DESIGN STANDARDS

SECTION DS 4

STORM DRAIN

DS 4-01 GENERAL:

A. INTENT: The intent of these Design Standards is to provide minimum standards for the design of a storm drain system that will collect storm water, consistently and safely, from throughout the City and convey it to approved drainage channels. These standards are intended to insure that watercourse and surface water laws are complied with and that runoff from storms up to the 100-year frequency event are conveyed through storm facilities and disposed of in a manner which protects public and private improvements from flood hazards.

B. GOVERNING CRITERIA: These Design Standards, in conjunction with the most current edition of the Solano County Water Agency (SCWA) Hydrology Manual, shall govern the engineering design of all storm drain improvements within the City of Vacaville. In the event that there is a conflict with the criteria between these two documents or with other "Current Standards" so defined hereafter, the Director of Public Works shall determine which document governs. Additionally, if there are criteria or issues not addressed in these documents, the Director of Public Works will determine the criteria to be used in the design. All drainage facilities shall be designed in accordance with accepted engineering principles. These standards are minimum standards and are intended to assist the Design Engineer, but not substitute for competent work. The City Engineer/Director of Public Works at their sole discretion may require more stringent requirements for unusual circumstances, special conditions, and/or environmental constraints.

C. CURRENT STANDARDS: Storm Drain design shall be completed in accordance with all current applicable laws, standards, and regulations, including but not limited to the American Association of State Highway and Transportation Officials (AASHTO), American Society For Testing and Materials (ASTM), American Concrete Institute (ACI), California Stormwater Quality Association – *Stormwater Best Management Practice Handbook – New Development and Redevelopment* (www.cabmphandbooks.com), State of California Department of Health Services, State of California Water Quality Control Board, Federal Emergency Management Agency (FEMA), State of California Department of Water Resources (DWR) Division of Safety of Damns, and the City of Vacaville: Municipal Code, Grading Ordinance, Storm Water Management Plan, Standard Drawings, and City Standard Specifications which include the Construction Standards, and these Design Standards.

D. STORM DRAIN MASTER PLANNING- TENTATIVE MAP SUBMITTAL: A Storm Drainage Master Plan Report for the entire tributary basin must be submitted by the Developer and accepted by the City prior to approval of a Planned Development, Tentative Master Parcel Map or Tentative Subdivision Map. The suggested outline for the Storm Drainage Master Plan is included as

"Exhibit A" located at the end of this section of the Design Standards. The Storm Drainage Master Plan Report as a minimum shall include the following:

1. General information about the project including but not limited to, the project name, location, and the Design Engineer preparing the master plan. The final report shall be stamped and signed by the Design Engineer who prepared the report prior to approval by the City.
2. A Location Map showing highways and streets within and adjoining the tributary basin, major drainage channels, and project boundary.
3. A map depicting the FEMA 100-year floodplain, or other accepted floodplain as approved by the City.
4. Summary of existing drainage facilities that may be impacted by the development of the proposed project, including conveyance capacity of these facilities. If it is determined that existing drainage facilities will be impacted by the proposed project, then alternative improvements shall be evaluated to provide adequate mitigation for these impacts.
5. Topographic map of the drainage shed and adjacent areas as necessary to define the study boundary. The map shall show existing and proposed ground elevations (including preliminary building pads), with drainage sub-shed areas in acres, and the layout of the proposed drainage improvements.
6. Map showing analysis points, proposed street grades, storm drainage facilities, and overland release paths with required easement locations for overland flow across private property.
7. Preliminary pipe sizes and/or typical channel geometry with hydraulic grade lines (HGL), design flows, inverts, and proposed ground elevations at analysis points. This information is to be provided on the map showing the layout of the proposed drainage facilities. The HGL and design flows can either be presented graphically or in tabular form, but shall be included on the above map.
8. If detention facilities are included in the project scope, the following information on any proposed detention and/or pumping facilities shall be included in the Master Plan Report:
   - **a.** Preliminary Grading Plan showing the layout, configuration, and elevations.
   - **b.** Preliminary Stage, storage, and discharge information for selected design storms.
   - **c.** Description of storage requirements, operation, and pumping operation to provide water quality benefits, route storm runoff, and depict dry weather operation.
   - **d.** If required by the City Engineer/Director of Public Works, pump operation shall include pump on/off levels and the impacts of varying pumping head on discharge capacity.
   - **e.** Preliminary site plan for the detention facilities, and sizing and layout for the pump station.

E. DRAINAGE DESIGN – FINAL MAP/PROJECT PLAN SUBMITTAL: Prior to scheduling the City Council acceptance of the Final Map on the Council agenda and approval of the Project Plans, the following items must be accepted as complete by the City Engineer and Director of Public Works:

1. Fully completed Project Plans and design calculations for the storm drain system improvements.
2. Design of all off-site downstream drainage facilities shall be completed unless otherwise approved by the City Engineer/Director of Public Works.
3. Fully completed Project Plans and design calculations for detention facilities, (if applicable) unless otherwise approved by the City Engineer/Director of Public Works.
4. Fully completed Project Plans and design calculations for pump stations, (if applicable) unless otherwise approved by the City Engineer/Director of Public Works.
5. Hydraulic analyses of existing and proposed drainage facilities, including those facilities required for ultimate build-out conditions of the entire tributary drainage shed.
6. If significant changes have occurred to the proposed drainage facilities since completion of the Storm Drainage Master Plan, the master plan shall be updated to reflect these changes.

DS 4-02 SYSTEM DESIGN:

A. HYDROLOGIC DESIGN: The Hydrologic design shall be based on full ultimate development of the tributary watershed, except in areas that cannot be developed. The methodology used for the hydrologic design shall be based on the criteria established in the *SCWA Hydrology Manual* (latest edition) except as modified by these Design Standards. Under this criterion, the hydrologic design for watersheds less than 200 acres may be based on either the Rational Method or Hydrograph Method. The hydrologic design shall be based on the Hydrograph Method for watersheds greater than 200 acres or that include detention/pumping facilities.

