Storm Water Management

City of Steubenville - Public Works

CHAPTER 1341
Storm Water Management

CROSS REFERENCES

Urban Sediment Pollution Abatement Rules - see OAC Ch. 1501:15-1
Drainage improvements - see P. & Z. 1117.05

1341.01 PURPOSE AND TITLE.

(a) The purpose of these regulations are:

(1) To minimize danger to public health and safety, and damages to property from storm water runoff;

(2) To preserve and restore the flood carrying capacity of streams;

(3) To maintain the existing flows and quality of streams;

(4) To protect and conserve groundwaters and groundwater recharge areas;

(5) To preserve to the maximum extent the existing natural drainage systems; and

(6) To provide for proper construction and maintenance of permanent storm water management structures and facilities.

(b) This chapter shall be known as and may be cited as the Storm Water Management Regulations of the City.

(Ord. 1991-122. Passed 11-18-91.)

1341.02 APPLICATION OF REGULATIONS; PLANS REQUIRED.

(a) The City is divided into the watersheds enumerated below and shown on the map entitled "Watershed Districts", which map is on file at the office of the City Engineer and made a part of this chapter by reference. These watershed districts are established to implement a long-range City plan to facilitate the orderly and beneficial growth of the City and its environs, and to promote the public health, safety, convenience, comfort, prosperity and general welfare.

(1) Cross Creek Watershed District
(2) Permars Run Watershed District
(3) Wills Creek Watershed District
(4) Ohio River Sand Bar Watershed District

(b) No person, the owner of any property or in possession or control of any property, shall cause, permit or allow any new development or subdivision of land except in conformance with an approved Storm Water Management Plan and the requirements of these regulations, provided however that in order to prevent undue hardship, no Storm Water Management Plan shall be required for:

(1) Normal cemetery operations including the opening or closing of graves or the construction of mausoleums;
(2) The construction of a single-family dwelling or two-family dwelling, or structures accessory thereto on a lot of record;
(3) Minor subdivisions containing no more than five lots, not including any new streets or easements of access and not requiring the extension of public water or sanitary sewer lines;
(4) Any townhouse/rowhouse or multi-family residential, commercial, industrial or institutional development of land with a site area of less than one acre, however a plot plan with the proposed method of controlling storm water runoff indicated, including specific requirements established by the City Engineer, shall be submitted; and
(5) Public highways, transportation and drainage improvements or maintenance thereof undertaken by a governmental agency provided that its standard storm water management policies have been approved by the City Engineer or the chief of the Division of Soil and Water Conservation of the Department of Natural Resources and provided further that such practices are no less restrictive than these regulations.

(c) No development or subdivision of land initiated pursuant to subsections (b)(1) through (5) hereof shall interfere with adequate drainage for the site or the drainage area of the land tributary to the site; impede or obstruct the flow of any watercourse; or adversely affect existing storm sewers or storm water management facilities. The submittal of specific information or documentation may be required to determine compliance.

(Ord. 1991-122. Passed 11-18-91.)

1341.03 DEFINITIONS.

For the purposes of this chapter, the words and phrases defined herein shall have the meanings therein respectively ascribed to them, unless a different meaning is clearly indicated by the context.

(a) "Channel" means the area between definite banks of a natural or man-made watercourse which confine and conduct the permanent or intermittent flow of water.

(b) "City Engineer" means a professional engineer employed by the City or any consultant designated by the City to perform the duties of City Engineer in the enforcement of the provisions of this chapter.

(c) "Critical storm" means that storm which is calculated by means of the percentage increase in volume of runoff by a proposed development. The critical storm is used to calculate the maximum allowable storm water discharge rate from a developed site.

(d) "Culvert" means a structure with appurtenant work which carries a stream under or through an embankment of fill.

(e) "Detention basin" means a storage area for storm water runoff that stores water for a short period and releases it at a controlled rate.

(f) "Development" means any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, streets and other paving, utilities, cutting or filling, grading, excavating and the subdivision of land.

(g) "Ditch" means an excavation either dug or natural for the purpose of drainage.

(h) "Diversion" means a channel across a hillside used to protect bottomland from storm water runoff or to divert water away from buildings or into other storm water management facilities.

(i) "Drainage" means the flow of water and the methods of directing such flow.

(j) "Drainageway" means an area of concentrated water flow other than a stream, ditch or grassed waterway.

(k) "Flood" means 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.

(l) "Flood control project" means any device or structure designed and constructed to protect a designated area from flood flows of a specified magnitude and probability (frequency) of occurrence.

(m) "Floodplain" means a normally dry land area adjacent to a stream channel that is susceptible to being inundated by overbank stream flows. For regulatory purposes, see the floodplain regulations in the City Zoning Code.

(n) "Grassed waterway" means a broad or shallow natural course or constructed channel covered with erosion-resistant grasses or similar approved vegetative cover and used to conduct surface water. Commonly referred to as a "swale".

(o) "Groundwwater" means that part of the subsurface water which is below the zone of saturation.

(p) "Groundwater recharge area" means any surface area from which water penetrates and subsequently passes into the groundwater supply.

(q) "High delay vegetative strip" means an area covered with erosion-resistant grasses or similar approved vegetative cover designed to delay storm water runoff and increase infiltration.

(r) "Impervious surface" means any surface or material which inhibits the passage of water.

(s) "Infiltration" means the penetration and movement of water through the earth's surface.

(t) "New development" means development for which an application for a building permit is submitted on or after the effective date of this chapter, and includes any subsequent improvement of such site or structures.

(u) "Obstruction" means any structure or assembly of materials including fill above or below the surface of the land or water, any activity which might impede, retard or change flood flows.

(v) "Pervious surface" means any surface or material which permits the passage of water.

(w) "Rate of storm water runoff" means instantaneous measurement of water flow expressed in a unit of volume per unit of time, also referred to as discharge. Examples: cubic feet per second (cfs); gallons per minute (gpm).

(x) "Professional engineer" means a person duly licensed as a professional engineer by the State of Ohio.

(y) "Retention basin" means a storage area for storm water runoff that maintains a planned permanent level of water even after storm runoff has ceased.

(z) "Runoff characteristics" means the surface components of any watershed which affect the rate, amount and direction of storm water runoff. These may include, but are not limited to: vegetation, soils, slopes and man-made landscape alterations.

(aa) "Site" means any lot or parcel of land or contiguous combination thereof.

(bb) "Storage capacity" means the volume expressed in acre-feet of the impounded water to the maximum storage level, that is, the top of the impoundment.

(cc) "Storm frequency" means the average period of time within which a storm of a given duration and intensity can be expected to be equaled or exceeded.

(dd) "Storm sewer" means a man-made pipe or conduit which collects and transports storm water.

(ee) "Storm water management facilities" means natural or man-made structures which collect and control storm water runoff, and which include, but are not limited to, storm sewers, culverts, detention or retention basins, rooftop storage, parking lot ponding, porous pavement, diversions, grassed waterways, underground storage, lined channels, high delay vegetative strips and other related storm water control facilities.

(ff) "Storm Water Management Plan" means the required plan providing for the control of runoff to allow precipitation falling on a given site to be absorbed or retained on site to the extent that after development, the peak rate of discharge leaving the site is not significantly different than if the site had remained undeveloped.

