2 - DRAINAGE STANDARDS

2.01 GENERAL

These standards are intended to ensure that watercourse and surface water laws are complied with and that runoff from storms up to the 100-year return frequency are conveyed through storm facilities and disposed of in a manner that protects public and private improvements from flood hazards. Storm drainage improvements shall be designed to serve the ultimate development level as defined in the current City General Plan and the current Storm Drainage Master Plan. Improvements shall comply with California drainage law by not causing damage to other property from construction, diversion, or inducing flooding.

The diversion of natural drainage will be allowed only within the limits of a proposed improvement. All-natural drainage must leave the improved area at its original horizontal location and elevation unless a special agreement, approved by the Public Works Director or their designee, has been executed with the affected downstream property owners.

Although these standards are intended to apply to physical development within the City, the standards may not apply for all situations. Compliance with these standards does not relieve the design Engineer of the responsibility to apply conservative and sound professional judgment. These are minimum standards and are intended to assist, but not substitute for competent work by design professionals. The City may, at its sole discretion due to special conditions and/or environmental constraints, require more stringent requirements than would normally be required under these standards.

A drainage system, which includes unreasonable and intensive maintenance or operational requirements as determined by the City, shall be rejected in favor of a drainage system which does not place undue burdens on the owner/operators of such system.

The Applicant may propose a deviation from the Standards. A non-standard system may take longer to review. The Applicant acknowledges these risks when submitting a non-standard system for review.

The City’s decision to grant, deny, or modify the proposed deviation shall be based upon evidence that the deviation request meets all of the following criteria:

1. The proposed system will achieve the intended result through a comparable or even superior design.
2. The proposed system will not adversely affect safety and/or operation.
3. The proposed system will not adversely affect maintainability.
4. The proposed system can reasonably be expected to provide equal or better protection to neighbors from flooding.
5. The proposed system will not adversely affect water quality.

2.02 DESIGN CRITERIA

All storm drainage facilities shall be designed to provide connections to future upstream facilities that may be constructed. No development shall discharge at a rate that exceeds the capacity of any portion of the existing downstream system. Calculations for storm drainage design within the development as well as calculations for runoff generated by upstream areas within the contributing watershed shall be submitted to the City for review and approval. Drainage facilities
shall be designed to carry a storm flow rate having the appropriate recurrence interval under ultimate anticipated development of the entire watershed maintaining the following conditions:

1. The water level in the drainage inlet boxes shall not exceed an elevation of 0.5 foot below gutter elevation, and the elevation in manholes or junction boxes shall not exceed an elevation 1 foot below street grade.

2. The allowable spread of water from the curb from 10-year storm runoff is limited by the requirement to maintain two-10-foot moving lanes of traffic for collector streets. One clear lane shall be maintained on sub collectors.

3. The 100-year return runoff (1% chance per year) shall be directed towards and contained within the street right of way unless a design exception is granted by the Public Works Director or their designee.

4. Flood waters shall be confined to streets or other approved rights-of-way by grading, levees or alternative means acceptable to the Director of Public Works.

The City Public Works Department has hydraulic data for most storm drains over 30 inches in diameter available in the City of Napa Storm Drain Master Plan.

Table 2.1 shows the recommended method and return period design criteria to estimate discharge.

**TABLE 2.1 – RECOMMENDED CRITERIA AND METHODS TO ESTIMATE DISCHARGE**

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>DESIGN CRITERIA</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STORM DRAINS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential under 40 Acres</td>
<td>10-Year with 100-Year overland release analysis</td>
<td>Rational Method or Napa Charts</td>
</tr>
<tr>
<td>Residential, over 40 Acres</td>
<td>25-Year with 100-Year overland release analysis</td>
<td>Rational Method or Napa Charts</td>
</tr>
<tr>
<td>Commercial and High Value Districts</td>
<td>25-Year with 100-Year overland release analysis</td>
<td>Rational Method or Napa Charts</td>
</tr>
<tr>
<td>Flood Control</td>
<td>100-Year</td>
<td>Napa Charts or HEC-1* unless otherwise provided by the PW Director</td>
</tr>
<tr>
<td>All bridges and roads with traffic index of 6 or greater</td>
<td>100-Year</td>
<td>Napa Charts or HEC-1* unless otherwise provided by the PW Director</td>
</tr>
<tr>
<td><strong>OPEN CHANNELS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-Year and 100-Year</td>
<td>Napa Charts or HEC-1* unless otherwise provided by the PW Director</td>
</tr>
<tr>
<td><strong>WATERSHEDS WITH ADDITIONAL ANALYSIS REQUIREMENT</strong></td>
<td>10-Year and/or 100-Year</td>
<td>HEC-1* unless otherwise provided by the PW Director</td>
</tr>
<tr>
<td><strong>DEVELOPING AREAS UPSTREAM OF EXISTING FACILITIES</strong></td>
<td>Varies, based on downstream capacity</td>
<td>Varies</td>
</tr>
<tr>
<td><strong>WATERWAYS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major waterways - drainage area of 4 square miles or more</td>
<td>100-Year</td>
<td>Napa Charts or HEC-1* unless otherwise provided by the PW Director</td>
</tr>
<tr>
<td>Secondary waterways - having a drainage area of between 1 and 4 square miles</td>
<td>50-Year</td>
<td>Napa Charts or HEC-1* unless otherwise provided by the PW Director</td>
</tr>
</tbody>
</table>
In some instances, the economic consequences of drainage system failure will be such that the City shall require a higher than minimum recurrence interval to be used in the design. This determination will be made at the time of project or Tentative Map approval.

In areas where the natural relief of the ground does not preclude the possibility of the backwater elevation exceeding existing or future building floor elevations, the capacity of the drainage system shall be sufficient to ensure that the backwater resulting from a 100-year return storm will not exceed the elevation of existing building floor elevations and be a minimum of one foot below all proposed finish floor elevations.

2.03 DRAINAGE ANALYSIS AND CALCULATIONS

2.03.01 STORM DRAINAGE ANALYSIS

Engineering calculations shall be submitted to establish the basis for the design of the drainage system. The engineering analysis shall be based on the following requirements:

1. The entire drainage basin in acres including any sub-areas, the location of the project within the drainage basin in the drainage calculations. For projects less than one acre, only local drainage analysis is required.

2. The grading plans provided by the Developer for review shall include the existing topography shown with contour lines labeled at one-foot intervals and extending a sufficient distance beyond the limits of the project site to indicate impacts on adjacent properties.

3. The minimum pipe size for publicly maintained drainage systems shall be 18 inches in diameter.

4. At intersections of pipes, the downstream pipe shall have a crown elevation that is equal to the crowns of all upstream connecting pipes unless otherwise approved by the Public Works Director or their designee.

5. Pipe diameters shall not decrease in the downstream direction.

6. Drainage inlets shall be located so that the maximum distance that water flows in the gutter does not exceed 500 feet.

7. All catch basins shall be Type D-2, unless otherwise approved by the Public Works Director or their designee and shall be placed at the low points of the gutter on grades of less than one percent. The capacity of a D-2 catch basin is approximately one cubic foot per second per linear foot of inlet width. Where the street grade exceeds five
percent or velocity exceeds five (5) fps, gallery extensions shall be required to intercept
the higher velocity and/or increased gutter flow. The Caltrans Type GO catch basin
shall be used only with the approval of the Public Works Director or their designee.

8. GO inlets spaced 50 feet apart, centered on the low point, shall be placed at the low
point of vertical sag curve locations on arterial and collector streets where there is
more than 1 cfs of gutter flow at the crosswalk.

9. All storm conveyance structures, unless otherwise approved by the Public Works
Director or their designee, shall be designed to function without surcharging for the
purposes of determining hydraulic capacity.

10. Minimum velocity in pipe shall be three (3) fps and of a self-cleaning design.

11. Storm drainpipe curvature shall not exceed 80% of the manufacturer's
recommendation.

12. Drain inlets shall be located on tangents upstream from crosswalks and access ramps
in the direction of the greater gutter flow. In certain cases, two drain inlets may be
required on a corner.

13. Either a manhole or a drainage inlet shall be provided every 400 feet, at angle points,
and at beginning and end of horizontal curves to maintain accessibility to the
underground drainage facilities.

14. Minimum horizontal separation from a storm drain facility to a water line or sewer line
shall be 5 feet from the outside of each pipe except at pipe crossings. Horizontal
separation from other utilities shall be a minimum of four feet clear.

15. Storm drainpipes, which terminate in a creek or river, will be required to have a rip rap
or concrete headwall constructed in accordance with Public Works Standard Detail D-
6 shown in the City of Napa Standard Plans. Flap gates are required when a storm
drain pipe discharges into the Napa River/Napa Creek Flood Protection Project limits
(Napa River from Imola Avenue to Trancas Street; Napa Creek from Jefferson Street
to Napa River) or in other conditions where the hydraulic gradient in the waterway may
cause reverse flow in the pipe, and cause flooding upstream of the inlet such as in
tidally influenced waterways. Standard design detail of this flap gate is shown on
Public Works Standard Detail D-11.

16. Main line storm drainpipes shall not be installed in the planting area between the curb
and the sidewalk. The storm drainage lines shall be installed parallel with street
centerline and entirely within the curb-curb street area. The edge outside of the pipe
closest to the curb shall be aligned with the face of the curb and the pipe warped into
the catch basin.

