DESIGN CRITERIA MANUAL

DEWITT COUNTY
DRAINAGE DISTRICT NO. 1

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1.0   INTRODUCTION

The purpose of this Design Criteria Manual (DCM) is to establish the storm drainage design criteria and procedures for development and system improvements within the jurisdictional boundaries of DeWitt County Drainage District No. 1 (DCDD1 or "the District"). These criteria and procedures were used in the preparation of the District's Master Drainage Plan (MDP) dated June 7, 2019 available under separate cover.

The purpose of this DCM is to serve as guidance manual providing standard practices and overall drainage policies of the District. This DCM is not intended to be a comprehensive educational document. It is assumed that the user of this DCM has a working knowledge of the basic mathematical theories involved in hydrology and hydraulics. A bibliography is included referencing applicable educational and technical resources.

Section 2 includes a list of deliverables that should be submitted to the District supporting an application for a proposed development within the District or a proposed connection to the District drainage system. These lists focus on completeness of what is to be submitted, whereas the specific methods used and content details are left to the discretion of the developer/designer within the parameters presented in this DCM.

2.0   DRAINAGE POLICIES

These policies shall govern the planning, design, and construction of storm drainage facilities within the District's legal boundary, as well as areas that discharge directly to or are located upgradient of the District drainage system. These areas constitute the "District jurisdictional boundary" as defined by the MDP.

2.1   GENERAL DRAINAGE POLICIES

The MDP adopted by the District establishes the baseline drainage conditions to be used in the management of stormwater within the District jurisdictional boundary, provides a set of hydrologic and hydraulic models for the major watersheds, outlines plans to eliminate or significantly reduce flooding along the District drainage systems, and describes the assumptions and methodologies used to develop this information. As part of the overall work associated with the MDP, this DCM was developed to provide consistent and standard policy and methods to design and evaluate drainage systems within the District.

In order to manage future development and to guide use of the MDP and DCM within the District's jurisdictional boundary, establishment of the District's drainage policies is required. These policies are being enacted such that new development can occur within the District jurisdictional boundary with thorough considerations for flood potential to property, existing homes, and future development within the community.

2.1.1   Definitions

1. <u>Development</u> – Any man-made change to improved or unimproved real estate, including, but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations located within the District jurisdictional boundary.

2. <u>Drainage Conditions</u> – There are several drainage conditions that shall be considered or evaluated in the preparation of a development application. Each drainage condition represents a different combination of level of development within a watershed and condition of the District drainage system serving that watershed.

   a. <u>Existing Conditions (Baseline)</u> – The baseline condition for areas within the District jurisdictional boundary shall be the existing conditions as defined in the MDP. The MDP provides a baseline set of existing conditions hydrologic and hydraulic models for the District drainage systems within the District jurisdictional boundary. The conditions established by the MDP represent the "present" level of development and associated hydrologic parameters within a watershed, as well as the "present" condition of the drainage systems and associated hydraulic parameters at the time of MDP development in 2018. The existing conditions models (i.e., pre-project) shall be used as the baseline for the determination of any impacts due to development activities that necessitate the implementation of interim or permanent flood control measures.

b. <u>Revised Existing Conditions (Alternate Baseline)</u> – In order to properly evaluate the potential for flood impacts associated with a development site, it may be necessary to update the hydrologic and/or hydraulic modeling conditions to reflect the state of the system and the development within a watershed at the time of the development application. If a designer/developer wishes to re-establish existing conditions to reflect changes in watershed or drainage system conditions that may have occurred since the establishment of "existing conditions" by the MDP, but prior to and unrelated to the proposed development, the applicant may modify the existing conditions models based on best available data using the methods described in the MDP and this DCM. These revised existing conditions models shall be submitted for review of the District, and may be used as baseline conditions for impact analyses upon District approval. The applicant must provide technical support data in order to justify any such revision to the existing conditions models.

c. <u>Proposed Conditions</u> – The proposed condition represents current (at the time of the development application) watershed conditions and drainage system conditions outside of the proposed development boundary and proposed conditions within the development boundary, specifically including effects of added impervious cover, land use modifications, flow path / time of concentration modifications, proposed detention or drainage features, etc.

3. <u>Impervious Cover</u> – Roads, parking lots, sidewalks, rooftops and other impermeable surfaces that tend to prevent the infiltration of rainfall into the ground, increase runoff volumes, increase runoff peak flows, increase runoff flow velocities, and decrease runoff times.

4. <u>Infill Development</u> – Development of small, undeveloped properties within larger, predominantly urbanized areas.

5. <u>District Drainage System</u> – The District drainage system is the network of open channel and closed conduit drainage infrastructure owned and maintained by the District that was studied in detail in the MDP. Refer to the MDP for a full description of the District drainage systems, which include:

- Alexander Channel
- Daule Channel
- Ice House Channel
- West End Lateral
- Main Channel
- Valley Channel

6. <u>Redevelopment</u> – The partial or complete demolition of a building, followed by the partial or complete building construction which occupies a different footprint than the original principal building.

7. <u>Regulatory Flood Elevations</u> – Refer to the District MDP and Rules & Regulations for additional definitions and requirements.

a. <u>FEMA Effective Base Flood Elevation (BFE)</u> – Elevations associated with this flood condition are defined as flood elevations that have a 1% chance of occurring in any given year. This 1% annual chance exceedance event defines the floodplains and flood elevations that are used in the determination of the need for, and cost of, flood insurance for a property. FEMA Flood Insurance Rate Maps (FIRMs) may be updated to be consistent with Special Flood Hazard Areas (SFHA) and BFEs identified by future phases of MDP hydrologic and hydraulic modeling.

b. <u>Baseline Flood Elevation</u> – Primary regulatory elevations to be used in consideration of all development within the District and are based on the 2-, 10-, 25-, and 100-year recurrence interval (i.e., 50-, 10-, 4-, and 1-percent annual chance exceedance) storm events with the assumptions of watershed development and District drainage system conditions as of 2018 as outlined in the MDP. Baseline conditions have been established by the hydrologic and hydraulic models in the MDP.

2.1.2 Drainage Impacts to the District Drainage System

Runoff-related impacts associated with a development may not increase water surface elevations within the District drainage system above the 2-, 10-, 25-, and 100-year recurrence interval (i.e., 50-, 10-, 4-, and 1-percent annual chance exceedance) baseline flood elevations established by the MDP. Any increase over the baseline flood elevations must be mitigated through onsite detention, additional conveyance increases, or additional purchase of drainage easements at the expense of the developer.

2.2 CONSTRAINTS AND REQUIREMENTS

2.2.1 Jurisdiction

The drainage policies provided in this Section shall apply to all areas within the District jurisdictional boundary as defined in the MDP.

2.2.2 Drainage Study

A drainage study using the District's DCM performed and/or supervised by a licensed professional engineer is required for all proposed development other than a single-family residential subdivision which includes a total impervious coverage area that is less than 10,000 square feet (including all pavement, rooftops, driveways, sidewalks, and concrete) and less than twenty (20) percent of the total land area of the development. The study must consider watershed existing (pre-development) and proposed (post-development) conditions and provide calculations and models developed to size onsite drainage and make any necessary modifications to adjoining drainage systems. Off-site evaluations of connected drainage systems are required in cases where one or both of the following conditions exist: 1) there is potential for increased flood risks along intervening drainage systems between the development and the major receiving system, or 2) the development directly modifies or discharges directly to one of the District drainage systems identified in the MDP. Such modifications include changes to the size or shape of an existing drainage

element, changing the characteristics of the drainage element (concrete lining, etc.), constructing or modifying a stream crossing or placing fill in the floodplain.