(gg) "Storm water runoff" means drainage runoff from the surface of the land resulting from precipitation or snow or ice melt.

(hh) "Stream" means a body of water running or flowing on the earth's surface or channel in which such flow occurs. Flow may be permanent or intermittent.

(ii) "Subdivision" as defined by Ohio R.C. 711.001(B) means:

(1) The division of any parcel of land shown as a unit or as contiguous units on the last preceding tax roll, into two or more parcels, sites or lots, any one of which is less than five acres for the purpose, whether immediate or future, of transfer of ownership, provided, however, that the division or partition of land into parcels of more than five acres not involving any new streets or easements of access, and the sale or exchange of parcels between adjoining lot owners, where such sale or exchange does not create additional building sites, shall be exempted; or

(2) The improvement of one or more parcels of land for residential, commercial or industrial structures or groups of structures involving the division or allocation of land for the opening, widening or extension of any street or streets, except private streets serving industrial structures; the division or allocation of land as open spaces for common use by owners, occupants or lease holders or as easements for the extension and maintenance of public sewer, water, storm drainage or other public facilities.

(jj) "Subwatershed" means a hydrologically defined area within a watershed which drains to a specific point.

(kk) "Volume of storm water runoff" means that quantity of water normally measured in inches, cubic feet or acre-feet. This quantity is determined analytically from the computations and procedures established in this chapter.

(ll) "Watercourse" means any channel or conveyance of surface water having a defined bed and banks, whether natural or man-made, whether with permanent or intermittent flow.

(mm) "Watershed" means the entire region or area drained by a river, stream or other watercourse, whether natural or man-made.

(Ord. 1991-122. Passed 11-18-91.)

1341.04 STORM WATER MANAGEMENT PLANS AND SPECIFICATIONS.

Building permit or subdivision approval shall not be granted until a Storm Water Management Plan, where applicable, is approved by the City Engineer. The Storm Water Management Plan shall be prepared by a professional engineer and shall include:

(a) A Soil Erosion and Sedimentation Control Plan prepared pursuant to Chapter 1339, including review comments from the Jefferson Soil and Water Conservation District;

(b) Approval from the Jefferson County Engineer or Ohio Department of Transportation when utilization of a township, County or State storm drainage system is contemplated;

(c) Horizontal and vertical profiles of any existing watercourse, channel or stream, including hydrologic capacity;

(d) Construction specifications, including the materials to be used for storm water management structures;
(e) The exact location of proposed storm water management facilities, including the locations of and distances to any existing storm sewer line to be connected to, with the size of such existing line to be indicated;
(f) A twenty foot access easement around all storm water management facilities not wholly contained within an individual lot or parcel and maintained by the owner of that parcel, and from such facilities to a public right-of-way;
(g) Storm water runoff and related hydrologic and storm water management structure computations necessary to substantiate the proposed storm water management facilities;
(h) An upstream watershed map and a determination of the effects of upstream storm water runoff on the site;
(i) A determination of the effect on downstream property within 100 feet of the parcel for a residential development and within 500 feet of the parcel for other uses or combinations of uses;
(j) A determination of the effect upon the City storm drainage system when utilization of such is contemplated;
(k) A description of maintenance requirements and identification of the legal party or entity responsible for ownership and maintenance of storm water management facilities;
(l) An estimate of the cost of construction and maintenance of storm water management structures; and
(m) Certification by a professional engineer that the Storm Water Management Plan meets the design criteria of the Storm Water Management Regulations of the City.
(Ord. 1991-122. Passed 11-18-91.)

1341.05 DESIGN CRITERIA.

All new development and subdivision of land shall be designed to adequately collect, control and dispose of storm water runoff from the site, including where necessary, but not limited to storm sewers, culverts, detention or retention basins, roof-top storage, parking lot ponding, porous pavement, grassed waterways, lined channels, diversions, underground storage, or high delay vegetative strips and other related storm water management facilities. Design criteria for watershed districts shall include, but not be limited to the following:

(a) All sites shall limit the rate of storm water runoff so that no greater runoff is permitted during and after site development than that of the site prior to development. If the volume of storm water runoff from a site during or after development shall be greater than that of the site prior to development, it shall be compensated so that:
(1) The peak rate of storm water runoff for the critical storm and all more frequent storms occurring on the development site does not exceed the peak rate of runoff from the one-year twenty-four hour storm event occurring on the same site under predevelopment conditions.

(2) Storms of less frequent occurrence (longer return periods) than the critical storm up to the 100-year storms have peak runoff rates no greater than the peak runoff rates from equivalent size storms under predevelopment conditions. Consideration of the one, two, five, ten, twenty-five, fifty and 100-year storms shall be considered adequate in designing and developing a site to meet this standard.

(b) All predevelopment calculations shall be based upon existing land use features, except where farm field or disturbed earth is the existing natural condition, meadowland shall be used as the starting base for such calculations instead of the existing condition.

(c) The critical storm for a specific development site is determined as follows:

(1) Use of procedures outlined in the U.S. Department of Agriculture, Soil Conservation service Publication, "Urban Hydrology for Small Watersheds," latest edition (Technical Release No. 55) or other professionally accepted methodology approved by the City Engineer, to determine the total volume of storm water runoff occurring on the development site before and after development;

(2) From the volumes determined in subsection (c)(1) hereof, determine the percent increase in volume of storm water runoff due to the development.

(3) Determine the watershed district from the map entitled "Watershed Districts", which is on file at the office of the City Engineer, and the corresponding watershed type from Table 1 below:

Table 1

Watershed District	Type
I. Cross Creek Watershed District	B
II. Permars Run Watershed District	A
III. Wills Creek Watershed District	B
IV. Ohio River Sand Bar Watershed District	C

(4) Using the volumes determined in subsection (c)(2) hereof, and the watershed type determined in subsection (c)(3) hereof, select the critical storm from Table 2 Below:

Table 2

If the percentage of increase in volume of runoff is:		The critical storm year for discharge limitation shall be:		
Equal to or Greater than	and Less than	Watershed Type A	B	C
--	10	1	1	1
10	20	2	1	1
20	50	5	2	1
50	100	10	5	1
100	250	25	10	2
250	500	50	25	5
500	--	100	50	10

(d) Maximum permitted velocities for water carrying structures shall be determined by using the U.S. Department of Agriculture, Soil Conservation Service Publication, "Water Management and Sediment Control for Urbanizing Areas", latest edition.

(e) The Storm Water Management Plan shall include calculations indicating velocities of flow, grades, sizes and capacities of water carrying structures and detention and retention basins, and sufficient design information to construct such facilities.

(f) Where a site is traversed by an important watercourse, channel or stream, there shall be provided a drainage easement conforming substantially with the line of such important watercourse, channel or stream, and of such width as shall be adequate to preserve the unimpeded flow of natural drainage or for the purpose of widening, deepening, improving or protecting such drainage facilities.

(g) Storm water management facilities and easements shall be designed such that development as proposed shall not adversely effect or cause hazards to existing use of adjacent properties.

(Ord. 1991-122. Passed 11-18-91.)

