TRUMBULL COUNTY

DRAINAGE
and
EROSION AND SEDIMENTATION CONTROL MANUAL

COOPERATIVE EFFORT OF THE

TRUMBULL COUNTY ENGINEERS
and
TRUMBULL COUNTY
SOIL AND WATER CONSERVATION DISTRICT

Approved this ___day of ___ 2012 by
Randy Smith, P.E. P.S., County Engineer

Adopted this 24th day of October, 2012 by The Trumbull County Commissioners as recorded in Commissioners Journal Volume ___ Page __

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Executive Summary

The federal Environmental Protection Agency has mandated portions of Trumbull County to comply with the National Pollution Discharge Elimination System (NPDES) Phase II Storm Water Program. Development of the Storm Water Management Program represents Trumbull County's commitment to preserving, protecting and improving water resources within the county. The program tasked the County Engineer, with assistance from the Trumbull County Soil and Water Conservation District, to implement portions of Minimum Control Measure 5, Post-Construction Runoff Control. As part of the County Engineer's effort to improve water quality in Trumbull County, this manual is being developed to simplify storm water requirements and as a tool to guide drainage design, erosion and sedimentation runoff control, post-construction runoff control and storm water management for construction and development within Trumbull County.

Due to Ohio Environmental Protection Agency storm water regulatory requirements (Municipal Separate Storm Sewer System [MS4] – Phase II) and water management within Trumbull County, the County Engineer's office is developing this manual as a tool to guide drainage, erosion/sedimentation control, post-construction runoff control and storm water management designs for development and construction within Trumbull 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 Trumbull County.
- Engineers responsible for design of storm water conveyance structures, storm water management plans, drainage systems, and infrastructure in support of development.
- Individuals and other professionals 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 pubic 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 with cooperation of the Trumbull County Soil and Water Conservation District. 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.

1.0 INTRODUCTION

1.1 Purpose

Experience has shown that most of the serious flooding, erosion, and water quality problems are "created." Usually this occurs from conveying more stormwater to a given area than can be carried away effectively. Ever increasing drainage problems emerge unless well-conceived, cooperative stormwater drainage and flood control programs are undertaken throughout the entire watershed. The stormwater management goals of Trumbull County, Ohio, are to prevent flooding, streambank erosion, and water quality degradation that may result from stormwater runoff from development and redevelopment projects. The County's Drainage and Erosion and Sedimentation Control Manual (the Manual) provides guidance and direction for achieving compliance with the Trumbull County Erosion and Sediment Control Rules

The purpose of the Manual is to protect existing natural stormwater resources, convey and control stormwater in a safe and responsible manner, and meet water quality goals. The Manual is intended to provide information to the general public on the stormwater policies and design practices, as well as assist developers, engineers, and staff in the preparation, review and approval of the Stormwater Management Report and Construction Drawings that must accompany private and public development proposals. This document is organized to facilitate specific design and submittal activities related to stormwater management infrastructure.

The Manual is intended to facilitate collaboration of storm water management regulations, specifically between the Trumbull County Erosion and Sediment Control Rules, Subdivision Regulations, Flood Damage Reduction Regulations and other community specific riparian setback, floodplain and storm water management regulations.

Storm water management, particularly in the area of storm water quality management, is an evolving science. The goal of the County is to be responsive to changes in storm water policy and design brought forth by the natural progression of the industry. As such, the Manual will be updated as necessary to reflect accepted standard practice in stormwater management.

The County also recognizes that there may be instances where alternative storm water standards may apply to protect sensitive ecological areas or to meet the goals of Total Maximum Daily Loads established by Ohio EPA. Where alternative standards conflict with the requirements of the Manual, the more stringent criteria shall apply.

1.2 Manual Organization

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 and Sedimentation Control Plan Requirements (Section 5)
- Flood Plain Regulations (Section 6)
- Administrative (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
- Permitting and promoting development while decreasing downstream flooding
- Urban and rural erosion and 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. If the alternative is specific to design of the water quality structure, the County Engineer will request the Administrator of the Trumbull County Soil and Water Conservation District to review and comment on the design prior to approval. Complete supporting documentation, including calculations, shall be required at the request of the County Engineer, which necessitates documentation submittal to the SWCD, for approval of these alternative methods.

1.3 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 Trumbull County. The following list provides recommendations on the use of this Manual for drainage design, construction projects, storm water management and compliance within Trumbull 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 subdivision and construction plans (Drainage designs with supporting calculations and requested, erosion and sedimentation control drawings along with storm water pollution prevention control plans) shall be submitted to the County Engineer and the Trumbull County Soil and Water Conservation District.
- Determine requirements to complete a Storm Water Pollution Prevention Plan.
- Complete Notice of Intent and submit to OEPA.
- Provide County Engineer and the Trumbull County Soil and Water Conservation District with approved copy of NOI.

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

1.4 Drainage Policy

The Trumbull County Engineer shall ensure that sound engineering practices, concepts, and methods are incorporated into planning and design of drainage infrastructure and conveyance systems within Trumbull 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 Manual specifically supports the policy of preservation and protection of lakes, rivers, streams, riparian setback zones, floodplains, flood hazard areas and wetlands. The following elements are the basis for Trumbull County's drainage criteria.

<u>Minor System</u> – The drainage system provided to accommodate relatively minor floods (2 to 10 year return period), and comprising the gutters, catch basins, storm sewers, and minor channels.

<u>Major System</u> – The route followed by runoff when the capacity of the minor drainage system is exceeded. The major drainage system consists of the roadway surface, median drains, boulevards, and storage areas; drainage swales, channels or roadside ditches conveying the major storm; or trunk storm sewers.

<u>Storm Water Storage Facilities</u> – 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/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, unless specified differently within this Manual.

1.5 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 Trumbull 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, setbacks, natural drainage features, etc.? Do these incorporated features meet local requirements?
- 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)?
- Does the project design allow for construction of BMP's capable of functioning prior to major earthwork activities?

1.6 Applicability Limitations

The Manual is being adopted as a rule of Trumbull County pursuant to the authority provided in the Ohio Revised Code. Unless otherwise exempted, the Manual shall be used for all public and private projects that change land use, existing stormwater flow patterns, and/or stormwater pollutant discharges as applicable to all premises within the County.

Any new development or redevelopment involving the following shall be subject to the Manual:

1) Construction of commercial, industrial or institutional facilities,

2) Expansion of commercial, industrial or institutional facilities,

3) Redevelopment of commercial, industrial or institutional facilities if the renovation will substantially affect stormwater drainage,

4) Construction of multi-family residential facilities,

5) Expansion of multi-family residential facilities,

6) Redevelopment of multi-family residential facilities if the renovation will substantially affect stormwater drainage,

7) Construction of residential subdivisions

8) Expansion of residential subdivisions

9) Redevelopment of residential subdivisions, if the renovation will substantially affect stormwater drainage, and

10) Construction, reconstruction, improvement, and/or modification of all private and public transportation and transit facilities which alter existing drainage patterns under this item. Routine maintenance of these facilities or the construction of elements that do not impact the existing drainage patterns are excluded.

The Manual is not applicable to the expansion, construction, or reconstruction of one single-family dwelling or one two-family dwelling on a single parcel; however, construction of this type may still fall within the jurisdiction of the Trumbull

County Erosion and Sediment Control Rules (the Rules) implemented by SWCD and the Ohio EPA NPDES General Construction Permit.

This manual will be effective thirty (30) days after adoption by the County. Any development that occurs after this date must comply with the Manual, unless a variance has been obtained as described in the manual.

The manual establishes uniform design criteria for storm water design and management practices within Trumbull County. The manual does not replace the need for sound engineering judgement nor does it preclude the use of information that may subsequently become available. The manual 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 Trumbull 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 Trumbull 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 Trumbull 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

Footing Drains	Foundation Drains	Landscape Irrigation	Lawn Watering
Dechlorinated Swimming Pool Discharges	Uncontaminated Ground Water Infiltration	Discharges from Portable Water Sources	Uncontaminated Pumped Groundwater
Street Wash Water	Air Conditioning Condensate	Individual Residential Car Washing	Water from Crawl Space Pumps
Discharges from Fire Fighting Activities	Flows from Riparian Habitats and Wetlands	Natural Springs	Water Line Flushing
Diverted Stream Flows	Irrigation Water	Rising Groundwater	

Contaminated water may not be discharged without treatment and, in some instances, permit/approval

Source: OEPA General ***Storm Water*** *Permit – Current Edition*

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 Trumbull County's Drainage Manual and other County storm water management regulations and to limit the discharge of storm water runoff from the project site to the Maximum Extent Practicable (MEP). The design engineer shall provide the certification of the plan cover sheet as detailed in Section 5.9 of this report stating that the design and plans have been prepared in accordance with the Manual and detail any deviations that do no comply.

Manual Updating

The County Engineer, with input and review from other Trumbull County Agencies, 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.

1.7 Contact Information

For specific questions regarding this manual contact:
Trumbull County Engineers Office
Design & Construction Engineer — Phone: (330) 675-2640
650 North River Road, N.W. — Fax: (330) 675-2642
Warren, OH 44483
Website – www.engineer.co.trumbull.oh.us

1.8 Design and Construction Criteria

The following criteria will be used for the design and construction and 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 Trumbull County Erosion and Sedimentation control requirements addressed in Section 5 of this manual and the Trumbull County Erosion and Sediment Control Rules implemented by the Soil and Water Conservation District.

- 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 impoundment's of runoff shall not exceed an impounded depth of 10 inches.

- Maintenance of all detention/retention facilities will be 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 Local, State and Federal Regulations

Addressing only the requirements associated with the Construction General Permit or the Trumbull County Soil and Water Conservation District regulations 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 Corps 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 Trumbull County Engineer shall require proof of compliance with these local, 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 and sedimentation control plans*) prior to plan approval.

1. OEPA – <u>Authorization of Storm Water Discharges Associated with Construction Activity</u> – Proof of compliance will consist of an OEPA approved Notice of Intent (NOI) including NPDES project permit number.

2. OEPA – <u>Municipal Separate Storm Sewer System</u> – Phase II permit – Trumbull 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. <u>Jurisdictional Determination</u> – 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. <u>Section 404 of Clean Water Act</u> – 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 the regulatory floodplain and floodway as defined by FEMA on the effective Flood Insurance Rate Map (FIRM) and corrected by Letter(s) of Map Change, as applicable. When FEMA has provided regulatory base flood elevations for the watercourse, the regulatory floodplain shall be delineated on the project site plan by elevation, not by scaling from the FEMA map. All project site plans shall identify the vertical datum used in the project and the translation equation between the project vertical datum and the vertical datum used by local FEMA mapping. Copies of the local FEMA mapping and Letter(s) of Map Change affecting the study area shall be submitted with the project site plan.

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 Trumbull 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 Trumbull 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. To assist with the permitting and review process the Trumbull County Engineer and the Soil and Water Conservation District recommend a pre-application meeting(s) to discuss, provide comments and/or review of potential designs prior to submittal. The Trumbull 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 Trumbull 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	Trumbull County Project Requirement	(1) Trumbull County Engineers Office (2) Trumbull County Soil and Water Conservation District (SWCD) 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.	(1) Ohio Environmental Protection Agency (OEPA) – Surface Water Division (2) Trumbull County SWCD Office	Trumbull County Engineers Office and SWCD requires that the Erosion and Sedimentation Control Plan be submitted in conjunction w/ the SWP3 plan.
Storm Water Pollution Prevention Plan (SWP3) + Post-Construction Best Management Practices • PCBMP Maintenance Plan • Notice of Intent (NOI) • Notice of Termination (NOT)	Large Construction Projects – 5 acres or greater. Small Construction Projects 1-5 Acres.	(1) Ohio Environmental Protection Agency (OEPA) – Surface Water Division (2) Trumbull County Engineers Office (3) Trumbull County SWCD Office	Trumbull County Engineers Office requires that the Post-Construction Plans be submitted in conjunction w/ the SWP3 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) (404) Ohio EPA (401)	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)). Trumbull County Engineer – Recommends that these types of activities/permits be minimized and alternatives considered prior to implementing this process and that permit copies should be supplied.
Floodplain Activities: • Letter of Map Revision (LOMR) • Conditional Letter of Map Revision – (CLOMR) • Trumbull County Flooding regulations	Associated with structures within floodplain/floodway. Requirement condition is no back water effect and no more than 0.5-foot of rise of water final surface elevation.	(1) Federal Emergency Management Agency (FEMA) (2) USACE (3) Trumbull County Planning Commission/ Trumbull County Floodplain Coordinator	FEMA – 45 Day permit application review period upon receipt of required information. Trumbull 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.

BASE FLOOD: The flood having a one percent chance of being equaled or exceeded in any given year. The base flood may also be referred to as the 1% chance annual flood or one-hundred (100) year flood.

BASE (100-YEAR) FLOOD ELEVATION (BFE): The water surface elevation of the base flood in relation to a specified datum, usually the National Geodetic Vertical Datum of 1929 or the North American Vertical Datum of 1988, and usually expressed in Feet Mean Sea Level (MSL). In Zone AO areas, the base flood elevation is the natural grade elevation plus the depth number (from 1 to 3 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 (CPWQv): Volume of storm water runoff that must be captured and treated before discharge from the developed site after construction is complete. CPWQv 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 <u>percentage increase in volume</u> 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 of the hydraulically unique drainage areas with individual outlet points on the development area.