1. Rational Method

a. The formula to be used for the Rational Method in the hydrologic design is as follows:

$$Q = CIA$$

Where:

Q = Peak flow in cubic feet per second (cfs)
C = Runoff coefficient
I = Rainfall intensity in inches per hour
A = Tributary area in acres

The Rational Method shall be applied using the procedure outlined below.

b. Runoff Coefficient (C)

The runoff coefficients for various land use types are provided in **Table DS 4-1**. Where the tributary area contains more than one land use type, the runoff coefficient shall be determined by use of a weighted average of each land use type with its corresponding C value from **Table DS 4-1**.

c. Time of Concentration (tc)

The time of concentration is the time required for runoff to flow from the most upstream point within the drainage area through the conveyance system to the point of interest. The time of concentration, t_c, shall be calculated based on the following:

$$\mathbf{t_c = t_o + t_g + t_p}$$

Where:

t_o = overland flow time
t_g = gutter flow time
t_p = pipe or channel flow time

The procedures and equations used to determine the flow time for each conveyance component is described below. The travel time is calculated by dividing the length of the conveyance system component by the corresponding velocity of flow. The travel time then must be converted into minutes.

i **Overland/Initial Flow time (t_o):** The procedure outlined in the *SCWA Hydrology Manual* shall be used to determine the overland flow time, except in urban developed areas where the overland flow time shall be 10 minutes. This overland/initial flow time in an urban developed area represents the time from the roof to the gutter or street.

ii **Gutter Flow Time (t_g):** Manning's equation for a triangular channel cross-section is used to determine the velocity. The gutter flow time shall be computed by dividing the distance from the point where the overland/initial flow reaches the street or gutter to the nearest inlet by the gutter velocity. The gutter velocity equation was derived using the following assumptions:

- The cross slope of the street is 0.02 ft/ft
- The flow in the gutter is six inches deep and contained by the curb
- The street surface is smooth asphalt or concrete

The gutter velocity is determined using the following equation:

$$V_g = \frac{1.12}{n} S_x^{0.67} S^{0.50} T^{0.67}$$

Where:

V_g	=	velocity of flow in the gutter, ft/s
S_x	=	street cross slope, ft/ft, use design value of 0.02
S	=	street longitudinal slope, ft/ft
T	=	spread of flow in the gutter = d/S_x, ft
d	=	depth of flow in the gutter, ft, use design value of the height of the curb above the gutter flow line if the depth is not calculated with the project hydraulics.
n	=	Manning's "n" for pavement, use design value of 0.02

iii Pipe or Channel Flow Time (t_p): Manning's equation shall be used to determine the velocity in pipes and channel as follows:

$$V = \frac{1.49}{n} R^{0.67} S^{0.50}$$

Where:

V	=	velocity in pipe, ft/s
R	=	hydraulic radius (defined as the flow area divided by the wetted perimeter), ft
S	=	pipe slope, ft/ft
n	=	Manning's "n", see **Table DS 4-7**

For circular pipes the travel time is usually calculated by assuming the pipe is full, where the hydraulic radius is one-fourth the pipe diameter. For pipe reaches where the HGL is above the crown of the pipe (pressure flow), travel time in the pipe shall be determined using the velocity calculated from the continuity equation:

$$\mathbf{Q = AV}$$

Where:

A	=	cross-sectional area of the pipe in square feet
V	=	average pipe velocity in feet per second (fps)

In all cases, if the calculated velocity is less than 2.5 fps, then a value of 2.5 fps shall be used to calculate the travel time.

d. Rainfall Intensity (I_{10})

The rainfall intensity is based on the assumption that the peak runoff occurs when the storm duration is equal to the time of concentration. The rainfall intensity can be determined either from the Table 3-4B in the *SCWA Hydrology Manual* (latest edition) or from the following equation.

$$I_{10} = \frac{10.257 \bullet MAP \bullet \left(\frac{t_c}{1440}\right)^{0.42908}}{t_c}$$

Where:

I_{10}	=	10-year rainfall intensity, in/hr
MAP	=	Mean Annual Precipitation (Figure 2-2, SCWA Hydrology Manual)
t_c	=	time of concentration, minutes

(Note: The equation for I_{10} is based on the *SCWA Hydrology Manual,* June 1999 edition which is subject to change.)

To calculate rainfall intensity using Table 3-4B from the *SCWA Hydrology Manual*, the mean annual precipitation (MAP) is determined from Figure 2-2 of the *SCWA Hydrology Manual*, the storm duration is set equal to the time of concentration (t_c), and rainfall depth is read/interpolated from Table 3-4B. The rainfall intensity is calculated by dividing the rainfall depth (from Table 3-4B) by the duration of the design storm (in hours).

e. Tributary Area (A)

This is the area tributary to the computation point and shall include all areas that will contribute runoff to the drainage system, regardless of the land area limits of the particular development.

Table DS 4-1

Runoff Coefficients for 10-Year Design Storm [(a)]

Land Use/Surface	Runoff Coefficient (C)
General Land Use	
Residential	
Rural Residential (less than 0.5 units/acre)	0.3
Single Family – Low Density (0.5 to 3.0 units/acre)	0.4
Single Family – Medium Density (greater than 3.0 units/acre)	0.5
Multi-Family – High Density (apartments)	0.7
Commercial & Industrial	0.9
Schools – building & paved areas	0.9
Schools – landscape & grass areas	0.35
Parks – paved areas	0.9
Parks – landscape & grass areas	0.35
Surface Types [(b)]	
Agricultural – Cultivated [(c)]	0.3 to 0.5
Agricultural – Pasture [(c)]	0.15 to 0.45
Open Space – Oak Timber & brush [(c)]	0.10 to 0.40
Asphalt & Concrete	0.95
Roofs	0.95
Lawns	0.3

(a) For design storms other than the 10-year use the follow conversion factors: 100-year storm multiply C_{10} by 1.26; 50-year storm multiply C_{10} by 1.20; and for the 25-year storm multiply C_{10} by 1.10.

(b) In lieu of using the values given under General Land Use, composite coefficients may be determined based on surface types within a given subshed.

(c) For areas with slopes of 1 percent or less, use values in the low end of the given range; for areas with slopes greater than 1 percent and up to 5 percent, use values in the middle of the given range; for areas with slopes greater than 5 percent, use values in the high end of the given range.

2. Hydrograph Method:

a. General:

For tributary watersheds greater than 200 acres or drainage facilities that include detention, retention, or pump station facilities, the HEC-1 or HEC-HMS software package available through the U.S, Army Corp of Engineers shall be used for the hydrologic design of the proposed project in

accordance with the SCWA Hydrology Manual. The Hydrograph Method does not replace the Rational Method and should not be used for detailed analysis of the proposed drainage facilities.

The following components are necessary to develop a HEC-1 model:

- **Watershed delineation**
- **Rainfall distribution and depth for a given storm event**
- **Rainfall losses due to infiltration and interception**
- **Transformation of rainfall excess into runoff**
- **Routing of the runoff hydrograph through conveyance facilities**

b. Watershed delineation

For runoff simulation using the Hydrograph Method, the project watershed should be subdivided into relatively homogeneous subsheds according the topography and location of major conveyance and/or detention facilities.

c. Rainfall distribution and rainfall depth

If a design-storm runoff hydrograph is to be computed, the temporal distribution of the design rainfall depth must be specified. For Vacaville, the Army Corps of Engineers (ACOE) temporal distribution is used for the 24-hour storm. **Table DS 4-2** provides the rainfall distribution. The total rainfall depth for a given storm event should be obtained from the SCWA Hydrology Manual (Table 3-4B), based the MAP for the given subshed (SCWA Hydrology Manual, Figure 2-2).

d. Rainfall losses due to infiltration and interception

i. Rainfall losses due to infiltration and interception shall be computed using the initial and constant loss rate method. The three following factors shall be considered for this computation:

- **Initial Rainfall Loss** (inches) – All rainfall is lost until the initial rainfall loss value is satisfied, which accounts for interception and depression storage. **Table DS 4-3** provides the initial loss values.
- **Constant Rainfall Loss** (inches/hour) – After the initial rainfall loss is satisfied, rainfall is lost at a constant rate to account for infiltration. **Table DS 4-4** provides the constant loss rates for various land use types and soil group classifications. Soil group classifications can be determined from the Soil Survey of Solano County, California – U.S. Department of Agriculture, Soil Conservation Service. Otherwise, assume soil group D.