1341.06 CONSTRUCTION REQUIREMENTS.

All storm water management facilities shall be designed and constructed in accordance with the standards and specifications of the City Engineer.

(a) Construction of storm water management facilities shall be in accordance with approved plans and accompanying specifications. The design and construction details shall be determined by using the U.S. Department of Agriculture, Soil Conservation Service Publication, "Water Management and Sediment Control for Urbanizing Areas", latest edition, and/or other methods approved by the City Engineer.

(b) Natural drainageways shall be utilized to the maximum extent possible.

(c) Storm water conduits shall be of a size large enough to adequately handle runoff from upstream sources.

(d) All storm water storage structures and facilities shall be equipped with emergency spillways.

(e) Energy dissipators shall be placed at the outlets of all water carrying structures where flow velocities exceed the maximum permitted velocities.

(f) Vertical structures, inlets and other surface water receiving structures shall be equipped with trash racks.

(g) Where a drainageway or ditch intersects a driveway or other access road, an adequately sized culvert, bridge or grassed waterway shall be provided.

(h) Roof drains and footing drains shall be controlled onsite.

(i) When the elevation of any entrance to a structure, including windows existing or to be constructed on a site is lower than the elevation of the street pavement serving that site, the Storm Water Management Plan shall show a method to minimize the risk of flooding from drainage moving from the street.

(Ord. 1991-122. Passed 11-18-91.)

1341.07 MAINTENANCE OF FACILITIES.

(a) In meeting maintenance requirements, the following priority is herein established:

(1) As a first priority, the storm water management facilities should be incorporated wholly within individual lots, tracts, parcels or sites, so that respective lot owners shall own and be responsible for maintenance of facilities in accordance with recorded deed restrictions binding the owner and his heirs and/or assigns to maintain the required facilities throughout the life of the use to which they are accessory.

(2) As a second priority, in the event the first priority cannot be achieved, ownership and maintenance of storm water management facilities should be the responsibility of a Home Owners Association. The stated responsibilities of the Home Owners Association in terms of owning and maintaining the storm water management facilities shall be submitted with Storm Water Management Plans for determination of their adequacy, and upon their approval, shall be recorded among the deed records of Jefferson County, Ohio. In addition, any deed written from a subdivision plat for a lot or lots shall contain a condition that it shall be mandatory for the owner or owners of such lot to be members of the Home Owners Association.

(3) The third priority, in the event the above priorities cannot be achieved, is to dedicate the storm water management facilities to the City, in accordance with established procedures. The City may accept only those storm water management facilities which are a part of the community's overall storm water collection system, and not those which are solely for the benefit of a particular site or development. As a condition of City acceptance of such facilities, the owner or person in control shall provide the City with financial security in an amount estimated by the City Engineer, to secure the structural integrity of storm water management facilities for a term not to exceed five years from the date of acceptance of dedication. The amount of such financial security shall not exceed ten percent (10%) of the actual cost of installation of such facilities.

(b) The failure of any person, owner of property, or organization in possession or control of any property to maintain storm water management facilities in accordance with the approved Storm Water Management Plan shall be considered a violation of these regulations.
(Ord. 1991-122. Passed 11-18-91.)

1341.08 ACCEPTANCE OF DEDICATION OFFERS.

The approval of any Storm Water Management Plan shall not be deemed to constitute or imply the acceptance of storm water management facilities by the City. No offer of dedication shall be accepted until the City Engineer has finally inspected and approved all storm water management facilities. Acceptance of formal offers of dedication shall be only by ordinance or deed of the City.
(Ord. 1991-122. Passed 11-18-91.)

1341.09 GUARANTEE OF COMPLETION.

Before any Storm Water Management Plan is approved which proposes to dedicate storm water management facilities to a Home Owners Association or the City, as may be applicable in a given case, the owner or person in control shall post financial security with a bonding or lending institution of his choice, provided such institution is authorized to conduct business in the State of Ohio (either a Federal or State chartered lending institution). The acceptable types of financial security are as follows:

(a) Performance bond or Corporate bond with an acceptable surety, and of form satisfactory to the City;
(b) Certified check payable to the City;
(c) Irrevocable letter of credit provided by a qualified lending institution which guarantees payment to the City should the owner or person in control fail to complete storm water management facilities satisfactorily.

Financial security in an amount approved by the City Engineer equal to one hundred percent (100%) of the cost of the required storm water management facilities shall be posted by the owner or person in control, to secure the completion of such facilities pursuant to these regulations. Additional financial security in an amount approved by the City Engineer to secure the structural integrity of such facilities for a term not to exceed five years from the date of acceptance and approval by the City Engineer shall be required. The amount of such financial security shall not exceed ten percent (10%) of the actual cost of replacement. All storm water management facilities shall be completed by the owner or person in control at no expense to the City.
(Ord. 1991-122. Passed 11-18-91.)

1341.10 PROCEDURES FOR SUBDIVISIONS.

Any person, the owner of property or in possession or control of any property involved in developing a subdivision within the City or within the City's three-mile jurisdictional area, shall be required to comply with the provisions of these regulations or when applicable, County storm water regulations, as well as the City's Subdivision Regulations.
(Ord. 1991-122. Passed 11-18-91.)

1341.11 SCHEDULE OF FEES.

Before any Storm Water Management Plan is approved, the City Engineer or his designee shall collect a fee, the amount of which shall be based upon total area of impervious surfaces on the site, which shall be one hundred fifty dollars ($150.00) for the first 5,000 square feet of impervious surface or fraction thereof, plus one dollar ($1.00) for each 1,000 square feet or fraction thereof, in excess of 5,000 square feet of impervious surface, to cover the cost of all necessary reviews, except that no fee shall be charged for work performed by a governmental agency.
(Ord. 1991-122. Passed 11-18-91.)

1341.12 RIGHT OF APPEAL TO THE BOARD OF BUILDING APPEALS.

Any person, the owner of property or in possession or control of any property who has a bona fide controversy with the City Engineer and whose rights have been materially affected by any decision of the City Engineer in the approval or disapproval of a Storm Water Management Plan as provided herein or in the administration of the provisions of this chapter, shall within thirty days from the approval or disapproval of the Storm Water Management Plan, be permitted to file with the City Engineer an appeal in writing to the Board of Engineering and Building Appeals as hereinafter provided.

The appeal shall be based upon one or both of the following grounds, to wit:

(a) That the action of the City Engineer was erroneous or constituted an erroneous application of the provisions of this chapter, related laws and ordinances, or was otherwise contrary to law; and/or

(b) That the action of the City Engineer imposes an undue hardship on the complainant, and a modified application or an alternative arrangement is available and feasible, whereby the hardship can be relieved without defeating the purpose and intent of this chapter.

The complainant shall set forth in his petition on appeal the interpretation, ruling or order appealed from, and the provisions of this chapter and related laws and ordinances involved, and shall state wherein the interpretation, ruling or order is erroneous. If the appeal is based on the grounds of hardship, the petition shall show the nature of the hardship and point out what kind of modified application or alternative arrangement can be put into effect which shall relieve the hardship without defeating the purposes and intent of the provisions of this chapter.

No appeal shall be accepted for filing, unless the complainant at the time of filing the appeal, deposits with the City Engineer the nonrefundable sum of two hundred and fifty dollars ($250.00) which shall be submitted to the Director of Finance, to compensate the City for the costs and expenditures incurred by the City as a result of such appeal.