2.2.3 **Phasing of Planned Developments**

Individual sections of larger planned developments will be considered on an individual basis. However, the entire planned development will also have to be evaluated at the time that the first phase is submitted. The required drainage study must show the impacts of the entire planned development as well as its various individual phases.

2.2.4 **FEMA Mapping Requirements**

Any proposed development or modification to drainage conditions or construction/modification of a stream crossing that results in an increase in the effective FEMA base flood elevation or change in the effective FEMA floodplain horizontal limits will require the preparation and submittal of a FEMA Conditional Letter of Map Revision (CLOMR) application to the District and, once approved by the local floodplain administrator, to FEMA. Once construction of the proposed development or stream modification is complete, the developer must prepare and submit a FEMA Letter of Map Revision (LOMR) application to the District and, once approved by the local floodplain administrator, to FEMA in order to document as-built conditions. All FEMA application fees must be paid by the applicant.

2.2.5 **Waiver for Small Developments**

The District may waive the requirement of a Drainage Study or any part of said study for development of a single-family residential subdivision which includes a total impervious coverage area that is less than 10,000 square feet (including all pavement, rooftops, driveways, sidewalks, and concrete) and less than twenty (20) percent of the total land area of the development if the District determines that drainage conditions would not change substantially and, therefore, there would be no increase in the potential flood risks caused by the development.

2.2.6 **Stormwater Detention**

Permanent, on-site stormwater detention upstream of discharge locations will be required in cases where the proposed development results in increases in the 2-, 10-, 25-, and 100-year recurrence interval (i.e., 50-, 10-, 4-, and 1-percent annual chance exceedance) baseline flood elevations within the District drainage system as defined in the MDP. The stormwater detention solution shall be maintained by the developer or another entity as approved in writing by the District.

2.3 DRAINAGE DESIGN POLICIES

2.3.1 **Direct Connections to District Drainage System**

The proposed addition or modification of stormwater drainage controls that discharge directly to the District drainage system including storm drain systems or open channels shall be designed in accordance with the design criteria provided in this DCM.

2.3.2   Erosion and Sedimentation Control

An adequate Stormwater Pollution Prevention Plan (SWPPP) with associated forms and documentation per the current Texas Commission on Environmental Quality (TCEQ) rules may be required for construction projects. All projects within the District jurisdictional boundary shall use Best Management Practices (BMP) to mitigate erosion and sedimentation. For developments that disturb more than than 1 acre, TCEQ construction activities may require submittal of Notice of Intent and other documentation required by TCEQ.

2.3.3   Design Calculations and Technical Support Data

Supporting calculations and models for all proposed drainage designs shall be submitted to the District for review and approval. Construction shall not begin until approval is obtained. The calculations shall be in a form as to facilitate an orderly and timely review by the District and to allow these calculations to be made a part of the District's permanent engineering records. These calculations shall bear the seal of a Registered Professional Engineer licensed in the State of Texas, and shall contain a statement by the Engineer that the design calculations have been prepared in compliance with the requirements of this DCM.

All projects shall be tied to standard horizontal and vertical datums for the District. The horizontal datum shall be the North American Datum of 1983 (NAD83). The vertical datum shall be the North American Vertical Datum of 1988 (NAVD 88). Coordinates shall be in the State Plan mappings system, South Central Zone 4204 with units of feet. In the event GPS surveying is used to establish benchmarks, at least two references to FEMA benchmarks must be identified. Equations may be used to translate other datum adjustments to the required adjustment.

2.3.3.1   Hydrologic Design

Support data for hydrologic calculations and modeling associated with both existing and proposed conditions shall include:

- A topographic drainage area map with all drainage areas and peak flow rate computation point locations delineated based on existing and proposed conditions;
- A table presenting all peak flow rate calculations with computation point locations clearly labeled;
- Documentation of the hydrologic calculation method and associated parameters used (Rational Method and/or HEC-1/HEC-HMS depending on drainage area size as discussed in Sections 3 and 4); and,
- Electronic copies of all hydrologic models developed for existing and proposed conditions.

2.3.3.2   Open Channel Design

Support data for open channel design calculations and modeling associated with both existing and proposed conditions shall include:

- A topographic map of the subject drainage basin(s) showing proposed drainage areas and proposed channel locations;
- Hydrologic computations used to determine the design discharge for channel(s) (See Section 2.3.4.1)
- For design using the Manning Equation, a listing of the following parameters is required:

  o Channel slopes (ft/ft)
  o Design peak flow rates (cfs)
  o Manning "n" values
  o Channel side slopes (Horizontal to Vertical)
  o Channel bottom width (feet)
  o Maximum computed velocities within the channel (fps)
  o Flow depths (feet)

- For design using USACE HEC-RAS hydraulic modeling software (or other software with prior approval of District), provide an output listing of the input data and a summary of the output. Additional information may be required upon review.
- Existing and proposed channel cross-sections with their locations delineated on a map; and,
- Electronic copies of all hydraulic models developed for existing and proposed conditions.

2.3.3.3   Culvert Design

Support data for culvert design calculations and modeling associated with both existing and proposed conditions shall include:

- Hydrologic computations used to determine the design discharge for culvert(s) (See Section 2.3.4.1)
- A summary table delineating the following (model output table will be acceptable):

  o Design peak flow rates
  o Culvert length
  o Culvert slope
  o Headwater depth
  o Tail-water depth
  o Selected culvert type, size, and material
  o Flow velocity at the culvert outlet
  o Energy dissipation device details
  o Designation of inlet or outlet control

- Electronic copies of all hydraulic models developed for existing and proposed conditions. Acceptable modeling software packages include FHWA HY-8, HEC-RAS, or others upon prior approval by the District.

2.3.3.4   Storm Drain Design

Support data for storm drain design calculations and modeling associated with both existing and proposed conditions shall include:

- A topographic map showing the proposed development, including existing and proposed storm drain pipe alignments, inlet locations, and drainage areas contributing to each inlet;
- A table summarizing drainage area, time of concentration, assumed C values or CN values (depending on drainage area size as discussed in Sections 3 and 4), design peak flow rates (assumed to enter the inlet), size and number of inlets at each inlet location, and computed inlet bypass flows (for inlets on grade rather than in sump/sag);
- Storm drain plans must have the HGL plotted on the profile for the 25- and 100-year recurrence interval storm events. FHWA HEC-22 equations should be used to compute minor losses. If storm drain hydraulic design is carried out by hand, present calculations of HGL profile including pipe friction and minor losses (bends, wyes, manholes, junction boxes, etc) at each computation point within the storm drain system.
- Electronic copies of all hydraulic models developed for existing and proposed conditions. Acceptable modeling software packages include EPA-SWMM, Bentley StormCAD, or others upon prior approval by the District.

2.3.3.5   Stormwater Detention Design

Support data for stormwater detention design calculations and modeling associated with both existing and proposed conditions shall include:

- Supporting data and calculations (including input and output files for model methods) for existing and proposed conditions. A flow routing analysis using detailed hydrographs must be applied for all detention pond designs. Hydrologic routing methods including Modified Puls and Muskingham Cunge (available in HEC-1 and HEC-HMS) may be used to analyze channel conveyance. Reservoir routing should be based on computed elevation-storage-discharge outflow rating curves or outfall structure data input directly into the model. The time of concentration within the detention basin shall be set at zero (0) minutes, allowing the routing calculations through the detention basin to control the overall site time of concentration. Also, the total impervious area within a development shall include the area of the detention basin as impervious area;
- Calculations used to determine outflow structure sizing and rating curves;
- Electronic copies of all hydraulic models developed for existing and proposed conditions. Acceptable modeling software packages include HEC-1, HEC-HMS, Bentley PondPack, or others

upon prior approval by the District.

