SECTION 1 - DRAINAGE POLICY

1.1.0 GENERAL

This manual represents the application of accepted principles of surface drainage engineering and is a working supplement to basic information obtainable from standard drainage handbooks and other publications on drainage. The policy statements of this section provide the underlying principles by which all drainage facilities shall be designed. The application of the policy is facilitated by the technical criteria contained in the remainder of the manual.

1.2.0 CITY OF AUSTIN DRAINAGE POLICY

The intent of Austin's drainage policy for stormwater management is to implement design principles and practices that control post-development runoff from all development such that no development will result in ~~identifiable~~ additional adverse flooding impacts in accordance with Chapter 25-7 of the Land Development Code.

1.2.1 Application

The City of Austin drainage policy shall govern the planning and design of drainage infrastructure within the City of Austin and within all areas subject to its extraterritorial jurisdiction. Definitions, formulae, criteria, procedures and data in this manual have been developed to support this policy. If any condition requiring some additional measure of protection is identified during design or construction, the engineer shall make provisions within the design. In order to receive a waiver ~~an administrative variance~~ to any of the criteria or ~~policy~~ policies in this manual, the applicant must receive approval from the Director of the Watershed Protection ~~Watershed Protection and Development Review~~ Department. A request for ~~an administrative~~ **a** waiver must comply with State law regarding engineering work and must include justification from the engineer that compliance is not feasible.

1.2.2 General

A. Stormwater runoff peak flow rates for the two (2), ten (10), twenty-five (25) and one-hundred (100) year frequency storms shall not cause increased inundation of any building or roadway surface or create any ~~identifiable~~ additional adverse flooding impacts.

B. Street curbs, gutters, inlets and storm ~~sewers~~ drains shall be designed to intercept, contain and transport all runoff from the 25-year frequency storm.

C. In addition to B above, the public drainage system shall be designed to convey those flows from greater than the 25-year frequency storm up to and including the 100-year frequency storm within defined public rights-of-way or drainage easements.

D. Stormwater runoff peak flow rates shall not be increased at any point of discharge from a site for the two (2), ten (10), twenty-five (25) and one hundred (100) year storm frequency events.

E. Regulation of peak flows to allowable levels, as determined by the provisions of this policy, shall be achieved by storage on-site or off-site or by participation in an approved Regional Stormwater Management Program. The Stormwater Management ~~Detention~~ Section of this manual provides a guide to acceptable methods, but does not limit the designer to the methods presented therein. Guidelines for participation in

the Regional Stormwater Management Program are contained in the Stormwater Management ~~Detention~~ Section of this manual.

F. For those developments which are immediately adjacent to and discharge directly into Lake Travis, Lake Austin, Lady Bird Lake and the Colorado River, on-site detention is not required.

G. Development activity is not subject to D. or E. above if the following conditions are satisfied:

1. The activity is located in the Waller Creek, Shoal Creek (downstream from the West 38th St. bridge), Boggy Creek, East Bouldin Creek, West Bouldin Creek, Blunn Creek, Johnson Creek, Harper's Branch or Lady Bird Lake watersheds**;** and

2. The activity involves an existing legal lot that is limited to single-family (SF-1, 2, or 3) land use by zoning, restrictive covenant or plat note**;** and

3. The proposed impervious cover does not exceed 45%**;** and

4. A site plan is not required**;** and

5. The existing lot size is equal to or less than 1.00 acre**;** and

6. The existing lot does not receive significant off-site drainage.

7 ~~6.~~ An engineer submits a signed, sealed and dated letter, addressed to the Director of the ~~Watershed Protection~~ Planning and Development Review Department, stating the following without qualification: "I certify that I have personally conducted a topographic review and field investigation of the existing and proposed flow patterns for stormwater runoff from the subject development ~~subdivision~~ to the main stem of (name of creek). At build-out conditions allowable by zoning, restrictive covenant or plat note, the stormwater flows from the subject development ~~subdivision~~ will not cause any additional ~~identifiable~~ adverse flooding impacts ~~increase in flooding conditions to the interior of existing building structures, including basement areas,~~ for storms of magnitude up through the 100-year event."

8. Calculations supporting the certification statement in Part 7 must be submitted if requested.

1.2.3 Street Drainage

A. No lowering of the standard height of street crown shall be allowed for the purposes of obtaining additional hydraulic capacity.

B. For non-curbed streets**,** all flows for the 100-year frequency storm shall be contained within paralleling roadside ditches, medians, drainage channels or other drainage facilities located within public rights-of-way or drainage easements.

C. No outlet structures from stormwater management facilities, groundwater collection, parking detention, or other improvements discharging concentrated flows shall be designed to discharge concentrated flow directly onto arterial or collector streets. For local streets, no concentrated discharge from sites larger than 0.25 acres shall be permitted. All concentrated discharges shall be conveyed by a closed conduit to the nearest existing storm drain.

D. Concentrated discharge across a sidewalk area will not be allowed. A channel section can be used under the sidewalk area, provided it is covered by a method approved by the Public Works Department and the outlet device utilizes sheet flow methods.

1.2.4 Drainage System

A. All drainage system components that are within public right-of-way or public drainage easements shall be manufactured and installed in compliance with the City of Austin Standard Specifications and Standards and shall comply with all applicable portions of the Transportation Criteria Manual published by the Department of Transportation, unless:

1. Those components receive stormwater runoff solely from private property,

2. That property consists solely of the property being developed, and

3. Those components are privately maintained.

~~This provision applies only to those drainage systems, which are to become an integral part of the public storm drain system, and excludes any private internal site systems. Drainage infrastructure to be constructed either in an easement that will not be privately maintained or in public or private right of way shall comply with all applicable portions of Section 11 of the Transportation Criteria Manual published by the Department of Public Works and Transportation.~~

B. Construction plans for proposed reinforced concrete box culverts, bridges and related structures may be adaptations of the Texas Department of Transportation (TxDOT) Standards.

C. For bridges and culverts ~~in~~ crossing ~~residential~~ local streets, runoff from the fully developed 100-year frequency storm shall not produce a headwater elevation at the roadway greater than either twelve (12) inches above the roadway crown elevation or any top of upstream curb elevation, whichever is lower.

D. For bridges and culverts ~~in~~ crossing streets other than a local ~~residential~~ street, runoff from the fully developed 100-year frequency storm shall not produce a headwater elevation at the roadway greater than six (6) inches above the roadway crown elevation or six (6) inches above any top of upstream curb elevation, whichever is lower.

E. All drainage facilities (including but not limited to headwalls, open channels, storm drains, area inlets, and detention, retention and water quality controls and their appurtenances) shall comply with the following requirements, unless otherwise noted in this section or the Environmental Criteria Manual (ECM). ~~(~~See Figure 1-1 ~~8-7~~ in DCM Appendix ~~E~~ D for approximate representation~~)~~. For the purposes of this section (1.2.4.E), the term "residential structure" means a building used for living accommodations.

1. (a) Where a portion of the stormwater ~~pond~~ facility either has an interior slope or wall steeper than three (3) feet horizontal to one (1) foot vertical with a height exceeding one (1) foot, or, an exterior slope or wall steeper than three (3) feet horizontal to one (1) foot vertical with a height exceeding three (3) feet above adjacent ground, barrier-type fences at least six (6) feet high, and/or steel grating are required for all single-family or duplex residential development, City ~~city~~ maintained stormwater ~~pond~~ facilities, and/or for any privately maintained stormwater ~~pond~~ facilities located within 500 feet of a residential structure. Barrier type fences include, but are not limited to chain link, solid wood, masonry, stone or wrought iron.

(b) Metal components of the fence shall be corrosion-resistant and wood components of the fence shall be weather-resistant. Placement of the fence~~,~~ shall be 20 feet past the toe of the embankment or to the edge of the property line. Any fence posts used shall be galvanized steel with a concrete footing of at least twelve (12) inches in diameter and at least eighteen (18) inches in depth (refer to City of Austin Standard Specification No. 701). All fences shall have at least one gate, which shall open fully inward and outward and shall be at least twelve (12) feet in width. The first gate shall provide access from either the easement or right-of-way. Access to the outfall structures ~~strtuctures~~ is required for inspection and maintenance. If the fencing prohibits access to the outfall structure, then a second gate shall be provided allowing access to the outfall structure. Corrosion-resistant aluminum or hot-dipped galvanized steel grates of load bearing strength are an acceptable means of vertical access control. Grates shall be securely bolted to the structure but shall allow for easy removal and replacement during maintenance operations.

2. The landscaping requirements of Section 2.9.1, part B. and C. only, of the ~~Environmental Criteria Manual~~ ECM apply for all detention, retention and water quality facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City. Landscaping and other vegetation shall not encroach into or impede use of any access drive or access strip, based upon the

nominal size of the landscaping or vegetation at maturity.

3. (a) A 12-foot maintenance access strip is required around the perimeter of detention, retention, and water quality facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City. This 12-foot maintenance access strip shall be outside the toe of any fill slope and the top of any cut slope and shall not have a post-construction longitudinal slope greater than 15% nor a post-construction transverse slope greater than 5%, shall not have a vertical grade break of greater than 12%, shall have an inside turning radius of no less than thirty-six (36) feet, shall be cleared and graded, and shall have vertical clearance from existing and proposed vegetation and all other objects of no less than 14 feet.

(b) A setback shall be provided for all detention, retention, and water quality facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City so that no such facility shall be located within 50 feet of a residential structure. All detention, retention and water quality facilities that will be for single-family or duplex residential development and/or for such facilities maintained by the City shall have a permanent maintenance equipment access ramp into each basin of the facilities, with a longitudinal slope not to exceed 4:1, a transverse slope not to exceed 5%, no vertical grade break greater than 12%, no vertical curve with a grade change greater than 1% per horizontal foot, an inside turning radius of no less than 36 feet, a minimum width of 12 feet and a clear distance from the bottom of the ramp to any facility interior slope of at least 15 feet.

(c) Access/drainage easements and access drives are required for those detention, retention and water quality facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City. Access drives shall have a longitudinal slope not to exceed 15%, a transverse slope not to exceed 5%, no vertical grade break greater than 12%, no vertical curve with grade change greater than 1% per horizontal foot, a centerline turning radius of no less than 50 feet, and a minimum width of 12 feet. The access drive shall include a means for equipment to turn around when located more than 200 feet from a paved public roadway. Access drives shall be cleared, graded and stabilized with stones in accordance with Figure 1-2 in Appendix D of this manual.

4. (a) For drainage facilities within a drainage easement, but not for single-family or duplex residential development or such facilities maintained by the City ~~city,~~ the ~~50 feet~~ set back rule discussed in section 3(b) above ~~in this section~~ is not applicable for the proposed internal building(s), if they have a restrictive covenant for maintenance and 4-foot ~~feet~~ high barrier-type fences with accessible maintenance ramp.

(b) Any new commercial or multi-family pond(s) shall have a minimum 50-foot ~~set back~~ setback from any adjacent existing residential structure.

5. The setback requirement shall be measured from the edge of any portion of the facility such as the top of facility embankment, end of concrete apron/rock rip rap or top of structural wall and shall be dedicated by deed restriction or restrictive covenant, and a note referencing the restriction will be placed on the plat, if a plat is being processed as part of the development. Replatting to add the note is not required.