(Ord. 1991-122. Passed 11-18-91.)

1341.13 SUSPENSION OF OPERATIONS.

The City Engineer shall have the authority to order stopped any operations contrary to the terms and conditions of the approved Storm Water Management Plan or these regulations as provided for under this chapter.

(Ord. 1991-122. Passed 11-18-91.)

1341.14 LIABILITY OF CITY.

Failure of the City Engineer or any official or public employee of the City to observe or recognize hazardous conditions or to recommend corrective measures shall not relieve the owner or person in control of property from liability for the condition or for injury to persons or property resulting therefrom. The approval of a Storm Water Management Plan or any action by the City under this chapter shall not create in the City, its officers, agents or employees any liability or responsibility for injury to persons or property caused by or related to such action. Nothing in this chapter shall be construed to relieve the owner or person in control of property from liability for injury to persons or property.

(Ord. 1991-122. Passed 11-18-91.)

1341.15 ISSUANCE OF PERMITS; SUBDIVISION APPROVAL.

The Building Inspector shall withhold the issuance of any permit under his authority and the Planning and Zoning Commission shall withhold final approval of any subdivision plat until the owner or the person in control has complied with the provisions of this chapter.
(Ord. 1991-122. Passed 11-18-91.)

1341.16 CORRELATION WITH OTHER CITY OR COUNTY PERMITS.

No department, board, official or public employee of the City or County vested with the duty or authority to issue permits, certificates or licenses for any new development or subdivision of land shall issue the same if such new development or subdivision of land would be in conflict with any of the provisions of these regulations, and if so issued the same shall be void.
(Ord. 1991-122. Passed 11-18-91.)

1341.17 CHANGES IN PLAN AFTER APPROVAL.

No change or revision shall be made to any approved Storm Water Management Plan unless authorization for such has been granted in writing by the City Engineer.
(Ord. 1991-122. Passed 11-18-91.)

1341.18 DUTIES OF CITY ENGINEER; LAW DIRECTOR.

It shall be the duty of the City Engineer to administer and enforce the provisions of these regulations. The Law Director shall, immediately upon a violation of these regulations having been called to his attention, institute appropriate legal action.
(Ord. 1991-122. Passed 11-18-91.)

1314.99 PENALTY.

Any person, the owner of property or in possession or control of any property who violates any terms or provisions of this chapter shall be deemed to be guilty of a misdemeanor of the first degree. Each day's violation shall be deemed to be a separate offense.
(Ord. 1991-122. Passed 11-18-91.)

FOR USE WITH TR-55 METHOD

TABLE OH-1

OHIO
24-HOUR RAINFALL (inches)

County	Frequency						
	1	2	5	10	25	50	100
Adams	2.5	2.8	3.5	4.0	4.6	5.0	5.5
Allen	2.3	2.7	3.3	3.8	4.3	4.8	5.2
Ashland	2.2	2.4	3.1	3.5	4.0	4.5	4.7
Ashtabula	2.1	2.3	3.0	3.5	4.0	4.5	4.7
Athens	2.3	2.5	3.3	3.8	4.3	4.7	4.9
Auglaize	2.4	2.7	3.4	3.9	4.4	4.9	5.2
Belmont	2.2	2.5	3.2	3.7	4.3	4.7	4.9
Brown	2.5	2.9	3.6	4.1	4.7	5.1	5.6
Butler	2.5	2.9	3.6	4.1	4.7	5.2	5.6
Carroll	2.2	2.4	3.1	3.6	4.1	4.6	4.8
Champaign	2.4	2.7	3.4	3.9	4.4	4.9	5.2
Clark	2.4	2.7	3.4	3.9	4.5	4.9	5.3
Clermont	2.5	2.9	3.6	4.1	4.7	5.1	5.6
Clinton	2.5	2.8	3.5	4.0	4.6	5.0	5.4
Columbiana	2.2	2.4	3.2	3.7	4.2	4.6	4.8
Coshocton	2.2	2.4	3.2	3.6	4.1	4.6	4.8
Crawford	2.2	2.5	3.2	3.6	4.1	4.6	4.8
Cuyahoga	2.1	2.2	3.0	3.4	3.9	4.4	4.6
Darke	2.4	2.8	3.5	4.0	4.5	5.0	5.5
Defiance	2.3	2.6	3.3	3.8	4.3	4.8	5.1
Delaware	2.3	2.5	3.3	3.7	4.2	4.7	4.9
Erie	2.2	2.4	3.1	3.5	3.9	4.4	4.7
Fairfield	2.3	2.5	3.3	3.7	4.3	4.7	4.9
Fayette	2.4	2.7	3.4	3.9	4.5	4.9	5.2
Franklin	2.3	2.6	3.3	3.8	4.3	4.7	5.0
Fulton	2.2	2.6	3.2	3.7	4.2	4.6	5.0
Gallia	2.4	2.6	3.4	3.8	4.4	4.9	5.1
Geauga	2.1	2.3	3.0	3.5	3.9	4.4	4.6
Greene	2.4	2.8	3.5	4.0	4.6	5.0	5.4
Guernsey	2.2	2.4	3.2	3.7	4.2	4.6	4.8
Hamilton	2.5	3.0	3.6	4.1	4.8	5.2	5.7
Hancock	2.3	2.6	3.3	3.7	4.2	4.7	5.0
Hardin	2.3	2.7	3.3	3.8	4.3	4.8	5.1
Harrison	2.2	2.4	3.2	3.7	4.2	4.7	4.9
Henry	2.3	2.6	3.3	3.7	4.2	4.7	5.0
Highland	2.5	2.8	3.5	4.0	4.6	5.0	5.4
Hocking	2.3	2.5	3.3	3.8	4.3	4.8	4.9
Holmes	2.2	2.4	3.1	3.5	4.0	4.5	4.7
Huron	2.2	2.4	3.1	3.5	4.0	4.5	4.7
Jackson	2.4	2.6	3.4	3.8	4.4	4.9	5.1
Jefferson	2.2	2.5	3.2	3.7	4.2	4.7	4.9
Knox	2.2	2.4	3.2	3.6	4.1	4.6	4.8
Lake	2.1	2.2	3.0	3.4	3.9	4.4	4.6
Lawrence	2.4	2.7	3.4	3.9	4.5	4.9	5.2
Licking	2.3	2.5	3.2	3.7	4.2	4.6	4.8
Logan	2.3	2.7	3.4	3.8	4.4	4.8	5.2