2.3.3.6 Final Design

The completed design documents shall be submitted for review, comment and final approval. Information included with this submittal shall include the following items:

- Copies of any documents that show approval of exceptions to the District design criteria.
- Design calculations for storm line sizes and grades, and for detention facilities, if any.
- Design calculations for the hydraulic grade line of each line or channel, and for detention facilities, if any.
- Contour map and drainage area map of the project.
- Plan and profile sheets showing stormwater improvements.
- Projects located within a FEMA Special Flood Hazard Area shall:
  - Show the floodplain boundary or floodplain area, as appropriate, on all sheets.
  - Comply with all rules of the FEMA National Flood Insurance Program (NFIP).

The final review set drawings should include a note stating that the drawings are a "not-for-construction" review set along with the engineer's name and registration number.

2.3.3.7 Quality Assurance

Calculations and construction drawings shall be prepared under the supervision of a Professional Engineer trained and licensed in Texas under the disciplines required by the drawings. The final construction drawings and all design calculations must be sealed, signed, and dated by the Professional Engineer responsible for the development of the drawings.

3.0   **DETERMINATION OF STORM RUNOFF FROM SMALL AREAS**

Small areas are defined as contiguous areas draining 100 or less acres.

3.1   **RATIONAL METHOD**

The rational method shall be used for the analysis of existing storm drainage systems and the design of proposed storm drainage systems for contributing areas up to 100 acres in size. Refer to the policy statement in Section 2.3.3.5 for information regarding the design of detention facilities for all contributing area sizes. The equation used in determining peak runoff flow is as follows:

$$Q = CiA$$

Where Q = Runoff in cubic feet per second,
            C = Runoff coefficient,
            i = Rainfall intensity in inches per hour,
            A = Contributing drainage area in acres.

3.1.1   **Runoff Coefficient**

The runoff coefficient "C" values in the Rational Method formula will vary based on the land use type. Land use types and "C" values that are to be used are presented in Table 3-1. Composite "C" values should be computed for drainage areas containing multiple land use types.

3.1.2   **Time of Concentration**

The time of concentration is the time for surface runoff to flow from the most hydrologically remote point in a drainage area to a discharge location (point of computation). 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:

1) Sheet flow (overland flow, limited to a maximum of 100 feet for developed areas and 200 feet for undeveloped areas);
2) Shallow concentrated flow; and
3) Channel flow, which may include open channel or closed conduit flow.

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. The minimum time of concentration for any drainage area shall be 5 minutes. The minimum slope used for calculation of sheet and shallow flow travel time components should be 0.002 feet per foot (0.2%). The preferred procedure for estimating time of concentration is the Natural Resource

Conservation Service (NRCS, formerly "Soil Conservation Service" or "SCS") method as described in NRCS's Technical Release 55 (TR-55, https://www.nrcs.usda.gov /Internet/FSE_DOCUMENTS/stelprdb1044171.pdf).

In general, times of concentration for the developed condition should be calculated based on conservative assumptions that consider the increased hydraulic efficiency expected with developed conditions. Times of concentration should be representative of the overall drainage area, not simply based on the longest flow path.

3.1.3 Rainfall Intensity

The rainfall intensity for each drainage area will be determined based on the values presented in Table 3-2 with storm duration equal to computed time of concentration. Values may be interpolated as necessary.

3.2   **SECTION 3.0 FIGURES AND TABLES INDEX**

Tables

Table 3-1: Rational Method Runoff Coefficients (C)

Table 3-2: Intensity-Duration-Frequency (IDF) Values

Table 3-1: Table 3-2. Rational Method Runoff Coefficients (C)

Land Use Type	Recurrence Interval (years)						
	2	5	10	25	50	100	500
DEVELOPED							
Asphaltic	0.73	0.77	0.81	0.86	0.9	0.95	1
Concrete	0.75	0.8	0.83	0.88	0.92	0.97	1
Grass Areas (Lawns, Parks, etc.)							
Poor Condition*							
Flat, 0-2%	0.32	0.34	0.37	0.4	0.44	0.47	0.58
Average, 2-7%	0.37	0.4	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.4	0.43	0.45	0.49	0.52	0.55	0.62
Fair Condition**							
Flat, 0-2%	0.25	0.28	0.3	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	0.4	0.42	0.46	0.49	0.53	0.6
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	0.4	0.44	0.47	0.51	0.58
UNDEVELOPED							
Cultivated							
Flat, 0-2%	0.31	0.34	0.36	0.4	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.6
Steep, over 7%	0.39	0.042	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.3	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	0.4	0.42	0.46	0.49	0.53	0.6
Forest/Woodlands							
Flat, 0-7%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2-7%	0.31	0.34	0.36	0.4	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58
Assumptions:							
1. Composite "C" value is : $C = I*C_1 + (1-I)*C_2$							
	Where: I = Impervious cover, percent C_1 = "C" value for impervious cover C_2 = "C" value for pervious area (grass, lawns, parks, etc.)						
* 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 3-2: Intensity-Duration-Frequency (IDF) Values

Storm Duration (min)	Intensity (in/hr) for Various Recurrence Intervals (years)						
	2	5	10	25	50	100	500
5	6.61	8.04	9.22	10.84	12.12	13.32	16.08
10	5.26	6.42	7.38	8.64	9.72	10.68	12.72
15	4.44	5.36	6.12	7.20	8.08	8.92	10.64
30	3.14	3.78	4.32	5.04	5.62	6.20	7.44
60	2.05	2.49	2.86	3.36	3.75	4.14	5.09
120	1.25	1.56	1.82	2.19	2.48	2.79	3.60
180	0.92	1.16	1.37	1.68	1.93	2.19	2.92
360	0.54	0.69	0.83	1.04	1.21	1.40	1.93
720	0.31	0.40	0.49	0.62	0.74	0.87	1.23
1440	0.18	0.23	0.29	0.37	0.44	0.52	0.75

4.0 DETERMINATION OF STORM RUNOFF FROM LARGE AREAS

Large areas are defined as contiguous areas draining over 100 acres. Hydrologic models were developed using USACE HEC-HMS as part of the District's MDP. These models shall be used as the basis for analysis of existing storm drainage systems and design of proposed storm drainage systems for contributing areas up to 100 acres in size of large areas. Determination of peak runoff flows for large areas shall be performed with either the USACE HEC-1 or HEC-HMS computer models.

4.1 RAINFALL DATA

4.1.1 Rainfall Duration and Total Rainfall

For design purposes, the rainfall duration for drainage areas of more than 100 acres will be no less than 24 hours in duration. Table 4-1 presents the precipitation depths for various recurrence intervals based on a 24-hour storm duration. The rainfall amounts were developed from the NOAA National Weather Service Precipitation-Frequency Atlas of the United States, Atlas 14, Volume 11, Version 2 (Texas). These precipitation depths were used in the MDP and shall be used for all analysis and design related to large areas within the District.

4.1.2 Rainfall Distribution

The NRCS Type III, 24-hour rainfall distribution shall be used for rainfall-runoff modeling. The Type III distribution is applicable for regions along the Gulf Coast. The cumulative form of this distribution is shown in Figure 4-1.

4.2 NRCS UNIT HYDROGRAPH METHOD

The NRCS Unit Hydrograph method will be used for rainfall runoff modeling. The parameters required to calculate a runoff hydrograph with this method include rainfall distribution, runoff curve numbers, time of concentration, and drainage area. Detailed information regarding the NRCS Unit Hydrograph method can be obtained from the NRCS at http://www.wcc.nrcs.usda.gov/.

