Mahoning County Drainage and Erosion and Sedimentation Control Manual

Cooperative Effort of the following:

Mahoning County Engineers Office

Mahoning County Soil and Water Conservation District

EXECUTIVE SUMMARY

Due to Ohio Environmental Protection Agency storm water regulatory requirements (Municipal Separate Strom Sewer System (MS4) - Phase II) and recurring significant flooding events within Mahoning County, the County Engineer's office is developing this manual as a tool to guide drainage designs, erosion/sedimentation control, post-construction runoff controls and storm water management for development and construction within Mahoning County.

The objectives of this manual are to provide engineering guidance to:

- Local communities and personnel responsible for implementing storm water management practices, programs, policies and operation/maintenance activities within Mahoning County.
- Engineers responsible for design of storm water conveyance structures, storm water management plans, drainage systems, and infrastructure in support of development.
- Individuals associated with storm water management at varying levels that may find the manual useful as a technical reference to illustrate storm water engineering design principals and techniques.

The intent of this drainage manual is to minimize impacts to:

- Human health and public safety
- Existing drainage infrastructure
- Flooding events and property damage
- Stream channel degradation

The County Engineer will provide updates and revisions to this manual periodically based on reviews of actual manual concepts implemented in the field and manual user suggestions and feedback on improving manual content and applicability. The County Engineer reserves the right to review drainage designs and construction plans submitted as a result of using this guidance manual. The County Engineer shall not be held liable as a result of information presented in this guidance manual. The manual has been developed primarily as a "tool" to guide developers, engineers, builders and contractors through the county's drainage design process and procedures. The County Engineer does not consider this as an all inclusive comprehensive design document or manual.

This manual has been prepared in cooperation with:

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SECTION 1 INTRODUCTION

1.0 INTRODUCTION

1.1 Purpose and Manual Organization

The primary purpose of this manual is to provide detailed and supporting information with examples which will allow developers, designers, contractors, builders and planners the tools necessary to address the sub-division regulations and OEPA permit requirements for both construction site runoff (erosion and sediment control) and post-construction storm water management within Mahoning County. The manual has been divided into the following technical sections:

- Introduction **(Section 1)**
- Drainage Design and Engineering **(Section 2)**
- Storm Drainage Systems **(Section 3)**
- Post-Construction Storm Water Management Requirements **(Section 4)**
- Storm Water Pollution Prevention Plans and Erosion/Sedimentation Control Requirements **(Section 5)**
- Floodplain Regulations **(Section 6)**
- Enforcement **(Section 7)**
- Appendices

Each section is subdivided to provide supporting details and example calculations to present a step by step process for implementing the drainage criteria in this manual. Application of concepts, methods, and engineering practices addressed in this manual should contribute toward effective and economic solutions for:

- Storm water management
- Sound planning, engineering and design of drainage and storm water infrastructure systems
- Permit and promote development while decreasing downstream flooding
- Urban erosion/sedimentation control
- Reducing negative impacts to receiving watercourses
- Local drainage and flooding issues

Alternate engineering design methods, other than those identified in this manual, may be used with approval of the County Engineer. Complete supporting documentation, including calculations, shall be required at the request of the County Engineer for approval of these alternative methods.

1.2 Using the Manual

The Manual has been developed with the ability to distribute sections independently or as a complete document. The primary objective of the manual is to provide a consistent approach to drainage design and storm water management within Mahoning County. The following provides recommendations on the use of this manual for drainage design, construction projects, storm water management and compliance within Mahoning County.

- Review current pre-developed site conditions
- Consider incorporation of natural site conditions, contouring and set backs which are practical.
- Review and select appropriate drainage methodology presented in manual. Refer to examples provided in manual as guidance during design.
- Drainage methodology selected shall include review and incorporation of both quantity and quality runoff controls, temporary erosion and sediment controls and post-construction control best management practices.
- Completed sub-division and construction plans (Drainage designs with supporting calculations as requested, erosion and sedimentation control drawings along with storm water pollution prevention control plans) shall be submitted to the County Engineer for review.
- Obtain necessary project permits, pay associated fees and provide copies of approved permits to County Engineer.
- Complete Notice of Intent and submit to OEPA.
- Provide County Engineer with approved copy of NOI.
- Determine requirements to complete a Storm water pollution prevention plan.

Project planners, developers and engineers should address both on-site, off-site runoff and downstream potential impact issues, local requirements and known flooding areas when developing project site plans for addressing project drainage and runoff.

1.3 Drainage Policy

The Mahoning County Engineer shall ensure that sound engineering practices, concepts, and methods are incorporated into planning and design of drainage infrastructure and conveyance systems within Mahoning County. Emphasis shall be placed on protecting and managing the following:

- Public safety
- Historic flooding areas
- Protecting stream channels and property
- Current drainage infrastructure

The following elements, as defined by the Mahoning County's Sub-division regulations, are the basis for Mahoning County's drainage criteria.

Minor Drainage Systems - Collects and conveys storm water run-off from frequently recurring storms. The purpose is to design and manage runoff associated with the 10 year storm through the Critical storm (where the Critical storm is greater than the 10 year storm). These storm events will form the basis for system designs and runoff controls. Minor drainage systems consist of, but are not limited to storm sewer systems- curb inlets, catch basins, manholes, curb and gutter systems, ditches, yard drains, open channels and other surface conveyance systems.

Major Drainage Systems - Collects and conveys storm water run-off from less frequently recurring storms. The purpose is to manage storm water run-off which exceeds capacity of the minor drainage systems in a manner that eliminates or minimizes risk to health and human safety. For the purposes of this manual, the 100 year storm event will serve as the design storm of record for the major drainage systems.

Storm Water Storage Facilities - Intent is to ensure storm water run-off is properly conveyed, detained, or managed as the run-off moves through public or privately managed systems. Elements include, but are not limited to: detention/retention, outlet controls, quantity volume controls, simultaneous peak release rates, and minimization of downstream quantity and erosive impacts.

The three elements are explained in detail with supporting example calculations in *Section 2.0 Drainage Design and Engineering* of this manual. Criteria and requirements set forth in this manual are intended to be used as tools in combination with sound hydraulic/hydrologic engineering practices for both public and private projects. The County Engineer requires that all designs, permits, supporting drawings, state and local storm water runoff requirements be reviewed and stamped by a professional engineer registered in the State of Ohio.

1.4 Planning

Locating permanent post-construction runoff controls and associated level of maintenance practices with regards to these controls are examples to be considered during initial project planning. The Mahoning County Engineer recommends that at a minimum, the following shall be considered and incorporated prior to submitting project construction plans:

- Has the project design incorporated naturally occurring site features such as stream buffers, natural site contours, green space where applicable, set backs, natural drainage features, etc.?
- Has the project design accounted for both off-site runoff and protection of streams and adjacent properties?
- Will the project drainage design minimize operation and maintenance activities from coming into contact with site storm water runoff?
- Has the project incorporated local storm water Best Management Practices (BMP's)?

1.5 Limitations

The manual establishes uniform design criteria for storm water design and management practices within Mahoning County. The manual does not replace the need for sound engineering judgment nor does it preclude the use of information that may subsequently become available. The manual, as mentioned in Section 1.1 is not intended to be a comprehensive document. The objective is to provide a guidance manual which establishes uniform criteria for consistency in design of drainage and storm water runoff controls.

The Mahoning County Engineer, in its review of submitted project plans, reserves the right to return and/or request additional supporting documentation as necessary to assure the above project elements have been addressed to the maximum extent practicable. The Mahoning County Engineer recognizes that this manual is not all inclusive or comprehensive and will require updates periodically.

Anything not composed entirely of storm water is considered an illicit discharge. The Mahoning County Engineer shall prohibit all non-storm water discharges except those shown in Table 1.1:

TABLE 1-1: Allowable County, Non-storm Water Discharges

Allowed Non-Storm Water Discharges			
Water line flushing	Uncontaminated pumped groundwater	Natural Springs	Flows from **riparian** habitats and **wetlands**
Landscape Irrigation	Discharges from portable water sources	Water from crawl space pumps	Dechlorinated swimming pool discharges
Diverted stream flows	Foundation drains	Footing drains	Street wash water
Rising groundwater	Air conditioning condensate	Lawn Watering	Discharges from flows from fire fighting activities
Uncontaminated ground water infiltration	Irrigation water	Individual residential car washing	

Source: OEPA General ***Storm water*** *Permit- March 2003*

By completing and submitting construction plans and Notice of Intent (NOI), you agree to comply with the requirements of the Construction General Permit (CGP) and Mahoning County's drainage manual regulations and to limit the discharge of storm water runoff from the project site to the Maximum Extent Practicable.

1.6 Manual Updating

The County Engineer will review regulatory requirements, best management practices, design criteria, and other supporting materials to provide necessary updates to the manual as required or necessary. The County Engineer will take under advisement, any design requirement suggestions or other manual revisions which will not be in conflict with the intent and purpose of this manual. Suggestions may be submitted at any time. Incorporation of submitted suggestions will be at the discretion of the County Engineer. Revisions to this manual will be made by addenda. All proposed revisions will undergo a public comment period prior to being added to this manual.

1.7 Contact Information

Submit **all** manual suggestions and comments to:

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1.8 Design and Construction Criteria

The following criteria will be used for the design and construction of all storm water conveyance, drainage and storage facilities:

- Design and installation of all storm water conveyance systems, storm sewers, storm water post-construction controls and detention/retention (Public and Private) shall comply with all applicable federal, state and local laws. Special attention shall be given to Mahoning County Erosion and Sedimentation control requirements addressed in Section 4 of this manual.
- In no case shall a structure be located within the impoundment area of any storm water (retention) storage facility or over any storm water drainage or sewer line.
- Roadway "Sags" and parking areas which also serve as temporary impoundments of runoff shall not exceed an impounded depth of 10 inches.
- Maintenance of all detention/retention facilities will be the responsibility of the property owner(s).
- Project downstream impacts shall not be allowed. Project storm water runoff shall be managed and maintained on site.

1.9 Compliance with State and Federal Regulations

Addressing only the requirements associated with the Construction General Permit does not relieve the applicant of responsibility for obtaining all subsequent permits and/or approvals from the Ohio Environmental Protection Agency (OEPA), the United States Army Corp of Engineers (USACE) or any other federal, state and/or county agencies. Should the requirements vary, the more restrictive requirements will govern. Additional permits may include, but are not limited to those listed below. The Mahoning County Engineer shall require proof of compliance with these state and federal regulations be submitted with the project construction plan packet *(Packet for the purposes of this manual means- Site drainage plan sheets, storm water pollution prevention plans and erosion/sedimentation control plans)* prior to plan approval.

1. OEPA - Authorization of Storm Water Discharges Associated with Construction Activity - Proof of compliance will consist of an OEPA approved Notice of Intent (NOI) including NPDES project permit number.
2. OEPA - Municipal Separate Storm Sewer System - Phase II permit - Mahoning County's Storm Water Management Plan
3. All proposed development sites must be checked for the existence of wetlands by a qualified professional. If no wetlands are on the site, a letter from the qualified professional stating so shall be included with the submittal of the project construction plan packet. If wetlands are found to be on the site one or all of the following may be required based on the determined extent of the impact:

   a. Jurisdictional Determination - Proof of compliance shall be a copy of the Jurisdictional Determination from the USACE, confirming the findings of a qualified professionals survey and report.

b. Section 404 of Clean Water Act - Proof of compliance shall be a copy of the USACE Individual Permit Application. Should an individual permit be required, public notification and meetings will be held. Should an individual permit not be required, proof of compliance shall be a copy of the USACE Nationwide Permit including a site plan indicating proposed fill areas in proximity to waters of the U.S.

4. Should a Section 404 Permit or Jurisdictional Determination not be necessary, the site owner shall submit a letter certifying that a qualified professional has surveyed the site and no waters of the United States were identified.

5. OEPA-Isolated Wetland Permit - Proof of compliance will consist of a copy of the OEPA's Isolated Permit Application, public notice or project approval or a letter from the site owner certifying that a qualified professional has surveyed the site and no waters of the state were identified.

6. Section 401 of Clean Water Act - Proof of compliance will consist of a copy of the OEPA's Water Quality Certification Application, public notice, project approval or a letter from the site owner certifying that a qualified professional has surveyed the site and no waters of the United States were identified.

7. Ohio Dam Safety Law - Proof of compliance will consist of a copy of the ODNR's - Division of Water permit application or a copy of the project approval letter for ODNR.

8. Federal Emergency Management Agency (FEMA) - Proof of compliance will consist of a copy of the project site showing all 100 year flood elevation limits. Should the project have been granted a waiver, copies of the approved Letter of Map Revision (LOMR) shall be submitted.

9. Notice of Intent (NOI)/ Notice of Termination (NOT) - Copies of the approved NOI shall accompany the construction plans. NOT's shall be applied for in a timely manner and a copy forwarded to the Mahoning County Engineer's office as documentation of project close out.

The permitting process may require extensive coordination, including project start time receipt of permit approval, construction sequencing and seasonal limitations. The Mahoning County Engineer recommends attention be given to "up-front" planning and consideration of alternatives before moving forward with potential time consuming permitting procedures and project design. The Mahoning County Engineer acknowledges that there will be times when multiple permits will be required, necessary and unavoidable. The following table is a summary of current permits being used on projects within Mahoning County:

The table is intended to be a summary of permits, submittals and project related issues:

TABLE 1-2: Permit Summary Table

Submittal Type	Requirement Drivers	Agency	Comments
Site **Drainage** Plan	Mahoning County Project Requirement	Mahoning County Engineers Office	Required as part of project package
Project **Erosion** and **Sedimentation** Control Plan	Construction General Permit- Land disturbance of 1 **acre** or greater E/S plan required.	Ohio Environmental Protection Agency (OEPA)- Surface Water Division	Mahoning County Engineers Office requires that the **Erosion /Sedimentation** plan be submitted in conjunction w/ the **SWP3** plan.
Storm Water Pollution Prevention Plan (**SWP3**) + Post-Construction **Best Management Practices** • **BMP** Maintenance Plan. • **Notice of Intent** (**NOI**) • **Notice of Termination** (**NOT**)	Large Construction Projects- 5 **acres** or greater. Small Construction Projects- 1 to 5 **Acres**.	Ohio Environmental Protection Agency (OEPA)- Surface Water Division	Mahoning County Engineers Office requires that the **SWP3** plan be submitted in conjunction w/ the E/S plan.
401/404 Nationwide General Permit: • 401-Water Quality Certification. • 404 – Nationwide General Permit Note: Associated with activities in and around waters of US.	Maintenance Activity- 200 feet maximum. Bank **Stabilization** – 500 feet maximum. **Drainage Ditch** Reshaping- 500 feet maximum (Waters of US). **Storm water Management** Facilities- 300 feet maximum streambed loss due to discharge (**Intermittent streams** only, not allowed for **perennial streams**). Include maintenance plan	U.S Army Corp. of Engineers (USACE)	USACE- 45 Day permit turn around period upon receipt of complete permit package. 30 days to review and provide notification of missing submittal components (Pre-Construction Notification (PCN)). Mahoning County **Engineer**- Recommends that these types of activities/permits be minimized and alternatives considered prior to implementing this process.
Floodplain Activities: • Letter of Map Revision- (LOMR) • Conditional Letter of Map Revision – (CLOMR) • Mahoning County Flooding regulations	Associated with structures within Floodplain/floodway. Requirement condition is no back water effect and no more than 1-foot of rise of water final surface elevation	Federal Emergency Management Agency (FEMA), USACE	FEMA- 45 Day permit application review period upon receipt of required information. Mahoning County **Engineer**- Recommends that any activities associated with structures within floodplain of floodway be minimized or implemented should no other alternatives be practical.

1.10 Definitions and Acronyms

For the purpose of these regulations certain rules or word usage apply to the text as follows:

A) Words used in the present tense include the future tense, and the singular includes the plural, unless the context clearly indicates the contrary.

B) The term "shall" is always mandatory and not discretionary; the word "may" is permissive. The term "should" is permissive, but indicates strong suggestion.

C) The word or term not interpreted or defined by this Section shall be construed according to the rules of grammar and common usage so as to give these regulations their most reasonable application.

MANUAL DEFINITIONS:

ACRE: A measurement of area equaling 43,560 square feet.

BEST MANAGEMENT PRACTICES (**BMP's**): Structural or nonstructural facilities or activities that control soil erosion and/or storm water runoff at a development site. This includes treatment requirements, operating and maintenance procedures, and other practices to control site runoff, leaks, or waste disposal.

CHANNEL: A natural bed that conveys water; a ditch excavated for the flow of water.

CHANNEL PROTECTION AND WATER QUALITY VOLUME ($CPWQ_V$): Volume of storm water runoff that must be captured and treated before discharge from the developed site after construction is complete. $CPWQ_V$ is based on the expected runoff generated by the mean storm precipitation volume from post-construction site conditions at which rapidly diminishing returns in the number of runoff events captured begins to occur.

CRITICAL STORM: That storm which is calculated using the post-construction percentage increase in volume of runoff from a proposed development. The critical storm is used to calculate the maximum allowable storm water discharge rate from a developed site.

DETENTION STRUCTURE: A permanent storm water management facility for the temporary storage of runoff, and is designed so as not to create a permanent pool of water.

DEVELOPMENT AREA: A lot or contiguous lots owned by one person or persons, or operated as one development unit, and used or being developed for commercial, industrial, residential, institutional, or other non-farm construction or alternative that changes runoff characteristics, upon which soil-disturbing activities occur.

DEVELOPMENT DRAINAGE AREA: A combination of each hydraulically unique drainage areas with individual outlet points on the development area.

DISTURBED AREA: An area of land subject to erosion due to the removal of vegetative cover and/or soil disturbing activities

DITCH: An open channel, either dug or natural, for the purpose of drainage or irrigation with intermittent flow.

DRAINAGE: The removal of excess surface water or groundwater from land by surface or subsurface drains.

DRAINAGE IMPROVEMENT: As defined in Ohio Revised Code (ORC). 6131.01 (C), and/or conservation works of improvement, ORC. 1511 and 1515.

DUMPING: Grading, pushing, piling, throwing, unloading, or placing

ENGINEER: A Professional Engineer registered in the State of Ohio.

EROSION: The process by which the land surface is worn away by the action of wind, water, ice, gravity, or any combination of those forces.

EROSION AND SEDIMENT CONTROL: The control of soil material, both mineral and organic, to minimize the removal of soil material from the land surface and to prevent its transport out of a disturbed area by means of wind, water, ice, gravity, or any combination of those forces.

FINAL STABILIZATION: All soil disturbing activities at the site have been completed and a uniform perennial vegetative cover with a density of at least 80% cover for the area has been established or equivalent stabilization measures, such as the use of mulches, geotextiles, have been employed.

GRASSED WATERWAY: A broad or shallow natural watercourse or constructed channel, covered with erosion-resistant grasses or similar vegetative cover, used to convey surface water.

HYDRIC SOILS: Soils that are saturated, flooded, or ponded for a long enough time period during the growing season that anaerobic conditions develop in the upper part of the soil. Soils that are considered “wetland” soils.

HYDROGRAPH: Time distribution of runoff from a watershed.

HYDROPHYTIC VEGETATION: Plants that are found in wetland areas. These plants have been classified by their frequency of occurrence in wetlands.

IMPERVIOUS: Not allowing infiltration which means any paved, hardened or structural surface regardless of its composition including (but not limited to) buildings, roads, driveways, parking lots, loading/unloading spaces, decks, patios, and swimming pools.

INTERMITENT STREAM: Stream which conveys flow periodically throughout the year. No permanent or consistent flow of water.

LANDSCAPE ARCHITECT: A Professional Landscape Architect registered in the State of Ohio.

LARGER COMMON PLAN OF DEVELOPMENT: A contiguous area where multiple separate and distinct construction activities may be taking place at different times on different schedules under one plan.

LOT: A tract of land occupied or intended to be occupied by a use, building, or group of buildings and their accessory uses and buildings as a unit, together with such open spaces and driveways as are provided and required. A lot may contain more than one contiguous lot.

MAXIMUM EXTENT PRACTICABLE: The level of pollutant reduction that site owners of small municipal separate storm sewer systems regulated under 50 C.F.R. Parts 9, 122, 123, and 124, referred to as NPDES Storm Water Phase II, must meet.

MULTI-FAMILY DEVELOPMENT: Apartments, condominiums, townhouses, duplexes, or other similar buildings housing more than one family.

NPDES: National Pollutant Discharge Elimination System. A regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into surface water of the United States without a permit.

Notice of Intent (**NOI**): Notice of Intent obtained from the Ohio EPA under the NPDES Phase 2 Program.

Notice of Termination (**NOT**): Notice of Termination obtained from the Ohio EPA under NPDES Phase 2 Program.

OHIO EPA: Ohio Environmental Protection Agency.

ODNR-DSWC: Ohio Department of Natural Resources, Division of Soil and Water Conservation.

PERENNIAL STREAM: A stream that maintains water in its channel throughout the year.

PERSON: Any individual, corporation, firm, trust, commission, board, public or private partnership, joint venture, agency, unincorporated association, municipal corporation, county or state agency, the federal government, other legal entity, or an agent of combination thereof.

PHASING: Clearing/grubbing/excavating a parcel of land in distinct sections, with the stabilization of each section occurring before clearing the next.

RAINWATER AND LAND DEVELOPMENT MANUAL: Ohio's standards for storm water management, land development, and urban watercourse protection. The most current edition of these standards shall be used with this regulation.

RETENTION STRUCTURE: A permanent storm water management facility that provides for the storage of runoff by means of a permanent pool of water.

RIPARIAN: Contiguous tract of land in contact with a stream and within the same watershed as the stream.

RUNOFF: The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and is eventually returned to water resources, watercourses, or wetlands.

SEDIMENT: Soils or other surface materials that are or have been transported or deposited by the action of wind, water, ice, gravity, or any combination of those forces, as a product of erosion.

SEDIMENTATION: The deposition of settling of sediment.

SEDIMENT BASIN: A barrier or other suitable retention structure built across an area of water flow to intercept runoff and allow transported sediment to settle and be retained, prior to discharge into water of the State.

SEDIMENT POLLUTION: Degradation of waters of the state by sediment as a result of failure to apply management or conservation practices to abate wind or water soil erosion, specifically in conjunction with soil-disturbing activities on land used or being developed for commercial, institutional, industrial, residential, or other non-farm purposes.

SETBACK: A designated transition area around water resources or wetlands that is left in a natural, usually vegetated, state to protect the water resources or wetlands from runoff pollution. Construction activities in this area are restricted or prohibited as required in this regulation.

SOIL AND WATER CONSERVATION DISTRICT: An entity organized under Chapter 1515 of the Ohio Revised Code; referring either to the Soil and Water Conservation District, Board, or its designated employee(s), hereinafter referred to as the Mahoning SWCD.

SOIL DISTURBING ACTIVITY: Clearing, grubbing, grading, excavating, filling, or other alteration of the earth's surface where natural or human made ground cover is destroyed and which may result in, or contribute to erosion and sediment pollution. This may also include construction of non-farm buildings, structures, utilities, roadways, parking areas, and septic systems that will involve soil disturbance or altering of the existing ground cover.

SOIL LOSS: Soil moved from a given site by the forces of erosion, measured using "T

STABILIZATION: The use of Best Management Practices, such as seeding and mulching, that reduce or prevent soil erosion by water, wind, ice, gravity, or a combination of those forces.

STORM FREQUENCY: The average period of time within which a storm of a given duration and intensity can be expected to be equaled or exceeded.

STORM WATER: Storm water runoff, snowmelt, surface runoff, and drainage

STORM WATER MANAGEMENT: Runoff water safely conveyed or temporarily stored and released at an allowable rate to minimize erosion and flooding.

SUBSOIL: That portion of the soil below the topsoil or plow layer, typically beginning 6-12" below the surface, but can also extend to 48" or deeper in the case of prime farmland soils, down to bedrock parent material.

SWP3: Storm Water Pollution Prevention Plan as defined and required by the Ohio EPA

TEMPORARY SOIL STABILIZATION: Establishment of temporary vegetation, mulching, geotextiles, sod, preservation of existing vegetation and other techniques capable of quickly establishing cover over disturbed areas to provide erosion control between construction operations.

TOPSOIL: The upper layer of soil that is usually darker in color and richer in organic matter and nutrients than the subsoil.

USDA-NRCS: United States Department of Agriculture, Natural Resources Conservation Service.

WATERCOURSE: A definite channel with defined bed and banks within which concentrated water flows, either continuously or intermittently, (e.g., brooks, **channels**, creeks, rivers, or streams.

WATER RESOURCE: Any public or private body of water including lakes and ponds, as well as streams, gullies, ditches, swales, or ravines that have banks, a defined bed, and a definite direction of course, either continuously or intermittently flowing.

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

WETLAND: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support and contain a predominance of hydric soils, and that under normal circumstances do support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs, and similar areas (40 CFR 232, as amended).

SECTION 2 DRAINAGE DESIGN AND ENGINEERING

2.0 DRAINAGE DESIGN AND ENGINEERING

2.1 Hydrologic Design Policies

A design storm is the defined precipitation pattern used in hydraulic system design. The design storm is not an actual storm of record. Rather, it is a fabricated storm compiled from average characteristics of previous storm events and therefore is used to predict future storm events.

There are various hydrologic techniques to estimate the design storm. These include, but are not limited to, the Rational Method, the S.C.S. Graphical Peak Discharge Method, and the S.C.S. Unit Hydrograph Method. Each of these methods has limitations and their results vary from peak discharge only to hydrograph generation.

The following sections describe in detail the methodology and resources to calculate the design storm for the desired application:

2.2 Rational Method

The rational method is a formula for estimation of peak flow rates for small, **drainage** areas. Its formula is a ratio between **runoff** and rainfall rates. *It shall be used primarily when designing the storm system (minor) in urban or rural areas.* It shall not be used for the overland system (major) when the drainage area is greater than 20 **acres**.

Rational Formula:

$Q = CIA$

Where: Q = rate of runoff (cfs)
C = runoff coefficient
I = rainfall intensity (in/hr)
A = drainage area (acres)

- The **runoff** coefficient, C, is a dimensionless decimal value that estimates the percentage of rainfall that becomes runoff. It incorporates most of the hydrological abstractions, soil types, antecedent conditions, etc. Values of typical C coefficients are listed in Table 2-1.

  Where small **watersheds** have various land use or ground covers, a Weighted “C” value shall be used. The following example illustrates how a Weighted “C” value is calculated:

Example

Area	Land Use	"C"	"CA"
5	Roof	0.95	4.75
15	Lawn	0.35	5.25
20	Summation		10.0

Weighted "C" (Cw) = CA/Area = 10/20 = 0.50

- The rational method assumes that the rainfall intensity, I, is uniform over the entire watershed during the entire storm duration. The maximum runoff rate occurs when the rainfall lasts as long, or longer, than the time of concentration.

- The time of concentration, Tc, is the time required for the runoff from the most remote part of the watershed to reach the point under design. The Tc for small watersheds (overland travel distance is less than 1,000 feet) can be determined using Figure 2-1. Once the Tc is calculated, the rainfall intensity can determined using Table 2-2.

Note: Peak runoff rates as determined using the rational method cannot be added together to determine a resultant peak discharge rate from two or more separate watersheds. These are not cumulative runoff values.

TABLE 2-1: Runoff Coefficients

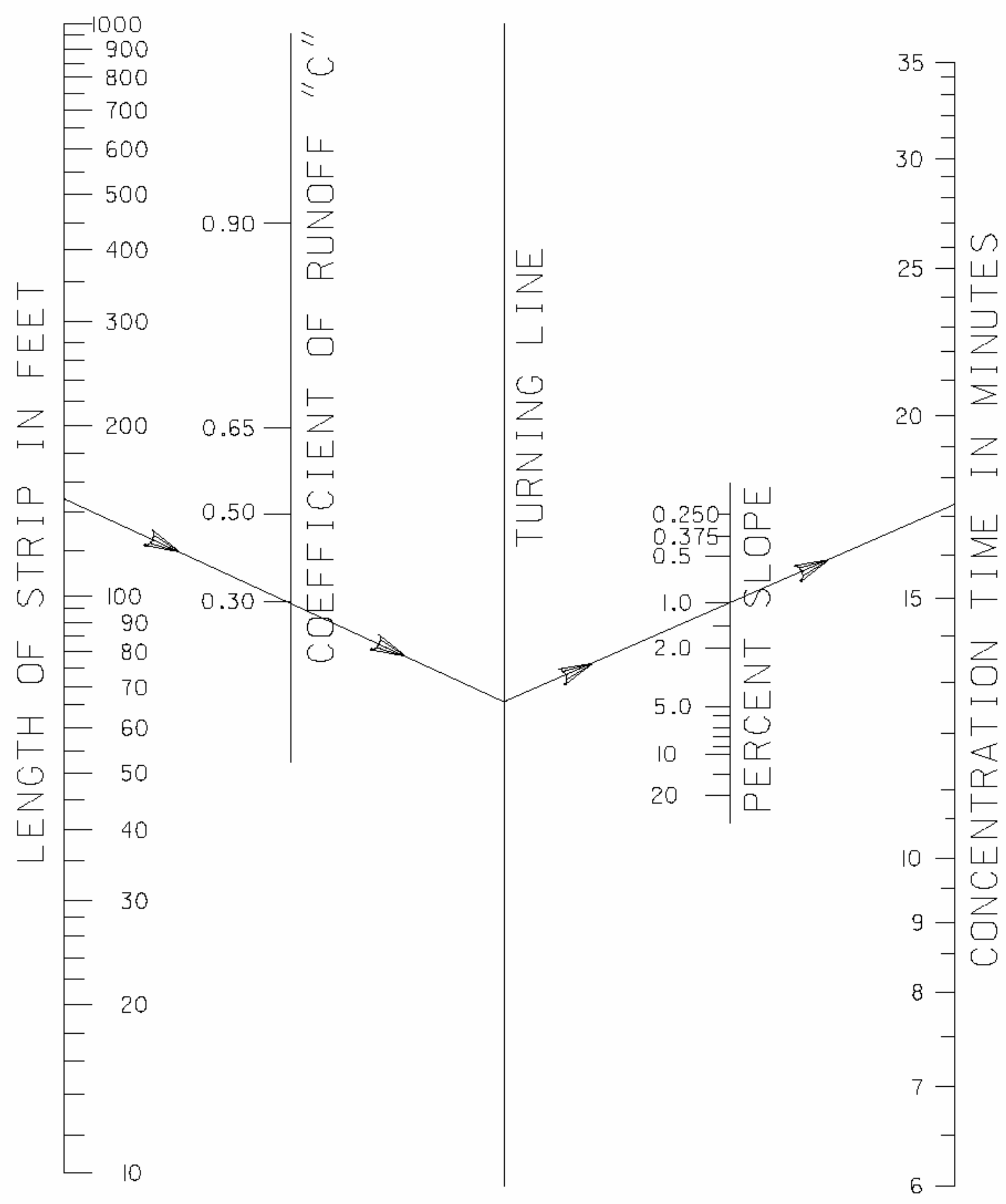
Recommended Runoff Coefficients	
Description of Area	**Runoff Coefficients**
Business	
Downtown	0.95
Neighborhood	0.70
Residential (**lot** size)	
12,000 – 25,000 FT^2	0.50
25,000 – And Over	0.40
Apartment	0.70
Industrial	
Light	0.80
Heavy	0.90
Other	
Parks, cemeteries	0.25
Playgrounds	0.35
Railroad yard	0.35
Undeveloped	0.30
Shopping centers	0.90

It often is desirable to develop a composite **runoff** based on the percentage of different types of surface in the **drainage** area. This procedure often is applied to typical "sample" blocks as a guide to selection of reasonable values of the coefficient for an entire area. Coefficients with respect to surface type currently in use are:

Character of Surface	**Runoff Coefficients**
	Post-Developed
Pavement	
Asphalt and Concrete	0.95
Brick	0.85
Roofs	0.95
Lawns	0.35

The coefficients in these two tabulations are applicable for storms of 5-to 10-yr frequencies. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on **runoff**. The coefficients are based on the assumption that the design storm does not occur when the ground surface is frozen.

FIGURE 2-1: Overland Flow Chart



Source: Ohio Department Of Transportation-Location and Design Manual- Vol-2 Figure 1101-1 (revised July, 1999)

TABLE 2-2: Rainfall Intensity for Mahoning County

Time of Concentration	2 Yr.	5 Yr.	10 Yr.	25 Yr.	50 Yr.	100 Yr.
5	4.51	5.45	6.19	7.11	7.80	8.50
6	4.31	5.21	5.91	6.77	7.42	8.08
7	4.11	4.97	5.63	6.44	7.05	7.66
8	3.92	4.72	5.34	6.10	6.67	7.24
9	3.72	4.48	5.06	5.77	6.30	6.82
10	3.52	4.24	4.78	5.43	5.92	6.40
11	3.39	4.09	4.61	5.24	5.71	6.18
12	3.26	3.93	4.44	5.05	5.51	5.96
13	3.13	3.78	4.26	4.85	5.30	5.73
14	3.00	3.62	4.09	4.66	5.10	5.51
15	2.87	3.47	3.92	4.47	4.89	5.29
16	2.81	3.40	3.84	4.38	4.80	5.19
17	2.74	3.32	3.76	4.30	4.70	5.09
18	2.68	3.25	3.68	4.21	4.61	5.00
19	2.62	3.18	3.60	4.12	4.52	4.90
20	2.55	3.11	3.52	4.03	4.42	4.80
21	2.49	3.03	3.44	3.95	4.33	4.70
22	2.43	2.96	3.36	3.86	4.24	4.60
23	2.36	2.89	3.28	3.77	4.14	4.51
24	2.30	2.82	3.20	3.68	4.05	4.41
25	2.24	2.74	3.12	3.60	3.96	4.31
26	2.17	2.67	3.04	3.51	3.86	4.21
27	2.11	2.60	2.96	3.42	3.77	4.11
28	2.05	2.53	2.88	3.33	3.68	4.02
29	1.98	2.45	2.80	3.25	3.58	3.92
30	1.92	2.38	2.72	3.16	3.49	3.82
35	1.80	2.23	2.56	2.98	3.29	3.61
40	1.67	2.08	2.39	2.79	3.09	3.40
45	1.55	1.94	2.23	2.61	2.90	3.19
50	1.43	1.79	2.06	2.42	2.70	2.98
55	1.30	1.64	1.90	2.24	2.50	2.77
60	1.18	1.49	1.73	2.05	2.30	2.56
70	1.10	1.39	1.61	1.91	2.14	2.38
80	1.01	1.28	1.49	1.77	1.98	2.21
90	0.93	1.18	1.37	1.63	1.83	2.03
100	0.85	1.08	1.25	1.48	1.67	1.85
110	0.76	0.97	1.13	1.34	1.51	1.68
120	0.68	0.87	1.01	1.20	1.35	1.50

Intensities determined from the Precipitation Frequency Data Server (PFDS) created and maintained by the Hydrometerological Design Studies Center, DOC/NOAA/National Weather Service. Values are averages of a range of data as determined across Mahoning County.
http://hdsc.nws.noaa.gov/hdsc/pfds/orb/oh_pfds.html

2.3 Simplified S.C.S. Graphical Peak Discharge Method

2.3.1 Methodology

Peak Discharge Method is applicable for estimating peak flows from storms of 24 hours in duration, the drainage area consists of homogenous soil types and land-surface cover, and drainage areas up to 20 square miles. *This method shall be used to design storm culverts*.