- **Percent Impervious** (%) – This factor represents that portion of the subshed that is impervious and no rainfall losses will occur for this portion of the subshed. **Table DS 4-4** provides the percent impervious for various land uses.

ii. Initial and constant losses for subsheds consisting of varying soil groups and land uses should be determined using an area-weighted average.

e. Transformation of rainfall excess into runoff

Kinematic Overland Flow is required for transforming the rainfall excess into a runoff hydrograph unless another method is approved by the Director of Public Works.

The values of the following four variables are required:

- Overland flow length (feet) – This represents the length of the overland flow from most upstream point within the subshed to point where the overland sheet flow becomes concentrated in a swale, ditch, pipe, gutter, or channel. Generally, the overland flow length should not be greater than 600 feet.
- Overland representative slope (feet/feet) – This represents the ground slope of the overland flow.
- Roughness Coefficient – **Table DS 4-5** provides a list of recommended resistance (**N**) factors for overland flow.
- Percentage of subshed area that this element represents (percent)

f. Hydrograph routing through conveyance facilities

The Muskingum-Cunge hydrograph routing method shall be used for routing the overland flow to the subshed outlet. For this method values for six variables are required, including:

- Channel Length (feet)
- Channel Slope (feet/feet)
- Channel Roughness (Manning's **n**, see **Table DS 4-7**)
- Channel Shape – Either trapezoidal, square, or circular
- Channel Bottom Width or Diameter (feet)
- Channel Side Slope – required for trapezoidal channels only

Table DS 4-2

24-hour Rainfall Distribution based on 1-inch of Rainfall

Time, hours	Rainfall, inches	Time, hours	Rainfall, inches	Time, hours	Rainfall, inches	Time, hours	Rainfall, inches
0.5	0.01	6.5	0.016	12.5	0.045	18.5	0.011
1.0	0.01	7.0	0.016	13.0	0.033	19.0	0.011
1.5	0.011	7.5	0.016	13.5	0.023	19.5	0.011
2.0	0.011	8.0	0.016	14.0	0.023	20.0	0.011
2.5	0.011	8.5	0.016	14.5	0.023	20.5	0.011
3.0	0.011	9.0	0.023	15.0	0.016	21.0	0.011
3.5	0.011	9.5	0.023	15.5	0.016	21.5	0.011
4.0	0.011	10.0	0.023	16.0	0.016	22.0	0.011
4.5	0.011	10.5	0.033	16.5	0.016	22.5	0.011
5.0	0.011	11.0	0.045	17.0	0.016	23.0	0.01
5.5	0.011	11.5	0.065	17.5	0.016	23.5	0.01
6.0	0.016	12.0	0.190	18.0	0.011	24.0	0.01

Source: Hydrologic Analysis of Ungaged Watersheds Using HEC-1 (April 1982) and the SCWA Hydrology Manual (June 1999), Table 3-4B.

Table DS 4-3

Initial Rainfall Losses

Land Use	Initial Loss inches
Wooded Areas	0.65
Open Space/Parks/Lawns	0.45
Rural Areas	0.40
Agricultural Areas	0.35
Urban – Residential (>4 units/ac)	0.20
Urban – Residential (<4 units/ac)	0.40
Urban – Multi-Family	0.15
Industrial/Commercial Areas	0.15

Source: U.S. Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds, TR-55, (June 1986).

Table DS 4-4

Constant Rainfall Losses and Percent Impervious

Land Use	Density Range, units/acre	Percent Impervious	Soil Group Constant Loss Rate, inches/hour		
			B	C	D
Highway/Parking	—	95	0.14	0.07	0.02
Industrial	—	90	0.16	0.08	0.03
Commercial/Office	—	80	0.162	0.082	0.032
School/Hospital/Place of Worship	—	50	0.165	0.085	0.035
Residential Urban High Density/ Multi-Family	20-36	80	0.167	0.087	0.037
Residential High Density/Mobile Home	14-20	75	0.17	0.09	0.04
Residential Medium Density	10-14	70	0.18	0.10	0.05
	8-10	60			
Residential Low/Med. Density	6-8	50			
	4-6	40			
Residential Low Density	3-4	30			
Residential Estate	2-3	25			
	1-2	20			
	0.5-1	15			
Residential Rural	0.1-0.5	10			
Park/Recreation	—	5	0.19	0.11	0.06
Open Space/Grassland/Agricultural	—	2	0.20	0.12	0.07
Open Space/Woodland/Natural	—	1	0.22	0.14	0.08
Dense Oak/Shrubs/Vines	—	1	0.25	0.16	0.09

Source: Adopted from the Sacramento City/County Drainage Manual, Volume 2 – Hydrology Standards (Dec. 1996)

(a) The Vacaville area does not contain significant area of Group "A" soils.

(b) Refer to *Soil Survey of Solano County, California*, U.S. Department of Agriculture, Soil Conservation Service, to determine soil group. Otherwise assume soil group D.

Table DS 4-5

Resistance Factors for Overland Flow

Surface	N factor
Residential Developed areas	0.20
Bare Packed Soil Free of Stones	0.10
Fallow – No Residue	0.008-0.012
Convential Tillage – No Residue	0.06-0.12
Convential Tillage – with Residue	0.16-0.22
Fall Disking – with Residue	0.30-0.50
No Tillage – No Residue	0.04-0.10
No Tillage – 20-40 percent Residue Coverage	0.07-0.17
No Tillage – 60-100 percent Residue Coverage	0.17-0.47
Sparse Vegetation	0.053-0.13
Poor Grass Cover on Moderately Rough	0.30
Light Turf	0.20
Average Grass Cover	0.40
Dense Turf	0.17-0.80
Dense Shrubbery and Forest Litter	0.4

Source: Modified from the HEC-1 Flood Hydrograph Package User's Manual (June 1998)

B. CONVEYANCE FACILITIES

1. Design Criteria

a. The capacity of conveyance facilities shall conform to the requirements specified in **Table DS 4-6** and the following criteria included in these Design standards. However, the conveyance criteria for infill projects will be determined on case-by-case basis as determined by the City Engineer/Director of Public Works. The Design Engineer is always required to analyze existing downstream facilities to determine potential impacts as determined by the City Engineer/Director of Public Works.