17. Minimum vertical separation (distance between outside of each pipe) from a storm
drain facility to a water line or sewer line shall be 4 ft. Vertical separation from other
utilities shall be a minimum of 3 feet clear. Vertical separations deviating from these
minimum requirements shall be approved by the City Engineer.

The following step-by-step procedure for analyzing a drainage situation is offered as a guide.
Its use is optional, and it should not be substituted for common sense or good judgment:

1. Determine the area in acres contributing runoff to the drainage inlet in the system.

2. Determine the coefficient of runoff for each of the drainage areas, under ultimate
anticipated development. Table 2.4 should be used as a guide in this determination.
3. Determine the time of concentration independently for each drainage area. Please see section 2.03.02 for the complete time of concentration guidelines. For residential lots, the time for water to reach the gutters can be assumed to be 10 minutes.

4. Determine the rainfall intensity for each of the times of concentration determined above. Table 2.3 of these standards or the most current NOAA Point Precipitation Frequency (PF) Estimates should be used for this determination. However, when using the NOAA PF Estimates, rainfall depth should be selected from the highest probable value.

5. Maximum storm runoff for developments whose gross drainage area is 200 acres or less shall be computed using the Rational Method.

6. Determine the gutter capacity immediately upstream from each inlet and at upstream points with a flatter grade. Chart 2.1 may be used to determine the capacity of the gutter.

7. Determine the capacity of all inlets or catch basins within each of the drainage areas.

8. Determine the required pipe size using Manning’s equation, under full flow conditions such that the freeboard requirements of Section 2.02 are met. The slope of the hydraulic grade line must be used in this equation. To determine the freeboard, the head on the entrance to the pipe, the entrance losses, the head converted to velocity head, and the head on the outlet must all be considered.

9. If more than one inlet is contributing to the flow in a pipe, revised inlet flows must be computed based on the time of concentration to the inlet furthest upstream, plus the travel time in the pipe to the point in question.

2.03.02 STORMWATER DRAINAGE CALCULATIONS

Stormwater drainage calculations or design drawings shall include the following:

1. Flow in cubic feet per second to each structure and in each pipe including the direction with arrows.

2. Time of concentration at each structure. (Figure 2.8)

3. Intensity of rainfall at each structure. (Table 2.3, Chart 2.2)

4. All applicable existing and proposed improvements including size, material type, length and slope of each pipe proposed between structures.

5. Invert elevation of each pipe structure.

6. Top of structure elevation.

7. Hydraulic grade line elevation at each structure.

8. Hydraulic gradient.

9. Gutter capacity immediately upstream from each inlet and at upstream points with a flatter grade.

10. Catch basin inlet capacities.

11. Calculation Sheets, which include all the appropriate coefficients, acreages and other design details and also summarizes the design in a clear, concise, and professional format.
12. Pipe sizes.

As noted in Table 2.1, several options are available for use in estimating discharge for storm events. Table 2.2 provides the Design Depth Frequency (DDF) for selected storms and Table 2.3 shows Rainfall Intensity Duration.

**TABLE 2.2 – RAINFALL DEPTH (DURATION)**

<table>
<thead>
<tr>
<th>DDF</th>
<th>5M</th>
<th>15M</th>
<th>1HR</th>
<th>2HR</th>
<th>3HR</th>
<th>6HR</th>
<th>12HR</th>
<th>24HR</th>
<th>2D</th>
<th>4D</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Yr</td>
<td>0.15</td>
<td>0.27</td>
<td>0.57</td>
<td>0.82</td>
<td>1.02</td>
<td>1.50</td>
<td>1.98</td>
<td>2.45</td>
<td>3.12</td>
<td>4.03</td>
</tr>
<tr>
<td>5-Yr</td>
<td>0.20</td>
<td>0.38</td>
<td>0.80</td>
<td>1.16</td>
<td>1.42</td>
<td>2.12</td>
<td>2.79</td>
<td>3.44</td>
<td>4.51</td>
<td>5.77</td>
</tr>
<tr>
<td>10-Yr</td>
<td>0.25</td>
<td>0.46</td>
<td>0.97</td>
<td>1.39</td>
<td>1.70</td>
<td>2.53</td>
<td>3.33</td>
<td>4.12</td>
<td>5.42</td>
<td>6.94</td>
</tr>
<tr>
<td>25-Yr</td>
<td>0.30</td>
<td>0.56</td>
<td>1.16</td>
<td>1.66</td>
<td>2.04</td>
<td>3.03</td>
<td>4.00</td>
<td>4.95</td>
<td>6.63</td>
<td>8.38</td>
</tr>
<tr>
<td>50-Yr</td>
<td>0.32</td>
<td>0.62</td>
<td>1.30</td>
<td>1.87</td>
<td>2.29</td>
<td>3.40</td>
<td>4.48</td>
<td>5.56</td>
<td>7.49</td>
<td>9.44</td>
</tr>
<tr>
<td>100-Yr</td>
<td>0.36</td>
<td>0.69</td>
<td>1.44</td>
<td>2.07</td>
<td>2.54</td>
<td>3.76</td>
<td>4.96</td>
<td>6.14</td>
<td>8.33</td>
<td>10.45</td>
</tr>
<tr>
<td>500-Yr</td>
<td>0.45</td>
<td>0.85</td>
<td>1.78</td>
<td>2.55</td>
<td>3.14</td>
<td>4.67</td>
<td>6.15</td>
<td>7.60</td>
<td>10.50</td>
<td>13.01</td>
</tr>
</tbody>
</table>

Source: City of Napa 2006 Storm Drainage Master Plan Table 3-1

**TABLE 2.3 – RAINFALL INTENSITY (DURATION)**

<table>
<thead>
<tr>
<th>DDF</th>
<th>5M</th>
<th>15M</th>
<th>1HR</th>
<th>2HR</th>
<th>3HR</th>
<th>6HR</th>
<th>12HR</th>
<th>24HR</th>
<th>2D</th>
<th>4D</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Yr</td>
<td>1.80</td>
<td>1.08</td>
<td>0.80</td>
<td>0.41</td>
<td>0.34</td>
<td>0.25</td>
<td>0.16</td>
<td>0.10</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>5-Yr</td>
<td>2.40</td>
<td>1.52</td>
<td>0.08</td>
<td>0.58</td>
<td>0.47</td>
<td>0.35</td>
<td>0.23</td>
<td>0.14</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>10-Yr</td>
<td>3.00</td>
<td>1.84</td>
<td>0.97</td>
<td>0.70</td>
<td>0.57</td>
<td>0.42</td>
<td>0.28</td>
<td>0.17</td>
<td>0.11</td>
<td>0.07</td>
</tr>
<tr>
<td>25-Yr</td>
<td>3.60</td>
<td>2.24</td>
<td>1.16</td>
<td>0.83</td>
<td>0.68</td>
<td>0.50</td>
<td>0.33</td>
<td>0.20</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>50-Yr</td>
<td>3.84</td>
<td>2.48</td>
<td>1.30</td>
<td>0.94</td>
<td>0.76</td>
<td>0.57</td>
<td>0.37</td>
<td>0.23</td>
<td>0.16</td>
<td>0.10</td>
</tr>
<tr>
<td>100-Yr</td>
<td>4.32</td>
<td>2.76</td>
<td>1.44</td>
<td>1.04</td>
<td>0.84</td>
<td>0.63</td>
<td>0.41</td>
<td>0.26</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>500-Yr</td>
<td>5.40</td>
<td>3.40</td>
<td>1.78</td>
<td>1.28</td>
<td>1.04</td>
<td>0.78</td>
<td>0.51</td>
<td>0.32</td>
<td>0.22</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Source: City of Napa 2006 Storm Drainage Master Plan Table 3-2

**A. Rational Method**

The 10- and 100-year peak runoff shall be determined for each analysis point using the Rational Method. The Rational Method provides reasonable estimates of peak runoff for small watersheds. The method relates a peak discharge for the project site, a runoff coefficient (C), and rainfall intensity (i). Runoff coefficients were found to vary between 0.35 and 0.90 for land use and storm frequency.

The Rational Method equation has the form: \( Q = CiA \)

Where:

- \( Q \) = rate of runoff, acre-inches per hour or cubic feet per second
- \( C \) = runoff coefficient, which is the ratio of peak runoff to average rainfall intensity
\[ i = \text{average rainfall intensity, inches per hour, adjust intensity using rainfall M.A.P. correction see Chart 2.2 or NOAA Point Precipitation Frequency Estimates.} \]

\[ A = \text{drainage area, acres} \]

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

1. Basic Information Preparation

Layout the proposed storm drainage system and delineate the sub-basins tributary to points of concentration for the design of inlets, junctions, pipelines, etc. delineates the land uses and runoff coefficients within each sub-basin.

2. Rainfall Intensity

Average rainfall intensity, \( i \), shall be selected from Table 2.3 of these standards or the highest probable value of the most current NOAA Point Precipitation Frequency (PF) Estimates (https://hdsc.nws.noaa.gov/hdsc/pfds). Table 2.3 intensity values are based on a M.A.P. of 26 inches. Values selected from this table should be converted to a site-specific intensity using Chart 2.2.

3. Runoff Coefficient Determination:

The runoff coefficients, \( C \), for a storm having a 10-year recurrence interval are presented in Table 2.4 by land use designation and average slope. For 25-year recurrence interval, table values shall be multiplied by 1.1; and for 100-year recurrence the table values shall be multiplied by 1.25; with the results not to exceed 1.0.

