June, 1969

TABLE OF CONTENTS

STORM DRAIN STRUCTURES (G 600)

LIST OF FIGURES

G 600 STORM DRAIN STRUCTURES

This section delineates the structures used by the City in storm drain design. The optimum design is generally the most economical structure that conforms to City standards and requirements. The construction of these structures shall be in accordance with the Standard Plans and the Standard Specifications for Public Works Construction (including supplements) unless otherwise approved by the supervisor.

G 601 DESIGN RESPONSIBILITY

The storm drain designer shall determine the types and configurations of storm drain structures not detailed on standard plans. Hydraulic considerations and existing physical conditions must be satisfied. Detailed design of the structural requirements of drainage structures is the responsibility of the Structural Engineering Division. Pipe bedding and D-Loads are determined by the storm drain designer and reviewed by the Structural Engineering Division.

G 602 STRUCTURAL CRITERIA

All drainage structures shall be designed for dead and live loading as determined by the Structural Engineering Division. Storm drain conduits in streets are generally designed for an earth loading of 120 pcf. and a highway loading of HS20-44. Conduits under railroads are usually designed for Cooper's E 80 loading or to meet the railroad company's requirements. Conduits in easements are usually designed for an earth loading of 120 pcf and the applicable live loading.

The relationship between depth of cover and load over a conduit is shown on Figure G 602. Note that the optimum depth (minimum load) occurs at about 4.5 feet of cover for highway loading and at about 12 feet of cover for railroad loading.

The class of concrete used for different structures is given in Table A, Section 2-24, of Standard Plan Notice to *Contractors-Comprehensive*.

G 610 CONDUITS

Storm drain conduits are normally designed for pressure flow under low heads. The City permits the use of both prefabricated pipes and cast-in-place conduits. Materials presently used in pipe fabrication are reinforced concrete, asbestos cement, and corrugated metal. The type of pipe used in streets at present is predominantly reinforced concrete. Cast-in-place structures usually are reinforced concrete box or channel. Except for perforated pipe subdrains, unreinforced concrete pipe and vitrified clay pipe shall not be used for storm drain purposes.

G 611 APPLICATIONS

For small closed conduits, pipe is usually more economical than cast-in-place box or horseshoe arch. The minimum pipe size is 24-inch diameter for mainlines and 18-inch diameter for catch basin connectors. For 84-inch diameter pipe and larger, an economic comparison with a box should be made. A horseshoe arch (Figure G 612B) is generally used in tunnels. Figure G 612 shows pipe and box conveyance factor equivalents. Figure G 612A shows hydraulic properties of corrugated metal pipe. Cast iron pipe, steel pipe, asbestos cement pipe, and reinforced concrete pipe may be used as force mains in conjunction with pumping stations. Open channels are lined with reinforced concrete, gunite, and grouted rip-rap. Asphalt concrete lining is not acceptable for permanent open channels.

G 612 CONFIGURATIONS

The shape of a storm drain conduit is based on hydraulic design principles and economic factors. Pipes are prefabricated and standardized, but an economical cross-section for a box conduit is one with the height greater than the width. A box height equal to the diameter of pipe shall be used if box and pipe alternates are specified on the plans. The most hydraulically efficient open channel is one with the largest hydraulic radius for a designated slope. A rectangular channel has a maximum hydraulic radius when the width equals twice the depth. For typical cross-sections of box and rectangular channel, see Page 26, Office Standard No. 117. A trapezoidal channel has a maximum hydraulic radius for given side slopes when proportioned as follows:

Z	1:1	1 1/2:1	2:1	2 1/2:1	3:01
b	0.83D	0.61D	0.47D	0.39D	0.32D

where Z is horizontal to vertical side slope, b is base width, and D is depth. Factors other than the most efficient hydraulic section (such as right of way, interfering utilities, depth of trench, and velocity) may dictate the conduit configuration.

G 613 LOADING AND BEDDING

Case of bedding and load factors are shown on the standard plan Pipe Laying in Trenches. The required D-Load for Case I, Case II, and Case III bedding of reinforced concrete pipe without or with bells is shown on Figure G 613. D-Loads for other Cases of Bedding may also be computed as shown below.