DISTURBED AREA: An area where clearing, grading, excavating, filling or other alteration of land surface where natural or man-made cover is destroyed in a manner that exposes soils.

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 (ESC): 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.

EROSION AND SEDIMENT(ATION) CONTROL (ESC) PLAN: For the purposes of the Manual an ESC Plan shall consist of a existing and proposed site conditions, a Site Drainage Plan and the ESC location plan with supporting details and calculations.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA): The agency with the overall responsibility for administering the National Flood Insurance Program.

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 to the satisfaction of the County Engineer.

FLOOD OR FLOODING: A general and temporary condition of partial or complete inundation of normally dry land areas from:

1. The overflow of inland or tidal waters, and/or
2. The unusual and rapid accumulation or runoff of surface waters from any source.

FLOOD HAZARD BOUNDARY MAP (FHBM): Usually the initial map, produced by the Federal Emergency Management Agency, or U.S. Department of Housing and Urban Development, for a community depicting approximate special flood hazard areas.

FLOOD INSURANCE RATE MAP (FIRM): An official map on which the Federal Emergency Management Agency or the U.S. Department of Housing and Urban Development has delineated the areas of special flood hazard.

FLOOD INSURANCE RISK ZONES: Zone designations on FHBMs and FIRMs that indicate the magnitude of the flood hazard in specific areas of a community. Following are the zone definitions:

Zone A:
Special flood hazard areas inundated by the 100-year flood; base flood elevations are not determined.
Zones A1-30 and Zone AE:
Special flood hazard areas inundated by the 100-year flood; base flood elevations are determined.
Zone AO:
Special flood hazard areas inundated by the 100-year flood; with flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths are determined.
Zone AH:
Special flood hazard areas inundated by the 100-year flood; flood depths of 1 to 3 feet U (usually areas of ponding); base flood elevations are determined.

Zone A99:
Special flood hazard areas inundated by the 100-year flood with average depths of less than 1 foot or with contributing drainage area less than 1 square mile; and areas protected by levees from the base flood.
Zone B and Zone X (shaded):
Areas of 500-year flood; areas subject to the 100-year flood with average depths of less than 1 foot or with contributing drainage area less than 1 square mile; and areas protected by levees from the base flood.
Zone C and Zone X (unshaded):
Areas determined to be outside the 500-year floodplain.

FLOOD INSURANCE STUDY (FIS): The official report in which the Federal Emergency Management Agency or the U.S. Department of Housing and Urban Development has provided flood profiles, floodway boundaries (sometimes shown on Flood Boundary and Floodway Maps), and the water surface elevations of the base flood.

FLOODWAY: A floodway is the channel of a river or other watercourse and the adjacent land areas that have been reserved in order to pass the base flood discharge. A floodway is typically determined through a hydraulic and hydrologic engineering analysis such that the cumulative increase in the water surface elevation of the base flood discharge is no more than a designated height. In no case shall the designated height be more than one foot at any point within the community.

FREEBOARD: A factor of safety usually expressed in feet above a flood level for the purpose of floodplain management. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, obstructed bridge openings, debris and ice jams, and the hydrologic effect of urbanization in a watershed.

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.

HYDROLOGIC AND HYDRAULIC ENGINEERING ANALYSIS: An analysis performed by a professional engineer, registered in the State of Ohio, in accordance with standard engineering practices as accepted by FEMA, used to determine flood elevations and/or floodway boundaries.

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

IMPERVOUS: 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.

LETTER OF MAP CHANGE (LOMC): A Letter of Map Change is an official FEMA determination, by letter, to amend or revise effective Flood Insurance Rate Maps, Flood Boundary and Floodway Maps, and Flood Insurance Studies. LOMC’s are broken down into the following categories:

Letter of Map Amendment (LOMA): A revision based on technical data showing that a property was incorrectly included in a designated special flood hazard area. A LOMA amends the current effective Flood Insurance Rate Map and establishes that a specific property is not located in a special flood hazard area.

Letter of Map Revision (LOMR): A revision based on technical data that, usually due to manmade changes, shows changes to flood zones, flood elevations, floodplain and floodway delineations, and planimetric features. One common type of LOMR, a LOMR-F, is a determination concerning whether a structure or parcel has been elevated by fill above the base flood elevation and is, therefore, excluded from the special flood hazard area.

Conditional Letter of Map Revision (CLOMR): A formal review and comment by FEMA as to whether a proposed project complies with the minimum National Flood Insurance Program floodplain management criteria. A CLOMR does not amend or revise effective Flood Insurance Rate Maps, Flood Boundary and Floodway Maps, or Flood Insurance Studies.

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.

NATIONAL FLOOD INSURANCE PROGRAM (NFIP): The NFIP is a Federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding. This insurance is designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods. Participation in the NFIP is based on an agreement between local communities and the Federal government that states if a community will adopt and enforce floodplain management regulations to reduce future flood risks to all development in special flood hazard areas, the Federal government will make flood insurance available within the community as a financial protection against flood loss.

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.

PERMANENT STABILIZATION: The establishment of permanent vegetation, decorative landscape mulching, matting, sod, rip-rap and landscaping techniques to provide permanent erosion control on areas where construction operations are complete or where no further disturbance is expected for at least one 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 Manual.

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 or 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 Trumbull SWCD.

SOIL DISTURBING ACTIVITY: Clearing, grubbing, grading, excavating, filling, or other alteration on 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.

SPECIAL FLOOD HAZARD AREA: Also known as "Areas of Special Flood Hazard", it is the land in the floodplain subject to a one percent or greater chance of flooding in any given year. Special flood hazard areas are designated by the Federal Emergency Management Agency on Flood Insurance Rate Maps, Flood Insurance Studies, Flood Boundary and Floodway Maps and Flood Hazard Boundary Maps as Zones A, AE, AH, AO, A1-30, and A99. Special flood hazard areas may also refer to areas that are flood prone and designated from other federal state or local sources of data including but not limited to historical flood information reflecting high water marks, previous flood inundation areas, and flood prone soils associated with a watercourse.

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: Water runoff from rain events, snowmelt, surface runoff, and drainage.

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

STORM WATER POLLUTION PREVENTION PLAN (SWP3): For the purpose of the Manual a SWP3 shall consist of a Site Drainage Plan, Erosion and Sedimentation Control Plan, Post-Construction Design Plan and Post-Construction Operation and Maintenance Plan with supporting details and calculations..

STRUCTURE: A walled and roofed building, manufactured home, or gas or liquid storage tank that is principally above ground.

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, 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).

1.11 Severability

If any provision of this manual is held invalid, the remainder of the manual and the application of such provisions shall remain in effect.

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.

Usage Limitations for Hydrologic Methodologies

Method	Minor Systems (Storm Sewers)	Major Systems (Culverts and Streams)	Critical Storm Determination	Pond Routing
Rational Method (2.2)	YES	NO	NO	NO
SCS Graphical Peak Discharge (2.3)	NO	YES	NO	NO
SCS Unit Hydrograph (2.4)	NO	YES	Tc > 0.1 HR	Tc > 0.1 HR
WRI 03-4164 (2.5)	NO	YES	NO	NO
WRI 93-4080 (2.5)	NO	YES	NO	NO
WRI 93-135 (2.5)	NO	YES	NO	NO
Alternate Detention Method (3.4.3)	NO	NO	Tc < 0.1 HR	Tc < 0.1 HR

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. The Rational Method is explicitly prohibited from use in volumetric calculations, including critical storm determination and storage routing calculations for runoff quantity control.

Rational Formula:

Q = FCIA

Where: Q = rate of runoff (cfs)
C = runoff coefficient
I = rainfall intensity (in/hr)
A = drainage area (acres)
F = correction factor (footnote 7 from Table 2-1)

- 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 "C" for Typical Land Uses

. Cover Type and Hydrologic Condition	Average percent impervious area (5)	Runoff Coefficient for Hydrologic Soil Group (7)			
		A	B	C	D
Fully developed urban areas (vegetation established) (1)					
Impervious areas: Paved parking lots, roofs, driveways, etc. (excluding unpaved right-of-way)		0.94	0.94	0.94	0.94
Open space (lawns, parks, golf courses, cemeteries, etc.) Poor condition (grass cover, 50%) Fair condition (grass cover 50% to 75%) Good condition (grass cover>75%)		 0.29 0.07 NA	 0.48 0.30 0.19	 0.63 0.48 0.39	 0.70 0.58 0.50
Commercial and business (TND – TC) (6)	85	0.70	0.77	0.83	0.85
Industrial	72	0.52	0.67	0.75	0.80
Residential Districts by Average Lot Size (6): Multi-family (TND – NC) 1/12 to 1/6 acre lots (TND – NG) 1/8 acre (TND – NE) ¼ acre ½ acre 1 acre	 80 75 65 38 25 20	 0.63 0.56 0.44 0.19 0.11 0.08	 0.75 0.70 0.60 0.40 0.32 0.29	 0.80 0.77 0.72 0.56 0.50 0.48	 0.83 0.83 0.77 0.65 0.60 0.58
Undeveloped or agricultural lands (1)					
Cultivated Land: Without conservation treatment With conservation treatment		 0.35 0.21	 0.52 0.34	 0.67 0.46	 0.75 0.52
Pasture, grassland, or range – continuous forage for grazing. (2)	Hydrologic condition: Poor Fair Good	 0.29 0.07 NA	 0.48 0.30 0.19	 0.63 0.48 0.39	 0.70 0.58 0.50
Meadow – continuous grass, protected from grazing and generally mowed for hay	--	NA	0.16	0.34	0.46
Brush – brush-weed-grass mixture with brush the major element (3)	Poor Fair Good	0.06 NA NA	0.27 0.13 0.06	0.44 0.32 0.25	0.56 0.44 0.37
Woods (4)	Poor Fair Good	0.04 NA NA	0.26 0.18 0.12	0.44 0.37 0.32	0.56 0.48 0.44
Farmsteads – buildings, lanes, driveways, and surrounding lots.	--	0.17	0.39	0.54	0.63

Notes:
NA – Method to derive value is not applicable for curve number values less than 40.
(1) Average runoff condition, and Ia=0.2s.
(2) Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.

Good: >75% ground cover and lightly or only occasionally grazed.

(3) Poor: <50% ground cover.
Fair: 50 to 75%
Good: >75% ground cover.

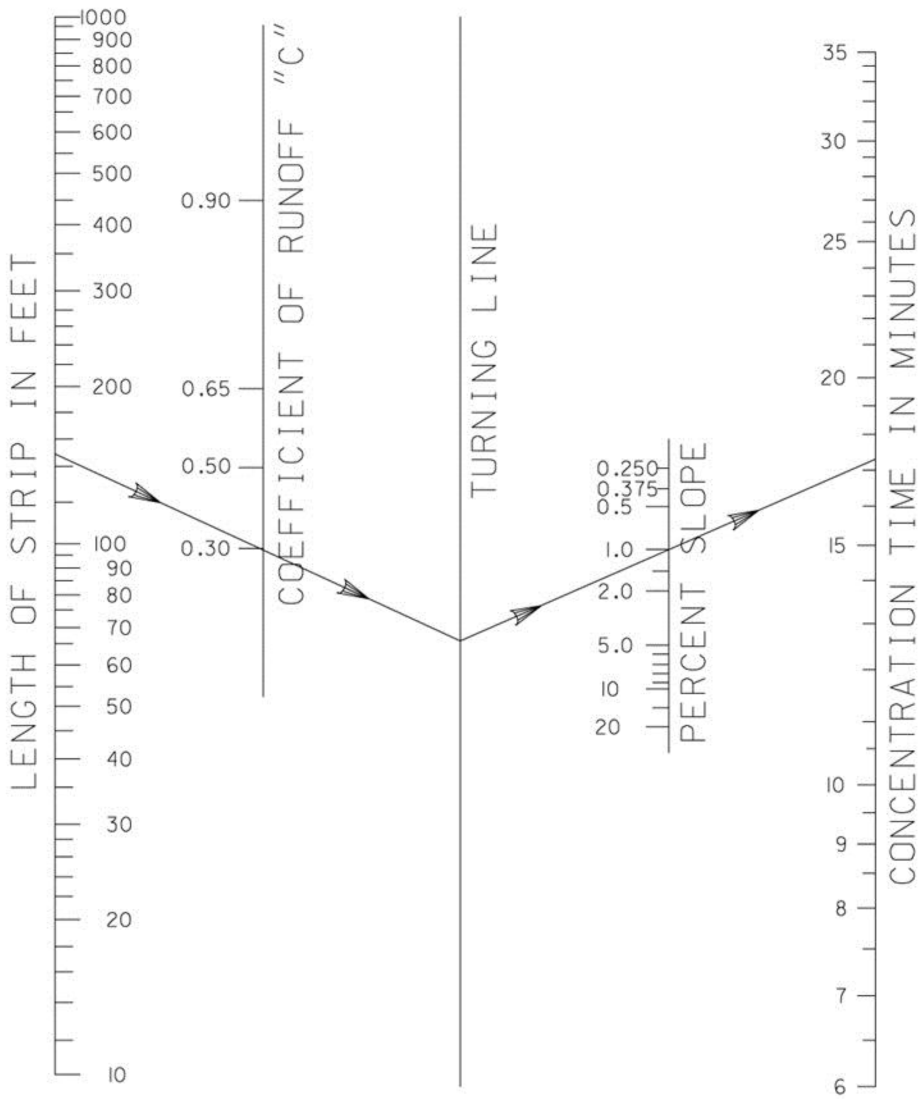
(4) Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

(5) The average percent impervious area shown was used to develop the composite CN's which were then used to derive runoff coefficient values. Other assumptions are as follows: impervious areas have a runoff coefficient of 0.94 (or CN of 98), and pervious areas are considered equivalent to open space in good hydrologic condition.