4.2.1 Runoff Curve Numbers

The NRCS has developed a rainfall runoff index called the runoff curve number (CN), which takes into account such factors as soil characteristics, land use/land condition, and antecedent soil moisture to derive a generalized rainfall/runoff relationship for a given area.

The NRCS classifies soils into four hydrologic soil groups: A, B, C, and D. These groups indicate the runoff potential of a soil, ranging from a low runoff potential (group A) to a high runoff potential (group D). Digital soil data is available from SSURGO database via the online Web Soil Service.

The NRCS provides runoff curve numbers for three Antecedent Moisture Conditions (AMC): I, II and III. AMC I represents dry soil conditions, and AMC III represents saturated soil conditions. AMC II is normally considered to be the average soil condition; however, studies have indicated that AMC II is not the average throughout Texas. Investigations have shown that the average condition ranges from AMC I in west Texas to between AMC II and III for east Texas. Runoff curve numbers vary from 0 to 100, with the smaller values representing soils with lower runoff potential and the larger values representing soils with higher runoff potential. AMC II values shall be used to represent average conditions within the District.

Table 4-2 lists CNs for the four (4) soil groups under various land uses, land treatment, and hydrologic conditions to be used within the District. HEC-1 and HEC-HMS compute 100-percent runoff from impervious areas, while runoff from pervious areas is computed using the selected CN value. Therefore, CNs may be evaluated independently of imperious cover. For drainage areas containing multiple land cover types and/or hydrologic conditions, a composite CN must be computed based on area weighting of each hydrologic soil group and land cover type within each sub-basin.

4.2.2 Time of Concentration

The time of concentration is the time for surface runoff to flow from the most hydrologically remote point in a drainage area to a discharge location (point of computation). 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:

4) Sheet flow (overland flow, limited to a maximum of 100 feet for developed areas and 200 feet for undeveloped areas);
5) Shallow concentrated flow; and
6) Channel flow, which may include open channel or closed conduit flow.

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. The minimum time of concentration for any drainage area shall be 5 minutes. The minimum slope used for calculation of sheet and shallow flow travel time components should be 0.002 feet per foot (0.2%). The preferred procedure for estimating time of concentration is the Natural Resource Conservation Service (NRCS, formerly "Soil Conservation Service" or "SCS") method as described in NRCS's Technical Release 55 (TR-55, https://www.nrcs.usda.gov/Internet/ FSE_DOCUMENTS/stelprdb1044171.pdf).

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. Lag time can be estimated by the following equation:

$$T_{lag} = 0.6 * T_c$$

In general, times of concentration for the developed condition should be calculated based on conservative assumptions that consider the increased hydraulic efficiency expected with developed conditions. Times of concentration should be representative of the overall drainage area, not simply based on the longest flow path.

4.2.3 Flow Routing

Stream routing is used to modify hydrographs to reflect the effects of translation and attenuation within a channel reach. The Modified Puls hydrograph routing method should be used where available. This method requires storage-discharge data generated from the results of hydraulic model (HEC-RAS) over a wide-range of flows.

Hydrograph routing in areas without detailed hydraulic models is to be performed with the Muskingum-Cunge method. Muskingum-Cunge is a relatively simple routing method that does not account for riverine valley storage (overbank storage). The required input for Muskingum-Cunge routing includes: channel length, channel slope, Manning's roughness coefficients, and an estimate of the hydraulic grade line slope. If flow is primarily routed through a storm sewer, then pipe parameters must be input. Manning's "n" roughness values should be in accordance with values provided in Table 4-3

4.3   SECTION 4.0 FIGURES AND TABLES INDEX

FIGURE 4-1
NRCS (SCS) TYPE III, 24-HOUR CUMULATIVE RAINFALL DISTRIBUTION
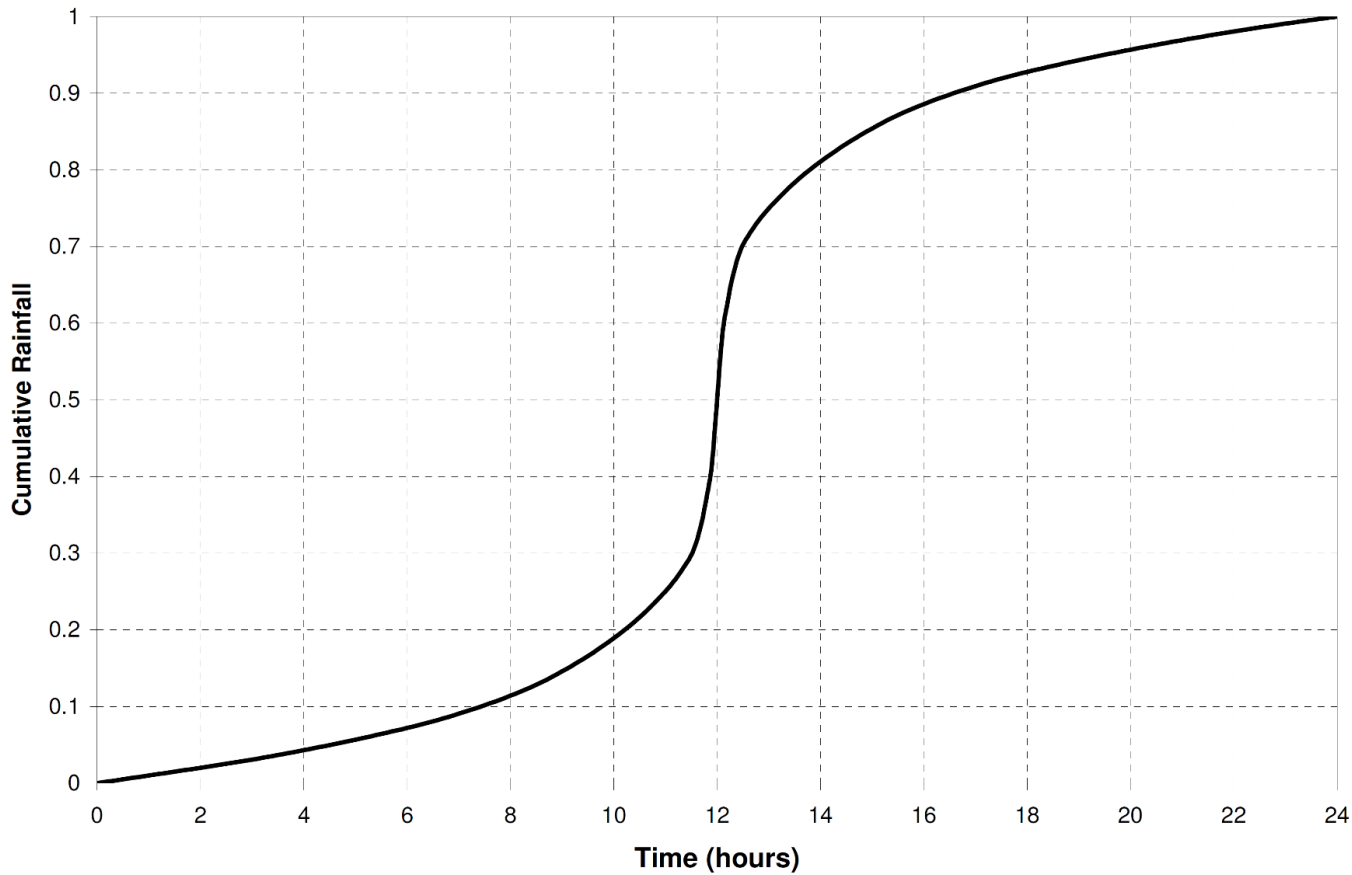
Table 4-1
Design Precipitation Depths