6. Discharge from storm drain outfalls shall not cause channel, bluff, or stream bank erosion. If the storm drain discharges to an open drainage facility (as determined by the City), the applicant must show acceptable nonerosive conveyance to that drainage facility, and appropriately designed outfall including adequate energy dissipation, which may include stream stabilization. ~~appropriate energy dissipation at the outfall and a stable headwall.~~

7. Free standing structural walls/facilities located on or adjacent to a residential structure ~~lot~~ shall not be greater than six (6) feet in height.

8. Drainage or drainage access easements that are required along side lot lines shall be located adjacent to a property line and shall not be centered on a property line.

~~9. Access/drainage easements and access drives are required for those detention, retention and water quality facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City. Access drives shall have a longitudinal slope not to exceed 15%, a transverse~~

~~slope not to exceed 5%, no vertical grade break greater than 12%, no vertical curve with grade change greater than 1% per horizontal foot, a centerline turning radius of no less than 50 feet, and a minimum width of 12 feet. The access drive shall include a means for equipment to turn around when located more than 200 feet from a paved public roadway. Access drives shall be cleared, graded and stabilized with stones in accordance with Figure 8-9 in Appendix E of this manual.~~

9. ~~10.~~ Access drives are required for those area inlets and headwalls for single-family or duplex residential development and/or for such facilities that will be maintained by the City when access is proposed between single-family lots or when access from any other location exceeds 20% grade. Access drives shall meet the criteria of section 3 (c) ~~9.~~ above.

10. ~~11.~~ Points of access to water quality and detention facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City shall have a standard City of Austin Type II concrete driveway approach and curb cut on the abutting street. A pipe gate is required at the end of the driveway at the ROW limits. See Figure 1-3 ~~8-8~~ in Appendix ~~E~~ D of the Drainage Criteria Manual for details.

11. ~~12.~~ Detention, retention and water quality facilities for ~~single-family or duplex residential development and/or for such~~ facilities that will be maintained by the City shall have a staging area not less than 800 square feet in area (with no dimension less than 20 feet) if the storage volume of the pond exceeds 2,000 cubic feet. No portion of the staging area shall be located further than 100 feet from the detention, retention or water quality facility and the access drive and the staging area shall be within an access easement. No portion of the staging area shall be located within or on any ponding area, interior slope of the facility, or access drive or strip. The staging area shall be cleared, shall have vertical clearance from existing and proposed vegetation and all other objects of no less than 14 feet and shall have no finished slope greater than 10%.

12. ~~13.~~ Section 1.6.3.B of the ~~Environmental Criteria Manual~~ ECM shall apply to ~~for~~ all drainage facilities for single-family or duplex residential development and/or for such facilities that will be maintained by the City.

13. ~~14.~~ All pond bottom**s**, side slopes and earthen embankments shall be compacted to 95% of maximum density in accordance with City of Austin ~~COA~~ Standard Specifications, excluding rain gardens and any water quality features that require infiltration to meet water quality standards. Side slopes for earthen embankments shall not exceed three (3) horizontal to one (1) vertical ~~(3H:1V)~~. Rock slopes may exceed these limits if a geotechnical report warrants a deviation. Actual field conditions may override the geotechnical report. Concrete walls shall be built to City of Austin ~~COA~~ Standard~~s~~ Specifications. Expansion joints on free-standing walls shall have water-tight seals as needed. Ponds for single-family or duplex residential development and/or for City maintained ponds with other than full concrete bottoms must have bottom slopes of no less than 2%. Ponds with full concrete bottoms must have bottom slopes of no less than 0.5%; all grass-lined portions of the pond bottom must have a slope of no less than 2% from that portion to the concrete-lined pilot channel. The pilot channel must be at least four (4) feet wide and have a V-shaped cross-sectional flow area two (2) inches deep. Pilot channels are discouraged in water quality ponds due to the creation of short-circuiting and standing water problems. Where it is deemed necessary due to topographic constraints**,** a pilot channel installed in a water quality pond must be designed to prevent short-circuiting, standing water problems, and shall have a flow spreader installed, refer to Section 1.6.2.D of the ~~Environmental Criteria Manual~~ ECM. The bottom slope for ponds is defined as the effective slope from any point in the bottom of the pond to the discharge elevation at the point of discharge from the pond, as measured by a straight line between those two points.

14. ~~15.~~ Section 8.3.~~4~~ 3 of this manual shall apply for all stormwater management facilities, including water quality facilities and stormwater management infrastructure.

15. ~~16~~. All mechanical stormwater management facilities ~~and systems for single-family or duplex residential development and/or for such facilities~~ to be maintained by the City shall meet City of Austin Water and Wastewater criteria. OSHA requirements for ingress and egress are also required for any facility that will be located in a confined space above or under ground.

16. ~~17.~~ Signs stating “Stormwater Facility - No Vehicles Allowed. No Dumping. Violators will be

prosecuted. For information call the City of Austin." are required on each side of a single-family residential, duplex residential, and/or City-maintained stormwater pond.

17. ~~18. No area within the limits of construction of the development shall allow stormwater to become stagnant.~~ Maximum retention or "draw-down" time for detention ponds shall not exceed 24 hours from the time of peak storage to the time of complete emptying of the pond, as determined by hydrograph routing or other calculations acceptable to the City. This requirement does not apply to facilities in which retention or "draw-down" time is required to be greater than 24 hours. All volume required for detention shall be available after 24 hours to allow for subsequent storms, including any portion of the water quality volume utilized for detention purposes.

18. ~~19.~~ In order to minimize vandalism and deterioration, use of exposed piping and appurtenances and any loose materials (other than access drive rock) shall be avoided or minimized. Use of all such items shall be approved by the City.

F. Any concentrated flow necessitates the dedication of a drainage easement to the larger of following: the limits of the fully developed 100-year storm water surface elevation, or minimum easements widths as required in this Drainage Criteria Manual.

G. An easement or right-of-way as required in this Drainage Criteria Manual must be of sufficient width to provide continuous access for the operation, maintenance, or repair of a drainage facility or conveyance of stormwater.

(1) A minimum of 25 feet in width for an open drainage system; or

(2) A minimum of 15 feet in width for an enclosed drainage system.

1.2.5 Computations

Computations to support all drainage designs shall be submitted to the appropriate City ~~city~~ departments for review. The computations should be in such form as to allow for timely and consistent review and also to be made a part of the permanent City ~~city~~ record for future reference. All computations submitted shall be certified by a professional engineer registered in the State of Texas.

1.2.6 Floodplain ~~Flood Plain~~ Delineations

A. City of Austin.

1. For purposes of this Drainage Criteria Manual, a drainage area of 64 acres or greater is required within a contributing watershed to create a "floodplain". For areas of flow with less than 64 acres of contributing area, no floodplain shall be defined unless the City or FEMA currently indicates the area as a floodplain. In all cases where a floodplain ~~flood plain~~ delineation is required, its determination shall be based on the projected full development of all properties contributing to the point of consideration. It is the responsibility of the design engineer to determine, based on the most accurate information available, what the floodplain delineation ~~fully developed drainage area~~ is.

2. The design engineer may elect to utilize a floodplain ~~flood plain~~ delineation previously approved by the Director of the Watershed Protection ~~and Development Review~~ Department, assuming the same is still applicable under present requirements and criteria. In so doing the engineer does not remove himself from the responsibility for the delineation's accuracy.

~~3. For purposes of this Drainage Criteria Manual, a drainage area of 64 acres or greater is required within a contributing watershed to create a "flood plain". For areas of flow with less than 64 acres of contributing area, no flood plain shall be defined; however, with regards to the drainage criteria contained in this manual any concentrated flow necessitates the dedication of a drainage easement.~~

B. Federal Emergency Management Agency.

1. The Federal Emergency Management Agency (FEMA) maintains Flood Insurance Rate Maps (FIRM's) that depict floodplain ~~and floodway~~ boundaries. The floodplain ~~and floodway~~ boundaries depicted on FIRM's are based on existing conditions of development in the contributing area at the time the floodplain study that delineated the floodplain was completed.

2. FEMA reviews and approves or denies all revisions or amendments to FIRM's. FEMA revises or amends FIRM's by approval of ~~a Letter of Map Amendment or Letter of Map Revision. These documents are referred to collectively as~~ a Letter of Map Change (LOMC). FEMA establishes the process and fees necessary for review of an application for a LOMC.

3. FEMA reviews the impact of proposed site developments and offers or denies conditional assurance that a FIRM may be changed by the proposed development. FEMA offers this assurance by a ~~Conditional Letter of Map Amendment or Conditional Letter of Map Revision. These documents are referred to collectively as a~~ Conditional Letter of Map Change (CLOMC). The CLOMC is a conditional statement that the FIRM may be changed if (1) the development is constructed as proposed in the CLOMC application, and if (2) a complete LOMC is submitted after construction of the proposed development.

4. As the local floodplain administrator, the City must review and acknowledge certain LOMC or CLOMC requests. The City establishes the process necessary for review of an application for a LOMC or CLOMC.

C. Coordination of City of Austin and FEMA Floodplain Delineations.

1. The 100-year floodplain as determined in accordance with this Manual is a standard for dedication of drainage easements. This floodplain is theoretically equal to or greater than the 100-year floodplain depicted by FEMA on the FIRM. If the floodplain on the FIRM extends beyond a drainage easement required by the Land Development Code, or offered by the applicant, then the floodplain depicted on the FIRM must be changed by FEMA. This requirement assures that floodplain boundaries and associated regulations are coordinated between the City of Austin and FEMA. Floodplain mapping may be changed due to updated analysis of the floodplain under existing conditions, or due to land development activities that alter existing conditions.

2. If the floodplain depicted on the FIRM is required to be changed, pursuant to C.1. above, due to updated analysis of the floodplain under existing conditions, then the following requirements are applicable:

(a) Prior to approval of a preliminary plan, the applicant must provide to the City a letter of acknowledgement by FEMA of receipt of a complete application for a LOMC.~~the applicant must provide to the City evidence of receipt by FEMA of an application for a LOMC.~~

(b) Prior to approval of a final plat, the applicant must provide to the City evidence of approval by FEMA of the LOMC submitted under C.2.(a). If the final plat is approved before it is determined that a LOMC is necessary or desired, ~~then~~ prior to release of a subdivision construction permit or site plan permit ~~plans~~, the applicant must provide to the City a letter of acknowledgement by FEMA of receipt of a complete application for a LOMC.

(c) Prior to final acceptance of the construction of the subdivision or issuance of building permits for buildings that are within the floodplain at the time of application, the applicant must provide to the City evidence of final acceptance by FEMA of the LOMC submitted under C.2.(a) above.

3. If the floodplain depicted on the FIRM is required to be changed, pursuant to C.1. above, due to land development activities that alter existing conditions, then the following requirements are applicable:

(a) Prior to approval of a preliminary plan, the applicant must provide to the City either: evidence that the proposed land development activities do not increase the level of the FEMA floodplain; or a letter of acknowledgement by FEMA of receipt of a complete application for a CLOMC. ~~the applicant must provide to the City evidence of receipt by FEMA of an application for a CLOMC.~~

(b) Prior to approval of a final plat, the applicant must provide to the City either: evidence that the proposed land development activities do not increase the level of the FEMA floodplain; or evidence of approval by FEMA of the CLOMC ~~submitted under (a).~~

(c) If the final plat is approved before it is determined that a CLOMC is necessary or desired, then prior to approval ~~release~~ of a subdivision construction permit or site plan permit ~~plans~~, the applicant must provide to the City either: evidence that the proposed land development activities do not increase the level of the FEMA floodplain; or a letter of acknowledgement by FEMA of receipt of a complete application for a CLOMC.