2.3.2 Equations and Concepts

Peak Discharge Equation:

Qp = quAQFp

Where: Qp = peak discharge (cfs)
qu = unit peak discharge (cfs/mi2/in.)
A = drainage area (mi2)
Q = rainfall (in.)
Fp = pond and swamp adjustment factor (Table 2-10)

The input requirements for this method are as follows:

- P = 24-hour design rainfall (See Table 2-3)
- Hydrological Soil Group
- CN = Curve Number (See Table 2-4)
- Tc = time of concentration, hours (See Figure 2-2)
- Rainfall Distribution Type (**Type II for Mahoning County**)
- **Storm Frequency**

TABLE 2-3: 24-Hour Cumulative Rainfall, P

Frequency	24-hour Rainfall (in.)
2-year	2.30
5-year	2.82
10-year	3.20
25-year	3.68
50-year	4.05
100-year	4.41

A. HYDROLOGIC SOIL GROUP CLASSIFICATION

SCS has developed a soil classification system that consists of four groups, identified as ***A***, ***B***, ***C***, and ***D***. Soils are classified into one of these categories based upon their ***minimum infiltration rate***. Soil characteristics associated with each Hydrologic Soil Group are generally described as follows:

Group A: Soils with low runoff potential due to high infiltration rates, even when thoroughly wetted. These soils consist primarily of deep, well to excessively drained sands and gravels with high water transmission rates (**0.30 in./hr.**). Group **A** soils include **sand, loamy sand,** or **sandy loam**.

Group B: Soils with moderately low runoff potential due to moderate infiltration rates when thoroughly wetted. These soils consist primarily of moderately deep to deep, and moderately well to well-drained soils. Group **B** soils have moderate water transmission rates (**0.15-0.30 in./hr.**) and include **silt loam or loam**.

Group C: Soils with moderately high runoff potential due to slow infiltration rates when thoroughly wetted. These soils typically have a layer near the surface that impedes the downward movement of water or soils. Group **C** soils have low water transmission rates (**0.05-0.15 in./hr.**) and include **sandy clay loam**.

Group D: Soils with high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly **impervious** parent material. Group **D** soils have very low water transmission rates (**0-0.05 in./hr.**) and include **clay loam**, **silty clay loam**, **sandy clay**, **silty clay**, or **clay**.

Refer to the latest version of the Soil Survey of Mahoning County to determine Soil Type and corresponding Hydrologic Group within project area or visit the following GIS website for soil and other useful information:

http://gis.mahoningcountyoh.gov/

B. RUNOFF CURVE NUMBER, CN

The soil group classification, cover type and the hydrologic condition are used to determine the **runoff** curve number, ***CN***. The *CN* indicates the runoff potential of an area when the ground is not frozen. **Table 2-4** provides the *CN's* for various land use types and soil groups.

"Good Condition" shall be used for determining the runoff curve number for pre-development.

The user is referred to TR-55 for additional cover types and general assumptions and limitations.

TABLE 2-4: Runoff Curve Numbers

Runoff Curve Numbers, CN (1)					
Runoff curve number for selected agricultural, suburban, and urban land use. (Antecedent moisture condition II, and $I_a – 0.2S$)					
LAND USE DESCRIPTION		**HYDROLOGIC SOIL GROUP**			
		A	B	C	D
Cultivated land[1] : without conservation treatment		72	81	88	91
: with conservation treatment		62	71	78	81
Pasture or range land: poor condition		68	79	86	89
: good condition		39	61	74	80
Meadow: good condition		30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch		45	66	77	83
: Good cover[2]		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% **impervious**)		89	92	94	95
Industrial districts (72% **impervious**)		81	88	91	93
Residential[3]					
Average **lot** size	Average % **Impervious**[4]				
1/8 **acre** or less	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
Paved parking **lots**, roofs, driveways, etc.[5]					
Streets and roads:					
paved with curbs and storm sewers[5]		98	98	98	98
gravel		76	85	89	91
Dirt		72	82	87	89

[1] For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, Aug. 1972.
[2] Good cover is protected from grazing and litter and brush cover soil.
[3] Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.
[4] The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.
[5] In some warmer climates of the country a curve number of 95 may be used.

Where watersheds, or sub-watershed areas, have various ground covers and hydrologic groups, a Weighted "CN" value shall be used. The following example illustrates how a Weighted "CN" value is calculated:

Worksheet 2: Runoff curve number and runoff

Project: Heavenly Acres	By: WJR	Date: 10/1/85
Location: Dyer County, Tennessee	Checked: NM	Date: 10/3/85

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	CN [1/] Figure 2-3	CN [1/] Figure 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
Memphis, B	25% connected impervious 1/2 acre lots, good condition	70			75	5250
Loring, C	25% impervious with 50% unconnected 1/2 acre lots, good condition			78	100	7800
Loring, C	Open space, good condition	74			75	5550
				Totals	250	18,600

[1/] Use only one CN source per line

$$\text{CN (weighted)} = \frac{\text{total product}}{\text{total area}} = \frac{18{,}600}{250} = 74.4\text{ ;}\quad \text{Use CN} = 74$$

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	6.0		
Runoff, Q (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	in	3.19		

Blank Worksheet 2, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

C. TIME OF CONCENTRATION, Tc

The time of concentration is the sum of the time increments for each flow segment present in the *tc* flow path, such as ***overland*** or ***sheet flow***, ***shallow concentrated flow***, and ***channel flow***.

$$Tc = T_{\text{sheet flow}} + T_{\text{shallow concentrated flow}} + T_{\textbf{channel}\text{ flow}}$$

These flow types are influenced by surface roughness, **channel** shape, flow patterns, and slope, and are discussed below:

a. Overland (sheet) flow is shallow flow over plane surfaces. For the purposes of determining time of concentration, overland flow usually exists in the upper reaches of the hydraulic flow path.

The kinematic solution to Manning's equation is used to compute *tc* for overland sheet flow:

$$Tc = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}S^{0.4}}$$

Where:

n = Manning's (See Table 2-5)
L = flow length in feet (<300 feet) See Note
P_2 = 2-year/24-hour rainfall (inches)
S = average land slope, ft/ft

NOTE: *Sheet flow can influence the peak discharge of small* ***watersheds*** *dramatically because the ratio of flow length to flow velocity is usually very high.* ***Surface roughness, soil types, and slope will dictate the distance before sheet flow transitions into shallow concentrated flow.*** *TR-55 stipulates that the maximum length of sheet flow is 300 feet. Many hydrologists and geologists will argue that, based on the definition of sheet flow that 100 to 150 feet is the maximum distance before the combination of quantity and velocity create shallow concentrated flow. In an urban application (usually a relatively small drainage area), the flow time associated with 300 feet of sheet flow will result in a disproportionately large segment of the total time of concentration for the watershed. This will result in a very slow overall tc and may not be representative of the drainage area as a whole.* ***As stated previously, the designer must be sure that the flow path chosen is not only representative of the drainage area, but also is the flow path for the significant portion of the total peak discharge.***

TABLE 2-5: Surface Description – Mannings "n"

Surface Description '*n*' Value
Smooth Surfaces (Concrete, Asphalt, Gravel, or
Bare Soil 0.011
Fallow (No Residue) 0.05
Cultivated Soils:
Residue Cover < 20% 0.06
Residue Cover > 20% 0.17
Grass:
Short Grass Prairie. 0.15
Dense Grasses2 . . . . 0.24
Bermuda grass 0.41
Range (Natural) 0.13
Woods:3
Light Underbrush 0.40
Dense Underbrush 0.80
1 The 'n' values are composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.
From 210-VI-TR-55, Second Edition, June 1986

b. Shallow Concentrated Flow usually begins where overland flow converges to form small rills or gullies. Shallow concentrated flow can exist in small manmade **drainage ditches** (paved and unpaved) and in curb and gutters. Figure 2-2 provides a graphical solution for shallow concentrated flow. The input information needed to solve for this flow segment is the land slope and the surface condition (paved or unpaved).

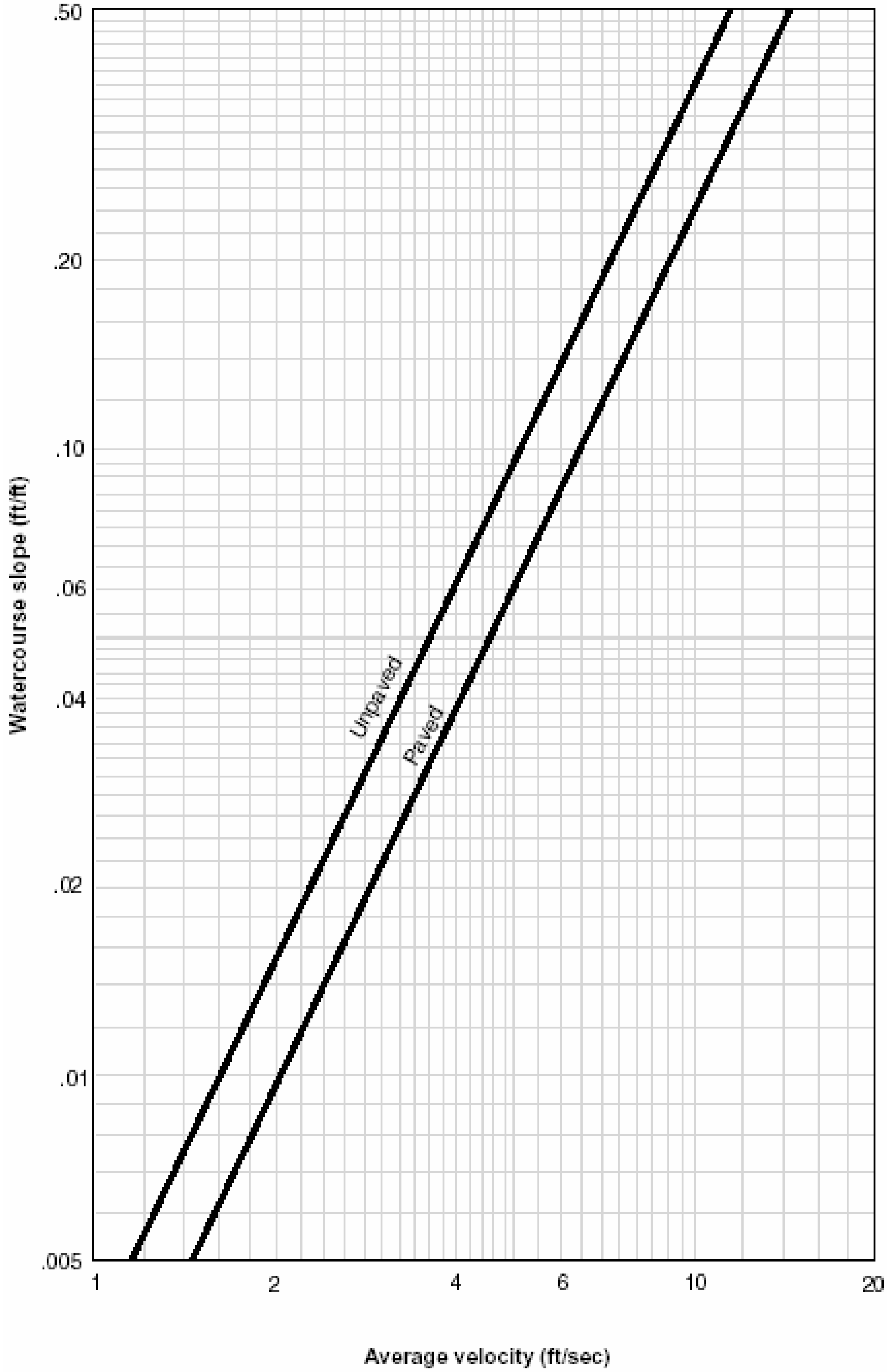
Once the average velocity (V) is determined, the Time of Travel for shallow concentrated flow can be determined using the following equation:

$$Tt = \frac{L}{3600V}$$

Where:

Tt = travel time (hr)
L = flow length (ft)
V = average velocity (ft/s)
3600 = conversion factor from seconds to hours

FIGURE 2-2: Average Velocities for Estimating Travel Time for Shallow Concentrated Flow



(210-VI-TR-55, Second Ed., June 1986)

c. Channel flow occurs where flow converges in gullies, ditches or swales, and natural or manmade water conveyances (including storm drainage pipes). **Channel** flow is assumed to exist in **perennial streams** or wherever there is a well-defined channel cross-section. The Manning Equation is used for open channel flow and pipe flow, and usually assumes full flow or bank-full velocity. Manning coefficients can be found in **Table 2-6** for pipe flow, **Table 2-7** for constructed channels, and **Table 2-8** for natural streams.

Manning's Equation is:

$$V = \frac{1.49 r^{2/3} s^{1/2}}{n}$$

Where:

- V = average velocity (ft/s)
- r =hydraulic radius (ft) and is equal to a/p_w
  - a = cross sectional flow area (ft^2)
  - p_w = wetted perimeter (ft)
- s = slope of the hydraulic grade line (**channel** slope, ft/ft)
- n = Manning's roughness coefficient for open **channel** flow

TABLE 2-6a: Manning's "n" – Smooth Lined Pipes

Manning's "n" for Pipe Flow	
Material*	**"n"**
Smooth lined 60" and under	0.015
Smooth lined, larger than 60"	0.013

Source: ODOT L&D **Drainage** Manual

*The Manning's "n" values in Table 2-6 apply to all smooth lined pipes, including concrete, vitrified clay, PVC or HDPE.

TABLE 2-6b: Manning's "n" – Corrugated Pipes

Manning's "n" for Pipe Flow									
Corrugations	Annular	Helical							
		8"	10"	12"	18"	24"	36"	48"	>60"
1 1/2x1/4		0.012	0.014						
2 2/3x1/2 in	0.024			0.011	0.014	0.016	0.019	0.020	0.021
3x1 in	0.027							0.023	0.024
6x2 in									0.033

TABLE 2-7: Manning's "n" for Constructed Channels

Lining Material	From	To
Concrete Lined	0.012	0.016
Cement Rubble	0.017	0.025
Earth, Straight and Uniform	0.017	0.022
Rock Cuts, Smooth and Uniform	0.025	0.033
Rock Cuts, Jagged and Irregular	0.035	0.045
Winding, Sluggish Canals	0.022	0.027
Dredged Earth **Channels**	0.025	0.030
Canals with Rough Stony Beds, Weeds on Earth Banks	0.025	0.035
Earth Bottom, Rubble Sides	0.028	0.033
Small Grass **Channels**:		
Long Grass – 13"	0.042	
Short Grass – 3"	0.034	

TABLE 2-8: Manning's "n" for Natural Stream Channels

Lining Material	From	To
1. Clean, Straight Bank, Full Stage, No Rifts or Deep Pools	0.025	0.030
2. Same as #1, but Some Weeds and Stones	0.030	0.035
3. Winding, Some Pools and Shoals, Clean	0.033	0.040
4. Same as #3, Lower Stages, More ineffective Slope and Sections	0.040	0.050
5. Same as #3, Some Weeds and Stones	0.035	0.045
6. Same as #4, Stony Sections	0.045	0.055
7. Sluggish River Reaches, Rather Weedy with Very Deep Pools	0.050	0.070
8. Very Weedy Reaches	0.075	0.125

Adapted from Handbook of Hydraulics, Sixth Edition, Brater & King

Once the average velocity (V) is determined, the Time of Travel for channel flow can be determined using the following equation:

$$Tt = \frac{L}{3600V}$$

The following Worksheet 3 example shows how time of concentration is calculated. A blank Worksheet 3, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

Worksheet 3: Time of Concentration (T_c) or travel time (T_t)

Project: Heavenly Acres	By: DW	Date: 10/6/85
Location: Dyer County, Tennessee	Checked: NM	Date: 10/8/85

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 T_c only)

Segment ID	AB		
1. Surface description (table 3-1)	Dense Grass		
2. Manning's roughness coefficient, n (table 3-1)	0.24		
3. Flow length, L (total L ≤ 300 ft) ... ft	100		
4. Two-year 24-hour rainfall, P_2 ... in	3.6		
5. Land slope, s ... ft/ft	0.01		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t ... hr	0.30	+	= 0.30

Shallow concentrated flow

Segment ID	BC		
7. Surface description (paved or unpaved)	Unpaved		
8. Flow length, L ... ft	1400		
9. Watercourse slope, s ... ft/ft	0.01		
10. Average velocity, V (figure 3-1) ... ft/s	1.6		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr	0.24	+	= 0.24

Channel flow

Segement ID	CD		
12. Cross sectional flow area, a ... ft^2	27		
13. Wetted perimeter, p_w ... ft	28.2		
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r ... ft	0.957		
15 Channel slope, s ... ft/ft	0.005		
16. Manning's roughness coefficient, n ...	0.05		
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V ... ft/s	2.05		
18. Flow length, L ... ft	7300		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr	0.99	+	= 0.99
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ... Hr			1.53

Initial abstraction (Ia) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. The Curve Number (CN) is used to determine the initial abstraction (Ia) from Table 2-9:

TABLE 2-9: Ia Values for Runoff Curve Numbers

Curve Number	Ia (in)	Curve Number	Ia (in.)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
55	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

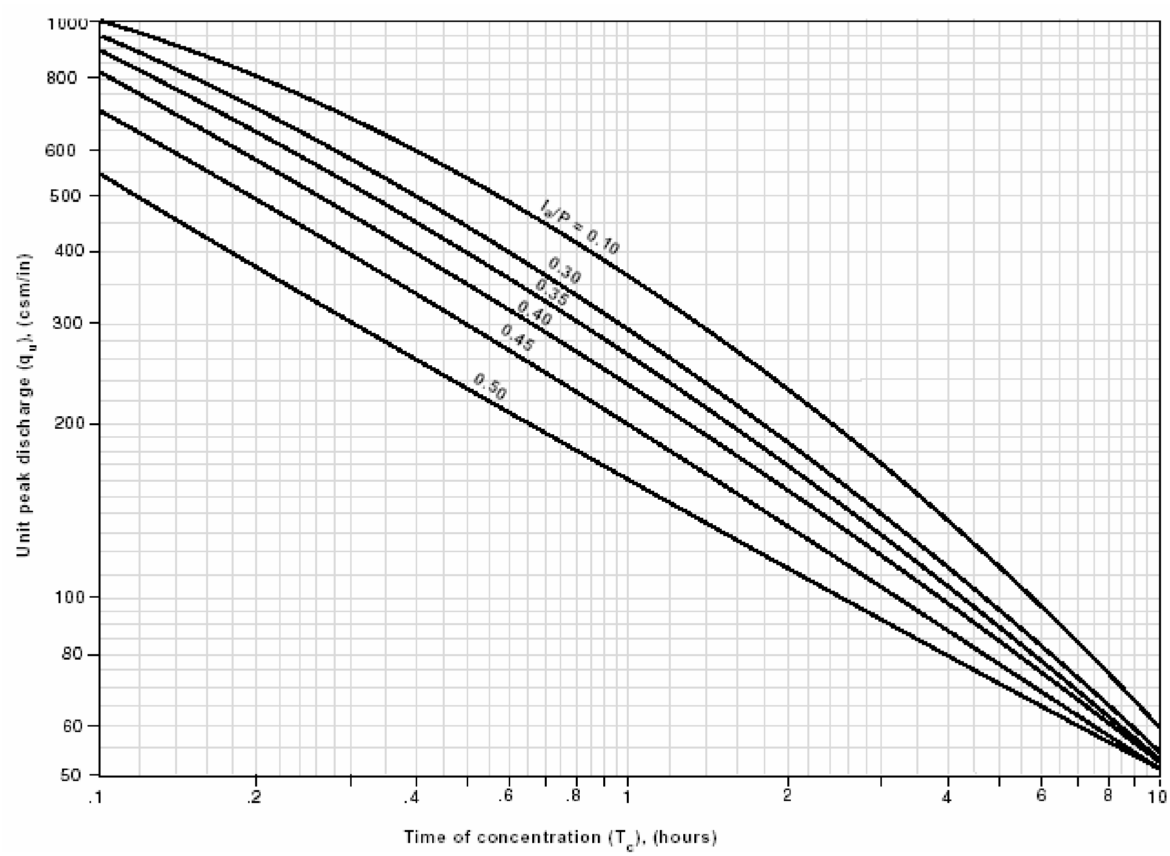
The Fp factor is an adjustment for pond and swamp areas that are spread throughout the watershed. It can only be applied for ponds or swamps that are not in the Tc path.

TABLE 2-10: Adjustment Factors for Pond and Swamp Areas, Fp

Pond & Swamp Areas (%)	Fp
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

The unit peak discharge, q_u, is calculated using Tc and Ia/P with Figure 2-3.

FIGURE 2-3: SCS Type II Unit Peak Discharge Graph



2.3.3 Design Procedure

Step 1: The 24-hour rainfall depth is determined from Table 2-3 for the selected **storm frequency**.

Step 2: The runoff curve number (CN) is estimated from Worksheet 2 and Table 2-4.

Step 3: The CN value is used to determine the initial abstraction (Ia) from Table 2-9. The ratio (Ia/P) is then computed.

Step 4: The watershed time of concentration is computed using Worksheet 3 and is used with the ratio Ia/P to obtain the unit peak discharge (qu) from Figure 2-3.

Step 5: The pond and swamp adjustment factor if estimated from Table 2-10.

Step 6: The peak runoff rate is computed using the Peak Discharge Equation.

$$Qp = quAQFp$$

The following Worksheet 4 example shows how the peak **runoff** rate is calculated. A blank Worksheet 4, taken from TR-55, Second Edition, June 1986, is included in the Appendix.

Worksheet 4: Graphical Peak Discharge method

Project: Heavenly Acres	By: RHM	Date: 10/15/85
Location: Dyer County, Tennessee	Checked: NM	Date: 10/17/85

Check one: ☐ Present ☒ Developed

1. Data

Drainage area .... A_m = 0.39 mi² (acres/640)

Runoff curve number .... CN = 75 (From worksheet 2), Figure 2-6

Time of concentration .... T_c = 1.53 hr (From worksheet 3), Figure 3-2

Rainfall distribution .... = II (I, IA, II III)

Pond and swamp areas sprea throughout watershed .... = – – percent of A_m (– – acres or mi² covered)

	Storm #1	Storm #2	Storm #3
2. Frequency .... yr	25		
3. Rainfall, P (24-hour) .... in	6.0		
4. Initial abstraction, I_a .... in (Use CN with table 4-1)	0.667		
5. Compute I_a/P	0.11		
6. Unit peak discharge, qu .... csm/in (Use T_c and I_a/P with exhibit 4– II)	270		
7. Runoff, Q .... in (From worksheet 2). Figure 2-6	3.28		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond ans swamp area.)	1.0		
9. Peak discharge, q_p .... cfs	345		

(Where $q_p = q_u A_m Q F_p$)

2.4 The S.C.S. - Unit Hydrograph Method

2.4.1 Methodology

SCS method described above to calculate the peak discharge can be applied to estimate a **hydrograph** when detention facilities are designed and pond routing is necessary. It may also be used to design culverts. The SCS has developed a tabular hydrograph procedure that can be used to determine the hydrograph for drainage areas less than 20 Sq. Mi.

2.4.2 Resources

The designer is referred to the procedures outlined by the SCS in Technical Release 55 "Urban Hydrology for Small Watersheds" (TR-55). Hydrologic computer models are made available for download at the **USDA** Natural Resources Conservation Service (**NRCS**) website.

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution

HYDROGRAPH TIME (HOURS)

TRAVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10															*** TC = 0.1 HR ***														IA/P = 0.10			
0.0	24	34	53	334	647	1010	623	217	147	123	104	86	76	66	57	51	46	42	38	34	32	29	26	23	21	20	19	18	15	13	12	0
.10	21	29	43	134	267	520	847	701	378	224	167	122	98	75	64	56	50	45	41	36	33	30	27	24	21	20	19	18	16	13	12	0
.20	18	26	35	61	110	215	419	704	702	486	312	209	151	94	73	62	54	49	44	38	34	31	28	25	22	21	19	18	16	14	12	0
.30	17	23	33	56	92	174	337	582	662	545	389	269	190	109	79	65	56	50	45	39	35	32	29	25	22	21	20	18	16	14	12	0
.40	15	20	28	41	51	78	142	272	478	601	563	447	328	172	104	76	63	55	49	42	37	33	29	26	23	21	20	19	17	14	12	0
.50	14	19	26	39	47	68	117	220	392	531	563	482	380	209	121	84	67	57	51	43	38	33	30	27	23	21	20	19	17	14	12	0
.75	12	15	21	29	33	38	49	73	126	224	343	432	464	385	252	156	103	76	62	50	43	36	31	28	25	22	21	19	17	15	12	0
1.0	9	12	15	21	23	26	29	33	40	55	86	148	238	406	434	317	205	130	89	62	50	41	34	30	27	24	22	20	18	16	12	0
1.5	7	8	10	14	15	16	18	20	22	25	29	34	45	101	220	339	373	320	234	131	80	53	40	34	30	27	24	21	19	17	12	2
2.0	4	6	7	9	9	10	11	12	13	15	16	18	20	25	37	72	150	252	336	312	216	109	59	42	34	30	27	24	20	18	13	8
2.5	3	4	5	6	7	7	8	8	9	10	11	12	13	16	19	25	39	75	142	262	308	229	108	58	41	34	30	27	22	19	14	11
3.0	1	2	3	4	4	5	5	6	6	7	7	8	8	10	12	14	17	22	31	76	169	288	236	122	64	43	35	30	24	20	16	11
IA/P = 0.30															*** TC = 0.1 HR ***														IA/P = 0.30			
0.0	0	0	0	154	568	936	524	217	172	149	126	107	97	86	76	69	63	58	53	48	46	42	38	34	31	30	28	27	24	20	19	0
.10	0	0	0	19	109	415	762	603	346	230	176	143	119	96	84	74	68	62	57	50	47	44	40	35	32	30	29	27	24	21	19	0
.20	0	0	0	0	13	77	302	609	605	432	297	217	167	115	94	81	73	66	60	53	48	45	41	37	33	31	29	28	25	21	19	0
.30	0	0	0	0	9	54	219	479	563	476	367	263	199	129	99	85	75	68	62	54	49	45	41	37	33	31	29	28	25	21	19	0
.40	0	0	0	0	0	6	38	159	372	500	484	399	309	183	123	96	82	73	66	58	51	46	42	38	34	31	30	28	25	22	19	0
.50	0	0	0	0	0	4	27	115	287	429	465	421	346	213	139	103	86	76	68	59	52	47	43	39	34	32	30	29	25	22	19	0
.75	0	0	0	0	0	0	1	10	46	132	246	338	381	341	243	165	119	94	80	67	58	50	45	41	37	33	31	29	26	23	19	0
1.0	0	0	0	0	0	0	0	1	4	22	69	149	241	357	331	246	170	122	96	76	64	54	47	42	39	34	32	30	27	24	19	0
1.5	0	0	0	0	0	0	0	0	0	0	0	1	4	41	142	258	310	285	224	142	97	71	55	47	43	39	35	32	29	26	20	4
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	49	130	221	279	255	182	108	70	56	47	42	38	34	30	27	20	11
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	14	52	119	224	256	193	107	70	55	47	42	38	32	28	22	17
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	52	141	240	199	117	74	66	48	43	35	30	24	18
IA/P = 0.50															*** TC = 0.1 HR ***														IA/P = 0.50			
0.0	0	0	0	0	70	539	377	196	171	154	134	117	108	99	89	83	77	72	67	61	59	56	51	46	43	42	40	38	34	30	28	0
.10	0	0	0	0	47	375	376	256	199	169	146	126	114	102	92	85	79	73	68	62	59	56	52	47	43	42	40	38	34	30	28	0
.20	0	0	0	0	0	31	260	338	283	227	189	160	138	112	99	90	83	77	72	64	60	57	53	48	44	42	41	39	35	30	28	0
.30	0	0	0	0	0	0	21	180	265	284	246	208	176	131	110	97	88	82	76	68	62	59	54	50	45	43	41	39	36	31	28	0
.40	0	0	0	0	0	0	14	125	232	266	253	223	192	142	115	100	91	83	77	69	63	59	55	50	45	43	41	40	36	31	28	0
.50	0	0	0	0	0	0	9	86	183	239	248	231	205	154	122	104	93	85	79	71	64	59	55	51	45	43	41	40	36	32	28	0
.75	0	0	0	0	0	0	3	31	87	147	190	211	213	184	147	121	103	92	84	75	67	61	57	52	47	44	42	40	37	32	28	0
1.0	0	0	0	0	0	0	0	0	1	13	45	92	141	205	197	165	134	112	98	84	75	65	59	55	50	46	43	41	38	34	28	0
1.5	0	0	0	0	0	0	0	0	0	0	0	2	9	51	118	170	183	167	143	111	92	77	65	59	54	50	45	43	39	35	28	2
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	15	51	103	148	168	156	127	96	76	65	58	54	49	45	41	37	29	12
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	31	69	131	159	140	101	78	66	59	54	50	43	39	31	24
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	46	101	151	134	99	77	65	59	54	45	41	33	26
RAINFALL TYPE = II															*** TC = 0.1 HR ***														SHEET 1 OF 10			

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

HYDROGRAPH TIME (HOURS)

TRAVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10															*** TC = 0.2 HR ***														IA/P = 0.10			
0.0	23	31	47	209	403	739	800	481	250	166	128	102	86	70	61	54	49	44	40	35	33	30	27	24	21	20	19	18	16	13	12	0
.10	19	26	39	86	168	325	601	733	565	355	229	161	122	83	69	59	53	47	43	37	34	31	28	25	22	21	19	18	16	14	12	0
.20	17	23	32	49	74	136	262	488	652	594	435	298	207	115	81	67	58	51	46	40	35	32	29	26	23	21	20	19	16	14	12	0
.30	16	22	30	46	64	112	212	396	566	585	485	360	258	139	90	71	60	53	48	41	36	32	29	26	23	21	20	19	16	14	12	0
.40	14	19	25	37	43	57	94	173	322	405	551	507	409	227	129	87	68	58	52	44	38	33	30	27	24	21	20	19	17	14	12	0
.50	13	18	24	35	40	52	80	142	262	410	504	506	441	269	153	98	73	61	53	45	39	34	30	27	24	22	20	19	17	15	12	0
.75	10	13	17	23	26	30	34	40	55	86	150	247	349	436	360	240	151	101	75	57	47	39	33	29	26	23	21	20	18	15	12	0
1.0	9	11	14	19	21	24	26	30	35	44	62	101	167	337	413	353	245	157	104	68	53	42	35	31	28	24	22	20	18	16	12	0
1.5	6	8	10	13	14	15	17	19	21	23	26	30	37	73	166	289	356	337	264	154	91	57	42	35	30	27	24	22	19	17	13	3
2.0	4	5	7	8	9	10	10	11	12	14	15	16	18	23	31	55	114	206	291	324	239	125	63	44	35	31	28	24	20	18	14	9
2.5	3	4	5	6	6	7	7	8	9	9	10	11	12	15	10	22	32	58	111	227	298	246	122	63	43	35	31	27	22	19	15	11
3.0	1	2	3	4	4	4	5	5	6	6	7	7	8	9	11	13	16	19	27	59	138	280	248	137	70	46	36	31	25	21	16	11
IA/P = 0.30															*** TC = 0.2 HR ***														IA/P = 0.30			
0.0	0	0	0	39	180	545	607	497	276	198	158	130	110	93	81	73	67	61	56	49	46	43	39	35	32	30	29	27	24	21	19	0
.10	0	0	0	2	27	129	407	600	532	361	252	190	150	106	90	79	71	65	59	52	48	44	41	36	32	31	29	28	25	21	19	0
.20	0	0	0	2	19	92	302	501	521	415	306	228	176	119	95	82	73	67	61	53	48	45	41	37	33	31	29	28	25	21	19	0
.30	0	0	0	0	1	13	66	223	408	484	438	350	269	163	114	93	80	72	65	57	51	46	42	38	34	31	30	28	25	22	19	0
.40	0	0	0	0	1	9	47	164	327	431	436	379	306	189	127	98	83	74	67	58	52	47	43	38	34	31	30	28	25	22	19	0
.50	0	0	0	0	0	0	6	33	120	258	374	415	391	271	173	121	95	81	72	62	55	48	44	40	35	32	30	29	26	22	19	0
.75	0	0	0	0	0	0	2	13	50	126	221	302	348	323	240	167	121	96	81	68	59	50	45	41	37	33	31	29	26	23	19	0
1.0	0	0	0	0	0	0	0	0	1	6	24	69	139	285	331	280	204	145	109	82	68	56	48	43	39	35	32	30	27	24	19	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	16	79	185	271	288	247	165	110	76	58	49	44	40	35	32	29	25	20	5
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	24	80	163	235	262	202	123	76	58	49	43	39	35	30	27	21	13
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	28	77	179	242	207	120	75	57	48	43	39	32	29	22	17
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	30	101	207	227	130	80	59	49	44	35	30	24	18
IA/P = 0.50															*** TC = 0.2 HR ***														IA/P = 0.50			
0.0	0	0	0	0	7	98	371	322	221	182	158	137	120	104	94	86	80	74	69	62	60	57	52	47	44	42	40	39	35	30	28	0
.10	0	0	0	0	4	67	270	305	249	204	174	149	130	108	97	88	82	76	71	64	60	57	53	48	44	42	41	39	35	30	28	0
.20	0	0	0	0	0	3	45	195	268	255	221	189	163	125	106	95	87	80	75	67	62	58	54	49	45	43	41	39	35	31	28	0
.30	0	0	0	0	0	2	31	140	226	245	229	203	176	134	111	98	89	82	76	68	62	59	55	50	45	43	41	39	36	31	28	0
.40	0	0	0	0	0	1	21	101	184	225	220	211	188	144	117	101	91	84	78	69	63	59	55	50	45	43	41	40	36	31	28	0
.50	0	0	0	0	0	0	1	14	72	146	199	218	213	175	137	113	99	89	82	73	66	60	56	52	47	43	42	40	36	32	28	0
.75	0	0	0	0	0	0	0	5	28	71	121	162	186	193	161	133	112	98	88	78	70	62	57	53	48	44	42	41	37	33	28	0
1.0	0	0	0	0	0	0	0	0	0	2	13	38	77	154	186	174	147	122	105	89	78	68	60	56	51	46	43	42	38	34	28	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	2	22	71	129	163	168	150	120	98	80	67	60	55	51	46	43	40	36	28	4
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	25	65	112	146	157	134	103	79	67	60	55	50	46	41	38	29	14
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	26	60	117	148	136	101	79	66	59	54	50	43	39	31	24
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9	40	90	142	130	99	78	65	59	54	45	41	33	26
RAINFALL TYPE = II															*** TC = 0.2 HR ***														SHEET 2 OF 10			