Table DS 4-6

Conveyance Design Capacity

Conveyance Facility	Design Flow*	Maximum HGL	Downstream Starting Water Surface Elevation (WSE)
Storm Drain Pipe	10-Year Storm	1.0 ft below drain inlet grate or gutter flowline	Maximum 10-year WSE
Open Channel	100-Year Storm	See Section 4-11, Open Channels.	Maximum 100-year WSE
Overland Release	100-Year Storm	0.5 ft above centerline of road and 1.0 ft below all building pads	Maximum 100-year WSE

*- See Section 4-02A, Hydrologic Design

b. Closed conduits shall be designed to convey the 10-year storm event and open channels shall be designed to convey the 100-year storm event with the specified freeboard contained within these Design Standards. All closed conduits shall be sized without considering static head at, storm drain inlets and manholes, unless specifically permitted by the Director of Public Works.

c. The design of a new storm drain system shall include consideration of the capacity of the downstream facilities and conditions as determined by the City Engineer/Director of Public Works. The Storm Drain Master Plan shall include analysis of existing storm drain facilities impacted by the proposed project. The analysis shall verify that the existing drainage facilities, including storm drain pipes, open channels and creeks can completely accommodate the drainage generated by the proposed project.

d. Streets and other public rights-of-way shall be designed to provide an overland release of runoff for the 100-year storm assuming that the underground storm drain system is plugged, all upstream areas are fully developed, and that antecedent rainfall has saturated the tributary watershed.

The 100-year storm flows shall be safely routed through and/or around the project to an acceptable downstream drainage facility, while maintaining a one (1) foot vertical clearance to building pads and shall not be higher than 0.5 feet above the roadway centerline elevation. This requires the design of each development to include an overland release for each phase and for the complete project. The City Engineer/Director of Public Works may require detention storage and/or downstream conveyance improvements for the 100-year storm such that the 100-year overland flow is mitigated to existing flow levels.

Streets, parking lots, playgrounds, parks, pedestrian areas, utility easements and open space areas may be utilized for the overland release path.

Drainage easements/rights-of-way shall be provided to the City for areas where overland release will cross private property. These easements are to be shown on the Project Plans and Final (Parcel and Subdivision) maps. Supporting documentation defining width, grade, and cross-section shall also be provided to the City. The easements shall be free and clear of any obstructions that would restrict flow.

e. Storm drain systems shall be designed to prevent any net detrimental change in runoff quality resulting from new development. Best management practices as approved by the City Engineer/Director of Public Works shall be employed in the design of storm drain systems so as to comply with section 4-01C of these Design Standards.

2. Pipeline Design

a. Allowable pipe materials: The pipe material used in construction for storm drain shall conform to Section CS-10, Storm Drain of these specifications and the following requirements.

i. The Design Engineer shall analyze the existing site, soil conditions, trench and backfill design, and other pipe design conditions when specifying the pipe material allowed below. The Project plans shall indicate a specific pipe material to be used in the construction of the storm drain.

ii. Pipe sizes of 15 to and including 33 inches in diameter shall be RCP Class III minimum.

iii. Pipe sizes of 36 inches in diameter and larger shall be either RCP Class III minimum or Cast-in-Place Concrete Pipe (CIPCP). RCP with less than 2 feet of cover shall be Class V. Use of CIPCP requires a geotechnical/engineering report supporting the use of CIPCP. The report as a minimum shall address ground water remediation, if present, the adequacy of the trench wall and bottom, and the requirements for backfill. The design civil/geotechnical engineer shall determine the adequacy of the pipe to carry the design load and demonstrate that the trench walls and bottom will provide sufficient lateral and vertical support to prevent deflection and cracking of the pipe due to backfill and live loads.

iv. Changes from one pipe material to another shall only be made at a junction structure such as a catch basin, or manhole, or made using a concrete collar.

b. Pipe joints: Rubber gasket joints are required where the pipeline is installed below the groundwater level.

c. Hydraulic criteria: Manning's Equation shall be used to determine the capacity of all drainage pipelines. Values for the Manning's roughness coefficient are given in **Table DS 4-7**. In addition to normal friction losses, energy losses due to entrance/exit conditions and manhole/inlet structures shall be considered. These energy losses shall be calculated using the following equations and **Table DS 4-8**. However, for certain pipe

materials including concrete, a higher Roughness Coefficient (n) may be used in lieu of calculating energy losses at manhole/inlet structures (see **Table DS 4-7** for specifications).

$$h_m = k_m \frac{V^2}{2g} \qquad \text{(Equation DS 4-1)}$$

Where:

h_m = Headloss (feet)

k_m = Headloss Coefficient (see **Table DS 4-8**)

V = Average pipe velocity in feet per second (fps)

g = Acceleration due to gravity, use 32.2 ft/s^2

$$h_m = \frac{V_o^2}{2g} - k_j \frac{V_i^2}{2g} \qquad \text{(Equation DS 4-2)}$$

Where:

h_m = Headloss (feet)

k_j = Junction loss coefficient (see **Table DS 4-8**)

V_o = Velocity in outlet pipe (fps)

V_i = Velocity in inlet pipe (fps)

g = Acceleration due to gravity, use 32.2 ft/s^2

d. Size: The minimum allowable pipe diameter in the public right of way shall be 15 inches. Pipe diameters shall not decrease in size in the downstream direction.

e. Velocity: The minimum velocity for storm drain pipe design shall be 2.5 feet per second (fps) except for cases where the minimum allowable pipe diameter requirement is the controlling factor in sizing the pipe rather than the flow rate. In those circumstances the pipe shall be installed on a minimum slope of 2% unless otherwise approved by the City Engineer /Director of Public Works. The maximum velocity shall be 12 fps. For pipes flowing partially full, the velocity shall be determined using Manning's Equation. For pipes flowing full (HGL is above the top of pipe), the velocity shall be determined using the continuity equation (Q = AV), where Q is the 10-year design flow.

f. Minimum Cover: No storm drain pipe shall have less than 18 inches of cover below finish grade, or be above the subgrade elevation, whichever is deeper. Where possible, the cover should be greater than the required minimum in order that sewer and water service line may cross over the top of the storm drain.

g. Clearance between storm drain and other utilities: The minimum clearance between storm drain pipe crossing other utilities shall be a minimum of 12 inches unless otherwise approved by the City Engineer/Director of Public Works.