4. Time of Concentration Determination:

The time of concentration or the travel time is the time required for runoff to flow from the most upstream point of the drainage area through the conveyance system to the point of interest. The travel time is calculated by dividing the length of the conveyance system component by the corresponding velocity of flow. For typical small residential lots, the time for water to reach the gutter shall be a minimum of 10 minutes. The travel time, \( T_c \), is computed as follows:

\[ T_c = T_o + T_g + T_p + T_{ch} \]

Where:

\( T_o \) = overland flow time of concentration
\( T_g \) = gutter flow travel time
\( T_p \) = pipe flow travel time
\( T_{ch} \) = channel flow travel time

The equation used to compute the travel time for each conveyance component is described below.

5. Overland Flow

The kinematic wave empirical equation based upon available SCS, COE, and FAA overland flow data (Papadakis, 1987) is:

\[ T_o = \frac{0.66 L^{0.50} n^{0.52}}{S^{0.31} i^{0.38}} \]
Where:

\[ T_o = \text{overland flow time of concentration, minute} \]
\[ L = \text{overland flow length, ft.} \]
\[ n = \text{roughness coefficient for overland flow} \]
\[ S = \text{average slope of flow path, ft/ft} \]
\[ i = \text{intensity of precipitation, in/hr} \]

Use of the overland time of concentration equation requires an iterative approach: an initial estimate of the time of concentration updated by successive estimates of precipitation intensity.

6. Gutter Flow: may be determined using Chart 2.1 of the City of Napa Standards.

7. Pipe Flow

Manning's equation can also be used to determine travel time of flow through pipes. Travel time is usually calculated by assuming full pipe flow. Flow velocity is calculated with the equation:

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

Where:

\[ V = \text{velocity in pipe, ft/s} \]
\[ R = \text{hydraulic radius, D/4 for full pipe flow, ft} \]
\[ D = \text{diameter of pipe, ft} \]
\[ S = \text{slope, ft/ft} \]
\[ n = \text{Manning’s “n”, design value = 0.015 for concrete} \]

8. Trapezoidal Channels

A modified Manning's equation is used for open channel flow to derive the velocity for trapezoidal grass-lined channels. The following assumptions were made in the derivation of the modified equation:

(a) Channel side slopes are 3:1.
(b) Channel bottom width equals the depth.
(c) Top width is seven times the bottom width.

\[ V = \frac{0.995}{n} b^{0.67} S^{0.50} \]

Where:

\[ V = \text{velocity, in ft/s} \]
\[ b = \text{bottom width, ft} \]
\[ n = \text{Manning’s “n” for channel flow} \]
\[ S = \text{slope, ft/ft} \]
9. **Intensity Determination:** The rainfall intensity shall be determined from Tables 2.2 and 2.3.

**TABLE 2.4 – RUNOFF COEFFICIENT FOR RATIONAL METHOD**

<table>
<thead>
<tr>
<th>ZONING OR SURFACE LAYER</th>
<th>RUNOFF COEFFICIENT (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paved Areas (asphalt or concrete)</td>
<td>0.95</td>
</tr>
<tr>
<td>Industrial Areas</td>
<td>0.85</td>
</tr>
<tr>
<td>Commercial Areas</td>
<td>0.85</td>
</tr>
<tr>
<td>Residential Areas</td>
<td></td>
</tr>
<tr>
<td>Single family, ave. slope less than 2%</td>
<td>0.50</td>
</tr>
<tr>
<td>Single family, ave. slope between 2% and 7%</td>
<td>0.55</td>
</tr>
<tr>
<td>Single family, ave. slope greater than 7%</td>
<td>0.65</td>
</tr>
<tr>
<td>Multi-family, detached</td>
<td>0.65</td>
</tr>
<tr>
<td>Multi-family, attached</td>
<td>0.70</td>
</tr>
<tr>
<td>Schools</td>
<td>0.45</td>
</tr>
<tr>
<td>Agricultural Land</td>
<td>0.45</td>
</tr>
<tr>
<td>Undeveloped open spaces, including pasture</td>
<td></td>
</tr>
<tr>
<td>Average slope less than 2%</td>
<td>0.40</td>
</tr>
<tr>
<td>Average slope between 2% and 7%</td>
<td>0.47</td>
</tr>
<tr>
<td>Average slope greater than 7%</td>
<td>0.55</td>
</tr>
<tr>
<td>Oak Timber and Heavy Brush</td>
<td></td>
</tr>
<tr>
<td>Average slope less than 2%</td>
<td>0.65</td>
</tr>
<tr>
<td>Average slope between 2% and 7%</td>
<td>0.42</td>
</tr>
<tr>
<td>Average slope greater than 7%</td>
<td>0.50</td>
</tr>
</tbody>
</table>

These coefficients are to be used for a return period of 10 years. For return periods of 25 and 100 years, modify the table values as follows:

- **25-Year Return:** \( C = \text{Table value} \times 1.10 \)
- **100-Year Return:** \( C = \text{Table value} \times 1.25 \)

Note, no value of “C” shall be modified beyond 1.0

**B. Napa Charts**

The 2006 City of Napa Storm Drainage Master Plan developed charts of discharge versus drainage area for the City of Napa watersheds, Figure 2.1. Charts to be used in residential, commercial (+20%) were developed as well. Included in these drainage standards are the most commonly used curves for 10-year and 100-year peak flows for residential, commercial and between 10 and 80 acres. For 25-year discharges multiply 10-year discharges by 1.20. Included in the charts is design flow versus drainage area curves for MAPs ranging from 22 to 36 inches per year. For development exceeding 80 acres in size, the appropriate curve in the City of Napa Storm Drain Master Plan shall be used.

**C. HEC Hydrology Modeling**

U.S. Army Corps of Engineer’s software HEC-HMS (Hydrologic Engineering Center Hydrologic Modeling System) should be used in watersheds over 80 acres and may be used in smaller watersheds if the design engineer desires. Modeling is also necessary when runoff peaks are to be combined, when runoff hydrographs are designed and when
detention and/or water quality BMPs volume-based storage is to be used. To establish some consistency when modeling in Napa runoff, it is recommended that unit hydrographs be derived based on one of two methods; Clark coefficients or TR-20. Both methods are available in HEC-HMS. Tr-20 is also available as stand-alone software or as a module in hydrology software programs.

1. Clark Coefficient Method

The Corps of Engineers developed values for the Clark time of concentration (Tc) and the Clark storage coefficient (R) as part of their local watershed studies in Napa.

The Corps data is the basis for the construction of Figure 2.8 showing Clark coefficients Tc + R plotted to drainage area. A best fit resulted in the adoption of the relationship R/(Tc + R) = 0.25. Entering Figure 2.8 with a drainage area and using the Tc + R from the curve, the Clark coefficients may be derived and used in the HEC-RAS or HEC-HMS model. In summary, the recommended criteria and methods to estimate discharge are presented in Table 2.1. For sizing detention basins in watersheds less than 250 acres, other methods (not including Clark limit hydrograph method) within HEC-RAS or HEC-HMS should be used to adequately represent how the runoff will be routed through the detention basin.

2. TR-20 Method

There are five basic data required to determine runoff using TR-20 – drainage area, runoff curve number, time of concentration, rainfall distribution and 24-hour rainfall depth.

Runoff Curve Number is an index used to rate the runoff potential of a watershed. It is based on the type of soil (hydrologic soil group) and land use/treatment class (surface condition of the watershed).

The National Resources Conservation Service (NRCS) created four synthetic rainfall distributions to represent the various rainfall intensities and geographical regions of the United States. The City of Napa falls under the Type 1A distribution, which corresponds to wet winters and dry summers. The 24-hour rainfall depth is the amount of total rainfall an area will receive in 24-hours during a rain event. This data may be obtained from the publication by the National Oceanic and Atmospheric Association (NOAA) Atlas 2, Volume XI (Northern California).

For a brief study of the TR-20 method and its processes, refer to the NRCS’s publication TR-55 – Urban Hydrology for Small Watershed, which is the non-automated version of the TR-20.

2.03.03 HYDROLOGY / HYDRAULICS
(STUDY REPORT / PLAN SUBMITTAL REQUIREMENTS)

A narrative report shall be provided discussing the hydrologic and hydraulic characteristics of the project and all applicable information specified in Section 2.03.02 of these standards. The report shall state the goals, assumptions, and design concepts underlying the drainage system and include, at minimum, the items listed below:

1. A discussion of pre-development and post-development site conditions. This analysis should include the proposed hydrologic and hydraulic modifications and a summary of the reported results.
2. A drainage basin map showing the limits of all drainage areas and their size in acres or square feet. Drainage basins may not necessarily be limited to project limits and should include the maximum extent of any area that contributes to total runoff. The drainage basin map should show at minimum the following drainage characteristics: Boundaries of all drainage basins, pervious and impervious surfaces, flowlines, and all drainage structures with associated flow elevations.

3. Calculations for all hydrologic properties specified in section 2.03.02 including but not limited to: time of concentration, weighted runoff coefficients, rainfall intensity, and total runoff predicted using the appropriate method specified in Table 2.1. Calculations should be provided for both pre-development and post-development conditions.

4. Hydraulic calculations that show flow capacities for all drainage structures including but not limited to: pipes, swales, gutters, inlets, and outfalls.

5. All charts, tables, and supporting documents used within the report. Additional information may be required as appropriate depending upon the size and complexity of the project. Incomplete submittals will require subsequent submittals with additional information. Any special issues should be discussed with City staff in advance of the submittal.