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

IA/P = 0.10 * * * TC = 0.3 HR * * * IA/P = 0.10

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	20	28	41	110	235	447	676	676	459	283	196	146	114	80	66	57	51	46	42	37	33	31	28	24	22	20	19	18	16	13	12	0
.10	19	26	39	99	189	361	571	641	520	362	251	181	136	89	70	60	53	48	43	37	34	31	28	25	22	21	19	18	16	14	12	0
.20	17	23	32	53	83	154	292	470	587	542	422	308	223	127	86	68	58	52	46	40	35	32	29	26	23	21	20	19	16	14	12	0
.30	16	22	30	49	72	127	237	398	524	536	460	369	268	151	97	73	61	53	48	41	36	32	29	26	23	21	20	19	16	14	12	0
.40	14	19	25	37	45	63	105	193	330	459	510	477	398	237	139	92	70	59	52	44	38	34	30	27	24	21	20	19	17	14	12	0
.50	13	18	24	35	42	56	89	158	272	397	472	475	424	274	163	104	76	62	54	46	39	34	30	27	24	22	20	19	17	15	12	0
.75	11	14	19	26	30	34	42	59	95	160	250	339	417	398	299	196	128	89	69	54	45	37	32	29	26	23	21	20	17	15	12	0
1.0	9	11	14	19	21	24	27	30	36	46	69	109	174	328	396	346	248	163	109	70	54	43	35	31	28	24	22	20	18	16	12	0
1.5	6	8	10	13	14	15	17	19	21	23	26	31	38	77	169	282	347	330	264	158	94	59	42	35	31	27	24	22	19	17	13	3
2.0	4	5	7	8	9	10	10	11	12	14	15	16	18	23	32	57	116	205	286	317	239	128	64	44	36	31	28	25	20	18	14	9
2.5	2	4	5	6	6	7	7	8	9	9	10	11	12	15	18	23	33	60	113	223	293	245	125	65	44	35	31	27	22	19	15	11
3.0	1	2	3	4	4	4	5	5	6	6	7	7	8	9	11	13	16	20	27	61	138	275	246	139	72	46	36	31	25	21	16	11

IA/P = 0.30 * * * TC = 0.3 HR * * * IA/P = 0.30

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	11	64	251	525	574	464	303	221	173	140	104	80	77	70	64	58	51	47	44	40	36	32	31	29	28	24	21	19	0
.10	0	0	0	0	7	45	183	411	520	476	360	268	205	133	101	85	76	69	62	55	49	45	41	37	33	31	30	28	25	21	19	0
.20	0	0	0	0	5	32	132	318	452	468	396	310	240	151	109	90	78	70	64	56	50	46	42	38	33	31	30	28	25	22	19	0
.30	0	0	0	0	0	3	22	96	244	383	440	411	344	217	142	105	87	76	69	60	53	47	43	39	35	32	30	29	26	22	19	0
.40	0	0	0	0	0	2	16	69	186	317	399	407	365	246	160	115	92	79	71	61	54	48	43	39	35	32	30	29	26	22	19	0
.50	0	0	0	0	0	0	2	11	50	140	258	362	389	327	223	149	110	89	77	66	57	50	45	41	36	33	31	29	26	23	19	0
.75	0	0	0	0	0	0	1	4	20	63	135	219	290	335	281	205	146	110	89	72	62	52	46	42	38	34	31	30	27	23	19	0
1.0	0	0	0	0	0	0	0	0	0	2	9	32	78	216	320	306	243	176	128	90	72	59	49	44	40	36	33	31	28	24	19	1
1.5	0	0	0	0	0	0	0	0	0	0	0	0	2	20	84	185	264	281	246	160	112	77	58	49	44	40	36	32	29	26	20	5
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	50	121	203	257	224	141	83	61	50	44	40	36	31	28	21	14
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	16	51	145	239	223	137	82	60	50	44	40	33	29	22	17
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	19	74	184	224	146	89	63	51	45	36	31	24	18

IA/P = 0.50 * * * TC = 0.3 HR * * * IA/P = 0.50

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	1	25	151	299	277	219	107	162	141	113	100	90	84	78	72	65	61	58	53	48	44	42	41	39	35	31	28	0
.10	0	0	0	0	1	17	105	235	263	234	202	175	152	120	104	93	85	79	73	66	61	58	54	49	44	42	41	39	35	31	28	0
.20	0	0	0	0	0	0	12	75	182	236	234	213	188	144	116	101	91	84	78	70	63	59	55	50	45	43	41	40	36	31	28	0
.30	0	0	0	0	0	0	8	52	138	203	224	217	197	154	123	105	94	86	79	71	64	59	55	51	46	43	42	40	36	32	28	0
.40	0	0	0	0	0	0	5	37	105	170	206	213	203	164	131	110	97	88	81	72	65	60	56	51	46	43	42	40	36	32	28	0
.50	0	0	0	0	0	0	0	4	26	78	140	184	203	191	155	126	107	95	86	76	69	62	57	53	48	44	42	41	37	33	28	0
.75	0	0	0	0	0	0	0	1	10	34	73	117	153	104	173	146	122	105	94	82	73	61	58	54	49	45	43	41	37	33	28	0
1.0	0	0	0	0	0	0	0	0	0	0	4	17	42	114	168	178	159	134	114	94	82	70	61	57	52	47	44	42	39	35	28	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	10	44	98	144	163	157	130	105	84	69	61	56	52	47	44	40	36	29	6
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	14	44	87	127	153	141	110	83	69	61	56	51	47	42	38	30	17
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	16	42	97	138	145	107	82	68	60	55	51	43	40	32	25
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	27	71	127	139	105	81	68	60	55	46	41	33	27

RAINFALL TYPE = II * * * TC = 0.3 HR * * * SHEET 3 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

IA/P = 0.10 * * * TC = 0.4 HR * * * IA/P = 0.10

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	18	25	36	77	141	271	468	592	574	431	298	216	163	104	77	63	55	49	44	38	34	31	28	25	22	21	20	18	16	14	12	0
.10	18	24	34	67	116	219	385	523	557	473	357	263	196	119	84	67	57	51	46	39	35	32	29	25	22	21	20	19	16	14	12	0
.20	15	20	28	44	59	97	179	316	454	523	489	401	309	178	112	81	65	56	49	42	37	33	30	26	23	21	20	19	17	14	12	0
.30	15	20	27	41	53	82	147	260	389	476	486	429	349	210	129	89	69	58	51	43	38	33	30	27	24	21	20	19	17	14	12	0
.40	13	17	23	33	38	48	71	121	214	331	429	467	442	308	189	120	85	66	56	47	41	35	31	28	24	22	20	19	17	15	12	0
.50	12	16	22	31	36	44	62	102	176	279	379	438	440	339	218	137	94	71	59	49	42	35	31	28	25	22	21	19	17	15	12	0
.75	10	13	17	24	26	30	35	45	65	106	170	251	326	393	341	245	164	112	81	59	48	39	33	30	26	23	21	20	18	15	12	0
1.0	8	10	13	17	19	21	24	27	31	37	50	75	118	251	360	376	292	205	138	83	60	45	36	32	28	25	22	21	18	16	12	1
1.5	6	7	9	12	13	14	15	17	19	21	23	26	31	56	121	224	311	333	293	192	115	66	45	36	31	28	25	22	19	17	13	4
2.0	4	5	6	8	8	9	10	10	11	12	14	15	16	20	27	43	85	159	243	306	264	154	74	47	37	32	28	25	21	18	14	9
2.5	2	3	4	5	6	6	7	7	8	9	9	10	11	13	16	20	27	46	65	184	285	262	147	74	47	37	32	28	22	19	15	11
3.0	1	2	2	3	4	4	4	5	5	6	6	7	7	8	10	12	14	17	23	47	109	227	268	160	83	50	38	32	25	21	16	11

IA/P = 0.30 * * * TC = 0.4 HR * * * IA/P = 0.30

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	4	26	133	295	480	495	413	306	234	186	127	100	84	74	67	61	54	49	45	41	37	33	31	29	28	25	21	19	0
.10	0	0	0	0	2	18	81	224	395	462	430	347	272	172	121	96	82	73	66	57	51	46	42	38	34	31	30	28	25	22	19	0
.20	0	0	0	0	2	13	59	169	320	414	424	373	305	196	134	103	85	75	67	59	52	47	43	39	34	32	30	29	25	22	19	0
.30	0	0	0	0	0	1	9	42	127	255	361	403	383	274	181	127	99	83	73	63	55	48	44	40	36	32	30	29	26	23	19	0
.40	0	0	0	0	0	1	6	30	94	202	308	372	379	298	203	141	106	87	76	65	56	49	44	40	36	32	31	29	26	23	19	0
.50	0	0	0	0	0	0	0	4	21	70	158	258	334	364	270	187	133	102	85	70	60	51	46	41	37	33	31	30	26	23	19	0
.75	0	0	0	0	0	0	0	2	8	30	76	145	219	321	305	241	177	130	102	78	65	55	47	43	38	34	32	30	27	24	19	0
1.0	0	0	0	0	0	0	0	0	0	1	4	15	42	150	267	308	272	209	154	103	79	62	51	45	41	37	33	31	28	25	19	1
1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	10	51	136	226	274	263	195	131	85	62	51	45	41	36	33	29	26	20	6
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	31	86	162	252	239	162	93	64	52	45	41	37	31	28	21	15
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	33	112	202	235	155	92	64	52	45	41	33	29	23	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	21	76	187	221	146	90	63	51	45	36	31	24	18

IA/P = 0.50 * * * TC = 0.4 HR * * * IA/P = 0.50

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	0	7	59	168	245	257	213	186	163	128	109	96	88	81	75	67	62	58	54	50	45	43	41	39	35	31	28	0
.10	0	0	0	0	0	0	5	41	125	205	240	222	198	154	123	106	94	86	79	71	64	60	56	51	46	43	42	40	36	32	28	0
.20	0	0	0	0	0	0	3	20	93	168	216	220	205	164	131	110	97	88	81	72	65	60	56	51	46	43	42	40	36	32	28	0
.30	0	0	0	0	0	0	0	2	20	69	135	189	209	192	155	126	107	95	86	77	69	62	57	53	48	44	42	41	37	33	28	0
.40	0	0	0	0	0	0	0	1	14	50	106	161	193	202	163	133	112	98	89	78	70	62	58	53	48	44	42	41	37	33	28	0
.50	0	0	0	0	0	0	0	1	9	37	83	135	174	194	171	140	117	102	91	80	71	63	58	54	49	45	43	41	37	33	28	0
.75	0	0	0	0	0	0	0	0	0	3	15	40	76	147	177	169	146	124	107	90	79	68	60	56	51	47	43	42	38	34	28	0
1.0	0	0	0	0	0	0	0	0	0	0	1	7	21	78	141	173	167	146	125	101	86	73	63	58	53	48	45	42	39	35	28	1
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	26	71	121	153	159	139	113	69	72	63	57	53	48	44	40	37	29	7
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	16	45	86	138	150	125	93	74	64	58	53	48	42	39	31	20
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	17	59	112	143	121	91	73	63	57	53	45	40	32	26
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	40	105	138	117	90	73	63	57	48	42	34	27

RAINFALL TYPE = II * * * TC = 0.4 HR * * * SHEET 4 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

HYDROGRAPH TIME (HOURS)

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC = 0.5 HR * * *														IA/P = 0.10				
0.0	17	23	32	57	94	170	308	467	529	507	402	297	226	140	96	74	61	53	47	41	36	32	29	26	23	21	20	19	16	14	12	0
.10	16	22	30	51	80	140	252	395	404	499	434	343	265	162	108	88	65	55	49	42	36	33	29	26	23	21	20	19	16	14	12	0
.20	14	19	25	30	47	69	116	207	332	434	477	449	370	230	149	101	77	62	50	45	39	34	30	27	24	22	20	19	17	14	12	0
.30	13	18	24	35	43	60	97	170	270	382	446	440	401	270	171	114	83	66	56	46	40	34	31	27	24	22	20	19	17	15	12	0
.40	12	15	21	29	33	40	53	83	141	233	332	400	434	361	243	157	107	79	64	51	43	36	32	28	25	22	21	20	17	15	12	0
.50	11	15	20	28	31	37	48	71	110	194	286	367	412	378	271	178	119	86	68	53	44	37	32	29	25	23	21	20	17	15	12	0
.75	9	11	14	19	21	24	27	31	37	49	74	110	182	319	374	320	244	169	117	76	56	43	35	31	28	25	22	21	18	16	12	1
1.0	7	9	12	16	17	19	21	24	27	32	40	55	83	180	309	359	322	245	172	102	68	49	38	32	29	26	23	21	19	16	12	1
1.5	5	7	8	11	12	13	14	15	17	19	21	23	27	43	89	175	269	322	309	225	140	77	49	38	32	29	25	23	20	17	13	5
2.0	3	4	6	7	8	8	9	10	10	11	12	14	15	18	23	35	65	123	202	297	280	181	88	52	39	33	29	26	21	19	14	10
2.5	2	3	4	5	5	6	6	7	7	8	9	9	10	12	15	18	24	36	66	150	244	278	171	87	52	39	33	29	23	20	15	11
3.0	1	1	2	3	3	4	4	4	5	5	6	6	7	8	9	11	13	16	20	37	86	198	263	182	96	56	40	33	26	21	16	11
IA/P = 0.30														* * * TC = 0.5 HR * * *														IA/P = 0.30				
0.0	0	0	0	1	9	53	157	314	433	439	379	299	237	159	118	95	81	71	66	56	50	46	42	39	34	31	30	28	25	22	19	0
.10	0	0	0	0	1	6	37	117	248	372	416	391	330	218	150	113	92	79	70	60	53	47	43	39	35	32	30	29	26	22	19	0
.20	0	0	0	0	1	4	26	87	194	313	382	380	349	244	167	122	97	82	72	62	54	48	43	39	35	32	30	29	26	22	19	0
.30	0	0	0	0	0	0	3	19	64	151	259	341	372	316	223	156	117	94	80	67	58	50	45	41	36	33	31	29	26	23	19	0
.40	0	0	0	0	0	0	2	13	47	116	211	298	354	328	245	172	127	100	83	69	59	51	45	41	37	33	31	29	26	23	19	0
.50	0	0	0	0	0	0	0	1	9	34	89	170	255	341	303	225	161	120	96	76	64	54	47	42	38	34	31	30	27	24	19	0
.75	0	0	0	0	0	0	0	1	4	14	41	89	152	270	305	268	207	155	118	87	70	57	48	44	39	35	32	30	27	24	19	0
1.0	0	0	0	0	0	0	0	0	0	0	2	7	22	98	212	205	285	237	181	120	88	67	53	46	42	38	34	31	28	25	19	2
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	30	95	183	249	265	217	152	96	66	53	45	41	37	34	30	26	20	8
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	18	59	126	221	245	182	105	69	54	47	42	38	32	28	22	16
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	21	84	174	230	172	103	69	54	46	42	34	30	23	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	13	56	157	217	163	101	68	53	46	37	31	25	18
IA/P = 0.50														* * * TC = 0.5 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	2	26	89	170	217	229	200	179	144	119	104	93	85	78	70	64	59	55	51	46	43	41	40	36	32	28	0
.10	0	0	0	0	0	0	1	18	65	135	190	216	205	170	137	115	101	91	83	74	67	61	56	52	47	44	42	40	36	32	28	0
.20	0	0	0	0	0	0	1	12	47	106	162	198	203	178	145	121	105	94	86	76	68	61	57	52	48	44	42	40	37	32	28	0
.30	0	0	0	0	0	0	0	1	8	34	82	135	177	194	168	139	117	102	92	80	71	63	58	54	49	45	43	41	37	33	28	0
.40	0	0	0	0	0	0	0	0	6	25	63	111	155	189	174	146	122	106	94	82	73	64	58	54	50	45	43	41	37	33	28	0
.50	0	0	0	0	0	0	0	0	4	18	48	90	133	184	177	152	128	110	97	84	74	65	59	55	50	45	43	41	38	33	28	0
.75	0	0	0	0	0	0	0	0	1	7	22	47	80	142	160	164	144	124	108	91	79	68	61	56	51	47	44	42	38	34	28	0
1.0	0	0	0	0	0	0	0	0	0	0	1	3	11	51	112	155	166	154	134	109	91	76	65	59	54	49	46	43	39	35	28	2
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2	16	50	97	136	154	145	121	95	75	64	58	54	49	45	41	37	29	10
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	18	47	86	134	146	125	94	75	64	58	53	49	42	39	31	21
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	11	44	95	140	127	97	77	65	58	54	45	41	33	26
3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	29	86	135	122	95	76	65	58	49	43	35	27

RAINFALL TYPE = II * * * TC = 0.5 HR * * * SHEET 5 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

HYDROGRAPH TIME (HOURS)

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC = 0.75 HR * * *														IA/P = 0.10				
0.0	13	18	24	36	46	68	115	194	294	380	424	410	369	252	172	123	93	74	61	49	41	35	31	27	24	22	20	19	17	15	12	0
.10	13	17	23	34	42	59	97	162	250	337	395	405	381	279	191	135	100	79	65	51	42	36	31	28	25	22	21	19	17	15	12	0
.20	11	15	20	28	32	39	52	82	135	211	295	362	391	351	255	178	127	95	75	57	46	38	32	29	26	23	21	20	17	15	12	0
.30	11	14	19	26	30	36	47	70	113	179	256	326	379	360	277	196	140	103	80	60	48	38	33	29	26	23	21	20	18	15	12	0
.40	10	12	16	22	25	28	33	42	61	96	151	221	291	367	336	255	182	131	98	69	54	42	34	30	27	24	22	20	18	16	12	0
.50	9	12	16	21	24	27	31	39	53	82	128	190	258	358	343	274	200	144	105	74	56	43	35	30	27	24	22	20	18	16	12	0
.75	8	10	13	17	18	21	23	26	31	39	56	82	122	230	314	329	281	217	161	104	72	51	38	33	29	26	23	21	19	16	12	1
1.0	6	8	10	13	14	15	17	19	21	23	27	32	42	89	177	272	319	303	240	163	105	66	45	36	31	27	24	22	19	17	13	3
1.5	4	6	7	9	10	10	11	12	14	15	16	18	20	27	46	90	163	241	295	275	204	119	66	45	35	31	27	24	20	18	13	7
2.0	3	4	5	6	7	7	8	9	9	10	11	12	13	16	20	28	48	89	151	245	274	213	115	65	44	35	30	27	22	19	14	10
2.5	1	2	3	4	4	5	5	6	6	7	7	8	8	10	12	14	17	24	37	86	170	260	219	127	71	47	36	31	24	20	16	11
3.0	1	1	2	3	3	3	4	4	4	5	5	5	6	7	8	10	11	14	17	30	64	157	247	205	122	70	46	36	27	22	17	12
IA/P = 0.30														* * * TC = 0.75 HR * * *														IA/P = 0.30				
0.0	0	0	0	0	1	6	30	86	174	266	326	348	320	246	181	138	110	92	79	66	57	49	44	40	36	32	31	29	26	23	19	0
.10	0	0	0	0	0	1	4	22	65	137	223	292	329	303	228	170	131	106	89	73	61	52	46	41	37	33	31	29	26	23	19	0
.20	0	0	0	0	0	0	3	15	48	108	185	256	305	321	245	184	141	112	93	75	63	53	46	42	37	34	31	30	27	23	19	0
.30	0	0	0	0	0	0	2	11	36	84	151	221	277	306	260	199	152	120	98	78	65	54	47	42	38	34	31	30	27	23	19	0
.40	0	0	0	0	0	0	0	1	8	27	65	122	168	286	301	243	187	144	114	87	71	57	48	43	39	35	32	30	27	24	19	1
.50	0	0	0	0	0	0	0	1	6	20	50	98	158	263	292	254	200	155	122	91	74	59	49	44	40	35	32	30	27	24	19	1
.75	0	0	0	0	0	0	0	0	0	2	8	23	51	140	231	269	253	211	167	119	90	68	53	46	42	37	34	31	28	25	19	2
1.0	0	0	0	0	0	0	0	0	0	0	0	1	4	29	96	186	249	261	231	169	120	84	61	50	44	40	36	33	29	26	20	5
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	34	91	163	220	241	197	131	83	61	50	44	40	35	31	27	21	12
2.0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	11	36	85	174	226	200	127	82	60	49	44	39	32	29	22	17
2.5	0	o	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	37	105	196	214	135	87	62	51	44	36	31	24	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	24	96	205	189	130	85	62	50	39	32	26	18
IA/P = 0.50														* * * TC = 0.75 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	0	2	16	45	92	137	166	185	170	146	125	110	98	89	79	70	63	58	53	48	44	42	41	37	33	28	0
.10	0	0	0	0	0	0	0	1	11	34	73	115	149	180	163	141	122	107	96	84	74	65	59	54	50	45	43	41	38	33	28	0
.20	0	0	0	0	0	0	0	1	9	25	57	96	131	173	166	146	126	111	99	86	76	66	59	55	50	46	43	41	38	34	28	0
.30	0	0	0	0	0	0	0	0	1	5	18	44	79	143	170	160	141	122	108	92	81	69	61	56	52	47	44	42	38	34	28	1
.40	0	0	0	0	0	0	0	0	0	4	14	34	64	127	166	162	145	127	111	95	82	70	62	57	52	47	44	42	38	34	28	1
.50	0	0	0	0	0	0	0	0	0	0	2	10	26	82	138	162	157	140	123	103	88	75	64	58	53	49	45	43	39	35	28	2
.75	0	0	0	0	0	0	0	0	0	0	1	4	12	47	98	139	154	148	135	113	96	80	67	60	55	50	46	43	39	36	29	3
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	30	73	119	146	151	134	113	91	74	63	58	53	48	45	41	37	29	7
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	30	66	105	143	143	117	90	73	63	57	52	48	42	39	30	18
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	30	77	121	137	114	88	72	63	57	52	44	40	32	25
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	19	56	111	132	111	87	71	62	56	47	42	34	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	12	51	112	128	108	86	71	62	51	44	36	27

RAINFALL TYPE = II * * * TC = 0.75 HR * * * SHEET 6 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC = 1.0 HR * * *														IA/P = 0.10				
0.0	11	15	20	29	35	47	72	112	169	231	289	329	367	313	239	175	133	103	83	63	50	40	33	29	26	23	21	20	17	15	12	0
.10	10	13	17	24	27	33	42	62	96	144	202	260	306	340	293	222	165	126	98	72	56	43	35	30	27	24	22	20	18	15	12	0
.20	10	13	17	23	26	30	30	54	92	123	176	232	281	332	303	230	179	136	105	76	59	45	35	30	27	24	22	20	18	16	12	1
.30	9	12	16	22	24	28	35	49	70	105	152	205	256	323	310	254	193	146	113	81	61	46	36	31	27	24	22	20	18	16	12	1
.40	8	11	14	19	21	23	27	32	42	61	91	132	181	276	318	294	237	181	138	95	70	51	39	32	28	25	23	21	18	16	12	1
.50	8	10	13	18	20	22	25	30	36	53	78	114	159	253	311	300	251	195	149	102	74	53	40	33	29	25	23	21	18	16	12	1
.75	7	8	11	14	16	17	19	21	25	30	38	53	76	146	228	284	293	256	208	143	99	66	46	36	31	27	24	22	19	17	13	2
1.0	5	7	8	11	12	13	14	16	17	19	22	25	31	57	111	188	256	286	272	209	144	90	56	41	33	29	26	23	20	17	13	4
1.5	4	5	6	8	8	9	10	11	12	13	14	15	17	22	33	59	107	171	231	268	235	157	88	56	41	33	29	25	21	18	14	8
2.0	2	3	4	5	5	6	6	7	7	8	9	9	10	12	15	19	27	44	78	157	231	252	167	96	59	42	34	29	23	20	15	11
2.5	1	2	2	3	4	4	4	5	5	6	6	7	7	8	10	12	15	19	27	58	120	214	241	159	94	59	42	34	26	21	16	11
3.0	0	1	1	2	2	3	3	3	4	4	4	5	5	6	7	8	10	12	14	22	44	113	214	231	152	91	58	42	29	23	17	12
IA/P = 0.30														* * * TC = 1.0 HR * * *														IA/P = 0.30				
0.0	0	0	0	0	1	4	16	42	83	137	195	243	271	292	227	178	143	117	98	79	66	55	47	42	38	34	31	30	27	23	19	0
.10	0	0	0	0	0	0	3	12	32	66	113	168	218	279	260	213	169	136	113	88	72	59	49	43	39	35	32	30	27	24	19	1
.20	0	0	0	0	0	0	2	9	24	52	93	143	193	271	271	225	180	145	119	92	75	60	50	44	39	35	32	30	27	24	19	1
.30	0	0	0	0	0	0	1	6	18	41	75	120	169	246	264	234	191	153	125	96	78	62	51	44	40	36	33	31	27	24	19	1
.40	0	0	0	0	0	0	0	1	4	14	32	61	100	190	251	259	222	181	146	109	86	67	53	46	41	37	33	31	28	25	19	2
.50	0	0	0	0	0	0	0	1	3	10	24	49	83	160	237	254	230	191	155	115	90	69	54	47	42	37	34	31	28	25	19	2
.75	0	0	0	0	0	0	0	0	0	1	4	12	25	76	150	213	239	228	198	149	112	82	61	50	44	39	35	32	29	26	20	4
1.0	0	0	0	0	0	0	0	0	0	0	0	1	2	15	51	113	182	226	234	197	150	104	72	56	47	42	38	34	30	27	20	7
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	19	51	104	162	220	210	158	102	71	56	47	42	37	31	28	22	13
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	20	49	121	187	200	152	100	70	55	47	41	34	29	23	17
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	32	87	171	199	146	98	60	54	46	37	31	24	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	13	62	159	192	151	103	73	56	41	34	26	18
IA/P = 0.50														* * * TC = 1.0 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	0	1	7	21	42	71	101	126	160	154	138	123	110	100	87	77	67	60	55	50	46	43	41	38	34	28	1
.10	0	0	0	0	0	0	0	1	5	15	33	58	87	134	156	149	134	120	108	93	82	71	62	57	52	47	44	42	38	34	28	1
.20	0	0	0	0	0	0	0	1	4	12	26	48	74	123	153	153	137	123	111	95	84	72	63	57	52	47	44	42	38	34	28	1
.30	0	0	0	0	0	0	0	0	3	9	20	38	62	111	143	150	140	127	114	98	86	73	63	58	53	48	45	42	39	35	28	1
.40	0	0	0	0	0	0	0	0	0	2	6	16	31	75	120	145	148	137	123	106	91	77	66	59	54	49	45	43	39	35	29	2
.50	0	0	0	0	0	0	0	0	0	1	5	12	25	64	109	139	146	139	127	108	94	79	67	60	55	50	46	43	39	36	29	3
.75	0	0	0	0	0	0	0	0	0	0	2	5	12	39	78	115	136	140	134	117	101	84	70	62	56	51	47	44	40	36	29	4
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	26	59	96	125	139	133	117	97	78	66	59	54	49	46	41	37	29	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9	26	54	86	123	133	119	95	77	66	59	54	49	43	39	31	17
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	25	64	104	129	116	93	76	65	58	53	45	41	33	24
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	34	84	125	117	96	78	66	59	49	43	35	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	32	69	122	114	94	77	66	53	45	37	27

RAINFALL TYPE = II * * * TC = 1.0 HR * * * SHEET 7 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution —continued

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
IA/P = 0.10														* * * TC = 1.25 HR * * *														IA/P = 0.10				
0.0	10	13	18	25	29	38	54	81	118	163	213	256	284	311	266	212	163	129	104	78	61	47	37	31	27	24	22	20	18	16	12	1
.10	10	13	17	23	27	34	47	69	102	143	189	234	267	297	274	226	175	138	111	82	64	48	38	31	27	24	22	20	18	16	12	1
.20	9	11	15	20	22	26	31	42	60	88	124	168	212	280	292	261	212	166	131	95	72	53	40	33	28	25	23	21	18	16	12	1
.30	8	11	14	19	21	24	29	38	53	76	108	148	190	263	288	268	224	177	140	101	76	55	41	34	29	25	23	21	18	16	12	2
.40	8	10	13	18	20	23	27	34	46	66	94	130	170	245	282	273	235	188	149	107	80	58	42	34	29	26	23	21	19	16	12	2
.50	7	9	12	16	17	19	22	25	31	41	58	82	114	190	256	279	262	222	178	127	93	65	46	36	31	27	24	22	19	17	13	2
.75	6	8	10	14	15	17	19	21	25	31	41	56	78	139	207	254	265	245	209	152	110	75	51	39	32	28	25	22	19	17	13	3
1.0	5	6	8	10	11	13	14	15	17	19	22	26	33	60	109	173	230	261	255	208	153	100	64	46	36	30	26	24	20	18	13	5
1.5	3	4	5	7	7	8	9	9	10	11	12	13	15	19	27	45	79	130	196	247	239	180	108	68	49	37	31	27	22	19	14	10
2.0	2	3	4	5	6	6	7	7	8	9	9	10	11	13	16	22	35	59	98	171	236	236	156	95	62	44	35	30	23	20	15	11
2.5	1	2	2	3	4	4	4	5	5	5	6	6	7	8	10	12	14	19	28	58	114	197	226	163	102	65	46	36	26	21	16	11
3.0	0	1	1	2	2	2	2	3	3	3	4	4	4	5	6	7	9	10	13	19	35	68	184	219	169	109	70	49	31	24	18	12
IA/P = 0.30														* * * TC = 1.25 HR * * *														IA/P = 0.30				
0.0	0	0	0	0	0	2	9	25	50	86	130	174	208	253	235	201	164	136	115	92	76	61	51	44	39	35	32	30	27	24	19	1
.10	0	0	0	0	0	0	1	6	19	40	71	110	153	217	247	227	191	157	131	103	84	66	53	46	41	36	33	31	28	24	19	2
.20	0	0	0	0	0	0	1	4	14	31	58	93	133	202	239	231	199	165	138	108	87	68	55	47	41	37	33	31	28	25	19	2
.30	0	0	0	0	0	0	0	1	3	10	24	46	77	152	210	236	222	190	150	122	97	74	58	49	43	38	34	32	28	25	20	3
.40	0	0	0	0	0	0	0	0	2	8	19	37	64	134	196	232	225	198	166	127	101	77	59	50	43	38	35	32	28	25	20	3
.50	0	0	0	0	0	0	0	0	0	2	6	14	30	82	151	206	220	217	189	146	113	85	64	52	45	40	36	33	29	26	20	5
.75	0	0	0	0	0	0	0	0	0	1	2	7	15	49	105	164	205	210	205	166	129	95	69	55	47	41	37	33	29	26	20	6
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	32	77	134	185	214	203	166	120	83	63	52	45	39	35	30	27	21	10
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	33	72	121	184	203	171	117	82	62	51	44	39	32	29	22	15
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	21	67	132	154	174	123	86	64	52	45	35	31	24	18
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	13	46	121	187	166	119	84	63	52	39	32	25	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	44	129	180	160	116	83	63	44	35	27	18
IA/P = 0.50														* * * TC = 1.25 HR * * *														IA/P = 0.50				
0.0	0	0	0	0	0	0	1	5	13	26	44	68	91	125	142	142	128	117	107	94	83	72	63	57	52	47	44	42	38	34	28	2
.10	0	0	0	0	0	0	0	0	3	10	20	36	57	100	129	140	136	125	114	100	88	76	65	59	54	49	45	43	39	35	29	3
.20	0	0	0	0	0	0	0	0	2	7	16	30	48	90	122	139	139	127	117	102	90	77	66	60	54	49	45	43	39	35	29	3
.30	0	0	0	0	0	0	0	0	0	2	5	12	24	59	98	126	137	134	125	109	96	82	69	61	56	51	46	44	40	36	29	4
.40	0	0	0	0	0	0	0	0	0	1	4	10	19	51	89	119	134	136	127	112	98	83	70	62	56	51	47	44	40	36	29	5
.50	0	0	0	0	0	0	0	0	0	1	3	7	15	43	79	112	131	135	129	114	100	85	71	63	57	52	47	44	40	36	29	6
.75	0	0	0	0	0	0	0	0	0	0	0	1	3	15	39	71	102	123	130	125	112	94	78	67	60	54	49	46	41	37	29	9
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	17	40	71	101	121	129	121	143	84	71	62	56	51	47	42	38	30	13
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	26	51	92	119	125	105	86	72	63	57	52	44	40	32	23
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	11	35	72	112	122	103	85	71	63	56	47	42	34	26
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	24	66	111	119	101	83	71	62	51	44	36	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	23	71	110	116	99	82	70	55	46	37	27

RAINFALL TYPE = II * * * TC = 1.25 HR * * * SHEET 8 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

HYDROGRAPH TIME (HOURS)

IA/P = 0.10 * * * TC = 1.5 HR * * * IA/P = 0.10

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	9	11	15	21	25	31	41	58	82	112	147	184	216	255	275	236	198	159	129	98	76	57	43	35	30	25	23	21	18	16	12	1
.10	8	10	13	18	20	23	28	37	51	72	90	131	166	226	265	254	226	187	151	113	86	63	46	37	31	26	23	21	19	16	13	2
.20	8	10	13	17	19	22	26	33	45	63	87	116	149	212	259	259	233	197	160	119	90	66	48	38	32	27	24	22	19	16	13	2
.30	7	9	12	16	18	21	24	30	40	55	76	103	134	197	244	255	236	206	169	125	95	68	49	38	32	27	24	22	19	17	13	2
.40	7	8	11	14	15	17	19	23	28	36	49	67	91	151	208	247	252	230	196	146	109	77	54	41	34	29	25	22	19	17	13	3
.50	6	8	10	13	15	16	18	21	26	33	43	59	83	136	194	238	249	235	204	154	115	81	56	42	34	29	25	23	20	17	13	3
.75	5	7	8	11	12	13	14	16	18	21	25	32	42	76	125	179	222	240	233	193	148	102	67	48	38	32	27	24	20	18	13	5
1.0	4	5	7	8	9	10	11	12	13	14	16	18	22	34	59	101	152	201	236	230	193	135	86	59	44	35	30	26	21	18	14	7
1.5	3	4	5	6	6	7	8	8	9	10	11	12	13	16	22	34	58	95	141	203	226	197	131	84	58	43	35	29	23	20	15	10
2.0	1	2	3	4	4	5	5	6	6	7	7	8	9	10	12	16	22	34	56	110	172	218	187	126	82	57	43	34	25	21	16	11
2.5	1	1	2	2	3	3	3	4	4	4	5	5	6	7	8	9	11	14	18	34	69	141	210	190	133	87	60	44	30	23	17	12
3.0	0	0	1	1	2	2	2	2	3	3	3	3	4	5	5	6	8	9	11	16	27	66	149	204	101	128	85	58	35	26	18	12

