6.18 provides a list of selected wetland plants for stormwater ponds and wetlands for hydrologic zones 1-4

Table 6.18 Wetland Plants (Herbaceous Species) for Stormwater Facilities

Scientific Name	**Common Name**	**Hydrologic Zone**
Acorus calumus	Sweetflag	2
Andropogon glomeratus	Bushy Broom Grass	3
Andropogon virginicus	Broom Grass	4
Canna flaccida	Golden Canna	2
Carex spp.	Caric Sedges	2
Chasmanthium latifolium	Upland Sea-Oats	3
Coreopsis leavenworthii	Tickseed	2
Coreopsis tinctoria	Dwarf Tickseed	3
Crinum americanum	Swamp Lily	2
Cyperus odoratus	Flat Sedge	2
Eleocharis cellulosa	Coastal Spikerush	2
Eleocharis interstincta	Jonited Spikerush	2
Eupatorium fistolosum	Joe Pye Weed	4
Helianthus angustifolius	Swamp Sunflower	2
Hibiscus coccinieus	Swamp Hibiscus	2
Iris louisiana	Louisiana Iris	2
Iris virginica	Southern Blue-Flag	2
Juncus effusus	Soft Rush	2
Leersia oryzoides	Rice Cut Grass	2
Liatris spicata	Spiked Gayfeather	3
Lobelia cardinalis	Cardinal Flower	3
Nuphar luteum	Spatterdock	1
Nymphaea mexicana	Yellow Water Lily	1
Nymphaea odorata	Fragrant Water Lily	1
Osmunda cinnamomea	Cinnamon Fern	3
Osmunda regalis	Royal Fern	3
Panicum virgatum	Switchgrass	2
Peltandra virginica	Green Arum	2
Polygonum hydropiperoides	Smartweed	2
Pontederia cordata	Pickerelweed	2
Pontederia lanceolata	Pickerelweed	2
Rudbeckia hirta	Black-eyed Susan	4
Sagittaria lancifolia	Lance-leaf Arrowhead	2
Sagittaria latifolia	Duck Potato	2
Saururus cernuus	Lizard’s Tail	2
Scirpus americanus	Three-square	2
Scirpus californicus	Giant Bulrush	2
Scirpus validus	Bulrush	2
Sorgham nutans	Yellow Indian Grass	4
Thalia geniculata	Alligator Flag	2
Typha spp.	Cat-tail	2
Vernonia gigantea	Ironweed	4
Woodwardia virginica	Virginia Chain Fern	2

Source: Aquascape, Inc.

List of recommended planting depths for the above list of plants

12 to 36 inch depth below normal pool elevation
Water Lily, Deep Water Duck Potato, Spatterdock, Wild Celery, Redhead Grass
0 to 12 inch depth below normal pool elevation
Arrowhead/Duck Potato, Soft Rush, various Sedges, Softstem Bulrush, Cattail, Switchgrass, Southern Blue Flag Iris, Swamp Hibiscus, Swamp Lily, Pickerelweed, Pond Cypress, various Asters
0 to 12 inch elevation above normal pool elevation
Various species from above, Broom Grass, Upland Sea-Oats, Dwarf Tickseed, various Ferns, Hawthorns, Boxelder, Ash, Willow, Red Maple, Willow Oak
1 to 4 foot elevation above normal pool elevation
Broom Grass, Yellow Indian Grass, Ironweed, Joe Pye Weed, various Lilies, Flatsedge, Hollies, Lovegrass, Hawthorn, Sugar Maple
Cpv to Qp25 or Qf water surface elevation
Many wildflowers or native grasses, many Fescues, many Viburnums, Witch Hazel, Blueberry, American Holly, American Elderberry, Red Oak
Qf water surface elevation and above
Many ornamentals as long as soils drain well, many wildflowers or native grasses, Linden, False Cypress, Magnolia, most Spruce, Mountain Ash, most Pine

6.13.6 Bioretention Areas
Bioretention areas are structural stormwater controls that capture and treat runoff using soils and vegetation in shallow basins or landscaped areas. Landscaping is therefore critical to the performance and function of these facilities. Below are guidelines for soil characteristics, mulching, and plant selection for bioretention areas.

Planting Soil Bed Characteristics
The characteristics of the soil for the bioretention facility are perhaps as important as the facility location and size. 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, or a loam/sand mix (should contain a minimum 35 to 60% sand, by volume). The clay content for these soils should by be less than 25% by volume. Soils should fall within the SM, ML, SC classifications or the Unified Soil Classification System (USCS). A permeability of at least 1.0 foot per day (0.5"/hr) is required (a conservative value of 0.5 feet per day should be 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, such as Johnson Grass, Mugwort, Nutsedge, and Canadian Thistle should not be present in the soils. 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 6.19.

Table 6.18 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 (P2O5)	75 lbs. per acre, minimum
Potassium (K2O)	85lbs. per acre, minimum
Soluble salts	500 ppm
Clay	10 to 25%
Silt	30 to 55%
Sand	35 to 60%

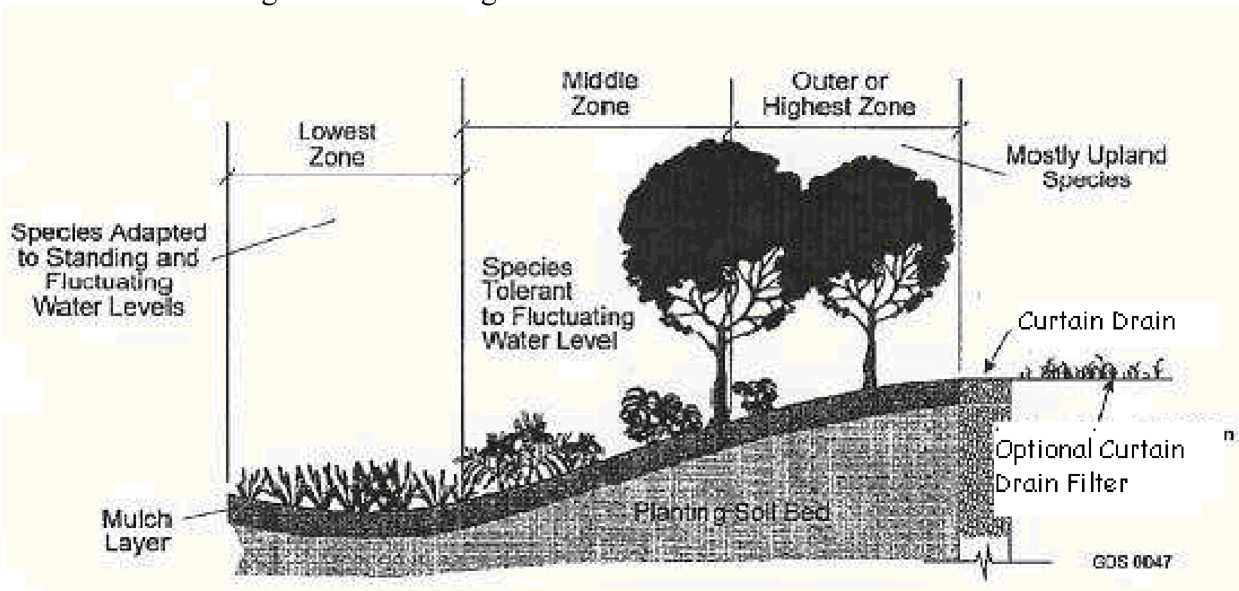
(Adapted from EQR, 1996; ETAB, 1993)

Mulch Layer
The mulch layer plays an important role in the performance of the bioretention system. The mulch layer helps maintain soil moisture and avoids surface sealing, which reduces permeability. Mulch helps prevent erosion, and provides a microenvironment 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 minimum 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 6.12). 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. Samples of appropriate plant materials for bioretention facilities are included in Table 6.20. More potential bioretention species can be found in the wetland plant list in Table 6.18.