2.04 DRAINAGE STRUCTURES

2.04.01 MANHOLES AND JUNCTION BOXES

Manholes and junction boxes shall conform to City of Napa Standard Plans. They shall be located at changes in grade or conduit size, at junction points, on curved pipe at the beginning and ending of the curve. Maximum spacing between manholes and/or accessible structures (catch basins) shall be 400 feet.

2.04.02 CATCH BASINS

Catch basins shall conform to the City of Napa Standard Plans. Catch basins shall be designed and spaced such that they intercept and fully contain the design storm required for the project. Under no circumstance shall the spacing of catch basins result in water flowing in gutters over 500 feet.

2.04.03 GUTTERS

Stormwater runoff in gutters shall be conveyed in underground structures when any one of the following criteria is met:

1. Gutter runoff exceeds 3.0 cfs.
2. Length of gutter flow exceeds 500 feet.
3. Water spread exceeds requirement of Design Criteria, Section 2.02.
4. The minimum longitudinal slope of gutters shall be 0.5 percent. Gutters can slope a minimum of 0.33 percent with a 2-foot-wide gutter pan with the approval of the Public Works Director or their designee.
2.04.04 BOX CULVERTS

Box culverts shall be required when specified by the Public Works Director or their designee and shall be designed on an individual basis per Caltrans Design Standards and Standard Plans.

2.04.05 HEADWALLS

Headwalls, wingwalls, endwalls, etc. shall be considered on an individual basis, and in general, designed in accordance with Section 51 of the Caltrans Standard Specifications.

2.04.06 DRAINAGE PUMP STATIONS

Drainage Pump Stations are not permitted unless approved by the Public Works Director or their designee.

2.04.07 TEMPORARY INLETS AND OUTLETS

Temporary inlets and outlets shall conform to good engineering practice and shall be specifically designed and detailed on the plans.

2.05 OPEN CHANNEL DESIGN

For the purposes of these drainage provisions, a ditch with a capacity of over 2.5 cfs shall be classified as an open channel. Drainage may not be conveyed through a development in open channels without written approval of the Public Works Director or their designee. Requirements for open channels are as follows:

1. Channel construction may require permits and design reviews from environmental regulators outside the City of Napa.

2. **Construction**: Channels shall be constructed to a typical cross section. Fully lined channels shall be designed with maximum side slopes of 2:1; channels with unlined sides shall be designed with maximum side slopes of 3:1. Lined channels shall have a minimum bottom width of at least twice the channel depth and shall have adequate access ramps for maintenance equipment. The lining shall be finished concrete, rip rap rock, or other lining approved by the Public Works Director or their designee. The minimum weight of sacked concrete shall be determined from Figure 2.9, (replacing sack concrete for rock) and in no case shall an individual sack of concrete weigh less than 60 pounds. For use in this figure, impinging velocities shall be 1.4x the mean velocity and the tangential velocity shall be 0.75x the mean velocity.

3. **Design**: Channels shall be designed to convey the 100-year design flow with a minimum velocity of two (2) fps. The maximum velocities shall be as follows:
   
   (a) Earth channels, six (6) fps.
   (b) Fully lined channels, ten (10) fps.

The hydraulic grade line shall be calculated and plotted on all channel profiles. All computations including a narrative of the design shall be submitted to the Public Works Director or their designee for approval.
A minimum of 3-feet or 1-foot of freeboard in channels with or without levees respectively shall be provided. The latest FEMA Regulations shall also apply.

4. **Curve Radius:** The centerline curve radius of an open channel shall be equal to or greater than twice the bottom width (35-foot minimum).

### 2.06 BENCH DRAINS AND DIVERSION DITCHES

A ditch shall be considered a bench drain or diversion ditch as long as its design capacity is does not exceed 2.5 cfs. Any ditch, which has a capacity greater than 2.5 cfs, shall be considered an open channel and designed as such.

Bench drains and diversion ditches shall be concrete lined and designed with a velocity range of between 3 and 20 feet per second. At changes in alignment and at inlets, adequate measures such as banking, circular curves or energy dissipaters shall be used to confine water to the channel. At locations where, in the opinion of the Public Works Director or their designee, the overflow of a bench drain or diversion ditch could cause flooding, erosion or other damage, the channel section shall be designed to carry the 100-year runoff.

### 2.07 LEVEES

Where new levees are constructed, the landside levee slope shall be 2:1. The waterside slope of the new levee embankment shall be constructed at 3:1. The top width of the levee berm will be 15 feet and shall also function as a patrol road. The limits of the right-of-way shall extend 10 feet beyond the toe of the landside slope of the new levee embankment to provide access for levee maintenance.

Levees may require permits and design reviews from environmental regulators outside the City of Napa.

### 2.08 SLOPE PROTECTION

Where channel slope protection is required, stone riprap protection shall be designed in accordance with USACE Standard EM 1110-02-1601, “Hydraulic Design of Flood Control Channels”.

Slope protection installation may require permits and design reviews from environmental regulators outside the City of Napa.

### 2.09 STRUCTURE OPERATION CRITERIA

All structures such as ponds, control gates, weirs, flap gates, temporary facilities, etc., shall be shown in detail on design and construction drawings. Their purpose, functional operation parameters and settings shall be described on the drawings. Pond ownership and maintenance responsibilities shall also be included.

### 2.10 DETENTION

#### 2.10.01 PURPOSE

The City of Napa’s stormwater systems as well as the Napa River Flood Protection Project do not provide protection for additional flow caused by increases in peak runoff generated by new
development. Much of the City’s storm drain does not have existing capacity to carry 10-year storm flow. Specific areas of the City also have unique drainage situations including the Big Ranch Specific Plan Area which requires “all projects of more than four units draining directly or indirectly to the Salvador Channel or Bel-Aire/Gasser Tributary to provide enough stormwater detention capacity to maintain post-project 100-year peak flows at pre-project levels.” Because of Salvador Creek flooding concerns the above standard is applied to all projects in the Salvador Creek watershed. See Figure 2.10 for a drainage basin map showing the limits of the Salvador Creek watershed. Other requirements also exist which affect the need for detention. Those concerning Water Quality are covered in the BASMAA Post-Construction Manual adopted by the City of Napa.

<table>
<thead>
<tr>
<th>DETENTION REQUIREMENTS</th>
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<tbody>
<tr>
<td><strong>PROJECT TYPE</strong></td>
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<tr>
<td>Residential</td>
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<tr>
<td>Commercial</td>
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<tr>
<td>Salvador Basin*</td>
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* Projects of 4 units or less are required to meet all other detention requirements listed in the above table.

Table Notes:

Existing storm drains may be required to be upsized or replaced if there is inadequate capacity for downstream conveyance.

See Figure 2.10 for location and limits of the Salvador Basin.

A residential unit is defined as any dwelling or place designed for human occupancy which contains a kitchen.

2.10.02 INTRODUCTION

This section is concerned with the planning and design of facilities and features for providing storage in drainage systems. An emphasis is placed in use of storage for flood control.

Storage can also be an effective tool for the management of stormwater runoff. Storage lends itself to multiple land uses and is often the least costly alternative for achieving a particular flood control objective. Temporarily detaining a few acre-feet of runoff can significantly reduce downstream flows and pipe and channel sizes, especially when the flood hydrograph has a rapid rise and fall. Storage can also remove sediment and debris that reduces sediment and pollutant loading on receiving waters.
However, the use of storage to reduce flood peaks is also potentially detrimental to flooding conditions. Storage facilities must be adequately maintained in order to function properly. Further, storage may potentially worsen downstream conditions for events larger or smaller than a single design event, and storage provided at some locations in a basin can actually increase total watershed peak flows by causing runoff peaks to coincide with peaks from other parts of the basin.

Detention facilities shall be designed to capture, temporarily hold and gradually release a volume of stormwater runoff to attenuate and delay stormwater runoff peaks. Outlet structures shall be sized to limit the maximum flow rates. Detention facilities shall drain completely after storm events, within a maximum of 72 hours.

Calculations for detention requirements shall be as outlined for storm drainage design.

Projects shall provide on-site detention of stormwater such that the peak flows from a storm with a two inches per hour intensity, 10-year storm, 25-year storm and 100-year storm does not exceed predevelopment runoff. The Applicant shall provide storm drain inlets with enough capacity to ensure 100-year stormwater enters the detention system. Detention facilities shall not be located within public street rights-of-way. Side slopes should not exceed 3:1 and shall include a 100-year overland escape.

Underground stormwater detention facilities shall be constructed within a Private Drainage Easement at the sole cost of the subdivider, developer and/or contractor. Detention facilities shall not be located within public street rights-of-way.

Maintenance responsibility for stormwater detention facilities shall be the responsibility of an appropriately established Homeowners Association (HOA), or other responsible entity, such as a private maintenance agreement, as approved by the Public Works Director or their designee and the City Attorney. A long-term operations and maintenance plan shall be submitted to and approved by the Public Works Department. The plan shall include a viable method of long term financing for such maintenance, inspection verification reporting and a third party beneficiary agreement. If the Homeowners Association, or other responsible entity, fails to maintain the detention facilities, then the City shall enforce the maintenance through this agreement.

The third party agreement shall allow, but not limit, the City of Napa to force the HOA, or other entity, to do the work, the right to enter onto the property to do the work, the right to charge for the work completed by the City of Napa, or its contractor, and the right to establish a lien to recoup the cost of the work.

2.10.03 CONCEPTS AND DEFINITIONS

A. Detention and Retention

Detention storage temporarily delays a portion of the inflow so that the maximum outflow is less than the maximum inflow. The storage of runoff is temporary, i.e. water stored is released soon after the maximum inflow has occurred.

