

SECTION 9
STORM DRAINAGE

CONTENTS	Page	
9-1	General Requirements.....	9-1
9-2	Definitions	9-2
9-3	Federal Flood Program	9-2
9-4	Drainage Diversions.....	9-2
9-5	Drainage Easements.....	9-3
9-6	Stormwater Detention and Storage	9-3
9-7	Design Computation	9-4
9-8	Design Runoff.....	9-5
9-10	Closed Conduits	9-6
	A. Material.....	9-6
	B. Cover Requirements	9-6
	C. Trench Requirements.....	9-8
	D. Spacing Requirements	9-8
	E. Alignment Requirements	9-8
	F. Velocity.....	9-8
	G. Entrances and Exits.....	9-9
	H. Water and Soil Tight System Testing	9-9
	I. Jack and Bore Pipe.....	9-10
9-11	Manholes.....	9-10
9-12	Junction Boxes	9-11
9-13	Inlets.....	9-11
9-14	Pipe Stubs	9-13
9-15	Headwalls, Wingwalls, Endwalls, Trash Racks, Access Control Racks And Railings	9-13
9-16	Drainage Pumps	9-14
9-17	Open Channels	9-14
9-18	Outfall Design.....	9-15
9-19	Fencing Requirements	9-15
9-20	Cross Culvert Criteria	9-16
9-21	Drainage Along Class “C” Streets	9-16

SECTION 9 STORM DRAINAGE

9-1 GENERAL REQUIREMENTS

- A.** The planning, design and construction of local drainage facilities and other related appurtenances to be owned, operated, and/or maintained by the County of Yolo shall comply with these standards.
- B.** Design rainfall data is provided in the “Yolo County City/County Drainage Manual”, and is incorporated herein by reference.
- C.** The “Yolo County City/County Drainage Manual” provides guidance for the planning, design, and construction of regional drainage facilities serving multiple communities, and may be referenced for criteria not addressed in these standards.
- D.** A registered Civil Engineer shall stamp and sign all design calculations prior to submission for plan review. All work shall be in accordance with these design standards and standard engineering practice.
- E.** The County Engineer shall decide all questions of interpretation of "good engineering practice" guided by the standards and manuals of the discipline in question.
- F.** All drainage facilities shall be located within County roads and streets or publicly dedicated easements unless otherwise approved by the County Engineer. Adequate access for maintenance of the system shall be provided.
- G.** All new habitable structures shall be protected from the 100-year (1%) flood event and all public roads are protected from the appropriate design flood events, unless more stringent standards are required by state law.
- H.** Finished floor elevations shall be set at least one foot (1') above the 100-year floodwater surface.
- I.** The design of a new storm drain system shall include consideration of the downstream creek or storm drain. The Design Engineer shall show that the existing storm water system can convey the proposed drainage without adverse upstream, downstream and adjacent impacts and that the upstream, downstream or adjacent facilities are being improved to carry post project flows.
- J.** Any development within a drainage area, for which the Board of Supervisors has adopted a drainage plan pursuant to Yolo County Code Section 8-1.1601, shall pay the required fee prescribed in the plan prior to approval of a Final Map or Parcel Map.
- K.** Development shall not:
 - 1. Result in any new or additional expense to any person other than the developer or beneficiary for flood protection or for lost environmental stream uses and functions; nor
 - 2. Significantly increase flood elevations or decrease flood conveyance capacity upstream or downstream of the development; nor
 - 3. Pose any new or additional increase in flood velocity or impairment of the hydrologic and hydraulic functions of streams and flood plains unless a watershed benefit is realized; nor
 - 4. Significantly degrade surface or ground water quality
- L.** A Developer must demonstrate to the County Engineer’s satisfaction that for all storm events, up to and including the critical duration 100-year event, the grading activity does not:
 - 1. Result in an increase in peak release rate; and,
 - 2. Result in a time decrease associated with the time of concentration; and,
 - 3. Contribute to adjacent flood problems; and,

4. Significantly alter the direction of runoff.
- M. Stormwater facilities shall be functional before building permits are issued in residential and nonresidential subdivisions.

9-2 DEFINITIONS

The following terms, abbreviations or definitions shall apply and the intent and meaning shall be interpreted as stated herein wherever they are encountered in these standards or in any documents or instruments referenced by these standards unless otherwise approved by the County Engineer.

<u>Abbreviation</u>	<u>Description</u>
ASTM	American Society for Testing and Materials.
FEMA	Federal Emergency Management Agency.
Right-of-Way	A strip of land dedicated, condemned or reserved for public use.
Drainage Easement	A strip of land dedicated, condemned or reserved for drainage use.
Overland Release Path	An alignment that allows the passage of floodwater through a development without damaging structures.