Figure 6.12 Planting Zones for Bioretention Facilities



The layout of plant material should be flexible, but should follow the general principals described below. The objective is to have a system that resembles a random and natural plant layout, while maintaining optimal conditions for plant establishment and growth.

- Native plant species should be specified over exotic or foreign species.
- Appropriate vegetation should be selected based on the zone of hydric tolerance
- Species layout should generally be random and natural.
- The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart.
- Plants should be placed at regular irregular intervals to replicate a natural forest.
- Woody vegetation should not be specified at inflow locations.
- 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 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 6.21 presents some typical issues for planting specifications.

Table 6.20 Commonly Used Species for Bioretention Areas

Trees	Shrubs	Herbaceous Species
Acer rubrum Red Maple	*Aesculus pariviflora* Bottlebrush Buckeye	*Andropogon virginicus* Broomsedge
Betula nigra River Birch	*Aronia arbutifolia* Red Chokeberry	*Eupatorium perpurea* Joe Pye Weed
Juniperus virginiana Eastern Red Cedar	*Fothergilla gardenii* Fothergilla	*Hemerocalis spp.* Day Lily
Koelreuteria paniculata Golden Rain Tree	*Hamemelis virginiana* Witch Hazel	*Iris pseudacorus* Yellow Iris
Nyssa sylvatica Black Gum	*Hypericum densiflorum* Common St. Johns Wort	*Lobelia cardinalis* Cardinal Flower
Platanus acerifolia London Plane-Tree	*Ilex glabra* Inkberry	*Panicum virgatum* Switchgrass
Platanus occidentalis Sycamore	*Ilex verticillata* Winterberry	*Pennisetum alopecuroides* Fountaingrass
Quercus palustris Pin Oak	*Juniperus horizontalis* Creeping Juniper	*Rudbeckia laciniata* Greenhead Coneflower
Quercus phellos Willow Oak	*Lindera benzoin* Spicebush	*Scirpus cyperinus* Woolgrass
Salix nigra Black willow	*Myrica pennsylvanica* Bayberry	*Vernonia gigantea* Ironweed

Table 6.21 Planting Plan 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.
Contractor's Responsibilities	Specify the contractor's 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&Bballed and burlaped, 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; 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 warranty period, the required survival rate, and expected condition of plant species at the end of the warranty.

6.13.7 Enhanced Swales, Grass Channels and Filter Strips

Table 6.22 provides a number of grass species that perform well in the stressful environment of an open channel structural control such as an enhanced swale or grass channel, or for grass filter strips. In addition, wet swales may include other wetland species (see Table 6.22). Select plant material capable of salt tolerance in areas that may include high salt levels.

Table 6.22 Common Grass Species for Dry and Wet Swales and Grass Channels

Common Name	**Scientific Name**	**Notes**
Bermuda grass	*Cynodon dactylon*	
Big Bluestem	*Andropogon gerardii*	
Creeping Bentgrass	*Agrostis palustris*	
Red Fescue	*Festuca rubra*	
Reed Canary grass	*Phalaris arundinacea*	
Redtop	*Agrostis alba*	
Smooth Brome	*Bromus inermis*	
Switch grass	*Panicum virgatum*	

Note 1: These grasses are sod-forming and can withstand frequent inundation, and are thus ideal for the swale or grass channel environment. Most are salt-tolerant, as well.
Note 2: Where possible, one or more of these grasses should be in the seed mixes

➢ <u>LIST OF REFERENCES</u>

1. Erosion Control Ordinance, “Ordinance 92-5”, (effective January 1st 2007,) City of Columbus, Bartholomew County, Indiana.

2. “A General Ordinance Establishing Storm Drainage Control, H-88-5”, Highway Extension and Research Project for Indiana Counties and Cities (HERPICC) Reports, Purdue University.

3. Highway Extension and Research Project for Indiana Counties (HERPIC), ”County Storm Drainage Manual”, Christopher B. Burke, Research Engineer, Purdue University.

4. “Time Distribution of Heavy Rainstorms in Illinois” ISWS/CIR-173/90, Floyd A. Huff.

5. “Federal Emergency Management Agency, National Flood Insurance Program and Related Regulations” FEMA, Washington, D.C. 20472.

Stormwater Pond Operation, Maintenance, And Management

Inspection Checklist For SQU Owners

Site Name:	Owner changed since last inspection? ☐Yes ☐No
Owner Name:	Parcel No.:
Owner Address:	
Location:	
Owner Phone Number:	Date:
Inspector Name:	Time:
Owner Inspection Record kept? ☐Yes ☐No	
File Code: SW-SQU Inspection Program-Stormwater Pond -<INSERT PERMIT NUMBER>	

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Embankment and Emergency Spillway (Inspect annually and after major storms)		
1. Vegetation	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Erosion on embankment	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Animal burrows	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Cracking, bulging or sliding of dam	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
A. Location:		
B. Describe:		
5. Drains clear and functioning	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
6. Leaks or seeps on embankment	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

A. Location:		
B. Describe:		
7. Slope protection failure	☐ Satisfactory ☐ Unsatisfactory	
8. Emergency spillway clear of obstructions	☐ Satisfactory ☐ Unsatisfactory	
9. Other (describe):		

Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
Riser and Principal spillway (Inspect annually)		
Circle Type: Reinforced concrete, corrugated pipe, masonry	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
1. Low flow orifice blocked	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Trash rack		
A. debris removal needed	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
B. Corrosion noted	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Excessive sediment buildup in riser	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Measured depth of sediment in riser	Inches	
5. Amount of sediment cleaned from unit	Cyds	
4. Concrete/Masonry condition		
A. cracks or displacement	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
B. spalling	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
5. Metal pipe condition	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

6. Control Valve operational	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
7. Pond drain valve operational 8. Outfall channels functioning	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable ☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
9. Other (describe):		
Permanent Pool (Inspect monthly)		
1. Undesirable vegetative growth	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Floatable debris removal needed	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Visible pollution	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Shoreline problem	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
5. Other (describe)	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Sediment Forebays		
1. Sedimentation noted	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Sediment cleanout needed (over 50% full)	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Measured depth of sediment in unit	Inches	
4. Amount of sediment cleaned from forebay	Cyds	

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Other (Inspect monthly)		
1. Erosion at outfalls into pond	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Headwalls and end walls	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Encroachment into easement area	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Complaints from residents	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
5. Public hazards (describe)		

Additional Comments:

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Actions to be taken: **Timeframe:**

COLUMBUS	Bioretention Operation, Maintenance, and Management Inspection Checklist For SQU Owners

File Code: SW-SQU Inspection Program-Bioretention-<INSERT PERMIT NUMBER>

Site Name:	Owner changed since last inspection? ☐Yes ☐No
Owner Name:	Parcel No.:
Owner Address:	
Location:	
Owner Phone Number:	Date:
Inspector Name:	Time:
Owner Inspection Record kept? ☐Yes ☐No	