(6) Acronyms for zoning of residential districts are as follows:
TND – TC: Traditional Neighborhood Development – Town Center
TND – NC: Traditional Neighborhood Development – Neighborhood Center
TND – NG: Traditional Neighborhood Development – Neighborhood General
TND – NE: Traditional Neighborhood Development – Neighborhood Edge

(7) These runoff coefficients were calculated from CN's drawn from the NRCS (SCS) Peak Discharge Method from TR-55 assuming a 10-year, 24-hour storm. For larger design storms, the runoff coefficients should be increased using the following C value correction factors:
1.0 for the 10-year design storm and less
1.1 for the 25-year design storm
1.2 for the 50-year design form
1.3 for the 100-year design storm

FIGURE 2-1 Overland Flow Chart



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

Table 2-2: Rainfall Intensity for Trumbull County

Time of Concentration	2 Yr.	5 Yr.	10 Yr.	25 Yr.	50 Yr.	100 Yr.
5	3.60	4.44	5.16	6.36	7.32	8.52
6	3.44	4.26	4.96	6.08	7.02	8.16
7	3.33	4.13	4.82	5.88	6.81	7.90
8	3.24	4.04	4.71	5.73	6.65	7.71
9	3.17	3.96	4.63	5.61	6.52	7.56
10	3.12	3.90	4.56	5.52	6.42	7.44
11	3.01	3.75	4.37	5.31	6.17	7.15
12	2.92	3.63	4.22	5.14	5.97	6.90
13	2.84	3.53	4.09	4.99	5.80	6.69
14	2.78	3.44	3.98	4.87	5.65	6.51
15	2.72	3.36	3.88	4.76	5.52	6.36
16	2.61	3.23	3.73	4.57	5.30	6.11
17	2.52	3.11	3.59	4.40	5.11	5.89
18	2.43	3.01	3.47	4.25	4.94	5.69
19	2.36	2.91	3.37	4.12	4.79	5.52
20	2.29	2.83	3.27	4.00	4.65	5.36
21	2.23	2.75	3.18	3.89	4.53	5.22
22	2.17	2.69	3.10	3.79	4.41	5.09
23	2.12	2.62	3.03	3.70	4.31	4.97
24	2.08	2.57	2.97	3.62	4.22	4.86
25	2.03	2.51	2.90	3.54	4.13	4.76
26	1.99	2.46	2.85	3.47	4.05	4.67
27	1.96	2.42	2.80	3.41	3.97	4.58
28	1.92	2.38	2.75	3.35	3.90	4.50
29	1.89	2.34	2.70	3.29	3.84	4.43
30	1.86	2.30	2.66	3.24	3.78	4.36
35	1.66	2.06	2.38	2.90	3.39	3.91
40	1.52	1.88	2.18	2.65	3.09	3.57
45	1.40	1.74	2.01	2.45	2.86	3.30
50	1.31	1.63	1.88	2.30	2.68	3.09
55	1.23	1.54	1.78	2.17	2.53	2.91
60	1.17	1.46	1.69	2.06	2.40	2.77
65	1.10	1.37	1.59	1.94	2.26	2.61
70	1.04	1.30	1.51	1.84	2.14	2.47
80	0.95	1.18	1.37	1.67	1.94	2.24
90	0.87	1.09	1.26	1.54	1.79	2.06
100	0.81	1.01	1.17	1.43	1.66	1.92
110	0.77	0.95	1.10	1.35	1.56	1.81
120	0.73	0.90	1.05	1.28	1.48	1.71

Intensities determined from the Bulletin 71 "Rainfall Frequency Atlas of the Midwest", created by the Midwest Climate Center and Illinois Water Survey, 1992.

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, where the drainage area consists of homogenous soil types and land-surface cover. This method shall be used to design storm culverts.

2.3.2 Equations and Concepts

Peak Discharge Equation:

$$Qp = q_u AQFp$$

Where: Qp = peak discharge (cfs)
q_u = unit peak discharge (cfs/mi^2/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 (SCS Type II)
- Storm Frequency

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

Frequency	24-Hour Rainfall (in.)
2-year	2.50
5-year	3.10
10-year	3.60
25-year	4.39
50-year	5.11
100-year	5.89

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 high runoff potential due to slow 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 Trumbull County to determine Soil Type and corresponding Hydrologic Group within project area.

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 Ią – 0.2S)					
LAND USE DESCRIPTION		**HYDROLOGIC SOIL GROUP**			
		A	B	C	D
Cultivated land: without conservation treatment		72	81	88	91
: with conversation 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		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.		39	61	74	80
good condition: grass cover on 75% or more of the area		49	69	79	84
fair condition: grass cover on 50% to 75% of the area					
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential					
Average lot size	Average % Impervious				
1/8 acre or less	65	77	85	90	92
¼ acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
½ acre	25	54	70	80	85
1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.					
Streets and roads:					
paved with curbs and storm sewers		98	98	98	98

[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

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

2. Runoff

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

A 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.

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

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 – Manning's "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 Grasses(2)	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 compiles 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).

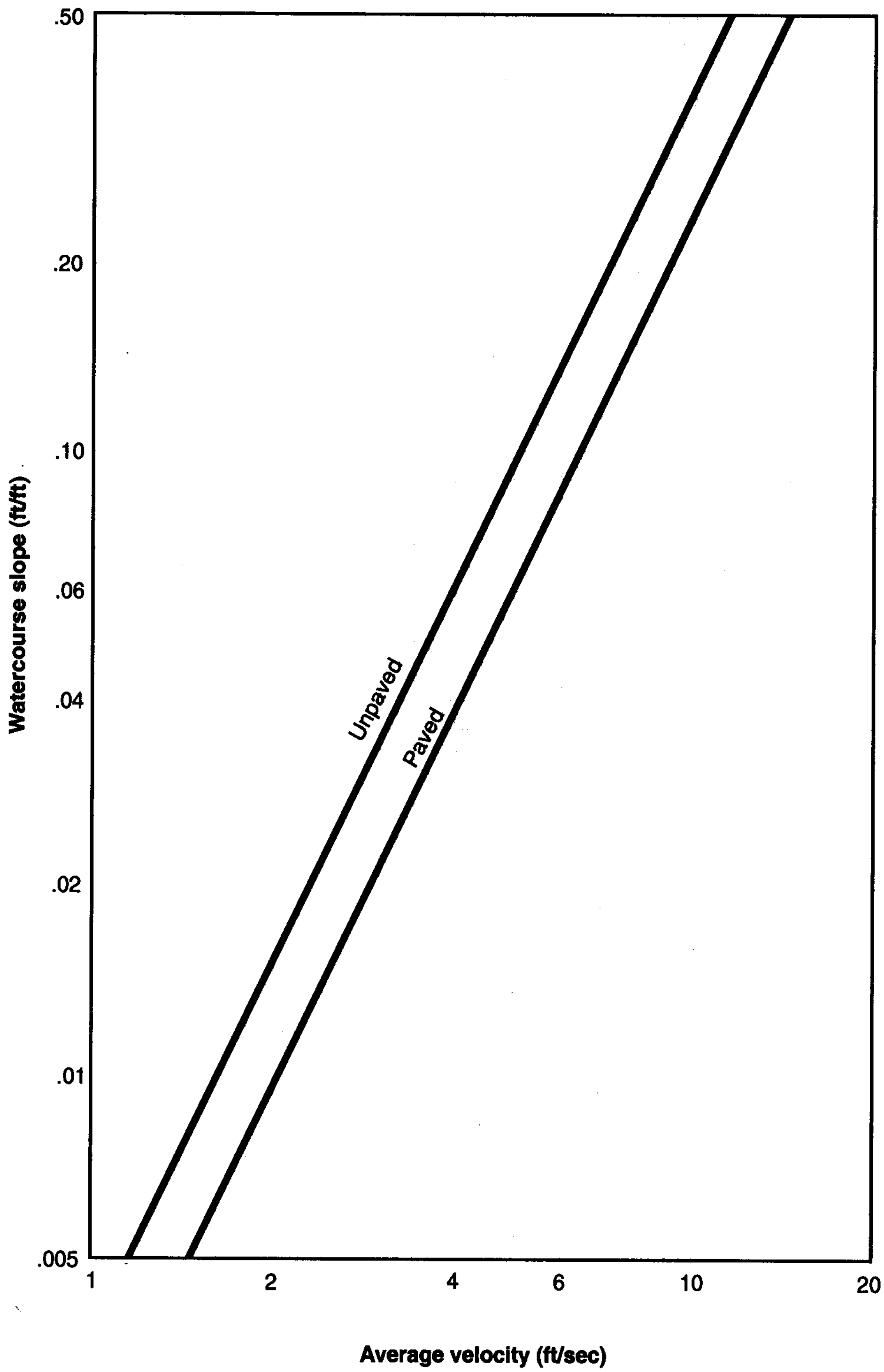
Once the average velocity (V) is determined, the Time of Travel for shallow concentrated flow can be determined using the following equation:

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

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



Source: 210-VI-TR-55, Second Edition, 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 2-6a and 2-6b for pipe flow, Table 2-7 for constructed channels, and Table 2-8 for natural streams.

Manning's Equation is:

$$Q = AV = \left(\frac{1.49}{n}\right) AR^{2/3}\sqrt{S}$$

$V = \dfrac{1.49R^{2/3}\sqrt{S}}{n}$	solved for velocity
$R = \left(\dfrac{V\,n}{1.49\,S^{1/2}}\right)^{3/2}$	solved for hydraulic radius
$S = \left(\dfrac{V\,n}{1.49\,R^{2/3}}\right)^{2}$	solved for hydraulic grade line
$n = \left(\dfrac{1.49\,R^{2/3}\,\sqrt{S}}{V}\right)$	solved for roughness coefficient

Where:

Q = Discharge (ft^3/s)
A = Cross-Sectional Area of Flow (ft^2)
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

*Factory values may be used if documentation is submitted.
*The Manning's "n" values in Table 2-6a and 2-6b 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									
	Annular	Helical							
Corrugations		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, Stone 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:

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

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 (Tc) or travel time (Tt)

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	
69	0.899		

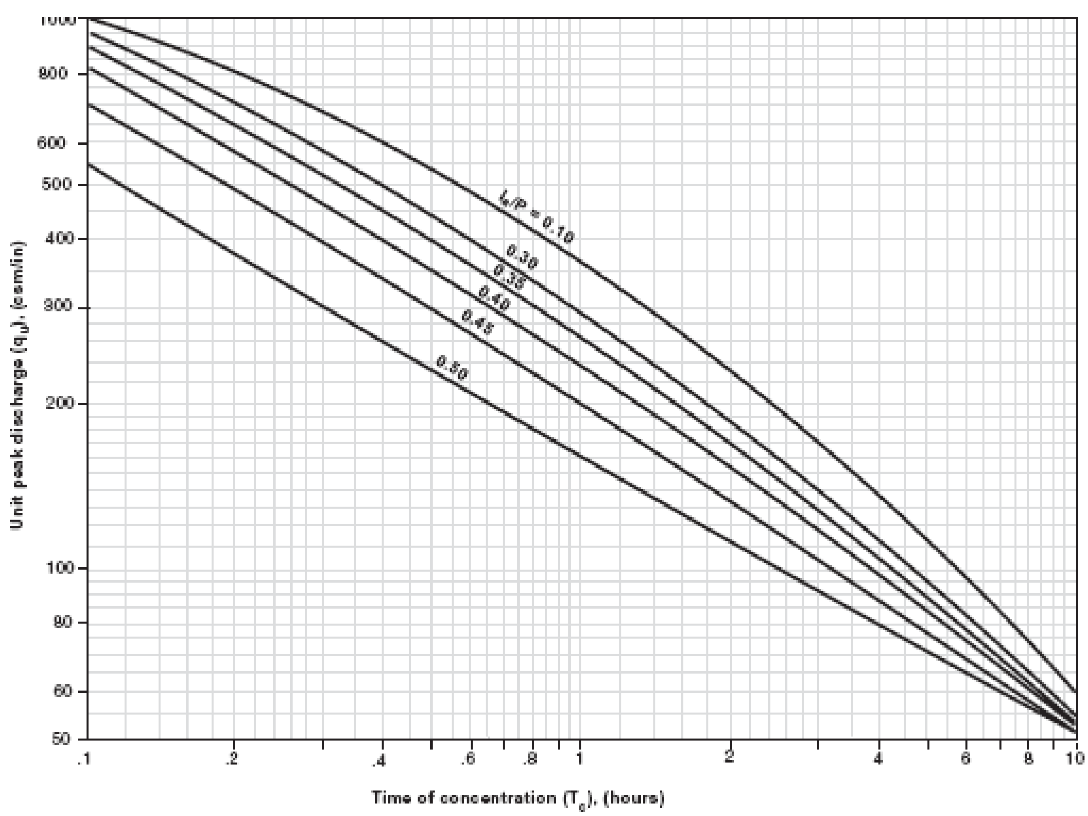
The Fp factor is an adjustment for pond and swamp areas that are spread throughout the watershed. It can only be applied for ponds or swamps that are not in the Tc path.