(d) Prior to final acceptance of the subdivision construction or site plan improvements ~~of the subdivision~~ or issuance of building permits for buildings that are within the portion of the FEMA floodplain affected by a required LOMC, the applicant must provide to the City evidence of final acceptance by FEMA of the CLOMC if required ~~submitted~~ under C.3 ~~(c)~~ above, and a letter of acknowledgement by FEMA of a complete application for a LOMC.

(e) Prior to issuance of a certificate of occupancy for buildings within the portion of the FEMA floodplain affected by a required LOMC, the applicant must provide to the City evidence of final acceptance by FEMA of the LOMC.

4. The applicant shall bear the cost of engineering services required to develop the application, respond to review comments, and obtain final approval of LOMC's and CLOMC's. The applicant shall bear the cost of any fees associated with review and disposition of LOMC's and CLOMC's that are established by FEMA.

1.2.7 City Ordinances

The ordinances empowering the drainage policies and criteria presented in this Manual ~~manual~~ are contained in Chapter 25-7 of the Code of the City of Austin as amended. Any revisions or changes to the policies, criteria or guidelines shall be posted in accordance with the notification procedures in the development code.

1.3.0 DEFINITIONS

All terms and abbreviations used in the text are presented in the " Glossary" of this manual.

1.4.0 DESIGNATION AND DELINEATION OF AUSTIN AREA WATERSHEDS

The Austin area is divided into drainage basins with outlets at the Colorado, Blanco and Brazos Rivers. These basins, in turn, are divided into drainage areas contributing to the main tributaries. Subareas are formed within the drainage areas by natural branches or by the construction of open or enclosed storm ~~sewers~~ drains. Please refer to http://www.austintexas.gov/page/austin-watersheds-list for a list of the Austin area watersheds, tributaries, and their codes. Watershed boundary delineations are maintained by the City. Use of any other delineation must be approved by the City and reflected on official City GIS maps, as designated by the Director of the Watershed Protection Department, prior to use.

~~Table 1-1 lists the Austin area watershed codes named after the primary watercourse of the watershed and indicates those watershed basins which are presently a part of the Regional Stormwater Management Program. However, this does not preclude a regional application in any watershed. Watershed boundary delineations are maintained by the City. Use of any other delineation must be approved by the City and reflected on official City GIS maps, as designated by the Director of the Watershed Protection and Development Review Department, prior to use.~~

~~**Table 1-1**~~
~~**CODE DESIGNATION OF AUSTIN AREA WATERSHEDS**~~

~~**CODE**~~	~~WATERSHED NAME~~	~~DISCHARGE INTO~~	~~RSMP~~
~~BAR~~	~~Barton Creek~~	~~Lady Bird Lake~~	~~Yes~~
~~BER~~	~~Bear Creek~~	~~Onion Creek~~	~~Yes~~
~~BRW~~	~~Bear Creek West~~	~~Lake Austin~~	~~No~~
~~BEE~~	~~Bee Creek~~	~~Lake Austin~~	~~No~~
~~BSY~~	~~Big Sandy Creek~~	~~Lake Travis~~	~~No~~
~~BLK~~	~~Block Creek~~	~~Brushy Creek~~	~~No~~
~~BLU~~	~~Blunn Creek~~	~~Lady Bird Lake~~	~~No~~
~~BOG~~	~~Boggy Creek~~	~~Colorado River~~	~~No~~
~~BOH~~	~~Bohls Hollow~~	~~Lake Austin~~	~~No~~
~~BRU~~	~~Brushy Creek~~	~~San Gabriel River~~	~~No~~
~~BUK~~	~~Buck Hollow~~	~~Barton Creek~~	~~Yes~~
~~BUL~~	~~Bull Creek~~	~~Lake Austin~~	~~Yes~~
~~BHW~~	~~Bullick Hollow~~	~~Lake Travis~~	~~No~~
~~BCP~~	~~Buttercup Creek~~	~~South Brushy Creek~~	~~No~~
~~BMK~~	~~Buttermilk Branch~~	~~Little Walnut Creek~~	~~No~~
~~CAR~~	~~Carson Creek~~	~~Colorado River~~	~~Yes~~
~~CDR~~	~~Cedar Creek~~	~~Colorado River~~	~~No~~
~~CED~~	~~Cedar Hollow~~	~~Lake Austin~~	~~No~~
~~CHK~~	~~Chalk Knob Hollow~~	~~Barton Creek~~	~~Yes~~
~~CHE~~	~~Cherry Creek Branch~~	~~Williamson Creek~~	~~Yes~~
~~CLK~~	~~Cluck Creek~~	~~South Brushy Creek~~	~~No~~
~~CMF~~	~~Commons Ford Creek~~	~~Lake Austin~~	~~No~~
~~CRN~~	~~Cuernavaca Creek~~	~~Lake Austin~~	~~No~~
~~CWR~~	~~Coldwater Creek~~	~~Lake Austin~~	~~No~~
~~CHW~~	~~Collier Hollow~~	~~Lake Travis~~	~~No~~
~~COL~~	~~Colorado River*~~	~~Gulf of Mexico~~	~~No~~
~~CNR~~	~~Connors Creek~~	~~Lake Austin~~	~~No~~

~~CTM~~	~~Cottonmouth Creek~~	~~Onion Creek~~	~~Yes~~
~~CTW~~	~~Cottonwood Creek~~	~~Brushy Creek~~	~~No~~
~~CCW~~	~~Country Club West~~	~~Colorado River~~	~~Yes~~
~~CCE~~	~~Country Club East~~	~~Colorado River~~	~~Yes~~
~~COW~~	~~Cow Fork Bull Creek~~	~~Bull Creek~~	~~Yes~~
~~CYP~~	~~Cypress Creek~~	~~Lake Travis~~	~~No~~
~~DNE~~	~~Dry Creek NE~~	~~Wilbarger Creek~~	~~No~~
~~DNZ~~	~~Danz Creek~~	~~Slaughter Creek~~	~~Yes~~
~~DVS~~	~~Davis Spring Branch~~	~~Lake Creek~~	~~Yes~~
~~DKR~~	~~Decker Creek~~	~~Gilleland Creek~~	~~Yes~~
~~DVL~~	~~Devil's Hollow~~	~~Lake Travis~~	~~No~~
~~DVP~~	~~Devil's Pen Creek~~	~~Lake Travis~~	~~No~~
~~DRN~~	~~Dry Creek North~~	~~Lake Austin~~	~~No~~
~~DRE~~	~~Dry Creek East~~	~~Colorado River~~	~~Yes~~
~~EAN~~	~~Eanes Creek**~~	~~Lady Bird Lake~~	~~No~~
~~EBO~~	~~East Bouldin Creek~~	~~Lady Bird Lake~~	~~Yes~~
~~ELM~~	~~Elm Creek~~	~~Colorado River/Gilleland Creek~~	~~Yes~~
~~ELS~~	~~Elm Creek South~~	~~Blanco River~~	~~No~~
~~FOR~~	~~Fort Branch~~	~~Boggy Creek~~	~~No~~
~~GIL~~	~~Gilleland Creek~~	~~Colorado River~~	~~Yes~~
~~GRG~~	~~Gragg Hollow~~	~~Lake Travis~~	~~No~~
~~GRP~~	~~Grape Creek~~	~~Barton Creek~~	~~Yes~~
~~HAN~~	~~Hancock Branch~~	~~Shoal Creek~~	~~Yes~~
~~HRP~~	~~Harper's Branch~~	~~Lady Bird Lake~~	~~No~~
~~HRS~~	~~Harris Branch~~	~~Gilleland Creek~~	~~Yes~~
~~HRN~~	~~Harrison Hollow~~	~~Lake Austin~~	~~No~~
~~HKS~~	~~Hickson Hollow~~	~~Little Barton Creek~~	~~No~~
~~HOG~~	~~Hog Pen Creek~~	~~Lake Austin~~	~~No~~

~~HOL~~	~~Holman Hollow~~	~~Barton Creek~~	~~Yes~~
~~HNY~~	~~Honey Creek~~	~~Lake Austin~~	~~No~~
~~HUK~~	~~Huck's Slough~~	~~Lake Austin~~	~~No~~
~~HUR~~	~~Hurst Creek~~	~~Lake Travis~~	~~No~~
~~JOH~~	~~Johnson Creek~~	~~Lady Bird Lake~~	~~No~~
~~KIN~~	~~Kincheon Branch~~	~~Williamson Creek~~	~~Yes~~
~~LKC~~	~~Lake Creek~~	~~Brushy Creek~~	~~Yes~~
~~LKT~~	~~Lake Travis~~	~~Lake Austin~~	~~No~~
~~LKA~~	~~Lake Austin~~	~~Lady Bird Lake~~	~~No~~
~~LIM~~	~~Lime Creek~~	~~Lake Travis~~	~~No~~
~~LWA~~	~~Little Walnut Creek~~	~~Walnut Creek~~	~~Yes~~
~~LBA~~	~~Little Barton Creek~~	~~Barton Creek~~	~~No~~
~~LBE~~	~~Little Bee Creek~~	~~Bee Creek~~	~~No~~
~~LBL~~	~~Lady Bird Lake~~	~~Colorado River~~	~~No~~
~~LBR~~	~~Little Bear Creek~~	~~Bear Creek~~	~~Yes~~
~~LDE~~	~~Little Devil's Hollow~~	~~Lake Travis~~	~~No~~
~~LOC~~	~~Lockwood Creek~~	~~Colorado River~~	~~No~~
~~LNB~~	~~Long Branch~~	~~Barton Creek~~	~~Yes~~
~~LNH~~	~~Long Hollow~~	~~Lake Travis~~	~~No~~
~~LHC~~	~~Long Hollow Creek~~	~~Lake Travis~~	~~No~~
~~MAH~~	~~Maha Creek~~	~~Cedar Creek~~	~~No~~
~~MAR~~	~~Marble Creek~~	~~Onion Creek~~	~~Yes~~
~~MAS~~	~~Mason Creek~~	~~Brushy Creek~~	~~No~~
~~MYR~~	~~Myrtle Creek~~	~~Barton Creek~~	~~Yes~~
~~NFB~~	~~North Fork Brushy Creek~~	~~Brushy Creek~~	~~No~~
~~NFD~~	~~North Fork Dry Creek~~	~~Dry Creek (East)~~	~~Yes~~
~~ONI~~	~~Onion Creek~~	~~Colorado River~~	~~Yes~~
~~OWL~~	~~Owl Hollow~~	~~Little Barton Creek~~	~~No~~
~~PAN~~	~~Panther Hollow~~	~~Lake Austin~~	~~No~~