The D-Load is the load per foot of pipe computed as follows:

$$\text{D - Load} = \frac{(\text{D.L.} + \text{L.L.})\,\text{S.F.}}{(D_i)\,\text{L.F.}}$$

where D.L. = Dead load-120 pcf (Marston)
L.L. = Live load-HS20-44 (Highway)
S.F. = Safety factor-
RC. Pipe = 1.25
Asbestos Cement Pipe = 1.88*
Vitrified Clay Pipe = 1.50
D_i = Internal diameter of pipe (feet)
L F. = Load factor -
Case I Bedding = 1.4
Case II Bedding = 1.8
Case III Bedding = 2.7
Case IV Bedding = 3.2
Case V Bedding = 4.5

*D-Load for A.C. Pipe is 1.5 times the D-Load for R.C. Pipe. When machined ends are used, the D-Load should be increased by 5 % to compensate for the thinner section, but because of the safety factor of 1.88, this charge is negligible.

Figure G 613A shows the gages of C.M. Pipe and Pipe-Arch at various depths of cover for a live loading of H-20. The Structural Engineering Division should be consulted for special loading conditions.

Special bedding is required for pipe conduits in railroad rights of way. Figure G 613B gives the general requirements for the installation of pipes under railroad tracks. Each installation in railroad right of way must be approved by the individual railroad company involved.

The structural requirements and bedding of reinforced concrete box or open channel are designed by the Structural Engineering Division. The storm drain designer should discuss with the structural designer use of gravel blankets, encasements, building and sidehill surcharges, etc., so that they may be considered as early as possible in the design.

G 620 STANDARD STRUCTURES

The standard structures (Subsection G 363.1) used in most storm drain projects are manholes, junctions, transitions, and catch basins. These structures are constructed in accordance with their respective standard plans. The designer must select the type of structure and determine the required dimensions for each application. The criteria and details needed to design these structures are delineated herein.

G 621 MANHOLES

The standard manholes used in storm drain design are MH "AX," MH "JM," MH "EZ," and MH “BX." Their application is summarized in Figure G 621. The spacing of manholes along the main line is given in Subsection G 337.1.

The four types of manhole frames and covers and their uses are as follows:

1. Non-rocking manhole frame and cover-used in streets and rights of way.

2. Pressure manhole frame and cover-used wherever the hydraulic gradient is at or above ground elevation.

3. Large manhole frame and cover-used where manhole steps are deleted for depths exceeding 20 feet.

4. Catch basin manhole frame and cover-used in offstreet locations for catch basins, junction chambers, and culverts-equipped with locking device as per standard plan.

An eccentric reducer as per standard plan shall be used at the top of manhole shafts to align the steps vertically.

G 622 JUNCTIONS

The standard manholes and junction structures and their application in storm drain design are summarized on Figure G621. On occasion, junction structures of special design are required.

Some of these are pipe to box, box to box, box to open channel, and open channel to open channel junctions. Junction Chamber No. 3 is used to join two or more small pipes in the parkway which require access. Special considerations must be given to high velocity flow junctions.

Increased structural dimensions or special design of junctions are necessary under the following conditions:

(a) Where structures are subject to railroad loadings.

(b) Where fills over structures are less than 1 foot or greater than 20 feet.

(c) Where fills over structures are greater than l0 feet and at the same time the inverts or soffits of the main line and lateral join, or where the difference in elevation between them is less than 4 inches.

(d) Where the outlet diameter of the junction structure exceeds 96 inches.

(e) Where an inlet encroaches through the top slab.

Monolithic connections when required may be extended in length up to 4 feet to meet standard pipe lengths. (See standard plan Typical C.B., M.H. and J.C. No. 3 Monolithic Connection for R.C. Pipes 12t" to 72" Inclusive and Subsection 3-31 of the standard plan Notice to Contractors-Comprehensive.) Only one Junction Structure B is permitted per pipe length (usually 8 feet). When a lateral inlet is greater than 39", a Junction Structure C shall be used. A Junction Structure C shall also be used where side inlets enter both sides of the conduit and an access shaft is not required. When side inlets enter both sides of a manhole, the manhole is lengthened as required so the access shaft is upstream of the inlets.