9-3 FEDERAL FLOOD PROGRAM

- A. The County of Yolo is a participant in the National Flood Insurance Program and all development in the County shall comply with the regulations of the Federal Emergency Management Agency (FEMA). Amendments or revisions of FEMA flood maps will be required for all commercial and subdivision development located in a federal Special Flood Hazard Areas (Zones A, AO, A1-30, AH, A99, or AE) flood zone. Petitions for a Letter of Map Amendment (LOMA) or Letter of Map Revision (LOMR), including any fee required by FEMA, shall be submitted to the Department before improvement plans are approved. These regulations do not preclude the Department from requiring additional standards to protect the public from projected runoff.
- B. Fill for the removal of land from a designated FEMA 100-year floodplain, or a watercourse where building pads will be created, must be compacted to 95 percent (95%) of the maximum density obtainable with the modified proctor test method (ASTM Standard D-1557) or an equivalent test method.

9-4 DRAINAGE DIVERSIONS

- A. The diversion of natural drainage is allowable only within the limits of the proposed improvement. All drainage must enter and leave the improved area at its original horizontal and vertical alignment unless an agreement, approved by the County Engineer, has been executed with the adjoining property owners or drainage is being discharged into a public right-of-way or other existing drainage feature.
- B. Temporary drainage diversions during construction may be approved by the County Engineer and shall be located and constructed in such a fashion as to permit their removal when necessary for the prevention of damage to adjoining properties.

9-5 DRAINAGE EASEMENTS

- A. Publicly owned drainage conduits and channels will not be allowed on private property, however in unusual circumstances, where the County Engineer or designee has given prior approval, storm drain facilities may be placed in easements. Such easements must be wide enough to accommodate normal construction equipment and shall be easily accessible to such equipment as necessary to construct, operate and maintain the facility. The easement shall be offered to the County of Yolo or other public entity responsible for storm drainage system operation and maintenance.
- B. Where improvements fall on adjacent property (such as daylighting ditch profiles) written permission from the adjacent property owner(s) for such construction shall be required. A copy of the documents which grant such approval shall be submitted to the County Engineer before approval of the improvement plans.
- C. When storm water discharge from a proposed upstream development enters a downstream conveyance on private property, the Department may require that the Developer obtain an easement to be publicly dedicated for operation and maintenance of the conveyance.
- D. In the event necessary permanent offsite easements cannot be acquired through negotiation, the County will condemn necessary rights-of-way providing the person, firm, or corporation requesting such condemnation enters into a written agreement to pay all costs and expenses of the condemnation. The agreement shall require a cash deposit that will consist of the estimated cost of condemnation plus 50%, including, but not limited to, land or easement purchase cost, temporary construction easements, staff, appraiser and attorneys fees. It shall require payment of all costs and expenses of the deposit as specified by the County. Any unspent funds will be returned.
- E. Acquisition and maintenance of temporary construction easements outside of the limits of the subdivision shall be the Developer's responsibility.
- F. Easements for storm drains shall meet the following width criteria:
 - 1. All easements for closed conduits shall have a minimum width equal to the greater of fifteen feet (15') or the required trench width according to the standard detail for pipe bedding and initial backfill plus two feet (2') of additional width for every foot of depth as measured from the bottom of the pipe to finished grade, whichever is greater. Exceptions to the minimum width require approval by the County Engineer.
 - 2. All conduits shall be centered within their easements.
 - 3. Drainage easements for open channels shall have sufficient width to contain the ultimate channel, fencing where required and a twenty-foot (20') service road with drainage ditch. Additional width shall be provided to allow equipment to safely negotiate the service road for the purposes of construction, operations and maintenance activities.
 - 4. Easements shall not be split along property lines.

9-6 STORMWATER DETENTION AND STORAGE

- A. Sufficient stormwater detention volume shall be provided such that the probability of the post development release rate exceeding 0.1 cfs/acre of development shall be less than one percent (1.0%) per year. The stormwater detention volume shall not be less than the difference between pre- and post- development flows from the development site in the 100-year, 24 hour storm event.
- B. Stormwater detention facilities shall be designed and constructed with the following characteristics:

1. Maximum side slopes of 1(vertical):3(horizontal), unless flatter slopes are indicated due to geotechnical conditions.
 2. Minimum 1 foot freeboard provided at design capacity, or as needed to account for wave action anticipated due to special wind conditions.
 3. Detention pond bottoms shall be sloped at 2%; flatter slopes may be allowed by the County Engineer in special cases.
 4. The detention facility shall be accessible in all weather conditions for maintenance personnel and equipment, and shall be designed to be easily maintained.
 5. Detention facilities shall provide an overflow structure and overflow path that can safely pass excess flows through the development site. Overflow elevation and route to be at least 1' below any top of foundation of development and nearby existing structures. The minimum design rate for overflows shall be 1.0 cfs/acre of area tributary to the detention facility.
 6. All outlet works shall function under gravity, without human intervention or outside power and shall operate with minimum maintenance, unless approved by the County Engineer.
 7. Water surface depths two feet above the base flood elevation will not damage the detention facility.
 8. Detention facilities shall facilitate sedimentation and catchment of floating material.
 9. Detention facilities shall minimize impacts of stormwater runoff on water quality by incorporating Best Management Practices.
 10. Detention facilities shall store the required site runoff under all stream flow and backwater conditions up to the base flood elevation.
 11. Detention facilities shall not allow design release rates to be exceeded under any stream elevation less than the base flood elevation.
 12. The detention facility shall be designed to allow for the 2- year predevelopment storm event flows to bypass the basin. When overland channels are required in basins, they shall be concrete lined, and shall not conflict with other potential uses of the basin.
- C.** Developments with stormwater detention facilities that have off-site flow tributary to the site either shall provide detention sufficient to accommodate runoff from the off-site tributary watershed and the site, or shall store the site runoff and convey off-site flows through the development while preserving the existing flow and storage of the site.
- D.** Stormwater detention facilities may be located off-site if the following conditions are met:
1. The off-site detention facility meets all of the requirements of these Improvement Standards;
 2. Adequate detention capacity in the off-site facility is dedicated to the development; and
 3. The development includes provisions to convey stormwater to the off-site detention facility.
- E.** Detention pond fencing shall comply with Section 9-19.