Table DS 4-7
Manning Roughness Coefficient for Various Conveyance Conduits

Conveyance Type	Roughness Coefficient (n)
Closed Conduit	
Concrete Pipe	0.013 (0.015 [b])
Corrugated Metal Pipe, plain [(a)]	0.024
Corrugated Metal Pipe, paved invert [(a)]	0.020
Corrugated Metal Pipe, fully paved [(a)]	0.015
HDPE Corrugated Pipe[(a)]	0.020 (0.022 [b])
HDPE Smooth Wall Pipe[(a)]	0.012 (0.014 [b])
Plastic Pipe [(a)]	0.011
Vitrified Clay Pipe [(a)]	0.013
Cast Iron Pipe [(a)]	0.013
Open Channels	
Lined Channels [(c)] (Annually Maintained)	
Concrete	0.015
Asphalt	0.018
Vegetated	0.030
Rubble or Rip-rap [(d)]	0.020-0.030
Excavated or Dredged Channels	
Earth, straight & uniform	0.030
Earth, winding & sluggish, with weeds	0.035
Earth, winding & sluggish, with weeds & stones	0.040
Unmaintained Channels	0.040-0.15
Natural Channels (minor streams)	
Regular Sections, some weeds and pools	0.040-0.060
Irregular Section, weedy and deep pools	0.040-0.150

Source: Chow, Ven Te, Open-Channel Hydraulics, McGraw-Hill Book Company, (1959); ADS Specification Manual, Technical Note 2.109 (May 2002)

(a) These pipe materials are not accepted for use in proposed storm drain systems and are only included for analysis of existing systems.

(b) Roughness coefficient values account for minor losses at manhole/inlet structures in lieu of calculating head losses at structures.

(c) Assumes uniform cross-section and flowline slope.

(d) The n-value depends on rock size.

Table DS 4-8.

Headloss Coefficients

Type of Structure	Loss Coefficient (k_m, k_j)	Equation
Entrance Loss Coefficients [(a)]		
Pipe projecting from fill – Socket end of pipe	0.2	Equation DS 4-1
Pipe projecting from fill – Square cut end of pipe	0.5	
Pipe with Headwall – Socket end of pipe	0.2	
Pipe with Headwall – Square cut end of pipe	0.5	
Pipe with Headwall – Rounded entrance	0.2	
Pipe mitered on conform to fill slope	0.7	
Pipe with End section conformed to fill slope	0.5	
Beveled edges or Side slope tapered inlet	0.2	
Exit Loss Coefficient [(b)]	1.0	
Manhole / Inlet / Junctions Loss Coefficients [(c)]		
Inlet or Manhole at Beginning of Line	1.25	Equation DS 4-1
Inlet on Main Line, with No Branch Laterals	0.50	Equation DS 4-2
Inlet on Main Line, with Branch Laterals	0.25	
Manhole on Main Line, with Branch Laterals at θ°		
$\theta = 22.5^\circ$	0.75	Equation DS 4-2
$\theta = 45^\circ$	0.50	
$\theta = 60^\circ$	0.35	
$\theta = 90^\circ$	0.25	

(a) U. S. Department of Transportation, Federal Highway Administration, *Hydraulic Design of Highway Culverts*, (September 2001)

(b) Exit losses include discharge of a storm drain system into a channel or detention basins.

(c) Water Environment Federation and American Society of Civil Engineers, *Design and Construction of Urban Stormwater Management Systems*, (1992)

h. Alignment:

i. Storm drain pipelines shall be installed adjacent to the curb and gutter in line with the curb inlet structure and within the public right of way, or with the approval of the Director of Public Works within dedicated public easements. Storm Drain pipe will only be considered for locating within easements when it is not possible to locate the pipe within the public street/sidewalk right of way.

ii. When storm drain pipelines are approved to be located within a public easement across private property, such easements must be wide enough to accommodate normal construction equipment and shall be easily accessible to such equipment. The easement shall be at least 15 feet wide and shall not be split between properties.

iii. Pipelines for storm drainage shall have a constant slope between manholes, catch basins, and other structures except as allowed under paragraph iv below.

iv. Vertical curves may be allowed by the City Engineer/Director of Public Works when surface profile grades are in excess of 5 percent. When the design allows for CIPCP, the minimum length of the vertical curve shall be 100 feet.

v. The minimum radius of horizontal curvature for storm drain pipe alignment shall be 130 feet. The joint overlap for RCP shall in all cases comply with Section 61-1.02 of the CALTRANS Standard Specifications. In no case shall the radius of curvature exceed the manufacturer's recommendation for the pipe material and size under consideration.

vi. Where smaller diameter pipe connect at structures with larger diameter pipe, the smaller diameter pipe crown shall intersect the structure at or above the larger diameter pipe crown whenever feasible as determined by the Director of Public Works.

DS 4-03 MANHOLES:

A. Manholes shall be located at the following points and only where it is not practical to use a curb inlet:

1. All changes in pipe size.

2. All changes in pipe slope.

3. Intersections of pipe lines (including inlet runs).

4. Angle points in pipe horizontal alignment.

B. In no case shall the distance between manholes or inlets exceed 400 feet.

C. Only one horizontal curve may occur between manholes.

DS 4-04 CATCH BASINS:

A. The design criteria for catch basins includes Curb Inlets and Field Inlets

B. Curb Inlets shall be included in the design to collect storm water runoff within the limits of the street and adjoining area and shall be located within the curb and gutter area at the following points in addition to the locations specified in Section 4-03 "Manholes" of these standards:

1. At all low points

2. At particular points such that the length of storm water flow in the gutter does not exceed 400 feet.

C. Curb inlets shall not be located within the curb return, or within the limits of Accessible Ramps.

D. A gallery shall be installed on the upstream side of curb inlets when the curb grades are in excess of 6 percent or when otherwise required by the City Engineer/Director of Public Works. The gallery length shall be specified to accommodate the design flow and shall be subject to the approval of the City Engineer/Director of Public Works.

E. Field Inlets shall be incorporated into the design of the storm drain system to collect drainage from locations outside the limits of the paved street. Field Inlets shall be individually designed or reference may be made to specific State Standard Plans. Adequate access shall be provided for City Maintenance to these structures.

DS 4-05 JUNCTION BOXES:

A. When a Standard manhole or curb inlet can not be used in the design, special junction boxes are required, and the Design Engineer shall submit design details and structural calculations for the junction box for approval by the City Engineer/Director of Public Works.

B. Junction boxes shall be rectangular in shape, consist of reinforced Portland Cement Concrete, and the inside dimension of the box shall be a minimum width of 48 inches.

DS 4-06 SIPHONS:

Inverted siphons are not permitted.

DS 4-07 Headwalls, Wingwalls, & Outfalls:

A. These structures shall be individually designed or reference may be made to specific State Standard Plans. Adequate access shall be provided for City Maintenance to these structures and bollards shall be installed subject to approval of the City Engineer/Director of Public Works.

B. Outfall structures shall include installation of rip-rap wherever a drainage pipe discharges into an open channel. Geotextile fabric shall be included under the area to receive rip rap. The rip rap shall be designed to accommodate the channel flow or pipe discharge, which ever is greater. Grouted rock slope protection is not allowed.