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Debris Cleanout (Inspect monthly)		
1. Bioretention area and contributing areas clean of debris	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Litter (branches, etc.) has been removed	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Vegetation (Inspect monthly)		
1. Plant height not less than design ponding depth	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Plant composition according to approved plan	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Grass height not more than 6 inches	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. No evidence of erosion	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

Additional Comments:

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Actions to be taken: **Time frame:**

File Code: SW-SQU Inspection Program-Swale -<INSERT PERMIT NUMBER>

	Water Quality Swale Operation, Maintenance, and Management Inspection Checklist For SQU Owners

Site Name:		Owner changed since last inspection? ☐Yes ☐No
Owner Name:		Parcel No.:
Owner Address:		
Location:		
Owner Phone Number:		Date:
Inspector Name:		Time:
Owner Inspection Record kept? ☐Yes ☐No		

Maintenance Item	**Satisfactory/ Unsatisfactory**	Comments
Debris Cleanout (Inspect monthly)		
1. Bioretention area and contributing areas clean of debris	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Litter (branches, etc.) has been removed	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Vegetation (Inspect monthly)		
1. Plant height note less than design ponding depth	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Plant composition according to approved plan	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Grass height not more than 6 inches	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. No evidence of erosion	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

Check Dams or Energy Dissipaters (Inspect annually)		
1. No evidence of flow going around structure	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. No evidence of erosion at the downstream toe	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Soil permeability	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Sediment Forebay		
1. Sediment cleanout needed (clean out when 50% full)	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Measured depth of sediment in forebay	Inches	
3. Amount of sediment cleaned from forebay	Cyds	

Additional Comments

Actions to be taken:	**Timeframe:**

	Biofilter and Buffer Operation, Maintenance and Management Inspection Checklist For SQU Owners

File Code: SW-SQU Inspection Program-Biofilter-<INSERT PERMIT NUMBER>

Site Name:	Owner changed since last inspection? ☐Yes ☐No
Owner Name:	Parcel No.:
Owner Address:	
Location:	
Owner Phone Number:	Date:
Inspector Name:	Time:
Owner Inspection Record kept? ☐Yes ☐No	

Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
Vegetation (Inspect monthly)		
1. Plant height not less than designed ponding depth	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Plant composition according to approved plan:	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Grass height not more than 6 inches:	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. No evidence of erosion	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Level spreader (Inspect monthly)		
1. Vegetation is healthy	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	☐Brown ☐ Yellow ☐ Green BAD……………………….Good
2. Lip of spreader showing no signs of erosion	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Sediment noted in spreader?	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Measured depth of sediment in unit	Inches	

5.Amount of sediment cleaned from unit	Cyds	

Additional Comments:

Actions to be taken: **Timeframe:**

	Sand Filter Operation, Maintenance, and Management Inspection Checklist For SQU Owners

File Code: SW-SQU Inspection Program-Sand Filter-<INSERT PERMIT NUMBER>

Site Name:	Owner changed since last inspection? ☐Yes ☐No	
Owner Name:	Parcel No.:	
Owner Address:		
Location:		
Owner Phone Number:		Date:
Inspector Name:		Time:
Owner Inspection Record kept? ☐Yes ☐No		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
Debris Cleanout (Inspect monthly)		
1. Filtration facility	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Inlet and outlet	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Oil and Grease (Inspect monthly)		
1. Evidence of filter surface clogging	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Vegetation (Inspect monthly)		
1. Surrounding areas stabilized	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. No evidence of leaking	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

Water retention where required (Inspect monthly)		
1. Water holding chambers at normal pool	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. No evidence of leaking	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Maintenance Item	**Satisfactory/ Unsatisfactory**	Comments
Sediment deposition (Inspect monthly)		
1. Filter chamber free of sediments	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Sediment chamber not more than 50% full	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Measured depth of sediment in unit	Inches	
4. Amount of sediment cleaned from unit	Cyds	
Oil and Grease (Inspect monthly)		
1. Structural soundness	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Grates in good condition	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. No evidence of structural spalling or cracking	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Outlet/overflow spillway (Inspect annually)		
1. Good condition, no need for repairs	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. No evidence of erosion	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Other (Inspect annually)		
1. No odors	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Evidence of flow bypassing the filter	☐ Satisfactory ☐ Unsatisfactory	

	☐ Not Applicable	

Additional Comments

Actions to be taken: **Timeframe:**

COLUMBUS	Constructed Wetlands Operation, Maintenance, and Management Inspection Checklist For SQU Owners

Site Name:	Owner changed since last inspection? ☐Yes ☐No
Owner Name:	Parcel No.:
Owner Address:	
Location:	
Owner Phone Number:	Date:
Inspector Name:	Time:
Owner Inspection Record kept? ☐Yes ☐No	

File Code: SW-SQU Inspection Program-Constructed Wetlands-<INSERT PERMIT NUMBER>

Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
Embankment and Emergency Spillway (Inspect annually and after major storms)		
1. Vegetation	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Erosion on embankment	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Animal burrows	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Cracking, bulging or sliding of dam	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
A. Location:		
B. Describe:		
5. Drains clear and functioning	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
6. Leaks or seeps on embankment	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

A. Location:		
B. Describe:		
7. Slope protection failure	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
8. Emergency spillway clear of obstructions	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
9. Other (describe):		
Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
Riser and Principal spillway (Inspect annually)		
Check Type: ☐Reinforced concrete, ☐corrugated pipe, ☐masonry		
1. Low flow orifice blocked	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Trash rack	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
A. debris removal needed:		
B. Corrosion noted:		
3. Excessive sediment buildup in riser	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Measured depth of sediment in unit	Inches	
5. Amount of sediment cleaned from unit	Cyds	
6. Concrete/Masonry condition	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
A. cracks or displacement:		
B. spalling:		
7. Metal pipe condition	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
8. Control Valve operational	☐ Satisfactory ☐ Unsatisfactory	

	☐ Not Applicable	

9. Pond drain valve operational	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
10. Outfall channels functioning	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
11. Other (describe):		
Permanent Pool (Inspect monthly)		
1. Undesirable vegetative growth	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Floatable debris removal needed	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Visible pollution	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Shoreline problem	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
5. Other (describe)	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
Sediment Forebays		
1. Sedimentation noted	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
2. Sediment cleanout needed (over 50% full)	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Measured depth of sediment in forebay	Inches	
4. Amount of sediment cleaned from forebay	Cyds	
Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
Other (Inspect monthly)		
1. Erosion at outfalls	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

2. Headwalls and endwalls	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	

3. Encroachment into easement area	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Complaints from residents	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
5. Public hazards (describe):		
Constructed Wetland Area (Inspect annually)		
1. Vegetation healthy and growing	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	☐ Brown ☐ Yellow ☐ Green
2. Evidence of invasive species	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
3. Excessive sediment in wetland area (clean out when 50% full or when vegetation damage noted)	☐ Satisfactory ☐ Unsatisfactory ☐ Not Applicable	
4. Measured depth of sediment in wetland area	Inches	
5. Amount of sediment removed from wetland area	Cyds	

Additional Comments

____

____

____

____

____

Actions to be taken:	**Timeframe:**

COLUMBUS	M-SQU Operation, Maintenance, and Management Inspection Checklist For SQU Owners

File Code: SW-SQU Inspection Program-MSQU-<INSERT PERMIT NUMBER>

Site Name:	Owner changed since last inspection? ☐Yes ☐No
Owner Name:	Parcel No.:
Owner Address:	
Location:	
Owner Phone Number:	Date:
Inspector Name:	Time:
Owner Inspection Record kept? ☐Yes ☐No	
Manufacturer:	Model No.:

Maintenance Item	**Satisfactory/ Unsatisfactory**	Comments
Inspection shall be conducted using the checklist from the O&M Manual		
M-SQU condition		
1. Measured depth of sediment in Unit		
2. Amount of sediment cleaned from Unit		
3. Stormwater is up to the outlet pipe flowline.		