Location: Example Site

Study Area: 20 Acres

Pre-development CN 78
Pre-development Tc 0.48 Hours

Tc min = 0.1
Tc max = 10.0

Post-developemnt CN 90
Post-development Tc 0.35 Hours

Storm Size ---------->	1	2	5	10	25	50	100
24 Hour Rainfall, P (inches)	2.2	2.5	3.2	3.7	4.2	4.7	4.9
PRE-DEVELOPMENT							
Pre-development CN	78	78	78	78	78	78	78
Pre-development Runoff, Q (in.)	0.60	0.79	1.27	1.65	2.05	2.46	2.63
Pre-dev Runoff Vol, Vr (Ac-ft)	1.00	1.32	2.12	2.75	3.42	4.10	4.38
Ia/P	0.256	0.226	0.176	0.152	0.134	0.120	0.115
Adjusted Ia/P	0.256	0.226	0.176	0.152	0.134	0.120	0.115
Unit Peak Discharge, qu	0.730	0.751	0.787	0.804	0.818	0.829	0.833
Peak Discharge, qp (cfs)	8.8	11.9	20.0	26.5	33.5	40.8	43.8
POST-DEVELOPMENT							
Post-development CN	90	90	90	90	90	90	90
Post-development Runoff, Q (in.)	1.27	1.53	2.17	2.64	3.11	3.59	3.78
Post-dev Runoff Vol, Vr (Ac-ft)	2.12	2.55	3.62	4.40	5.18	5.98	6.30
Ia/P	0.101	0.089	0.069	0.060	0.053	0.047	0.045
Adjusted Ia/P	0.101	0.100	0.100	0.100	0.100	0.100	0.100
Unit Peak Discharge, qu	0.984	0.985	0.985	0.985	0.985	0.985	0.985
Peak Discharge, qp (cfs)	25.0	30.1	42.7	52.0	61.3	70.7	74.5
Percent Increase (Total Volume)	112%	93%	71%	60%	51%	46%	44%

$$\frac{(2.12 - 1.00)}{1.00} \times 100$$

Location: Example Site

STORAGE REQUIREMENTS (Percent increase by Total Volume)

			WATERSHED TYPE A		B		C	
Criteria Storm				1		1		1
Percent Increase (Total Volume)				112%		112%		112%
Critical Storm				25		10		2
Allowable Discharge (cfs)	Storm	Pre-Devel	In	Out	In	Out	In	Out
	1	8.8	25.0	8.8	25.0	8.8	25.0	8.8
	2	11.9	30.1	8.8	30.1	8.8	30.1	8.8
	5	20.0	42.7	8.8	42.7	8.8	42.7	20.0
	10	26.5	52.0	8.8	52.0	8.8	52.0	26.5
	25	33.5	61.3	8.8	61.3	33.5	61.3	33.5
	50	40.8	70.7	40.8	70.7	40.8	70.7	40.8
	100	43.8	74.5	43.8	74.5	43.8	74.5	43.8
Storage Calculation (Ac-ft)	Storm	Vr	qo/qi	Vs	qo/qi	Vs	qo/qi	Vs
	1	2.12	0.35	0.74	0.35	0.74	0.35	0.74
	2	2.55	0.29	0.98	0.29	0.98	0.29	0.98
	5	3.62	0.21	1.62	0.21	1.62	0.47	1.05
	10	4.40	0.17	2.12	0.17	2.12	0.51	1.20
	25	5.18	0.14	2.65	0.55	1.34	0.55	1.34
	50	5.98	0.58	1.48	0.58	1.48	0.58	1.48
	100	6.30	0.59	1.54	0.59	1.54	0.59	1.54
Storage (Cubic Feet)	Storm							
	1			32200		32200		32200
	2			42700		42700		42700
	5			70600		70600		
	10			92300		92300		
	25			115400				
	50			64500				
	100			67100				
	Maximum Value:			115400		92300		42700

Excerpt from

"APPLIED HYDROLOGY"

by

Ven Te Chow
David R. Maidment
Larry W. Mays

McGraw-Hill, Inc. 1988

Pages 522 to 527

storage in basins and ponds, parking lot storage, and rooftop detention.

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The shape of the hydrograph produced by the modified rational method is a trapezoid, constructed by setting the duration of the rising and recession

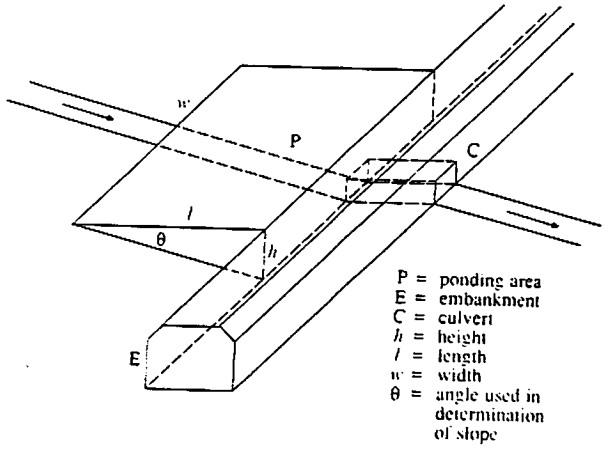

FIGURE 15.4.1
Schematic representation of wedge-shaped ponding area with box culvert outlet. (*Source*: Craig and Rankl, 1978. Used with permission.)

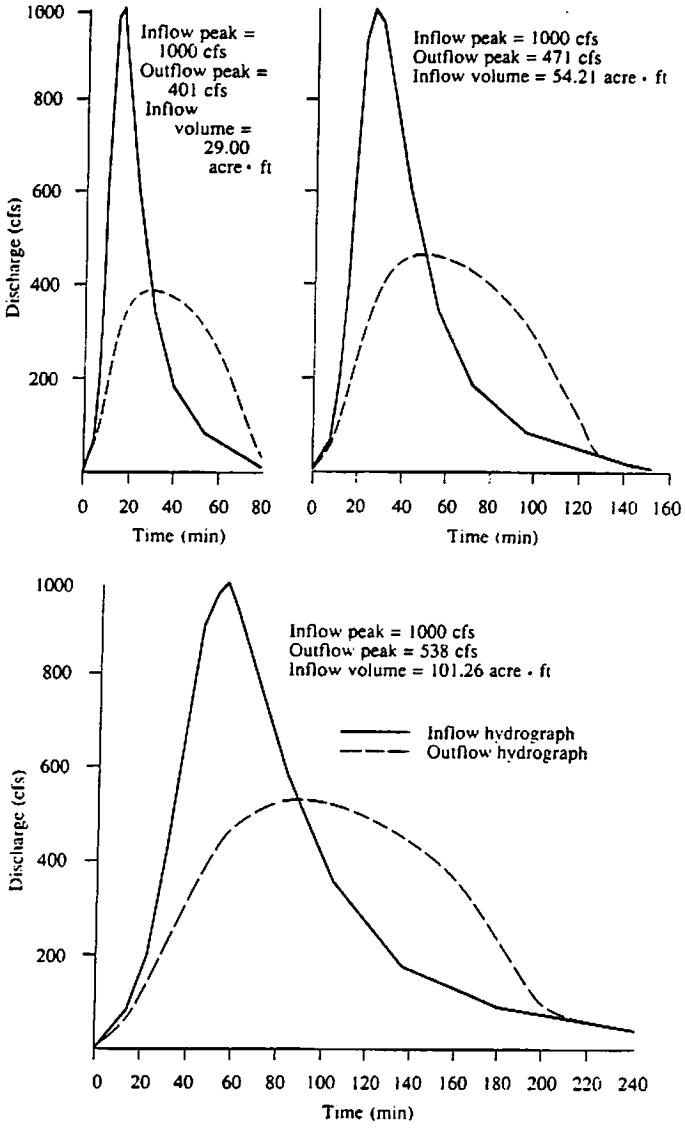

FIGURE 15.4.2
Comparison of inflow and outflow hydrographs for a detention basin. The inflow peaks are all 1000 cfs; however, the inflow volumes vary. The ponding area is a hypothetical wedge-shaped storage area (Fig. 15.4.1), and a 4 ft × 4 ft box culvert serves as the outlet. The pond width is 60 ft with a slope of 0.02 ft/ft. The flow with the largest volume results in the highest outflow rate from the pond. (*Source*: Craig and Rankl, 1978. Used with permission.)