In designing a junction, the shortest practical structure that meets hydraulic and structural requirements should be determined. This is best accomplished by drawing a sketch of the relative positions of stub and main line to natural scale (usually 1" = 1.0') to determine the values called for on the standard plan. Figure G 622 delineates the requirements and controls for design of junctions with pipe and box conduits. A manhole shaft is generally located upstream of inlets to provide clearance for steps.

The vertical alignment of the main line through a junction must have a minimum slope to maintain a 4 ft./sec. velocity. For a size increase downstream, soffits are joined. For a size decrease downstream, inverts are joined. The centerline of the side inlet is generally aligned to intersect the centerline of the main line. Steep inlets should not protrude into the manhole or Junction Structure top slab. To avoid this, the top slab may be thickened (see Figure G 622, dimension Q) or the inlet grade may be broken at the location of elevation R, otherwise special structural design is required. For inlets into box structures or open channels, the inlet invert should not encroach into the side wall longitudinal or vertical construction joints.

Saddle connections in accordance with the Standard Plan shall not be used, except for private or roof drain connections of 10-inch diameter or less. The longitudinal axis of the connection shall intersect the longitudinal axis of the main line, and the entrance angle shall not be less than 70 degrees. The opening in the main line shall be core drilled using a drill the size of the connector pipe.

G 623 TRANSITIONS

A storm drain transition is a structure of varying cross-section designed to provide smooth flow between two conduits. A transition is usually required to change conduit size, to change type of conduit, or to avoid obstructions. For a transition with pipe conduits, standard manholes and junction structures are generally used. Special design is required for transitions with box, arch, or open channel conduits, or to join two different types conduits.

A transition must be hydraulically efficient yet practical to construct. The length of the transition is usually the prime consideration, as it ordinarily determines the cost. Straight-line connections are usually used on all transitions except on an expansion transition in free water surface high-velocity flow. For pipe or box conduits, soffits are joined for a size increase downstream and inverts are joined for size decrease downstream. For rectangular or trapezoidal channels, tops of walls or tops of side slopes are joined. A summary of transitions is shown on Figure G 623 with design criteria for each, including two special cases used to avoid obstruction in low-velocity flow.

Most transition designs are for full flow. This design shall incorporate the following objectives:

1. Maintain full flow at design capacity.
2. Maintain or increase the minimum invert slope.
3. Set the horizontal and/or vertical rate of expansion or contraction from 5:1 to 10:1 ratio based on the allowable head loss through the transition (see Subsection G 343.4).
4. Set transition dimensions proportional to those of a Venturi Meter where the normal cross-sectional area is reduced by half or more.

The design of high-velocity free water surface transitions is different for expansion than it is for contraction. An expansion transition is designed to retain flow against the sidewalls to prevent cavitation. A sample expansion transition design is shown on Figure G 623A including calculation on reverse parabolic curves. A contraction transition is designed to minimize wave disturbances. A sample contraction transition design is shown on Figure G 623B. Should a transition require an increase in slope, the vertical curve criteria given on Figure G 411.2 must be applied.

G 624 CATCH BASINS

The standard catch basins used in storm drain design are side opening and grating as summarized in Figure G 352.1. Catch basins shall be reinforced as per Standard Plans. Where warranted, standard catch basins may be modified to fit local conditions. When joining or modifying another agency's catch basin, that agency's standards shall be applied. The design of special inlet structures in streets in lieu of catch basins must be approved by the supervisor.

Side opening catch basins in streets shall normally be designed for a 9-inch curb face with warped gutter as per Figure G 624. If this curb face exceeds 9g4 inches, a protection bar shall be centered horizontally across the opening 3 ½ inches above the gutter flow line. Near schools, protection bars -may be specified for catch basins with 9" curb face if hydraulically feasible.

A grating catch basin next to a curb shall normally be placed in the plane of the gutter or pavement (without warped gutter). A grating catch basin should not normally extend more than one grate in width from the curb or two grates in length along the curb except in alleys.