Retention storage functions similarly to detention storage except that water is stored for a significantly longer period. Water may be released from retention storage after a storm has ended or it may be retained for a much longer period for other uses such as recreation, surface water supply, or ground water recharge.
**B. On-site Storage**

The storage of water close to the points of rainfall occurrence is considered on-site storage. On-site storage is typically small scale and includes ponding in parking lots, property line swales, small ponds in green areas, underground tanks and infiltration trenches.

Parking lot detention for industrial/business development shall provide pedestrian access through the ponded areas. Depths of ponding shall not exceed four (4”) inches.

Conduit storage can be utilized by over sizing the underground drainage facilities. Care should be taken to prevent siltation problems.

Channel storage can be utilized by over sizing the open channel facilities. Care again should be taken to prevent siltation problems, and allowances must be made for a minimum capacity at a maximum silt buildup.

**2.10.04 PRINCIPLES AND POLICIES**

**A. Avoiding Detrimental Effects**

A storage facility shall not worsen conditions downstream. Any storage facility, especially a detention basin, has a potential for creating worse conditions downstream by altering the timing of peak flows in the stream and its tributaries. In order to avoid detrimental effects, the following criteria are required to be met:

1. A hydrologic study of the watershed in which the basin would be sited is to be conducted. The downstream limit of the study would be the point beyond which changes in peak flows would not be measurable such as tidally influenced water bodies. Where they exist, the HEC watershed models supported by the City should be used.

2. Storage basins must limit outflows to pre-development levels for the 10, 25 and 100-year event peak flow rates with the basin initially empty.

3. The spillway must carry the 100-year storm hydrograph with the basin initially full and provide one foot of freeboard above 100-year event spillway design water surface.

4. Best management practices such as low impact development shall be used to minimize hydromodification to the maximum extent practicable.

**B. On-site Storage**

On-site storage mitigation of increased runoff shall be used to provide storage where appropriate. Project features, which can be used for incidental storage, include parking lots, parks, and other common areas along with underground storage facilities. On-site storage may create incidental storage, which is effective in reducing peak flows downstream. The ponding function of on-site storage should be considered with the planning and design of the project and coordinated with the master drainage plan.

**2.10.05 HYDROLOGIC EVALUATION**

The evaluation of the effects of storage on flows is the same, regardless of the scale of the storage facility. The objectives of the hydrologic evaluation are to determine the required storage capacity and to verify the effectiveness of the outlet design in achieving objective
flows.

The required capacity of a storage basin is a function of the objective outflows, design inflows, and required freeboard. Carryover and multi-purpose storage are also factors when retention is involved. A routing of the design storm inflows is required to determine the capacity for storage basins. The outflows used in the detailed routing shall be based upon hydraulic rating curves for the outlet works proposed for the basin.

Note that if the actual storage capacity is limited by topography or costs of land acquisition and constructions, it may be necessary to reformulate the objective outflows.

A. Objective Outflows

When storage is to be used to mitigate downstream impacts due to increased flows generated by development of a site, the objective outflow shall be taken as the estimated pre-development peak flow rate.

B. Outflow Control

It is desirable to design the storage to operate under hydraulic control: i.e. the hydraulics of the outlet controls the outflow rates. In no case shall the spillway be manually operated.

C. Duration

The duration of flood routings shall be sufficiently long for stream flows and storage levels to return to initial conditions. Runoff from storms of increasing durations shall be routed through the storage basin to determine the maximum volume required considering carryover from one period of high runoff to the next. Detention facilities shall be designed to drain completely within 72 hours of the end of the design storm.

2.10.06 DETENTION TANKS AND VAULTS

Tanks and vaults provide underground storage of stormwater as part of the runoff quantity control system. As with any underground structure, they must be designed not only for their function as runoff quantity control facilities, but also to withstand an environment of periodic inundation, potentially corrosive chemical or electrochemical soil conditions and heavy ground surface loadings. They must also be accessible for maintenance.

Tanks and vaults typically do not have a built-in design feature for containing sediment, as do multi-cell ponds. Therefore, when tanks or vaults are used for detention storage either a surface sediment containment pond or other sediment control BMP shall be placed upstream of the tank or vault.

Tanks and vaults can be used in conjunction with other detention storage facilities, such as ponds or parking lot ponds, to provide initial or supplemental storage.

A. Design Requirements

The following criteria shall apply to detention tank and vault design:

1. All areas of a tank or vault shall be within 200 feet of a minimum 24-inch diameter access entry cover. All access openings shall have round solid locking lids.

2. Privately owned detention tanks and vaults are not permitted within the public right-of-way. If developments are served with publicly operated and maintained tanks and vaults that are not located within the right-of-way, the tanks/vaults shall be located in
separate open space tracts with private drainage easements. All privately owned and maintained facilities shall be located to allow easy maintenance and access.

3. All tanks and vaults shall be designed as flow-through systems, unless separate sediment containment is provided.

4. If the collection system piping is designed also to provide storage, the resulting maximum water surface elevation shall maintain a minimum 0.5-foot of freeboard in any catch basin below the catch basin grate. Pipe capacity shall be verified utilizing backwater analysis, using an accepted methodology approved by the City. The minimum internal height of a vault or tank shall be 3 feet and the minimum width shall be 3 feet. The maximum depth of the vault/tank invert shall be 20 feet.

5. All tank and vault shop drawings shall be included with improvement plans for the project.

B. Materials and Structural Stability

Pipe materials and joints shall conform to the City of Napa Standards. For pipes outside of City right-of-way, pipe material used may be SDR-35 or PVC Schedule 40 plastic.

All tanks and vaults shall meet structural requirements for overburden support and traffic loadings, if appropriate. HS-20 live loads shall be accommodated for tanks and vaults under roadways and parking areas. End plans and caps shall be designed for structural stability at maximum hydrostatic loading conditions.

Detention vaults shall be constructed of structural reinforced concrete (3000 psi, ASTM 405). All construction joints shall be provided with water stops.

In soils where groundwater may induce flotation and buoyancy, measures shall be taken to counteract these forces. Ballasting with concrete or earth backfill, providing concrete anchors or other counteractive measures shall be required. Calculations shall be required to demonstrate stability.

Tanks and vaults shall be placed on stable, consolidated native soil with suitable bedding. Tanks and vaults shall not be allowed in fill slopes, unless a geotechnical analysis is performed for stability and construction practices.

2.10.07 CONTROL STRUCTURES

Detention control structures shall be either weir structures or orifice structures. Weir structures may be enclosed in a catch basin, manhole, or vault or may be installed in the open provided they are accessible for maintenance and are not exposed to damage. Riser type restrictor devices also provide some incidental oil/water separation and spill control. Weir structures provide some oil/water separation when fitted with a baffle plate located upstream of the weir.

The following criteria shall apply to control structure design:

1. Flow control manholes shall have solid locking covers. Open grates shall not be permitted in control manholes.

2. Multiple orifices are usually necessary to meet the design storm performance requirements for a detention system.
2.12 DRAINAGE EASEMENTS

Drainage easements shall be established when drainage facilities exist, or are designed to be constructed, on private property. Clear access must be provided and maintained to all public structures on the drainage system.

Publicly maintained drainage conduits and channels will not be allowed on private property unless they lie within dedicated public drainage easements. When minor improvement of a drainage channel falls on adjacent property (such as day lighting a ditch profile) written permission from the adjacent property owner(s) for such construction shall be required. A copy of the document which grants said approval shall be submitted to the Public Works Director or their designee prior to the approval of the improvement plans.

Easements for closed conduits shall have a minimum width of either 15 feet or a width in feet equal to the required trench width according to the standard detail for trench backfill plus 2 additional feet of width for every foot of depth of the pipe as measured from the bottom of the pipe to finished grade, whichever is wider. For pipes outside the City right-of-way and less than 10” in diameter, a 10’ wide minimum easement shall be provided. All conduits shall be centered at the quarter point within their easements. Drainage easements for open channels with flows of over 3 cubic feet per second shall have sufficient width to contain the open channel and two 17-foot wide service roads. The toe of a bank shall not be within 17 feet of an easement boundary. Easement boundary lines shall, at changes of alignment, have a 50-foot radius sufficient to provide turning room for vehicles operating on the service road.

Easements shall be categorized as follows:

- **Public drainage easements** cover fully improved drainage and detention facilities that provide for the drainage of publicly owned and maintained areas, such as streets and parks. Public drainage easements shall be dedicated to the City and will be accepted by the City. The City will be responsible for the maintenance of drainage facilities within these easements.

- **Private drainage easements** cover improved or unimproved drainage and detention facilities that are constructed on private property for the purpose of draining adjacent privately-owned lots. In a subdivision, these private drainage easements are typically a result of the overall drainage design of the subdivision and may serve many lots. Private easements are generally not dedicated to nor accepted by the City. The private property owner is responsible for the maintenance of all drainage facilities contained within private drainage easement and may be liable for any damage to adjacent properties resulting from a failure to do so. In a subdivision, the CC&R’s or Maintenance Agreement between property owners shall indicate that the maintenance of these private drainage easements is the responsibility of the respective property owner.

There may be situations where, at the City’s election, an irrevocable offer to dedicate a private drainage easement may be required. Normally this would only be necessary to provide overall drainage to an area upstream of a development for future extension of a drainage system that may be a public system in the future.