Recurrence Interval (years)	Precipitation Depth (inches)
2	4.20
5	5.55
10	6.86
25	8.84
50	10.6
100	12.5
500	18.1

Table 4-2: NRCS Runoff Curve Numbers for Urban Areas and Agricultural Lands (AMC II)

Cover Description	Condition	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)					
Poor condition (grass cover 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover 75%)		39	61	74	80
Impervious areas					
Paved parking lots, roofs, driveways, etc. (excluding ROW)		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)		89	92	93	
Gravel (including right of way)		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		30	58	71	78
Brush—brush-weed-grass mixture[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 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) *CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs 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: National Resources Conservation Service. TR-55: Urban Hydrology for Small Watersheds

Table 4-3: Manning's "n" Roughness Values

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.03	0.033
b. same as above, but more stones and weeds	0.03	0.035	0.04
c. clean, winding, some pools and shoals	0.033	0.04	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.05
e. same as above, lower stages, more ineffective slopes and sections	0.04	0.048	0.055
f. same as "d" with more stones	0.045	0.05	0.06
g. sluggish reaches, weedy, deep pools	0.05	0.07	0.08
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.1	0.15
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.03	0.04	0.05
b. bottom: cobbles with large boulders	0.04	0.05	0.07
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.03	0.035
2. high grass	0.03	0.035	0.05
b. Cultivated areas			
1. no crop	0.02	0.03	0.04
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.03	0.04	0.05
c. Brush			
1. scattered brush, heavy weeds	0.035	0.05	0.07
2. light brush and trees, in winter	0.035	0.05	0.06
3. light brush and trees, in summer	0.04	0.06	0.08
4. medium to dense brush, in winter	0.045	0.07	0.11
5. medium to dense brush, in summer	0.07	0.1	0.16
d. Trees			
1. dense willows, summer, straight	0.11	0.15	0.2
2. cleared land with tree stumps, no sprouts	0.03	0.04	0.05
3. same as above, but with heavy growth of sprouts	0.05	0.06	0.08
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.08	0.1	0.12
5. same as 4. with flood stage reaching branches	0.1	0.12	0.16
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.02
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.03
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth winding and sluggish			
1. no vegetation	0.023	0.025	0.03
2. grass, some weeds	0.025	0.03	0.033
3. dense weeds or aquatic plants in deep channels	0.03	0.035	0.04
4. earth bottom and rubble sides	0.028	0.03	0.035
5. stony bottom and weedy banks	0.025	0.035	0.04
6. cobble bottom and clean sides	0.03	0.04	0.05
c. Dragline-excavated or dredged			
1. no vegetation	0.025	0.028	0.033
2. light brush on banks	0.035	0.05	0.06
d. Rock cuts			
1. smooth and uniform	0.025	0.035	0.04
2. jagged and irregular	0.035	0.04	0.05
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.05	0.08	0.12
2. clean bottom, brush on sides	0.04	0.05	0.08
3. same as above, highest stage of flow	0.045	0.07	0.11
4. dense brush, high stage	0.08	0.1	0.14

Table 4-3: Manning's "n" Roughness Values (continued)

5. Lined or Constructed Channels	Minimum	Normal	Maximum
a. Cement			
1. neat surface	0.01	0.011	0.013
2. mortar	0.011	0.013	0.015
b. Wood			
1. planed, untreated	0.01	0.012	0.014
2. planed, creosoted	0.011	0.012	0.015
3. unplaned	0.011	0.013	0.015
4. plank with battens	0.012	0.015	0.018
5. lined with roofing paper	0.01	0.014	0.017
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.02
4. unfinished	0.014	0.017	0.02
5. gunite, good section	0.016	0.019	0.023
6. gunite, wavy section	0.018	0.022	0.025
7. on good excavated rock	0.017	0.02	
8. on irregular excavated rock	0.022	0.027	
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.02
2. random stone in mortar	0.017	0.02	0.024
3. cement rubble masonry, plastered	0.016	0.02	0.024
4. cement rubble masonry	0.02	0.025	0.03
5. dry rubble or riprap	0.02	0.03	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.02	0.025
2. random stone mortar	0.02	0.023	0.026
3. dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. glazed	0.011	0.013	0.015
2. in cement mortar	0.012	0.015	0.018
g. Masonry			
1. cemented rubble	0.017	0.025	0.03
2. dry rubble	0.023	0.032	0.035
h. Dressed ashlar/stone paving	0.013	0.015	0.017
i. Asphalt			
1. smooth	0.013	0.013	
2. rough	0.016	0.016	
j. Vegetal lining	0.03		0.5

Table 4-3: Manning's "n" Roughness Values (continued)

Type of Conduit and Description (Closed Conduit, Flowing Partially Full)	Minimum	Normal	Maximum
1. Brass, smooth:	0.009	0.01	0.013
2. Steel:			
Lockbar and welded	0.01	0.012	0.014
Riveted and spiral	0.013	0.016	0.017
3. Cast Iron:			
Coated	0.01	0.013	0.014
Uncoated	0.011	0.014	0.016
4. Wrought Iron:			
Black	0.012	0.014	0.015
Galvanized	0.013	0.016	0.017
5. Corrugated Metal:			
Subdrain	0.017	0.019	0.021
Stormdrain	0.021	0.024	0.03
6. Cement:			
Neat Surface	0.01	0.011	0.013
Mortar	0.011	0.013	0.015
7. Concrete:			
Culvert, straight and free of debris	0.01	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016
Unfinished, rough wood form	0.015	0.017	0.02
8. Wood:			
Stave	0.01	0.012	0.014
Laminated, treated	0.015	0.017	0.02
9. Clay:			
Common drainage tile	0.011	0.013	0.017
Vitrified sewer	0.011	0.014	0.017
Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
Vitrified Subdrain with open joint	0.014	0.016	0.018
10. Brickwork:			
Glazed	0.011	0.013	0.015
Lined with cement mortar	0.012	0.015	0.017
Sanitary sewers coated with sewage slime with bends and connections	0.012	0.013	0.016
Paved invert, sewer, smooth bottom	0.016	0.019	0.02
Rubble masonry, cemented	0.018	0.025	0.03

5.0 DRAINAGE DESIGN

The District drainage system is intended to prevent or minimize structural flooding during frequent and more extreme rainfall events. A review of storm drainage is conducted by the District as part of the review process for planning and platting of new development within the District jurisdictional boundary. Recognizing that each site has unique differences that can enhance the opportunity to provide proper drainage, the intent of these criteria is to specify minimum requirements to maintain or even improve current drainage conditions within the District.

In addition to the requirements of Section 2.1.2 regarding drainage impacts, all designs for drainage facilities within the District jurisdictional boundary shall meet the requirements in this Section.

5.1 DESIGN OF STORM DRAINS

5.1.1 Storm Drain Sizes and Materials

A. Storm drains discharging directly to the District drainage system shall have a minimum inside diameter of 18 inches. Box culverts shall be at least 2' x 2'.

B. All storm drain outlets discharging directly to the District drainage system should include concrete headwalls, safety end treatment, and/or energy dissipation features as appropriate in accordance with the TxDOT Hydraulic Design Manual and standards.

C. Approved materials for closed storm drain system connecting directly to the District drainage system include reinforced concrete pipe, pre-cast concrete box and cast-in- place concrete box. The District may consider and approve alternative materials. Corrugated metal pipe will not be approved for permanent installation within District easements.