~~PLM~~	~~Plum Creek~~	~~Blanco River~~	~~No~~
~~POK~~	~~Post Oak Creek~~	~~Brushy Creek~~	~~No~~
~~QUB~~	~~Quail Creek Branch~~	~~Little Walnut Creek~~	~~Yes~~
~~RAT~~	~~Rattan Creek~~	~~Lake Creek~~	~~Yes~~
~~RDR~~	~~Running Deer Creek~~	~~Lake Austin~~	~~No~~
~~RIN~~	~~Rinard Creek~~	~~Onion Creek~~	~~Yes~~
~~RKY~~	~~Rocky Creek~~	~~Barton Creek~~	~~Yes~~
~~SHL~~	~~Shoal Creek~~	~~Lady Bird Lake~~	~~Yes~~
~~SSB~~	~~Short Spring Branch~~	~~Barton Creek~~	~~Yes~~
~~SLA~~	~~Slaughter Creek~~	~~Onion Creek~~	~~Yes~~
~~SBG~~	~~South Boggy Creek~~	~~Onion Creek~~	~~Yes~~
~~SBR~~	~~South Brushy Creek~~	~~Brushy Creek~~	~~No~~
~~SFB~~	~~South Fork Brushy Creek~~	~~Brushy Creek~~	~~No~~
~~SFD~~	~~South Fork Dry Creek~~	~~Dry Creek (East)~~	~~Yes~~
~~SPN~~	~~Spanish Oak Creek~~	~~Brushy Creek~~	~~No~~
~~SPL~~	~~Spillman Hollow~~	~~Little Barton Creek~~	~~No~~
~~SPH~~	~~Spring Hollow~~	~~Bear Creek~~	~~No~~
~~STP~~	~~St. Stephens Creek~~	~~Lake Austin~~	~~No~~
~~STN~~	~~Steiner Creek~~	~~Lake Austin~~	~~No~~
~~SYC~~	~~Sycamore Creek~~	~~Barton Creek~~	~~Yes~~
~~TAN~~	~~Tannehill Branch~~	~~Boggy Creek~~	~~No~~
~~TRB~~	~~Tar Branch~~	~~Walnut Creek~~	~~Yes~~
~~TRH~~	~~Tar Hollow~~	~~Lake Austin~~	~~No~~
~~TYN~~	~~Taylor Slough North~~	~~Lake Austin~~	~~No~~
~~TYS~~	~~Taylor Slough South~~	~~Lake Austin~~	~~No~~
~~THO~~	~~Thomas Spring Branch~~	~~Barton Creek~~	~~Yes~~
~~TRK~~	~~Turkey Creek~~	~~Lake Austin~~	~~No~~
~~WLR~~	~~Waller Creek~~	~~Lady Bird Lake~~	~~No~~
~~WLN~~	~~Walnut Creek~~	~~Colorado River~~	~~Yes~~

~~WLL~~	~~Walter E. Long Lake~~	~~Decker Creek~~	~~Yes~~
~~WLS~~	~~Wells Branch~~	~~Walnut Creek~~	~~Yes~~
~~WBL~~	~~West Bull Creek~~	~~Bull Creek~~	~~Yes~~
~~WBO~~	~~West Bouldin Creek~~	~~Lady Bird Lake~~	~~No~~
~~WHT~~	~~White Branch~~	~~Barton Creek~~	~~Yes~~
~~WLB~~	~~Wilbarger Creek~~	~~Colorado River~~	~~No~~
~~WMS~~	~~Williamson Creek~~	~~Onion Creek~~	~~Yes~~
~~WLW~~	~~Willow Creek~~	~~Wilbarger Creek~~	~~No~~
~~YAU~~	~~Yaupon Creek~~	~~Lake Travis~~	~~No~~
~~YET~~	~~Yett Branch~~	~~Walnut Creek~~	~~Yes~~
~~* Colorado River is separated into four reaches: Lake Travis (upstream of Mansfield Dam), Lake Austin (Mansfield Dam to Tom Miller Dam), Lady Bird Lake (Tom Miller Dam to Longhorn Dam) and Colorado River (downstream of Longhorn Dam).~~			
~~** Two unofficial names are used for Eanes Creek. The others are Dry Creek (South) and Lanes Creek.~~			

~~Sources (For Table 1-1):~~

~~1. Continental Map Inc., Austin Map, 1986 edition.~~

~~2. Continental Map Inc., Round Rock, Georgetown, Leander and Cedar Park Map, 1986 edition.~~

~~3. Texas Highway Department, General Highway Maps, 1974.~~

~~4. U.S. Geological Survey, Quadrangle Maps (Austin, Bee Cave, Jollyville, Montopolis, Mansfield Dam, Oak Hill, Pflugerville, Signal Hills, Travis Peak), 1968.~~

~~5. City of Austin, Drainage Criteria Manual, First Edition, Austin, Texas, January, 1977.~~

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SECTION 2 - DETERMINATION OF STORM RUNOFF

2.1.0 GENERAL

If continuous records of the amounts of runoff from urban areas were as readily available as records of precipitation, they would provide the best source of data on which to base the design of storm drainage and flood protection systems. Unfortunately, such records are available in very few areas in sufficient quantity to permit an accurate prediction of ~~the~~ stormwater runoff. The accepted practice, therefore, is to relate runoff to rainfall, thereby providing a means for predicting the amount of runoff to be expected from urban watersheds at given recurrence intervals.

Numerous methods of rainfall runoff computations are available on which the design of storm drainage systems may be based. The method chosen is dependent upon the engineer's technical familiarity and the size of the area to be analyzed. For ~~Within~~ the method chosen**,** the engineer will be responsible for making reasonable assumptions as to the development characteristics of the study area.

2.2.0 EFFECTS OF URBANIZATION

It has long been recognized that urban development has a pronounced effect on the rate of runoff from a given rainfall event. The hydraulic efficiency of a drainage area is generally ~~improved~~ increased as a byproduct of ~~by~~ urbanization**,** which in effect reduces the storage capacity of a watershed. This reduction of a watershed's storage capacity is a direct result of the elimination of pervious ~~porous~~ surfaces, small ponds, and holding areas. This comes about by the grading and paving of building sites, streets, drives, parking lots, and sidewalks and by construction of buildings and other facilities characteristic of urban development. The result of the improved hydraulic efficiency is illustrated graphically in Figure 2-1 in Appendix ~~E~~ D of this manual, which is a plot of the runoff rate versus time for the same storm with two different stages of watershed development.

2.2.1 Design Assumptions For Storm Runoff ~~Stormflow~~ Analysis

A. When analyzing an area for channel or storm drain design purposes, urbanization of the full watershed without stormwater detention facilities ~~ponds~~ shall be assumed (except as noted in (D**.** ~~E.~~) below). Zoning maps, future land use maps, and master plans should be used as aids in establishing the anticipated surface character of the ultimate development. The selection of design runoff coefficients and/or percent impervious cover factors are explained in the following discussions of runoff calculation.

B. An exception to (A.) above may be granted if the channel is immediately downstream of a City maintained regional detention ~~pond~~ facility and written approval is obtained from the Director of the Watershed Protection ~~and Development Review~~ Department.

C. In designing a storm drain system ~~within a residential subdivision~~, full development of adjoining and interior tracts without detention shall ~~must~~ be assumed.

~~D. In designing a storm drain system within a commercial or multifamily subdivision, 25-year stormflows can at the Engineer's discretion, reflect the flow reduction anticipated by future detention ponds. This applies exclusively to the flows generated by those properties contained within the subdivision. Provisions for conveyance of the 100-year undetained flows within the right-of-way or drainage easements still apply. (See Sec. 1.2.2)~~

D ~~E.~~ In the event the engineer desires to incorporate the flow reduction benefits of existing upstream

detention facilities ~~ponds~~, the following field investigations and hydrologic analysis will be required: (Please note that under no circumstances will the previously approved construction plans of the upstream detention facilities ~~ponds~~ suffice as an adequate analysis. While the responsibility of the individual site or subdivision plans rests with the engineer of record, any subsequent engineering analysis must ensure ~~assure~~ that all the incorporated detention facilities ~~ponds~~ work collectively.)

1. A field survey of the existing physical characteristics of both the outlet structure and ponding volume. Any departure from the original engineer's design must be accounted for. If a dual use for the detention facility ~~pond~~ exists, (e.g., storage of equipment) then this too should be accounted for.

2. A comprehensive hydrologic analysis which simulates the flow attenuation produced by the existing detention facility in ~~of~~ the upstream contributing area ~~ponds~~. This should not be limited to a linear additive analysis but rather a network of hydrographs ~~hydrographies~~ which considers incremental timing of discharge and potential coincidence of outlet peaks.

2.3.0 METHOD OF ANALYSIS

Numerous methods of rainfall-runoff computation are available on which the design of storm drainage and flood control systems may be based. The Rational Method is accepted as adequate for drainage areas totaling 100 acres or less. The ~~Soil Conservation Service (now called the~~ National Resources Conservation Service~~)~~ (formerly the Soil Conservation Service) hydrologic methods (available in the NRCS ~~SCS~~TR-20, and the US Army Corps of Engineers' Hydrologic Engineering Center's~~:~~ ~~(HEC) HEC-1 (note that HEC-1 is DOS based and will not be updated) and~~ HEC-HMS program~~s)~~ should be used for drainage areas larger than 100 acres but may also be used for drainage areas of any size. The method of analysis must remain consistent when drainage areas are combined~~.~~ ~~In cases where the Rational Method is used for storm drainage system design and NRCS methods are used for off-site drainage calculations, detention facility analysis or design or evaluation of downstream impacts, the results of the Rational and NRCS Methods should be consistent at common analysis points.~~ and the method which applies to the largest combined drainage area should be used unless the situation requires the use of NRCS hydrologic methods (i.e., a detention ~~pond~~ facility connected to a downstream storm drainage system). The engineer can use other methods but must have their acceptability approved by the Director of the Watershed Protection ~~and Development Review~~ Department.

2.4.0 RATIONAL METHOD

The Rational Method is based on the direct relationship between rainfall and runoff, and is expressed by the following equation:

$Q_p = CiA$ (Eq. 2-1)

Where:

Q_p is defined as the peak runoff in cubic feet per second. Actually, Q_p is in units of acre-inches per hour~~. inches per hour per acre.~~ Since this rate of acre-in/hr ~~in/hr/ac~~ differs from cubic feet per second by less than one (1) percent (1 acre-in/hr ~~in/hr/ac~~ = 1.008 cfs), the more common units of cfs are used.

C is the composite coefficient of runoff representing the ratio of peak runoff rate "Q_p" to average rainfall intensity rate "i" for the soil types and land uses characteristic of the contributing drainage area. ~~a specified area "A".~~

i is the average intensity of rainfall in inches per hour for a period of time equal to the time of concentration (tc) for the drainage area to the design point under consideration.

A is the area in acres contributing runoff to the point of design.

The following basic assumptions are associated with the Rational Method:

A. The storm duration is equal to the time of concentration.

B. The computed peak rate of runoff at ~~to~~ the design point is a function of the average rainfall rate over a duration equal to ~~during~~ the time of concentration at ~~to~~ that point.

C. The return period or frequency of the computed peak flow is the same as that for the design storm.

D. The necessary basin characteristics can be identified and the runoff coefficient does not vary during a storm.

E. Rainfall intensity is constant during the storm duration and spatially uniform for the area under analysis.

F. The maximum rate of discharge at the point of design will occur when the entire area above the point of design is contributing runoff.