Physical improvements, beyond landscaping such as grass and low-lying vegetation, are prohibited (including fill) in a public drainage easement. Any obstructions placed in this public drainage easement are subject to removal by the City of Napa with the expense billed to the property owner.

All drainage easements that result from a subdivision development shall be shown on the Final Map, including descriptions for type of easements shown.
The following definitions are provided solely for historical knowledge and are no longer used to designate drainage easements by the City of Napa:

- **Type A** easements cover fully improved drainage facilities that provide for the drainage of publicly owned and maintained areas, such as streets and parks. The City will be responsible for the maintenance of drainage facilities within Type A easements.

- **Type B** easements cover unimproved drainage facilities that serve public as well as privately owned lands. The most common use of Type B easements are for unimproved natural water sources. These easements are dedicated to the City, but will not be accepted by the City and, therefore, will not be maintained by the City. The private property owner is responsible for the maintenance of all drainage facilities contained within Type B easements.

- **Type C** easements cover improved or unimproved drainage facilities that are constructed on private property for the purpose of draining adjacent privately-owned lots. In a subdivision, Type C easements are typically a result of the overall drainage design of the subdivision and may serve many lots. Type C easements are private storm drain easements and shall not be dedicated to nor accepted by the City.

### 2.13 SPECIAL PROVISIONS

All storm drainage pipes installed within public streets or easements shall be a minimum of 18 inches in diameter and shall be a minimum Class III reinforced concrete pipe with rubber gasketed joints, unless otherwise approved by the Public Works Director or their designee.

Whenever a storm drainage pipe is installed in paved public streets, the sides of the trench shall be cut to a neat line in a manner satisfactory to the Public Works Director or their designee. The trench shall be backfilled with ¾” Class II AB and a temporary patch of cold mix asphalt shall be placed on the trench at the end of the workday. Permanent pavement shall be placed on the trench within 48 hours after the storm drainage pipe has been installed unless otherwise approved by the Public Works Director or their designee. Attention is directed to City Standard Plan D-12, “Storm Drain Trench”.

#### 2.13.01 ASPHALT PLACEMENT

After backfilling and compacting trenches passing through pavements, three inches (3”) of asphalt cutback shall be placed to grade. Temporary asphalt cutback shall be maintained at Contractor’s expense until permanent paving is installed.

All trenches through existing asphalt concrete (AC) shall be permanently paved with a minimum of five inches (5”) of AC placed in two (2) lifts. All trenches shall be “T” cut prior to the placement of the permanent AC. The “T” cut shall be created after the trench is recompacted.

Existing AC or Portland Cement Concrete (PCC) shall be saw-cut or planed only. Jackhammered edges shall not be allowed. AC must be compacted to 95% minimum.

#### 2.13.02 CRACK SEALING OF TRENCH PATCH

After all permanent ACC or PCC trench patches have been installed, the joint between the existing concrete and the newly placed patch shall be crack sealed. Crack sealing shall be per Section 37-5, “Parking Area Seals”, of the Standard Plans. The cost of crack sealing shall
be at no additional City expense.

The placement and compaction of backfill material shall conform to the provisions in Section 19-3, “Structure Excavation and Backfill”, of the Standard Specifications, the Storm Drain Trench City Standard Plan, D-12, and as directed by the Public Works Director or their designee.

2.13.03 TRENCHING, BORING, BACKFILL AND COMPACTION

A. Description

A trench is defined as an excavation in which the depth is greater than the width. Excavation for appurtenant structures such as, but not limited to, manholes, transition structures, junction structures, catch basins/drain inlets, and bore pits shall be deemed to be on the category of trench excavations.

Excavation shall include the removal of all water and material of any nature which interfere with the construction work. Placement of spoil materials on the paved street area shall only be allowed under written approval from the Public Works Director.

Installation of conduits shall be by open trench unless otherwise specified or shown on the drawings. If a Contractor elects to tunnel or bore and jack any portion of the work, written approval shall be obtained from the Public Works Director. (See Section G, “Tunneling, Boring, and Jacking”).

Open trenching shall be prohibited on all newly paved streets for a period of not less than three (3) years from the date of the latest overlay without written approval by the Public Works Director.

B. Maximum Length of Open Trench

The maximum length of open trench, where prefabricated pipe or other structures are to be placed, shall be the distance necessary to accommodate that amount of pipe which can be installed and backfilled in a single day. The distance is the collective length at any location, including open excavation, pipe laying and appurtenant construction and backfill which have not been temporarily resurfaced. The use of steel plates as open trench or excavation cover shall be allowed only with prior approval of the Public Works Director. All trenches or excavations within a sidewalk area or driveway shall be covered with steel plates. The use of plywood for open trench or excavation cover shall not be allowed within or adjacent to the City right-of-way.

C. Temporary Pavement

Backfilled excavations shall be covered with a minimum 3-inch layer of temporary cold-mix asphalt concrete to create a smooth driving surface, pending placement of the permanent surface. The contractor shall be responsible for checking the temporary driving surface daily to ensure that the surface remains smooth. Any settling or cavitation of the temporary asphalt surface shall be corrected immediately. If the contractor fails to maintain the temporary surface in a safe and clean manner, the City may require that trench plates be used to cover the trench.

D. Trench Plates

When an excavation in the public right of way cannot be backfilled and permanently paved within a workday, steel plate bridging with a non-skid-surface and trench shoring may be
required to preserve traffic flow and to ensure public safety. This includes excavations within a paved street section or within the concrete curb, gutter, and sidewalk area, whether transverse or longitudinal. Excavations shall remain covered with steel plates until permanent pavement is installed unless the City Engineer approves in writing an alternative method of temporary surface restoration.

Steel plate bridging and shoring shall be installed using Method A (as described below), unless the City Engineer approves in writing the use of Method B (as described below), which may be used only where the traffic speed is less than 35 mph. The Contractor is responsible for all temporary excavation surfaces in the public right of way, including the maintenance of cold asphalt concrete, steel plates, and shoring.

- **Method A:** If the traffic speed is 35 mph or more, the road surface shall be cold milled to a depth equal to the thickness of the trench plate and the trench plate shall be installed so that the top is flush with the adjacent road surface. The width and length of the cold milling shall match the width and length of the steel plate as closely as possible, and any edge gaps shall be filled with compacted cold-mix asphalt concrete.

- **Method B:**

  For speeds less than 35 mph and with written approval of the City Engineer, steel plate bridging may be placed on top of the asphalt surface without cold milling the existing pavement.

  The plate(s) shall be prevented from sliding by being attached to the roadway by dowels pre-drilled into the corners of the plate(s) and drilled 2 inches into the pavement as follows:

  i. If only one plate is used, all four corners shall be drilled and dowelled.

  ii. If a row of plates is being used across the direction of traffic, all four corners of each plate shall be drilled and dowelled.

  iii. If a row of plates is being used in the direction of traffic, two dowels shall be located at the beginning of the approach plate and two dowels shall be located at the end of the ending plate.

  Fine-graded cold-mix asphalt concrete shall be placed and tightly compacted around all exposed edges of the trench plates to create a ramp up to the top of the plates. The asphalt shall have a maximum slope of 12:1 (8.3%) and a minimum aper length of 12 inches.

  When the steel plates are removed, any dowel holes in the pavement shall be backfilled with either fine-graded cold-mix asphalt, concrete slurry, or an equivalent slurry satisfaction to the City Inspector.

Regardless of the method of steel placement, the following conditions shall apply:

1. Steel plates shall be of ASTM A36 steel, or better, with F_y = 36 ksi. min.

2. Steel plates used for bridging shall extend a minimum of 12 inches beyond the edges of the span, with the span being either:

   (a) The trench width, for trenches cut into a hard surface such as concrete or pavement; or

   (b) The trench width plus 12 inches, for trenches cut into native soil.

3. Trenches and excavations shall be adequately shored or braced to withstand the bridging and traffic loads.
4. Steel plates within the City Right of Way whether used in or out of the traveled way shall be without deformation. The City Engineer shall determine the trueness of the steel plate by using a straight edge and will reject any plate that is permanently deformed.

5. Contractor shall not install any steel plate that is delivered without the required surfacing or is permanently deformed.

6. Where multiple trench plates are to be used, all plates shall be tightly butted and tack-welded together at the end of each day. At least two tack welds shall be used to secure a pair of adjacent plates, and the aggregate length of the welds shall be at least 6 inches per pair of plates.

7. The Contractor shall maintain a skid resistant surface on the steel plate having a minimum coefficient of friction equivalent to 0.35 per California Test Method 342.

   (a) If a different test method is used, the permittee may utilize a standard test plate with known coefficients of friction available from each Caltrans District Materials Engineer to correlate skid resistance results to California Test Method 342.

8. A “Steel Plates Ahead” (W8-24) sign shall be used in advance of all trench plates.

9. A “Rough Road” (W8-8) sign shall be used in advance of all temporary paving.

10. Signs shall have black lettering on an orange background and shall be used in conjunction with a traffic control plan approved by the City Engineer.

11. All trench plating shall be designed for a minimum of HS-20-44 Truck loading and shall not be accessed by construction vehicles exceeding this loading.