See Sections 3-30, 3-31, and 3-32 of Standard Plan Notice to Contractors-Comprehensive for additional catch basin criteria.

G 630 SPECIAL STRUCTURES

A special structure is one specifically designed for a particular application. Such structures are inlets, outlets, debris basins, energy dissipators, flapgates, subdrains, street culverts, outlet chambers, and small curb outlets. Their construction details must be delineated on the plans. The use, criteria, and standards for the geometric design of these structures are given herein.

G 631 INLET STRUCTURES

All runoff entering a storm drain requires an inlet structure. Standard catch basins are normally adequate in streets. In natural channels, an inlet structure must be designed to meet specific field requirements. Generally, an inlet structure intercepts and directs the flow to the conduit and protects property from flood damage and erosion. This should be done economically and with mini-mum head loss. The quantity and velocity of flow usually determines how extensive an inlet structure must be to perform satisfactorily. Three typical inlet structures and their general applications are shown on Figure G 631.

There are many situations in which the type of inlet used and its location require special considerations. Where erosion deposits at the outlet of a drain are objectionable, a debris basin should be constructed upstream of the inlet. A debris barrier to prevent plugging of an inlet should be provided where floating debris is present. Fencing and a protection barrier should be provided for large conduit inlets in populated areas. At the top of cut or bench drains where water overflow is a serious hazard, inlets should be designed for total flow interception and protection from plugging. It is therefore necessary for the designer to evaluate properly the requirements of each situation before starting design.

G 631.1 Geometric Design: The hydraulic and structural considerations shall dictate the geometry of an inlet structure. Where applicable, an inlet structure shall consist of a headwall to protect the conduit and embankment, wingwalls to direct the flow to the conduit, a drop inlet apron to accelerate the flow, and a rounded inlet to diminish head loss.

The location of the headwall in an embankment generally determines the height and width of the wall. The minimum height of headwall shall provide one foot of cover over the conduit, and should extend to the height of expected headwater. The minimum width of headwall without integral wingwalls shall be the width of the conduit plus 12 inches on each side. The headwall width may be extended to the existing banks of the watercourse. The top of the headwall should protrude 6 inches above the embankment slope.

Wingwalls may be either straight vertically or warped according to their application as shown on Figure G 631. The length and height of wingwalls depend on the height of the headwall, the slope of the embankment, and the angle of horizontal flare. This angle of flare (a) is usually 45 degrees.

At inlets the smoothness of the joints between the headwall, wingwalls, and apron is an important hydraulic consideration. The inside surfaces of wingwalls and box conduit sidewalls as well as the apron and box conduit floor should join flush. For pipe conduits, the inside surface of wingwalls should be flush with the inside surface of the pipe at the springline. For small inlets, the apron should be warped to join the inside surface of the bottom half of the pipe. The inlet apron should extend at least one pipe diameter upstream of the conduit and should slope down toward the inlet a sufficient depth to maintain a safe headwater level. Pipe inlets shall have a 3-inch minimum radius. R.C. box inlets shall have a radius of 3 to 6 inches at the headwall face.

G 632 OUTLET STRUCTURES

Where a drain outlets into an improved storm drain or river, a conventional junction structure or confluence is used. However, some drains discharge into City streets, the ocean, or unimproved watercourses. These are the outlets which require special design considerations.

The prime consideration in outletting a storm drain into a street is City liability. The designer shall check his design against the criteria given in Section G 012. For small flows, a culvert or a "burp" catch basin with bleeder line is adequate. For large flows or flows beyond street capacity, a storm drain system will probably be required.

Where a storm drain outlets directly into the ocean, the designer must consider tidal action, littoral drift, and saline conditions. Outlets to a harbor channel subject to backflow at high tide should be protected by a flapgate or overflow weir. The collection of sand from littoral drift at a beach outlet is difficult to predict and even more difficult to prevent. Outletting between high and low tide lines and the construction of a rock groin should reduce this problem. The use of Type V cement for concrete structures will prevent deterioration from salt water. If the outlet is located near a beach or public area, fencing and a protection barrier should be provided to prevent entrance into the conduit.