2.4.1 Runoff Coefficient (C)

The proportion of the total rainfall that will reach the drainage system depends on the surface vegetation condition, soil type, imperviousness of the surface**,** ~~and the~~ land slope and ponding characteristics of the area. Impervious surfaces, such as asphalt pavements and roofs of buildings, will be subject to approximately 100 percent runoff (regardless of the slope). On-site inspections and aerial photographs may prove valuable in estimating the nature of the surfaces within the drainage area.

~~The runoff coefficient "C" in the Rational Formula is also dependent on the character of the soil. The type and condition of the soil determines its ability to absorb precipitation. The rate at which a soil absorbs precipitation generally decreases as the rainfall continues for an extended period of time. The soil infiltration rate is influenced by the presence of soil moisture (antecedent precipitation), the rainfall intensity, the proximity of the ground water table, the degree of soil compaction, the porosity of the subsoil, and ground slopes.~~

It should be noted that the runoff coefficient "C" is the Rational Method variable ~~of the Rational Method~~ which is least amenable ~~susceptible~~ to precise determination. A reasonable coefficient must be chosen to represent the integrated effects of infiltration, surface ponding ~~detention storage~~, evaporation, ~~retention,~~ flow routing and interception, all of which affect the time distribution and peak rate of runoff.

~~Table 2-1 presents recommended ranges for "C" values based on specific land use types and ground slope.~~

It is often desirable to develop a composite runoff coefficient based upon the percentages of different types of surfaces in the drainage area. This procedure is often applied to typical "sample blocks" as a guide to selection of reasonable values of the coefficient for an entire area. Suggested coefficients with respect to specific surface types are given in Table 2-1~~2~~. “C” values for developed conditions should be based on maximum allowable impervious cover as listed in the City’s ~~city’s~~ zoning and watershed ordinances.

2.4.2 Time of Concentration

The time of concentration is the time for surface runoff ~~a drop of water~~ to flow from the most remote point in the watershed to the point of interest. This applies to the most remote point in time, not necessarily the most remote point in distance. Runoff from a drainage area usually reaches a peak at the time when the entire area is contributing. However, runoff ~~Runoff~~ may reach a peak prior to the time the entire drainage area is contributing if the area is irregularly shaped or if land use characteristics differ significantly within the area. Sound engineering judgment should be used to determine a flow path representative of the drainage area and in the subsequent calculation of the time of concentration. The time of concentration to any point in a storm drainage system is a combination of the sheet flow (overland), the shallow concentrated flow and the

channel flow, which may include~~s~~ storm drains. The minimum time of concentration for any drainage area shall be 5 minutes. Additionally, the minimum slope used for calculation of sheet and shallow flow travel time components should be 0.005 feet per foot (0.5%). The preferred procedure for estimating time of concentration is the NRCS method as described in NRCS's Technical Release 55 (TR-55). This method is outlined below. The overall time of concentration is calculated as the sum of the sheet, shallow concentrated and channel flow travel times. Note that there may be multiple shallow concentrated and channel segments depending on the nature of the flow path.

$$T_c = T_{t(sheet)} + T_{t(shallow\ concentrated)} + T_{t(channel)} \qquad \text{(Eq. 2-2)}$$

A. Sheet Flow. Sheet flow is shallow flow over land surfaces**,** which usually occurs in the headwaters of streams. The engineer should realize that sheet flow occurs for only very short distances**,** especially in urbanized conditions. ~~While sheet~~ Sheet flow for both natural (undeveloped) and developed ~~existing~~ conditions should be ~~is typically~~ limited to a maximum of 100 ~~300~~ feet.~~,~~ ~~sheet~~ Sheet flow for developed conditions should be based on the actual pavement or grass conditions for areas that are already developed and should be representative of the anticipated land use within the headwater area in the case of currently undeveloped areas. In a typical residential subdivision, sheet flow may be the distance from one end of the lot to the other or from the house to the edge of the lot. ~~limited to 150 feet~~. In some heavily urbanized drainage areas, sheet flow may not exist in the headwater area. The NRCS method employs equation 2-3, which is a modified form kinematic wave equation, for the calculation of the sheet flow travel time. ~~The following equation 2-2 has been developed for sheet flow of less than 300 feet.~~

$$T_t = 0.007(nL)^{0.8}/(P_2)^{0.5}s^{0.4} \qquad \cancel{T_t = Ln/(42s^{0.5})} \qquad \text{(Eq. 2-3~~2~~)}$$

Where,

T_t = Sheet flow travel time in minutes
L = Length of the reach in ft.
n = Manning's n (see Table 2-2 ~~table 2-3~~)
P_2 = 2-year, 24-hour rainfall in inches (see Table 2-3)
s = Slope of the ground in ft/ft

B. Shallow Concentrated Flow. After a maximum of approximately 100 ~~300~~ feet, sheet flow usually becomes shallow concentrated flow~~.~~ collecting in swales, small rills, and gullies. Shallow concentrated flow is assumed not to have a well-defined channel and has flow depths of 0.1 to 0.5 feet. The travel time for shallow concentrated flows can be computed by equations 2-4 and 2-5. ~~2-3~~: These two equations are based on the solution of Manning's equation with different assumptions for n (Manning's roughness coefficient) and r (hydraulic radius, ft). For unpaved areas, n is 0.05 and r is 0.4; for paved areas, n is 0.025 and r is 0.2.

Unpaved $T_t = L/(60(16.1345)(s)^{0.5})$ (Eq. 2-4)

Paved $T_t = L/(60(20.3282)(s)^{0.5})$ (Eq. 2-5)

~~$T_t = Ln/(60s^{0.5})$ (Eq. 2-3)~~

Where,

T_t = Travel time for shallow concentrated flows in minutes
L = Length of the reach in ft.
~~n = Manning's n (see Table 2-3)~~
s = Slope of the ground in ft/ft

C. Channel or Storm Drain Flow. The velocity in an open channel or a storm drain not flowing full can be determined by using Manning's Equation. Channel velocities can also be determined by using backwater profiles. For open channel flow, average flow velocity is usually determined by assuming a bank-full condition. Note that the channel flow component of the time of concentration may need to be divided into

multiple segments in order to represent significant changes in channel characteristics. The details of using Manning's equation and selecting Manning's "n" values for channels can be obtained from Section 6.

For storm drain flow under pressure conditions (hydraulic grade line is higher than the lowest crown of a storm drain) the following equation should be applied:

$V = Q/A$ (Eq. 2-6~~4~~)

Where:

V = Average velocity, ft/s
Q = Design discharge, cfs
A = Cross-sectional area, ft^2

Flow travel time through a channel can be calculated by equation (2-7~~5~~):

$T_t = \sum \cancel{S} (L_i/60\ V_i)$ (Eq. 2-7~~5~~)

Where:

Li = The i-th channel segment length, ft
Vi = The average flow velocity within the i-th channel segment, ft/s
T_t = Total Flow travel time through the channel, min

~~TABLE 2-1~~
~~**RATIONAL METHOD RUNOFF COEFFICIENTS BY LAND USE TYPE**~~
~~*FOR USE IN Q = CiA Runoff Coefficient (C)*~~

~~**Land Use***~~	~~**100-Year Runoff Coefficients (C) for Basin Slopes**~~			
~~I.C. %~~	~~0-2%~~	~~2-7%~~	~~7%+~~	
~~Single Family (SF-1)~~	~~40~~	~~0.60~~	~~0.66~~	~~0.69~~
~~Multifamily (MF-3)~~	~~65~~	~~0.76~~	~~0.79~~	~~0.81~~
~~Commercial (LR), General Office (GO)~~	~~80~~	~~0.85~~	~~0.87~~	~~0.88~~
~~Commercial Service (CS)~~	~~95~~	~~0.94~~	~~0.94~~	~~0.95~~

~~Assumptions:~~

~~1. Composite "C" value for developed conditions (C_{DEV}) is : $C_{DEV} = IC_1 + (1 - I)C_2$~~

~~Where:~~
~~I = Impervious cover, percent~~
~~C_1 = "C" value for impervious cover~~
~~C_2 = "C" value for pervious area (grass, lawns, parks, etc.)~~

~~*2. For other land use and corresponding maximum allowable impervious coverage values refer to the Zoning Ordinance.~~

~~Source: 1. City of Ausitn, Watershed Engineering Division~~

~~2. City of Austin Zoning Ordinance~~

TABLE 2-1~~2~~
RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE ANALYSIS

Runoff Coefficient (C)							
Character of Surface	Return Period						
	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	500 Years
DEVELOPED							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass Areas (Lawns, Parks, etc.)							
Poor Condition*							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair Condition**							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good Condition***							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
UNDEVELOPED							
Cultivated							
Flat, 0-2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0-7%							
Average, 2-7%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Steep, over 7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56

	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Assumptions:

1. Composite "C" value for developed conditions (C_{DEV}) is : $C_{DEV} = I\,C_1 + (1 - I)C_2$

Where:
I = Impervious cover, percent
C_1 = "C" value for impervious cover
C_2 = "C" value for pervious area (grass, lawns, parks, etc.)

2. For maximum allowable impervious coverage values for various land use types, refer to the City of Austin Zoning Ordinance.

* Grass cover less than 50 percent of the area.
** Grass cover on 50 to 75 percent of the area.
*** Grass cover larger than 75 percent of the area.

Source: 1. Rossmiller, R.L. "The Rational Formula Revisited."
2. City of Austin, Watershed Engineering Division

TABLE 2-2~~3~~
Manning's "n" for overland flow ~~and shallow concentrated flow~~

Manning's "n"[1]	Surface Description
0.015	Concrete (rough or smoothed finish)
0.016	Asphalt
0.05	Fallow (no residue)
	Cultivated Soils:
0.06	Residue Cover ≤ 20%
0.17	Residue cover > 20%
	Grass:
0.15	Short-grass prairie
0.24	Dense grasses[2]
0.13	Range (natural)
	Woods:[3]
0.40	Light underbrush
0.80	Dense underbrush

[1] The Manning's *n* values are a composite of information compiled by Engman (1986).
[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3] When selecting *n*, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

~~**Manning's "n"**~~	~~Condition~~
~~0.016~~	~~Concrete (rough or smoothed finish)~~
~~0.02~~	~~Asphalt~~
~~0.1~~	~~0-50% vegetated ground cover, remaining bare soil or rock outcrops, minimum brush or tree cover~~
~~0.2~~	~~50-90% vegetated ground cover, remaining bare soil or rock outcrops, minimum- medium brush or tree cover~~

~~0.3~~	~~100% vegetated ground cover, medium- dense grasses (lawns, grassy fields etc.) medium brush or tree cover~~
~~0.6~~	~~100% vegetated ground cover with areas of heavy vegetation (parks, green- belts, riparian areas etc.) dense under- growth with medium to heavy tree growth~~
~~Source: City of Austin, Watershed Engineering Division~~	

2.4.3 Rainfall Intensity (i)

Rainfall intensity (i) is the average rainfall rate in inches per hour, and is selected on the basis of design rainfall duration and design frequency of occurrence. The design duration is equal to the time of concentration for the drainage area under consideration. The design frequency of occurrence is a statistical variable which is established by design standards or chosen by the engineer as a design parameter.