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

Pond & Swamp Areas (%)	Fp
0.0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

The unit peak discharge, qu, 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 is estimated from Table 2-10.

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

$$Qp = q_u AQFp$$

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

Worksheet 4: Graphical Peak Discharge Method

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

The 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.

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

Other accepted hydrologic computer models for performing SCS hydrograph calculations include:

- TR-20 (February 1992)
- TR-20 Win v. 1.00.002 (January 2005)
- TR-55 (June 1986)
- WinTR-SS v. 1.0.08 (January 2005)
- HEC-1 4.0.1 and up (May 1991)
- HEC-NMS 1.1 and up (March 1998)
- SWMM (Runoff) 4.30 (May 1994) and 4.31 (January 1997)
- SWMM 5 Version 5.0.005 and up (May 2005)
- Pond Pack v. 8 and up (May 2002)
- XP-SWMM 8.52 and up
- XP-Storm 10.0 (May 2006)

List adopted from FEMA Nationally Accepted Models Meeting the Minimum Requirement of the NFIP.

In addition, Hydraflow Hydrographs will be considered acceptable for non-FEMA related calculations (use of Rational Method for volume calculations is not allowed).

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

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 = 0.1 HR * * *)																															
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	157	122	98	75	64	56	50	45	41	36	33	30	27	24	21	20	19	18	16	13	12	0
.20	18	25	35	61	110	215	418	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	553	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	58	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 * * *)																															
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	357	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	138	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	38	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	25	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	55	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	56	48	43	35	30	24	18
IA/P = 0.50 (* * * TC = 0.1 HR * * *)																															
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	285	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	46	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)

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 = 0.2 HR * * *)																															
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	485	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	438	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	288	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	18	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 * * *)																															
0.0	0	0	0	39	180	545	697	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	108	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	186	271	288	247	165	110	76	58	49	44	40	35	32	29	26	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 * * *)																															
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	228	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	66	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

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 = 0.3 HR * * *																IA/P = 0.10			
0.0	20	28	41	118	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	478	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	359	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	68	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	58	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	285	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			
0.0	0	0	0	11	64	251	525	574	454	303	221	173	140	104	88	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	352	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	168	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	200	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			
0.0	0	0	0	0	1	25	151	299	277	219	187	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	106	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	184	173	146	122	105	94	82	73	64	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

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 = 0.4 HR * * *																IA/P = 0.10			
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	478	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	85	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			
0.0	0	0	0	4	26	113	296	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	182	221	148	90	63	51	45	36	31	24	18
IA/P = 0.50													* * * TC = 0.4 HR * * *																IA/P = 0.50			
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	28	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	89	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	101	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

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 * * *																																
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	484	499	434	343	265	162	108	80	65	55	49	42	36	33	29	26	23	21	20	19	16	14	12	0
.20	14	19	25	38	47	69	116	207	332	434	477	449	378	238	149	101	77	62	53	45	39	34	30	27	24	22	20	19	17	14	12	0
.30	13	18	24	35	43	60	97	170	278	382	446	448	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	408	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	118	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	118	182	319	374	328	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	188	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 * * *																																
0.0	0	0	0	1	9	53	157	314	433	439	379	299	237	159	118	95	81	71	65	56	50	46	42	38	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	388	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	295	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	46	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	125	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 * * *																																
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	85	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	169	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	45	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

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 * * *																																
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	106	74	56	43	35	30	27	24	22	20	18	16	12	0
.75	8	10	13	17	18	21	23	26	31	39	55	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	249	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 * * *																																
0.0	0	0	0	0	1	6	30	86	174	266	326	348	328	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	308	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	188	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	0	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 * * *																																
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	8	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	55	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

HYDROGRAPH TIME(HOURS)

IA/P = 0.10 * * * TC = 1.0 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	11	15	20	29	35	47	72	112	168	231	289	329	357	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	95	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	38	54	82	123	176	232	281	332	303	238	179	136	105	76	59	45	35	30	27	24	22	20	18	16	12	1
.30	9	12	16	22	24	28	35	48	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	38	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	208	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

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	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	168	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	18	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	209	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	69	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	158	192	151	103	73	56	41	34	26	18

IA/P = 0.50 * * * TC = 1.0 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	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	8
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	89	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

HYDROGRAPH TIME(HOURS)

IA/P = 0.10 * * * TC = 1.25 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	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	208	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	186	247	239	180	108	68	48	37	31	27	22	19	14	10
2.0	2	3	4	5	6	6	7	7	8	8	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	88	184	218	169	109	70	49	31	24	18	12

IA/P = 0.30 * * * TC = 1.25 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	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	158	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	228	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	218	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	194	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

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	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	103	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

TRVL TIME (hr) / 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 = 1.5 HR * * *																IA/P = 0.10				
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	98	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	238	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	80	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	181	128	85	58	35	25	18	12
IA/P = 0.30												* * * TC = 1.5 HR * * *																IA/P = 0.30				
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	178	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	108	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	55	47	41	36	33	29	26	20	5
.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	48	37	28	19
IA/P = 0.50												* * * TC = 1.5 HR * * *																IA/P = 0.50				
.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	35	29	4
.10	0	0	0	0	0	0	0	2	6	12	22	35	51	84	110	125	128	123	114	102	91	79	68	61	55	50	46	43	39	35	29	4
.20	0	0	0	0	0	0	0	0	1	4	10	18	29	60	91	114	126	128	120	108	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	60	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	108	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	48	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	58	48	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

TRVL TIME (hr) / 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 = 2.0 HR * * *																IA/P = 0.10				
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	198	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	191	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	178	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				
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	8
.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	51	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	118	150	140	113	88	57	42	29	19
IA/P = 0.50												* * * TC = 2.0 HR * * *																IA/P = 0.50				
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	18	33	52	71	88	104	108	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	95	102	95	83	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

Trumbull 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 Reports 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 Reports 93-135

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

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

3.0 STORM DRAINAGE SYSTEMS

3.1 Overview

Proposed development sites and existing improvements shall be protected from flood damage and excess 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.

3.1.1 General Provisions

Development shall not:

- Result in any new or additional expense to any person other than the Applicant for flood protection or for lost environmental stream uses and functions; nor
- Increase flood elevations or decrease flood conveyance capacity upstream or downstream of the area under the ownership or control of the Applicant; nor
- Pose any new or additional increase in flood velocity or impairment of the hydrologic and hydraulic functions of streams or floodplains; nor
- Unreasonably or unnecessarily degrade surface or ground water quality; nor
- Violate any provision of this manual either during or after construction

Storm water and erosion and sediment control facilities shall be constructed at the beginning of all construction projects and prior to site grading. Considerations for timing of erosion and sediment control BMP’s include the ability to convey, pond and treat on-site sediment laden water discharges prior to major earthwork activities.

100-year flood elevations shall be identified for all drainage paths within the project limits. All usable space in new buildings or added to existing buildings shall be elevated at least one foot above the adjacent base flood elevation to prevent the entry of surface stormwater.

All parcels constructed on fill material in or adjacent to the 100-year inundation area for a drainage path shall be graded in accordance with the recommendations in FEMA Technical Bulletin 10-01.

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 twelve (12) inches in diameter.

Lateral storm connections to building sites shall be 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.

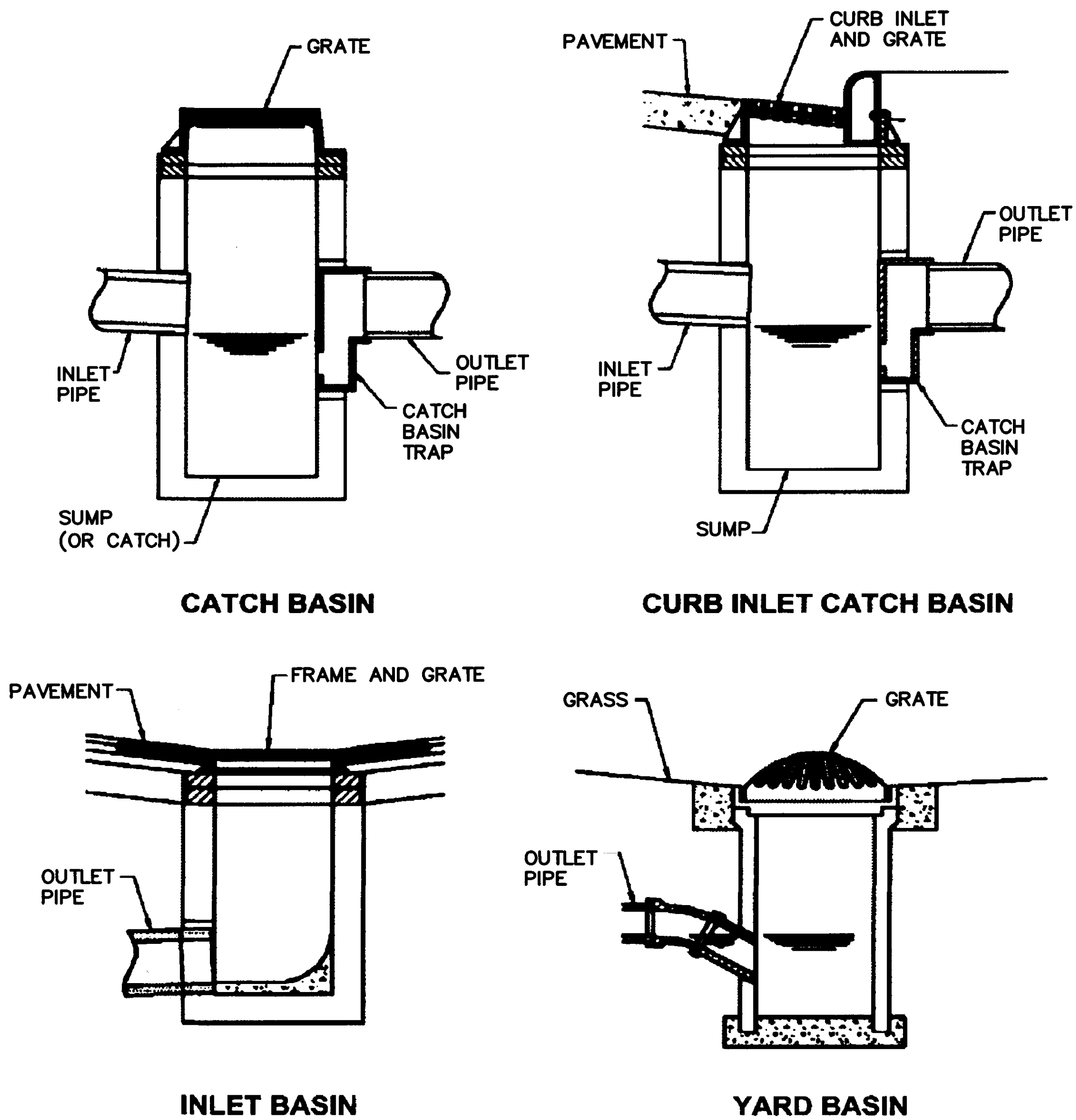
For sewers sized less than 36 inches in diameter, manholes shall be spaced at not over 400 feet. For sewers 36 inches through 60 inches in diameter, manholes shall be spaced at not over 600 feet. In sewers larger than 60 inches in diameter, manhole spacing shall not exceed 1,000 feet.

Design details must follow Trumbull County or ODOT Design Standards as a minimum criteria.

All easements for all storm drainage systems shall be 30 foot in width.

3.2.2 Inlet Types and Locations

FIGURE 3-1: Storm Inlet Types



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 ODOT CMS and ODOT Standard Details. The location of these structures is as follows:

- Place upstream of all intersections, bridges, pedestrian ramps, commercial drive aprons, intersection return radii, and curb termini.
- Structures should be placed 10' off drive aprons, intersection return radii, pedestrian ramps, or curb termini when practicable.
- Place structure in pavement sags.
- 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 sewer 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 (CMP) 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 ΔA from the current structure to the ΣA 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 ΣT (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 ΔCA value of the current structure added to the upstream ΣCA value.

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

Column 14: The design discharge found by the multiplication of the ΣCA 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 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 the ODOT Location and **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.

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

A culvert design form will be required for submittal. A blank form is included in the appendix.

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 "CDSS"

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/culvermaster/

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 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 three outlets or spillways: a water quality outlet, a principal outlet and a secondary (or emergency) outlet. The purpose of the water quality outlet is to capture and treat the most frequent rainfall events in Ohio for pollutants associated with storm water discharges. Rainfall of approximately 0.75-inches encompasses approximately 85% of all events in a given year. Water quality outlet design variations and techniques are plentiful but typically incorporate a protected reverse flow or perforated outlet designed to release the retained water volume within 24 to 48 hours. 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. A Professional Engineer shall certify that the receiving watercourse has adequate capacity to convey the runoff from the project site.