IA/P = 0.30 * * * TC = 1.5 HR * * * IA/P = 0.30

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	0	1	6	15	31	53	80	112	144	193	225	208	186	157	134	108	89	70	56	48	42	37	34	31	28	25	20	2
.10	0	0	0	0	0	0	1	4	12	25	43	68	97	157	198	219	203	176	151	120	98	77	60	50	44	38	35	32	28	25	20	3
.20	0	0	0	0	0	0	0	1	3	9	19	35	57	114	168	201	213	196	171	135	100	84	64	53	46	40	36	33	29	26	20	4
.30	0	0	0	0	0	0	0	1	2	7	15	29	48	100	155	193	210	200	177	140	113	87	66	54	46	41	36	33	29	26	20	5
.40	0	0	0	0	0	0	0	0	2	5	12	23	39	87	141	184	207	202	182	146	117	89	68	56	47	41	36	33	29	26	20	6
.50	0	0	0	0	0	0	0	0	0	1	4	9	18	51	101	153	190	205	197	164	131	99	73	58	49	43	38	34	30	26	20	7
.75	0	0	0	0	0	0	0	0	0	0	2	4	9	30	68	116	160	189	197	179	147	110	80	62	52	45	39	35	30	27	21	8
1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	20	49	92	138	175	195	178	137	97	72	57	48	42	37	31	28	21	12
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	21	47	85	145	187	178	133	95	71	57	48	42	34	29	23	16
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	13	45	97	162	180	138	99	74	58	49	38	32	25	18
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	31	89	161	174	133	97	72	58	42	34	26	18
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	29	98	160	169	129	95	71	40	37	28	19

IA/P = 0.50 * * * TC = 1.5 HR * * * IA/P = 0.50

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
.0	0	0	0	0	0	0	0	3	8	16	27	42	59	92	116	128	130	121	112	100	90	78	67	60	55	50	46	43	39	36	29	4
.10	0	0	0	0	0	0	0	2	6	12	22	35	51	84	110	125	128	123	114	102	95	79	68	61	55	50	45	43	39	35	29	4
.20	0	0	0	0	0	0	0	0	1	4	10	10	29	60	91	114	126	128	120	100	97	83	71	63	57	52	47	44	40	36	29	5
.30	0	0	0	0	0	0	0	0	1	3	8	14	24	52	83	108	123	126	122	110	98	85	72	63	57	52	48	44	40	36	29	6
.40	0	0	0	0	0	0	0	0	0	1	2	6	12	31	69	90	112	124	126	116	104	90	75	66	59	54	49	45	41	37	29	8
.50	0	0	0	0	0	0	0	0	0	0	2	4	9	26	53	83	106	121	125	118	106	91	77	67	60	54	49	46	41	37	29	8
.75	0	0	0	0	0	0	0	0	0	0	1	2	5	16	36	62	88	108	119	122	112	97	81	69	62	56	51	47	42	38	30	11
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	26	49	75	98	118	121	109	90	76	66	59	54	49	43	39	31	16
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	11	25	45	80	107	118	106	89	75	65	59	53	45	41	32	23
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	11	32	63	100	115	104	87	74	65	58	48	42	34	26
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	16	49	94	113	105	89	76	66	53	45	36	27
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	15	54	96	111	103	88	75	50	46	38	28

RAINFALL TYPE = II * * * TC = 1.5 HR * * * SHEET 9 OF 10

Exhibit 5-II: Tabular hydrograph unit discharges (csm/in) for type II rainfall distribution—continued

HYDROGRAPH TIME (HOURS)

IA/P = 0.10 * * * TC = 2.0 HR * * * IA/P = 0.10

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	7	9	12	16	18	21	27	36	49	64	82	104	127	171	201	226	208	193	171	132	105	79	58	45	36	30	26	23	20	17	13	3
.10	6	8	10	14	15	17	20	25	33	43	57	74	94	139	179	204	218	205	188	150	118	88	63	48	38	32	27	24	20	17	13	4
.20	6	8	10	13	14	16	19	23	29	39	51	66	84	128	169	190	213	207	192	157	123	91	65	49	39	33	28	24	20	17	13	4
.30	6	7	9	12	14	15	18	21	27	35	45	59	76	117	159	191	211	208	196	163	128	95	68	51	40	33	28	25	20	18	13	4
.40	5	6	8	11	12	13	15	17	20	24	31	41	53	87	128	167	197	209	205	180	145	106	75	55	43	35	30	26	21	18	14	5
.50	5	6	8	10	11	13	14	16	18	22	28	37	48	78	118	158	190	208	208	185	151	111	77	57	44	36	30	26	21	18	14	5
.75	4	6	7	9	10	11	12	13	15	18	22	27	35	58	91	129	164	195	202	194	167	125	87	63	48	38	32	27	22	18	14	6
1.0	3	4	6	7	8	8	9	10	11	12	14	16	18	28	46	74	110	147	176	201	193	156	108	76	56	43	35	30	23	19	14	8
1.5	2	3	3	5	5	5	6	6	7	8	8	9	10	12	16	23	36	57	86	137	178	195	160	113	79	58	45	36	26	21	16	11
2.0	1	2	2	3	3	4	4	4	5	5	6	6	7	8	10	12	16	23	35	67	112	169	190	154	110	78	57	44	30	23	17	11
2.5	0	1	1	2	2	2	3	3	3	4	4	4	5	6	7	8	9	12	16	28	52	105	170	185	149	107	76	56	35	26	18	12
3.0	0	0	1	1	1	1	1	2	2	2	2	3	3	3	4	5	6	7	8	12	18	41	99	161	180	152	112	80	45	30	19	12

IA/P = 0.30 * * * TC = 2.0 HR * * * IA/P = 0.30

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	0	1	3	8	15	25	38	54	74	115	148	168	185	170	159	131	110	89	70	57	49	42	38	34	29	26	20	5
.10	0	0	0	0	0	0	0	2	6	12	21	32	47	85	124	153	169	180	168	145	120	96	75	60	51	44	39	35	30	26	20	6
.20	0	0	0	0	0	0	0	2	4	10	17	27	41	75	114	146	165	175	170	149	124	99	76	62	52	45	39	35	30	27	21	6
.30	0	0	0	0	0	0	0	0	1	3	7	14	23	49	86	122	151	170	174	160	136	107	82	66	54	47	41	37	31	27	21	8
.40	0	0	0	0	0	0	0	0	1	2	6	11	19	43	77	113	144	165	173	163	140	111	85	67	55	47	41	37	31	27	21	9
.50	0	0	0	0	0	0	0	0	1	2	4	9	16	37	68	104	136	160	171	165	144	114	87	69	56	48	42	37	31	27	21	9
.75	0	0	0	0	0	0	0	0	0	0	1	2	5	15	34	62	96	127	152	167	160	132	100	77	62	52	45	40	32	28	22	11
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	24	48	79	111	150	166	153	118	90	71	58	49	43	34	29	23	14
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	10	24	45	88	130	161	148	115	88	70	57	48	37	31	24	17
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	10	32	68	122	157	143	113	87	68	56	42	34	26	18
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	16	53	114	153	144	116	89	70	49	38	27	19
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	15	59	110	150	140	113	88	57	42	29	19

IA/P = 0.50 * * * TC = 2.0 HR * * * IA/P = 0.50

TRVL TIME (hr)	11.0	11.3	11.6	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3	14.6	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	22.0	26.0
0.0	0	0	0	0	0	0	0	1	4	8	13	20	28	51	73	92	104	111	112	106	97	86	75	66	60	54	49	46	41	37	30	7
.10	0	0	0	0	0	0	0	1	3	6	11	17	24	45	68	87	101	109	112	107	98	88	76	67	60	55	50	46	41	37	30	8
.20	0	0	0	0	0	0	0	1	2	5	9	14	21	40	62	82	98	107	111	108	100	89	77	68	61	55	50	47	41	37	30	8
.30	0	0	0	0	0	0	0	0	0	2	4	7	12	26	46	67	86	100	108	111	104	93	80	70	63	57	52	48	42	38	30	10
.40	0	0	0	0	0	0	0	0	0	1	3	6	10	22	41	62	81	96	106	110	105	94	81	71	63	57	52	48	42	38	30	11
.50	0	0	0	0	0	0	0	0	0	0	1	2	4	13	27	46	67	85	99	110	108	98	85	74	66	59	54	49	43	39	31	13
.75	0	0	0	0	0	0	0	0	0	0	0	1	2	7	16	33	52	71	90	104	100	102	89	77	68	61	55	50	44	39	31	15
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	13	25	43	62	87	103	108	97	84	73	65	59	53	45	41	32	20
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	12	24	48	74	99	106	95	83	72	64	58	48	43	34	25
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	17	37	69	99	104	94	82	72	64	52	45	36	27
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	27	65	55	102	95	93	73	58	49	38	28
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	32	68	95	101	93	82	64	52	40	28

RAINFALL TYPE = II * * * TC = 2.0 HR * * * SHEET 10 OF 10

2.5 Other Methods

Mahoning County will accept the following USGS methods to calculate storm water runoff. These methods are not described here but the designer is directed to obtain copies of the individual reports from USGS:

2.5.1 Water-Resources Investigations Report 03-4164

Techniques for Estimating Flood-Peak Discharges of Rural, Unregulated Streams in Ohio

http://www.dot.state.oh.us/research/2003/Hydraulics/14740-FR.pdf

2.5.2 Water-Resources Investigations Report 93-4080

Estimation of Flood Volumes and Simulation of Flood **Hydrographs** for Ungaged, Small Rural Streams in Ohio

http://oh.water.usgs.gov/reports/Abstracts/wrir.93-4080.html

2.5.3 Water-Resources Investigations Report 93-135

Estimation of Peak-Frequency Relations, Flood **Hydrographs**, and Volume-Duration-Frequency Relations of Un-gauged Small Urban Streams in Ohio

http://oh.water.usgs.gov/reports/Abstracts/ofr.93-135.html

SECTION 3 STORM DRAINAGE SYSTEMS

3.0 STORM DRAINAGE SYSTEMS

3.1 Overview

Proposed development sites and existing improvements shall be protected from flood damage and excessive ponding of water, springs, and other surface waters. The design and construction of **drainage** facilities within the proposed development shall be such that **runoff** passing through the development will be carried through and away from the site without causing flood damage to any structure. Additionally, these waters must not adversely affect the proposed sanitary sewer system or individual sewage systems. **Runoff** entering the proposed development shall be received and discharged from the site at the locations and, as nearly as possible, in the same manner that existed prior to construction.

The **drainage** system layout should be made in accordance with the urban **drainage** objectives, following the natural topography as closely as possible. Design of **drainage** systems shall not cause **runoff** to be diverted from one **watershed** to another. Existing natural **drainage** paths and **watercourses** such as streams and creeks should be incorporated into the storm **drainage** system.

3.2 Minor System Design

The minor system consists chiefly of the storm system comprised of inlets, conduits, manholes and other appurtenances designed to collect and discharge into a major system outfall storm **runoff** for frequently occurring storms (10 year).

3.2.1 Layout of Storm Sewers

The layout of the storm system shall place the storm and sanitary sewers on opposite sides of the roadways and within the tree lawn areas where practical. Where opposite side construction is not practical, every effort shall be made to separate the storm and sanitary sewers by six feet (6') barrel to barrel.

The minimum size of all storm sewers, excluding connections and yard drains, shall be 12 inches in diameter. The minimum yard drain size shall be 8 inches in diameter.

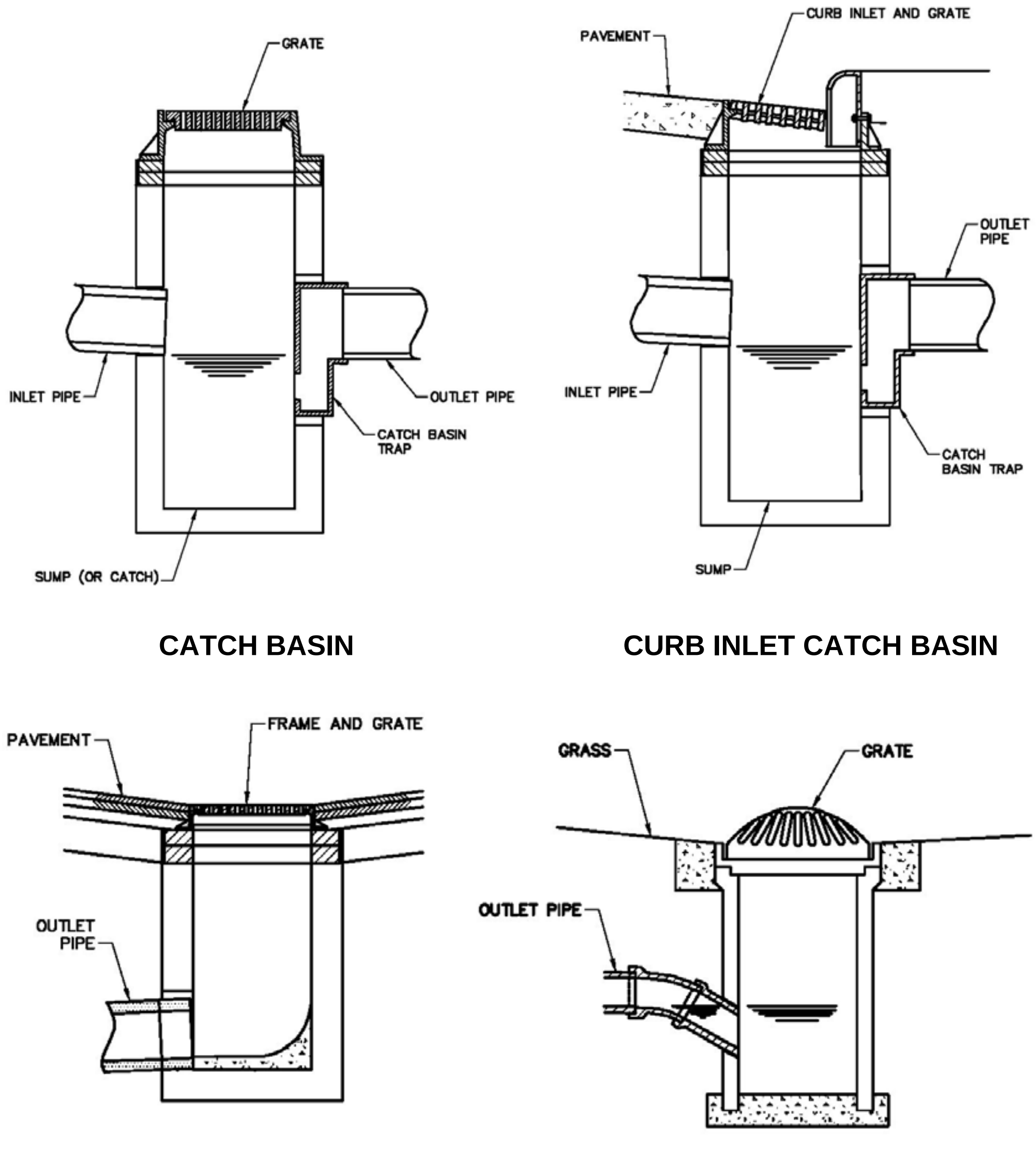
Lateral storm connections to building sites shall be a minimum of six inches in diameter.

Storm sewers shall have a minimum flowing full velocity of three feet (3) per second and a maximum velocity of 12 feet per second.

For sewers sized less than 36 inches in diameter, manholes shall be spaced at not over 400 feet. For sewers 36 inches through 60 inches in diameter, manholes shall be spaced at not over 600 feet. In sewers larger than 60 inches in diameter, manhole spacing shall not exceed 1,000 feet.

3.2.2 Inlet Types and Locations

FIGURE 3-1: Storm Inlet Types



CATCH BASIN **CURB INLET CATCH BASIN**

INLET BASIN **YARD BASIN**

NOTE: The inlet structure details above are for illustrative purposes only and shall not be used for construction. The user is referred to the following ODOT website to download current standard details:

http://www.dot.state.oh.us/se/standard/Hydraulic/index.htm

Storm Inlet structures are defined in Figure 3-1. The location of these structures is as follows:

- o Place upstream of all intersections, bridges, pedestrian ramps, commercial drive aprons, intersection return radii, and curb termini.
- o Structures should be placed 10' off drive aprons, intersection return radii, pedestrian ramps, or curb termini when practicable.
- o Place structure in pavement sags.
- o Flank catch basin in sag on both upstream directions at 0.2 feet above the flow line of the inlet of the sag catch basin when practicable.

3.2.3 Storm Sewer Requirements

The design storm frequencies for each type of development are as follows:

• Residential/Subdivisions	10 Year Frequency
• Multifamily	10 Year Frequency
• Schools	10 Year Frequency
• Industrial/Commercial	10 Year Frequency
• Major Urban Business Area	10 Year Frequency

The hydraulic grade line shall be determined for the 25 year storm event. The hydraulic grade line shall be below the grate and/or cover of all structures. Note: The hydraulic grade line should never be below the normal depth of flow in the conduit. If it is, then use the normal depth of flow elevation as the hydraulic grade line elevation.

3.2.4 Storm Sewer Design

A **drainage** map delineating each sub-basin area and labeled accordingly shall be prepared. The **drainage** map shall show the proposed improvements, contours and storm sewers system.

The rational method as described in Section 2.2 shall be used to determine the contributing inflow into the system.

The Storm Sewer Computation Sheet shall be used and completed to correctly size the storm sewers. A blank Storm Sewer Computation Sheet is included in the appendix.

Regardless of the type of smooth-lined pipe, ie RCP, PVC, HDPE – the Manning's "n" value shall be as shown on Table 2-6a. Values for Corrugated Metal pipe shall be as shown on Table 2-6b.

The increased values are recommended for sewers to compensate for minor head losses incurred at catch basins, inlets and manholes located in a storm sewer system.

3.2.5 Storm Sewer Computation Sheet – Design Procedures

Please refer to example sheet (Figure 3-2).

Column 1: Structure number. Assigned by the designer. Usually numbered from lowest elevation to highest elevation. The main line trunk is numbered first and then the laterals.

Column 2: Station of the structure as referenced from the centerline or baseline.

Column 3: Right, Left or on the Centerline.

Column 4: **Drainage** area for the referenced structure.

Column 5: Total **drainage** area. This number is found by summing the DA from the current structure to the SA directly upstream of it.

Column 6: Time of concentration to the current structure. In some cases, this time may be calculated based upon the length of the conduit and the velocity of the flow if there is no discharge into the next adjacent structure.

Column 7: Total time of concentration. This number is found by summing the individual time of concentration from the current structure (column 6) to the structure directly upstream of it.

Column 8: The rainfall intensity based upon the design year storm. At time equal to ST (column 7)

Column 9: The rainfall intensity based upon the hydraulic grade year storm. This intensity is based upon the greatest time of concentration to the outlet. It is used for the entire upstream storm sewer system. Do not complete until the greatest Tc is known. This intensity is used for the entire storm upstream.

Column 10: The weighted coefficient for the **watershed**.

Column 11: The multiplication of the **drainage** area for the structure and the weighted coefficient for the **watershed** (column 4 x column 10)

Column 12: Summation of the DCA value of the current structure added to the upstream SCA value.

Column 13: The design discharge found by the multiplication of the SCA and the design intensity (column 12 x column 8).

Column 14: The design discharge found by the multiplication of the SCA and the hydraulic grade intensity (column 12 x column 9). Do not complete until #9 is determined.

Column 15: The diameter of the conduit.

Column 16: The length of the conduit.

Column 17: The slope of the conduit.

Column 18: The invert of the incoming conduit to the current structure.

Column 19: The invert of the outgoing conduit from the structure.

Column 20: The velocity based upon the Manning's "just full equation". *(see notes)*

Column 21: The discharge based upon the Manning's "just full equation".

Column 22: The hydraulic friction slope. **

Column 23: The headloss due to friction in the conduit. hL=L*(Sf) or other equation

Column 24: The elevation of the hydraulic grade line. Calculated by adding the head loss to the hydraulic grade elevation of the downstream structure. At the outlet the hydraulic grade elevation is either the water surface elevation or it is calculated by the (critical depth+diameter)/2.

Column 25: The elevation of the structure grate or cover.

Column 26: The difference of the structure grate or cover elevation and the hydraulic grade elevation (column 25- column 24).

Notes:

· A common mistake is to not use the smallest intensity (longest time of concentration) for the hydraulic grade check.
· The critical depth is calculated using the nomographs in the appendix of ODOT The Location and Design Manual, Volume 2 or it can be approximated by using 0.8 x Diameter.
**Sf= [(Q*N)/(0.465*D^(8/3))]^(2)

A blank Storm Sewer Computation Sheet, taken from the ODOT Location and Design Manual, is included in the Appendix.

FIGURE 3-2: Storm Sewer Computation Sheet (Example)

Form LD-34
(Revised July 2002)

STORM SEWER COMPUTATION SHEET

Calculated by........JES........Date.....06-27-02.....
Checked by........DAG........Date.....06-27-02.....

Just Full Capacity ....10.....Yr. Frequency
Hydraulic Gradient ....25.....Yr. Frequency
Interstate Sag ....50.....Yr. Frequency

Project........LAW-7-2.17........
Sheet.....1.....of.....1.....

Manning's "n" for ..0.015... Year Design Frequency..10...
Manning's "n" for ..0.015... Year H.G. Frequency...25...

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	MH CB or I	Station	Side	Drainage Area In Acres		Time of Concentration In Minutes		Rainfall in Inches/Hour		Runoff Coef.	C X A		Discharge in cfs CA X i		Size of Pipe in Inches	Length of Pipe in Feet	Slope of Pipe in Ft./Ft.	Inlet F/L of Pipe	Outlet F/L of Pipe	Mean Velocity in Ft./Sec.	Just Full Capacity (......Year Q)	Friction Slope in Ft./Ft.	Head Loss in Feet	Elevation of Hyd. Gradient (for 25 year Q)	Grate or Cover Elev.	Cover Elev minus H.G. Elev.
	No.			ΔA	ΣA	Δt	Σt	i.10.	i.25.	C	ΔCA	ΣCA	Q.10.	Q.25.	Ø	L	S_o	Elev.	Elev.	V_m	cfs	S_f	H	Elev.	Elev.	
CB	1	210+50	RT	1.6	1.6	15	15	4.6	5.19	0.68	1.09	1.09	5.0	5.65												
															15	200	0.008	610.55	610.55	4.51	5.4	0.010	2.03	616.59	618.00	1.41
CB	2	208+50	RT	1.9	3.5	18	18	4.2	5.19	0.68	1.29	2.38	10.0	12.35												
															15	225	0.035	608.95	608.95	9.43	11.31	0.048	10.94	614.56	615.50	0.94
MH	3	206+25	RT	0	3.5	0.39	18.39	4.19	5.19	0	0	2.38	9.97	12.35												
															15	100	0.035	601.08	601.08	9.43	11.31	0.048	4.86	603.62	605.00	1.38
HW	4	206+50	RT			0.17	18.57		5.19		0	2.38		12.35												
																		597.58						598.76		
																						$\frac{Qc+Qo}{2}$ =	$\frac{1.1+1.25}{2}$	= 1.18		

..\Example Storm\stormcalc.dgn 06/19/2003 10:13:54 AM

3.2.6 Culvert Design

Culverts shall be designed to easily convey the 10-year design storm. As a check, the headwater depth shall not be within 12" of the final pavement (crown) elevation for the 25-year storm.

Hydraulic analysis of all culverts shall be performed per the following report:

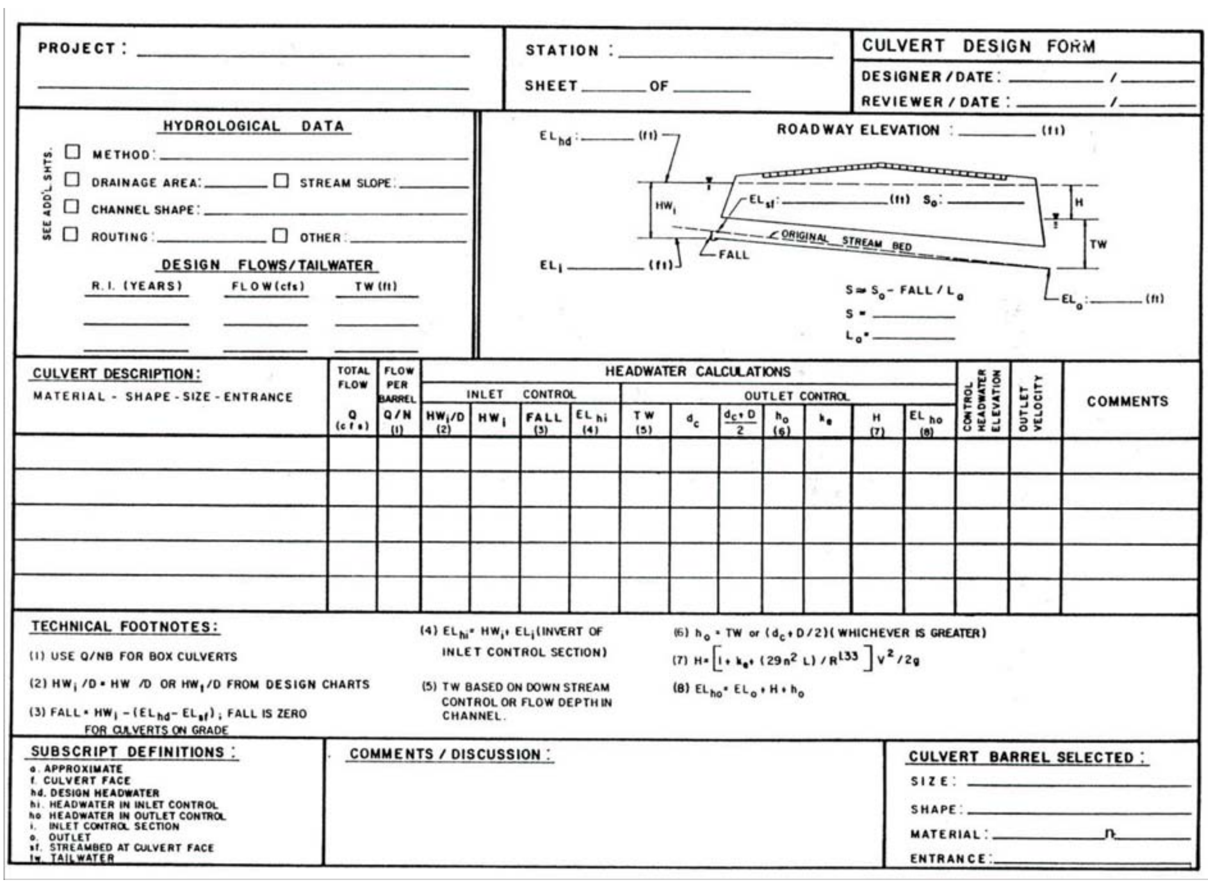
Federal Highway Administration, Report No. FHWA-IP-85-15, Hydraulic Design Series No. 5, "Hydraulic Design of Highway Culverts", September 1985.

A copy of the report can be obtained at:

http://www.fhwa.dot.gov/bridge/hds5SI.pdf

Figure 3-3 is an example culvert design form that will be required for submittal. A blank form is included in the appendix.

FIGURE 3-3: Culvert Design Form



PROJECT: ______________________

STATION: ______________________

SHEET ______ OF ______

CULVERT DESIGN FORM

DESIGNER / DATE: ________ / ________

REVIEWER / DATE: ________ / ________

HYDROLOGICAL DATA

SEE ADD'L SHTS.

☐ METHOD: ______________________

☐ DRAINAGE AREA: ________ ☐ STREAM SLOPE: ________

☐ CHANNEL SHAPE: ______________________

☐ ROUTING: ________ ☐ OTHER: ________

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW	FLOW PER BARREL	HEADWATER CALCULATIONS											CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
			INLET CONTROL				OUTLET CONTROL									
	Q (cfs)	Q/N (1)	HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)			

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i / D = HW / D$ OR HW_i / D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29n^2 L) / R^{1.33}\right] V^2 / 2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

a. APPROXIMATE
f. CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf. STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED:

SIZE: ______________

SHAPE: ______________

MATERIAL: ________ n ________

ENTRANCE: ______________

Computer programs such as FHWA's "HY-8", ODOT's "HYDRA", or Haestad Methods "CulvertMaster" software packages may be used. HY-8 and HYDRA can be downloaded at the following websites:

FHWA "HY-8"

http://www.fhwa.dot.gov/bridge/hyddescr.htm#hy_8_culvert_analysis

ODOT "HYDRA"

http://www.dot.state.oh.us/se/hy/dloads.htm

Haestad Methods "CulvertMaster" can be ordered at the following website:

http://www.haestad.com/software/culvertmaster/

3.3 Major System Design

The major **drainage** system will come into operation once the minor system's capacity is exceeded during storm events larger than the minor system's design storm. Thus, an overflow system must be planned to insure that the storm **runoff** will be directed to the **storm water** storage facility(s). The major **drainage** system may consist of open **channels** (including roadway, parking lot, swales, etc.), an over designed storm sewer system, or combinations of both. For the purposes of this manual, the 100 year storm event will serve as the design storm of record for the major **drainage** systems.

3.4 Storm Water Storage Facilities Design

This section discusses the general design procedures for designing storage to provide standard detention of **storm water runoff** to meet **critical storm** requirements.

Storm water storage(s) can be classified as surface detention, underground detention, extended dry detention or wet retention. Some facilities include one or more types of storage. See Section 4.0 for detailed information regarding each of these storage types.

NOTE: The design procedures for all structural control storage facilities are the same whether or not they include a permanent pool of water. In the latter case, the permanent pool elevation is taken as the "bottom" of storage and is treated as if it were a solid basin bottom for routing purposes.

A stage-discharge curve defines the relationship between the depth of water and the discharge or outflow from a storage facility. A typical storage facility has two outlets or spillways: a principal outlet and a secondary (or emergency) outlet. The principal outlet is usually designed with a capacity sufficient to convey the design flows without allowing flow to enter the emergency spillway. A pipe culvert, weir, or other appropriate outlet can be used for the principal spillway or outlet.

The emergency spillway is sized to provide a bypass for floodwater during a flood that exceeds the design capacity of the principal outlet. This spillway should be designed taking into account the potential threat to downstream areas if the storage facility were to fail. The stage-discharge curve should take into account the discharge characteristics of both the principal spillway and the emergency spillway.

*NOTE: The location of structural **storm water** controls is very important as it relates to the effectiveness of these facilities to control downstream impacts. In addition, multiple storage facilities located in the same **drainage** basin will affect the timing of the **runoff** through the conveyance system, which could decrease or increase flood peaks in different downstream locations. Therefore, a downstream peak flow analysis should be performed as part of the storage facility design process.*

In multi-purpose multi-stage facilities such as **storm water** ponds, the design of storage must be integrated with the overall design for water quality treatment objectives. See Chapter 4.0 for further guidance and criteria for the design of structural **storm water** controls.

3.4.1 Design Procedures

A general procedure in order to design storage facilities is presented below:

Step 1: Compute the inflow **hydrographs** for **runoff** from each of the design storms using the hydrologic methods outlined in Section 2.4. Calculate the allowable discharges for each of the design storms. See **Critical Storm** Method in Section 3.4.2.

Step 2: Perform preliminary calculations to approximate detention storage requirements for the **hydrographs** from Step 1. See Sections 3.4.3 or 3.4.4.

Step 3: Determine the physical dimensions necessary to hold the estimated volume from Step 2, including freeboard. Locate and grade the proposed **storm water** facility using contours. Determine the stage-storage curve using the methods described in Section 3.4.5, or other acceptable methods – ie. Conical, to compute the incremental volume between pond contours. The incremental volumes are then summed to create a volume rating table of cumulative pond volumes.

Step 4: Select the type of outlet and size the outlet structure. Determine the stage-discharge curve for chosen outlet using the methods described in Section 3.4.6.

Step 5: Perform routing calculations using inflow **hydrographs** from Step 1 to check the preliminary design using a storage routing computer model. If the routed post-development peak discharges exceed the allowable development peak discharges, then revise the available storage volume, outlet device, etc., and return to Step 3.

Step 6: Evaluate the downstream effects of detention outflows to ensure that the routed **hydrograph** does not cause downstream flooding problems.

Step 7: Evaluate the control structure outlet velocity and provide **channel** and bank **stabilization** if the velocity will cause **erosion** problems downstream.

3.4.2 Critical Storm Method

Where runoff for proposed development and redevelopment sites can be calculated using an S.C.S. method, the allowable discharges shall be determined using the critical storm method.

When the time of concentration is less than 6 minutes for either the pre- or post-developed conditions, i.e., small buildings, expanded parking lots, building additions, etc., the allowable discharges and required storage volume shall be determined using the method in Section 3.4.3. However, the post developed runoff shall never be greater than the pre-developed.

The allowable discharges from proposed development and redevelopment sites shall be designed using the critical storm method. The post-construction **storm water** control methods chosen shall meet the following criteria:

1. The peak discharge rate of **runoff** from the **critical storm** and all more frequent storms occurring under post-development conditions does not exceed the peak discharge rate of **runoff** from a two (2)-year frequency, 24-hour storm occurring on the same **development drainage area** under pre-development conditions. The peak discharge rate of **runoff** from the one (1)-year storm post-developed conditions shall not exceed the one (1)-year storm pre-developed conditions.

2. Storms of less frequent occurrence (longer return periods) than the **critical storm** up to and including the 100-year storm have peak **runoff** discharge rates no greater than the peak **runoff** rates of the pre-developed 10 year storm.

3. The **critical storm** for a specific **development drainage area** is determined as follows:

   Step 1: Use SCS TR-55 or other appropriate and approved hydrologic simulation model to determine the total volume (**acre**-feet) of **runoff** from a two (2)-year, 24-hour storm occurring on the

development drainage area before and after development. Include clearly in your calculations the **lot** coverage assumptions used for full build out of the proposed condition. Curve numbers for pre-developed or improvements or expansion to a developed condition must reflect the average type of land use over the past 10 years and not only the current land use. *(To account for unknown future cosmetic improvements to a construction site, an assumption of an **impervious** surface such as asphalt or concrete must be utilized for all parking areas or driveways, even if stone/gravel is to be utilized in construction.)*

For sites which are currently developed and are scheduled to be re-developed, the pre-developed condition shall be defined to be 100% of the site as grassland for critical storm and volume storage calculations.

Step 2: From the volumes determined in step 1 above, determine the percent increase in volume of **runoff** due to development. Using this percentage, select the 24 hour **critical storm** from the following table:

TABLE 3-1:
Critical Storm Determination Table

IF THE PERCENTAGE OF INCREASE IN VOLUME OF RUNOFF IS:		THE CRITICAL STORM WILL BE:
EQUAL TO OR GREATER THAN:	**LESS THAN:**	
	10	1 year
10	20	2 year
20	50	5 year
50	100	10 year
100	250	25 year
250	500	50 year
500		100 year

For example, if the percent increase between the pre-development and post-development **runoff** volume for a 2 year storm is 35%, the **critical storm** is a 5-year storm. The peak discharge rate of **runoff** for all storms up to this frequency shall be controlled so as not to exceed the peak discharge rate from the 2-year frequency storm under pre-development conditions in the **development drainage area**. The post-development **runoff** from all less frequent storms, up to and including the 100-year storm, need only be controlled to meet the pre-development peak discharge rate for the 10 year storm.