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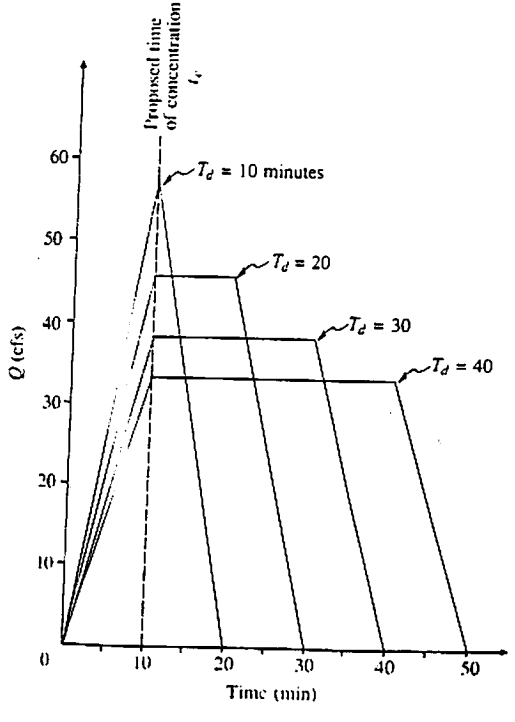

FIGURE 15.4.3
Typical storm water runoff hydrographs for the modified rational method with various rainfall durations.

Figure 15.4.4 is a representation of inflow and outflow hydrographs for a detention basin design. In this figure, α is the ratio of the peak discharge before development, Q_A (or peak discharge from the detention basin), and the peak discharge after development, Q_p:

$$\alpha = \frac{Q_A}{Q_p} \tag{15.4.1}$$

The ratio of the times to peak in the two hydrographs is γ. V_r is the volume of runoff after development. The volume of storage V_s needed in the basin is the accumulated volume of inflow minus outflow during the period when the inflow rate exceeds the outflow rate, shown shaded in the figure.

Using the geometry of the trapezoidal hydrographs, the ratio of the volume of storage to the volume of runoff, V_s/V_r, can be determined (Donahue, McCuen, and Bondelid, 1981):

$$\frac{V_s}{V_r} = 1 - \alpha\left[1 + \frac{T_p}{T_d}\left(1 - \frac{\gamma + \alpha}{2}\right)\right] \tag{15.4.2}$$

where T_d is the duration of the precipitation and T_p is the time to peak of the inflow hydrograph.

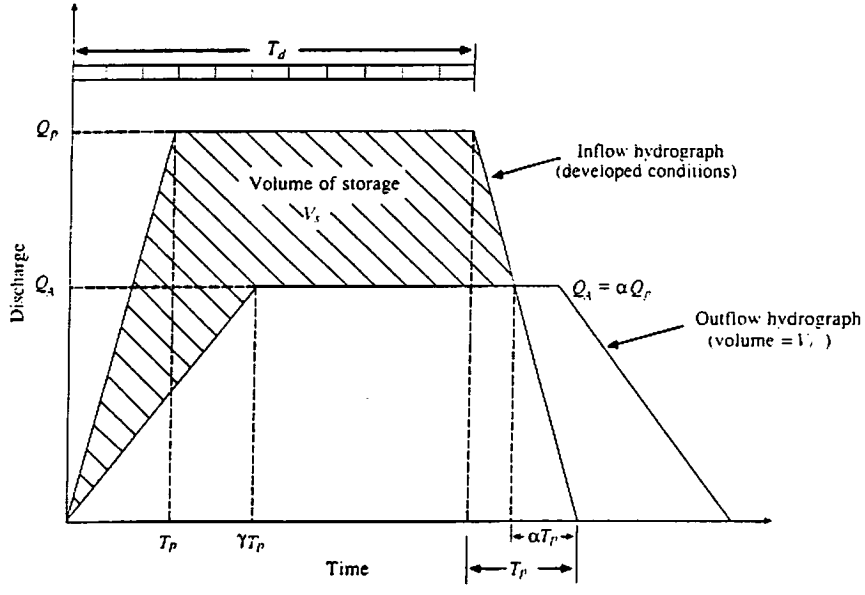

FIGURE 15.4.4
Inflow and outflow hydrographs for detention design. The outflow hydrograph is based on the inflow hydrograph for predeveloped conditions or on other more restrictive outflow criteria. (*Source*: Donahue, McCuen, and Bondelid, 1981. Used with permission.)

Consider a rainfall intensity-duration relationship of the form

$$i = \frac{a}{T_d + b} \tag{15.4.3}$$

where i is rainfall intensity and a and b are coefficients. The volume of runoff after development is equal to the volume under the inflow hydrograph:

$$V_r = Q_p T_d \tag{15.4.4}$$

The volume of storage is determined by substituting (15.4.4) into (15.4.2), and rearranging to get

$$V_s = Q_p T_d \left\{ 1 - \alpha \left[1 + \frac{T_p}{T_d} \left(1 - \frac{\gamma + \alpha}{2} \right) \right] \right\} \tag{15.4.5}$$

$$= T_d Q_p - Q_A T_d - Q_A T_p + \frac{\gamma Q_A T_p}{2} + \frac{Q_A^2 T_p}{2} \frac{1}{Q_p} \tag{15.4.6}$$

where α has been replaced by Q_A/Q_p.

The duration that results in the maximum detention is determined by substituting $Q_p = CiA = CAa/(T_d + b)$, then differentiating (15.4.6) with respect to T_d and setting the derivative equal to zero:

$$\frac{dV_s}{dT_d} = 0 = T_d \frac{dQ_p}{dT_d} + Q_p - Q_A + \frac{Q_A^2 T_p}{2} \left[\frac{d(1/Q_p)}{dT_d} \right]$$

$$= \frac{-T_d CAa}{(T_d + b)^2} + \frac{CAa}{T_d + b} - Q_A + \frac{Q_A^2 T_p}{2CAa}$$

$$= \frac{bCAa}{(T_d + b)^2} - Q_A + \frac{Q_A^2 T_p}{2CAa}$$

where it is assumed that Q_A, T_p, and γ are constants. Solving for T_d,

$$T_d = \left(\frac{bCAa}{Q_A - \dfrac{Q_A^2 T_p}{2CAa}} \right)^{1/2} - b \tag{15.4.7}$$

The time to peak T_p is set equal to the time of concentration.