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.

Storage facilities shall be designed and constructed with the following characteristics:

- Water surface depths two feet above the base flood elevation will not damage the storage facility.
- The storage facilities shall be accessible and easily maintained. All facilities shall have 30 foot ingress/egress easements and other provisions as required for maintenance access.
- All outlet works shall function without human intervention or outside power and shall operate with minimum maintenance.
- Outlet works shall have an outlet pipe of minimum 12 inches diameter.
- Control orifices shall incorporate anti-clogging measures when the orifice measures less than 4 inches in the shortest direction.
- Storage facilities shall facilitate sedimentation and catchment of floating material.
- Storage facilities shall minimize impacts of stormwater runoff on water quality by incorporating best management practices.

- Storage facilities shall provide an overflow structure and overflow path that can safely pass excess flows through the development site. The minimum design rate shall be the undetained peak flow rate of the upstream watershed for the 100-year design rainfall event. See Section 2.2 for conveyance calculation requirements.

Storage facilities shall not be located within 1) regulatory floodplain 2) the area inundated by the base flood or other major stormwater systems with tributary drainage area greater than one square mile 3) a stream channel unless authorized by all governing regulatory agencies.

Developments with storage facilities that have off-site flow tributary to the site either shall provide storage sufficient to accommodate runoff from the off-site tributary watershed and the site, or shall store the site runoff and convey off-site flows through the site around the storage facility.

- When the ratio of off-site tributary area to onsite tributary area is greater than five, the off-site runoff shall be conveyed through the site and around the storage facility.

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 six 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 predevelopment 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-year 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 storage volume 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:**	
0	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-developed 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	
Business-Neighborhood			0.70	
Res. 12,000-25,000 S.F.			0.42	
Res. 25,000-and over			0.30	
Apartment			0.70	
Industrial – Light			0.80	
Industrial – Heavy			0.90	
Parks, Cemeteries			0.07	
Playgrounds			0.13	
Railroads Yards			0.40	
Unimproved			0.02	
Shopping Center			0.90	
Pave-Asph & Conc.			1.	
Pave – Brick			1.	
Roofs			0.90	
Lawns			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 <u>Soil Group</u>	**<u>Infiltration</u> <u>(in/hr)</u>**
A	1.0
B	0.6
C	0.5
D	0.5

Step 4: **Determine Allowable Discharge Rate (D)**

D = ________(cfs/acre)

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 5: **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**	**<u>In.</u>** **Hr.**	**___ x I** **C.F.S.**	**I - ___** **In./Hr.**	**__R__$_y$ T** **Cu. Ft.**	**$V_i - \Delta T$** **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:

Qy___ = 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:

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

Column (4): END OF RUNOFF TIME:

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

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

$V_o = D \times (T_e / 2) \times 60$ (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" = 0.94 (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	dT	I	Q	R	Vi	Te	Vo	Storage
Min.	Min.	In/Hr.	Cfs	In./Hr.	Cu. Ft.		Cu. Ft.	Cu. Ft.
10	5	4.56	4.29	4.51	2729	16.2	146	2583
15	10	3.88	3.65	3.83	3476	21.8	196	3280
20	15	3.27	3.07	3.22	3896	27.3	245	3651
30	25	2.66	2.50	2.61	4737	38.2	343	4394
40	35	2.18	2.05	2.13	5155	48.8	440	4715
50	45	1.88	1.77	1.83	5536	59.4	535	5001
60	55	1.69	1.59	1.64	5953	69.9	629	5324
70	65	1.51	1.42	1.46	6183	80.2	722	5461
80	75	1.37	1.29	1.32	6389	90.4	813	5575
90	85	1.26	1.18	1.21	6588	100.4	904	5685
100	95	1.17	1.10	1.12	6776	110.4	993	5783
110	105	1.10	1.03	1.05	6988	120.3	1082	5905
120	115	1.05	.99	1.00	7260	130.2	1172	6088
180	**175**	**0.77**	**0.72**	**0.72**	**7805**	**186.0**	**1674**	**6131**
360	355	0.45	0.42	0.40	8712	331.5	2984	5728

*The required storage volume for this example is 6,131 cft. Please note that the user is instructed to complete this table for all storm events to determine the largest required volume. Additional storm duration may need to be added to find the critical duration for a given storm event.

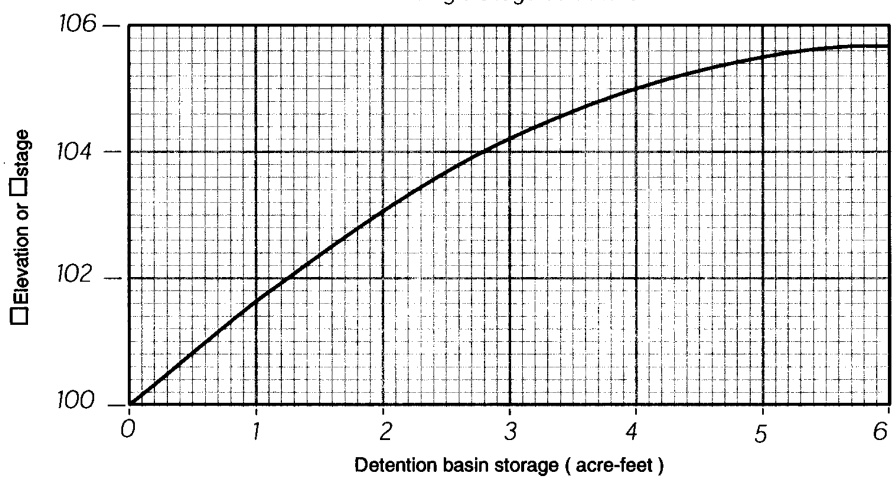
3.4.4 Estimate Storage Requirements using S.C.S. Methods

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*



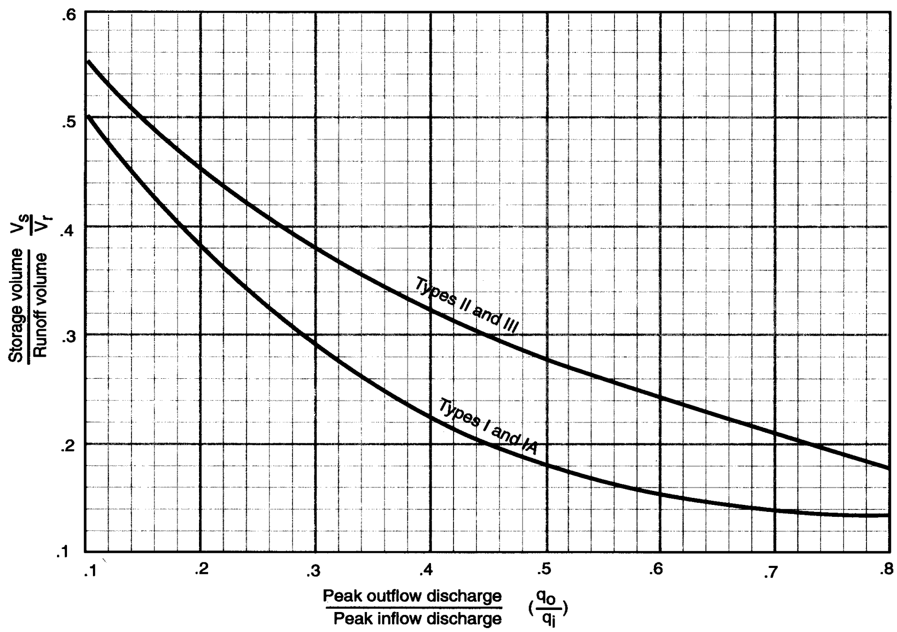
1. Data:
   Drainage area .... A_m = 0.117 mi²
   Rainfall distribution type (I, IA, II, III) = II

	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 ($V_r = QA_m 53.33$)	21.2	
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.

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 ________

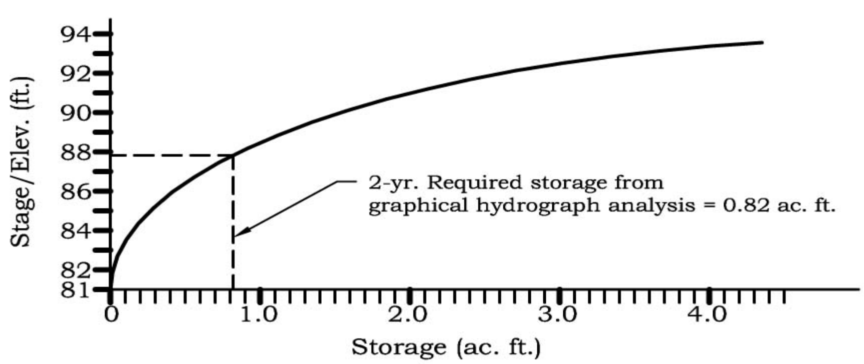
DESCRIPTION: ______________________________

ATTACH COPY OF TOPO: SCALE - 1"= ______ ft.

1	2	3	4	5	6	7	7
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).

NOTE: All discharge calculations shall be verified under a full range of expected tailwater conditions.

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:

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

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
0.4	Ragged Edge Orifice Cut by Torch.
0.54	Uniform Orifice Project Into Control Structure
0.61	Uniform Orifice with Thickness Less than Twice Orifice Diameter
0.82	Uniform Orifice with Thickness 2-3 Times Orifice Diameter

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

The most common types of sharp crested weirs are:

- Contracted Rectangular
- Suppresed Rectangular
- Cipolletti Contracted
- Contracted Triangular or V-Notch

The equations for each type are described below:

- **Contracted Rectangular Weir**

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

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)
$C = 3.33$

- **Suppressed Rectangular Weir**

$$Q = CLH^{3/2}$$

Where:

Q = discharge, (ft^3/s)
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)
$C = 3.33$

- **Contracted Cipolletti Weir (trapezoidal)**

$$Q = CLH^{3/2}$$

Where:

Q = discharge, (ft^3/s)
L = length of crest (ft)
H = depth of flow above elevation of crest (ft)
$C = 3.367$

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

$$Q = CH^{2.48}$$

Where: Q = discharge, (ft^3/s)
H = depth of flow above elevation of crest (ft)
$C = 2.49$

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. Therefore, the discharges for the first stages of flow are calculated using the weir equation.

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:

S_1 – is the storage at t_1 (the beginning of the routing interval).
O_1 – is the outflow at t_1
S_2 – is the storage at t_2 (the end of the routing interval)
O_2 – is the outflow at t_2
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.

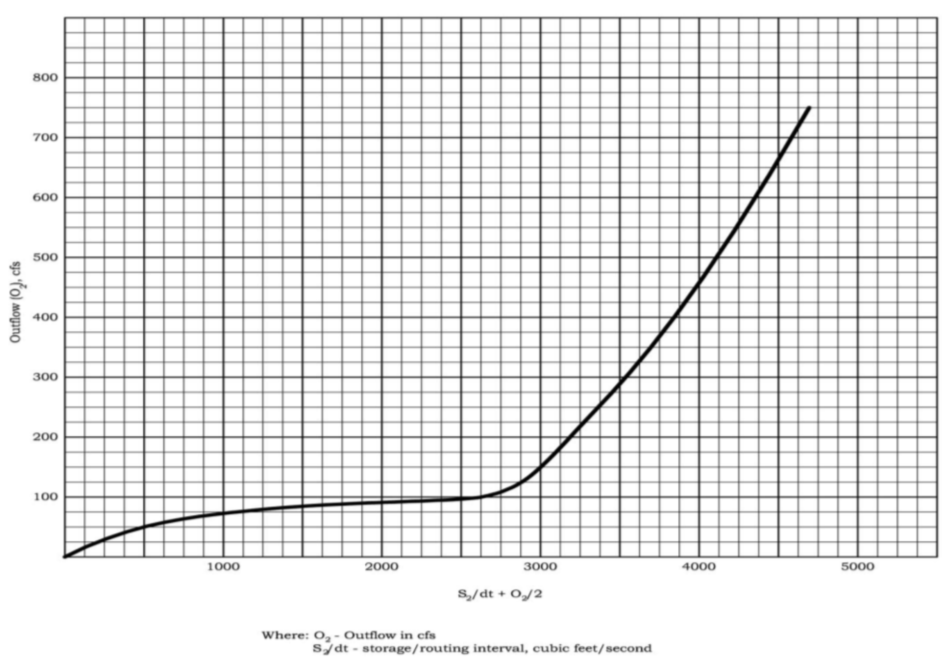
Table 3-5: Storage-Discharge Relationship (Example)

Elevation (ft.)	**Storage (100,000 cu. ft.)**	**Discharge (cfs)**
604.3	0.0	0
606.0	8.3	61
607.0	13.1	74
608.	17.9	87
609.	23.1	100
610.0	28.3	200
611.	33.5	420
612.	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)	(2)	(3)	(4)	(5)
Time	**Inflow**	**Avg. Inflow**	**S_2/dt=O_2**	**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)	(2)	(3)	(4)	(5)
Time	**Inflow**	**Avg. Inflow**	**S_2/dt=O_2**	**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)	(2)	(3)	(4)	(5)
Time	**Inflow**	**Avg. Inflow**	**S_2/dt = O_2**	**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 from 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:

- TR-20
  http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/WinTR20.html

- 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.