In no case shall the post developed runoff exceed the pre-developed runoff condition for an equivalent storm event.

3.4.3 Storage Volume Requirements for non-S.C.S. Method Projects

When development sites are limited from being evaluated using S.C.S. Methods (Tc < 6 min.), the method described here shall be used to calculate the required storage volume. This method uses the rational method to estimate storage and is adequate for the final design of small detention basins and underground detention.

3.4.3.1 Methodology

Step 1: Complete Site Data

Area = “A” = ____________________ Acres

Time of Concentration = ____________ Minutes

Existing Land Use = _____________

Proposed Land Use = ____________ @ “C” = _____ (TABLE 2-1)

Rainfall Frequency __________ years

S.C.S. Hydrologic Soil Group ________

Step 2: Determine Impervious Factor (P_w)

P_w = (5) / (3) = ______ **(FIGURE 3-4)**

FIGURE 3-4: Impervious Factor Worksheet

(1) Land Use	(2) Run-off Coefficient "C"	(3) Area (acres) "A"	(4) Impervious Factor "P"	(5) Weighted "P_w" (3)x(4)
Business-Downtown	0.95		0.95	
Business-Neighborhood	0.70		0.70	
Res. 12,000-25,000 S.F.	0.50		0.42	
Res. 25,000-and over	0.40		0.30	
Apartment	0.70		0.70	
Industrial - Light	0.80		0.80	
Industrial - Heavy	0.90		0.90	
Parks,Cemeteries	0.25		0.07	
Playgrounds	0.35		0.13	
Railroad Yards	0.35		0.40	
Unimproved	0.30		0.02	
Shopping Center	0.90		0.90	
Pave-Asph & Conc.	0.95		1.00	
Pave – Brick	0.85		1.00	
Roofs	0.95		0.90	
Lawns	0.35		0.00	
Totals			**A x P =**	

Step 3: **Determine Infiltration Rate (F)**

F = ______ (in/hr) **(TABLE 3-2)**

TABLE 3-2: Infiltration Rates	
SCS Hydrologic Soil Group	Infiltration (in/hr)
A	1.0
B	0.6
C	0.5
D	0.5

Step 3: **Determine Allowable Discharge Rate (D)**

D = ______ (cfs/acre) **(TABLE 3-3)**

TABLE 3-3: Allowable Discharge Rates for Detention Ponds (cfs/acre)			
	SOIL GROUP		
RAINFALL FREQUENCY	A	B	C & D
2-year	0.02	0.04	0.06
5-year	0.07	0.13	0.17
10-year	0.13	0.23	0.30
25-year	0.24	0.41	0.52
100-year	0.50	0.85	1.00

Step 4: **Complete Design Spreadsheet (Figure 3-5)**

FIGURE 3-5: Small Detention Pond Design Spreadsheet

T	ΔT	I	(1) Q_y__	(2) R_y __	(3) V i	(4) T_E	(5) Vo	* Storage Required
Min.	$T - T_c$ Min	In. Hr.	__ x I C.F.S.	I - ___ In./Hr.	__R_y T Cu. Ft.	V_i - ΔT 30 Q__y	__T_E Cu. Ft.	V_i – Vo Cu. Ft.
10								
15								
20								
30								
40								
50								
60								
70								
80								
90								
100								
110								
120								

A blank, full-size Figure 3-5 is included in the Appendix.

Column (1): **PEAK INFLOW RATE:**

Q_y___ = C x I x A = ________ I x ________ = ________ I (cfs)

Column (2): **RUN–OFF RATE:**

R = (I x P) + (1 - P) x (I - F) = ______ (in/hr)

Column (3): **TOTAL INFLOW VOLUME:**

V_i = 60.5 x R x A x T = _____ R x T (CF)

Column (4): **END OF RUNOFF TIME:**

$$Te = \frac{V_T}{30 \times Q} - \Delta T \qquad \text{(min.)}$$

Column (5): **TOTAL DISCHARGE VOLUME DURING RESERVOIR FILL PERIOD:**

V_o = D x (Te / 2) x 60 (CF)

* Largest storage volume determined is the design volume

3.4.3.2 Example

Given:

Area = “A” = 1.0 Acres
Time of Concentration = 5 Minutes
Existing Land Use = Lawn
Proposed Land Use = Roof @ “C” = 0.95 (From Table 2-1)
Rainfall Frequency 10 years
S.C.S. Hydrologic Soil Group = D

Determine:

F = 0.5 in/hr (From Table 3-2)

D = 0.30 cfs/acre (From Table 3-3)

P = 0.90 (From Figure 3-4)

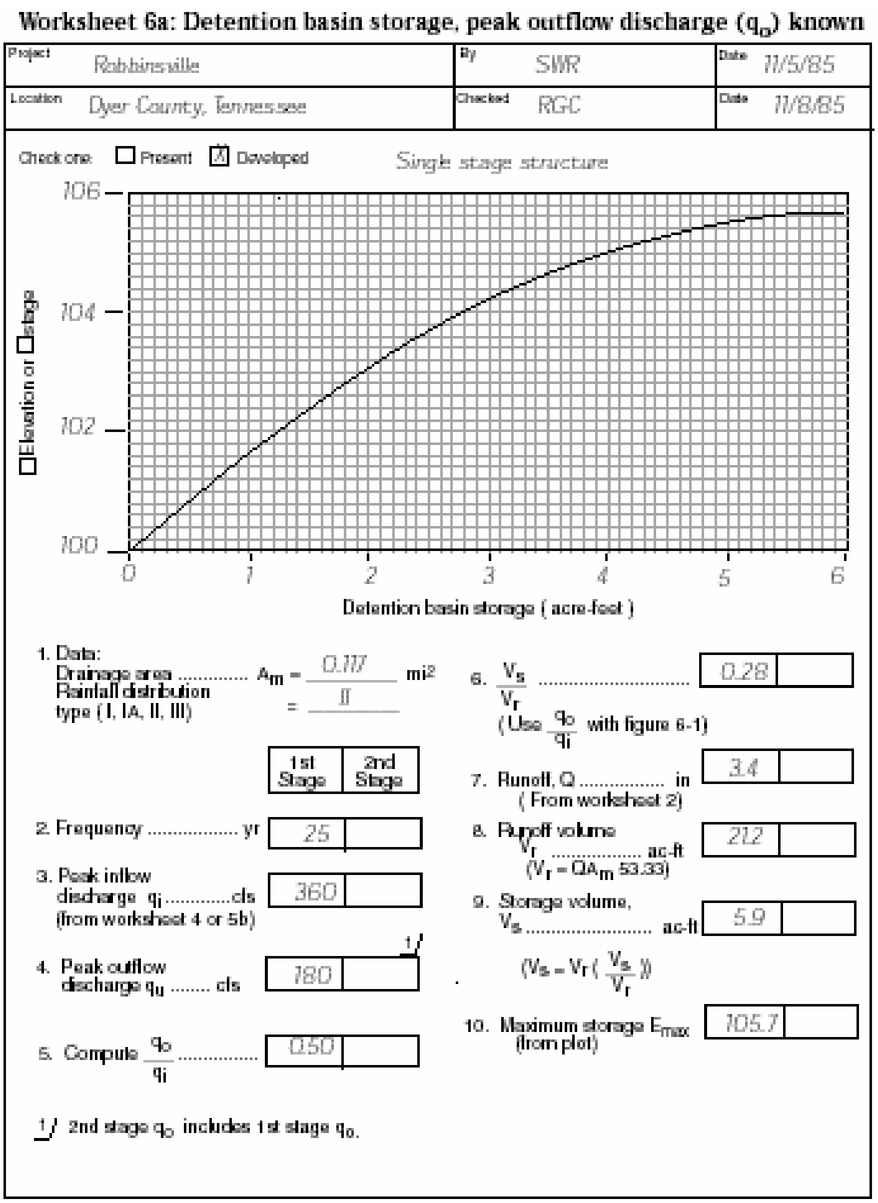
Complete the Table (Example):

T	ΔT	I	(1) Q_y___	(2) R_y ___	(3) V_i	(4) T_E	(5) V_o	* Storage Required
Min.	Min	In/Hr.	C.F.S.	In./Hr.	Cu. Ft.		Cu. Ft.	Cu. Ft.
10	5	4.78	4.54	4.73	2862	16.0	144	2718
15	10	3.92	3.72	3.87	3512	21.5	193	3319
20	15	3.52	3.34	3.47	4199	26.9	242	3957
30	25	2.72	2.58	2.67	4846	37.6	338	4508
40	35	2.39	2.27	2.34	5663	48.2	433	5229
50	45	2.06	1.96	2.01	6080	58.4	526	5555
60	55	1.73	1.64	1.68	6098	69.0	621	5478
70	65	1.61	1.53	1.56	6607	78.9	710	5896
80	75	1.49	1.42	1.44	6970	88.6	797	6172
90	85	1.37	1.30	1.32	7187	99.3	894	**6294**
100	95	1.25	1.19	1.20	7260	108.4	975	6285
110	105	1.13	1.07	1.08	7187	118.9	1070	6117
120	115	1.01	0.96	0.96	6970	127.0	1143	5827

*The required storage volume for this example is 6,294 Cu. Ft. Please note that the user is instructed to complete this table for all storm events to determine largest required storage volume.

3.4.4 Estimate Storage Requirements using S.C.S. Methods

When using S.C.S. methods to calculate runoff the necessary storage volume can be estimated using Worksheet 6a. The following is a completed example worksheet. A blank Worksheet 6a, taken from TR-55, Second Edition, June 1986, is included in the Appendix.


Worksheet 6a: Detention basin storage, peak outflow discharge (q_o) known

Project: Robbinsville	By: SWR	Date: 11/5/85
Location: Dyer County, Tennessee	Checked: RGC	Date: 11/8/85

Check one: ☐ Present ☒ Developed — Single stage structure

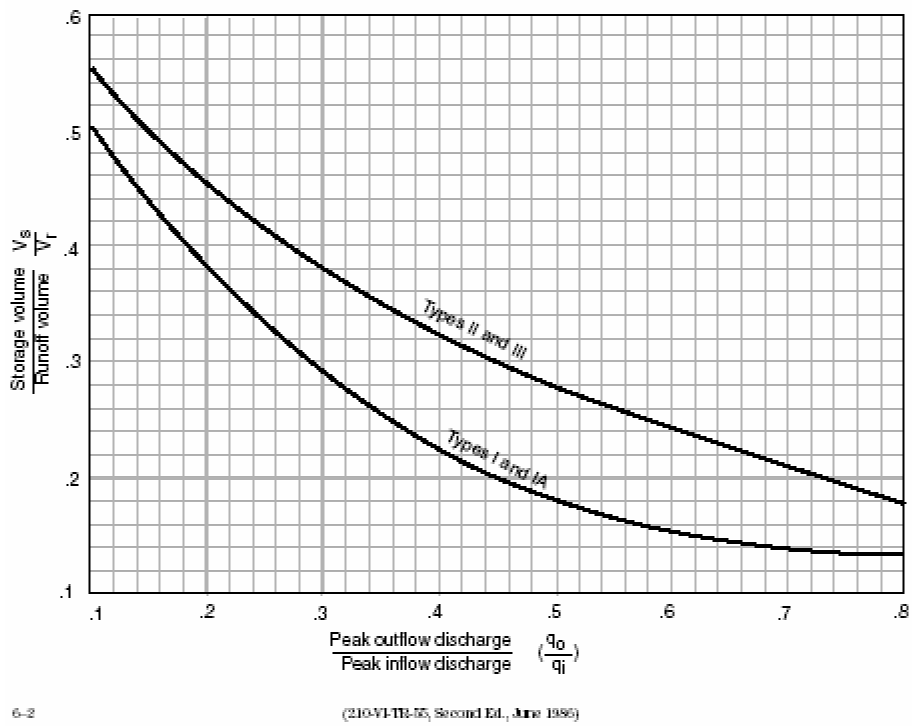
1. Data:
   Drainage area .... A_m = 0.117 mi²
   Rainfall distribution type (I, IA, II, III) = II

	1st Stage	2nd Stage
2. Frequency .... yr	25	
3. Peak inflow discharge q_i .... cfs (from worksheet 4 or 5b)	360	
4. Peak outflow discharge q_o .... cfs [1/]	180	
5. Compute $\frac{q_o}{q_i}$	0.50	
6. $\frac{V_s}{V_r}$ .... (Use $\frac{q_o}{q_i}$ with figure 6-1)	0.28	
7. Runoff, Q .... in (From worksheet 2)	3.4	
8. Runoff volume V_r .... ac-ft ($V_r = QA_m$ 53.33)	2.12	
9. Storage volume, V_s .... ac-ft ($V_s = V_r(\frac{V_s}{V_r})$)	5.9	
10. Maximum storage E_{max} (from plot)	105.7	

1/ 2nd stage q_o includes 1st stage q_o.

Calculation 6 shall be determined by using the following figure:

FIGURE 3-6: Approximate detention basin routing graph



3.4.5 Stage-STORAGE Calculations

For retention/detention, basins with vertical sides such as tanks and vaults, the storage volume is simply the bottom surface area times the height. For basins with graded (2H:1V, 3H:1V, etc.) side slopes or an irregular shape, the stored volume can be computed by the following procedure. Figure 3-7 is a stage-storage computation worksheet, a copy of which is included in the Appendix.

Note: Other methods for computing basin volumes are available, such as the Conic Method for Reservoir Volumes, but they are not presented here.

Step 1: Planimeter or otherwise compute the area enclosed by each contour and enter the measured value into Columns 1 and 2 of Figure 3-7. The invert of the lowest control orifice represents zero storage. This will correspond to the bottom of the facility for extended-detention or detention facilities, or the permanent pool elevation for retention basins.

Step 2: Convert the planimetered area (often in square inches) to units of square feet in Column 3 of Figure 3-7.

Step 3: Calculate the average area between each contour.

The average area between two contours is computed by adding the area planimetered for the first elevation, column 3, to the area planimetered for the second elevation, also Column 3, and then dividing their sum by 2. This average is then written in Column 4 of Figure 3-7.

This procedure is repeated to calculate the average area found between any two consecutive contours.

Step 4: Calculate the *volume* between each contour by multiplying the average area from step 3 (Column 4) by the contour interval and placing this product in Column 6. From Figure 3-7:

This procedure is repeated for each measured contour interval.

FIGURE 3-7: Stage Storage Worksheet

PROJECT: ______________________ SHEET _____ of _____

COUNTY: __________ COMPUTED BY: __________ DATE: __________

DESCRIPTION: ______________________

ATTACH COPY OF TOPO: SCALE – 1"=_______ *ft.*

1	2	3	4	5	6	7	8
ELEV.	AREA (in^2)	AREA (ft^2)	AVG. AREA (ft^2)	INTERVAL	VOL. (ft^3)	TOTAL VOLUME (ft^3)	($ac. ft.$)

Figure 3-8 is an example Stage-storage curve used to determine required storage.

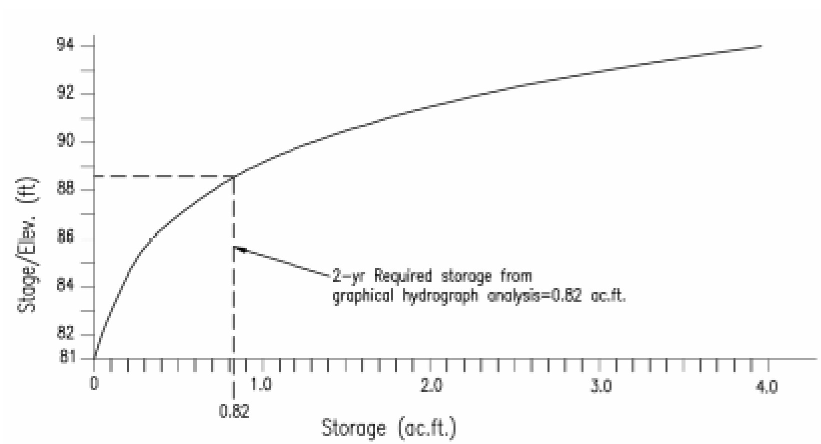


FIGURE 3-8: Stage vs. Storage Curve, Example

3.4.6 Stage-DISCHARGE Calculations

A principal spillway system that controls the rate of discharge from a **storm water** facility will often use a multi-stage riser for the outlet structure.

A multi-stage riser is a structure that incorporates separate openings or devices at different elevations to control the rate of discharge from a **storm water** basin during multiple design storms. Permanent multi-stage risers are typically constructed of modified pre-cast catch basins or manholes. The geometry of risers will vary from basin to basin.

In a **storm water management** basin design, the multi-stage riser is of utmost importance since it controls the design water surface elevations. In designing the multi-stage riser, many iterative routings are usually required to arrive at a minimum structure size and storage volume that provides proper control. Each iterative routing requires that the facility's size (*stage-storage* curve) and outlet shape (*stage-discharge table* or *rating curve*) be designed and tested for performance.

The most common types of devices to control discharge are discussed below. These include orifice, weir, inlet box and circular culvert (with inlet control).

1. OUTLET STRUCTURE TYPE - ORIFICE

An **orifice** should be provided to allow for smaller storms to bypass the structure without damage to the detention basin or surrounding area.

The equation for a single orifice is:

$$Q = AC\,(64.4H)^{1/2}$$

Where:

A = Area of orifice (ft^2)
H = Head on orifice as measured to the centerline of the orifice (ft)
C = Orifice coefficient

Table 3-4:
Orifice Coefficients

C	Description
0.66	Use for thin materials where the thickness is equal to or less than the orifice diameter.
0.80	Use when the material is thicker than the orifice diameter.

Source: CALTRANS, Storm Water Quality Handbooks, Project Planning and Design Guide, September 2002.

Due to the increased probability of blockage, the minimum allowable diameter for any orifice in a control structure is 4". *This requirement pertains to the primary spillway of a storm water storage facility only and not to the outlet structure of a water quality pond.* This requirement does not relieve the designer from considering all means to prevent blockage of all sized orifices.

2. OUTLET STRUCTURE TYPE – SHARP CRESTED WEIRS

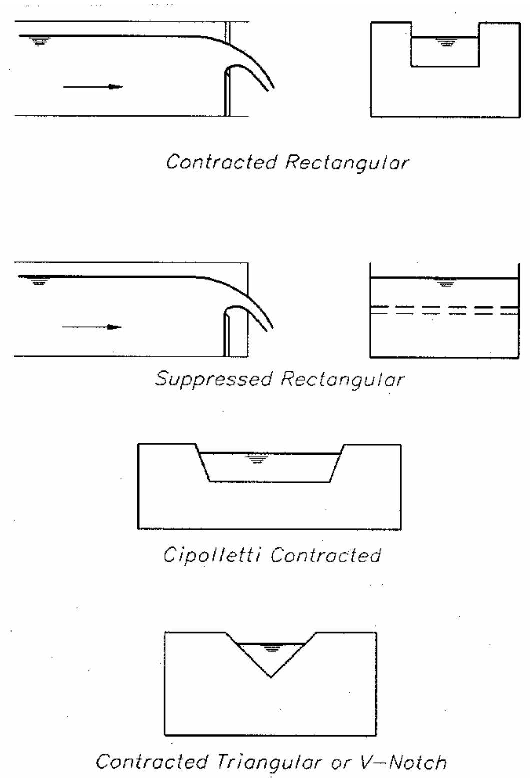


FIGURE 3-9: Weir types

The most common types of sharp crested weirs are shown in Figure 3-9. The equations for each type are described below:

- **Contracted Rectangular Weir**

$$Q = 3.33H^{3/2}(L-0.2H)$$

Where:

Q = discharge in ft^3/s neglecting velocity of approach
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)

- **Suppressed Rectangular Weir**

$$Q = 3.33LH^{3/2}$$

Where:
Q = discharge, (ft^3/s)
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)

- **Contracted Cipolletti Weir (trapezoidal)**

$$Q = 3.367 L H^{3/2}$$

Where:
Q = discharge, (ft^3/s)
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)

- **Fully Contracted Standard 90-Degree V-Notch Weir**

$$Q=2.49H^{2.48}$$

Where:
Q = discharge, (ft^3/s)
H = depth of flow above elevation of crest (ft)

NOTE: The user may choose to use any one of a variety of orifice shapes or geometries. Regardless of the selection, the orifice will initially act as a weir until the top of the orifice is submerged. See Figure 3-10. Therefore, the discharges for the first stages of flow are calculated using the weir equation.

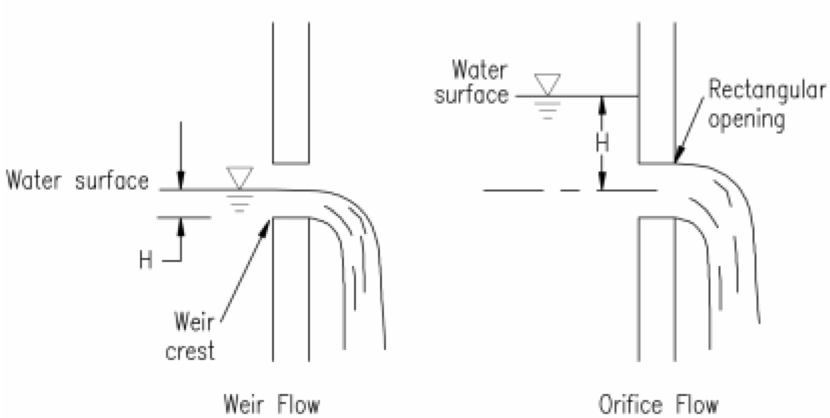


Figure 3-10: Weir and Orifice Flow

3. OUTLET STRUCTURE TYPE - INLET BOX

This structure is an inlet riser with its opening oriented parallel with the water surface. It is typically made from a modified pre-cast catch basin. During low head flow the perimeter of the structure behaves as a weir. As the head increases, the flow transitions from a weir to horizontal orifice condition. The flow can be calculated using the orifice and suppressed rectangular weir equations as described above for the respective condition.

The transition from weir to orifice flow is not instantaneous; rather it occurs during a "zone" of transition. For the purposes of this manual, the transition height shall be considered the head elevation over the structure when the weir flow equals the orifice flow.

4. OUTLET STRUCTURE TYPE – CULVERT

There are various types of culverts for outlet structures, the circular culvert with inlet control being the most widely used. The user is referred to Section 3.2.6 for culvert design.

Full height concrete headwalls, or wingwalls, shall be installed on the inlet end of all culvert structures. Anti-seep collars shall be designed and installed on the length of the culvert through the embankment (See Section 3.4.10).

3.4.7 Hydrograph Routing Procedures and Resources

Of the various methods available to route a flood flow through a detention pond, the **storage-indication method** will be the only one discussed briefly in this manual. If additional information is needed on other routing techniques, it is suggested that the user refer to the SCS's National Engineering Handbook Section 4 Hydrology (reference 49).

The primary idea behind a routing is to determine the impact that the detention pond will have on the inflowing flood peak by using the **continuity equation.** The equation can be thought of as **Inflow** (to the detention basin) minus **outflow** (from the detention basin) equals **change in storage** (in the detention basin). In equation form:

$$I_{ave} + S_1/dt - O_1/2 = S_2/dt + O_2/2$$

where:

- $\mathbf{S_1}$ - is the storage at t1 (the beginning of the routing interval).
- $\mathbf{O_1}$ - is the outflow at t_1
- $\mathbf{S_2}$ - is the storage at t_2 (the end of the routing interval).
- $\mathbf{O_2}$ - is the outflow at t_2.
- $\mathbf{I_{ave}}$ - is the average inflow for the time interval $(I_1 + I_2)/2$.

The following steps can be used to route a flood hydrograph through a detention basin by "hand", using the storage indication method.

Step 1: **Develop stage-storage curve for the detention pond**. This curve can be developed using procedures discussed in Section 3.4.5. The storage units should be consistent with the stage-discharge curve (such as acre-feet or cubic feet).

Step 2: **Develop a rating curve for the outlet structure**. The rating curve can be developed using procedures discussed in Section 3.4.6. The rating curve will show the discharge for a given elevation for the outlet structure. The discharge should be expressed in units that are consistent with the storage volume. Units of acre-feet will result in numbers that are considerably smaller than if cubic feet are used. (One acre-foot = 43560 cubic feet, one cubic foot/second = .083 acre-feet /hour).

Step 3: **Combine the curves developed** in steps 1 & 2 to form a relationship between storage and discharge. The following table is an example of storage volumes and discharges for a range of elevations.

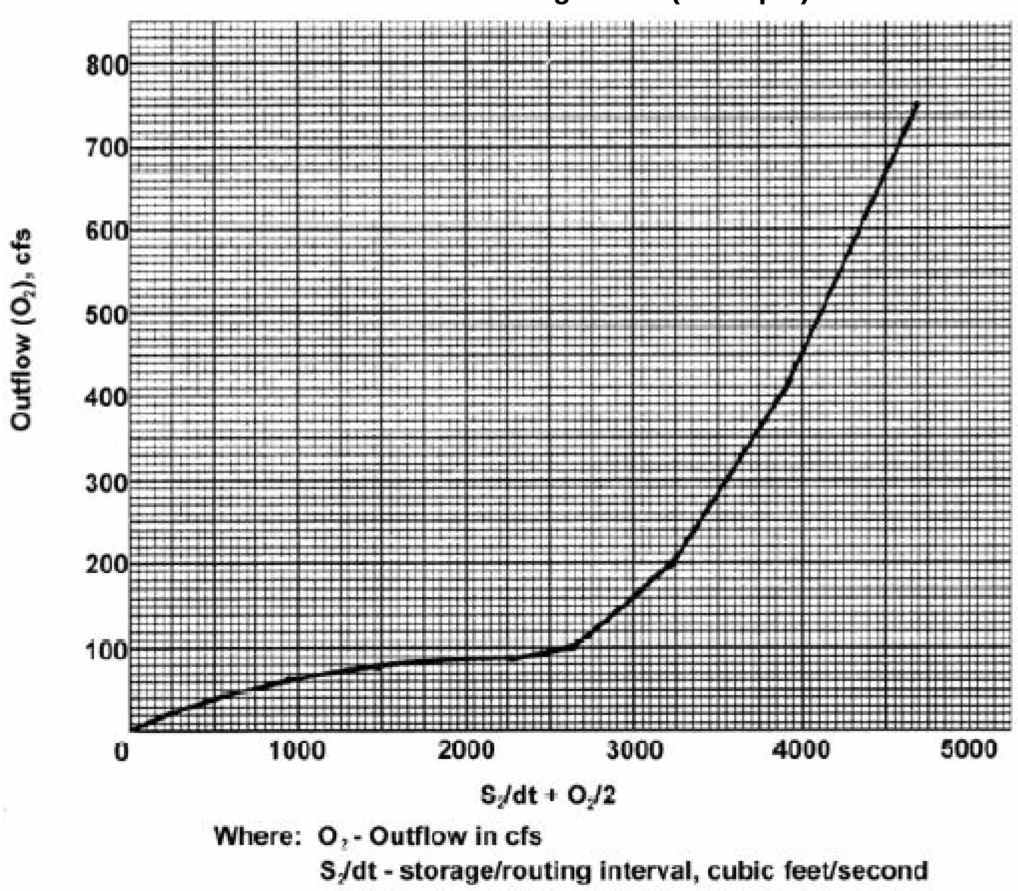
Table 3-5: Storage-Discharge Relationship (Example)

Elevation	Storage	Discharge
	100,000	
feet	cubic feet	cfs
604.3	0.0	0
606.0	8.3	61
607.0	13.1	74
608.0	17.9	87
609.0	23.1	100
610.0	28.3	200
611.0	33.5	420
612.0	38.8	750

Step 4: **Select a routing interval (dt)**. Typically for small watersheds the routing interval will be less than an hour, usually 0.25 hour to 0.5 hour.

Step 5: **Prepare the working curves**, and plot O_2 versus $S_2/dt + O_2/2$ (Figure 3-11). Using the storage-discharge relationship in Table 3-5, an example working curve is developed below:

FIGURE 3-11: Working Curve (Example)



Step 6: **Set-up operations table**. Column 1 contains the time at the selected increment, and column 2 contains the inflow taken from the inflow hydrograph. The average inflow in column 3 is the average of the flow at the current time and the previous time interval. As an example, at a time of 0.50 hrs, the average inflow of 43 cfs is the average between 0.25 hrs (30 cfs) and 0.50 hrs (55 cfs).

TABLE 3-6a: Working Table A (Example)

(1) Time	(2) Inflow	(3) Avg. Inflow	(4) $S_2/dt=O_2$	(5) O_2
(hrs)	(cfs)	(cfs)	(cfs)	(cfs)
0.00	0	0		
0.25	30	15		
0.50	55	43		
0.75	80	68		
1.00	100	90		
1.25	138	119		
1.50	190	164		
1.75	380	285		
2.00	610	495		
2.25	785	698		
2.50	850	818		
2.75	730	790		
3.00	620	676		
3.25	485	552		
3.50	440	463		
3.75	395	418		
4.00	370	383		
4.25	335	353		
4.50	315	325		

The last two columns (4 & 5) will be completed during the routing.

Step 7: **Route the inflow through the detention pond**.

The routing would include:

a) Determine inflow, storage, and outflow for initial conditions. In many cases, the initial inflow, outflow, and storage will be 0.

b) Subtract outflow (column 5) from column 4 and add average inflow (column 3) for the next time increment. The computed value is placed in column 4 for the next time increment. (In the table below under initial conditions, columns 4 and 5 are each 0. At the time of 0.25 hours, the average inflow is 15 cfs. Column 4, at the time of 0.25 hours, is equal to 0 - 0 + 15 = 15). As a further example, at the time of 0.75 hours, column 4 shows a value of 123 cfs; from Figure 3-11, the outflow in column 5 is 11 cfs; the average inflow at time 1.00 hour is 90 cfs. Column 4 at 1.00 hours is 123 - 11 + 90 = 202).

TABLE 3-6b: Working Table B (Example)

(1) Time	(2) Inflow	(3) Avg. Inflow	(4) $S_2/dt=O_2$	(5) O_2
(hrs)	(cfs)	(cfs)	(cfs)	(cfs)
0.00	0	0	0	0
0.25	30	15	15	1
0.50	55	43	57	2
0.75	80	68	123	11
1.00	100	90	*202	

* (123 - 11 + 90)

c) From the plot of $S_2/dt + O_2$ vs. O_2, determine the outflow O_2, for the computed value of $S_2/dt + O_2$. As examples, from Figure 3-11, when $S_2/dt + O_2 = 123$, the outflow is 11 cfs; when $S_2/dt + O_2 = 202$, $O_2 = 19$ cfs.

TABLE 3-6c: Working Table C (Example)

(1) Time	(2) Inflow	(3) Avg. Inflow	(4) $S_2/dt=O_2$	(5) O_2
(hrs)	(cfs)	(cfs)	(cfs)	(cfs)
0.00	0	0	0	0
0.25	30	15	15	1
0.50	55	43	57	2
0.75	80	68	123	11
1.00	100	90	202	19
1.25	138	119	302	27
1.50	190	164	439	33
1.75	380	285	724	50
2.00	610	495	1169	70
2.25	785	698	1797	81
2.50	**850**	818	2534	95
2.75	730	790	3229	200
3.00	620	675	3704	343
3.25	485	552	3913	413
3.50	440	463	3963	**433**
3.75	395	418	3948	422
4.00	370	383	3809	408
4.25	335	353	3854	392

d) Repeat the steps until routing is complete.

The results of the partial routing indicate that the peak inflow has been reduced from a discharge of 850 cfs, to an outflow of 433 cfs. From the outlet rating curve (Table 3-5) the maximum stage on the detention pond is 611.1 feet.

If required, the routing could be continued until the entire outflow hydrograph is developed.

Hand routing of **hydrographs** through storage facilities is very time consuming, especially when several different designs are evaluated. It is encouraged for the designer to use one of the many available computer programs to perform **hydrograph** routing and modeling of storage facilities. The following are sources for **hydrograph** routing computer programs:

- Haestad Methods "PondPack"

  http://www.haestad.com/software/pondpack

- HydroCAD

  http://www.hydrocad.net

3.4.8 Emergency Spillway Design

An emergency spillway must be included to handle storms greater than the 100-year storm . An emergency spillway typically consists of a wide channel cut over the embankment to provide a flow path for a major storm event. The spillway must be designed and installed to protect against erosion problems.

The banks should be constructed such that a minimum of one (1) foot of freeboard is above the emergency spillway.

3.4.9 Berm Embankment/Slope Stabilization

- Pond embankments are exempt from the ODNR Dam classification if the following are met; 1) is 6 feet or less in height regardless of total storage, 2) less than 10 feet in height with not more than 50 acre-feet of storage, or 3) not more than 15 acre-feet of total storage regardless of height. If the embankment does not meet these criteria, the design is subject to review and approval from ODNR.

  NOTE: Height of dam is defined as the vertical dimension as measured from the natural streambed at the downstream toe of a dam to the low point along the top of the dam.

- Pond embankments over six (6) feet shall require design by a Geotechnical or Civil engineer licensed in the State of Ohio. For berm embankments of 6 feet or less (including 1 foot freeboard), minimum top width shall be 6 feet or as recommended by the geotechnical or civil engineer.

- Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) free of loose surface soil materials, roots and other organic debris.

- Exposed earth on the side slopes and bottom should be sodded or seeded with the appropriate seed mixture as soon as is practicable. If necessary, geotextile or matting may be used to stabilize slopes while seeding and sodding become established.

3.4.10 Anti-Seep Collar Design

An anti-seep collar shall be installed on conduits through earth fills. The following criteria apply to anti-seep collars:

A. Spacing between adjacent collars shall be between 5-14 times the vertical projection of each collar.

B. Place all collars within the saturation zone.

C. All anti-seep collars and their connections shall be watertight.

3.4.10.1 Methodology

The assumed normal saturation zone (phreatic line) shall be determined by projecting a line at a slope of 4:1 from the point where the normal water depth (riser grate) touches the upstream slope of the embankment to a point where this line intersects the invert of the culvert. The area below this projected line is assumed to be within the saturated zone.

The length of the saturated zone (Ls) must first be determined). The nomograph below should then be used to determine the number and size of collars.