Additional Comments:

Actions to be taken:	**Time frame:**

City of Columbus Stormwater Manufactured Quality Unit (M-SQU) Selection Guide

(Check (WEBSITE) for current Selection Guide)

Table 1
Rate Based SQUs

Performance Matrix for Manufactured SQUs that remove 80% or more of OK 110 (110□m sized Particles)

****PLEASE NOTE: All SQUs should be configured as off-line units unless a detailed hydraulic analysis is provided. The analysis must demonstrate the up- and downstream pipes will have the capacity as required by the Stormwater Design and Construction Specification Manual and surcharging created by high rainfall storms will not result in loss of previously captured material.**

Table 1

Manufactured SQU	**M-SQU System Model**	**Max Treatment Flow (cfs)**
Stormceptor® [1]	STC 450	0.3
	STC 900	0.64
	STC 2400	1.06
	STC 4800	1.77
	STC 7200	2.47
	STC 11000	3.53
	STC 16000	4.94
Downstream Defender® [1]	4 Foot Diameter	1.3
	6 Foot Diameter	4.1
	8 Foot Diameter	9.4
	10 Foot Diameter	17.7
VortSentry®	VS30	0.26
	VS40	0.58
	VS50	1.07
	VS60	1.77
	VS70	2.70
	VS80	3.90
Vortechs® [1]	1000	0.6
	2000	1.0
	3000	1.6
	4000	2.3
	5000	3.2
	7000	4.1
	9000	5.2
	11000	6.4

Manufactured SQU		M-SQU System Model	Max Treatment Flow (cfs)
		16000	9.3
		PC1319 or 1319 CIP	10.9
		PC1421 or 1421 CIP	12.7
		1522 CIP	14.6
		1624 CIP	16.6
		1726 CIP	18.7
		1827 CIP	21.0
		1929 CIP	23.4
		2030 CIP	25.9
		2131 CIP	28.5
		2233 CIP	31.3
		2334 CIP	34.2
		2436 CIP	37.3
		2538 CIP	40.4
		2639 CIP	43.7
		2740 CIP	47.2
		2842 CIP	50.7
		2943 CIP	54.4
		3045 CIP	58.2
		3146 CIP	62.2
		3349 CIP	70.5
		3958 CIP	98.4
		4060 CIP	103.5
Aqua-Swirl™ [2]		AS-2	0.29
		AS-3	0.50
		AS-4	0.75
		AS-5	1.20
		AS-6	1.70
		AS-7	2.30
		AS-8	3.00
		AS-9	3.80
		AS-10	4.70
		AS-12	6.80
CDS Technologies [1,2]	Offline	PMIU20_15_4	0.33
		PMIU20_15	0.33
		PMSU20_15_4	0.33
		PMSU20_15	0.33
		PMSU20_20	0.52
		PMSU20_25	0.75
		PMSU30_20	0.94
		PMSU30_30	1.41

Manufactured SQU		M-SQU System Model	Max Treatment Flow (cfs)
		PMSU40_30	2.12
		PMSU40_40	2.82
	Offline	PSWC20_15	0.33
		PSWC20_20	0.52
		PSWC20_25	0.75
		PSWC30_20	0.94
		PSWC30_30	1.41
		PSWC40_30	2.12
		PSWC40_40	2.82
		PSWC56_40	4.23
		PSWC56_53	6.58
		PSWC56_68	8.93
		PSWC56_78	11.75
	Offline	PSW30_30	1.41
		PSW50_42	4.23
		PSW50_50	5.17
		PSW70_70	12.22
		PSW100_60	14.10
		PSW100_80	21.62
		PSW100_100[b]	30.08
ADS Stormwater Quality Units[2]		3620WQB	0.7
		3640WQB	1.6
		4220WQB	0.86
		4240WQB	1.83
		4820WQB	1.13
		4840WQB	2.39
		6020WQB	1.47
		6040WQB	3.12

[1] *Temporary Approval*
[2] *Off-line use only*

Table 2 Volume Based SQUs*

Manufactured SQU	SQU System Model	Max Treatment Flow (cfs)
Stormvault ®	N/A	N/A*

*Storage volume to be calculated per Section 6.0.1

Appendix 3 Design Treatment Flow Rate Determination for Table 1 SQUs

Design Treatment Flow Rate Determination
For
Table 1 SQUs

Stormwater Quality Flow Rate Determination – Table 1 SQUs

The design flow rate for manufactured stormwater quality units (SQUs) shall be determined using the following SCS runoff methodology as outlined below.

1. Delineate the watershed basins. Tabulate the total impervious and pervious areas. *Please note impervious and pervious area runoff rates MUST be calculated as separate basins. The sizing calculation assumes the impervious area is connected directly to the SQU and the Tc calculation must be adjusted for this assumption (i.e. no flow over grass).*

2. Determine the time of concentration using the TR-55 methodology (Worksheet 3) for each basin.

3. Calculate the curve numbers (CN) for each basin, using CN=98 for the impervious basin.

4. Determine the peak discharge from the 0.3 in storm using the appropriate Huff, 50% rainfall distribution (Storm duration 0 up to and including 6 hrs – 1st Quartile, 6.1 to 12 hrs – 2nd Quartile, 12.1 to 24 hrs – 3rd Quartile. See Table below for Huff ordinates.). A single hydrograph for each basin should be determined and all basin hydrographs added to determine the peak flow. Storm durations of 15-, 30- and 45 minutes as well as 1-, 2-, 3- 6- 12- and 24- hours should be checked to determine the peak SQU flow.

Huff Ordinates Table

% Storm Time	Columbus Huff Quartile			
	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
0	0.00	0.00	0.00	0.00
10	20.00	6.50	5.26	6.67
20	40.80	18.13	11.55	14.25
30	54.95	35.85	17.06	20.00
40	62.50	52.94	24.24	26.09
50	68.75	67.86	37.78	33.33
60	76.67	76.52	58.33	40.00
70	83.05	83.81	78.03	50.00
80	89.70	90.67	88.68	68.57
90	95.00	95.89	95.29	88.37
100	100.00	100.00	100.00	100.00

Stormceptor Checklists

The following notes / maintenance items should be included in the operations and Maintenance Manual **(O & M Manual):**

_____ 1. The maximum sediment depth should be clearly specified, e.g. 8”.

_____ 2. Graphical and written description of sediment measuring procedure. This should include the use of a dipstick tube equipped with a ball valve (e.g. Sludge Judge®)

_____ 3. Oil removal procedure during routine cleanout.

_____ 4. The O & M Manual should specify if entry into the SQU should be considered an OSHA confined space and guidelines followed.

_____ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_____ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_____ 7. Off-line configurations must include inspection and maintenance of connecting manhole and diversion weir.