Additional test for section 3.4.8:

Emergency spillways shall be designed as a broad crested weir. The design calculations will be similar to the calculations for a sharp-crested weir presented in Section 3.4.6, except a lower discharge coefficient is used to account for the breadth of the weir. Table 3-7 presents discharge coefficients for use with broad crested weirs from the Federal Highway Administration publication HEC-22 "Urban Drainage Design Manual".

Table 3-7
Broad-Crested Weir Discharge Coefficients

Broad-Crested Weir Coefficient C Values as a Function of Weir Crest Breadth and Head (coefficient has units of $ft.^{0.5}/sec.$). [(1)]											
Head[(2)] (ft)	Breadth of Crest of Weir (ft)										
	0.50	0.75	1.00	1.5	2.0	2.50	3.00	4.00	5.00	10.00	15.00
0.2	2.80	2.75	2.69	2.62	2.54	2.48	2.44	2.38	2.34	2.49	2.68
0.4	2.92	2.80	2.72	2.64	2.61	2.60	2.58	2.54	2.50	2.56	2.70
0.6	3.08	2.89	2.75	2.64	2.61	2.60	2.68	2.69	2.70	2.70	2.70
0.8	3.30	3.04	2.85	2.68	2.60	2.60	2.67	2.68	2.68	2.69	2.64
1.0	3.32	3.14	2.98	2.75	2.66	2.64	2.65	2.67	2.68	2.68	2.63
1.2	3.32	3.20	3.08	2.86	2.70	2.65	2.64	2.67	2.66	2.69	2.64
1.4	3.32	3.26	3.20	2.92	2.77	2.68	2.64	2.65	2.65	2.67	2.64
1.6	3.32	3.29	3.28	3.07	2.89	2.75	2.68	2.66	2.65	2.64	2.63
1.8	3.32	3.32	3.31	3.07	2.88	2.74	2.68	2.66	2.65	2.64	2.63
2.0	3.32	3.31	3.30	3.03	2.85	2.76	2.72	2.68	2.65	2.64	2.63
2.5	3.32	3.32	3.31	3.28	3.07	2.89	2.81	2.72	2.67	2.64	2.63
3.0	3.32	3.32	3.32	3.32	3.20	3.05	2.92	2.73	2.66	2.64	2.63
3.5	3.32	3.32	3.32	3.32	3.32	3.19	2.97	2.76	2.68	2.64	2.63
4.0	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.70	2.64	2.63
4.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.74	2.64	2.63
5.0	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.64	2.63
5.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.64	2.63

3.4.9 Berm Embankment/Slope Stabilization

- Pond embankments are exempt from the ODNR Dam classification if the following are met: 1) 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.

- Retaining walls greater than 3 feet in height used as pond embankments shall be designed by a Structural engineer licensed in the State of Ohio.

- 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.

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

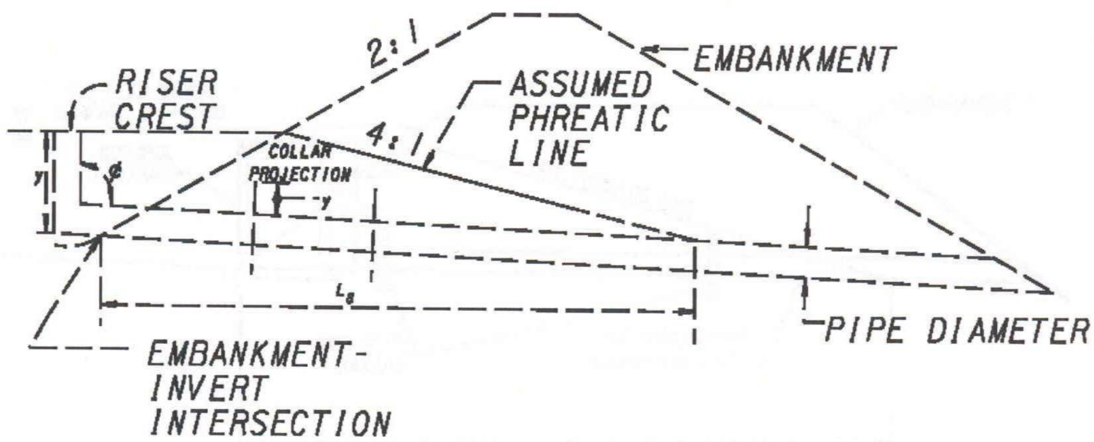
Where: L_S = length of pipe in the saturated zone (ft.)

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.

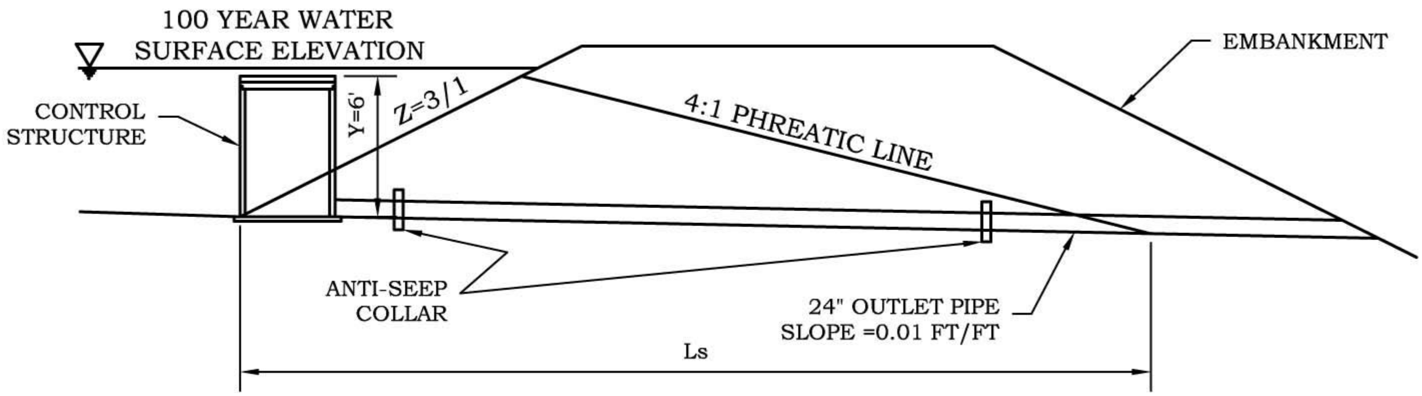
Pipe slope = slope of pipe in feet per foot.

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:

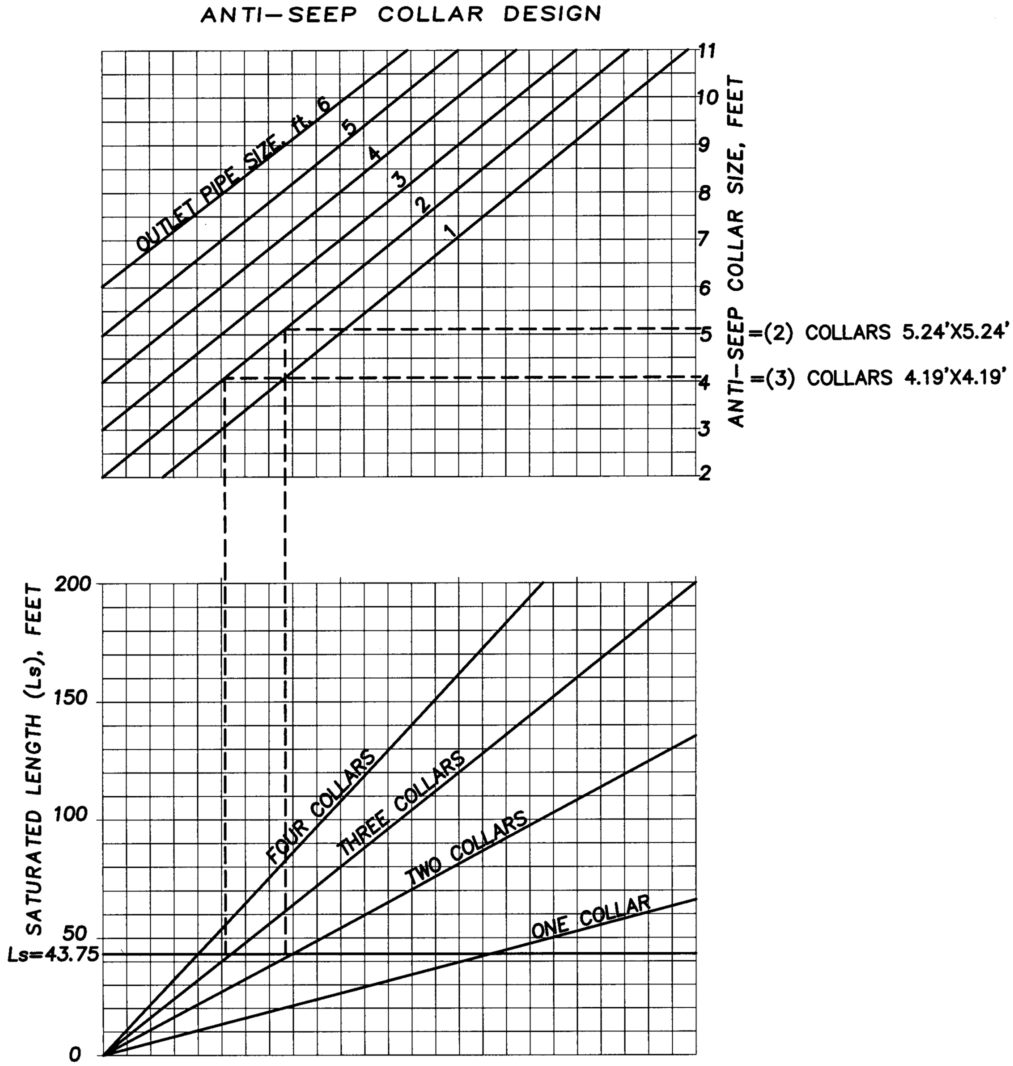
Beginning from the lower graph (see Appendix) with an Ls = 43.75'

- 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' x 4.19'

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

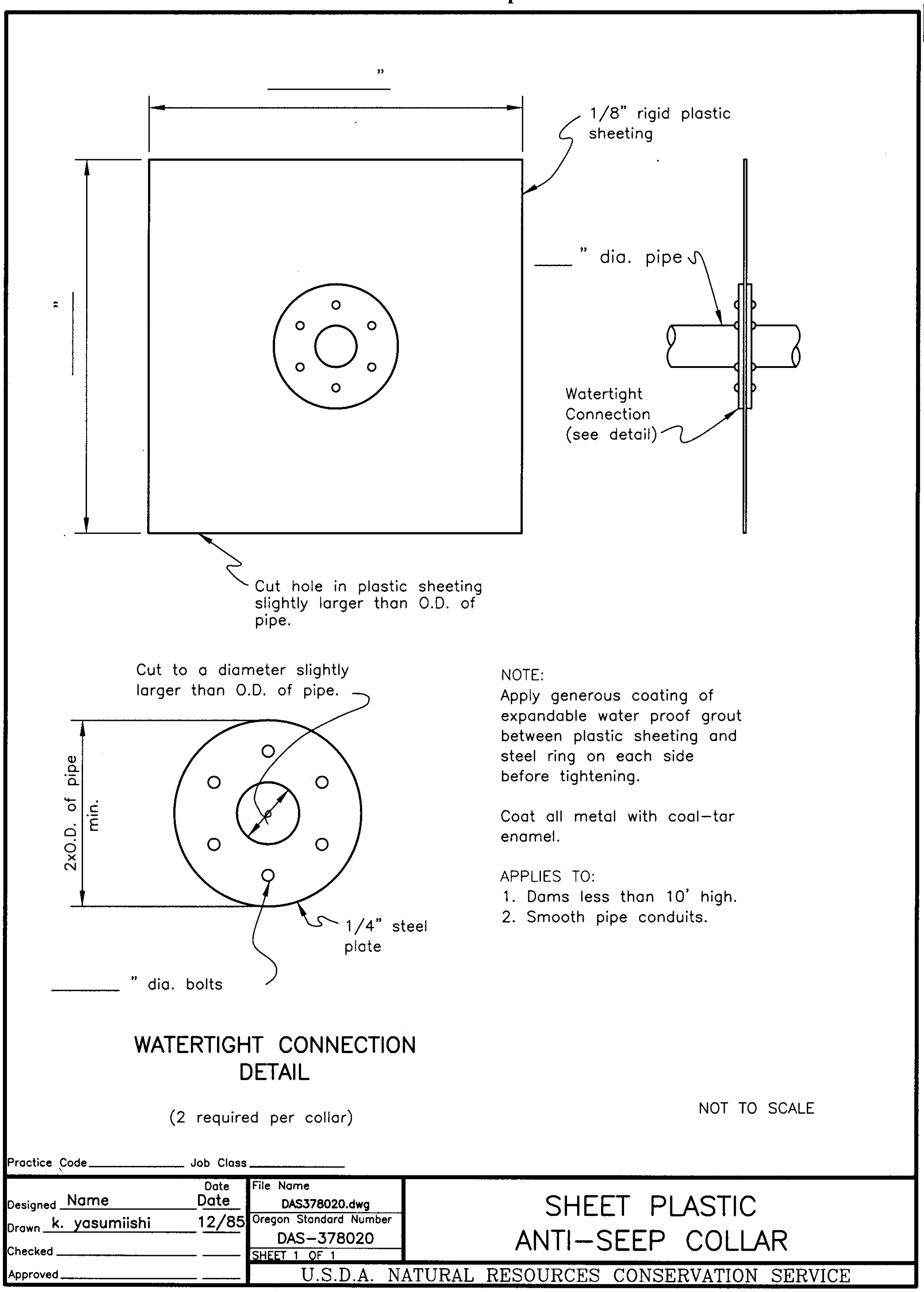
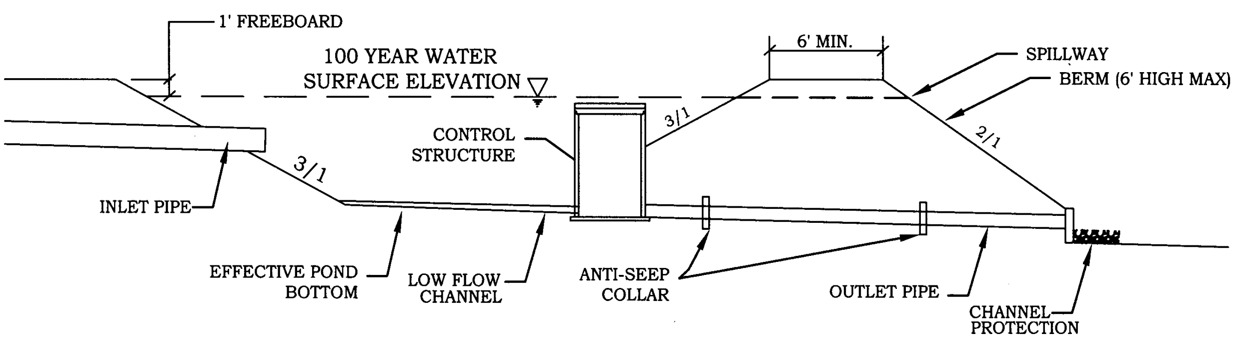