A common use of an outlet structure is to control the discharge of water in a natural watercourse. Precautions must be taken to avoid property damage. The best assurance against damage is to discharge the flow at all stages into the watercourse just as the former channel did. Since this is not always economical, good judgment must be used to determine the amount and type of protection that must be provided.

Erosion of the channel bed and banks is one of the designer's basic problems. If the velocity of discharge is greater than the normal velocity of the stream, the channel bed will erode. Eddy currents caused by an excessively rapid discharge will erode the channel banks. To prevent such erosion, the velocity must be decreased, the flow aligned and shaped to the natural channel, and the channel and conduit protected against scour.

Outlet structures are classified as either low or high velocity. A low velocity structure is one that can discharge water without the use of a special energy dissipator and not cause excessive erosion. This type of outlet structure is generally for subcritical outlet velocities. The two outlet structures shown on Figure G 632 are typical for the types of channel shown thereon. These are intended only as a guide. Each outlet must be designed according to its requirements. Since experimental data are not available, the designer must predict the hydraulic behavior of each outlet structure designed.

The choice of an outlet that will assure reasonable control of the water must consider the following factors:

1. The quantity and velocity of conduit outlet flow.
2. The normal velocity of the existing channel downstream.
3. The vulnerability of the soil to erosion.
4. The adaptability of the structure to the location.
5. The simplicity of construction and low maintenance cost.

The existing channel "n" factors are selected from Figure G 402. Allowable Velocities for Erodible Linings are given on Figure G 632A. It is important that the existing channel conditions are properly evaluated and the "n" factor and lining chosen are consistent with those conditions. The best location for an outlet structure is generally one that requires the minimum amount of earthwork and erosion protection close to the location of the desired end of conduit.

When the outlet velocity is supercritical, the principal consideration is the dissipation of energy (see Section G 633).

G 632.1 Geometric Design: As with the inlet structure, the hydraulic and structural considerations shall dictate the geometric design of the outlet structure. It usually consists of an endwall, wingwalls, apron with cut-off wall, and bank protection. The size of the endwall is determined by the same considerations given in Section G 631.1 for a headwall. The wingwalls are straight vertically with a horizontal flare angle (α) and length (L_A) as shown on Figure G 632. The concrete apron should be at ground level and should terminate with a cut-off wall at least 2 feet deep. Wherever the bed or banks of an existing channel at the outlet are subject to erosion, they should be protected. See Example 6, Pages V-10 to V-18 of the ITTE Booklet, Street and Highway Drainage, Volume I (1965) for different methods of channel protection and lining. Outlet flow conditions must be checked to assure that no hydraulic jump or other undesirable effect detrimental to the outlet can occur.

G 633 ENERGY DISSIPATORS

A high-velocity outlet is one which requires an energy dissipator to prevent excessive erosion or property damage. Means of dissipating energy at outlets are submergence, pool, hydraulic jump, and impact. A submerged outlet or plunge pool requires too large a structure to be economical under conditions encountered in the City. The control of a hydraulic jump at all stages of flow and the possible erosion resulting therefrom is also considered uneconomical for most City applications. Dissipation of energy by impact has the widest application by the City.

The Impact Type Energy Dissipator has been tested by the City Hydraulic Laboratory and is recommended for use with closed conduits. The geometric design is as indicated in Figure G 633. The structural design is done by the Structural Engineering Division. The limit of use is given in Note 4 thereon. Other types of Stilling Basins and Energy Dissipators are given in the U.S. Department of Interior, Bureau of Reclamation Engineering Monograph No. 25, by A. J. Peterka. Whatever method is used to reduce velocity, the dissipation of energy must be contained within the confines of the structure for all stages of flow.-Failure to recognize a possible hydraulic jump or an area susceptible to excessive erosion may result in structural failure and property damage. The designer should consult his supervisor on the design of all major energy dissipators. Where values of Q and/or velocity exceed values in the Bureau of Reclamation Booklet, a model study should be made.