_____ 8. Detail drawing of proposed SQU should be included.

_____ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_____ 10. A note should be provided indicating disposal of all sediment must be in accordance with all federal, state and local requirements.

The following items should be specified on all **plans** referencing a Stormceptor SQU submitted for approval by the City Engineer:

_____ 1. The elevation of the outlet pipe should be a minimum of 1” (0.0833’) below the elevation of the inlet pipe.

_____ 2. There is a minimum requirement for 2 ft of cover above the crown of the pipe to grade for the unit.

_____ 3. A 6” stone base should be shown on the detail.

_____ 4. The backfill should be specified as required by the adjoining pipe.

_____ 5. Detail drawing of SQUs should be included on plans.

_____ 6 Detail of connecting structures and diversion for off-line configurations should be included.

The following requirements should be addressed in drainage design **reports**:

_____ 1. The design storm must not create a hydraulic tailwater condition on the SQU. A first flush hydraulic gradeline evaluation should be included in the report.

_____ 2. The design storm should be the peak runoff for a 0.3 inch rainfall depth using the Appropriate Huff, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number.

_____ 3. The velocity of the water entering the unit must be below 4.27 ft/s up to the treatment design flow rate.

_____ 4. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by the Stormwater Design Manual.

_____ 5. Diversion structure design should be documented with calculations as appropriate.

Checklists for Downstream Defender

The following notes / maintenance items should be included in the operations and Maintenance Manual **(O & M Manual):**

_______ 1. The maximum sediment depth should be clearly specified, e.g. 8”.

_______ 2. Graphical and written description of sediment measuring procedure. This should include the use of specific equipment (e.g. Sludge Judge®).

_______ 3. Oil removal procedure during routine cleanout.

_______ 4. The O & M Manual should specify if entry into the SQU should be considered an OSHA confined space and guidelines followed.

_______ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_______ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_______ 7. Off-line configurations must include inspection and maintenance of connecting manhole and diversion weir.

_______ 8. Detail drawing of proposed SQU should be included.

_______ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_______ 10. A note should be provided indicating disposal of all sediment must be in accordance with all federal, state and local requirements.

The following items should be specified on all **plans** referencing a Downstream Defender SQU submitted for approval by City Engineer:

_______ 1. The minimum cover above the crown of the pipe to grade for the unit should be as required by Stormwater Design Manual.

_______ 2. A 6” stone base should be shown on the detail.

_______ 3. The backfill should be specified as required by the adjoining pipe.

_______ 4. Detail drawing of SQUs should be included on plans.

_______ 5 Detail of connecting structures and diversion weirs etc. for off-line configurations should be included.

The following requirements should be addressed in drainage design **reports**:

_______ 1. The design storm should not create a hydraulic tailwater condition on the SQU. A first flush hydraulic gradeline evaluation should be included in the report.

_______ 2. The design storm should be the peak runoff for a 0.3 inch rainfall depth using the appropriate Huff, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number.

_______ 3. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by the Stormwater Design Manual.

_______ 4. Diversion structure design should be documented with calculations as appropriate.

Checklist for VortSentry

The following notes / maintenance items should be included in the operations and Maintenance Manual (**O & M Manual**):

_______ 1. The maximum sediment depth should be clearly specified, e.g. 8”.

_______ 2. Graphical and written description of sediment measuring procedure. This should include the use of any specific equipment (e.g. Sludge Judge®).

_______ 3. Oil removal procedure during routine cleanout.

_______ 4. The O & M Manual should specify if entry into the SQU should be considered an OSHA confined space and guidelines followed.

_______ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_______ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_______ 7. Off-line configurations must include inspection and maintenance of connecting manhole and diversion weir.

_______ 8. Detail drawing of proposed SQU should be included.

_______ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_______10. A note should be provided indicating disposal of all sediment must be in accordance with all federal, state and local requirements.

The following items should be specified on all **plans** referencing a VortSentry SQU submitted for approval by City Engineer:

_______ 1. The minimum cover above the crown of the pipe to grade for the unit should be as required by Stormwater Design Manual.

_______ 2. A 6” stone base should be shown on the detail.

_______ 3. The backfill should be specified as required by the adjoining pipe.

_______ 4. Detail drawing of SQUs should be included on plans.

_______ 5. Detail of connecting structures and diversion weirs etc. for off-line configurations should be included.

The following requirements should be addressed in drainage design **reports**:

_______ 1. The design storm should not create a hydraulic tailwater condition on the SQU. A first flush hydraulic gradeline evaluation should be included in the report.

_______ 2. The design storm should be the peak runoff for a 0.3 inch rainfall depth using the appropriate Huff, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number.

_______ 3. Diversion structure design should be documented with calculations as appropriate.

_______ 4. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by the Stormwater Design Manual.

Checklist for Vortechs Systems

The following notes / maintenance items should be included in the operations and Maintenance Manual (**O & M Manual**):

_____ 1. The maximum sediment depth should be clearly specified, e.g. 8".

_____ 2. Graphical and written description of sediment measuring procedure. This should include the use of any specific equipment (e.g. Sludge Judge®).

_____ 3. Oil removal procedure during routine cleanout.

_____ 4. The O & M Manual should specify entry into the SQU should be considered an OSHA confined space and guidelines followed.

_____ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_____ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_____ 7. Off-line configurations must include inspection and maintenance of connecting manhole and diversion weir.

_____ 8. Detail drawing of proposed SQU should be included.

_____ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_____ 10. Inspection of each chamber for sediment should be addressed.

_____ 11. A note should be provided indicating disposal of all sediment must be in accordance with all federal, state and local requirements.

The following items should be specified on all **plans** referencing a Vortechs SQU submitted for approval by City Engineer:

_____ 1. The minimum cover above the crown of the pipe to grade for the unit should be as required by Stormwater Design Manual.

_____ 2. A 6" stone base should be shown on the detail.

_____ 3. The backfill should be specified as required by the adjoining pipe.

_____ 4. Detail drawing of SQUs should be included on plans.

_____ 5 Detail of connecting structures and diversion weirs etc. for off-line configurations should be included.

_____ 6. Note on detail for contractor to level unit.

The following requirements should be addressed in drainage design **reports**:

_____ 1. The design storm should not create a hydraulic tailwater condition on the SQU. A first flush hydraulic gradeline evaluation should be included in the report.

_____ 2. The design storm should be the peak runoff for a 0.3 inch rainfall depth using the appropriate Huff Quartile, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number.

_____ 3. Inlet must be 90 degrees to side of unit.

_____ 4. The unit MUST be off-line if peak design flow greater than 100 gpm / ft^2 (0.22275 cfs / ft^2) of treatment (grit) chamber.

_____ 5. Diversion structure design should be documented with calculations as appropriate.

_____ 6. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by the Stormwater Design Manual.

Checklists for Aqua-Swirl

The following notes / maintenance items should be included in the operations and Maintenance Manual (**O & M Manual**):

_____ 1. The maximum sediment depth should be clearly specified, e.g. 8”.

_____ 2. Graphical and written description of sediment measuring procedure. This should include the use of any specific equipment (e.g. Sludge Judge®).

_____ 3. Oil removal procedure during routine cleanout.

_____ 4. The O & M Manual should specify entry into the SQU should be considered an OSHA confined space and guidelines followed.

_____ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_____ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_____ 7. Off-line configurations must include inspection and maintenance of connecting manhole and diversion weir.