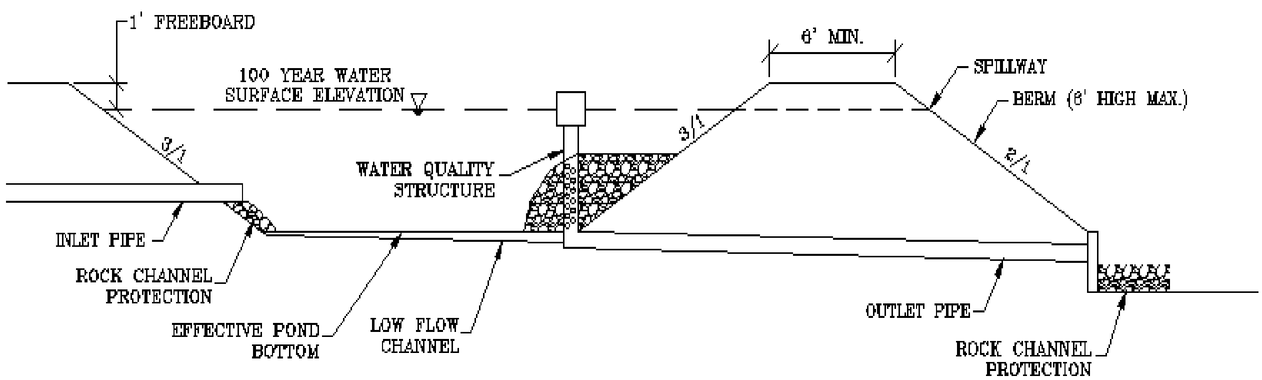
FIGURE 3-16: Typical Pond Section



- Pond Length to width ratios should be 3:1.
- Placement of inlet and outlet should be at maximum distance possible apart.

TYPICAL SECTION – DRY DETENTION POND

- Easement access to all facilities must be provided.



3.4.11 Agricultural Field Tiles

Agricultural field tiles generally shall not be used as a receiving drainage way for stormwater runoff due to concerns of conveyance capacity and long-term maintenance. The county may approve connection to an agricultural field tile to control nuisance runoff flows or when used in conjunction with a separate water quality outlet for the purpose of maintaining a dry pond bottom. The discharge rate shall be restricted to the site's "fair share" of the field tile conveyance capacity. "Fair share" is defined as the field tile full flow capacity as determined by Manning's Equation multiplied by the onsite tributary area divided by the overall tributary area of the field tile at the discharge point. When field tile connections are authorized, the developer shall be required to provide a controlled surface outlet for discharge of runoff exceeding the permitted discharge rate to the field tile. Field tile connections shall not restrict field tile flows from adjacent properties.

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. This section shall apply to new development and redevelopment projects. 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 by the developer or property owner 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 Trumbull County Engineer, with review and comment provided by the Trumbull County Soil and Water Conservation District and could require monitoring to ensure compliance with OEPA's Construction General Permit (CGP) requirements and requires approval from the OEPA for sites 5 acres or over. The Post-Construction portion of the Storm Water Pollution Prevention Plan (SWPPP) 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.
- Outlet pipes shall have minimum diameter of 12 inches.
- Clog-prevention design for control orifices measuring less than 4 inches in shortest direction.
- BMP Maintenance Plan shall be developed for all BMP's selected and presented to post-construction regulations.
- Maintenance plan shall include a disposal statement so that 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 and erosion and sedimentation control plan.

4.2 Post-Construction Storm Water Quantity Control Method

The Trumbull County Engineer and Trumbull County Soil and Water Conservation District 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 construction activities that will disturb one or more acres of land or will disturb less than one acres but are part of a larger common plan of development or sale which will disturb one or more acres of 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 redeveloped, 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:**	
0	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 Storm Water Quality Control Method

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 from the OEPA's construction general permit:

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

<u>Table 4-3</u>:
Structural Post-Construction BMPs & Associated Drain (Drawdown) Times

Best Management Practice	Drain Time of WQv
Infiltration Basin^	24 - 48 hours
Enhanced Water Quality Swale	24 hours
Dry Extended Detention Basin*	48 hours

Wet Extended Detention Basin**	24 hours
Constructed Wetland (above permanent pool)+	24 hours
Sand & Other Media Filtration	40 hours
Bioretention Cell^	40 hours
Pocket Wetland#	24 hours
Vegetated Filter Strip	24 hours

* Dry basins must include forebay and micropool each sized at 10% of the WQv
** Provide both a permanent pool and an EDv above the permanent pool, each sized at 0.75
* WQv
+ Extended detention shall be provided for the full WQv above the permanent water pool.
^ The WQv shall completely infiltrate within 48 hours so there is no standing or residual water in the BMP.
# Pocket wetlands must have a wet pool equal to the WQv, with 25% of the WQv in a pool and 75% in marshes. The EDv above the permanent pool must be equal to the WQv.

4.4 Recommended Post-Construction Best Management Practices

OEPA has identified six structural BMP's to be considered and incorporated into storm water management for site development. The Trumbull County Engineer and Trumbull County Soil and Water Conservation District will also consider non-structural practices in combination with these structural practices in reviewing site plans requiring supporting documentation of non-structural BMP's 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 as well as two additional recommendations by the Trumbull County Engineers and Trumbull SWCD:

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

2. **Infiltration Methods** - General principal is that treatment occurs through the interaction of storm water runoff and 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.

3. **Extended Detention Basins (Dry)** – General principal is that 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 in sizing of basin, which may impact site layout considerations. Sizing needs to account for both quantity and quality factors.

   A. A dry detention pond is designed to temporarily detain runoff during storm events. Plans shall be approved by the Trumbull County Engineer for the following parameters and physical constraints:

Design Parameters	**Physical Constraints**
• Groundwater	Drainage Area Size

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

Elevation Difference/Fall
Groundwater Consideration
Soil Types
Local Climate
Precipitation Volume
Land Cost

4. **Retention Basin (Wet)** – The general principal is that treatment occurs in the permanent pool portion of the basin and pollutants settle out during the hold times, then runoff is released over a period of time to allow for settlement. Suggested design considerations include drainage area size, which influences basin size, which in turn could impact site layout. There are also health considerations (i.e. West Nile virus), perimeter protection needs (fencing, maintenance access gates, ingress/egress, easements), and maintenance issues.

5. **Constructed Wetlands** –Engineered wetlands that utilize natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist, at least partially, in treating an effluent or other water source. Suggested design considerations can includelarge surface areas, limiting site layouts, and additional permitting.

6. **Bio-retention** –Bioretention practices are stormwater basins that utilize a soil media, mulch and vegetation to treat runoff and improve water quality for small drainage areas. Bioretention practices provide effective treatment for many runoff quality problems including reduction of total suspended solids, heavy metals, organic compounds, bacteria and nutrients (phosphorous and nitrogen) by promoting settling, adsorption, microbial breakdown, and nutrient assimilation by plants. Suggested design considerations include site locations, maintenance, drainage area size, site slopes and soil infiltration rate.

7. **Permeable paving** - A range of materials and techniques for paving roads, cycle-paths, parking lots and sidewalks which allows the movement of water and air around the paving material so storm water can percolate and infiltrate through areas that would traditionally be impervious. Suggested design considerations include weight and speed of vehicles using the surface, soil infiltration rate, the site's contamination risk, slope/grade of land and proximity to water features, including wells.

8. **Sand Filters –** Sand filters utilize a sedimentation chamber and a filtration chamber to treat stormwater. The first chamber (sedimentation) removes larger particles from stormwater by allowing them to settle out of suspension, while the second chamber (filtration) removes finer particles by filtering stormwater through a bed composed of sand or a combination of sand and organic material overlying a drain system. Suggested design considerations include site locations, maintenance, drainage area size, site slopes and soil infiltration rate.

9.

**The recommended post-construction BMPs list above is not an endorsement of the Manual that each is suitable throughout Trumbull County. Multiple post-construction BMPs listed above have critical limiting factors present in large portions of Trumbull County. The Professional Engineer should account for possible limiting factors such as soil conditions (fill vs. in-situ), soil type, on-site infiltration rates, perched groundwater tables, seepage considerations, etc. prior to designing a specific BMP.*

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.

4.5 Operation and Maintenance Plan

A maintenance plan for stormwater controls must be prepared and submitted for review and approval by the Trumbull County Engineers office and Trumbull SWCD for the Applicant during the plan approval process. At a minimum, maintenance plans for stormwater controls shall include a method and frequency for the following activities:

- Routine and non-routine inspection tasks of all permanent structures
- Schedule for inspection and maintenance
- Debris/clogging control through appropriate removal and disposal
- Vegetation control (mowing, harvesting, wetland plants)
- Erosion repair
- Non-routine maintenance should include pollutant and sediment removal and the "rejuvenation" or replacement of filters and appropriate soils
- Disposal of collected pollutants, sediments, and filter media in accordance with local, state, and federal regulations
- Mosquito monitoring and abatement, encompassing inspections for conditions conducive to mosquito breeding, routine (e.g. vegetation control, debris and sediment removal) and non-routine (e.g., restoration of grade to eliminate ponding) activities to address these conditions, and conditions where the use of insecticides may be warranted.

It should be noted that individual(s) or business assuming the responsibility of long-term operation and maintenance of the post-construction BMP(s) do not possess knowledge of or prior experience necessary to conduct proper maintenance. For this reason the maintenance plan shall be a smaller, more specific, stand-alone document which contains the designated entity responsible for the storm water inspection and routine maintenance activities. Accompanied with the plan should also be a location plan showing all access and maintenance easements and outlet design drawings/photos to assist the designated inspector with reviewing all critical components and providing a means to properly maintain the structure(s). To ensure the future property owner or business is aware of their responsibilities the plan should also include a sign-off.

4.6 As-Built Drawings

As-built surveys will be required from the Applicant responsible for constructing stormwater facilities and conveyance systems. The purpose of as-built surveys is to demonstrate conclusively that the facilities are constructed to the elevations, slopes, grades, and volumes shown on the approved plans on file with the County.

An as-built survey shall be conducted once:

- All structures on surrounding lots of a stormwater control facility are constructed and final lot grading for each lot is established, and
- The conversion of a temporary sediment basin to a permanent stormwater control facility is complete after the site is built-out to the point where the temporary sediment basin is no longer needed. As-built surveys will only be accepted if they are conducted after the sediment in the temporary basin has been removed and regraded, vegetation has been established, and the permanent riser structure(s) is in place.

As-built surveys shall be conducted by a Professional Surveyor registered in the State of Ohio and shall employ standard survey techniques. The Professional Surveyor performing the as-built survey shall be responsible for reduction of notes and any plotting necessary to make the notes interpretable. A final report and original field notes shall be furnished to the County for review and record purposes. A minimum of two bench marks that are referenced to the same vertical datum as the construction plans shall be provided on the as-built survey drawings. The Applicant, contractor, or other entity constructing the stormwater facilities shall correct the discrepancies necessary to ensure that the stormwater facility will function as designed. The as-built surveys shall be re-performed as necessary to demonstrate plan conformance.