5.1.2 Velocity Considerations

A. Storm drains should be constructed to flow in subcritical hydraulic conditions if possible.

B. Minimum velocities should not be less than 2.5 feet per second under the 25-year design condition.

C. Maximum velocities should not exceed 8 feet per second without use of energy dissipation at outfalls to downstream open systems

D. Maximum velocities should not exceed 12 feet per second.

5.2   DESIGN OF CULVERTS

A. Culverts within District easements shall be designed based on the methodology outlined in either the current Texas Department of Transportation Hydraulic Design Manual or the Federal Highway Administration (FHWA) Hydraulic Design Series Number 5. The FHWA publication presents a number of nomographs that can be used to facilitate the design of culverts. Calculations from applications such as HY-8, CulvertMaster, or HEC-RAS that are consistent with these publications will be accepted.

B. Head losses in culverts shall conform to the guidelines contained in the TxDOT Hydraulics Manual, Chapter 4 - Culverts.

C. Corrugated metal pipe will not be approved for permanent installation of culverts within District easements.

5.3   DESIGN OF STORMWATER DETENTION FACILITIES

A. All detention basins shall have a maintenance berm clear and free of all other easements or encroachments, except as noted below, in accordance with the following guidelines for all detention basins serving a single property owner:

Depth	Side Slopes	Berm Width
(ft)	(h:v)	(ft)
	3:1	10
<3.0	4:1	10
	3:1	15
3.0-6.0	4:1	15
	3:1	20
6.0-9.0	4:1	15
	3:1	30
>9.0	4:1	20

Concrete paved parking and driveway areas may share areas of the maintenance berm for detention basins serving a single property owner and user.

B. Dry bottom detention basins shall also meet the following criteria:

1. Inlet and outlet structures shall have erosion control measures approved by the City of Cuero, DeWitt County, and the District.

2. A concrete pilot channel shall be constructed in the bottom of the basin with a minimum

slope of 0.10%.

3. The bottom of the basin shall slope to the pilot channel with a minimum side slope of 1.0%

4. Basin side slopes shall be in accordance with Paragraph C.1 or C.2 above.

5. The detention basin shall have an emergency spillway, which shall be designed to pass the 100-year release rate within the limits of the detention basins freeboard.

6. The detention basin shall be designed with six inches (6") of freeboard above the 100-year maximum water surface elevation.

C. Wet bottom detention basins shall also meet the following criteria:

1. Inlet structures shall be completely below the normal water surface elevation of the basins. Inlet and outlet structures shall have erosion control measures approved by the City of Cuero, DeWitt County, and the District.

2. Side slopes below the normal water surface elevation basin shall be a minimum of 3:1 (H:V).

3. Side slopes between the top bank and the normal pool elevation may be increased to a minimum of 6:1 (H:V) to reduce the berm width outside the top bank to 15 feet for basins under Paragraph C.1 or C.2 above.

4. The detention basin shall have an emergency spillway, which shall be designed to pass the 100-year release rate within the limits of the detention basins freeboard.

5. The detention basin shall be designed with six inches (6") of freeboard above the maximum water surface elevation.

D. Detention basins may be constructed with side slopes less than 3:1 (H:V) under the following conditions:

1. The property shall be owned and occupied by the same person and business.

2. Minimum maintenance berm width shall be 10 feet for basins with a depth less than or equal to 6 feet, and 15 feet for basins with a depth greater than 6 feet.

3. Detention basin shall be secured with a chain link fence and locked gate. Fence shall be at least six (6) feet in height with three (3) strands of intruder wire above top of fence. Fence and gate shall be kept in good condition.

4. Detention basin walls shall not be earthen, but shall be permanent walls constructed of concrete or masonry materials, or other materials approved by the District. The permit application shall be accompanied by a geotechnical report signed and sealed by a Registered Engineer licensed in the State of Texas certifying to the stability of the basin walls.

E. Pumped detention may be approved under the following conditions:

1. Redundant capacity shall be built within the pump station, i.e., the station capacity shall be met with largest pump out of service.

2. The detention basin shall have an emergency spillway, which shall be designed to pass the 100-year release rate within the limits of the detention basins freeboard.

3. Emergency power to the pump station is not required.

F. The detention basin shall be designed with six inches (6") of freeboard above the maximum water surface elevation.

G. Any surface drainage directed to the basin shall be collected by a backswale channel or other District approved structure to prevent overbank flow.

H. Private parking areas, private streets, and private storm drains may be used for detention provided the maximum depth of flooding does not exceed 9 inches directly over the inlet and paved parking areas are clearly marked.

I. In addition to a pipe outlet, the detention basin should be provided with a gravity spillway that will protect adjacent and upstream structures from flooding should the detention basin be overtopped.

5.3.1   Ownership and Easements

I. Private Facilities

1. Pump discharges into a roadside ditch shall require the submittal of pump specifications on the design drawings.

2. The District reserves the right to prohibit the use of pump discharges where their use may aggravate flooding in the public right-of-way.

3. Responsibility for maintenance of detention facilities must be indicated by letter submitted to the District as part of the design review.

4. All private properties being served by a detention facility must have drainage access to the facility.

5. No public properties should drain into a private detention facility.

6. A private maintenance agreement must be provided when multiple tracts are being served.

J. Public Facilities

1. The District will only accept facilities for maintenance in cases where public drainage is provided.

2. The District will require a maintenance work area of 20-foot width surrounding the extent of the detention area. Public rights-of-way or permanent access easements may be included as a portion of this 20-foot width.

3. A dedication of easement must be provided by plat or by separate instrument.

4. Proper dedication of public access to the detention pond must be shown on the plat or by separate instrument. This includes permanent access easements with overlapping public utility easements.

6.0   DISTRICT MASTER DRAINAGE PLAN

The DCDD1 Master Drainage Plan (MDP), included under separate cover, provides a comprehensive hydrologic and hydraulic analysis of the 5.6-square mile drainage area that discharges to the District drainage system and ultimately to the Guadalupe River. The major drainage channels and contributing watersheds in this area include the:

- Alexander Channel
- Daule Channel
- Ice House Channel
- West End Lateral
- Main Channel
- Valley Channel

Development of the MDP involved the identification and location of problem areas, the gathering of pertinent data for the areas identified, the hydrologic/hydraulic analysis of the areas, and conceptual design of stormwater structural and non-structural control measures for the individual problem areas. This continuing effort will be organized and carried out on a watershed and sub-watershed basis considering the interactions of the hydrologic and hydraulic systems within the overall watershed. Care will be taken to avoid creating new problems while solving the original problems. In that regard, flood mitigation projects will generally be phased from downstream to upstream within the District drainage system.

The MDP documents the development of a series of models for hydrologic and hydraulic (open and closed system) analyses. These models were created for the existing condition hydrology based on 2018 watershed and drainage system conditions. These models were used to evaluate the existing open channel and closed systems and to develop recommendations for improvements to these systems. Future efforts may also evaluate fully-developed or ultimate watershed conditions for flood mitigation planning purposes.

7.0 FENCING

In urban settings, the District prohibits any fencing across channels.

In rural settings, the District recommends perimeter fencing set back 3' from the top of bank, unless the District determines that vehicular access is needed between the fence and top of bank. The fencing should be constructed of materials which allow for flow of water, i.e. barbed wire fencing. Perimeter fencing which runs parallel to the flow of water, together with specifically sited low water crossings for livestock, will allow the landowner the best use of the property for grazing while leaving the channel unobstructed. Elimination of fencing which is perpendicular to flow has several benefits: reduction in flooding risk to the landowner and surrounding properties, reduction in maintenance requirements, and increased safety of livestock as debris can allow any water gap fencing to remain stuck in the open position.