_____ 8. Detail drawing of proposed SQU should be included.

_____ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_____ 10. Inspection of each chamber for sediment should be addressed.

_____ 11. Use of adsorbent pads for oil removal from unit should be discussed.

_____ 12. A note should be provided indicating disposal of all sediment must be in accordance with all federal, state and local requirements.

The following items should be specified on all plans **referencing an Aqua-Swirl SQU submitted for approval by City Engineer:**

_____ 1. The minimum cover above the crown of the pipe to grade for the unit should be as required by Section 4.3.3.Stormwater Design Manual.

_____ 2. A base of 12” of Class I material, as defined by ASTM D 2321, compacted to 95% proctor density must be provided.

_____ 3. Backfill must be Class I, compacted to 90% proctor density, extend at least 3.5 ft beyond the outside of the unit and for the full height.

_____ 4. The connection is made with a flexible connector and a sheer guard.

_____ 5. Detail drawing of SQUs should be included on plans.

_____ *6. Detail of connecting structures and diversion weirs etc. for the off-line configurations should be included.*

_____ *7. A reinforced concrete pad must be provided when traffic loading (roadway, parking areas) is anticipated. The pad should extend 12" beyond the outside diameter of the unit.*

_____ *8. Bollards should be installed around the unit in non-traffic areas.*

The following requirements should be addressed in drainage design **reports**:

_____ 1. The first flush design storm should not create a hydraulic tailwater condition on the SQU outlet. A first flush hydraulic gradeline evaluation should be included in the report.

_____ 2. The design storm should be the peak runoff for a 0.3 inch rainfall depth using the appropriate Huff Quartile, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number).

_____ 3. Diversion structure design should be documented with calculations as appropriate.

_____ 4. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by Section 4.1.2.the Stormwater Design Manual.

Checklists for CDS Technologies

The following notes / maintenance items should be included in the operations and Maintenance Manual (**O & M Manual**):

_____ 1. The maximum sediment depth should be clearly specified, e.g. 8”.

_____ 2. Graphical and written description of sediment measuring procedure. This should include the use of any specific equipment (e.g. Sludge Judge®).

_____ 3. Oil removal procedure during routine cleanout (if equipped with oil baffle or if absorbants are used).

_____ 4. The O & M Manual should specify entry into the SQU should be considered an OSHA confined space and guidelines followed.

_____ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_____ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_____ 7. Off-line configurations must include inspection and maintenance of connecting manhole and diversion weir.

_____ 8. Detail drawing of proposed SQU should be included.

_____ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_____ 10. Inspection of both inner and outer areas of the screen for sediment should be addressed.

_____ 11. Disposal according federal, state and local requirements should also be noted for sediments etc.

The following items should be specified on all **plans** referencing a CDS SQU submitted for approval by City Engineer:

_____ 1. The 2400 µm must be specified and shown on the detail drawing. The 4800µm screen should not be approved.

_____ 2. The minimum cover above the crown of the pipe to grade for the unit should be as required by Section 4.3.3Stormwater Design Manual.

_____ 3. A 6” stone base should be shown on the detail.

_____ 4. The backfill should be specified as required by the adjoining pipe.

_____ 5. Detail drawing of SQUs should be included on plans.

_____ 5 Detail of connecting structures and diversion weirs etc. for off-line configurations should be included.

_____ 7. A minimum 24” access opening / casting should be shown.

The following requirements should be addressed in drainage design **reports**:

_____ 1. The design storm should not create a hydraulic tailwater condition on the SQU. A first flush hydraulic gradeline evaluation should be included in the report.

_____ 2. The design storm should be the peak runoff for a 0.3 inch rainfall depth using the appropriate Huff Quartile, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number.

_____ 3. Diversion structure design should be documented with calculations as appropriate.

_____ 4. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by Section 4.1.2.the Stormwater Design Manual.

Checklists for Stormvault®

The following notes / maintenance items should be included in the Operations and Maintenance Manual **(O & M Manual):**

_____ 1. A detailed cleaning procedure should be provided

_____ 2. A maximum sediment depth should be clearly specified, e.g. 8”.

_____ 3. Oil removal procedure during routine cleanout.

_____ 4. The O & M Manual should specify entry into the SQU should be considered an OSHA confined space and guidelines followed.

_____ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_____ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_____ 7. The Manual must include inspection and maintenance of connecting manhole and diversion weir.

_____ 8. Detail drawing of proposed SQU should be included.

_____ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_____ 10. Inspection of each chamber or treatment zone should be addressed.

_____ 11. A note should be provided indicating disposal of all sediment must be in accordance with all federal, state and local requirements.

The following items should be specified on all **plans** referencing a Stormvault SQU submitted for approval by City Engineer:

_____ 1. The backfill should be specified as required by the manufacturer and copies provided on the plans.

_____ 2. Detail drawing of SQUs should be included on plans.

_____ 3 Detail of connecting structures and diversion weirs etc. for off-line configurations should be included.

The following requirements should be addressed in drainage design **reports**:

_____ 1. The WQv should be calculated per the SQU Manual and the outlet sized to detain the volume over 24 hrs.

_____ 2. The design of the diversion structure should be documented.

_____ 3. Diversion structure design should be documented with calculations as appropriate.

_____ 4. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by the Stormwater Design Manual Section 4.1.2.

Checklists for ADS SQU

The following notes / maintenance items should be included in the operations and Maintenance Manual **(O & M Manual):**

_____ 1. The maximum sediment depth should be clearly specified, e.g. 8", and not just referenced to diameter of unit.

_____ 2. Graphical and written description of sediment measuring procedure. This should include the use of any specific equipment (e.g. Sludge Judge®)

_____ 3. Oil removal procedure during routine cleanout.

_____ 4. The O & M Manual should specify entry into the SQU should be considered an OSHA confined space and guidelines followed.

_____ 5. The O & M Manual should clearly state water and sediment from cleaning procedures should NOT be dumped into a sanitary sewer.

_____ 6. A minimum inspection frequency of 6 months should be specified in the narrative and the tabular inspection schedule.

_____ 7. Inspection and maintenance of connecting manhole and diversion weir should be included in narrative and checklist.

_____ 8. Detail drawing of proposed SQU should be included as well as diversion structure.

_____ 9. Note in the manual to clean unit immediately if there is a hydrocarbon spill (e.g. gasoline or oil).

_____ 10. Disposal according federal, state and local requirements should also be noted for sediments etc.

_____ 11. THE MANUAL MUST CLEARLY NOTE THE UNIT MUST BE REFILLED WITH WATER AFTER EACH CLEANING.

_____ 12. Cleanout should be specified for once a year at a minimum.

The following items should be specified on all **plans** referencing an ADS SQU submitted for approval by City Engineer:

_____ 1. The bedding / backfill must be #57 or #8 stone

_____ 2. The installation details (6 steps) provided by the manufacturer should be included on the plans. They are available from the website.

_____ 3. Concrete collar around risers for traffic loading conditions.

_____ 4. The minimum cover above the crown of the pipe to grade for the unit as required by manufacturer.

_____ 5. Detail drawing of SQUs should be included on plans.

_____ 6 Detail of connecting structures and diversion weirs etc. should be included.

_____ 7. A minimum of two 24” access opening / casting should be shown.

_____ 8. All diversion structures and connecting pipes should meet the current requirements of this Stormwater Design Manual requirements.

The following requirements should be addressed in drainage design **reports**:

_____ 1. The design storm should not create a hydraulic tailwater condition on the SQU. A first flush hydraulic gradeline evaluation should be included in the report.