C. Inlet structures shall include consideration for appropriate wing wall, headwall and/or rip-rap installation wherever drainage from an open channel enters a storm drain system.

D. Bollards shall be provided in accordance with the requirements of the Standard Drawings when in the opinion of the City Engineer/Director of Public Works they are necessary to prevent clogging of the storm drain pipe or for safety purposes.

DS 4-08 SUBDRAINAGE:

Subdrain facilities shall be provided when required by the geotechnical engineer.

DS 4-09 VALLEY GUTTERS:

Valley gutters are not be allowed to be used in the public right of way unless approved by the City Engineer/Director of Public Works on a case-by-case basis.

DS 4-10 CONNECTION TO PRIVATE SYSTEMS:

Connection of private storm drain systems to a public storm drain system where the storm drain is outside the limits of the paved street shall be made at the back of street curb inlets, manholes, or junction boxes and the pipe material is not subject to the City Standards. However, private storm drain piping located within the limits of the paved street shall conform to City Standards.

DS 4-11 OPEN CHANNELS:

A. GENERAL: Open channels are classified into two categories: Channels and Ditches. A Channel is defined as having a capacity greater than 25 cfs, while a Ditch is defined as having a capacity of less than or equal to 25 cfs.

B. CHANNELS: Channels shall be designed based on the following minimum criteria; however, the City Engineer/Director of Public Works may impose additional requirements at his sole discretion on a case-by-case basis.

1. Channels shall be designed to convey the 100-year storm event while maintaining at least one foot of freeboard to the top of the channel in cut sections. Levied sections shall not be considered as a design solution.

2. The maximum permissible velocities for various soils types are provided in **Table DS 4-9**. Velocities greater than those listed in **Table DS 4-9** will require erosion protection lining. Soils types shall be determined by a geotechnical engineer.

3. The 10- and 100-year water surface profiles shall be computed for all Channels and clearly shown on the Project Plans. Computations of the water surface profiles should use standard backwater methods, such as the Army Corps of Engineers HEC-2 or HEC-RAS computer programs, or similar methodology and/or computer program. The roughness coefficients shall be based on the values presented in **Table DS 4-7**. All computations and design considerations/constraints shall be clearly documented and submitted to the CityEngineer/Director of Public Works for approval.

4. The maximum allowable side slope shall be 2 feet horizontal to 1-foot vertical, but may be required to be flatter based upon soil conditions as determined by a Geotechnical Engineer.

5. Drop structures may be used and/or required to decrease the bed slope and velocity to control erosion. Drop structures shall be designed with reinforced concrete, grouted rock or gabions. A low-flow notch shall be provided for drainage and, where applicable, to allow for fish passage.

6. An easement shall be provided to the City of Vacaville. The easement width shall not be less than the width of the top of the Channel plus 15 feet on both sides unless otherwise approved by the Director of Public Works. A 12-foot wide gravel road, serviceable for year-round (all weather) use, shall be constructed along one side of the channel within the easement. The edge of the gravel road shall be located a minimum of two feet from the top of the Channel. The elevation of the edge of the gravel road shall match the elevation of the adjacent ground. Fencing shall be installed where required by the Director of Public Works. The fencing shall be typical 6 feet high chain link in accordance with the CALTRANS Standard Specifications unless another design is approved by the Director of Public Works.

7. The centerline radius of a Channel shall be not less than twice the width of the channel measured at the 100-year water surface elevation.

8. Special headwalls, endwalls, reinforced concrete transitions to culverts, rip-rap, concrete aprons, energy dissipaters, and other hydraulic devices shall be included in the design and incorporated into the Project Plans.

Table DS 4-9.

Permissible Velocities for Earth-Lined Channels

Soil Type	Permissible Velocity, fps
Fine Sand (noncolloidal)	2.0
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Silty Clay	3.5
Fine Gravel	5.0
Stiff Clay (very noncolloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (noncolloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Pan	6.0

Source: Chow, Ven Te, Open-Channel Hydraulics, McGraw-Hill Book Company, (1959)

C. DITCHES: In most cases, the City will not accept ditches as a permanent drainage solution. In hillside construction, the City Engineer/Director of Public Works may allow a ditch as a permanent drainage measure. A temporary ditch may be allowed by the City Engineer/Director of Public Works where there is phased development and there is no disadvantage for the City to accept this temporary measure. Ditches where allowed shall be designed based on the following criteria:

1. Temporary and Permanent Ditches

a. Adequate measures such as banking, circular curves, or energy dissipater shall be used to confine water to the ditch at changes in alignment and inlets.

b. All Ditches to be constructed as a part of a development project shall include a gravel access road which shall be contained within a drainage easement. The access road shall be a minimum of 12 feet in width, serviceable for year-round (all weather) use, and shall be constructed along one side of the ditch within the easement. The edge of the gravel road shall be located a minimum of two feet from the top of the ditch. The elevation of the edge of the gravel road shall match the elevation of the adjacent ground. Where the ditch is located within terrain that exceeds a slope of 5%, the road shall be located down gradient of the ditch and the road cross

section shall be sloped at a minimum of 2% towards the ditch. The grade for the access road and its connection to the public street shall be subject to the approval of the City Engineer/Director of Public Works. Where the ditch access road also serves as an emergency vehicle access road, the road shall be 20 feet wide. All ditch access roads shall be connected to a public street.

c. The width of the drainage easement shall be determined by the Director of Public Works on a case by case basis considering the width of the ditch and access road and other maintenance factors.

2. Temporary Ditches

a. The ditch may be an unlined earthen ditch with hydro seeding if the design velocity conforms to the criteria included in **Table DS 4-9.** Otherwise the ditch shall be concrete lined.

b. The ditch shall be designed to convey the 100-year storm while maintaining 1 foot of freeboard to the top of the ditch unless otherwise approved by the City Engineer/Director of Public Works.

3. Permanent Ditches

a. The ditch shall be concrete lined unless otherwise approved by the City Engineer/Director of Public Works.

b. The minimum velocity within the ditch shall be 2.5 fps.

c. The ditch shall be designed to convey the 100-year storm while maintaining at least six inches of freeboard to the top of the ditch.

d. The ditch shall be less than 3 feet deep.

DS 4-12. DETENTION FACILITIES:

A. New development, on a case-by-case basis, shall provide on-site detention storage at the discretion of the CityEngineer/Director of Public Works. The design of these facilities shall conform to the following criteria:

1. New development on a case by case basis shall mitigate the increase of the 10- and 100-year peak runoff from the project site over the predevelopment conditions (due to higher peak flows from the site, filling or building in overflow area, or altered flow paths). The mitigation shall be satisfied by either providing onsite storage or by paying into the City Development Impact Fee for Storm Drain Detention. In the Alamo Creek watershed upstream of Peabody Road, which includes Alamo Creek, Laguna Creek, and Encinosa Creek, the 10- and 100-year post development peak flows shall be reduced to 90 percent of pre-development levels. In addition, the 5-year storm shall be evaluated for the Alamo Creek watershed upstream of Peabody Road to ensure the proposed drainage facilities, including the detention facilities, do not

increase the peak 5-year flows in downstream Open Channels and receiving waters.