$L_S = y\ (z + 4)\ [1 + (\text{pipe slope}/(0.25 - \text{pipe slope}))]$

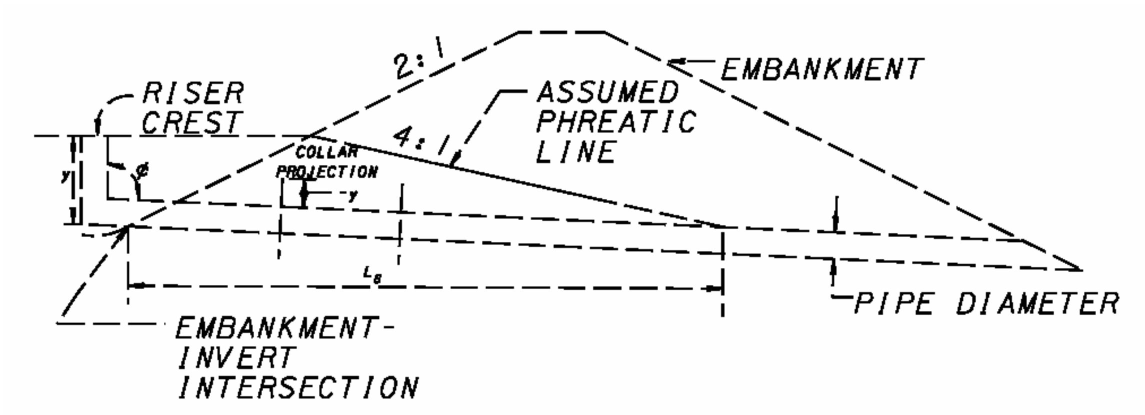
Where: L_S = length of pipe in the saturated zone (ft.)

y = distance in feet from upstream invert of pipe to highest normal water level expected to occur during the life of the structure, usually the top of the riser.

z = slope of upstream embankment as a ratio of z ft. horizontal to 1 ft., vertical.

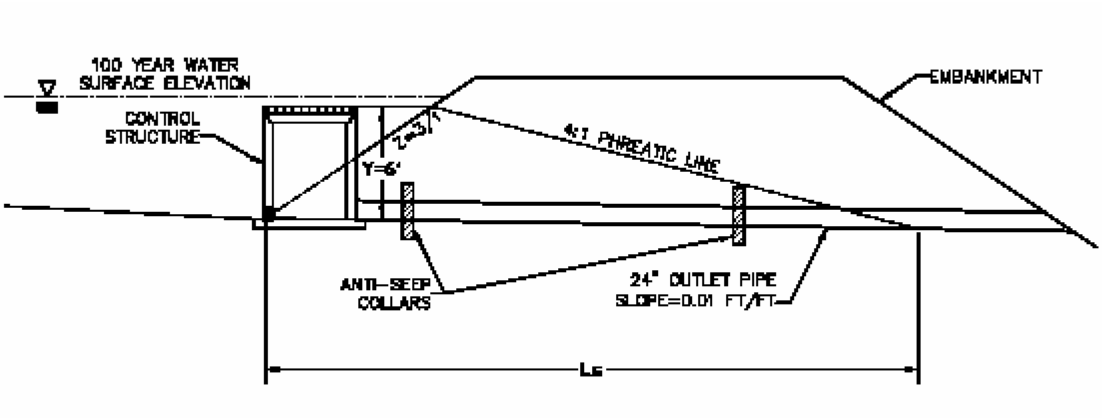
Pipe slope = slope of pipe in feet per foot.

FIGURE 3-12: Anti-Seep Collar Schematic



3.4.10.2 Example

FIGURE 3-13: Anti-Seep Collar Design (Example)



Step 1: Determine Saturation Length (Ls):

Ls = Y(Z+4)[1+(PIPE SLOPE/(.25-PIPE SLOPE))]

Given: Y = 6'
Z = 3/1
Pipe Slope = 0.01

Ls = 6'(3+4)[1+(0.01/(.25-0.01))]
Ls = 6'(7)[1+0.04166]
Ls = 43.75'

Step 2: Determine Size of Collars:

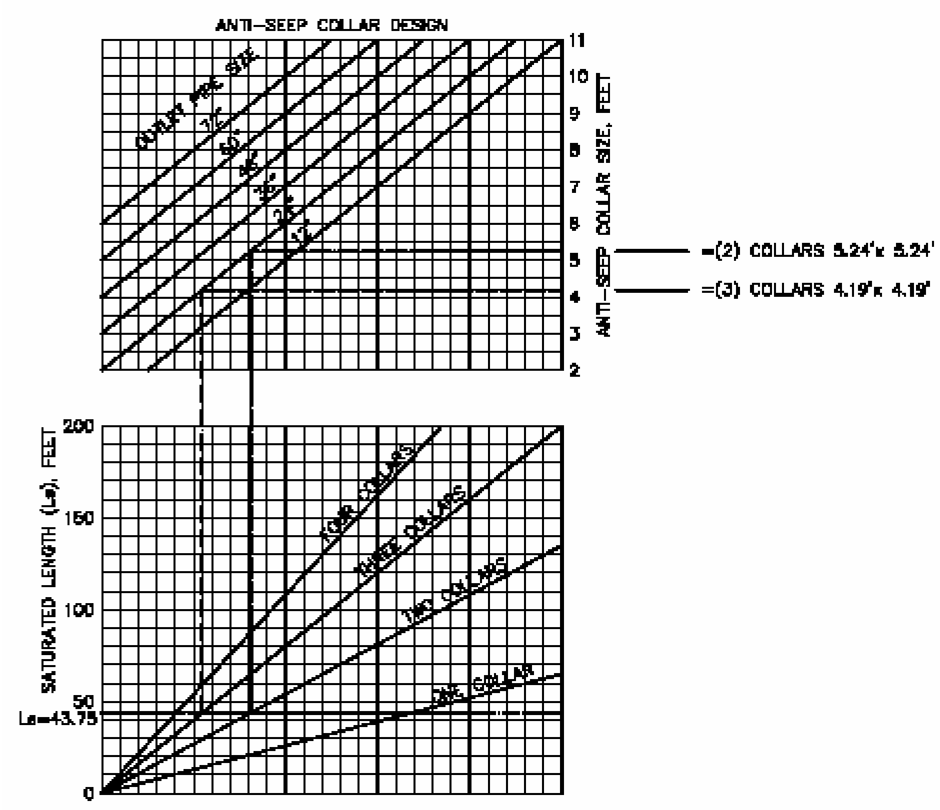
Beginning from the lower graph with an Ls = 43.75'

- 1-4 collars may be used, however spacing may limit the amount.

Assuming 2 collars – project up to the 24" pipe at a collar size = 5.24'x5.24'

Assuming 3 collars – project up to the 24" pipe at a collar size = 4.19'x4.19'

FIGURE 3-14: Anti-Seep Collar Graph



A blank copy of the anti-seep collar graph is included in the appendix.

Step 3: Spacing of the Collars:

- Note that the collars must be fully in the saturated zone.
- Spacing can vary from 5-14 times the vertical projection of the collars. The vertical projection is defined as the height of the collars above the outlet pipe.

The 5.24' collars have a vertical projection above the 24" outlet pipe = (5.24'-2')/2 = 1.62'. Therefore, the collars need to be spaced (1.62'*5) up to (1.62'*14) feet apart, or 8.1' to 22.68', respectively.

The 4.19' collars have a vertical projection above the 24" outlet pipe = (4.19'-2')/2 = 1.10'. Therefore, the collars need to be spaced (1.10'*5) up to (1.10'*14) feet apart, or 5.5' to 15.4', respectively.

- The length of the saturation zone may limit the number of collars that can fit based upon their minimum spacing requirements.

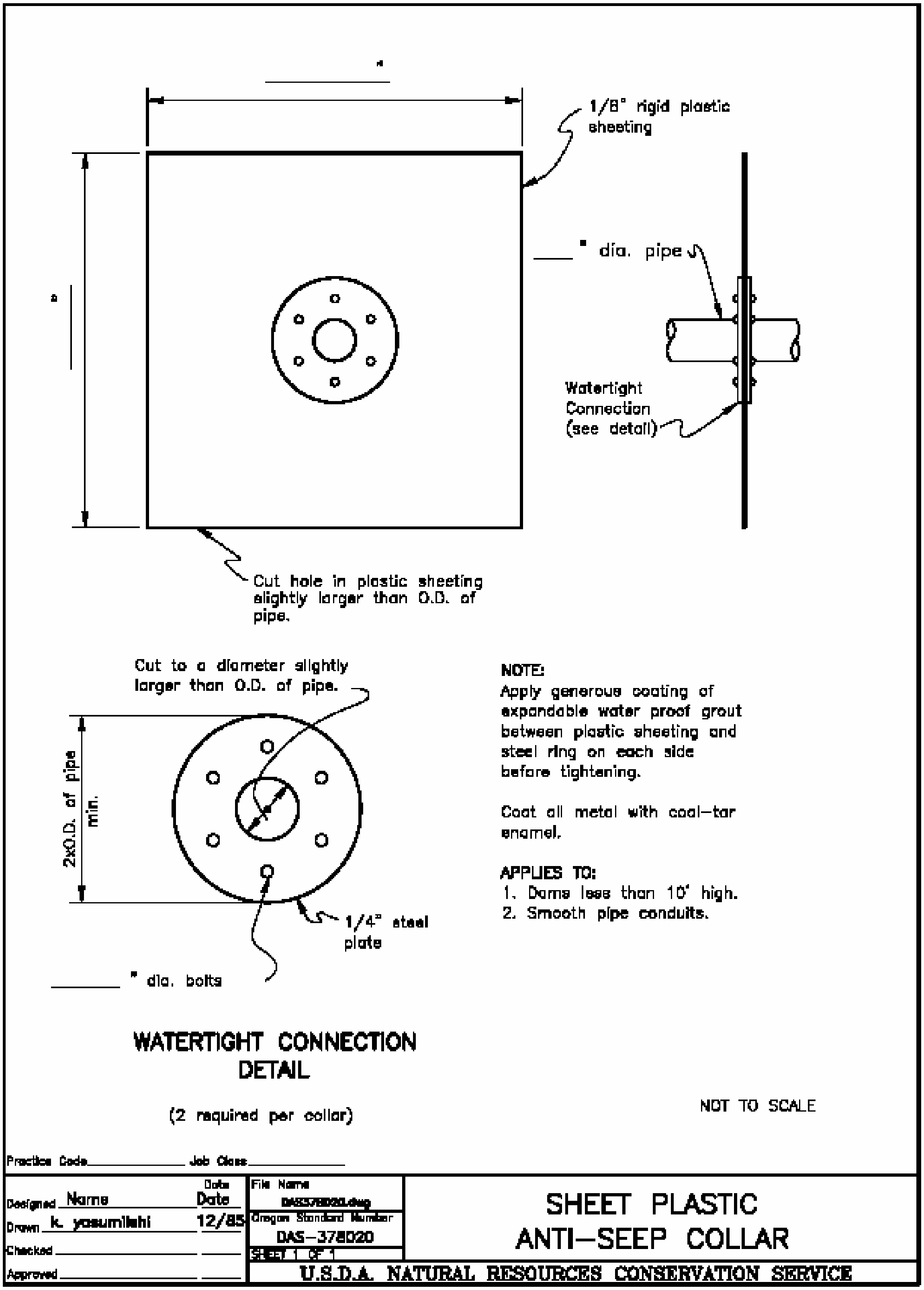
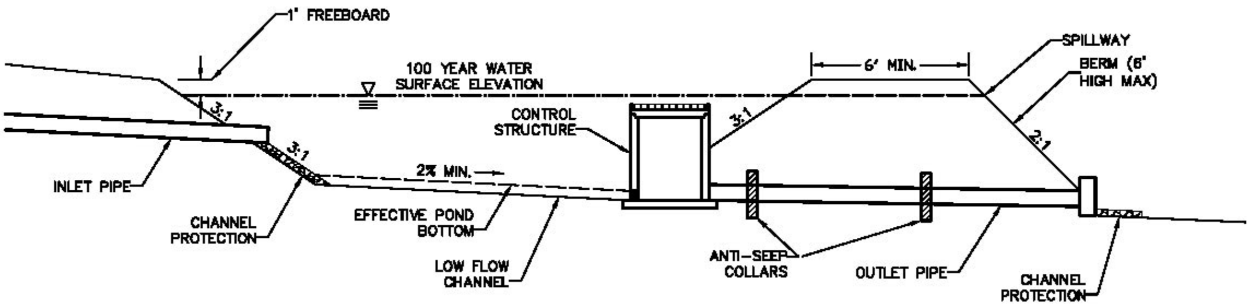


FIGURE 3-15: Anti-Seep Collar Detail

FIGURE 3-16: Typical Pond Section



TYPICAL SECTION – DRY DETENTION POND

SECTION 4 POST-CONSTRUCTION STORM WATER MANAGEMENT REQUIREMENTS

4.0 POST-CONSTRUCTION STORM WATER MANAGEMENT REQUIREMENTS

4.1 OVERVIEW

Post-construction **runoff** controls are permanent controls which are intended and shall be designed to increase or maintain a receiving stream's physical, chemical and biological characteristics. In addition, stream functions are maintained and post-construction **storm water** practices shall provide continued management of both quality and quantity facilities.

Detailed drawings and maintenance plans shall be provided for all post-construction **Best Management Practices** (**BMP's**). Maintenance plans shall also be provided by the permittee to the post-construction operator of the site (including homeowner associations). For sites located within a community with a regulated municipal separate storm sewer system (MS4), the permittee, land owner or other entity with legal control over the property shall be required to develop and implement a maintenance plan to comply with local MS4 requirements. The use of innovative and/or emerging **storm water management** post-construction technologies shall be at the discretion of the Mahoning County **Engineer** and could require monitoring to ensure compliance with OEPA's Construction General Permit (CGP) requirements part III, section G.2.e. The Post-Construction portion of the **Storm Water** Pollution Prevention Plan shall include the following required elements:

- Description of post-construction **BMP's** to be installed during construction. Description shall include estimated installation schedule and sequencing plan.
- Rationale for selection shall incorporate anticipated impacts on the **channel** and floodplain, morphology, hydrology and water quality.
- Detailed Post-Construction **BMP** drawings shall be provided.
- **BMP** Maintenance plan- Maintenance plan shall be developed for all **BMPs** selected and presented to post-construction operator.
- Maintenance plan shall include a disposal statement for structural **BMP's**- Ensure pollutants collected within structural **BMP's** are disposed of in accordance with local, state and federal regulations.
- Linear Projects – No net increase in **impervious** areas, no need to comply with the conditions of Part III. G.2.e. of the CGP permit. Linear projects must minimize number of stream crossings and width of disturbance. **Erosion** and **sedimentation** controls are required for all projects with a minimum of 1-**acre** of land disturbance. Linear projects shall be required to document land disturbance area estimates and develop an **erosion**/**sedimentation** control plan.

4.2 Post-Construction Storm Water Control Method

The Mahoning County **Engineer** requires that the increased peak rates and volumes of **storm water runoff** shall be controlled to reduce **sediment** laden pollution from entering public waterways and protect **watercourses** and water bodies from the effects of

erosion caused by accelerated **storm water runoff** from developed or developing areas.

For large construction activities that will disturb five or more **acres** of land or will disturb less than five **acres** but is part of a **larger common plan of development** or sale which will disturb five or more **acres** of a land, the post-construction **storm water** control methods chosen shall meet the following criteria:

1. The peak discharge rate of **runoff** from the **critical storm** and all more frequent storms occurring under post-development conditions does not exceed the peak discharge rate of **runoff** from a two (2)-year frequency, 24-hour storm occurring on the same **development drainage area** under pre-development conditions. The peak discharge rate of **runoff** from the one (1)-year storm post-developed conditions shall not exceed the one (1)-year storm pre-developed conditions.

2. Storms of less frequent occurrence (longer return periods) than the **critical storm** up to the 100-year storm have peak **runoff** discharge rates no greater than the peak **runoff** rates of the pre-developed 10 year storm.

3. The **critical storm** for a specific **development drainage area** is determined as follows:

    a. Use SCS TR-55 or other appropriate and approved hydrologic simulation model to determine the total volume (**acre**-feet) of **runoff** from a two (2)-year, 24-hour storm occurring on the **development drainage area** before and after development. Include clearly in your calculations the **lot** coverage assumptions used for full build out of the proposed condition. Curve numbers for pre-developed or improvements or expansion to a developed condition must reflect the average type of land use over the past 10 years and not only the current land use. *(To account for unknown future cosmetic improvements to a construction site, an assumption of an **impervious** surface such as asphalt or concrete must be utilized for all parking areas or driveways, even if stone/gravel is to be utilized in construction.)*

       For sites which are currently developed and are scheduled to be re-developed, the pre-developed condition shall be defined to be 100% of the site as grassland for critical storm and volume storage calculations.

    b. From the volumes determined in (a) above, determine the percent increase in volume of **runoff** due to development. Using this percentage, select the **critical storm** from Table 4-1:

TABLE 4-1:
Critical Storm Determination Table

IF THE PERCENTAGE OF INCREASE IN VOLUME OF RUNOFF IS:		THE CRITICAL STORM WILL BE:
EQUAL TO OR GREATER THAN:	LESS THAN:	
	10	1 year
10	20	2 year
20	50	5 year
50	100	10 year
100	250	25 year
250	500	50 year
500		100 year

(For example, if the percent increase between the pre-development and post-development **runoff** volume for a 2 year storm is 35%, the **critical storm** is a 5-year storm. The peak discharge rate of **runoff** for all storms up to this frequency shall be controlled so as not to exceed the peak discharge rate from the 2-year frequency storm under pre-development conditions in the **development drainage area**. The post-development **runoff** from all less frequent storms need only be controlled to meet the pre-development peak discharge rate for the 10 year storm.)

In no case shall the post developed runoff exceed the pre-developed runoff condition for an equivalent storm event.

4.3 Post-Construction Design Methodology

The structural **BMP** selected shall be additionally sized for protection of **watercourses** from **erosion** (quantity) and include water quality volumes for controlling **sediment** volumes. The following method is taken directly form the OEPA's construction general permit:

- WQ_v = Volume of **runoff** from a 0.75 inch rain event (Blended average rainfall event).
- WQ_v determined according to one of the two following methods:
-
    - o Through a site hydrologic study approved by the Mahoning County Engineers Office that uses continuous hydrologic simulation and local long-term hourly precipitation records or,
    - o Using the following equation: WQv = C * P * A/12

<u>**Where:**</u>

WQv = **channel** protection and water quality volume in **acre**-feet

C = **runoff** coefficient appropriate for storm less than 1 inch (See Table 4-2)

P = 0.75 inch precipitation depth

A = area draining into the **BMP** in **acres**

TABLE 4-2:
Runoff Coefficients Based on Type of Land Use for (WQv) Calculation

Land Use	Runoff Coefficient (C)
Industrial & Commercial	0.8
High Density Residential (>8 dwellings/acre)	0.5
Medium Density Residential (4 to 8 dwellings/acre)	0.4
Low Density Residential (<4 dwellings/acre)	0.3
Open Space and Recreational Areas	0.2

Where the land use will be mixed, the runoff coefficient should be calculated using a weighted average. For example, if 60% of the contributing drainage area to the storm water treatment structure is Low Density Residential, 30% is High Density Residential, and 10% is Open Space, the runoff coefficient is calculated as follows (0.6)(0.3) + (0.3)(0.5) + (0.1)(0.2) = 0.35

- An additional volume equal to 20 percent of the WQv shall be incorporated into the BMP for sediment storage and/or reduced infiltration capacity during construction.

- BMP's shall be designed such that the drain time is long enough to provide settlement treatment, but short enough to provide storage available for successive rain events as described in Table 4-3 below.

TABLE 4-3:
Target Drawdown (Drain) Times for Structural Post-Construction Treatment Control Practices

Best Management Practice (BMP)	Drain Time of WQv
Infiltration	24 - 48 hours
Vegetated Swale or Filter Strip	24 hours
Extended Detention Basin (Dry Basins)	48 hours
Retention Basins (Wet Basins) *	24 hours
Constructed Wetlands (above permanent pool)	24 hours
Media Filtration, Bio-retention	40 hours

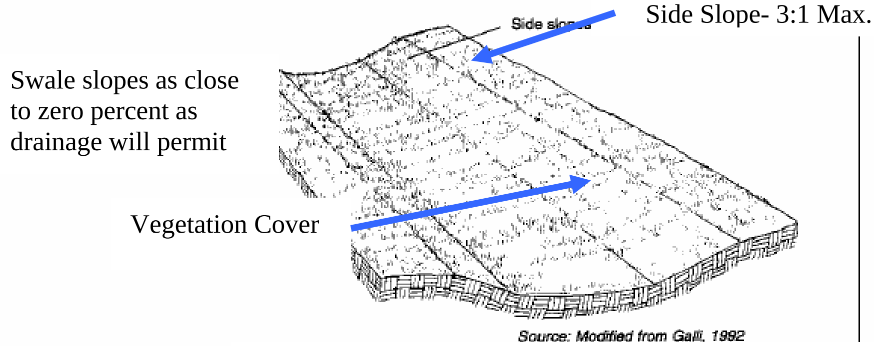
* Provide both a permanent pool and an extended detention volume above the permanent pool, each sized at 0.75 * WQv

4.4 Recommended Post-Construction Best Management Practices

The following post-construction best management practice controls are identified in OEPA's CGP and shall be incorporated in project development and design. OEPA has identified six structural **BMP's** to be considered and incorporated into **storm water management** for site development. The Mahoning County **Engineer** will also consider non-structural practices in combination with these structural practices in reviewing site plans. The Mahoning County **Engineer** requires supporting documentation of non-structural **BMP** estimated pollutant removal information, map of BMP locations on-site, description of **BMP** type, and frequency with which the **BMP** will be performed or maintained. Examples of non-structural BMP's include: site **impervious** area sweeping, natural buffers, creative mowing practice, etc. The six (6) post-construction structural **BMP's** (as presented in the CGP) are addressed below::

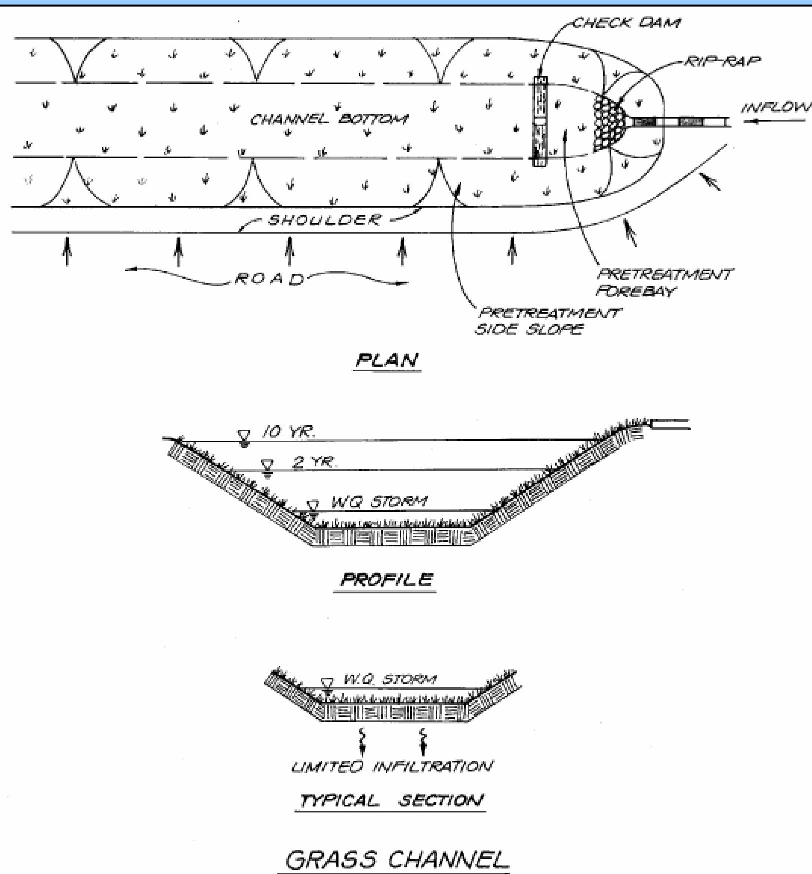
1. **Vegetated Swales and Filter Strips** – General principal is that treatment of **storm water** occurs via the interaction of vegetation with pollutants in the **storm water runoff**, specifically suspended solids. Suggested design considerations include quantity of flow, size of **drainage** area and slopes need to be reviewed prior to selection.

Vegetated Swale Schematic



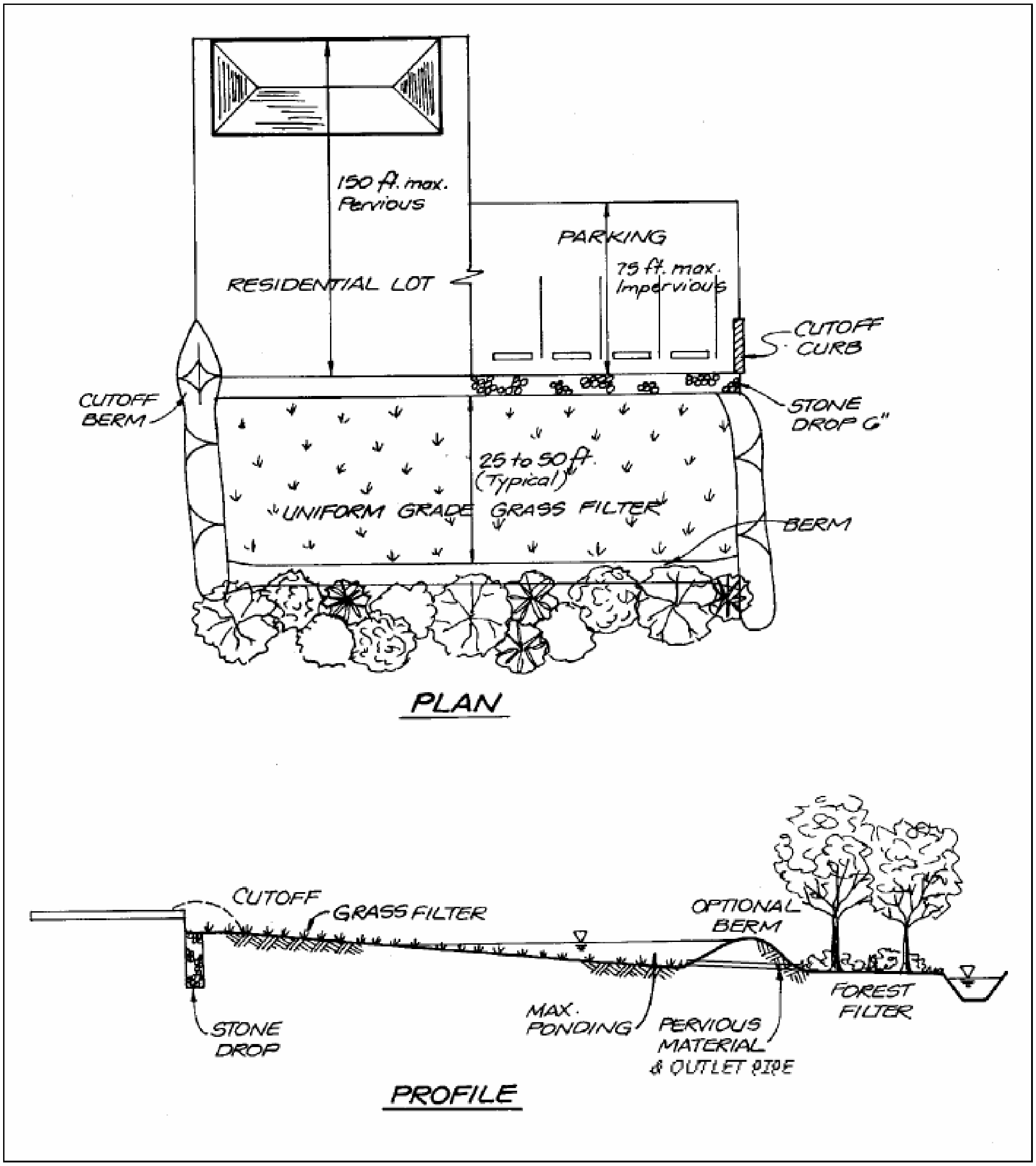
Source: Modified from Georgia Storm Water Manual

Typical Grass Channel



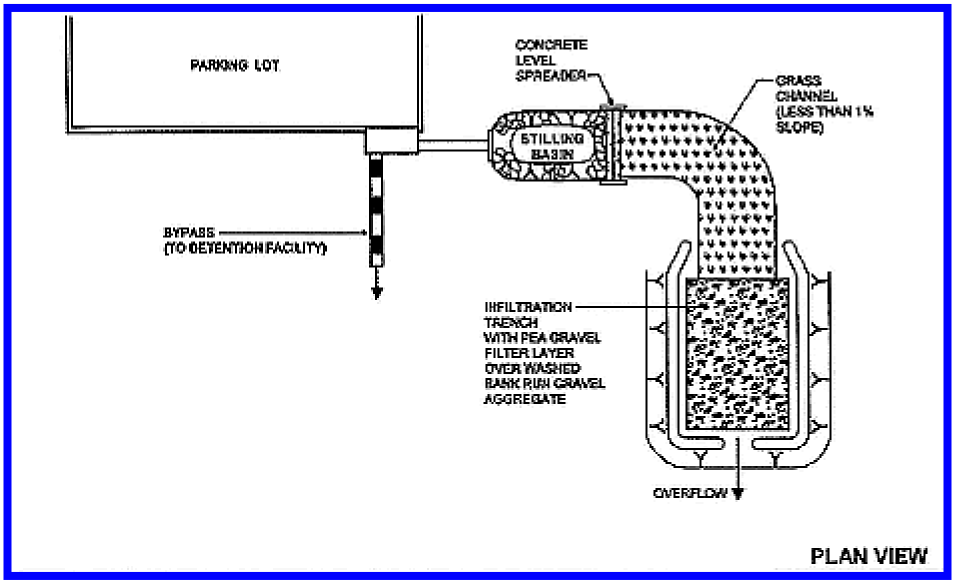
Schematic Grass Channel

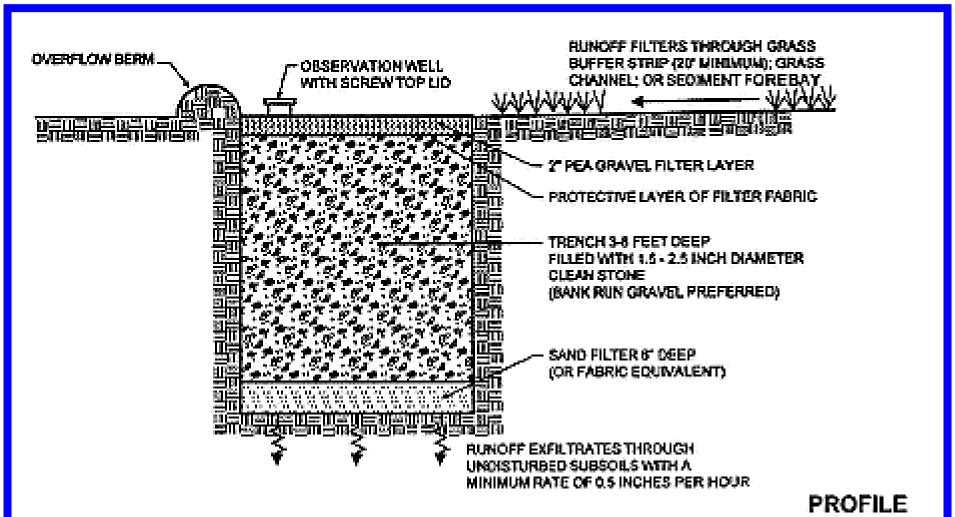
Filter Strip Schematic



Source: State of Georgia Storm Water Manual

2. **Infiltration** – General principal is that treatment occurs through **storm water runoff** interacting with a filtering substrate usually soil, sand or gravel. These could be trench or basin type structures. The captured treated **storm water** is discharged into the ground water rather than surface water. Suggested design considerations include quantity and velocity of **runoff**, slopes, site locations- these **BMP's** potentially require high maintenance and could be expensive to operate.





A schematic of an infiltration trench (Source: MDE, 2000)

3. **Extended Detention Basins (Dry)** – General principal is the treatment occurs when **storm water runoff** is captured during rain events and is slowly released over a period of time. These could be above or below ground type structures. Suggested design considerations include size of **drainage** area will be in sizing of basin, which may impact site layout considerations. Sizing needs to account for both quantity and quality factors.