9-7 DESIGN COMPUTATION

- A.** The “Yolo County City/County Drainage Manual” provides design rainfall data for use throughout Yolo County.
- B.** All drainage systems shall be designed to accommodate the ultimate development of the entire upstream watershed. The peak discharge from the 10-year design storm shall be used in the

design of local drainage systems components (closed conduits and gutters.) All open channel drainage systems shall be designed for both the 10-year and the 100-year frequency design storm conditions, with freeboard as required by the County Engineer.

- C.** The Design Engineer shall design an overland release path which ensures that the 100-year-design storm flows through the proposed development will prevent flooding to existing and proposed structures in the event of malfunction or overloading of the drainage system. The overland release path shall be shown on the grading plan for the project. The overland release path shall be designed and constructed in a manner to transport the peak rate of runoff from the 100-year frequency storm falling on fully developed and saturated tributary watershed. Streets, parking lots, playgrounds, pedestrian areas, pedestrian walkways, utility easements and other open space areas may be considered compatible uses with the overland release.
- D.** The design computations for drainage shall include the following information that shall be submitted before the plans will be accepted for checking:
1. Topographic map showing existing and proposed ground elevations that show on-site and off-site watershed boundaries draining onto the site. It shall also include total and sub-shed areas in acres.
 2. Quantity of flow (cfs) to each structure with corresponding area and land uses that generate the quantity.
 3. Quantity of flow (cfs) in each pipe.
 4. Flow line elevation of manhole or structure.
 5. Top of structure elevation.
 6. Hydraulic grade line elevation at each structure.
 7. Hydraulic gradient.
 8. Pipe size, type, class, length and gradient.
 9. Channel dimensions, flow and water surface profile computations.
 10. Electronic copies of all computer input files used for analysis and design on an acceptable electronic media.

9-8 DESIGN RUNOFF

- A.** For all watersheds greater than 10 acres, design runoff volumes shall be calculated using continuous simulation or event hydrograph methods. If event hydrograph methods are used to calculate design runoff volumes, they must be either HEC-1 SCS runoff method with outlet routing option, TR-20 with outlet control routing option, or TR-55 tabular method with outlet control routing, HEC-HMS, HEC-RAS, or EPA Storm Water Management Model (SWMM). Event methods shall incorporate the following assumptions:
1. Antecedent moisture condition = 2; and
 2. Huff or SCS Type II rainfall distribution; and
 3. Twenty-four (24) hour duration storm with a one percent (1.0%) probability of occurrence in any one year.
- B.** For sites where the undeveloped release rate is less than the maximum release rate of 0.1 cfs/developed acres, the developed release rate and corresponding site runoff detention volume shall be based on the existing undeveloped release rate for the development site.

- C. All hydrologic and hydraulic computations must be verified under the full range of expected downstream water surface elevations, from low flow through the base flood elevation.
- D. Responsibility for maintenance all detention facilities shall be provided for either through the establishment, or incorporation into, a County Service Area, or establishment of a financing mechanism with Conditions, Covenants and Restrictions recorded against the properties served by the facility.
- E. The longest flow paths shall be documented and shown on watershed map.

9-9 HYDRAULICS

All storm drain pipelines and open channels shall be designed to convey the design peak runoff and shall conform to the following requirements:

- A. **Hydraulic Grade Line** – The hydraulic grade line for the 10-year discharge shall be a minimum of one foot below all inlet grates, manhole covers, and all other drainage structures in the system. The hydraulic grade line shall be shown on the plans when it is above the top of the pipe.
- B. **Manning's Formula** - The "n" value used in Manning's formula shall conform to the following:
 1. Manning's formula shall be used to compute capacities of all open and closed conduits other than culverts.
 2. A minimum "n" value of 0.015 shall be used for sizing conduits.
 3. Minimum velocity in closed conduits shall be 2.5 feet per second. Maximum velocity shall be 5 feet per second. Velocities shall be based on full flow conditions.
- C. A flap gate shall be installed in all laterals that flow into a mainline storm drain whenever the hydraulic grade line of the main line is higher than the surrounding area drained by the lateral. The flap gate must be set back from the main line drain so that it will open freely and not interfere with the main line flow. A junction structure shall be constructed for this purpose.