12. The following table shows the maximum allowable span of each standard plate thickness and is for HS-20-44 loading and 36 ksi steel:

<table>
<thead>
<tr>
<th>PLATE THICKNESS</th>
<th>MAXIMUM ALLOWABLE TRENCH PLATE SPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>2' 6&quot;</td>
</tr>
<tr>
<td>7/8&quot;</td>
<td>3' 4&quot;</td>
</tr>
<tr>
<td>1&quot;</td>
<td>4' 6&quot;</td>
</tr>
<tr>
<td>1 ¼&quot;</td>
<td>7' 0&quot;</td>
</tr>
<tr>
<td>1 ½&quot;</td>
<td>10' 0&quot;</td>
</tr>
<tr>
<td>2&quot;</td>
<td>14' 0&quot;</td>
</tr>
</tbody>
</table>

13. For trenches and excavations with spans greater than fourteen feet (14’), a structural design shall be prepared by a Registered Civil Engineer and approved by the City Engineer.

14. Unless specifically noted in the provisions of the encroachment permit, steel plate bridging shall not be left in place for more than 5 consecutive working days in any given week.

15. Steel plates shall not be left in place over a weekend without prior written approval by the City Engineer or City Inspector. If permission is granted, the plates must be checked a minimum of two (2) times a day to ensure stability.
E. Trenching

The maximum clear width of the trench at the top of the pipe shall not be more than the outside diameter of the pipe at any point plus two (2') feet on each side. Greater width of the trench at the top of the pipe shall be permitted only on written approval by the Public Works Director or by plan design. In no case shall the free working space on each side of the pipe be less than six inches (6") without Public Works Director’s approval.

If maximum trench width is exceeded, the Contractor shall provide additional bedding, another type of bedding, a higher strength of pipe, or any other additional work, as required or approved by the Public Works Director, to adequately install and protect the pipe equal to the original design, at no additional City cost.

F. Bracing and Shoring Excavations

The manner of bracing and shoring excavations shall be as set forth in the rules, orders and regulations of the State of California Construction Safety Orders, Division of Industrial Safety.

Contractors may be required at the discretion of the Public Works Director to provide drawings or calculations by a registered engineer five (5) working days prior to beginning construction for specially designed bracing and shoring of an excavation where standard pre-manufactured bracing or shoring cannot be used.

Contractors shall submit a copy of their current Annual Excavation Permit issued by the State of California Division of Industrial Safety (CAL-OSHA) along with the Contractor’s own Trench Safety Plan prior to the start of construction.

G. Tunneling, Boring, and Jacking

Any pipe or facility placed underground in any method other than open cut trenching shall be considered as tunneling or boring and jacking.

All tunneling or boring and jacking shall receive the Public Works Director’s approval prior to work start. All existing utilities shall be potholed for actual depth prior to tunneling or boring and jacking operations. A borepath sheet, showing all potholed utilities, shall be submitted for approval by the City Engineer five (5) days prior to start of work. The City shall receive a copy of all permits and orders for the installation of any facilities that require boring and jacking or tunneling that will be within the City right-of-way or within any other agency’s jurisdiction. Including, but not limited to, Caltrans, railroads, and private property within City Limits.

All voids between the inside of the casing and the pipe shall be completely backfilled by blowing sand or pumping grout between the casing and the facilities within the casing as directed by the Public Works Director. Casing inside diameter shall be a minimum of twice the outside diameter of the facility to be placed within the casing. The wall thickness of the casing shall be 0.375 inches or as directed by the Public Works Director. All casings shall be fully fusible C-905 PVC at each joint. All casings shall have a sealed end cap sealing the end of the casing.

All pipes to be installed within the casing shall be installed on plastic skids or spacers with a maximum spacing of three feet (3’) between skids or spacers and banded to the pipe using stainless steel bands or as approved by the City Engineer. All installations shall be per the boring and jacking detail.
2.13.04 COVER REQUIREMENTS

All stormwater conveyance structures shall be designed to allow a minimum of two feet of cover as measured from bottom of sub-grade to the top of pipe. If achieving this cover is not possible due to some sound engineering reason, the pipe shall be encased in concrete or provided with a one-foot concrete cover as approved by the Public Works Director or their designee.

2.13.05 REINFORCED CONCRETE PIPE (RCP)

All storm drainage pipes installed within public streets or easements shall be a minimum of 18 inches in diameter and shall be a minimum of Class III reinforced concrete pipe with rubber gasketed joints, unless otherwise approved by the Public Works Director or their designee.

Reinforced concrete pipe (RCP) shall conform to ASTM Designation C76-08a (or latest ASTM adopted standard). A Certificate of compliance with ASTM C76-08a shall be provided to the City inspector prior to the installation of RCP. Tests results per ASTM C497-17 (or latest ASTM adopted standard) including the following shall also be provided to the City inspector prior to installation of RCP:

- External load crush test
- Hydrostatic: 13 PSI for 20 minutes
- Absorption
- Permeability
- Cylinder strength
- Allowable leakage: none

The following chart lists the minimum allowable classes of reinforced concrete pipe and cover requirements for each class of pipe.

<table>
<thead>
<tr>
<th>MINIMUM CLASS, RCP</th>
<th>COVER (IN FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL V (3000D)</td>
<td>Less than 2.5</td>
</tr>
<tr>
<td>CL III (1500D)</td>
<td>2.5-7.9</td>
</tr>
<tr>
<td>CL IV (2000D)</td>
<td>8.0-11.9</td>
</tr>
<tr>
<td>CL V (3000D)</td>
<td>12.0-17.0</td>
</tr>
</tbody>
</table>

No storm drainpipe, which lies totally or in part within the structural section of a street, shall be allowed unless approved by the Public Works Director or their designee.

A geotextile must be placed, per the manufacturer’s directions, between the clean crushed rock and the overlying material.

2.13.06 CAST IN PLACE PIPE (CIPP)

Cast in place pipe (CIPP) is not accepted unless specifically approved by the Public Works Director or their designee. If the use of CIPP is approved the following standards shall apply:

A City approved independent inspector under the direct supervision of an independent Registered Civil Engineer experienced in the manufacture and placement of CIPP shall be
required for continuous inspection of the construction process. The inspection shall be certified in writing and signed by the inspector and the Registered Civil Engineer. The certification to be done on a daily basis of operation shall include, as a minimum, the following:

- Review of trench form, soil conditions, and trench grade.
- Report on method of operation and compliance with these specifications.
- Report on concrete mix used, temperature, transit method, machinery condition.
- Report on visual appearance of the pipe as poured for smoothness, rock pockets if any, alignment, grade, and compliance with these specifications.
- Report on deficiencies that require repair or replacement.
- Report on curing method.
- Report on backfill placement.
- Review of concrete test results and adequacy of the finished product.

The minimum allowable wall thicknesses for CIPP are as follows:

<table>
<thead>
<tr>
<th>INTERNAL DIAMETER</th>
<th>MINIMUM WALL THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>24&quot; to 30&quot;</td>
<td>3&quot;</td>
</tr>
<tr>
<td>36&quot;</td>
<td>3½&quot;</td>
</tr>
<tr>
<td>42&quot;</td>
<td>4&quot;</td>
</tr>
<tr>
<td>48&quot;</td>
<td>5&quot;</td>
</tr>
<tr>
<td>54&quot;</td>
<td>5½&quot;</td>
</tr>
<tr>
<td>60&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>66&quot;</td>
<td>6½&quot;</td>
</tr>
<tr>
<td>72&quot;</td>
<td>7&quot;</td>
</tr>
<tr>
<td>84&quot;</td>
<td>8&quot;</td>
</tr>
<tr>
<td>96&quot;</td>
<td>9&quot;</td>
</tr>
<tr>
<td>108&quot;</td>
<td>10½&quot;</td>
</tr>
<tr>
<td>120&quot;</td>
<td>12&quot;</td>
</tr>
</tbody>
</table>

The Contractor shall provide adequate means of providing fresh air delivery to the inside of the pipe. This shall be for the use of workers during construction and for the use of the City Engineer during inspection. The methods and quantities of fresh air delivery shall be suitable for the purpose and shall conform to applicable requirements of local, state and federal rules, regulations, laws and ordinances.

2.13.07 VIDEO INSPECTION
(Cleaning and Closed-Circuit Television Inspection of Newly Constructed Storm Drain Pipelines)
A. Objective

These specifications define the minimum requirements for the preparatory cleaning and closed-circuit television (CCTV) inspection of newly constructed storm drainage pipelines, and for required warranty CCTV inspections of pipelines. The purpose of this work will be to determine the condition of the pipeline, document the location of connections and other key features, identify any structural deficiencies, and to locate defects that may be allowing groundwater to infiltrate into the pipeline. All storm drains shall be CCTV inspected at the completion of construction and at the one-year warranty. A ¾” or 1” gauge shall be used for all CCTV inspections.

B. General

Experienced and pre-qualified personnel utilizing equipment and materials meeting the requirements of these specifications shall perform all work. Pre-qualification shall require that the contracting company and the job supervisor each have a minimum of three (3) years experience in the performance of the type of work specified and shall have specifically performed at least 100,000 feet of cleaning and television inspection within the past three years. A company with less than three (3) years experience may pre-qualify if they can demonstrate to the satisfaction of the City that they have the capabilities and overall experience, equipment and expertise to satisfactorily complete the project in accordance with these specifications.

All work shall be performed to the minimum standards of the industry. Where not conflicting with the requirements of these specifications, the most current available edition of the National Association of Sewer Service Companies (NASSCO) Specifications Guidelines and the NASSCO Inspector Handbook shall be used as a measure of the standard of practice for this work.

The Contractor shall use designated City and standard industry terminology in the performance and documentation of the CCTV inspection work. A pipeline joint, as used within these specifications, refers to the junction of two pipes. The term, “manhole section” as used in these specifications shall mean the length of pipe connecting two manholes or a manhole and a clean-out.