_____ 2. The design storm should be the peak runoff for a 0.3-inch rainfall depth using the appropriate Huff Quartile, 50% rainfall distribution. The contributing watershed should be modeled with the pervious and impervious areas inputted as separate areas (i.e. not combined using a single curve number).

_____ 3. Diversion structure design should be documented with calculations as appropriate. The diversion should be designed to limit the flow to the unit.

_____ 4. The 10-yr pipe capacity up and downstream of any diversion structure should be documented with calculations to demonstrate the water surface for the 10-yr storm is below the crown of the pipe as required by the Stormwater Design Manual Section 4.1.2.

DECLARATION OF COVENANTS

For Storm and Surface Water Facility,

This DECLARATION OF COVENANTS, made this _____ day of _____ by hereinafter referred to as the "Covenanter(s)" to and for the benefit of City of Columbus, Indiana and its successors and assigns hereinafter referred to as the "City".

WITNESSETH:

WHEREAS, the City is authorized and required to regulate the control the disposition of storm and surface waters under IAC 327 15-13 under City's Stormwater Management Ordinance #_____ in City of Columbus, Indiana and

WHEREAS, Covenanter(s) is (are) the owner(s) of a certain tract or parcel of land more particularly described as: being all or part of the land which it acquired by deed dated grantors, _____ and _____ recorded Book _____ Page _____ in the office of the Recorder Bartholomew County Indiana, hereinafter referred to as the "the property"; and

WHEREAS, the Covenanter(s) desires to construct certain improvements on its property which will alter the extent of storm and surface water flow conditions on both the property and adjacent lands; and

WHEREAS, in order to accommodate and regulate these anticipate changes in existing storm and surface water flow conditions, the Covenanter(s) desires to build and maintain at its expense, as storm and surface water management facility and system more particularly described and shown on plans titled _____. And further identified under approval number _____; and

WHEREAS, the City has reviewed and approved these plans subject to the execution of this agreement.

NOW THEREFORE, in consideration of the benefits received by the Covenanter(s), as a result of the City approval of this plans, Covenanter(s), with full authority to execute deeds, mortgages, other covenants, and all rights, title and interest in the property described above do hereby covenant with the City as follows:

1. Covenanter(s) shall construct and perpetually maintain, at its sole expense, the above-referenced storm and surface management facility and system in strict accordance with the plan approval granted by the City.

2. Covenanter(s) shall, at its sole expense, make such changes or modifications to the storm drainage facility and system as may, in the City discretion, be determined necessary to ensure that the facility and system is properly maintained and continues reasonable times and in reasonable manner, the storm and surface water facility and system in order to

ensure that the system is being properly maintained and is continuing to perform in an adequate manner.

3. The Covenanter(s) agrees that should it fail to correct any defects in the above described facility and system within ten (10) days from the issuance of written notice, or shall fail to maintain the facility in accordance with the approved design standards and with the law ans applicable executive regulation or, in the event of an emergency as determined by the City in its sole discretion, the City is authorized to enter the property to make all repairs, and to perform all maintenance, construction and reconstruction as City deems necessary. The City shall then assess the Covenanter(s) and/or all landowners served by the facility for the cost of the work, both direct and indirect, and applicable penalties. Said assessment shall be a lien against all properties served by the facility and may be placed on the property tax bills of said properties and collected as ordinary taxes by the City.

4. Covenanter (s) shall indemnify, save harmless and defend the City from and against any and all claims, demands, suits, liabilities, losses, damages and payments including attorney fees claimed or made by persons not parties to this Declaration against the City that are alleged or proven to result or arise from the Covenanter(s) construction, operation, or maintenance of the storm and surface water facility and system that is the subject of this Covenant.

5. The covenants contained herein shall run with the land and the Covenanter(s) further agrees that whenever the property shall be held, sold and/or conveyed, it shall be subject to the covenants, stipulations, agreements and provisions of this Declaration, which shall apply to, bind and be obligatory upon the Covenanter(s) hereto, its heirs successors and assigns and shall bind all present and subsequent owner's of the property served by the facility.

6. The Covenanter(s) shall promptly notify the City when the Covenanter(s) legally transfers any of the Covenanter(s) responsibilities for the facility. The Covenanter(s) shall supply the City with a copy of any document of transfer, executed by both parties. The provisions of this Declaration shall be severable and if any phrase, clause, sentence or provisions is declared unconstitutional, or the applicability thereof to the Covenanter is held invalid, the remainder of this Covenant shall not be affected thereby.

7. The Declaration shall be recorded in the office of the Recorder Bartholomew County Indiana at the Covenanter(s) expense. In the event that the City shall determine at its sole discretion at future time that the facility is no longer required, then the City shall at the request of the Covenanter(s) execute a release of this Declaration of Covenants, which the Covenanter(s) shall record at its expenses.

IN WITNESS WHEREOF, the Covenanter(s) have executed this Declaration of Covenants as of this _____ day of _____, 20_____.

ATTEST: FOR THE COVENANTOR(S)

___________________________ ______________________________
(Signature) (Signature)

___________________________ ______________________________
(Printed Name) (Printed Name and Title)

STATE OF ____________________: COUNTY OF ____________________:

On this _____ day of _____, 20_____, before me, the undersigned officer, a Notary Public in and for the State and County aforesaid, personally appeared, _____ who _____ acknowledged themselves to be _____, of _______ _____, and as such authorized to do so, executed the foregoing instrument for the purposes therein contained by signing their name as _____for said _____.

WITNESS my hand and Notarial Seal

My commission expires: ____

Notary Public Seen and approved: ________________________

CERTIFICATION OF SUFFICIENCY PLAN

Permit Number- _____

Address where land alteration is occurring: _____

Plan Date: _____

I hereby certify that to the best of my knowledge and belief:

(1) The stormwater runoff for this project is in compliance with stormwater requirements (as set forth in the Soil Erosion and Sedimentation Control and Post Construction Stormwater Runoff Ordinance of the City of Columbus, Indiana) pertaining to this class of work.

(2) The calculations, designs, reproducible drawings, masters and original ideas reproduced in this stormwater plan are under my dominion and control and they were prepared by me and my employees.

______________________________ ____________________

Signature Date

______________________________ ______________________

Typed or Printed Name Phone

(SEAL)

Business Address: ____

Professional Registration No. ______________________________________

CERTIFICATE OF OBLIGATION TO OBSERVE

To Be Completed By The Registered Professional

Project Name _____

Address of Land Alteration: _____

Stormwater Permit Number: _____

I hereby certify that myself or a person under my direct supervision will inspect the subject project site at the time designated below and found that such land alteration is in accordance with both the applicable stormwater requirements and the stormwater plan for this project submitted for a stormwater approval to the Office of the City Engineer, Columbus, Indiana. I also certify that myself or the person performing the inspection is thoroughly knowledgeable of all applicable stormwater standards of the City of Columbus, Indiana.

______________________________ ____________________
Signature Date

______________________________ ______________________
Typed or Printed Name Phone

Business Address ____

Professional Registration No. ______________________________________

(SEAL)

PERIOD OF INSPECTION

Erosion Control Practices Installed
Construction 30 Percent Complete
Final Inspection __________________

CERTIFICATE OF COMPLETION AND COMPLIANCE

Project Name _____

Address of Land Alteration: _____

Stormwater Permit Number: _____

I hereby certify that myself or a person under my direct supervision inspected the subject project site and associated stormwater plan at sufficient intervals of construction progress to determine that the land alteration is in accordance with both the applicable stormwater requirements and the stormwater plan. I also certify that myself or the person performing the inspection is thoroughly knowledgeable of all applicable stormwater standards of the City of Columbus, Indiana.