2. All detention facilities shall be designed for the 100-year, 24-hour storm event.

3. All detention basins shall have outlets capable of emptying a full facility within 24 hours of continued subsidence.

a. Detention basin with gravity outlet facilities will operate without and with backwater (tailwater) effects under the design conditions. The outlet facilities shall be evaluated under varying tailwater conditions.

b. A drainage pump may be designed as the detention basin outlet control with approval of the City Engineer/Director of Public Works. A backup power generator will be required to accompany any drainage pump.

4. Detention basin facilities shall maintain a minimum freeboard of 2 feet above the emergency spillway. The emergency spillway shall be located six inches above the100-year water surface elevation in the detention basin.

5. The detention basin facility shall be configured with side slopes no steeper than 3 feet horizontal to 1 foot vertical.

6. The bottom of a detention basin facility shall be sloped at a minimum of 1 percent toward the outlet works or to a defined swale within the basin at a slope approved by the Director of Public Works.

7. Wherever possible, a low flow channel through the facility shall be incorporated into the design. The low flow channel shall be V shaped with maximum 4:1 side slopes. The minimum depth of the low flow channel shall be 0.5 feet.

8. A maintenance access road shall encircle the perimeter of the detention basin. An all weather access road to the pipe outlets/inlets shall be included. An access ramp or ramps to the basin bottom shall be provided and have a maximum slope of 10 percent and a minimum width of 12 feet. Access ramps shall be serviceable for year-round (all weather) use.

9. The detention basin shall be fenced and the limits for fencing are subject to the approval of the City Engineer/Director of Public Works.

DS 4-13 WATER QUALITY CONTROL:

A. Storm Drain system improvements shall be designed to prevent any net detrimental change in runoff quality resulting from new development. Best management practices shall be employed in the design of storm drain systems so as to comply with the standards for the National Pollutant Discharge Elimination System as stipulated by the Federal Environmental Protection Agency, the State Water Quality Control Board, and the City of Vacaville Storm Water Management Plan

B. The Design Engineer shall demonstrate compliance with the City of Vacaville Stormwater Management Plan, which shall include but not be limited to the implementation of "Best Management Practices" (BMPs) in the design of the project.

A separate Erosion Control Plan shall be included as part of the Project Plans and shall be submitted to and approved by the City Engineer/Director of Public Works prior to approval of the Project Plans. The Erosion Control Plan shall be in full compliance with the Storm Water Pollution Prevention Program (SWPPP) or Water Pollution Control Program (WPCP) plan prepared for the project. The Design Engineer shall demonstrate compliance with the City of Vacaville SWPPP "Checklist for Construction Requirements" and "Checklist for Permanent Stormwater Quality Controls" forms as completed by the City Engineer/Director of Public Works.

The following references shall be utilized in developing the design, Project Plans, and conforming to the City Stormwater Management Plan:

- The City of Vacaville Stormwater Management Plan
- California Stormwater Quality Association – Stormwater Best Management Practice Handbook (2003). Copies of the Handbooks can be either ordered or viewed online at www.cabmphandbooks.com

C. Water quality control facilities or BMPs are intended to reduce pollutants in runoff in proposed development areas. These facilities are designed for more frequent storm events than flood control facilities. Consequently, BMPs shall not be used solely in place of storm drain facilities.

The California Stormwater Quality Association – Stormwater Best Management Practice Handbook for New Development and Redevelopment provides a comprehensive selection of BMPs available for implementation. Those BMPs proposed for implementation must be reviewed and approved by the City Engineer.

Vegetated Swales: Vegetated swales may be implemented as a water quality BMP. Vegetated swales shall include vegetated side slopes and bottoms that slowly convey shallow depths of runoff. Vegetated swales shall be designed based on the following criteria:

1. Vegetated swales shall not be used to treat drainage areas greater than 10 acres in size.

2. Vegetated Swales shall be designed based on the "Flow-based BMP" design criteria as outlined in the California Stormwater Quality Association – Stormwater Best Management Practice Handbook – New Development and Redevelopment (www.cabmphandbooks.com). The California Stormwater BMP Handbook approach shall be utilized. In addition, swales shall be designed to convey the 10-year storm, unless additional facilities are provided to collect and convey the 10-year storm. The design of grass swales should be based on the criteria outlined in **Table DS 4-10.**

Table DS 4-10.

Vegetated Swale Design Criteria

Design Condition	Design Depth	Manning's "n" Value	Maximum Velocity	Bottom Width
Water Quality Treatment	4"	0.15	< 1 fps	Manning's Equation
10-year Storm	Use Manning Equation + 6"	0.03	**See Table DS 4-11**	Set per water quality criteria

3. The length of the swale should be designed to provide a minimum hydraulic residence time of 10 minutes. The minimum channel length shall be 100 feet.

4. Swales shall have a trapezoidal or parabolic cross section with side slopes of 3 feet horizontal to 1 foot vertical or flatter.

5. Swales bed slopes shall not exceed 2.5 percent and not be less than 1.0 percent.

6. Check dams shall be provided approximately every 50 feet. The check dam shall be designed to consist of cobble run stones of 2 inches diameter and greater and shall allow water to flow through it at low flow. Other designs may be considered for approval by the Director of Public Works.

7. The maximum bottom shall not exceed 8 feet, unless a dividing berm is provided. The minimum bottom width is 2 feet.

8. The grass lining used shall be capable of surviving without irrigation, and have a thick root structure for keeping the bank soils in place. Grasses approved for this use are included in **Table DS 4-11**.

9. Culvert crossings and /or outlet pipes shall not be used to achieve the required hydraulic residence time. Culverts shall be sized to convey the 10-year storm. The minimum culvert size shall be 15 inches. Culverts shall be RCP minimum Class V.

10. A legally binding and enforceable maintenance agreement shall be executed between the facility owner and the City to ensure the following:

    - Waterway capacity, vegetative cover, and the outlet are maintained
    - Vegetation damage is repaired promptly
    - Sediment build-up within the bottom of the channel is removed regularly as needed to function properly, but at a minimum annually.
    - Vegetation is mowed, as required, during the growing season to maintain grass heights between 4 to 6 inches.

Table DS 4-11.