The selection of the frequency criteria is necessary before applying any hydrologic method. Storm drainage improvements in Austin must be designed to intercept and carry the runoff from a 25-year frequency storm (4% annual chance event), with an auxiliary or overflow system capable of carrying a 100-year frequency storm (1% annual chance event).

The rainfall intensity used in the rational method can be read from the intensity-duration-frequency (IDF) curves based on the selected design frequency and design duration. The design engineer can also calculate the value of rainfall intensity from the best-fit IDF equation (2-~~6~~8) to be discussed later in this sub-section with known Tc value for the entire drainage area of interest.

In 1998, William Asquith at the USGS Texas Office analyzed virtually all rainfall data available in the State of Texas using L-moment methodology and published the results in a USGS Water Resources Investigations Report (WRIR 98-4044). In November 2001, Dr. Asquith summarized his rainfall study of 1998 and generated the IDF and the DDF (depth-duration-frequency) values that are suitable for use in the City of Austin and Travis County. These DDF and IDF values are shown in Table 2-3~~4~~ and Table 2-4~~5~~.

An explanation of the derivation of the Austin intensity-duration-frequency curves is given in Appendix B.

The Austin intensity-duration-frequency curves are shown in Figure 2-2 in Appendix ~~E~~ D of this manual.

Table 2-3~~4~~. Depth-Duration-Frequency Table for Austin and Travis County									
Depth of Precipitation (in inches)									
Recurrence Interval (year)	5 min*	15 min	30 min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	0.48	0.98	1.32	1.72	2.16	2.32	2.67	3.06	3.44
5	0.62	1.26	1.71	2.28	2.89	3.13	3.56	4.07	4.99
10	0.71	1.47	1.98	2.68	3.42	3.71	4.21	4.81	6.1
25	0.84	1.76	2.36	3.28	4.2	4.55	5.14	5.9	7.64
50	0.94	2.01	2.68	3.79	4.88	5.28	5.94	6.86	8.87
100	1.05	2.29	3.04	4.37	5.66	6.11	6.85	7.96	10.2
250	1.21	2.73	3.57	5.26	6.86	7.38	8.24	9.67	12

500	1.33	3.11	4.02	6.06	7.94	8.51	9.47	11.2	13.5

* The 5-min rainfall depths were calculated using the 5-min rainfall intensity values from Table 2-4~~5~~.

Table 2-4~~5~~. Intensity-Duration-Frequency Table for Austin and Travis County									
Intensity of Precipitation (inches per hour)									
Recurrence Interval (year)	5 min*	15 min	30 min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
2	5.76	3.92	2.64	1.72	1.08	0.773	0.445	0.255	0.143
5	7.39	5.04	3.42	2.28	1.45	1.04	0.593	0.339	0.208
10	8.57	5.88	3.96	2.68	1.71	1.24	0.702	0.401	0.254
25	10.1	7.04	4.72	3.28	2.10	1.52	0.857	0.492	0.318
50	11.2	8.04	5.36	3.79	2.44	1.76	0.990	0.572	0.370
100	12.5	9.16	6.08	4.37	2.83	2.04	1.14	0.663	0.424
250	14.5	10.9	7.14	5.26	3.43	2.46	1.37	0.806	0.501
500	15.9	12.4	8.04	6.06	3.97	2.84	1.58	0.934	0.564
* The 5-min rainfall intensity values were calculated using Equation 2-8~~6~~ and the coefficients listed in Table 2-5~~6~~ for the return periods of 2, 5, 10, 25, 100, 250, and 500 years.									

The following equation mathematically represents ~~mathematically~~ the Austin area intensity-duration-frequency curves:

$$i = a/(t+b)^c \qquad \text{(Eq. 2-8~~6~~)}$$

Where,

i = Average rainfall intensity, inches per hour
t = Storm duration in minutes, which is equal to the time of concentration for the entire drainage area of interest
a, b and c = Coefficients for different storm frequencies.

The final best-fit coefficients of a, b, and c for equation (2-8~~6~~) are listed in Table 2-5~~6~~ below:

Table 2-5~~6~~ Austin Intensity-Duration-Frequency Curve Coefficients			
Return Period	Fitting parameters for IDF equation (2-8~~6~~)		
Year	a~~A~~	b	c
2	54.767	11.051	0.8116
5	62.981	10.477	0.7820

10	70.820	10.396	0.7725
25	82.936	10.746	0.7634
50	100.60	12.172	0.7712
100	118.30	13.185	0.7736
250	150.10	14.892	0.7822
500	188.00	17.233	0.7959
Source: Asquith, W.H., "Depth-Duration Frequency and Intensity-Duration Frequency for Austin and Travis County, Texas, 2001. ~~Watershed Engineering Division of City of Austin~~			

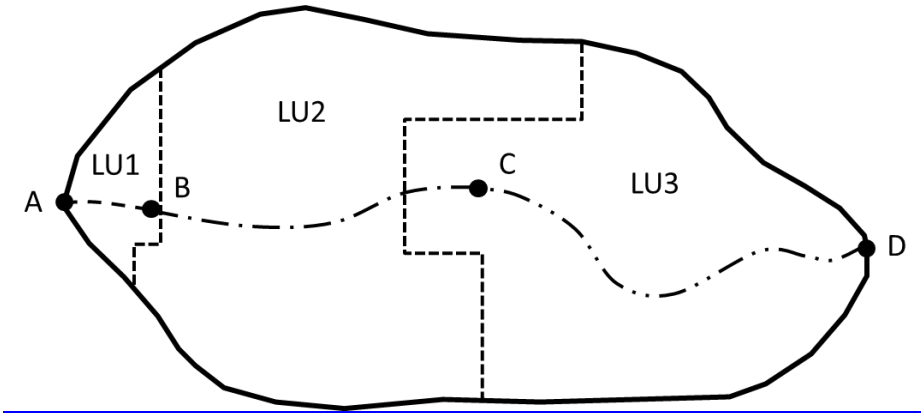
The a, b and c parameters listed in Table 2-5 were derived using nonlinear regression methods and the data included in Table 2-4. The IDF curves and the IDF equations are applicable for all design frequencies shown. They are required for use in determining peak flows by the Rational Method or other appropriate methods.

2.4.4 Drainage Area (A)

The size (acres) of the watershed needs to be determined for application of the Rational Method. The area may be determined through the use of topographic maps, supplemented by field surveys where topographic data has changed or where the contour interval is too great to distinguish the direction of flow. The drainage divide lines are determined ~~by~~ based on topography, street layout, lot grading, building structure configuration and orientation, drainage system layout and ~~many~~ other features that are created by the urbanization process.

Example 2-1

An urbanized watershed is shown on the following figure. Three types of flow conditions exist between the most distant point in the watershed and the outlet. The calculation of time of concentration and travel time in each reach is as follows**:**



Reach	Description of Flow	Slope (%)	Length (Ft.)	~~Drainage Area (Acre)~~	"n" Value/Surface Type

A to B	Sheet flow (grass lawn)	1.8 ~~4.5~~	50 ~~150~~	~~3~~	0.3
B to C	Shallow concentrated flow (gutter)	2.0	840	~~20~~	Paved ~~0.016~~
C to D	Storm drain with inlets (~~n=0.015;~~ D=3 feet)	1.5	1,200	~~30~~	0.015

For reaches A-B and B-C, the travel time can be calculated from Equations 2-3~~2~~ and 2-5~~3~~.

$T_{t(A-B)}$ = 0.0070.24 X 50)$^{0.8}$/(3.44)$^{0.5}$s$^{0.4}$ ~~150(0.3)/42(s)$^{0.5}$~~

= 0.028 ~~1.07~~/(0.018~~0.045~~)$^{0.5}$

= 0.21 ~~5.05~~ min.

$T_{t(B-C)}$ = 840/(60(20.3282)(s)$^{0.5}$) ~~840(0.016)/60(s)$^{0.5}$~~

= 0.69 ~~0.22~~/(0.02)$^{0.5}$

=4.87 ~~1.6~~ min.

The flow velocity in reach C-D needs to be calculated from Manning's Equation, using the assumption of full pipe flow, as follows:

V(C-D) = (1.49/n) $R^{0.67}s^{0.5}$

= (1.49/n) $(D/4)^{0.67}s^{0.5}$

= (1.49/0.015) $(3/4)^{0.67}$ $(0.015)^{0.5}$

= 10.0 ft/s

The channel flow travel time is calculated by dividing the length by the velocity.

T_t (C-D) = 1200/(60x10.0) = 2.0 min

The total time of concentration is calculated by adding the component sheet, shallow concentrated and channel flow segments.

Tc = 0.21+4.87+2.0 = 7.08 min

The runoff coefficients (C) for the three (3) areas are given as follows for the 100-year storm (1% annual chance event). ~~The channel flow travel time is calculated by dividing the length by the velocity~~

Area	Land Use	C	Area (acre)
LU1	Grass Area (fair condition, flat)	0.41	3
LU2	Commercial (composite of paved and grassed areas)	0.85	20
LU3	Industrial (composite of paved and grassed areas)	0.81	30
Total			53

~~Reach~~	~~Length (ft.)~~	~~Velocity (fps)~~	~~T_t (min)~~	~~C~~	~~Area (acre)~~
~~A-B~~	~~300~~	~~--~~	~~5.05~~	~~0.41~~	~~3~~
~~B-C~~	~~840~~	~~--~~	~~1.6~~	~~0.85~~	~~20~~
~~C-D~~	~~1200~~	~~10.0~~	~~2.0~~	~~0.81~~	~~30~~
~~-~~	~~-~~	~~-~~	~~8.65~~	~~-~~	~~53~~

The rainfall intensity (i) of the 100-year storm can be calculated using equation (2-~~6~~8) together with the coefficients in Table 2-5~~6~~ for a time of concentration of 7.08 ~~8.65~~ minutes as 11.54 ~~10.9~~ inches per hour.

The composite runoff coefficient (C) = (0.41 X 3 + 0.85 X 20 + 0.81 X 30)/53= 0.80

Thus the peak flow Qp = CiA = 0.80 X 11.54 ~~10.9~~ in/hr X 53 acre = 489 ~~462~~ cfs

2.5.0 THE SOIL CONSERVATION SERVICE METHOD FOR CALCULATION OF PEAK FLOWS

The Soil Conservation Service hydrologic method is ~~has been~~ widely used by engineers and hydrologists for analyses of small urban watersheds. This method is based on ~~results from~~ extensive analytical work using a wide range of statistical data concerning storm patterns, rainfall-runoff characteristics and many hydrologic observations in the United States.

The SCS method can be applied to urban drainage areas of any size. ~~Major~~ The major parameters required to calculate a runoff ~~the~~ hydrograph with the method include the rainfall distribution, runoff curve numbers, time of concentration and drainage area. For detailed information regarding the SCS method and the TR-20 program, the user is referred to the following NRCS ~~SCS~~ publications. These can be obtained from the Natural Resources Conservation Service at http://www.wcc.nrcs.usda.gov/. They are:

NEH-4: "Hydrology," Section 4, National Engineering Handbook
TR-20: Computer Program for Project Formulation, Hydrology
TR-55: Urban Hydrology for Small Watersheds
TP-149: A Method for Estimating Volume and Rate of Runoff in Small Watersheds

The ~~HEC-1 and~~ HEC-HMS programs can be downloaded from the US Army Corps of Engineers website at http://www.hec.usace.army.mil/. Refer to Section 8.2.3 for information regarding watershed hydrologic models that are maintained by the City. These models may be requested by the public and used as the basis for drainage analysis where applicable. Any results based on models obtained from the City must be certified by a Texas Licensed Professional Engineer.