Example 15.4.1. Determine the critical duration T_d (i.e., the one that requires the maximum detention storage) for a 25-acre watershed with a developed runoff coefficient $C = 0.825$. The allowable discharge is the predevelopment discharge of 18 cfs. The time of concentration for the developed conditions is 20 min, and for undeveloped conditions is 40 min. The applicable rainfall-intensity-duration relationship is

$$i = \frac{96.6}{T_d + 13.9}$$

Solution. The critical duration is found from Eq. (15.4.7):

$$T_d = \left(\frac{(13.9)(0.825)(25.0)(96.6)}{18 - \dfrac{(18)^2(20)}{2(0.825)(25)(96.6)}} \right)^{1/2} - 13.9$$

$$= 27.23 \text{ min}$$

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Solution. The peak discharge for the duration of 27.23 min is

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$$= (0.825)(25) \left(\frac{96.6}{27.23 + 13.9} \right)$$

$$= 48.44 \text{ cfs}$$

By Eq. (15.4.6), then,

$$V_s = (27.23)(48.44) - (18)(27.23) - (18)(20) + (18)(20)\frac{2}{2} + \frac{(18)^2(20)}{2} \frac{1}{48.44}$$

$$= 895.77 \text{ cfs} \cdot \text{min} \times 60 \text{ s/min}$$

$$= 53,746. \text{ ft}^3$$

As a comparison, from (15.4.4), $V_r = Q_p T_d = 48.44 \times 27.23 = 1319$ cfs · min = 79,140 ft^3, so $V_s/V_r = 53,746/79,140 = 0.68$. Hence the detention pond will store 68% of its inflow hydrograph in this example.

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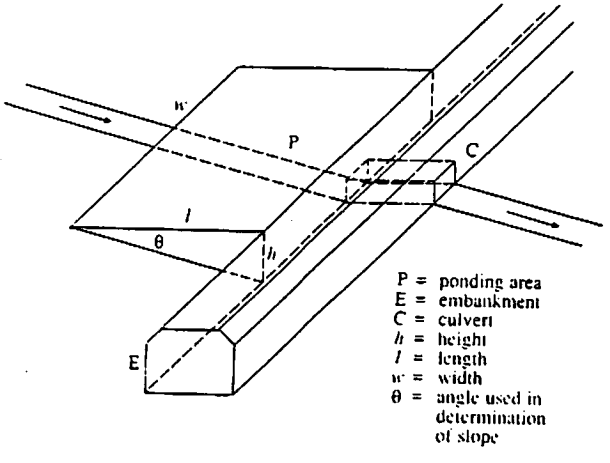

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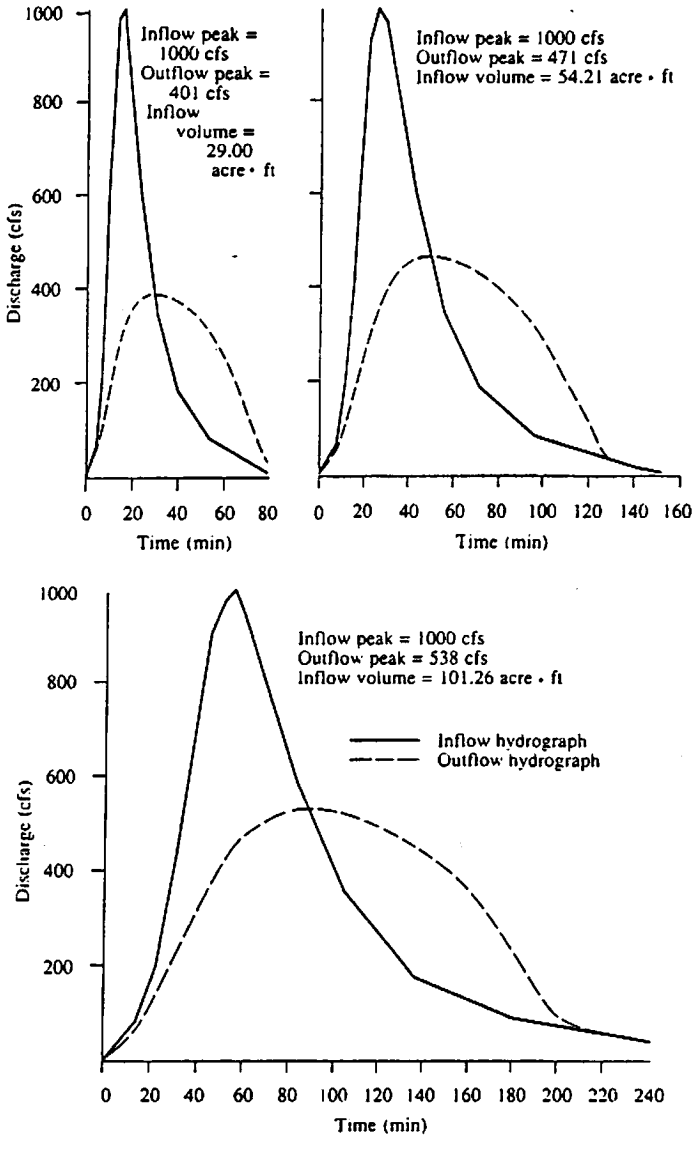

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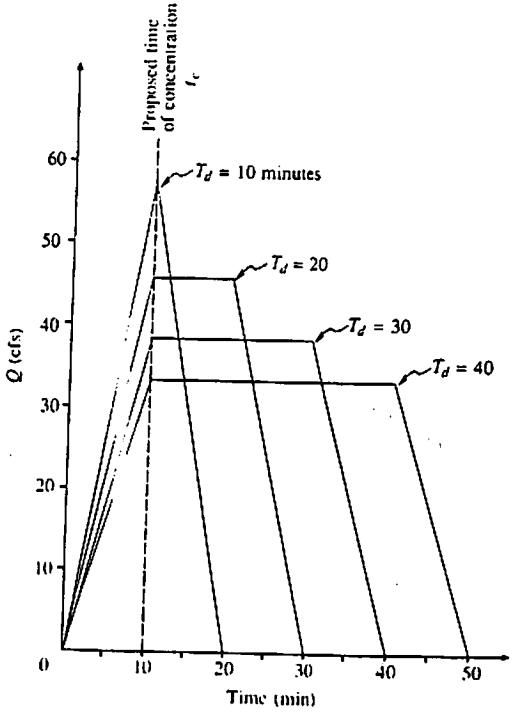

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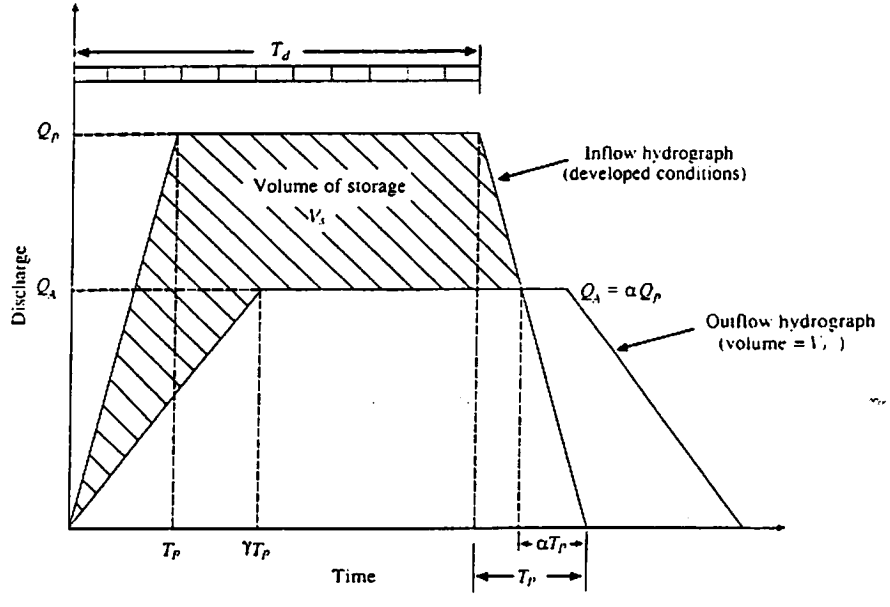