Before final acceptance of the work by the City, the Contractor shall review with the City the findings of the fieldwork to confirm that all necessary work has been performed as needed. This shall include a review of finished written records of defects found, the videotapes, and any sketches or diagrams prepared to illustrate defects found. Videotapes or other acceptable electronic files shall be submitted to the City and become the property of the City.

2.13.08 VERTICAL GRADE / STANDING WATER ALLOWANCE

Any new installed storm drain pipe up to 10 inches in diameter shall have no more than 1/2 inch of standing water in the flow line after construction is completed (3/4 inch for pipes larger than 10 inches). After one year, as part of the warranty inspection, the storm drain pipe shall not have more than 3/4 inch of standing water in the flow line (1 inch for pipes larger than 10 inches). Laterals shall have no standing water in the flow line after construction is completed and after one year of construction. This standing water measurement shall be taken during televised inspections of the storm drainage lines and laterals (see section 2.13.07, “Video Inspection” of these City Standard Specifications), after water is introduced and allowed to leave for measurement indicator to function correctly.
2.13.09 CAPS/STOPPERS

Caps or stoppers shall be furnished with branch pipes that are to be left unconnected. Caps and stoppers shall be prefabricated and watertight fitting the bell of the branch pipe and installed according to the manufacturer’s recommendations.

2.14 STORMWATER QUALITY

In order to achieve compliance with the State Water Resources Control Board’s National Pollutant Discharge Elimination System (NPDES) General Permit for Small Municipal Separate Storm Sewer Systems (2013-0001-DWQ) development activity shall implement stormwater quality control measures and best management practices and shall also comply with Chapter 8.36, “Stormwater Runoff Pollution Control”, of the City of Napa Municipal Code (NMC).

Any construction activity that results in the disturbance of one (1) acre or greater total land area, or is part of a larger common plan of development that disturbs one (1) acre or greater total land area, the developer shall file a Notice of Intent with the California State Water Resources Control Board ("SWRCB") and obtain a Waste Discharger Identification (WDID) number prior to any grading or ground disturbing activities. Construction activity resulting in less than (1) acre of land disturbance must follow an approved Erosion and Sediment Control Plan (ESCP).

Industrial/commercial facilities shall file a Notice of Intent with the State Water Board in accordance with the Industrial General Permit prior to establishment of the use.

Development projects shall incorporate Low-Impact Development (LID) standards designed to reduce runoff, treat storm water, and provide baseline hydromodification management.

Development projects over an acre in the City of Napa are required to limit the post-development peak stormwater runoff discharge rate leaving certain projects to the estimated pre-development discharge rate.

2.14.01 POST CONSTRUCTION SITE DESIGN MEASURES

All projects creating and/or replacing between 2,500 square feet and 5,000 square feet of impervious surface and are not part of a larger development shall incorporate site design measures to treat and infiltrate stormwater runoff.

Projects that create and or replace more than 5,000 square feet of impervious surface are required to treat stormwater runoff by incorporating site design measures using LID standards.

Regulated projects shall incorporate source control measures for all pollutant generating activities where applicable.

Low Impact Development Standards shall be met by all regulated projects.

Projects that create and or replace more than one acre of impervious surface shall incorporate hydromodification management into the project to match pre-project flow rates. Post project runoff shall not exceed the estimated pre-project flow rate for both the 2-year, 24-hour storm and the 10-year, 24-hour storms events.

The responsible entity shall enter into a long-term maintenance agreement for the maintenance of post construction stormwater quality treatment facilities with the City of Napa.
A long-term operations and maintenance plan shall be incorporated as part of the agreement and shall include a viable method of long term financing for such maintenance, inspection verification reporting and a third party beneficiary agreement. If the Homeowners Association, or other responsible entity, fails to maintain the post construction treatment facilities, then the City shall enforce the maintenance through this agreement.

The third party agreement shall allow, but not limit, the City of Napa to force the HOA, or other entity, to do the work, the right to enter onto the property to do the work, the right to charge for the work completed by the City of Napa, or its contractor, and the right to establish a lien to recoup the cost of the work.

Complete post construction design details can be found by referring to the City adopted BASMAA Post Construction Manual.

2.15 MISCELLANEOUS ITEMS

2.15.01 CREEK SETBACKS

The Napa Municipal Code Chapter 17.52.110 regulates the requirements for stream bank safety and protection and enhancement of riparian habitat corridors.

2.15.02 FENCING

All open channels shall be enclosed by a 6’ high chain link fence per Caltrans Standard Plan A85, or other type as approved by Public Works Director or designee.

The fence shall be located 6 inches inside the required easement lines. Gates must be provided for access through any fence crossing a public storm drain easement. Where vehicular access is required for maintenance, minimum 14’ wide gates must be provided with sliding gates preferred. Where vehicular access is not required 4’ wide gates for pedestrian access must be provided.

2.15.03 SERVICE ROADS

Two service roads shall be provided within the boundary of all open channels. They shall be a minimum of 17 feet wide, each graded for vehicular traffic and clear of trees, shrubbery and other obstructions for its full width. Fourteen feet of the road’s width shall be paved or graveled all-weather (surface type to be determined by the Public Works Director or their designee for each case) with a minimum unpaved shoulder width of 1-foot on each side of the roadway. Service roads are required on both sides of the channel.

2.15.04 FLOOD CONTROL

Flood Plain regulations apply to all new and redevelopment, which would be inundated by the 100-year flood (Floodway and Hazard Area) and are contained in NMC Chapter 17.38. There are several basic requirements which must be met including but not limited to the following:

- All applications for a floodplain permit shall include plans drawn to scale showing at a minimum the nature, location, dimension, and elevation of the area in questions, existing or proposed structures, fill, storage of materials or equipment, and drainage facilities.
• All new residential construction and substantial improvements to residential units must have the lowest floor, including basement, elevated to one foot or more above the base flood elevation.

• All new non-residential construction and substantial improvements to non-residential structures must have the lowest floor, including basement, elevated to one foot or more above the base flood elevation or be flood proofed to one foot or more above the base flood elevation.

• All attendant utilities and sanitary facilities must be constructed to resist flood damage.

• Upon completion of the building the elevation of the lowest floor including basement shall be certified by a professional engineer or surveyor and verified by the Building Inspector.

• Flood evacuation plans required by NMC Chapter 17.38.070, Additional Regulations for Certain Residential Development in Portions of the Floodplain (Flood Evacuation Area) shall be completed and approved by the City prior to occupancy of residential structures in the floodplain evacuation area.
2.16 CHARTS AND FIGURES

2.16.01 CHARTS

Chart 2.1 Flow in Triangular Gutter Sections
Chart 2.2 Isohyetal Map of Napa City
FLOW IN TRIANGULAR GUTTER SECTIONS

NOTES

1. FOR V-SHAPE, USE THE NOMOGRAPH
   WITH $S_x = (S_{xt}/S_{x3})^{1/3}$

2. TO DETERMINE DISCHARGE IN GUTTER
   WITH COMPOSITE CROSS SLOPES, FIND
   $Q_3$ USING $T_3$ AND $S_x$, THEN, USE CHART
   A TO FIND $D_0$. THE TOTAL DISCHARGE IS
   $Q = Q_3/[1-D_0]$ AND $Q_w = Q - Q_3$.

$Q = 0.0058 \cdot 0.37 \cdot T^2 \cdot S_x^2$

$Q = \text{FLOW RATE, CFS}$

$T = \text{WIDTH OF FLOW \{SPREAD\}, FT}$

$S_x = \text{CROSS SLOPE, FT/FT}$

$S_w = \text{CROSS SLOPE OF GUTTER, FT/FT \{MEASURED FROM CROSS SLOPE OF PAVEMENT\}}$

$S = \text{LONGITUDINAL SLOPE, FT/FT}$

$N = \text{MANNING'S COEFFICIENT}$

FLOW RATE
($N=1.016$)

$Q_3 = \text{FLOW RATE, CFS}$

$T_3 = \text{WIDTH OF FLOW \{SPREAD\}, FT}$

$S_x = \text{CROSS SLOPE, FT/FT}$

$S_w = \text{CROSS SLOPE OF GUTTER, FT/FT \{MEASURED FROM CROSS SLOPE OF PAVEMENT\}}$

$S = \text{LONGITUDINAL SLOPE, FT/FT}$

$N = \text{MANNING'S COEFFICIENT}$

CHART A
2.16.02 FIGURES

Figure 2.1  City of Napa Discharge vs. Drainage Area
Figure 2.2  Residential Area 10-Year Peak Flow - 0 to 80 Acres
Figure 2.3  Commercial Area 10-Year Peak Flow - 0 to 80 Acres
Figure 2.4  Rural Area 10-Year Peak Flow - 0 to 80 Acres
Figure 2.5  Residential Area 100-Year Peak Flow - 0 to 80 Acres
Figure 2.6  Commercial Area 100-Year Peak Flow - 0 to 80 Acres
Figure 2.7  Rural Area 100-Year Peak Flow - 0 to 80 Acres
Figure 2.8  Tc+R and Area Relationship for Napa
Figure 2.9  Bank and Shore Protection
Figure 2.10 Salvador Drainage Basin
y = 1.5691x^{0.5488}

1971 Linda Vista Drainage Study By HJK, 1-5-71
COE Appendix D, June 1995
Rational Method
Power (1971 Linda Vista Drainage Study By HJK, 1-5-71)

CHART IS FROM CITY OF NAPA 2006 STORM DRAIN MASTER PLAN FIGURE 3-2