7.1 WATER GAPS

The District does not install or pay for the construction of water gaps, because free flow of water is most beneficial to the area served by the District. However, the District also understands that at times, water gaps across channels are still preferable to landowners for livestock control and to discourage trespassing. Any such water gaps must be hinged or be comprised of breakaway panels and shall conform to the design criteria as follows:

Water gaps require adequate end brace assemblies of the same kind, grade and size of materials as adjacent fences on both sides of the water gap. Special considerations are needed when crossing channels to prevent washout or uplifting of posts out of the ground.

Fencing sections that cross drainage channels are particularly subject to damage during flood events. Free swinging flood gates are essential at large, active drainages. Water gaps are to be built by suspending horizontal or vertical bars (e.g., large diameter solid rods or rebar) across the drainage, at close spacing. The bars should be sized and spaced to prevent wildlife or livestock from pushing through but move with sufficient force from flood waters.

Large water gaps in fence lines usually require a more complex fence solution from a fence professional or engineer. In a typical water gap fence solution, a water gate, aka flood gate or swing gate, is suspended from a firm support and its shape conforms to the shape of the channel into which it us suspended. The water gate swings or pivots on the support when under pressure from high water, without impeding flow. It returns to vertical when water subsides. The wider the gap and deeper the channel, the more complex the gate will have to be. Wide gaps will likely require multiple water gates.

NOTE: flood gates suspended by wire are an unacceptable design. The horizontal bars must be made of substantial, solid material and flood gates must swing freely from the horizontal bars. If the fence designer or engineer recommends vertical downstream braces for stability, these must be part of the construction.
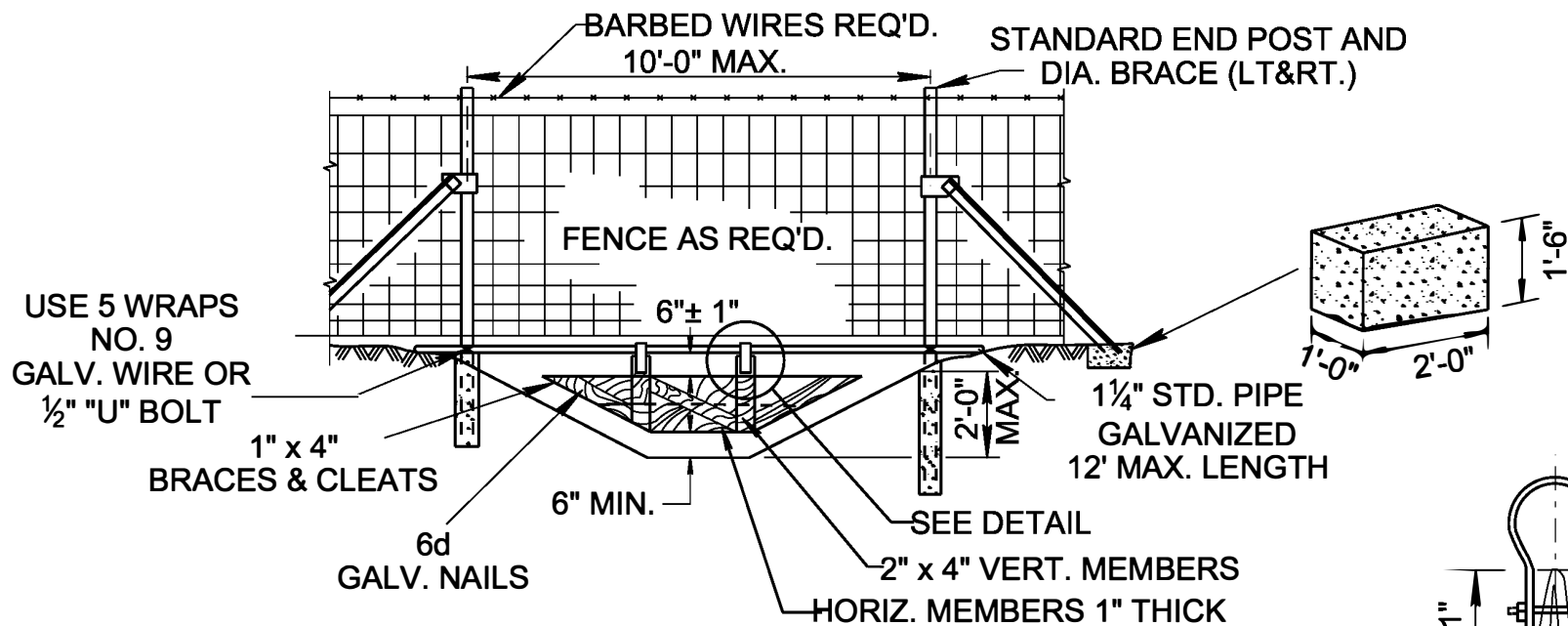
Three typical gates sketches are shown for varying channel widths. These schemes are typical and not to be construed as representative of all conditions which will be encountered. Construction may be required to meet other field conditions not shown, or as otherwise directed by an engineer.

MAINTENANCE: WHILE THE DRAINAGE DISTRICT ENDEAVORS TO KEEP ITS DRAINAGE SYSTEM CLEAR OF DEBRIS, IT IS THE RESPONSIBILITY OF THE LANDOWNER TO MAINTAIN THE WATER GAP / FLOOD GATE. Check water gaps and flood gates after heavy flooding. Fence maintenance items to be expected include broken stubs, stub wires broken, wire corrosion, tension of wire, broken line wires, pulled staples or clips, bent or broken stays, bent metal posts, post alignment and stability, sagging gates and wildlife concerns.

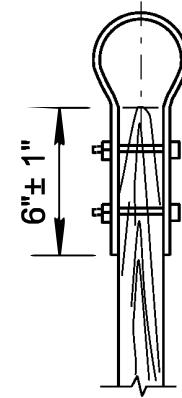**SAFETY NOTE:** All landowners should have contact information on file with the District. Water gates may be removed by the District without prior notice if severe flooding or heavy rainfall is expected; however District staff will always attempt to contact landowners prior to such removal of water gap fencing.

EXAMPLE OF WATER GAP DESIGN WITH SOLID HORIZONTAL BARS AND ADDITIONAL DOWNSTREAM BRACES

BARBED WIRES REQ'D.
10'-0" MAX.

STANDARD END POST AND
DIA. BRACE (LT&RT.)

FENCE AS REQ'D.

USE 5 WRAPS
NO. 9
GALV. WIRE OR
½" "U" BOLT

6"± 1"

1'-6"

1'-0"   2'-0"

1¼" STD. PIPE
GALVANIZED
12' MAX. LENGTH

1" x 4"
BRACES & CLEATS

6d
GALV. NAILS

6" MIN.

2'-0" MAX.