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INTENSITY and TOTAL RAINFALL CHART

FOR MODIFIED RATIONAL METHOD

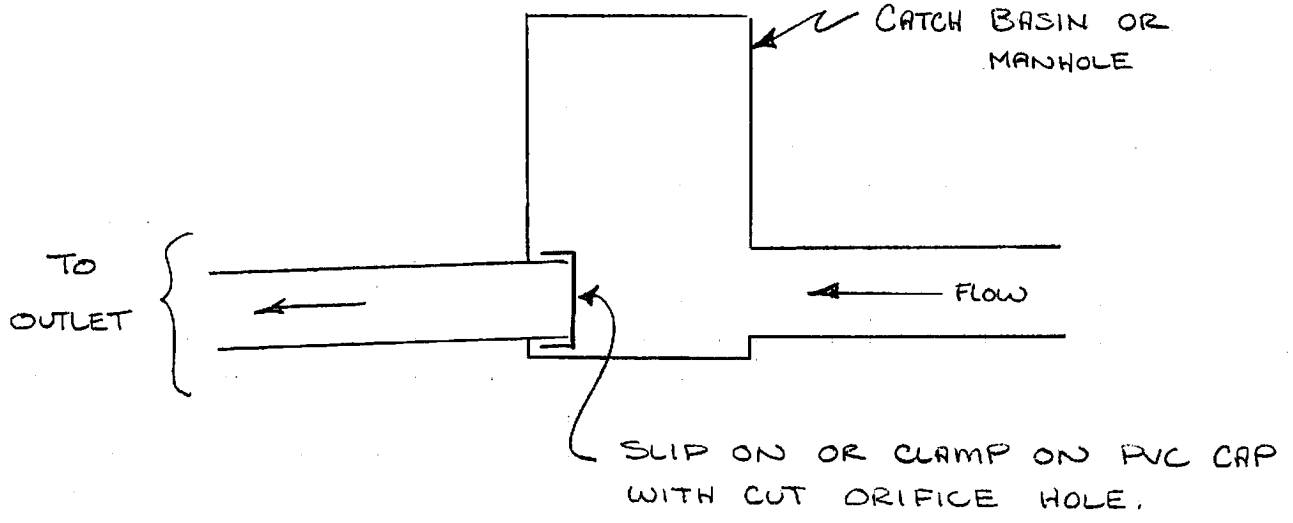
Time	1 Year		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year	
	i	Total	i	Total	i	Total	i	Total	i	Total	i	Total	i	Total
min	in/hr	in	in/hr	in	in/hr	in	in/hr	in	in/hr	in	in/hr	in	in/hr	in
10	2.70	0.45	3.80	0.63	4.60	0.77	5.50	0.92	6.75	1.13	7.30	1.22	8.10	1.35
15	2.30	0.58	3.12	0.78	3.90	0.98	4.60	1.15	5.70	1.43	6.10	1.53	6.90	1.73
20	1.95	0.65	2.81	0.94	3.45	1.15	4.00	1.33	4.95	1.65	5.40	1.80	6.10	2.03
25	1.70	0.71	2.57	1.07	3.10	1.29	3.60	1.50	4.40	1.83	4.75	1.98	5.50	2.29
30	1.55	0.78	2.23	1.12	2.75	1.38	3.20	1.60	3.95	1.98	4.30	2.15	4.90	2.45
35	1.40	0.82	2.03	1.18	2.50	1.46	2.90	1.69	3.60	2.10	3.90	2.28	4.45	2.60
40	1.30	0.87	1.83	1.22	2.30	1.53	2.70	1.80	3.30	2.20	3.60	2.40	4.10	2.73
45	1.20	0.90	1.70	1.28	2.10	1.58	2.50	1.88	3.00	2.25	3.30	2.48	3.75	2.81
50	1.14	0.95	1.55	1.29	1.95	1.63	2.30	1.92	2.80	2.33	3.00	2.50	3.45	2.88
55	1.06	0.97	1.45	1.33	1.80	1.65	2.10	1.93	2.60	2.38	2.80	2.57	3.15	2.89
60	0.98	0.98	1.37	1.37	1.70	1.70	2.00	2.00	2.45	2.45	2.65	2.65	2.93	2.93
70	0.85	0.99	1.20	1.40	1.45	1.69	1.75	2.04	2.10	2.45	2.30	2.68	2.53	2.95
80	0.75	1.00	1.08	1.44	1.30	1.73	1.60	2.13	1.90	2.53	2.00	2.67	2.30	3.07
90	0.70	1.05	0.98	1.47	1.17	1.76	1.45	2.18	1.75	2.63	1.85	2.78	2.08	3.12
100	0.65	1.08	0.91	1.52	1.10	1.83	1.35	2.25	1.63	2.72	1.70	2.83	1.95	3.25
110	0.61	1.12	0.85	1.56	1.01	1.85	1.25	2.29	1.52	2.79	1.57	2.88	1.83	3.36
120	0.59	1.18	0.80	1.60	0.97	1.94	1.15	2.30	1.45	2.90	1.50	3.00	1.70	3.40
140	0.52	1.21	0.71	1.66	0.88	2.05	1.05	2.45	1.30	3.03	1.40	3.27	1.55	3.62
160	0.48	1.28	0.65	1.73	0.80	2.13	0.95	2.53	1.20	3.20	1.30	3.47	1.40	3.73
180	0.44	1.32	0.60	1.80	0.73	2.19	0.85	2.55	1.10	3.30	1.20	3.60	1.30	3.90

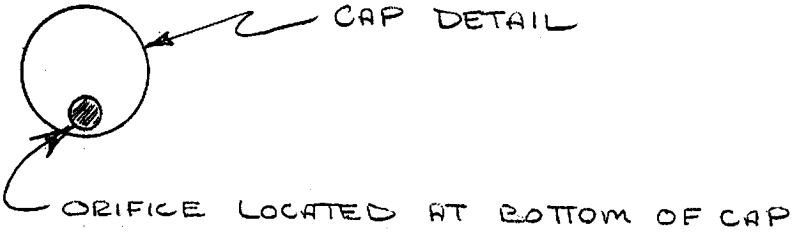
Ref: ODOT L&D Manual Figure 1152-2, October 1981 - Area D

Note: The 1 year storm developed from US Weather Bureau Rainfall Data

USE 10 MINUTES AS MINIMUM TIME OF CONCENTRATION

INTERPOLATE BETWEEN MINUTES





OUTLET CONTROL USING PVC CAP W/ORIFICE