9-10 CLOSED CONDUITS

The specific type of pipe to be used in the development shall be shown on the plans. The minimum inside diameter for storm drain pipes shall be eighteen inches (18"). No storm drain conduit shall have a diameter less than that of the conduit immediately upstream of it. Drainage systems shall be constructed of the following materials.

- A. **Material**
 1. Reinforced Concrete Pipe - Class III reinforced concrete pipe, minimum, conforming to ASTM C76, latest revision. The Design Engineer shall specify on the plans that the assembly of joints shall be in accordance with the pipe manufacturer's recommendations and the requirements of ASTM C 443.
 2. High Density Polyethylene Pipe
 - a. High Density Polyethylene Pipe (HDPE) may be used upon written approval of the County Engineer, and shall be backfilled with lean concrete backfill.
 - b. HDPE pipe shall be double wall, ribbed, meeting the requirements of ASTM F 667, with splice collars and flared end sections.
 3. Corrugated Metal Pipe
 - a. Corrugated Metal Pipe may only be used for private driveway cross culverts and shall be privately owned and maintained by the adjacent property owner.
 - b. Corrugated metal pipe shall be 16 gauge (minimum) corrugated steel, with splice collars and flared end sections.
- B. **Cover Requirements** At locations where the minimum cover requirements cannot feasibly be obtained, the conduit shall be either encased in concrete or provided with a concrete cover or other

methods of pipe protection as approved by the County Engineer. Cover shall be measured from the top of a rigid pavement or the bottom of a flexible pavement.

1. Minimum and Maximum Cover - The minimum cover height shall be per Table 9-1. The maximum cover shall be per Table 9-2.

TABLE 9-1 MINIMUM PIPE COVER REQUIREMENTS	
Pipe Material Type and Location	Minimum Cover Requirement
Reinforced Concrete under rigid pavements	A nine-inch (9") space between top of pipe collar and bottom of slab consisting of compacted granular fill shall be maintained at a minimum.
Reinforced Concrete in unpaved areas and under flexible pavements	1/8 the diameter or rise (the greater of) but not less than twelve inches (12")
Corrugated Metal or Ribbed HDPE driveway cross culverts	Twelve inches (12") gravel or earth Six inches (6") asphalt or Portland cement concrete
Note: All depths shown are for a minimum trench width equal to the outside diameter of the pipe plus sixteen inches (16") measured at the top of the pipe collar.	

TABLE 9-2 MAXIMUM PIPE COVER REQUIREMENTS – CONCRETE PIPE						
DIA.	RCP					Cast In Place
	Class					
	I	II	III	IV	V	
12	Not Permitted	Not Permitted	12	30	No Limit	Not Permitted
15			15	35		
18			16	38		
21			17	39		
24			18	39		
27			19	39		
30			19	38		
33			20	38		
36			17	27	69	
42			18	29	62	
48			19	30	60	
54			20	31	58	
60			21	31	57	
66			22	32	56	
72			23	33	56	
Note: 1. All depths shown are for a minimum trench width equal to the outside diameter of the pipe plus 24" measured at the top of the pipe. 2. Depths are measured to bottom of trench in feet.						

2. Temporary Construction Vehicle Loading: A note shall be made on the plans stating the minimum cover requirements during construction for temporary construction vehicle loading. For metal pipes, place at least four feet (4') of cover over the top of the pipe. For reinforced concrete pipe, place at least three feet (3') of cover over the top of the pipe.

C. Trench Requirements

1. Trenches shall be excavated with full depth and vertical sides whenever possible.
2. The minimum trench width shall not be less than the outside diameter of the pipe barrel plus twenty four inches (24"), measured at the top of the pipe. The maximum trench width shall not exceed six (6) nominal pipe diameters, measured at the top of the pipe.
3. In fill areas, or in areas with poor soil conditions where it is anticipated that a good, firm, vertical-walled trench cannot be constructed, the Design Engineer shall design the pipe structural requirements in accordance with good engineering practice. A note shall be placed on the plans directing the contractor to place the proper strength pipe if trench conditions encountered differ from the design trench.
4. Where conditions require side sloping of trenches, the minimum vertical trench shall be from the bottom of the trench to one foot (1') over the top of the pipe.

D. Spacing Requirements

When multiple lines of pipes or pipe arches greater than forty-eight inches (48") in diameter or span are used, they shall be spaced so that the sides of the pipes shall be no closer than one-half diameter or three feet (3'), whichever is less, to permit adequate compaction of backfill material. For diameters less than forty-eight inches (48"), the minimum clear spacing shall not be less than two feet (2').