SEE DETAIL

2" x 4" VERT. MEMBERS
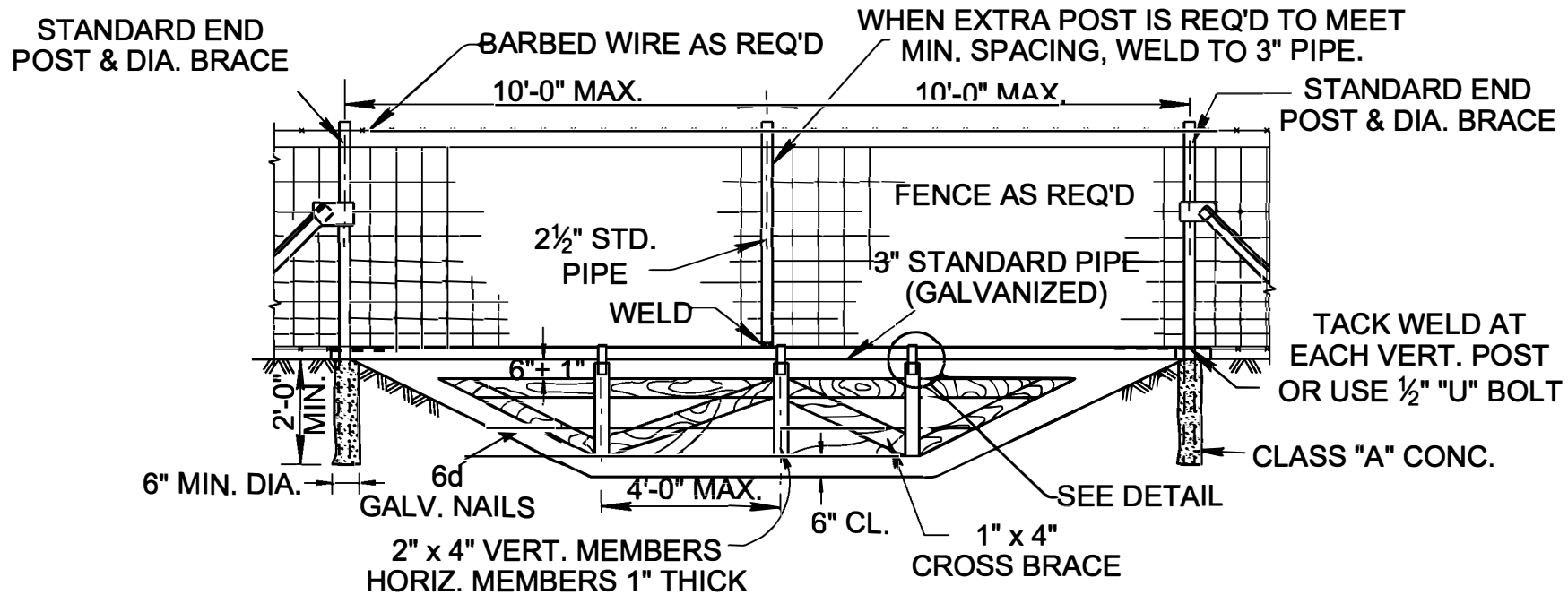
HORIZ. MEMBERS 1" THICK

TYPICAL GATE FOR DITCH WIDTH 10' OR LESS
TYPE A

6"± 1"

¼" x 3" MILD
STEEL HANGER
BOLTED TO FACE OF
2" x 4" WITH 2-⅜" x 3"
MACHINE BOLTS
BEND HANGER FOR LOOSE
FIT ON PIPE REQUIRED.

DETAIL
ELEVATION VIEW

STANDARD END POST & DIA. BRACE

BARBED WIRE AS REQ'D

WHEN EXTRA POST IS REQ'D TO MEET MIN. SPACING, WELD TO 3" PIPE.

10'-0" MAX.

10'-0" MAX.

STANDARD END POST & DIA. BRACE

FENCE AS REQ'D

2½" STD. PIPE

3" STANDARD PIPE (GALVANIZED)

WELD

TACK WELD AT EACH VERT. POST OR USE ½" "U" BOLT

2'-0" MIN.

6"+ 1"

CLASS "A" CONC.

6" MIN. DIA.

6d GALV. NAILS

4'-0" MAX.

6" CL.

SEE DETAIL

2" x 4" VERT. MEMBERS HORIZ. MEMBERS 1" THICK

1" x 4" CROSS BRACE

TYPICAL GATE FOR DITCH WIDTH 10'-20' TYPE B

10'-0" MAX. 10'-0" MAX. 10'-0" MAX.

BARBED WIRE REQ'D

2" STANDARD PIPE (LENGTH AS DIRECTED BY THE ENGINEER)

2" STD. PIPE (GALV)

SEE DETAIL

6"± 1"

6" 6"

FENCE AS REQ'D.

DIAGONAL BRACE 1¼" STD. PIPE

4 STRANDS @ 9" MAX. SPACING.

3'-0" MIN.

LOW SIDE

6" MIN.

6" CL.

1'-6" MIN. DEPTH

2'-0"

CLASS "A" CONC.

1'-0"
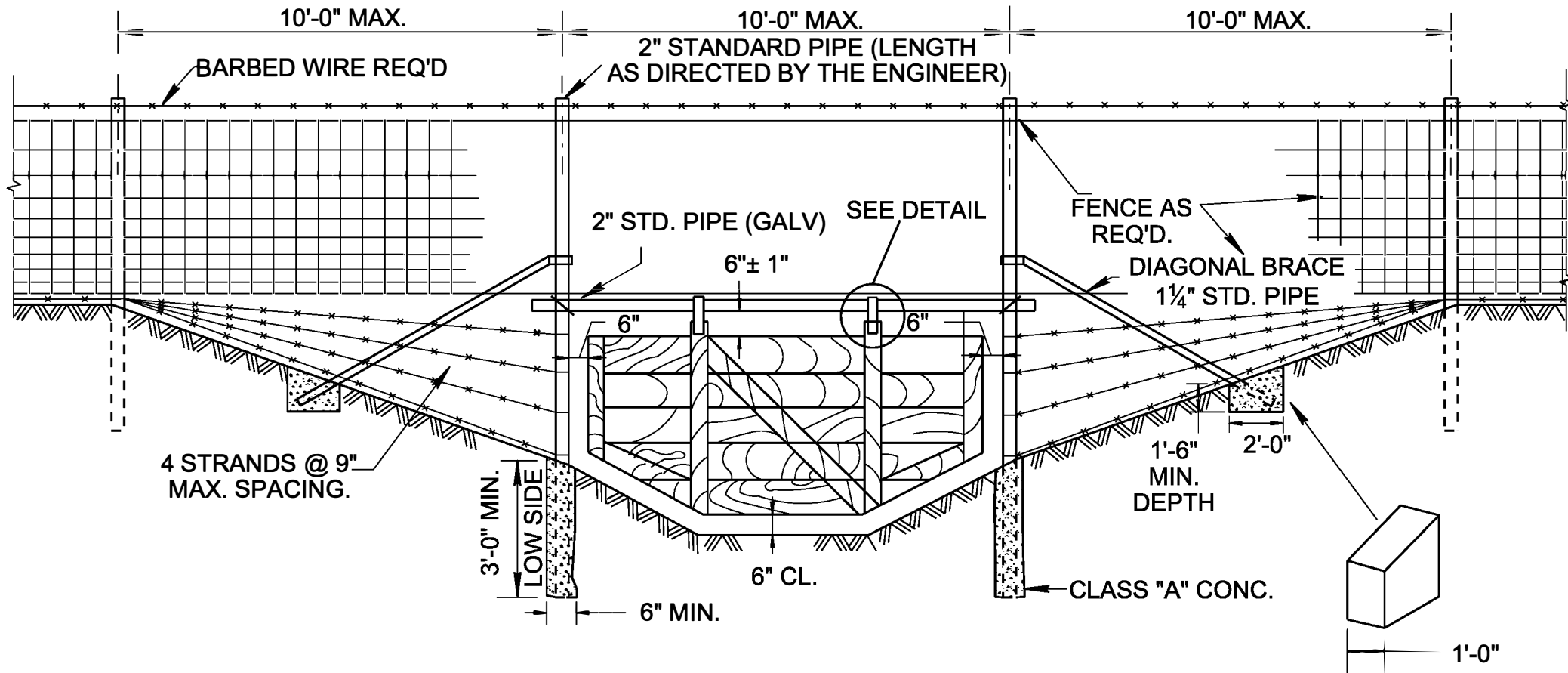
TYPICAL GATE FOR DITCH WIDTH 20'-30'
TYPE C

DETAILS NOT SHOWN ABOVE ARE SAME AS FOR TYPE "B" GATE

8.0 REFERENCES

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