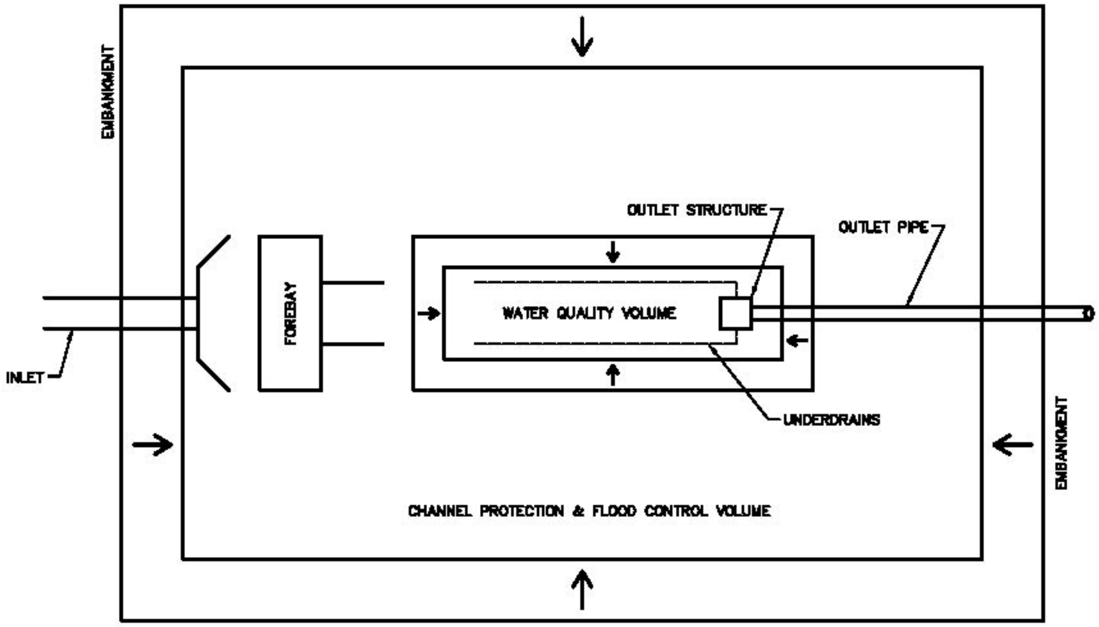
A dry extended detention pond is designed to temporarily detain runoff during storm events

Design Parameters

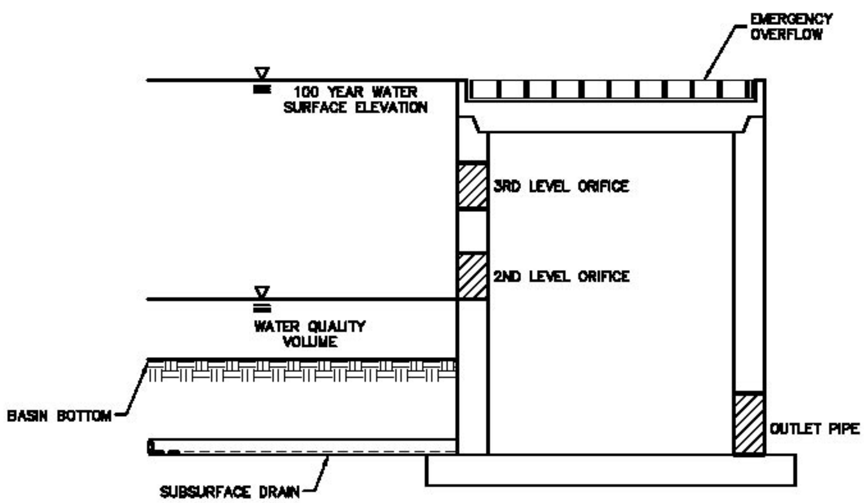
- Groundwater
- Two Stage Design
- Extended Detention Control Device (orifice)
- Low Flow Channel
- Shape (Length:Width)
- Side Slopes
- Pond Buffer
- Benches
- Freeboard
- Outlet Control Structure
- Emergency Spillway
- Inlet Headwalls
- Earthen Dams/Embankments
- Accessibility/Security
- Maintenance – Sediment Removal
- Maintenance Easements

Physical Constraints

- Drainage Area Size
- Elevation difference/fall
- Groundwater consideration
- Soil Types
- Local Climate
- Precipitation volume
- Land Cost

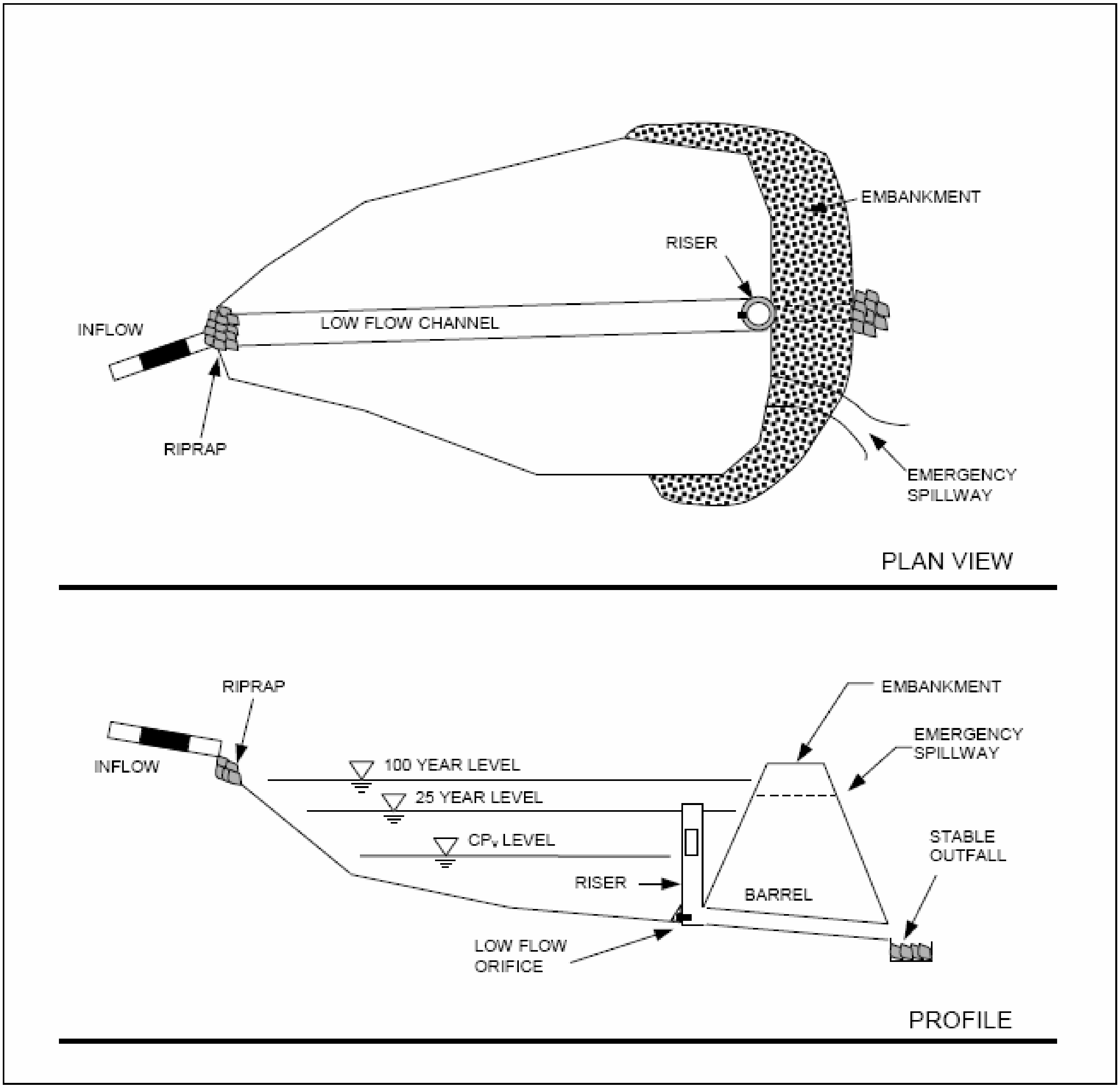


EXAMPLE – EXTENDED DETENTION POND



EXAMPLE – OUTLET STRUCTURE

Schematic – Extended Detention Pond and Outlet Structure



Schematic – Extended Dry Detention Basin

Extended Dry Detention Design Parameters

- Permanent Pool Volume = 1/3 runoff volume of 2-year 24-hour storm
- Detention Basin Geometry:
  - Single cell basins
  - Long, Narrow basins are recommended to reduce short circuiting potential and maximize available treatment area.
  - Length: Width Ratio – Recommended 3:1, if practical 5:1.
  - Placement of inlet and outlet structures should be at the maximum distance practical. Goal to achieve maximum length flowpaths.
  - Side slopes – Interior = 3:1, Exterior = 2:1
  - Bottom Slopes – 2% grade to allow for complete basin drainage.

Berm Embankment/Slope Stabilization

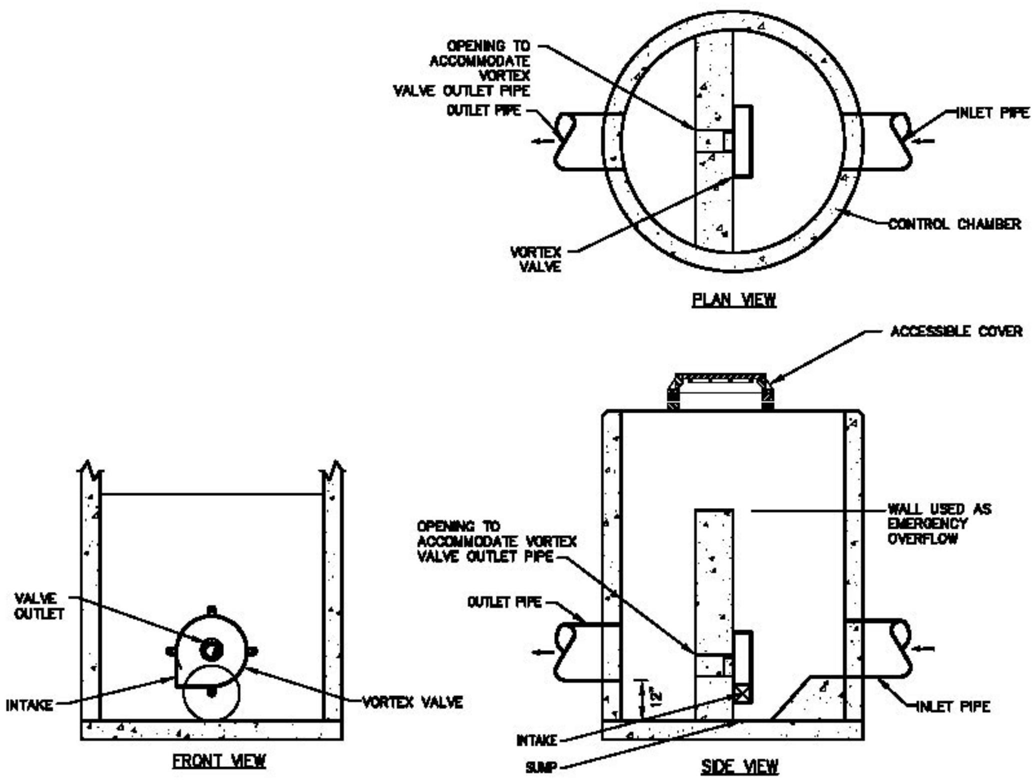
- Pond embankments over six (6) feet shall require design by Geotechnical – Civil engineer licensed in the state of Ohio. For berm embankments of 6 feet or less (including 1 foot freeboard), minimum top width shall be 6 feet or as recommended by the geotechnical-civil engineer.

- Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) free of loose surface soil materials, roots and other organic debris.

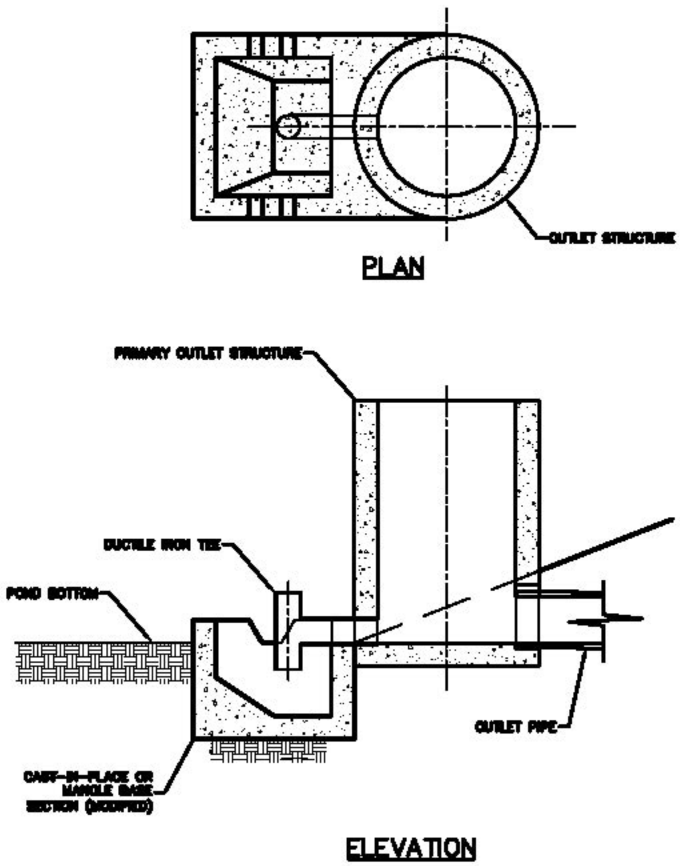
- Exposed earth on the side slopes and bottom should be sodded or seeded with the appropriate seed mixture as soon as is practicable. If necessary, geotextile or matting may be used to stabilize slopes while seeding and sodding become established.

Outlet Control Structure

An outlet structure should be provided that allows the structure to be fully drained in 48 hours. The outlet requires a flow control structure such as a perforated riser pipe to restrict the discharge in order to obtain the 48 hour discharge time.

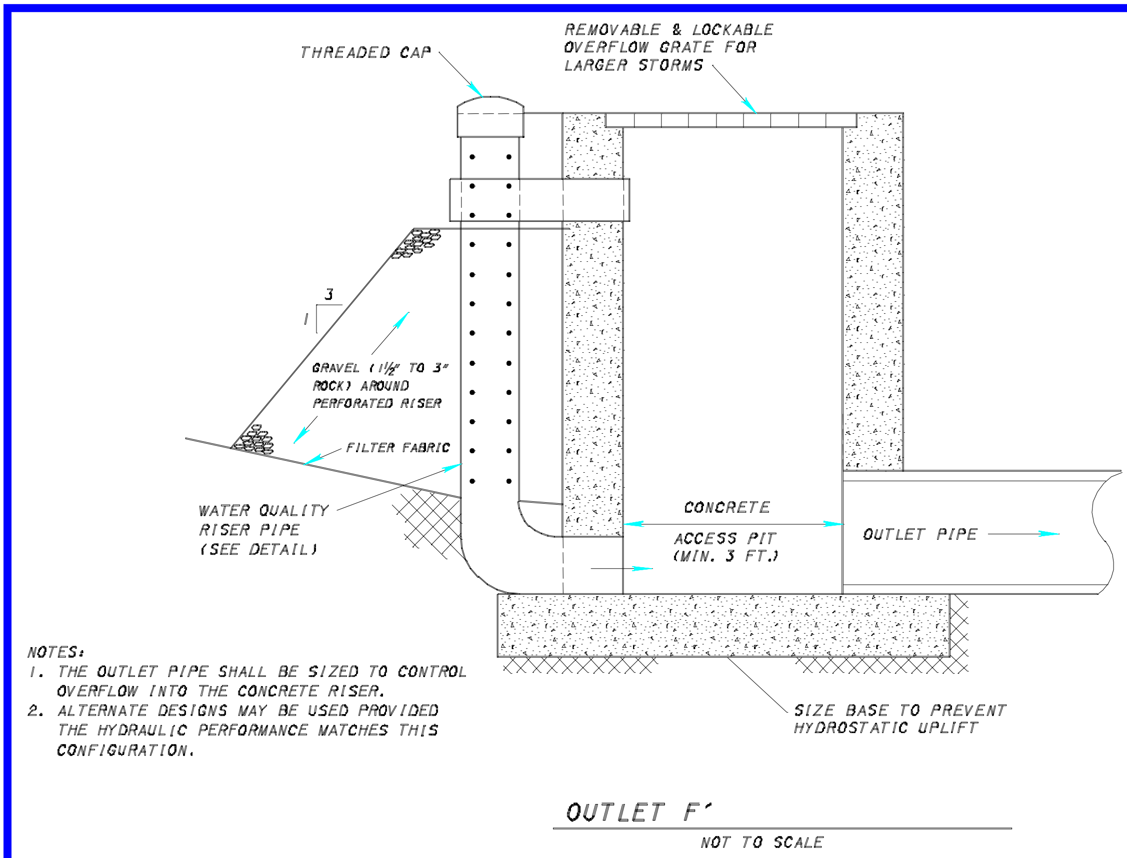


EXAMPLE – CONTROL STRUCTURE WITH OUTFLOW VORTEX VALVE
NOT TO SCALE

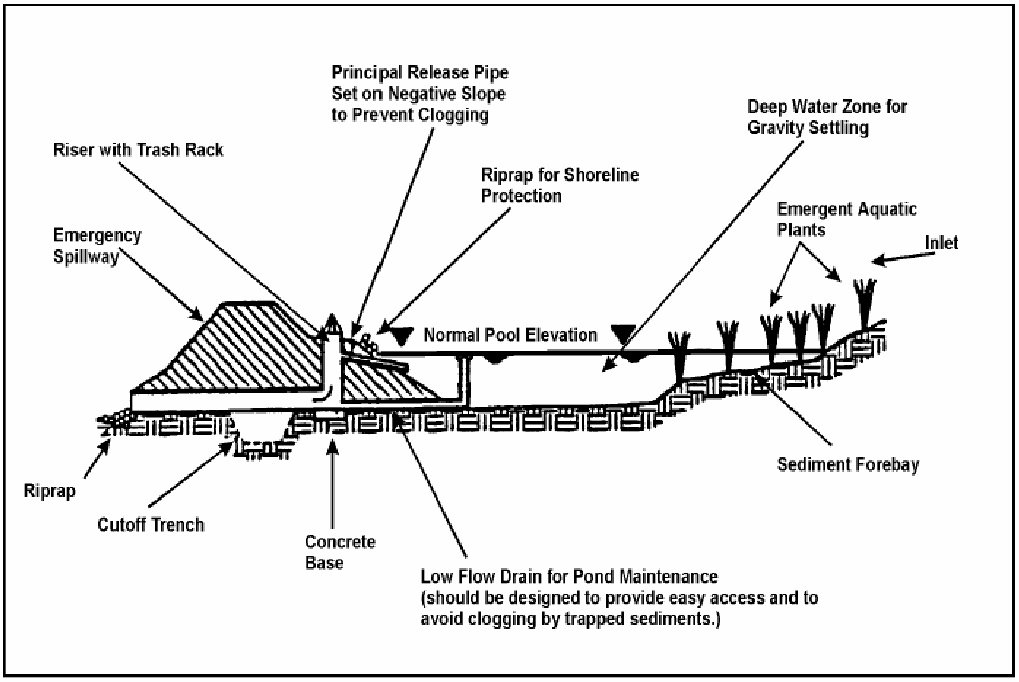


EXAMPLE – CONTROL STRUCTURE WITH TEE

The **perforated riser pipe** is recommended for smaller basins. It uses a catch basin as an outlet structure with a perforated riser pipe on the inlet side and culvert on the outlet side. The perforated riser pipe is used for flow control. A gravel envelope should surround the perforated riser pipe along the inlet side of the catch basin to prevent blockage of the orifice holes in the pipe.



4. **<u>Retention Basins (Wet)</u>** – General principal is that treatment occurs in the permanent pool portion of the basin and pollutants settle out during the hold times and runoff is released over a period of time to allow for settlement. Suggested design considerations include drainage area size, will influence basin size, which in turn could impact site layout. Health considerations include (i.e. West Nile virus), perimeter protection (fencing, maintenance access gates, ingress/egress, easements), maintenance issues.



Source: Maryland Department of the Environment, 1986.

FIGURE 1 TYPICAL LAYOUT OF A WET DETENTION POND

The primary functions of a wet pond are to detain storm water and facilitate pollutant removal through settling and biological uptake

Retention Basin (Wet)

A retention basin is a "wet" pond that has a minimum water surface elevation between storms that is defined as the permanent pool. Above the permanent pool is a detention pool that provides storage for 75% of the WQv and discharges within 24 hours. The full storage water depth is typically between 3-6 feet and the volume is less than 15 Ac-ft. The permanent pool is sized to provide storage for 75% of the WQv. A retention basin is ideal for large tributaries, but it may require a large amount of space. Consider the following when designing a retention basin:

A. A retention basin is not considered feasible until the WQv is at least 0.1 Acre-ft.

B. Use RCP or concrete matting at the inlet of the basin to provide energy dissipation and erosion control.

C. Allow for 1 foot freeboard above the WQv.

D. Use side slopes of 3:1 (max).

E. Provide bypass or overflow for larger events (25 year storm).

F. Vegetate the sides using hearty plants that can withstand prolonged inundation and are salt tolerant.

G. Use a length to width ratio of at least 3:1 to prevent short-circuiting.

H. When practicable, provide a forebay (7-10% of the total retention volume) to extend the service life of the BMP.

I. Provide an anti-seep collar around the outlet pipe.

J. Provide a trash rack or gravel pack protection at the outlet structure.

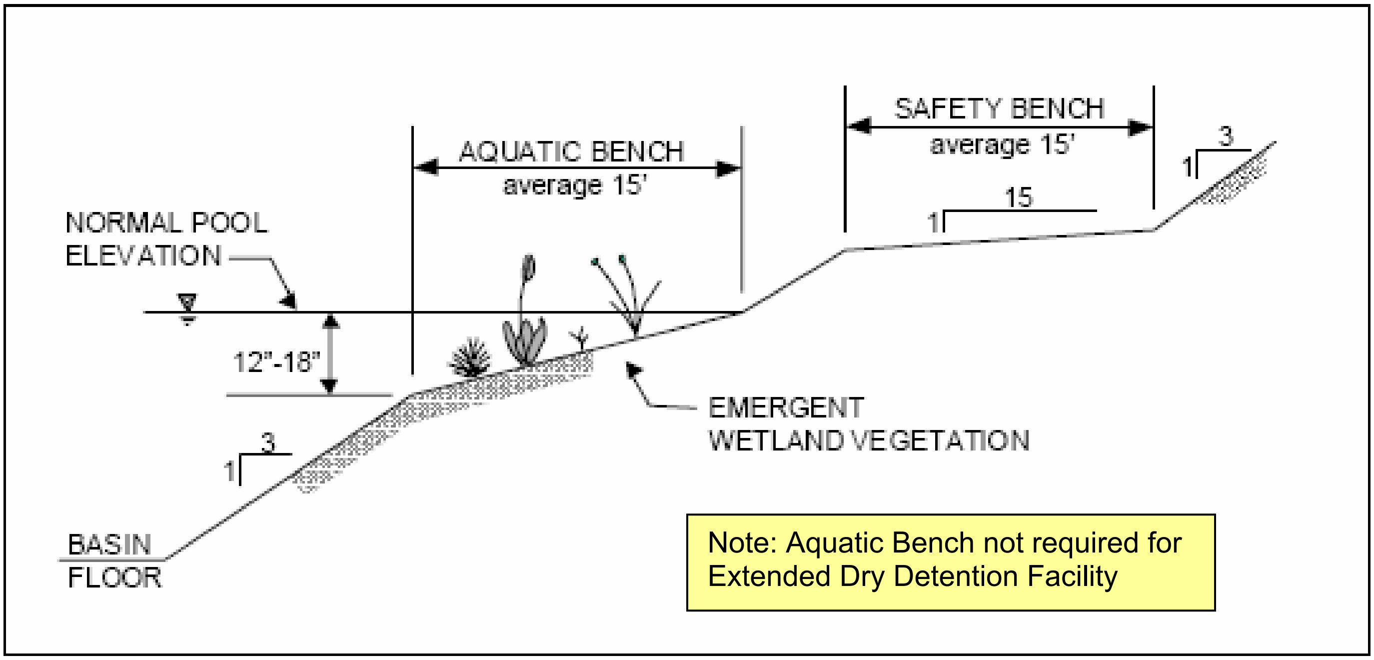
K. The underlying soils should be compacted to prevent infiltration of the permanent pool or an impervious liner should be used.

L. Provide vehicle access to the basin for periodic maintenance.

M. Consideration should be given to the potential problems with mosquitoes.

Retention Basin Outlet Structure

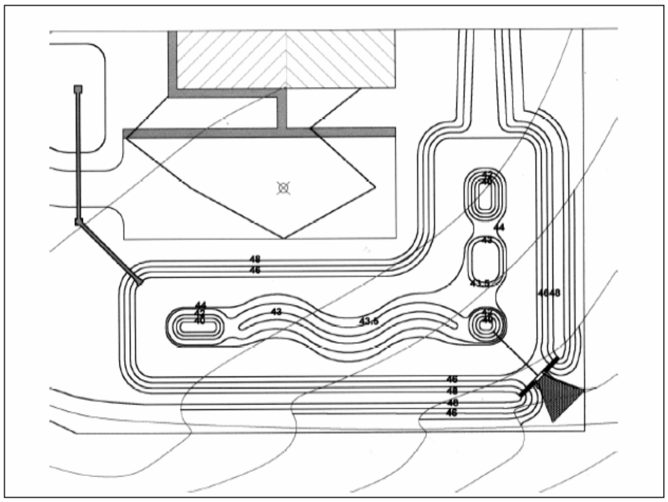
A retention basin outlet structure is designed similar to the outlet structure for a detention basin. The primary difference is that 75% of the WQv should be discharged out of the basin within 24 hours. The outlet structures are of a similar type, except the openings will be set at a high enough elevation to maintain 0.75% of the WQv in the permanent pool.



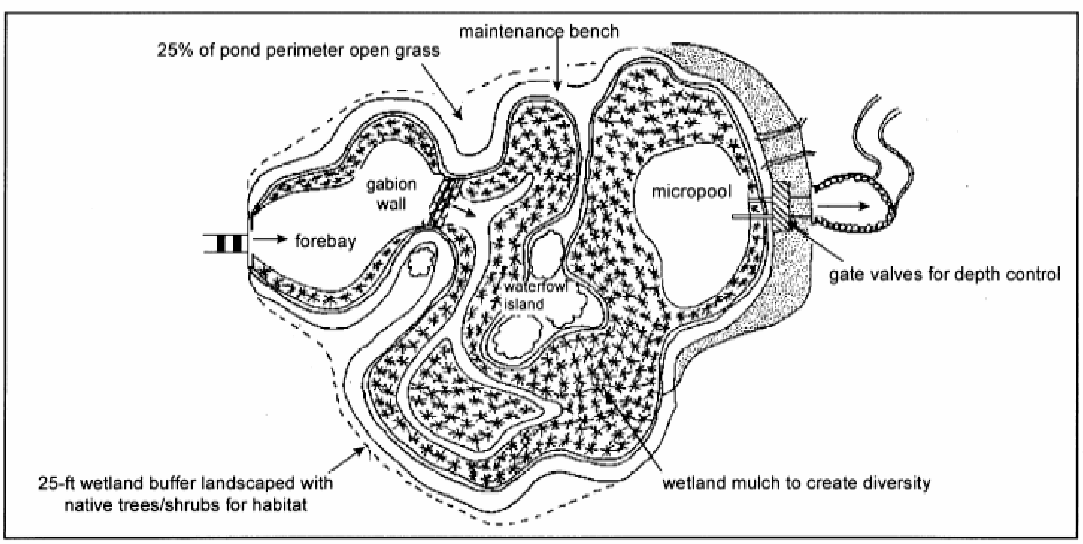
Typical Storm Water Pond Geometry (Wet or Dry)

5. <u>Constructed Wetlands</u> – General principal is **storm water runoff** is treated through bio-retention. Suggested design considerations can include: 1.) Large surface areas, 2.) limit site layout, and 3.) Require additional permitting..

State Route 50, Athens County, Ohio- Ohio Department of Transportation



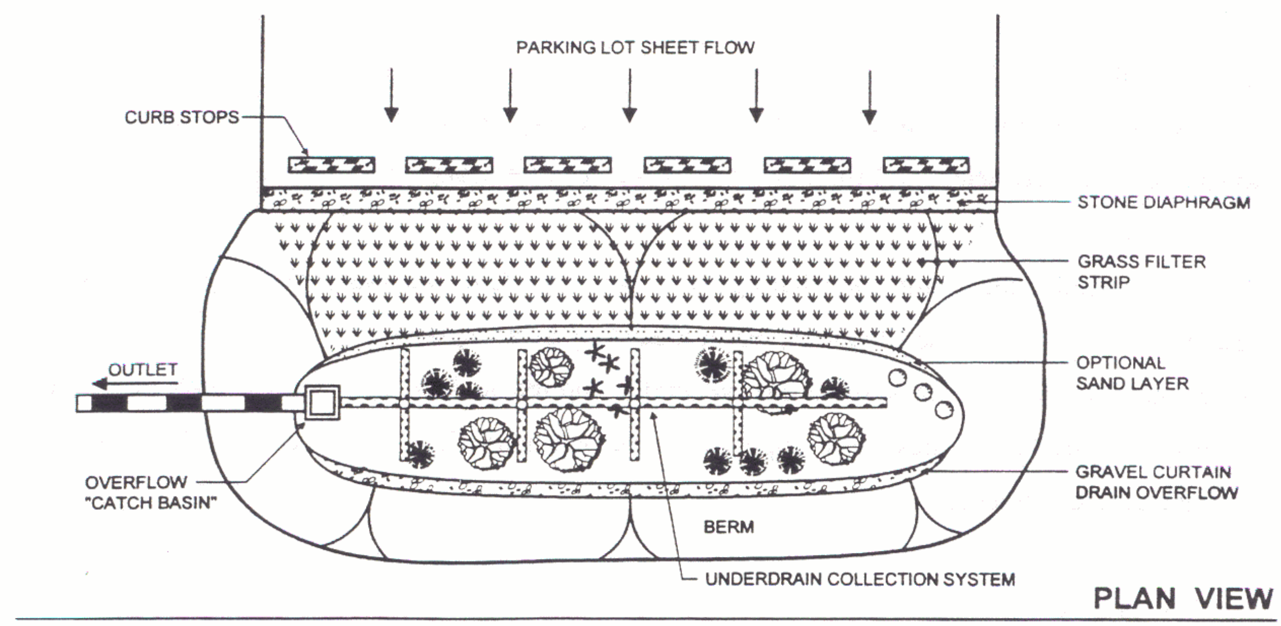
Shallow Marsh Design Example



Source: MWCOG, 1992a.

FIGURE 1 SHALLOW MARSH WETLAND

6. **Bio-retention** – General principle is that **storm water runoff** is treated via evapotranspiration and filtration. These are generally depressed areas which collect **runoff**. Suggested design considerations include site locations, maintenance, **drainage** area size, site slopes.



The County Engineer will consider alternatives to these structural post-construction **BMP's** after all have been considered during the project development process. Supporting rationale as to why they cannot be implemented, designed or incorporated into the site development must be provided. The County Engineer reserves the right to review and recommend alternatives or accept/reject alternatives based on level of maintenance requirements, public health or safety risks, limited water quality benefits and functionality.

SECTION 5 STORM WATER POLLUTION PREVENTION PLANS AND EROSION/SEDIMENTATION CONTROL REQUIREMENTS

5.0 STORM WATER POLLUTION PREVENTION PLANS AND EROSION/SEDIMENTATION CONTROL REQUIREMENTS

5.1 Construction General Permit (CGP) Regulatory Framework

This section highlights portions of the Ohio Environmental Protection Agency (OEPA) *Authorization for* ***Storm Water*** *Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System permit no.OHC000002*, Ohio Revised Code (ORC) and Ohio Administrative Code (OAC) as they apply to the Construction General Permit and to outline permit requirements.

- OEPA – Construction General Permit – After March 10, 2003, construction activities disturbing one or more **acres** of total land are eligible for coverage under this permit. The threshold **acre**age includes the entire area disturbed in the **larger common plan of development** or sale.

- Ohio Revised Code (ORC) – Chapter 6111- Ohio Water Pollution Control Act- Discharges of **storm water** from sites where construction activity is being conducted, as defined in part 1B of Ohio Environmental Protection Agency (OEPA) permit OHC000002 are authorized to discharge from the outfalls at the sites and to receiving surface waters of the state identified in the **Notice of Intent** (**NOI**) application.

- Ohio Administrative Code (OAC) – Rule 3745 – 38-06 – The permit is conditioned upon payment of applicable fees, submittal of a complete **NOI** application form and written approval of coverage form the director of OEPA in accordance with OAC 3745-38-06.

5.2 Principals of Erosion and Sediment Control

The process of development and urbanization creates conditions of **erosion** and **sedimentation** which potentially can adversely impact large numbers of citizens, property, downstream **drainage** systems, functions and infrastructure. Excessive **erosion** and **sedimentation** will potentially increase construction costs by requiring additional grading, **storm water** facility maintenance and **sediment** cleanup.

Effective **erosion** and **sedimentation** control requires first that the soil surface be protected from the erosive forces of wind, rain and run-off and second that eroded soil be captured on-site. The following principals are not complex but are effective. They should be integrated into a system of control measures and management practices to control **erosion** and prevent off-site **sedimentation**. The following should be considered when developing plans for the site building footprint, ancillary structures and site **drainage**:

5.2.1 Fit the Development to the Existing Site Conditions

Review and consider all existing conditions in the initial site selection for the project. Select a site that is suitable rather than force the terrain to conform to the development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding and soils easily eroded severely limit a site use, while level, well –drained areas offer few restrictions.

5.2.2 Minimize the Extent and Duration of Exposure

Sequencing can be a very effective means of reducing the hazards of **erosion**. Schedule construction activities to minimize the exposed area and duration of exposure, sequencing should account for short term conditions, seasonal changes and stabilize **disturbed areas** as soon as possible.

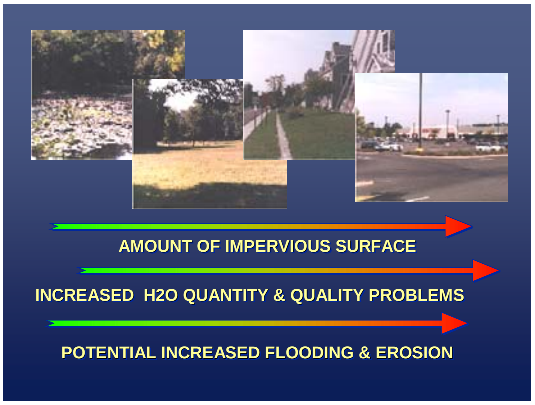
5.2.3 Protect Disturbed Areas from Storm Water Runoff

Use dikes, diversions and waterways to intercept **runoff** and divert it away from the cut/fill slopes or other **disturbed areas**. Sequencing will aid in reducing **erosion** with these measures installed before clearing and grading.

5.2.4 Stabilize Disturbed Areas

Removing the vegetative cover and compacting the surface alters the soil structure and increases an area's susceptibility to **erosion**. Apply stabilizing measures as soon as possible after the land is disturbed. Develop and implement plans for temporary and permanent re-vegetation, place mulch or take other protective measures corresponding with construction activities. Protect **channels** from erosive forces by using linings and the appropriate **channel** design. Inspect and provide on going maintenance as necessary during construction for these practices.

5.2.5 Keep Runoff Velocities Low



SOURCE: URS/Ohio Storm Water Task Force

Clearing existing vegetation reduces the surface roughness and infiltration rate and thereby increasing run-off velocities and volumes. Use measures that break the slopes to reduce the problem associated with concentrated flow volumes and **runoff** velocities. Practical ways to reduce velocities include conveying **storm water runoff** from steep slopes to stabilized outlets, preserving natural vegetation where possible and vegetating exposed areas immediately after construction.

5.2.6 Retain Sediment on Site

Even with careful planning some **erosion** is unavoidable. The resulting **sediment** must be trapped on the site. Determine where **sediment** deposition will occur and provide maintenance access for sediment removal. Protect low points down grade of **disturbed areas** by building barriers to reduce **sediment** loss.

5.2.7 Inspect and Maintain Control Measures

Inspection and maintenance is vital to the performance of **erosion** and **sedimentation** control measures. If improperly maintained, control measures may cause more damage than they prevent. Failure of control measures may be hazardous to health and human safety. When deciding which control measure to use, consider the consequences of a control measure failing. Assign responsibility for routine checks to verify the proper functioning of active **erosion** and **sedimentation** control measures.

5.2.8 Structural Erosion Control Practices

In general these are constructed or manufactured controls or systems which assist in managing or controlling construction site **storm water runoff** (i.e. Inlet protection, rock check dams, filter fabric, etc.).

5.2.9 Non-Structural Preservation Methods

The County Engineer will consider incorporation of non-structural preservation methods which will preserve natural conditions as long as these methods do not impede or redirect project **storm water runoff** off the project site, cause downstream impacts or require increased levels of operation and maintenance effort.

5.2.10 Installation of Sediment Controls

Sediment basin and traps, diversion dikes, **sediment** barriers and other measures intended to trap **sediment** on –site shall be constructed as a first step in grading and made functional before upslope land disturbance takes place. Earthen structures whether permanent or temporary such as dams, dikes, **sediment basin**s, **storm water** basins and diversions shall be seeded and mulched within 7 days after installation is complete.

1. The County Engineer recommends using structural and non-structural controls in combination to manage **erosion** and **sedimentation** control on construction projects within Mahoning county. These are recommended practices and sound engineering and design principals shall be applied/incorporated into any submitted plan designs. The plans shall incorporate measures as recommended by the most current edition of Ohio Department of Natural Resources (**ODNR**) ***Rainwater and Land Development Manual*** or an approved equal (Georgia Soil and Water Conservation Commission- *Manual for* ***Erosion and Sediment Control*** *in Georgia*, Fifth Edition 2000, State of North Carolina, North Carolina

Department of Environmental Health and Natural Resources – *Erosion and Sediment Control Planning and Design Manual*.).