E. Alignment Requirements

1. The centerline of drainage pipelines in new streets shall be approximately one foot (1') from the flowline of the gutter, in front of the face of curb. Stormdrain pipes shall be placed to enter the curb inlets at the center of the box.
2. All new storm drains shall be placed a minimum of one hundred feet (100') from existing and proposed water wells. Encroachments less than one hundred feet (100') require approval of the County Environmental Health Department prior to plan approval.
3. Meandering and unnecessary angular changes of pipelines will not be allowed. Angular changes, when necessary, shall be larger than 90 degrees.
4. Pipelines shall be laid straight in both horizontal and vertical planes between manholes unless otherwise approved by the County Engineer.
5. Pipeline Radius Criteria: Special permission must be granted by the County Engineer for any curved gravity pipes. The minimum radius of curvature shall be 200 feet, and shall be 30% larger than the radius of curvature recommended by the pipe manufacturer' for curved alignment. All curves, radii, length of pipe joints, and types of pipe shall be shown on the plans.
6. Where storm drain pipelines of different diameter join, the invert elevations shall be adjusted to maintain a uniform energy gradient.

F. Velocity

1. The minimum full flow velocity shall be no less than two and one half (2.5) feet per second, unless otherwise approved by the County Engineer. The maximum velocity shall be less than the critical velocity at full flow.
2. When full-flowing pipelines that produce velocities greater than five (5) feet per second are approved by the County Engineer, special provisions shall be taken to prevent erosion or pipe displacement and to keep the EGL contained underground.

G. Entrances and Exits

1. Headwalls and other structures shall be designed to increase hydraulic efficiency, prevent erosion adjacent to the conduit and provide a counterweight to prevent flotation.
2. Where exits are necessary, headwalls or flared end sections should be used for culverts. Where drainage systems discharge into a channel, standard headwalls shall be installed per the Caltrans Standard Plans. The vertical face of the headwall shall be set back a sufficient distance from the channel side slope to accommodate flap gates or duckbill-style check valves, as approved by the County Engineer, in a fully opened position without encroachment of the flap past the channel side slope face.
3. Energy dissipation shall be designed at outlets where velocities are erosive.

H. Water and Soil Tight System Testing

1. All storm drain pipe, manholes, and fitting connections shall be water and soil tight.
2. All stormdrain lines and manholes shall be tested for acceptability following placement of aggregate base, but prior to paving, using low pressure air, or hydrostatic testing. No sealant shall be used in any newly installed storm drain without the prior approval of the County Engineer. Using sealant in a storm drain is not the equivalent of a sound storm drain pipe. Structural repair work shall be approved by the County Engineer. The County inspector shall witness all low-pressure air tests and verify the accuracy and acceptability of the equipment utilized.
3. Table 9-3 specifies minimum times required for a one pound per square inch, gauge (1 psig) pressure drop from a starting pressure of at least three and one-half pounds per square inch, gauge (3.5 psig) greater than the average back pressure of any groundwater above the pipe's invert.

TABLE 9-3 MINIMUM TIME REQUIRED FOR A 1.0 PSIG PRESSURE DROP FOR LOW PRESSURE AIR TEST											
Pipe Dia. (in.)	Min. Time (minutes)	Length for Minimum Time (ft)	Time for Longer Length (sec)	Minimum Time for Length (L) Shown (minutes:seconds)							
				100	150	200	250	300	350	400	450
12	11:20	199	3.418L	11:20	11:20	11:24	14:15	17:05	19:56	22:47	25:38
15	14:10	159	5.342L	14:10	14:10	17:48	22:15	26:42	31:09	35:36	40:04
18	17:00	133	7.692L	17:00	19:13	25:38	32:03	38:27	44:52	51:16	57:41
21	19:50	114	10.470L	19:50	26:10	34:54	43:37	52:21	61:00	69:48	78:31
24	22:40	99	13.674L	22:47	34:11	45:34	56:58	68:22	79:46	91:10	102:33
27	25:30	88	17.306L	28:51	43:16	57:41	72:07	86:32	100:57	115:22	129:48
30	28:20	80	21.366L	35:37	53:25	71:13	89:02	106:50	124:38	142:26	160:15
33	31:10	72	25.852L	43:05	64:38	86:10	107:43	129:16	150:43	172:21	193:53

36	34:00	66	30.768L	51:17	76:55	102:34	128:12	153:50	179:29	205:07	230:46
----	-------	----	---------	-------	-------	--------	--------	--------	--------	--------	--------

4. For hydrostatic testing, the water exfiltration for any length of the storm drain pipe between manholes shall be measured and shall not exceed five hundred (500) gallons per inch of internal pipe diameter per mile of pipe per day. During exfiltration testing, the maximum internal pipe pressure at the lowest end shall not exceed eleven feet (11') of water or 5.0 psi and the internal water head shall be two feet (2') higher than the top of the pipe or two feet (2') higher than the ground water level, whichever is greater. Vacuum go/no-go testing method or alternate testing methods may be submitted for thirty-inch (30") or greater internal diameter pipes.
5. A note shall be placed on the improvement plans stating these requirements and that the contractor is responsible for providing equipment and labor for performing tests and making measurements when directed to do so by the County’s inspector.