_____________________________ ____________________
Signature Date

_____________________________ ______________________
Typed or Printed Name Phone

Business Address ____

Professional Registration No. ____________________________________

(SEAL)

Appendix14 Time of Concentration, Manning's Coefficient and Curve Numbers

Worksheet 3: Time of Concentration (T_c) or travel time (T_t)

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet.
Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to Tc only)

	Segment ID		
1.	Surface description (table 3-1)		
2.	Manning's roughness coefficient, n (table 3-1)		
3.	Flow length, L (total L † 300 ft) .... ft		
4.	Two-year 24-hour rainfall, P_2 .... in		
5.	Land slope, *s* .... ft/ft		
6.	$T_t = \dfrac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute T_t .... hr	+	=

Shallow concentrated flow

	Segment ID		
7.	Surface description (paved or unpaved)		
8.	Flow length, L ....ft		
9.	Watercourse slope, s .... ft/ft		
10.	Average velocity, V (figure 3-1) .... ft/s		
11.	$T_t = \dfrac{L}{3600\ V}$ Compute T_t .... hr	+	=

Channel flow

	Segment ID		
12.	Cross sectional flow area, a .... ft^2		
13.	Wetted perimeter, p_w .... ft		
14.	Hydraulic radius, $r = \dfrac{a}{p_w}$ Compute r .... ft		
15	Channel slope, s .... ft/ft		
16.	Manning's roughness coefficient, n		
17.	$V = \dfrac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V ....ft/s		
18.	Flow length, L .... ft		
19.	$T_t = \dfrac{L}{3600\ V}$ Compute T_t .... hr	+	=
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... Hr		

Worksheet 3.2.1: Time of Concentration or Travel Time Worksheet

Worksheet 2: Runoff curve numbe

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2			Area ☐ acres ☐ mi² ☐ %	Product of CN x area

[1/] Use only one CN source per line

Totals ➡ | | |

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ______________ = _______ ; Use CN ➡ ☐

210-VI-TR-55, Second Edition, June 1986

Worksheet ##(TR-55 Worksheet 2): Runoff Curve Number Worksheet

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table ## (TR-55 Table 2-2a): Runoff Curve Numbers for Urban Areas

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table ## (TR-55 Table 2-2b): Runoff Curve Numbers for Cultivated Agricultural Lands

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table ## (TR-55 Table 2-2c): Runoff Curve Numbers for Other Agricultural Lands

	Cumulative Storm Rainfall (percent) for Given Storm Type			
Cumulative Storm Time (Percent)	**First Quartile**	**Second Quartile**	Third Quartile	**Fourth Quartile**
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92

(SOURCE: Rainfall Frequency Atlas of the Midwest by Huff and Angel)

Table ##: Median Time Distributions of Heavy Storm Rainfall at a Point

Stormwater Management Plan Technical Review Checklist NA – Not Applicable; S – Satisfactory; U – Unsatisfactory				
Description	**NA**	**S**	**U**	**Comment**
General Grading				
Existing Contours				
Proposed Contours				
Lot corner and intermediate spot grades				
Lowest adjacent grades				
Finished floor elevations				
Lowest Opening Grades				
Section VI - Major Drainage System; Routing Path; Detention and Retention				
Allowable Release Rate				
Release rate of 0.13 cfs / acre for each outlet				
Depressional storage accounted for properly				
Downstream / Receiving Facilities				
Waterway exists downstream				
Downstream waterway has capacity				
Executed Certification of Adequate Outlet				
Management of Off-Site Runoff				
Off-site runoff is managed appropriately				
Runoff from upstream is not being obstructed				
Outlet structure designed appropriately to pass on-site and off-site flows				
Compensatory Storage				
Compensatory storage in accordance with Section VI				
Overland Flow and Grading Requirements				
Overland flow paths and computations				
Overland flow paths shown on plans as hatched area (30’ min.)				
2-foot freeboard				
Modeling of overland flow paths				
Maximum street depth of 12-inches				
Detention Volume Determination				
NRCS Hydrograph methods used if area > 5 acres				
Runoff Curve Numbers or Runoff Coefficients				
Times of Concentrations				
Rainfall intensities and depths				
Rainfall distributions				
Rational method for detention				
Hydrograph methods – critical duration volumes / flows				
Calculated stage, storage, discharge curves match plans				
Detention Outfall Design				
Outlet calculations match model and plans				
Outlet designed to prevent clogging				
Hoods / trash racks				
Riser pipes				
Outlet directed to waterway with easement				
Emergency overflow calculations match design plans				
Erosion protection of emergency overflow				
Retention / Infiltration Volume Determination				
Documentation is provided that demonstrates to the County that an infiltration basin is the only feasible method to manage stormwater.				
Back to back 100-year storm events (w/o infiltration)				

Stormwater Management Plan Technical Review Checklist NA – Not Applicable; S – Satisfactory; U – Unsatisfactory				
Description	**NA**	**S**	**U**	**Comment**
72-hour maximum drain time				
Geometry Requirements				
Side slopes				
Freeboard				
Distance between inlet and outlet is maximized				
Irregularity of shorelines				
Permanent pools				
Water table / basin bottom				
Inlet Design Requirements				
Pre-treatment design				
Erosion protection				
Inlet pipes are not submerged at normal level				
Public Safety Requirements				
Ledge				
IDNR Criteria				
Construction and Maintenance Requirements				
Access route				
Location of outlet structures				
Stabilization of upland areas				
Infiltration basin construction considerations				
Section VII – Conveyance Design				
Storm Sewers				
10-year storm analysis				
25-year storm HGL analysis				
Rainfall intensities				
Manning n values				
Minimum and maximum velocities				
Minimum diameter				
Minimum cover				
End treatments				
Material				
Inverts, diameters, slopes consistent between plans and calculations				
Manholes, Catch Basins and Inlets				
Location and spacing				
Details and dimensions				
Materials				
Markings				
Inlet Design				
10-foot clear lane for local road				
Two 10-foot clear lanes for collectors				
50% clogging at sag inlets				
Spacing				
Swales, Ditches and Overland Flow Paths				
Freeboard				
Velocities				
Geometry				
Longitudinal Slope				
Protection from Erosion				
Culverts and Bridges				
Approvals				
Minimum size				
End treatment				
Material				
Minimum cover				
Drainage Easements				
Regulated drains				
Surface drainage				

Stormwater Management Plan Technical Review Checklist NA – Not Applicable; S – Satisfactory; U – Unsatisfactory				
Description	**NA**	**S**	**U**	**Comment**
Yard drainage				
Outside the development				
Stormwater management facilities				
Agreements				
Existing easements				
Consistent between plat and construction plans				
Section VIII – Construction Water Quality				
Rule 5 requirements				
Construction sequence				
Stockpile locations and measures				
Erosion control plan elements shown on plans				
Section IX – Post-Construction Water Quality				
Water quality volume(s)				
Water quality rate(s)				
Pre-treatment volume(s)				
Operation and Maintenance				
Calculations consistent with plans				