2.5.1 Austin Twenty-Four (24) Hour Storm Rainfall Distributions

The ~~COA~~ City of Austin has adopted the use of an SCS 24-hour storm duration with a Type ~~type~~ III distribution for use with the SCS method. The DDF and IDF values to be used for the Austin area are shown in Table 2-3~~4~~ and 2-4~~5~~ above. For use in spreadsheet calculations, Table 2-6~~7~~ below provides the Type III distribution ordinates in 5-minute increments as derived from the HEC-HMS program. The ordinates should ~~to~~ be multiplied by the total 24 hour ~~storm~~ precipitation depth ~~depth in 5 minute increments for use in the HEC-1 program.~~ to produce the design rainfall distribution. When using the HEC-HMS model, the computational time interval should be selected based on criteria for the minimum lag time. The maximum computational time interval used in a HEC-HMS model should be 6 minutes.

Table 2-6~~7~~
Type III Distribution Ordinates In 5-Minute Time Increment

Time	Incremental	Cumulative	Time	Incremental	Cumulative	Time	Incremental	Cumulative
0:00	0.0000	0.0000	8:05	0.0023	0.1163	16:10	0.0021	0.8903
0:05	0.0008	0.0008	8:10	0.0022	0.1185	16:15	0.0021	0.8924
0:10	0.0009	0.0017	8:15	0.0023	0.1208	16:20	0.0020	0.8944
0:15	0.0008	0.0025	8:20	0.0025	0.1233	16:25	0.0020	0.8964
0:20	0.0008	0.0033	8:25	0.0025	0.1258	16:30	0.0020	0.8984
0:25	0.0009	0.0042	8:30	0.0026	0.1284	16:35	0.0019	0.9003
0:30	0.0008	0.0050	8:35	0.0027	0.1311	16:40	0.0019	0.9022
0:35	0.0008	0.0058	8:40	0.0028	0.1339	16:45	0.0019	0.9041
0:40	0.0009	0.0067	8:45	0.0028	0.1367	16:50	0.0018	0.9059
0:45	0.0008	0.0075	8:50	0.0030	0.1397	16:55	0.0019	0.9078
0:50	0.0008	0.0083	8:55	0.0030	0.1427	17:00	0.0017	0.9095
0:55	0.0009	0.0092	9:00	0.0031	0.1458	17:05	0.0018	0.9113
1:00	0.0008	0.0100	9:05	0.0032	0.1490	17:10	0.0016	0.9129
1:05	0.0008	0.0108	9:10	0.0032	0.1522	17:15	0.0017	0.9146
1:10	0.0009	0.0117	9:15	0.0033	0.1555	17:20	0.0016	0.9162
1:15	0.0008	0.0125	9:20	0.0034	0.1589	17:25	0.0016	0.9178
1:20	0.0008	0.0133	9:25	0.0035	0.1624	17:30	0.0016	0.9194
1:25	0.0009	0.0142	9:30	0.0035	0.1659	17:35	0.0015	0.9209
1:30	0.0008	0.0150	9:35	0.0037	0.1696	17:40	0.0015	0.9224
1:35	0.0008	0.0158	9:40	0.0037	0.1733	17:45	0.0015	0.9239
1:40	0.0009	0.0167	9:45	0.0038	0.1771	17:50	0.0014	0.9253
1:45	0.0008	0.0175	9:50	0.0039	0.1810	17:55	0.0014	0.9267
1:50	0.0008	0.0183	9:55	0.0040	0.1850	18:00	0.0013	0.9280
1:55	0.0009	0.0192	10:00	0.0040	0.1890	18:05	0.0013	0.9293
2:00	0.0008	0.0200	10:05	0.0041	0.1931	18:10	0.0014	0.9307
2:05	0.0008	0.0208	10:10	0.0044	0.1975	18:15	0.0012	0.9319
2:10	0.0009	0.0217	10:15	0.0045	0.2020	18:20	0.0013	0.9332

2:15	0.0008	0.0225	10:20	0.0047	0.2067	18:25	0.0014	0.9346
2:20	0.0009	0.0234	10:25	0.0048	0.2115	18:30	0.0012	0.9358
2:25	0.0009	0.0243	10:30	0.0050	0.2165	18:35	0.0012	0.9370
2:30	0.0009	0.0252	10:35	0.0051	0.2216	18:40	0.0013	0.9383
2:35	0.0009	0.0261	10:40	0.0054	0.2270	18:45	0.0013	0.9396
2:40	0.0009	0.0270	10:45	0.0055	0.2325	18:50	0.0012	0.9408
Time	Incremental	Cumulative	Time	Incremental	Cumulative	Time	Incremental	Cumulative
2:45	0.0009	0.0279	10:50	0.0057	0.2382	18:55	0.0013	0.9421
2:50	0.0010	0.0289	10:55	0.0058	0.2440	19:00	0.0012	0.9433
2:55	0.0009	0.0298	11:00	0.0060	0.2500	19:05	0.0012	0.9445
3:00	0.0010	0.0308	11:05	0.0064	0.2564	19:10	0.0011	0.9456
3:05	0.0009	0.0317	11:10	0.0070	0.2634	19:15	0.0012	0.9468
3:10	0.0010	0.0327	11:15	0.0077	0.2711	19:20	0.0012	0.9480
3:15	0.0010	0.0337	11:20	0.0084	0.2795	19:25	0.0011	0.9491
3:20	0.0010	0.0347	11:25	0.0089	0.2884	19:30	0.0012	0.9503
3:25	0.0010	0.0357	11:30	0.0096	0.2980	19:35	0.0012	0.9515
3:30	0.0010	0.0367	11:35	0.0131	0.3111	19:40	0.0011	0.9526
3:35	0.0010	0.0377	11:40	0.0187	0.3298	19:45	0.0011	0.9537
3:40	0.0011	0.0388	11:45	0.0261	0.3559	19:50	0.0011	0.9548
3:45	0.0010	0.0398	11:50	0.0289	0.3848	19:55	0.0011	0.9559
3:50	0.0010	0.0408	11:55	0.0425	0.4273	20:00	0.0011	0.9570
3:55	0.0011	0.0419	12:00	0.0727	0.5000	20:05	0.0011	0.9581
4:00	0.0011	0.0430	12:05	0.0727	0.5727	20:10	0.0011	0.9592
4:05	0.0011	0.0441	12:10	0.0425	0.6152	20:15	0.0011	0.9603
4:10	0.0011	0.0452	12:15	0.0289	0.6441	20:20	0.0010	0.9613
4:15	0.0011	0.0463	12:20	0.0261	0.6702	20:25	0.0010	0.9623
4:20	0.0011	0.0474	12:25	0.0187	0.6889	20:30	0.0011	0.9634
4:25	0.0011	0.0485	12:30	0.0131	0.7020	20:35	0.0010	0.9644
4:30	0.0012	0.0497	12:35	0.0096	0.7116	20:40	0.0010	0.9654

Comment [PK1]: Please include as header for each page containing this chart

4:35	0.0012	0.0509	12:40	0.0089	0.7205	20:45	0.0010	0.9664
4:40	0.0011	0.0520	12:45	0.0084	0.7289	20:50	0.0010	0.9674
4:45	0.0012	0.0532	12:50	0.0077	0.7366	20:55	0.0010	0.9684
4:50	0.0012	0.0544	12:55	0.0070	0.7436	21:00	0.0010	0.9694
4:55	0.0011	0.0555	13:00	0.0064	0.7500	21:05	0.0010	0.9704
5:00	0.0012	0.0567	13:05	0.0060	0.7560	21:10	0.0010	0.9714
5:05	0.0012	0.0579	13:10	0.0058	0.7618	21:15	0.0009	0.9723
5:10	0.0013	0.0592	13:15	0.0057	0.7675	21:20	0.0010	0.9733
5:15	0.0012	0.0604	13:20	0.0055	0.7730	21:25	0.0010	0.9743
5:20	0.0013	0.0617	13:25	0.0054	0.7784	21:30	0.0009	0.9752
5:25	0.0013	0.0630	13:30	0.0051	0.7835	21:35	0.0010	0.9762
5:30	0.0012	0.0642	13:35	0.0050	0.7885	21:40	0.0009	0.9771
5:35	0.0012	0.0654	13:40	0.0048	0.7933	21:45	0.0009	0.9780
5:40	0.0014	0.0668	13:45	0.0047	0.7980	21:50	0.0010	0.9790
5:45	0.0012	0.0680	13:50	0.0045	0.8025	21:55	0.0009	0.9799
5:50	0.0013	0.0693	13:55	0.0044	0.8069	22:00	0.0009	0.9808
5:55	0.0014	0.0707	14:00	0.0041	0.8110	22:05	0.0008	0.9816
6:00	0.0013	0.0720	14:05	0.0040	0.8150	22:10	0.0009	0.9825
6:05	0.0013	0.0733	14:10	0.0040	0.8190	22:15	0.0009	0.9834
6:10	0.0014	0.0747	14:15	0.0039	0.8229	22:20	0.0009	0.9843
6:15	0.0014	0.0761	14:20	0.0038	0.8267	22:25	0.0009	0.9852
6:20	0.0015	0.0776	14:25	0.0037	0.8304	22:30	0.0008	0.9860
6:25	0.0015	0.0791	14:30	0.0037	0.8341	22:35	0.0008	0.9868
Time	Incremental	Cumulative	Time	Incremental	Cumulative	Time	Incremental	Cumulative
6:30	0.0015	0.0806	14:35	0.0035	0.8376	22:40	0.0009	0.9877
6:35	0.0016	0.0822	14:40	0.0035	0.8411	22:45	0.0008	0.9885
6:40	0.0016	0.0838	14:45	0.0034	0.8445	22:50	0.0008	0.9893
6:45	0.0016	0.0854	14:50	0.0033	0.8478	22:55	0.0009	0.9902
6:50	0.0017	0.0871	14:55	0.0033	0.8511	23:00	0.0007	0.9909

Comment [PK2]: Please include as header for each page containing this chart

6:55	0.0016	0.0887	15:00	0.0032	0.8543	23:05	0.0008	0.9917
7:00	0.0018	0.0905	15:05	0.0030	0.8573	23:10	0.0008	0.9925
7:05	0.0017	0.0922	15:10	0.0030	0.8603	23:15	0.0008	0.9933
7:10	0.0019	0.0941	15:15	0.0030	0.8633	23:20	0.0008	0.9941
7:15	0.0018	0.0959	15:20	0.0028	0.8661	23:25	0.0007	0.9948
7:20	0.0019	0.0978	15:25	0.0028	0.8689	23:30	0.0008	0.9956
7:25	0.0019	0.0997	15:30	0.0027	0.8716	23:35	0.0008	0.9964
7:30	0.0019	0.1016	15:35	0.0026	0.8742	23:40	0.0007	0.9971
7:35	0.0020	0.1036	15:40	0.0025	0.8767	23:45	0.0008	0.9979
7:40	0.0020	0.1056	15:45	0.0025	0.8792	23:50	0.0007	0.9986
7:45	0.0020	0.1076	15:50	0.0023	0.8815	23:55	0.0006	0.9992
7:50	0.0021	0.1097	15:55	0.0022	0.8837	24:00	0.0008	1.0000
7:55	0.0021	0.1118	16:00	0.0023	0.8860			
8:00	0.0022	0.1140	16:05	0.0022	0.8882			

2.5.2 ~~Soil~~ National Resources Conservation Service Runoff Curve Numbers

The ~~Soil~~ National Resources Conservation Service has developed an index, the runoff curve number, to represent the combined hydrologic effect of soil type, land use, agricultural land treatment class, hydrologic condition, and antecedent soil moisture. These watershed factors have the most significant impact in estimating the volume of runoff, and can be assessed from soil surveys, site investigations and land use maps.