I. Jack and Bore Pipe

Where use of conductor casing is specified, the casing shall be reinforced concrete pipe, or welded steel pipe. The casing shall be of sufficient diameter to allow dry sand to be blown into the void between the carrier and the conductor and to allow adjustment of the carrier pipe to grade. Normally, an inside diameter of the casing that is six inches greater than the outside diameter of the couplings of the storm drain pipe is sufficient. Welded steel conductor pipe shall have a minimum wall thickness of ¼ inch for sizes up to and including 24 inches in diameter and 5/16 inch for sizes 27 inches to 36 inches in diameter. Every reinforced concrete pipe conductor must be designed for the loading condition and, if jacked, the additional loading imposed by the jacking operation.

Direct dry boring of reinforced concrete pipe and of the portion of storm drain pipes which pass beneath curbs and gutter, sidewalks, and other obstructions, up to a maximum length of 15 feet, is permissible. Installation and other material specifications shall conform to the requirements of the Caltrans Standard Specifications.

Backfill in bore pits shall be given special attention with respect to preventing structural failure of the pipe entering or exiting the conductor, and adequate bedding and initial backfill shall be specified. The ends of the casing shall be sealed to the storm drain pipe to prevent loss of the sand packing. Voids created outside the casing due to cave-ins shall be backfilled to the satisfaction of the County Engineer.

9-11 MANHOLES

- A. Standard precast concrete manholes shall be used except where special manholes or junction boxes are required. The design must be submitted to the County Engineer for approval. In no case will junction boxes or manholes be allowed which are smaller than forty-eight inches (48") greatest inside dimension. Precast concrete manholes shall be manufactured in accordance with ASTM C 478.
- B. Manholes shall be located at junction points, and changes in conduit size. On curved pipe lines, manholes shall be placed at the B.C. and E.C. and on 200-foot maximum intervals along the curve.
- C. Spacing of manhole, junction boxes or inlets of such size as to be accessible for maintenance shall not exceed 400-feet for drains between eighteen inches (18") and forty-eight inches (48") in diameter, and 500-feet for pipes equal to or greater than fifty-four inches (54") in diameter. The

spacing of manholes shall be nearly equal whenever possible. Manholes shall not be placed in roadway intersections unless necessary as a junction point.

- D. All manholes and junction boxes other than inlets shall have standard manhole frames and covers as shown in Standard Drawings 9-3 and 9-4. Manholes will not be allowed in the gutter flow line.
- E. Slotted manhole covers may be used to pick up minor drainage in non-traffic areas. Covers shall conform to Standard Drawing 9-5.
- F. Improvement plans shall include a special detail for all manholes at junction points where there is a change in pipe direction and pipe diameter exceeds forty-eight inches (48").
- G. The maximum 24” barrel section height is twelve inches (12”).
- H. Resilient connectors are required between the manhole and pipe as shown in Standard Drawing 9-14. The resilient connector shall be manufactured in accordance with ASTM C 923. Use of non-shrinking or expansive grout for making connections of pipe and water stop to manhole walls is required.
- I. Preformed plastic gaskets are required between manhole barrel sections.

9-12 JUNCTION BOXES

Drop inlets may be used as junction boxes provided that no pipe entering or leaving the box is larger than 18 inches inside diameter. For any junction box with a pipe 21 inches or larger in diameter, the inlet shall have a manhole base and top slab. The inlet shall be mounted on top of the top slab. All other non-inlet junction boxes shall conform to the requirements for manholes. All junctions shall be located in drop inlets or manholes.

9-13 INLETS

Typical curb inlets shall be Caltrans Type “GO” precast curb inlet as shown on Standard Drawing 9-6, with guard rod.

Requirements for inlets are as follows:

- A. Inlets shall be placed so that the length of flow in the gutter does not exceed 300-feet. Exceptions to the 300-foot limit may be granted by the County Engineer, provided the Design Engineer submits hydrology calculation to the satisfaction of the County Engineer that show street inundation will not exceed the limits shown in Table 9-3.

TABLE 9-3 ALLOWABLE STREET INUNDATION		
Street Type	10-Year Storm	100-year storm
Local Residential, Primary Residential	<p><u>At continuous grade:</u> Travel lanes remain clear and do not carry storm water.</p> <p><u>At sag points:</u> Stormwater elevation shall not exceed top back of curb or sidewalk elevation. Maximum depth in travelled way shall be 6 inches.</p>	<p><u>At continuous grade:</u> Minimum depth at gutter flow line shall not exceed 4” above the top back of curb or a maximum of 10”. Maximum depth at centerline shall be 4 inches.</p> <p><u>At sag points:</u> Stormwater shall be a minimum of one foot below building pads. Ponding shall not extend more than 120’ from inlet along any street segment.</p>

	Centerline shall be dry.	
Collector, Industrial	Same as above	Storm water flow is contained within the right of way. The center 12' of roadway shall remain clear of storm water.
Arterials		Storm water flow is contained within the right of way. All travel lanes are clear of storm water flow. Bike lanes are allowed to be inundated.

- B. Inlets shall be placed to minimize the gutter flow at pedestrian crossings & ramps.
- C. The figure below is a cross section of a typical compound gutter.