5.3 General Applicability Criteria: Storm Water Pollution Prevention Plans and Erosion/Sedimentation Control Plan

This criteria shall cover all new and existing discharges composed entirely of **storm water runoff** associated with construction activity that enter surface waters of the state or a storm drain leading to surface waters of the state. No **person**(s) shall allow or cause soil disturbing activities to occur within a project or **development area** without compliance with the criteria set forth in this manual:

- A **Storm Water** Pollution Prevention Plan (**SWP3**) must be submitted to Mahoning County **Soil and Water Conservation District** for approval and **Erosion**/**Sedimentation** Plan must be submitted to Mahoning County **Engineer** and Mahoning County **Soil and Water Conservation District** for approval for all soil disturbing activities of **one (1) acre or more, or less than five (5) acres and part of a larger common plan or development**. Excluded are soil disturbing activities directly connected to single family residential development on individual **lots**.

- A **Storm Water** Pollution Prevention Plan (**SWP3**) must be submitted to Mahoning County **Soil and Water Conservation District** for approval and **Erosion**/**Sedimentation** Plan must be submitted to Mahoning County **Engineer** and Mahoning County **Soil and Water Conservation District** for approval for all soil disturbing activities, including **those related to single family residential development on individual lots, disturbing <u>one (1) or more acres on parcels less than five (5) acres</u> and not part of a larger common plan of development.**

- **Submittal of an erosion** and **sedimentation** control plan is recommended when construction activities disturb less than one **acre**, including single family residential development on individual **lots.**

- Compliance with other requirements shall be consistent with applicable state and/or local waste disposal, sanitary sewer or septic system regulations. All discharges regulated under this general permit must comply with the lawful requirements of municipalities, counties and other local agencies regarding discharges of **storm water** from construction sites. All **erosion and sediment control** plans and **storm water management** plans approved by local officials shall be retained with the **SWP3** prepared in accordance with this permit. When the project is located within the jurisdiction of a regulated municipal separate storm sewer system (MS4) the permittee must certify that the **SWP3** complies with the requirements of the **storm water management** program of the MS4 operator.

- Submittal of the **erosion** and **sedimentation** control plans does not relieve the responsible party from complying with the requirements set forth in the OEPA - *Authorization for **Storm Water** Discharges Associated with Construction Activity* *under the National Pollutant Discharge Elimination System permit no.OHC000002*, permit where and when applicable.

- Exceptions –
  - o Should specific site conditions prohibit implementation of any of the control practices contained in this permit or,
  - o Site specific conditions are such that implementation of any **erosion** and **sedimentation** control practices contained in this permit will result in no environmental benefit,
- Then the permittee shall provide supporting documentation as justification for non-implementation of each practice due to site specific conditions.

- All practices, designs and controls are to be developed and implemented to the MEP.

- Plan Amendments – The construction plan shall be amended whenever these is a change in design, construction, operation or maintenance which has a significant effect on the potential for the discharge of pollutants to surface waters of the state or if the **SWP3** proves to be ineffective at achieving objectives of controlling pollutants in **storm water** discharges associated with construction activity.

- Duty to inform contractors and sub-contractors – Permittee shall inform all contractors and subcontractors who will be involved in the implementation of **SWP3** and terms and conditions of this permit. Permittee shall maintain a written document containing signatures of all contractors/sub-contractors who are involved with SPW3 installation and implementation.

5.4 General Construction Plan Submittal Requirements

For the purposes of this manual, the use of Construction Plans includes the following:

- Site **Drainage** Plan
- **Storm Water** Pollution Prevention Plan
- **Erosion** and **Sedimentation** Control Plan

When referenced in this manual "Construction Plans" will be include all three types of plans mentioned above.

The **Storm Water** Pollution Prevention Plan and **Erosion**/**Sediment** Control Plan shall incorporate measures as recommended by the most current edition of the ***Rainwater and Land Development*** **manual** or an approved equivalent. In certain applications the Ohio Department of Transportation (ODOT) Location and Design Manual- Volume 2 should referenced for roadway projects for recommended **erosion and sediment control** practices. In addition, ODOT's Location and Design Manual Volume 2 shall be reviewed when selecting Post-Construction Controls for roadway projects. The following represent measures to be integrated into plan design:

A. Certification Requirement - The Mahoning County **Engineer** recommends that a Registered Professional **Engineer** shall certify **storm water** and **erosion**/**sediment** control calculations, designs and plan sheets.

B. Permitted Activities and Limitations on Coverage- For the purpose of this manual construction activities include, but are not limited to:

- Clearing and grubbing operations.
- Site Grading Operations.
- Excavating or filling activities.
- Trench /Groundwater dewatering- No turbid discharges to surface waters of the state allowed.
- Construction project support activities directly related to the project (Storage yards, batch plants, excavated material disposal areas and borrow areas).

C. Submit complete and accurate **Notice of Intent** (**NOI**) application (**NOI** form included in appendix). The **NOI** and accompanying fee should be submitted at least 21 days prior to commencement of construction activity. **NOI** and appropriate fee should be forwarded to:

OEPA
Office of Fiscal Administration
P.O. Box 1049
Columbus, Ohio 43216-1049

D. Regulatory submittal clarification - All construction plans developed to meet regulatory and manual requirements shall be submitted to the County **Engineer** and Mahoning County **Soil and Water Conservation District** (MCSWCD). Unless requested to do so, **construction plans** are not required to be submitted to OEPA related to **erosion**/**sediment** control or **storm water** pollution prevention. A **Storm Water** Pollution Prevention Plan (**SWP3**) must be submitted to Mahoning County **Soil and Water Conservation District** with appropriate fee for review of plans. Fee schedule can be found in Appendix J.

5.5 Plan Narrative and Site Description Requirements

Operators, developers, general contractors and home builders who intend to obtain initial coverage for **storm water** discharge associated with construction activity under this general permit shall develop and submit the following:

- Site Type – Residential, Commercial, Industrial, Subdivision, Institutional.
- Construction **Phasing** or Sequencing Plan
- OEPA **NPDES** permit number
- Location information- Address, City, Village, Township, parcel information if available.
- **Watershed** Name and Hydrologic Unit Code (HUC) - 11 digit code.
- Total area of site and limits of earth disturbing activity.

- Location and description of any off-site land disturbing activities (borrow/fill areas, Concrete or Asphalt plants).
- Name and location of immediate receiving stream or surface water(s) - Names of subsequent receiving waters, **wetlands** or special aquatic sites.
- Identify all existing easements on project site (Utility, conservation, public, etc.)
- **Storm Water runoff** calculations - Pre and post development site conditions, peak discharges and volume of **channel** protection and water quality information. Include **critical storm** determination and demonstrate that **runoff** from upper **watershed** areas and off site **drainage** contributions have been incorporated into site **drainage** and post-construction control calculations.
- Estimate of **impervious surface** generated by development/project **by area and percent**.
- If available prior site land-use and **storm water** discharge information.
- Existing soil data.
- Proposed location of concrete truck wash-out areas on site and **runoff** controls associated w/these areas.
- Proposed site ingress/egress locations and BMP for these locations.

5.6 Storm Water Pollution Prevention Plans and Erosion/Sedimentation Control Plan Requirements

The submitted construction plans shall include **drainage**, **erosion, sediment, and storm water management** controls for the site during and after construction. The following is a recommended plan component list and is not intended to be all inclusive:

- Vicinity Map
- Site Plan shall include the following:

  - Soil types.
  - Existing and proposed 2'contours labeled accordingly.
  - Limits of clearing, grading, excavation, off site spoil/borrow areas.
  - Surface water locations within 200' of project site.
  - Existing and planned buildings, roads, parking facilities and other ancillary structures.
  - Location of temporary **sediment** and **storm water management** basins. Include settling volume and delineated **drainage** area sizes.
  - Location of permanent post-construction **storm water management** practices.
  - **Wetland** conservation easement buffer fence or barrier locations.
  - Project **Wetland** Information

- Trench dewatering discharge locations and procedures.
- Designated soil storage/disposal areas.
- Project ingress/egress areas.
- Detailed drawings of all permanent and temporary structural **storm water management** and **erosion** control methods shall be provided.
- Proposed project stream crossings.
- Locations of known 100 year floodplains and known historic flooding areas, identified on construction plans.
- Description and specifications for project site **stabilization including** temporary seeding, permanent seeding (include any time of year restrictions), mulching, buffer strips, **phasing** and sequencing of construction operations.

Table 5-1 – Permanent Stabilization

Area Requiring Permanent Stabilization	Time Frame to Apply Erosion Control
Any area that will lie dormant for one year of more.	Within 7-days of the must recent disturbance.
Any area within 50 feet of a **watercourse** and at final grade.	Within 2 days of achieving final grade.
Area at final grade.	Within 7 days of reaching final grade.

Table 5-2- Temporary Stabilization

Areas Requiring Temporary Stabilization	Time Frame to Apply Erosion Control
Any **disturbed area** within 50 feet of a **watercourse** and not at final grade.	Within 2- days of the most recent disturbance.
For all construction activities, including stockpiles, that will be dormant for more than 21 days but less than 365 days and not within 50 feet of a **watercourse**.	Within 7 days of the most recent disturbance.
Exposed areas which will be idle over the winter.	Prior to November 1.
Note: *Where vegetative **stabilization** techniques will cause structural instability or are otherwise unattainable, alternative **stabilization** techniques must be implemented.*	

- Plan shall consider non-structural **BMP's** where possible. The Mahoning County Engineer recommends incorporating **riparian and** buffer areas, **phasing** construction operations to minimize project land disturbance activities at any given time, identifying and preserving project tree areas to the maximum extent practical, implementing project protective clearing and grubbing practices, and maintaining project natural areas to the maximum extent practical.

- Construction Sequence should clearly identify project **erosion**, **sediment** and **storm water management** control methods, sequence (i.e. when each method will be implemented and the responsible party for implementation of each respective control.)

- Pre-Construction Meeting shall be scheduled between Owner/Developer/Operators/Mahoning County **Soil and Water Conservation District** and Mahoning County **Engineer** to review **storm water** pollution prevention plan (**SWP3**) no less than 7 days prior to **soil disturbing activity**.

- **Required Construction Plan General Notes:**

  - Methods, timing and implementation schedule of all temporary and permanent **storm water management**, **erosion and sediment control** elements.

  - Owner of Record Contact information (Phone, address and Fax number)

  - Post-Construction **BMP** Inspection Maintenance schedule. Ancillary information to be provided shall include:

    - **BMP** locations on site
    - Required maintenance, recommended frequency for maintenance.
    - Easements for access to **BMP** for inspection /maintenance (Private and Public).
    - Contact information for to follow up on maintenance.

  - To the maximum extent practical limit project ingress/egress locations to one entrance.

  - Complete all pre-winter site **stabilization** by no later than September 30.

  - Owner of record shall provide required inspections and maintenance for all project **erosion and sediment controls**. Permanent inspection records are to be kept on site throughout construction. Inspection frequency- once every 7 days and immediately after storm events greater than 0.5 inches of rainfall within a 24 hour period.

  - All **storm water runoff** control facilities and **erosion**/**sediment** controls shall be installed and constructed during the initial project grading or within 7 days from the start of clearing/grubbing. Upon completion of constructing project **sediment** ponds, seeding and mulching shall immediately follow to aid in site **stabilization** and minimization of **erosion** and **sediment** transport prior to **runoff** leaving project site. All **erosion and sediment control**s shall be maintained and continue to function throughout the active construction portion of the project.

- **Runoff Control Practices -** Shall incorporate measures which control flow of **runoff** from **disturbed areas** to prevent **erosion** and **sediment** transport. Practices may include inlet protection, rock check dams, pipe slope drains, diversions to direct flow away form exposed soil areas.

- **Inlet Protection** – Storm Sewer inlet protection must be provided to minimize **sediment** laden water from entering storm drain systems, unless the storm drain system discharges to a **sediment**-settling pond. All storm sewer inlets and catch basins that are made functional during construction shall be protected from **sediment** laden **runoff**. Provisions shall be made for these inlets/catch basins to operate and be maintained before, during and after the final surface is completed. Silt fence alone shall not be utilized as inlet protection. A sturdy frame must be constructed such as 2 x 4 wood to support the silt fence around the inlets. The inlet protection shall encircle the entire inlet and be properly entrenched. Maintenance of these controls shall be preformed on a regular basis.

- **Sediment Control Practices -** Shall include a description of structural practices that will store **runoff** allowing for settle and/or divert flows away from exposed soil or limit **runoff** from exposed areas. Practices may include but are not limited to **sediment basins**/ponds, silt fences, and/or earthen dikes or **channels** which direct flow to settlement basins/ponds.

- o Sediment settling pond requirements:

  - ✓ Required for 10 or more **acres** of disturbance at one time.

  - ✓ For areas serving less than 10 **acres** smaller settlement ponds or **sediment** traps shall be used.

  - ✓ Basin sizing criteria:

    Basin location selection and maximization of performance shall consider the following criteria:

    - Maximize Basin effectiveness – Location selected based on intercepting largest possible amount **runoff** from project **disturbed areas**.
    - Un**disturbed area runoff** shall be diverted form temporary **sediment** control facilities when ever practical.
    - No basin shall be located within 50 feet of designated floodways.

The Mahoning County Engineer recommends maximizing trapping and retaining incoming **sediment** by designing the basin with a permanent pool (wet storage) which will protect against **sediment** re-suspension by promoting extended settlement times. The basin shall also include a dry storage component which will protect against "short circuiting" of the basin during larger storm events. The recommended standard storage sizing criteria are presented in table 4-3. The following table identifies recommended basin minimums. Basin designs shall address project site conditions and maximize length to width ratios as practical to increase settlement times. Basin designs will **not** have to include storage volumes for the following:

- Diversion of undisturbed project area **runoff**,
- Diversion of off-site **runoff** from outside project area.

- Project stabilized areas.

Should no diversion be implemented, the basin shall be sized to accommodate both disturbed and undisturbed **runoff drainage** areas.

The developer, **engineer**, builder or contractor can provide supporting calculations in defense of not implementing the additional storage volumes for the basin. The final decision shall be at the discretion of the County **Engineer.** Should the project location be located adjacent to streams, creeks or other surface conveyance features, the County **Engineer** may require the additional storage volume. For all other basins the additional volume shall be required.

Table 5-3 – Standard Temporary Sediment Basin Sizing Criteria

Basin Design Elements	Basin Design Criteria
Basin Wet Storage	33.5 cubic yards/**Acre**
Basin Dry Storage	33.5 cubic yards/**Acre**
Maximum Depth	5- feet
Length: Width Ratio	2:1

The modified **sediment basin** is to be used when modifying a permanent **storm water** control facility for use as a temporary **sediment** control facility. The Mahoning County **Engineer** recommends that a 134 cubic yard/drainage acre (including off-site if not diverted) volume be used for sizing the temporary storage control facility or that a series of additional temporary **sediment basin**s be constructed up-gradient of the permanent **storm water** control facility, one for every inlet pipe discharging into the facility to reduce or eliminate “short circuiting” of the permanent facility during construction. Either method is acceptable. Supporting design calculations for either method are required.

Table 5-3a – Modified Permanent Control as Temporary Sediment Basin Sizing Criteria

Basin Design Elements	Basin Design Criteria
Basin Wet Storage	67 cubic yards/**Acre**
Basin Dry Storage	67 cubic yards/**Acre**
Maximum Depth	5- feet
Length: Width Ratio	2:1

1. Maintenance requirement – Accumulated sediment must be removed when basin is approximately 40 % full of **sediment**.
2. Spoil material shall be disposed of properly and the County **Engineer** can request documentation of proper disposal in the form of Landfill **dumping** receipts. Spoil and borrow areas must be included during preparation of SWP3, ensuring that erosion

and sediment control BMP's are designed to minimize impacts and that sediment is not transported to surrounding properties.

3. Basin shall have safety bench designed into basin footprint. Bench shall be designed with a maximum of 2 foot depth.
4. Side slopes from bench to 5 foot depth shall be minimized when ever practical.

- Silt fence and diversions- Sheet flow **runoff** from disturbed or denuded areas shall be intercepted by silt fence or alternative diversion practices to protect adjacent properties and **water resources** from **sediment** transport contained in sheet-flow **runoff**.

  Silt Fence shall be placed on a level contour and not placed where concentrated flow is directed toward it. Silt fence shall be pulled tight and trenched 4” to 6” into the ground and backfilled to prevent **runoff** from cutting underneath and short circuiting the intended use of the fence. Sections of silt fence shall be joined so there are no gaps in the fence. The ends of the fence shall be brought upslope of the rest of the fence to prevent **runoff** from going around the ends of the fence. Silt fence shall not control large **drainage** areas. The estimated maximum **drainage** area to silt fence for a particular slope interval is shown in the table below:

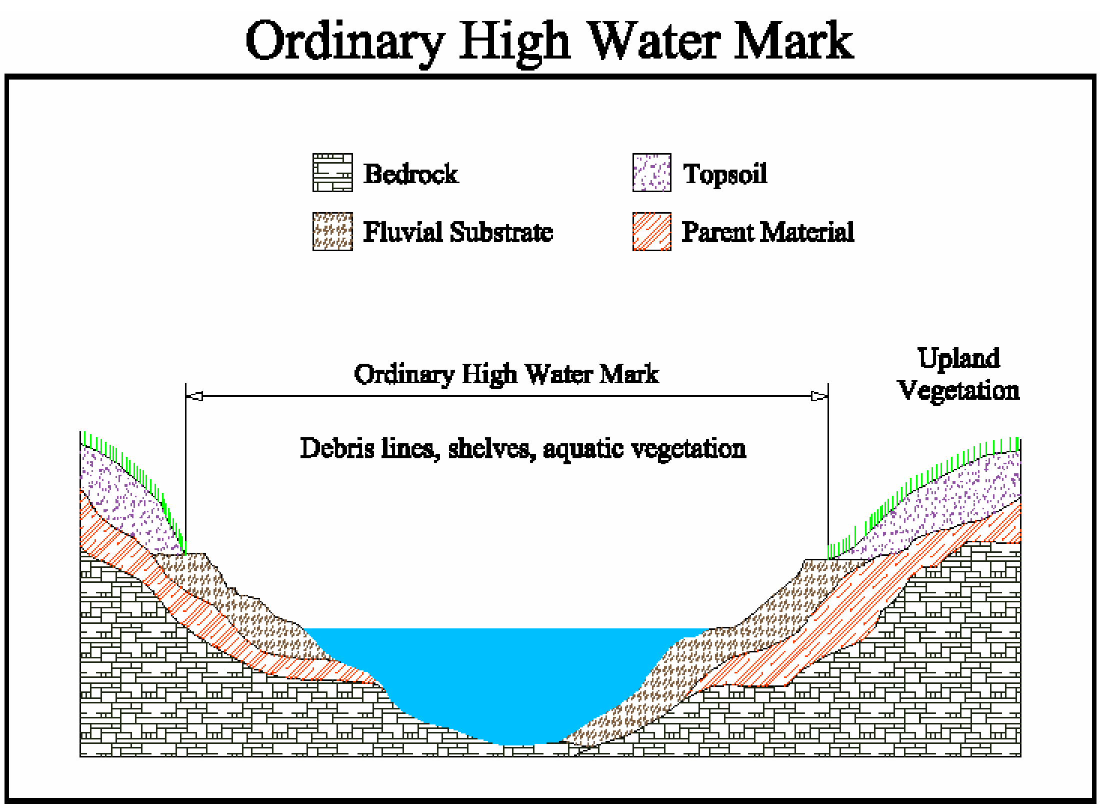
Table 5-4 - Maximum Drainage Area to Silt Fence

Maximum Drainage Area (Acres)/ 100 linear ft. of silt fence	Interval of slope for a particular drainage Area (Percent)
0.5	<2%
0.35	> 2% but < 20%
0.125	> 20% but < 50%

Routine maintenance is required in order to maintain the silt fence in proper functioning order. The maintenance shall be noted in the weekly inspection logs which are required to be kept updated on the project site.

Storm water diversion practices shall be used to keep **runoff** away from **disturbed areas** and steep slopes where practical. Such diversion devices include dikes and berms which can receive and divert **runoff** from up to 10 **acres**.

- o Stream Protection – During construction activities which disturb areas adjacent to streams, structural practices shall be designed and implemented on site to protect all adjacent streams from **sediment** transport impacts. No land disturbances within 40' of the ordinary high water mark.



Ordinary High Water Mark – Ordinary High Water Mark (OHWM) - is an elevation that marks the boundary of a lake, marsh or streambed. An Ordinary high water mark is created when the presence and action of water is so persistent that the morphological and natural vegetation is distinctly different from upland areas.

- Site **stabilization**, either temporary or permanent, shall follow table 5-1 and 5-2 as applicable.

- Filling a **NOT** is required for all projects which had a **NOI** filed and approved.

- Disposing of Temporary Measures – All temporary measures shall be disposed of within 30 days after **final stabilization** of the site is achieved and approved by Mahoning County SWCD.

- County Engineer recommends that all Total Maximum Daily Load (TMDL) stream segments within project boundaries be identified on the general notes plan sheet. Should a TMDL be approved for any waterbody into which the permittee's site discharges and requires specific **BMP's** for construction, the OEPA director may require the permittee to revise the **SWP3**.

5.7 Limitations on coverage

The following **storm water** discharges associated with construction activity are not covered by this permit:

- **Storm water** discharges that originate from the site after construction activities have been completed, including temporary supporting activity and final site **stabilization**.

- **Storm water** discharges associated with construction activity that the OEPA director has shown to be or may reasonably expect to be contributing to a violation of a water quality standard.

- **Storm water** discharges associated w/other **NPDES** permits.

5.8 Permit Waivers

The Construction General Permit allows for 2 different waviers to be considered:

- Rainfall Erosivity Waiver (REW) - discretion of director.

- Total Maximum Daily Load waiver (TMDLW) – **Storm water** controls are not needed based on a TMDL approved that addresses the pollutant(s) of concern. Pollutants of concern include **sediment** or a parameter that addresses **sediment** (such as total suspended solids, turbidity or siltation or Urban **storm water**

runoff) and any other pollutant that has been identified as a cause of impairment of any water body that will receive a discharge from project construction activity.

5.9 Submittal and Review

The Storm Water Pollution Prevention Plan (**SWP3**) shall be prepared in accordance with sound engineering and/or conservation practices by a professional experienced in the design and implementation of standard **erosion** and **sedimentation** controls and **storm water management** practices addressing all phases of construction. The following are required as part of the SWP3:

- **SWP3** and **Erosion** /**sedimentation** plans shall be completed prior to the timely submittal of the **NOI**.

- Permittee shall make the SWP3 available upon request of the local agency approving **sediment** and **erosion** control plans, grading plans, **storm water** pollution prevention or **storm water management** plans, to local governmental officials, or to operators of Municipal Separate Storm Sewer Systems (MS4) receiving **drainage** from the permitted site.

- County Engineer requires:

    1. **Storm water** Pollution Prevention Plans (**SWP3**) – separate sheet
    2. **Erosion**/**Sedimentation** Control Plan – separate sheet
    3. Post-Construction Controls and Maintenance plan – separate sheet
    4. Permanent (Post-Construction) Detention being modified as temporary **sediment** control basin , or multiple temporary **sediment** control basins: Provide design calculations for each inlet and discharge pipe - separate sheet.

    Two copies shall be submitted, one set for Mahoning County **Engineer** and one set for Mahoning County **Soil and Water Conservation District**.

- For proposed subdivisions the **SWP3** and **Erosion**/**Sedimentation** plan shall be submitted to Mahoning County SWCD after acceptance of the preliminary plat by Mahoning County Planning Commission and concurrently with the submittal of site construction drawings to the county **engineer**. The review period will commence upon full payment of review fees to the Mahoning County Engineer (see Appendix J). The County Engineer and SWCD will review the SWP3 and provide comments, questions and/or recommendations for revision, or an approval letter, within 30 days. If no response is provided by the SWCD within 30 days, the owner, or appointed representative, may assume concurrence and submit the NOI. A revised plan shall be submitted to the SWCD within 30 days of receipt of notice of deficiencies. The Mahoning County **Engineer** shall not allow any land disturbance activities prior to plan approval and proof of compliance with all necessary project permits as outlined in Section 1.8 *Compliance with State and Federal Regulations* of this manual.

- Within 30 days of receipt of a complete plan, including fees. Mahoning County SWCD shall indicate the submitted and revised status of compliance or non-compliance to the owner of appointed representative. Indication of non-compliance shall include specific deficiencies and procedures for filing a revised plan. Revised plan shall be submitted within 30 days of receipt of notification of deficiencies.

- Filing **Notice of Termination** (**NOT**) - Terms and conditions of this permit shall remain in effect until a signed **Notice of Termination** form is submitted. Failure to submit a **NOT** constitutes a violation of this permit and may affect the ability of the permittee to obtain general permit coverage in the future.

- Submitting an **NOT** - Compliance with this permit is required until an **NOT** form is submitted (Form is included in Appendix D). Permittee's authorization to discharge under this permit terminates at midnight of the day the **NOT** form is submitted. All permittees must submit an **NOT** within 45 days of completing all permitted land disturbance activities. Enforcement actions may be taken if a permittee submits an **NOT** form without meeting one or of the following conditions:

    - **Final stabilization** has been achieved on all portions of the site.
      Another operator has assumed control over all areas of the site that have not been finally stabilized. Final stabilization status will be determined by Mahoning SWCD or OEPA. Owner, or appointed representative, may request inspection upon completion of project, prior to submittal of NOT.
    - Temporary **stabilization** has been completed and the **lot** has been transferred to homeowner (residential construction only).
    - Individual **lots** sold by the developer without housing must undergo **final stabilization** prior to termination of permit coverage (residential construction only).

During site development, layout and planning, consideration shall be given to selection of proper **erosion and sediment control** practices and designs. Site layout and **drainage** shall integrate sound **erosion** and **sedimentation** practices and should be developed or design by **persons** experienced in **drainage**, hydraulics, **storm water management** or other **erosion** and **sedimentation** control techniques.

The following statement shall be included with all submitted **erosion** and **sedimentation** control plans and **SWP3** plans:

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the ***person*** *or* ***persons*** *who manage the system or those* ***persons*** *directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.*

SECTION 6 FLOOD PLAIN REGULATIONS

6.0 FLOOD PLAIN REGULATIONS

6.1 General

The current Mahoning County **Flood Damage Prevention Regulations** have been included in the appendix for reference. These regulations are currently being revised and will be incorporated by addendum to this manual when completed. The following represents current submittal requirements and a general summary of the Flood Damage Prevention Regulations. Refer to Appendix I for technical issues and specifics related to the regulations.

The user can obtain FEMA floodzone delineations from the Mahoning County GIS website at:

http://gis.mahoningcountyoh.gov/

6.2 What is required to be submitted?

Mahoning County, through the Mahoning County Planning Commission and the Mahoning County Engineer, regulates construction and other land use activities in special flood hazard areas. A **Development Permit** is required before construction or development begins within a special flood hazard area.

- Development Permit must be obtained before construction or development begins within any area of special flood hazard.
- Permit forms may be obtained from the Mahoning County Planning Commission.
- Applications must include a duplicate set of plans, drawn to scale, showing the nature, locations and elevations of the area.

6.3 Where is the Completed Development permit submitted?

Approved permits are to be submitted to:

- Mahoning County Engineer
- Mahoning County Commissioners

Requests for variance shall be submitted to an established Variance board. The Mahoning County Planning Commission shall maintain records of all variance requests and report any variance to the Federal Emergency Management Agency (FEMA) upon request.

6.4 Current schedule for submissions

The current regulations require development permits to be completed and approved prior to commencing any construction related activities within the floodplain areas. Applying for variances will follow the following schedule:

- Variance applied for and submitted to variance board.
- Variance board sets meeting date to hear variance.
- Variance board has 20 days to rule on pending variance.

6.5 General Regulation Information

The following information is presented here as a summary of the Flood Damage Prevention Regulations and is not intended to supplement the rules in any way.

6.5.1 Anchoring

All new construction and substantial improvements must be anchored to prevent flotation, collapse or lateral movement of the structure due to hydrodynamic and hydrostatic loads, including the effects of buoyancy.

All manufactured homes (unless otherwise regulated by the Ohio Revised Code) shall be anchored as stated above. Methods of anchoring may include, but are not limited to, use of over-the-top or frame ties to ground anchors.

6.5.2 Construction Materials and Methods

All new construction and substantial improvements shall be made with materials resistant to flood damage, and using methods and practices that minimize flood damage.

All new construction and substantial improvements shall be constructed with electrical, heating, ventilation, plumbing and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within their components during flooding conditions.

All new members and replacement water supply systems shall be designed to minimize or prevent infiltration of floodwaters into the systems.

All new and replacement sanitary sewage systems shall be designed to minimize or prevent infiltration of floodwaters into the systems and sewage discharge from the systems to the floodwaters. Individual wastewater treatment systems shall be located to avoid impairment or contamination from floodwaters.

6.5.3 Subdivisions

All proposals for subdivisions located in areas of special flood hazards, including manufactured home subdivisions, shall:

- Be consistent with the need to minimize flood damage.
- Have public utilities and facilities such as sewer, gas, electrical and water systems located and constructed to minimize flood damage;
- Have adequate **drainage** provided to reduce exposure to flood damage.
- Include base flood elevation data for developments of at least 50 **lots** or 5 **acres** (whichever is less).

6.5.4 Specific Standards

In all areas of special flood hazards for which base flood elevation data are known, the following provisions shall apply:

6.5.4.1 Residential Construction

For new construction and substantial improvement of any residential structure, the lowest floor, including the basement, shall be elevated to 1 foot above the base flood elevation.

6.5.4.2 Non-residential Construction

New construction and substantial improvement of any commercial, industrial or other nonresidential structure shall either have the lowest floor, including the basement, elevated to the level of the base flood elevation, or, together with attendant utility and sanitary facilities, shall:

- Be flood-proofed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water;
- Have structural components capable of resisting hydrostatic and hydrodynamic loads and the effects of buoyancy..
- Be certified by a registered professional **engineer** or architect that the design and methods of construction are in accordance with accepted standards of practice for meeting the standards of this subsection. Such certification shall be provided with the Development Permit application.

6.5.4.3 Accessory Structures

An exception to the elevation of dry flood-proofing standards given above may be granted for accessory structures such as sheds, detached garages, etc., having a gross floor area of 576 square feet or less. Such structures must meet the floodway encroachment provisions in Section 5.3(1) of the Regulations, and the following additional standards:

- They shall not be used for human habitation;
- They shall be designed to have low flood damage potential
- They shall be constructed and placed on the building site so as to offer the minimum resistance to the flow of flood waters;
- They shall be firmly anchored to prevent flotation; and

- There service facilities such as electrical and heating equipment shall be elevated or flood-proofed.

6.5.4.4 Manufactured Homes

The following standards shall apply to all new and substantially improved manufactured homes not subject to the manufactured home requirements of Section 37733.01 of the Ohio Revised Code:

- They shall be anchored in accordance with Section 5.1-1(2) of the Mahoning County Flood Damage Prevention Regulations.

- Manufactured homes shall be elevated on a permanent foundation such that the lowest floor is at or above the base flood elevation.

6.5.4.5 Enclosures below Base Flood Elevation (BFE)

The following provisions shall apply to all new and substantially improved residential and nonresidential structures that are elevated to or above the base level flood elevation using pilings, columns or posts that enclose a crawl space. These structures may enclose the area below the base flood elevation provided the conditions presented below are met. Enclosures meeting these requirements shall be considered to have met the anchoring requirements of the Regulations.

Fully enclosed areas below the base flood elevation shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must by certified by a registered professional **engineer** or architect, or must meet or exceed the following criteria:

- A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area shall be provided;

- The bottom of all openings shall be no higher than one foot above grade, and openings may be equipped with screens, louvers or other coverings or devices provided that they permit the automatic entry and exit of floodwaters.

6.5.4.6 Floodways

The Regulations identify segments within areas of special flood hazard as a floodway. Floodways may also be identified or delineated in other sources of flood information, as specified in the Regulations. A **floodway** is an extremely hazardous area due to the velocity of floodwaters that may carry debris and potential projectiles, and due to the potential for soil **erosion**. The following provisions apply within all delineated floodways:

- Encroachments into the floodway, including fill, new construction, substantial improvements and other development, are prohibited unless a technical evaluation demonstrates that the encroachment(s) will not result in any increase in flood levels during occurrence of the base flood. If this condition is met, all new construction and substantial improvements must comply with all applicable flood hazard reductions of Section 5.0 of the Flood Damage Prevention Regulations.

SECTION 7 ADMINISTRATIVE

7.0. ADMINISTRATIVE

7.1 Inspection and Compliance

1. The Mahoning County SWCD will perform regular inspections of project areas to determine and document compliance with OEPA's Construction General Permit (CGP) requirements as well as requirements set forth in this manual. Inspection reports will be forwarded to the Mahoning County Commissioners, the owner, or appointed representative, and other relevant agencies, regarding site compliance status. Should an apparent violation or deficiency be noted or reported from a third party or others, the Mahoning SWCD will investigate the alleged violation and complete a 'Complaint Inspection Report'; the results and recommendations will be forwarded to necessary entities.

   Should the deficiency or non-compliance not be corrected, or plans submitted addressing the situation, deficiency or non-compliance will be forwarded to the commissioners as a "Notice-of-Violation" containing details of the nature of the violation. If sections of the Ohio Revised Code have been violated, then the Notice of Violation will also be forwarded to the Ohio EPA.

2. In the event that the Mahoning SWCD determines a deficiency or non-compliance to be causing immediate and significant damage to waters of the State of Ohio, then the Commissioners may be approached for priority consideration without delay.

3. Should the Commissioners determine that a violation does exists, the Prosecuting Attorney for Mahoning County will request in writing an injunction, or other appropriate relief to reduce excessive erosion and sedimentation and secure compliance with the requirements set forth in this manual. In seeking a resolution, the court may order the maintenance or construction of Best Management Practices (BMPs) per the approved SWP3. The court may also require the installation of additional measures if deemed necessary by site conditions.

4. When a third consecutive Notice-of-Violation is issued for non-compliance, a re-inspection fee is due and payable to the Mahoning SWCD prior to the compliance date cited within the Notice-of-Violation. Failure to pay a re-inspection fee may result in a revoked permit.

Re-inspection fee:	$100.00
Re-inspection fee, 2nd:	$100.00

7.2 Variance

The Commissioners may grant variances to these regulations where the owner of their representative can show that a hardship exists or where compliance with these regulations is not appropriate based on the following:

- Unique topographical or physical site conditions exist on project site.
- Literal interpretation of the regulations would deprive the owner of rights enjoyed by other property owners.
- Adverse economic hardships shall not be considered a valid reason for a variance request to be granted.