Permissible Velocities for Well Maintained Grass-Lined Swales

Cover [a]	Permissible Velocity, fps [b]	
	Erosion Resistant Soils	Easily Eroded Soils
Annual Ryegrass Blando Brone Zoro Fescue Luna Wheatgrass Topar Wheatgrass Hardingrass	4.0	3.5
Kentucky Bluegrass Tall Fescue	6.0 [c]	5.0
Alta or Fawn Fescue	5.0	4.0
Reed Canarygrass [d]	5.0	4.0

(a) The permissible velocities are for dense stands of grasses. The species chosen must be compatible with climate and soil conditions. Check with the local National Resources Conservation Service office for plant mix recommendations.
(b) Permissible velocities based on a channel slope ranging from 0 to 5 percent.
(c) For channel with flow velocities greater than 5 fps, a synthetic erosion control lining or anchored jute matting are required.
(d) Requires irrigation, but tolerates flooding and standing water.

DS 4-14. PROJECT PLANS REQUIREMENTS:

A. Any revisions and/or updates to the drainage calculations presented in the Storm Drainage Master Plan shall be included with the submittal of the Project Plans. At the discretion of the City Engineer/Director of Public Works the proposed revisions to the drainage system presented in the Project Plans may require the Design Engineer to provide an updated Storm Drainage Master Plan.

B. The Project Plans shall include the following information:

1. The plan and profile views of the proposed storm drain pipes and/or channels.

2. The Project Plans shall note the limits for each pipe material and class of pipe.

3. The plan view shall show the location (station and offset) of all pipelines, manholes, inlets, outlets, channels and all other features of the design including but not limited to bollards. The plan view shall show pipe sizes, pipe flow directions, and special requirements for joints where applicable. The plan view shall also show the location of all other utilities that cross the path of the proposed storm drain system improvements.

4. The profile view shall show invert elevations, length, slope, size, design flow, for each mainline pipe or channel section. The profile view shall show

manhole, junction box, field inlet, and curb inlet locations, with stationing, rim or top-of-curb elevations, invert elevations and 10-year frequency storm hydraulic grade line at each structure. In addition the water surface elevation shall be shown at each outlet. The profile view shall also show all other pipelines or structures (with elevations noted) that cross the path of the proposed storm drain system improvements.

5. Open Channel profiles shall show the channel flow line, the proposed top-of-bank, and the existing ground elevation along the centerline of the channel. Invert elevations shall be shown at all grade changes. Open channel profiles shall show both the 10- and 100-year water surface profiles and elevations shall be noted at each change in slope.

6. All inlets, outfalls and subdrain facilities shall also be shown in both plan and profile view.

7. Details depicting the type, location, and scope of slope protection. Rock slope protection fabric shall be placed in all areas that receive rip-rap.

8. Details for headwalls, endwalls, wing walls, reinforced concrete transitions to culverts, rip-rap, concrete aprons, energy dissipaters, and other hydraulic devices.

9. The features of the overland release shall be noted and/or depicted on the Grading Plan component of the Project Plans. The dimensions and conveyance capacity of features in the path of the overland release such as but not limited to openings in walls and other constrictions shall be noted on the Project Plans where required by the City Engineer/Director of Public Works

DS 4-15. TRENCH LOADING:

A. GENERAL: The minimum standards for pipe material, trench excavation, and trench bedding, foundation, and backfill are included in the Construction Standards of the City Standard Specifications. However, the Design Engineer responsible for the preparation of the Project Plans shall evaluate the actual site conditions and prepare calculations to ensure that the proposed pipe material, trench width, and the design of bedding and backfill material are adequate based upon the criteria specified below. When certain site conditions and design criteria require a pipe material with greater strength or stiffness, or a trench design, bedding or backfill more stringent than the City minimum standards, these factors shall be included in the Project Plans.

B. DESIGN CALCULATIONS:

1. The Design Engineer shall use the minimum of the following criteria in selecting the appropriate pipe material and determining the design for the installation of the pipe. The design calculations may exclude use of one of the allowable pipe materials or require a more stringent design for the trench and backfill than the City Standards.

2. The Marston and Spangler equations and other methods approved by the Director of Public Works shall be used by the Design Engineer in calculating the loads imposed upon the pipe.

3. A minimum soil weight of 140 pounds per cubic feet shall be assumed for trench backfill unless geotechnical soils report data can substantiate other values.

4. All pipes with less than 10 feet of cover (including areas not intended for vehicular traffic) shall be designed with AASHTO H-20 truck loading.

5. The design procedure for **RCP** material shall be in accordance with the most current edition of the American Concrete Pipe Association "Concrete Pipe Design Manual". The earth load (dead load) shall be calculated based upon the positive projecting embankment condition.

6. The design procedure for **CIPCP** pipe material shall be in accordance with the most current edition of the American Concrete Institute Specification for Cast-in-Place Concrete Pipe. The concrete pipe design shall be based upon a minimum of six sacks of Portland cement per cubic yard and be capable of achieving a minimum strength of 3000 psi at 28 days.

C. MAXIMUM COVER: The Maximum Cover over the top of pipe shall not exceed the values indicated in **Table DS 4-12** unless calculations are submitted to the City Engineer/Director of Public Works for review and approval. As a minimum, these calculations shall consider the pipe design, trench soil conditions and design and backfill. Use of this table does not relieve the designer from the responsibility for determining the existing site conditions, pipe material, and trench design are suitable for use in the design.

Table DS 4-12

Pipe Size	Pipe Material	Maximum Cover Over Top of Pipe
15 inch & larger	Class III RCP	8 feet
15 inch & larger	Class IV RCP	12 feet
36 inch & larger	CIPCP	18 feet

DS 4-16. BEDDING AND INITIAL BACKFILL: Bedding and initial backfill type shall be as necessitated by height of cover over the pipe, trench width, pipe strength, and other factors used to determine safe pipe loading. Any special backfill requirements shall be noted on the plans. The minimum design for bedding and backfill shall conform to the Standard Drawings and Section CS–3 Trench Bedding and Backfill and Section CS-10 Storm Drain of the Construction Standards contained in the City Standard Specifications.

EXHIBIT A

STORM DRAINAGE MASTER PLAN

(Suggested Outline)

Introduction
- Overview
- Purpose

Existing Conditions
- Land Use
- Topography and Soil Type
- Existing Drainage Facilities
- FEMA Floodplain Information

Methodology
- Hydrologic Modeling/Analysis (including land use, subshed map, precipitation losses, basis for HEC-1 (HMS) modeling and /or Rational Method analysis, precipitation depths, etc.).
- Hydraulic Modeling/Analysis (type and basis of modeling/analysis, starting conditions, basis or source for data, etc.).

Drainage Analysis
- Existing Drainage Facilities
- Proposed Drainage Facilities
- Off-site Drainage and Constraints.
- Site Grading/Overland Release
- Open Channels/Wetlands
- Detention Storage Facilities (including description of operation)

Water Quality

Required Drainage Facilities & Improvements
- On-site Drainage Facilities
- Offsite Drainage Facilities (if applicable)

References (if applicable)

Appendix
- Geotechnical Information (if applicable)
- Backup/background Documentation
- Model Input
- Model Output Summaries