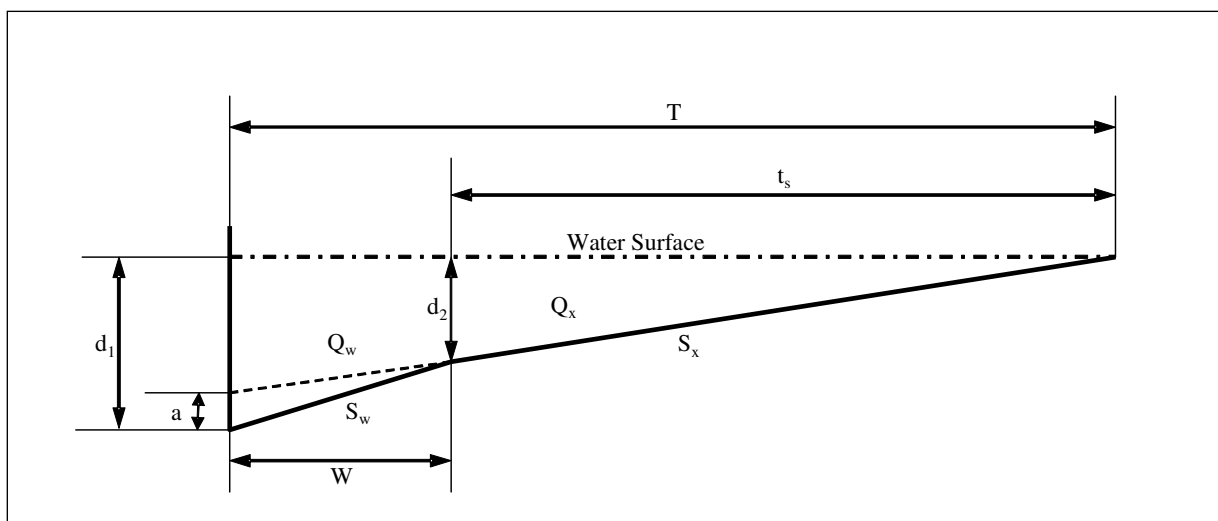


Figure: Flow in Compound Gutters

The equations for determining spread and depth in compound gutter sections are given below.

$$d_1 = TS_x + a \quad S_w = a/W + S_x \quad A = (T^2S_x + Wa)/2$$

$$d_2 = (T - W)S_x \quad t_s = (Q_s n / 0.56 S_x^{5/3} S^{1/2})^{3/8} \quad Q = Q_w + Q_s$$

$$Q_s = 0.56[(T - W)S_x]^{2.67} S^{0.5} / n S_x$$

$$Q_w = 0.56\{(TS_x + a)^{2.67} - [(T - W)S_x]^{2.67}\} S^{0.5} / n(a/W + S_x)$$

Where:

- T = width of flow or spread, ft
- Q = gutter flow rate, cfs
- S_x = pavement cross slope, ft/ft (typically 0.02)
- W = width of depressed gutter section, ft
- S = longitudinal slope, ft/ft
- Q_w = depressed section flow, cfs
- S_w = depressed section slope, ft/ft
- a = gutter depression, ft

9-16 DRAINAGE PUMPS

Drainage pumping plants are generally discouraged, and require that a funding mechanism be established to operate, maintain, and replace the equipment. Drainage pumping plants shall be designed in accordance with the latest edition of the Hydraulic Institute Standards and as specified by the County Engineer. In addition to the requirements for wastewater pumping stations described in Section 7, consideration shall be given to the following minimum criteria:

- Redundant pumping capability.
- Back up power supply, using natural gas or propane (LPG) driven engines.
- Trash cleaning from waste stream during pumping operations.
- Automate control system and telemetry for alarm notification, including integration into any existing SCADA system.
- Minimum life-cycle costs for the pumping facilities including construction costs.
- Site security and lighting.
- Aesthetics such as landscaping and fencing.

9-17 OPEN CHANNELS

- A.** Open channels are required whenever one or more of the following applies:
1. The design flow rate exceeds the capacity of a seventy-two inch (72") pipe.
 2. The outfall is at an elevation such that minimum cover cannot be obtained over the pipe.
 3. County policy, or project approvals, require the channel to remain natural.
- B.** Open channels shall consist of natural earth channels, lined bottom channels or concrete lined channels as approved by the County Engineer.
- C.** Criteria for open channels shall be as follows:
1. Open channel design shall include a water surface profile analysis using the Corps of Engineers HEC RAS computer program or their UNET program or other hydraulic program, if approved by the County Engineer.
 2. Open channels shall be designed to convey the 100-year flood event with a minimum one-foot (1') of freeboard. The County Engineer or FEMA may specify additional levee and freeboard requirements.
 3. Minimum velocity: Two-feet per second (ft/s)
 4. Maximum velocity:
 - i. Earth channels, six ft/s
 - ii. Lined channels, ten ft/s
 - iii. Bottom-lined channels, eight ft/s
 5. The Design Engineer shall determine if super-elevating the outside bank on bends is required.
 6. The centerline curve radius of an open channel shall be equal to or greater than twice the bottom width (thirty -five foot (35') minimum).
 7. Natural earth channels shall be vegetated with native grasses or other permanent vegetative cover as determined by the County Engineer.