The curve number is an indication of the potential runoff ~~producing potential of the drainage area~~ for a given antecedent soil moisture condition, and it ranges in value from zero to 100. The ~~Soil~~ National Resources Conservation Service runoff curve numbers are grouped into three (3) antecedent soil moisture conditions -- Antecedent Runoff ~~Moisture~~ Condition (ARC) I, ARC ~~Antecedent Moisture Condition~~ II and ARC ~~Antecedent Moisture Condition~~ III. Values of runoff curve numbers for all three (3) conditions may be computed following guidelines in Part 630, Chapter 10 of the National Engineering Handbook. ARC ~~Antecedent Moisture Condition~~ I is the dry soil condition and ARC ~~Antecedent Moisture Condition~~ III is the wet soil condition. ARC ~~Antecedent Moisture Condition~~ II is normally considered to be the average condition. The Antecedent Runoff Condition (ARC) was previously referred to as the Antecedent Moisture Condition (AMC) in older NRCS publications.

However, studies of hydrologic data indicate that ARC ~~Antecedent Moisture Condition~~ II is not necessarily representative of the average condition throughout Texas. Instead, investigations have shown that the average condition ranges from ARC ~~Antecedent Moisture Condition~~ I in west Texas to between ARC ~~Antecedent Moisture Condition~~ II and ARC ~~Antecedent Moisture Condition~~ III in east Texas. The NRCS curve number values provided ~~given~~ in Table 2-7~~11~~ are for an ARC ~~Antecedent Moisture Condition~~ II. If it is desired to change to an ARC ~~Antecedent Moisture Condition~~ I or Ill condition, the adjustments given **in** ~~or~~ Part 630, Chapter 10 of the National Engineering Handbook should be used. Justification must be provided for the selection of an ARC other than condition II.

~~(Note that the Antecedent Moisture Condition is also referred to as the Antecedent Runoff Condition).~~

The ~~Soil~~ National Resources Conservation Service has classified more than 4,000 soils into four (4) hydrologic groups, identified by the letters A, B, C, and D, to represent watershed characteristics.

Group A: (Low runoff potential). Soils having a high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well-drained to excessively drained sands or gravels.

Group B: Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse texture.

Group C: Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soil with moderately fine to fine texture.

Group D: (High runoff potential). Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

~~The list of most soils in the United States along with their hydrologic soil classification is given in the TR-55 publication. The minimum infiltration rates for the four (4) soil groups are:~~

~~Group~~	~~Minimum Infiltration Rate (in/hr)~~
~~A~~	~~0.30 - 0.45~~
~~B~~	~~0.15 - 0.30~~
~~C~~	~~0.05 - 0.15~~
~~D~~	~~0.00 - 0.05~~

Table 2-~~8~~7 lists the curve numbers for the four (4) soil groups under various land uses, land treatment and hydrologic conditions. Curve numbers for fully developed conditions should be based on maximum allowable impervious cover listed in Austin zoning and watershed ordinances. When calculating fully developed peak runoff rates it is recommended that the undeveloped curve number and the maximum allowable impervious cover be used as input parameters. In order to determine the soil classifications in the Austin area, the ~~Soil~~ Natural Resource Conservation Service Soil Surveys of Travis, Williamson or Hays County, Texas should be used. Digital versions of these soil datasets are available online at http://soildatamart.nrcs.usda.gov (accessed 12/18/2012).

Table 2-7~~8~~
~~SCS~~ NRCS Runoff Curve Numbers for Urban Areas and Agricultural Lands (assuming ARC-II condition)

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover type and Hydrologic Condition	Average % Impervious Area[1]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)		68	79	86	89
Poor condition (grass cover 50%)		49	69	79	84
Fair condition (grass cover 50% to 75%)		39	61	74	80

Good condition (grass cover 75%)					

Table 2-7~~8~~ (Continued)
~~SCS~~ NRCS Runoff Curve Numbers for Urban Areas and Agricultural Lands

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover type and Hydrologic Condition	Average % Impervious Area[1]	**A**	B	C	D
Impervious areas: Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storms drains (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94
Agricultural lands					
Grassland, or range-continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow-continuous grass, protected from grazing and generally mowed for hay		30	58	71	78
Brush—brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods—grass combination (orchard or tree farm).[4]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[5]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways and surrounding lots		59	74	82	86

[1] Poor: less than 50 percent ground cover or heavily grazed with no mulch.
Fair: 50 to 75 percent ground cover and not heavily grazed.

Good: greater than 75 percent ground cover and lightly or only occasionally grazed. [2] Poor: less than 50 percent ground cover. Fair: 50 to 75 percent ground cover. Good: greater than 75 percent ground cover. [3] Curve numbers shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the curve numbers for woods and pasture. [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.
Source: ~~Soil~~ National Resources Conservation Service. TR-55: Urban Hydrology for Small Watersheds

2.5.3 Time of Concentration

The procedures for estimating time of concentration for the ~~SCS~~ NRCS method are described in the SCS'~~s~~ Technical Release 55 (TR-55) and in Section 2.4.2 of this manual. Three (3) types of flow (sheet flow, shallow concentrated flow and channel flow) are considered. Note that Table 2-2 shall be used for determination of sheet flow Manning's roughness coefficients rather than the table included in TR-55.

In hydrograph analysis, the time of concentration can be defined as ~~is~~ the time from the end of excess rainfall to the point of inflection on the falling limb of the hydrograph. The time of concentration determines the shape of the runoff hydrograph. Times of concentration are required for the existing and developed conditions to adequately model the impact of the development on stormwater runoff. The methodology presented in TR-55 provides a reasonable approach for the estimation of time of concentration. The lag time, defined as the time between the center of mass of excess rainfall to the runoff peak, is typically used in the HEC-HMS implementation of the SCS methodology. The lag time can be estimated with equation 2-9.

$$T_{lag} = 0.6\ T_c \qquad \text{(Eq. 2-9)}$$

In general, times of concentration for the developed condition should be calculated based on conservative assumptions that consider ~~concerning~~ the increased hydraulic efficiency expected with an ultimate developed condition. Times of concentration should be representative of the overall drainage area, not simply based on the longest (in either distance or time) flow path. ~~For instance, while sheet~~ Sheet flow for both existing and proposed conditions ~~is typically limited to 300 feet, sheet flow for developed conditions~~ should be limited to 100 ~~150~~ feet. This length ~~These lengths~~ should be considered ~~are~~ considered a ~~to be~~ maximum~~s~~; sheet flow lengths should be measured and justified for all conditions. Additionally, the minimum slope used for calculation of sheet and shall flow travel time components should be 0.005 feet per foot (0.5%).

2.6.0 PROBABLE MAXIMUM STORM/FLOOD DEVELOPMENT

The purpose of this section is to describe a method for developing the Probable Maximum Flood (PMF) within the City of Austin jurisdiction. The PMF is calculated by obtaining the Probable Maximum Precipitation (PMP) for a specific storm duration and drainage area. The PMP rainfall depths presented in this section were derived for the Austin area and are only applicable for designing and managing dams within City of Austin's full purpose, limited purpose and extraterritorial jurisdictions. Typically, a PMF runoff model requires both a temporal and spatial distribution of the PMP. However, if the drainage area is less than 10 square miles, the spatial distribution is not required (i.e. the drainage area is considered small enough that the PMP values can reasonably be considered point rainfall values). The PMP values shown in this section are valid only for drainage areas less than 10 square miles.

2.6.1 Probable Maximum Precipitation (PMP)

The PMP values were derived using Hydrometeorological Report No. 52 (HMR-52) and Hydrometeorological Report No. 51 (HMR-51) per the guidance provided in the Hydrologic and Hydraulic Guidelines for Dams in Texas (January 2007) available from the Dam Safety Program at the Texas Commission on Environmental Quality (TCEQ). Table 2-~~9~~ 8 contains a summary of PMP depths and intensities for various storm durations for drainage areas less than 10 square miles.

Table 2-~~9~~8 Probable Maximum Precipitation Depths for the City of Austin	
Storm Duration	Depth (in)
1 hr	17.4
2 hr	21.6
3 hr	24.9
6 hr	31.1
12 hr	37.6
24 hr	44.7
48 hr	50.0
72 hr	53.4
1. All values are valid for drainage areas less than 10 square miles.	
2. Do not use these depths with the Soil Conservation Service (SCS) Type III distribution. The relevant storm distributions are provided in DCM Section 2.6.2 "Probable Maximum Flood (PMF)" and were derived using the Hydrologic and Hydraulic Guidelines for Dams in Texas.	

2.6.2 Probable Maximum Flood (PMF)

To determine the PMF, each of the possible storm durations (1, 2, 3, 6, 12, 24, 48, and 72 hour storms) needs to be analyzed in order to determine the critical duration. The critical duration is the storm duration that produces the highest water surface elevation behind the dam. The PMF for each storm duration is derived using the PMP depths from Table 2-~~9~~ 8 and using a rainfall-runoff model (i.e.~~HEC-1,~~ HEC-HMS, TR-20). The rainfall-runoff model should use the temporal distribution as provided in the Hydrologic and Hydraulic Guidelines for Dams in Texas. The temporal distribution for each storm duration has been reproduced in Figure 2-4, Appendix ~~E~~ D. Figure 2-4 provides the temporal distribution ordinates to be multiplied by the associated storm depths for use in the various rainfall-runoff models. The runoff parameters used in the PMF model are the same as those used for runoff analyses of the more frequent storm events, with the exception of curve numbers and the temporal distribution of rainfall.

Runoff curve numbers for the PMF need to reflect the assumption that the soils will be saturated. Therefore the runoff curve number should be based on ARC ~~Antecedent Moisture Condition~~ III ~~(AMC)~~. ~~Runoff curve numbers are discussed in the Drainage Criteria Manual (DCM), Section 2.5.2 "Soil Conservation Runoff Curve Numbers".~~ The appropriate curve number should be chosen using the tables provided in the DCM Section 2.5.2. These ~~values~~ are ARC ~~AMC~~ II values which ~~and~~ can be converted to ARC ~~AMC~~ III values using Table 10.1 in Part 630, Chapter 10 of the National Engineering Handbook. Note that the ARC was previously ~~The Antecedent Moisture Condition (AMC) is~~ referred to as the ~~Natural Resource Conservation Service~~ Antecedent Moisture ~~Runoff~~ Condition (AMC ~~ARC~~) in ~~the Hydrologic and Hydraulic Guidelines for~~

~~Dams in Texas.~~ older NRCS publications.

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