STORM WATER POLLUTION PREVENTION PLAN AND EROSION AND SEDIMENTATION CONTROL PLAN AUTHORIZATIONS AND REQUIREMENTS

5.1 Trumbull County Erosion and Sediment Control (ESC) Rules and Construction General Permit (CGP) Regulatory Framework

This section highlights portions of the Trumbull County Erosion and Sediment Control Rules implemented by the Trumbull County Soil and Water Conservation District and the Ohio Environmental Protection Agency (OEPA) Authorization for Storm Water Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System permit no. OHC000003 (or current edition), Ohio Revised Code (ORC) and Ohio Administrative Code (OAC) as they apply to the Construction General Permit.

- Trumbull County Erosion and Sediment Control Rules – Construction activities disturbing one or more acres of total land, or residential sub-lots in a larger plan of development, requires authorization when conducted within unincorporated areas of Trumbull County and municipalities that possess MOUs with Trumbull County Soil and Water Conservation District. The threshold acreage includes the entire area disturbed in the larger common plan of development or sale.

- 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 acreage 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 OHC000003 (or current edition) 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 from 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 has the potential to adversely impact large numbers of citizens, property, downstream drainage systems, functions and infrastructure. Excessive erosion and sedimentation can also potentially increase construction cost 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 stabilization of disturbed areas as soon as possible.

5.2.3 Protect Disturbed Areas from Storm Water Runoff

Use dikes, diversions and watercourses 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 perform maintenance on a regular basis or after large storm events as necessary during construction for these practices.

5.2.5 Keep Runoff Velocities Low

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. Review local community zoning requirements and County Subdivision Regulations for applicability to certain riparian and wetland setback and preservation methods.

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. Centralized sediment traps and basins should be designed along existing contours, facilitate the collection of surface runoff, include minimal embankment construction and be located near the existing surface runoff outflow point(s). Care should be taken to ensure the highest design storage volume elevation will not be greater than the existing inflow grade such that the sediment control feature can collect runoff and function from the onset of earthwork. Traps or basins which are only capable of collecting runoff from proposed storm sewers or raised grade conditions or where constructed above proposed fill will likely require secondary structures for initial site treatment until the permanent sediment control can be installed. Earthen structures whether permanent or temporary such as dams, dikes, sediment basins, storm water basins and diversions shall be seeded and mulched within 7 days after installation is complete.

A combination or structural and non-structural controls is recommended to manage erosion and sedimentation control on construction projects within Trumbull 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 and Sedimentation Control Plans

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:

- Storm Water Pollution Prevention Plans (SWP3) must be submitted to the Trumbull County Engineer and Trumbull County Soil and Water Conservation District for approval of all soil disturbing activities of one (1) acre or more. Projects which require only an Erosion and Sedimentation Control (ESC) Plan and result in no impervious installation(s) must submit to Trumbull County Soil and Water Conservation District for approval for all disturbing activities of one (1) acre or more. Excluded from the requirements of thee Trumbull County Engineer's Office are soil disturbing activities directly connected to single family residential development on individual lots of less than 5 acres. This statement does not in any way waive the requirements for compliance with all conditions of the Trumbull County Erosion and Sediment Control Rules, the Ohio EPA NPDES Construction General Permit or other local requirements.

- Soil disturbing activities of less than one (1) acre shall not be required to file a SWP3 or an ESC Plan with the Trumbull County Engineers's Office; however, said project shall comply with all other provisions of the Trumbull County Erosion and Sediment Rules and other applicable local requirements. For this reason, 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 or 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 all regulatory agencies 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 SWP3 and/or ESC Plan 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. OHC000003 (or current edition), where and when applicable.

- Exceptions of this Manual –

    - Should specific site conditions prohibit implementation of any of the control practices contained in this permit or,
    - 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 Maximum Extent Practical.

- Plan Amendments – The construction plan shall be amended whenever there 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 and/or ESC Plan 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/or ESC Plan and terms and conditions of this permit. Permittee shall maintain a written document containing signatures of all contractors/sub-contractors who are involved with SWP3 installation and implementation.

5.4 General Construction Plan Submittal Requirements

For the purpose 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 include all three types of plans mentioned above.

The Storm Water Pollution Prevention Plan and Erosion and 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 – A Registered Professional Engineer shall certify storm water conveyance and post-construction calculations, designs and plan sheets. A Registered Professional Engineer or Landscape Architect or a Certified Professional in Erosion and Sediment Control shall certify erosion and sedimentation 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 a complete and accurate Notice of Intent (NOI) application (NOI form and mailing address can be found on the Ohio EPA's website: www.epa.state.oh.us). 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:

D. Regulatory submittal clarification – All construction plans developed to meet regulatory and manual requirements shall be submitted to the County Engineer and the Trumbull County Soil and Water Conservation District (TCSWCD). Unless requested to do so, construction plans are not required to be submitted to OEPA related to erosion and sediment control or storm water pollution prevention. A Storm Water Pollution Prevention Plan (SWP3) or Erosion and Sedimentation Control Plan must be submitted to Trumbull County Soil and Water Conservation District with appropriate fee for review of plans. The Trumbull County Soil and Water Conservation District fee schedule can be found at www.swcd.co.trumbull.oh.us. Trumbull County Engineers Office Review fees will be based on the County Standard Hourly Rate Table that will be incorporated into a signed agreement with the developer at the time of the document submission.

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 and 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 or more	Within 7-days of the most recent disturbance
Any area within 50 feet of a watercourse and at final grade	Within 2 days of achieving final grade
Any other 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 if the area will remail idle for more than 21 days
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 For residential sudivisions, disturbed areas must be stabilized at least seven days prior to transfer of permit coverage for the individual lot(s)
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 Trumbull 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/Trumbull County Soil and Water Conservation District and Trumbull County Engineer to review the 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 the designated entity 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 operational 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 controls 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. Individual inlets receiving runoff from drainage areas, whether completely or partially disturbed, of one or more acres will require a sediment-settling pond. 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.

- 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.
    - Undisturbed area runoff shall be diverted from temporary sediment control facilities when ever practical.
    - No basin shall be located within 50 feet of designated floodways.

To maximize trapping and retention of incoming sediment basins shall be designed with a permanent pool (wet storage) which will protect against sediment re-suspension by promoting extended settlement times. The basin shall also include a dewatering pool (dry storage) which will protect against "short circuiting" of the basin during larger storm events. The standard storage sizing criteria are presented in table 4-3. The following table identifies 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 off-site runoff diversion be implemented, the dry storage component of the basin shall be sized to accommodate both disturbed and undisturbed runoff drainage areas. The wet storage component is based off expected sediment volumes from the disturbed area and does not need to increase with an increased drainage area.

The developer, engineer, builder or contractor shall provide supporting calculations in defense of not implementing the additional storage volumes for the basin. The final decision shall be at the discretion ofTrumbull SWCD. 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 SedimentBasin and Modified Permanent Control as Temporary Basin Sizing Criteria

Basin Design Elements	Basin Design Criteria
Basin Wet (Permanent) Storage	37 Cubic Yards (1000 ft^3)/Acre
Basin Dry (Dewatering) Storage	67 cubic Yards (1800 ft^3)/Acre
Maximum Depth	5-feet
Length: Width Ratio	2:1
Minimum Drain Time	48 hours
Maximum Drain Time	7 days

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 Trumbull 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 basins 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. Minimum design criteria can be found in table 5-3.

1. Maintenance requirement – Accumulated sediment must be removed when wet (permenant) storage of the basin once it’s 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 if considered hazardous. 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 whenever practical.

5. A length to width ratio of 4:1 is recommended to provide a greater flow treatment distance to increase the efficiency of the sediment basin.

- 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 around the ends of the fence. It is recommended to provide structural backing to the silt fencing in the form of chicken wire fence or other similar material to increase the durability of the silt fence and reduce the time and costs associated with maintenance. Silt fence shall not control large drainage areas and placement in parallel series does not increase the maximum drainage area. The estimated maximum drainage to silt fence for a particular slope interval is show 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%
0.25	>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.

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.

> 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.

- Filing 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 Trumbull 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 manual:

- 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 OEPA Permit Waivers

The OEPA General Construction Permit allows for 2 different waivers 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) or Erosion and Sedimentation Control (ESC) Plan 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 and/or ESC Plan.

- SWP3 and ESC Plans shall be completed prior to the timely submittal of the NOI.

- County Engineer requires:

  1. Storm Water Pollution Prevention Plans (SWP3) – separate sheet.
  2. Erosion and Sedimentation Control Plan (ESC Plan) – separate sheet.
  3. Post-Construction Controls 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.
  5. Long-Term Post-Construction Operation and Maintenance Plan – stand alone document

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

- For proposed subdivisions the SWP3 and/or ESC Plan shall be submitted to Trumbull County SWCD after acceptance of the preliminary plat by Trumbull 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 Trumbull County Soil and Water Conservation District and the Trumbull County Engineers requests. The County Engineer will review the SWP3 and/or ESC Plan and provide comments, questions and/or recommendations for revision, or an approval letter, within 30 days. A revised plan shall be submitted to the Engineer's Office and SWCD within 30 days of receipt of notice of deficiencies. The Trumbull 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 1.10 Compliance with Local, State and Federal Regulations of this manual.

- Within 30 days of receipt of a complete plan, including fees, Trumbull County Engineers shall indicate the submitted and revised status of compliance or non-compliance to the owner or appointed representative in cases of after the fact or unauthorized construction. 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.

- The Trumbull County Engineer's Office may impose such special terms and conditions as are appropriate or necessary to ensure compliance with the applicable laws and rules and to protect human health or the environment.

- Incomplete permit applications shall not be considered. Failure to provide a complete application or to respond to requests by the agency for additional information will result in denial of the application.

- The permittee shall make the approved SWP3 and ESC Plan 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.

- Submitting an NOT – Compliance with construction permits is required until an NOT form is submitted (a form can be found at the Ohio EPA's website: www.epa.state.oh.us) to Ohio EPA. A copy of the NOT shall be provided to both the Trumbull County Engineering and Trumbull Soil and Water Conservation District which will relieve the permittee of the erosion and sediment control requirements. 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 Trumbull 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 designed 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."

6.0 Flood Plain Regulations

The Trumbull County **Flood Damage Prevention Regulations** provide additional requirements for construction within Trumbull County flood plains. A copy of the effective **Flood Damage Prevention Regulations** can be obtained from the Trumbull County Planning Commission:

Flood Plain Coordinator
c/o Trumbull County Planning Commission
347 North Park Avenue
Warren, OH 44481
Phone: (330) 675-2480

7.0 ADMINISTRATIVE

7.1 Inspection and Compliance

1. The Trumbull County Soil and Water Conservation District will perform regular inspections of project areas to determine and document compliance with OEPA's Construction General Permit (CGP) requirements and may comment on any other requirement set forth in this manual. Inspection reports will be forwarded to the Trumbull County Engineer, 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, the Trumbull SWCD will investigate the alleged violation and complete a 'Complaint Inspection Report'; the results and recommendations will be forwarded to necessary entities.

   Should be 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 Trumbull 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 exist, the Prosecuting Attorney for Trumbull 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 Trumbull 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, 2^{nd}:	\$100.00

7.2 <u>Variances to Rules</u>

In the event that a practice, activity or other action is in violation of these Rules, the Trumbull County Board of Commissioners acting through the Administrator of these Rules or other designated agent and after public hearing and notice (as described hereunder) to interested persons including applicant, abutting landowners, the political subdivision wherein the real property subject to the variance is located, and any other person whose property would be substantially affected by the granting of the variance (the determination of the meaning of "substantially affected by" to be the sole decision of the Administrator or other Board designee whose decision is final), may grant a variance to these Rules if all of the following are found to exist:

(a) There are exceptional or extraordinary circumstances or conditions applying to the land;

(b) Owing to special conditions, literal enforcement of the Rules would cause unnecessary hardship and the spirit of these Rules would be observed and substantial justice done;

(c) The exceptional or extraordinary circumstances or conditions and the unnecessary hardship were not the result of any prior actions of the owner (or applicant) of the land;

(d) The variance is necessary for the preservation and enjoyment of substantial property rights of the owner of the land;

(e) The variance will not be a substantial detriment to adjacent land and will not materially impair the purposes of these Rules;

(f) Adverse economic conditions shall not be a valid reason to grant a variance;

(g) A request for a variance shall be in writing and shall be in a form or manner approved by the Administrator/designee and shall state specifically the reasons for the request and shall include all data and information in support of the request. The Administrator/designee shall fix a time and date for the public hearing, give at least a ten (10) day notice in writing to the parties in interest, give notice of such public hearing by publication in a general circulation newspaper in the County at least ten (10) days prior to such hearing. The request shall be reviewed and approved, disapproved or approved with modifications within thirty (30) working days unless extended by the Board for a reasonable time not to exceed an additional thirty (30) days;

(h) Any appeals of the final decision of a variance shall be made to the Board of Supervisors of Trumbull Soil & Water Conservation District;

(i) Variance requests, that involve tasks under the jurisdiction of the local governing engineering entity, whether fully or jointly, must separately obtain approval (if applicable) from said entity prior a variance of these Rules being granted

(j) A variance may not allow applicants to fall below the minimum standards of the Environmental Protection Agency (EPA)