8. Channels shall be constructed to a typical cross section. Fully lined channels shall be required where side slopes are steeper than 3 horizontal to 1 vertical (3:1); channels with unlined sides shall be designed with side slopes of 3 horizontal to 1 vertical (3:1) or flatter. The County Engineer may approve exceptions. Standard Drawing 9-8 shall be used in the design of lined channels.
9. All channels shall have a minimum bottom width of six feet (6') and shall have access ramps for maintenance equipment. An access ramp may be required between each set of culverts or other above grade channel obstructions and at the upstream and downstream ends of the channel. Standard Drawing 9-9 shows the typical ramp and transition detail. A twenty foot (20') service road shall be provided having a sixteen-foot (16') improved surface and two-foot (2') shoulders on each side. Roads having a radius tighter than forty-two feet (42') shall require additional width as determined by the County Engineer.
10. For all channels, either improved or natural, the following items shall be shown on improvement plans in addition to information heretofore required:
 - i. Typical sections and cross-sections.
 - ii. Profile of the existing channel and top of bank profile for a minimum of 1,000-feet each side of the development in order to establish an average profile grade through the development.
 - iii. Interceptor Ditches - Interceptor ditches or approved alternates shall be placed at the top of the cut or bank where deemed necessary by the County Engineer to prevent erosion of the channel bank. Runoff shall not be allowed to "sheet drain" over top of bank.
11. Erosion Protection – All natural or graded surfaces disturbed by construction operations shall be protected from erosion by installation of temporary and permanent erosion control improvements. Standard Drawings 9-10 and 9-11 show details for both pipe and ditch discharge erosion.

9-18 OUTFALL DESIGN

Requirements for outfall design are as follows:

- A. All drainage outfalls shall be shown in plan and profile on the improvement plans for a distance of 1,000 feet or until a definite "daylight" condition is established.
- B. All existing and proposed drainage ditches upstream and downstream of the improvement shall be shown on the plans and profile for a distance of at least 500 feet or until an average profile grade through the improvement is established.
- C. The profiles shall include ditch flow-line and top of bank elevations (right and left when different).
- D. When improvements have more than one unit or phase, the drainage outfall shall be shown as extending to the property boundary and beyond, if required, although it may not be constructed with the current unit development. All temporary outfalls shall be shown in both plan and profile on the improvement plans.

9-19 FENCING REQUIREMENTS

The requirements for fencing (see Standard Drawing 9-12) shall be as follows:

- A. Detention facilities, pumping stations and improved channels exceeding four feet (4') in depth with side slopes steeper than 3:1 shall be fenced with six foot (6') chain link fence with slats or tubular steel open style fencing. The approval of the County Engineer is necessary for open style fencing other than chain link fencing.

- B.** In all other areas, fencing shall be placed only upon the recommendation of the County Engineer.
- C.** Drive gates shall be minimum 12-feet (12') wide, and walk gates shall be 4-feet (4') wide minimum. Drive gates shall be set a minimum of 20-feet (20') back from the edge of pavement to allow for a safe parking area off of the traveled way while opening /closing gates. AC paving shall be provided between the traveled way and drive gate. AC paving design shall be per Section 4 – “Transportation” of these Improvement Standards.
- D.** Fences shall be located 6-inches (6") inside the drainage right-of-way and easement lines and a minimum three feet (3') from top of bank.

9-20 CROSS CULVERT CRITERIA

The design of cross culverts shall be as follows:

- A.** Cross culverts shall be designed in accordance with procedures outlined in the U.S. Department of Transportation "Hydraulic Design of Highway Culverts," Hydraulic Design Series No. 5, latest revision.
- B.** Cross culvert size shall be determined based on runoff as specified in these standards.
- C.** Cross culverts shall be checked against 100-year runoff to assure that no adverse effect will occur upstream and downstream because of the higher design event.
- D.** Cross culvert profile will be determined by an examination of the overall profile of the channel for a minimum distance of 500-feet on each side of the installation.

9-21 DRAINAGE ALONG CLASS "C" STREETS

The criteria for design of drainage along Class "C" streets are as follows:

- A.** Roadside ditches shall be sized to convey anticipated runoff. If the roadside ditch extends beyond the dedicated right-of-way, either the right-of way shall be extended to contain the ditch in the right-of -way or a drainage easement shall be dedicated over the portion of the ditch outside the right-of-way.
- B.** Side slopes of roadside ditches shall be per Standard Drawing 4-8 of these Improvement Standards.
- C.** Hydraulic gradients for roadside ditches shall be shown on the plans and shall be below the structural section of the roadway. Ditches shall be designed to convey the 100-year design flow.
- D.** Driveway culverts sized for each individual lot shall be included in the plans.