G 634 DEBRIS BASIN

A debris basin intercepts storm runoff debris at storm drain inlets located in the debris production zones given on Figure G 634. A permanent debris basin consists of an earthfill embankment, outflow system, standpipe, trash barrier, and slope protection against erosion. The basin outflow system must pass the design storm runoff (as determined in Chapter G 200) without overtopping the embankments. The basin must provide a debris storage capacity as determined by the Debris Production Curves shown on Figure G 634A. A source of information for the design of a debris basin can be obtained from the Bureau of Reclamation Book Design of Small Dams. The designer shall consult the state pamphlet for the determination of *Rules and Regulations Pertaining to Supervision of Dams in California.*

Before a debris basin is designed, the basin site must be selected. Sufficient right of way shall be provided for the full improvement of the debris basin and other area of debris settlement. Consideration may also have to be given to the temporary water storage area An access road of adequate width must be provided to facilitate the removal and hauling of storm deposited debris. Debris racks or check dams should be used in watercourses with less than ten acres tributary in lieu of a debris basin.

Borings and soil analysis must be obtained for the debris basin area. Recommendations pertaining to all phases of work relating to soil mechanics on embankment and foundation engineering shall be requested from the Geology and Soils Engineering Section, Street Opening and Widening Division.

The debris basin capacity is calculated as the volume contained between the natural or graded ground and a plane extending upstream from the crest of the overflow spillway (or ogee storm drain inlet) at approximately 60% of the average original stream bed slope. Experience indicates that while the debris surface slope seldom exceeds 4% it may be as high as 8%. Extensive excavation below the level of the streambed should be avoided because of soil erosion. The application of the debris basin capacity computation should be approved by the Division/District Engineer because of wide variety of basin shapes and inflow conditions.

The debris basin dam is a compacted earthfill embankment with stable upstream and downstream slopes as recommended by the Geology and Soils Engineering Section. The fill embankment shall be designed safe against internal erosion from seepage flow, external erosion from overtopping or sloughing at seepage outlet, and excessive stresses upon the foundation for all conditions of operation. The upstream slope shall be Paved with concrete extending 3 feet vertically below the bottom of the basin and 1 foot into the abutments as a deterrent to piping. The downstream slope shall be planted or otherwise protected from erosion. The crest of the embankment shall be 10 feet wide or wider if used as an access road to the basin and shall slope up from the spillway walls toward the abutments. The path of percolation can be critical and should be checked to prevent piping. The areas of contact between dam fills and abutments shall provide a minimum length of path of percolation, for maximum head differentials, on slopes of at least 8:1 (8=level length of path and 1 = head differential between ends of path).

The debris basin outflow system consists of a spillway and/or ogee type storm drain inlet and shall be designed for the peak flow of a 50-year storm. For a closed conduit outlet, an ogee type inlet as shown on plan D-19450 is recommended shall be designed for the peak flow of a 50-year (see Design of Small Dams). For an open channel outlet, a broad-crested weir (C=2.80) spillway is recommended. The minimum freeboard at the spillway crest shall be 3 feet.

An adequate bar rack (or grate) shall be provided upstream of the spillway and/or storm drain inlet to prevent clogging, especially when the outlet is a closed conduit (see Section G 645). The freeboard between the crest of embankment and water level shall be 3 feet.

A standpipe structure with holes and its outlet conduit to the outflow system conduit shall be provided to drain the water at all levels of the debris basin (see D-19450). The standpipe shall be located at the lowest point of the debris basin. The top of the structure shall be open end (with bar grate) and shall protrude at least one foot above the debris surface. The capacity of the standpipe and its outlet conduit shall be 20% of the 50-year peak flow. The standpipe holes shall provide this capacity for any six feet of standpipe height. The standpipe outlet conduit shall be designed for inlet control with a minimum grade of 5%. The alignment of standpipe outlet conduit shall not be located under the outlet system alignment.

Temporary debris basins are sometimes installed to meet situations that will exist for only a short time. They usually consist of an earthfill embankment with a paved overflow spillway similar to the temporary desilting basin shown on Figure G 154.

The removal of debris after every storm is required to continue effective protection of property downstream. Therefore, upon completion of construction of a debris basin, the designer shall notify the Sewer Maintenance Division of the Bureau of Sanitation so that proper maintenance can be scheduled.

G 635 SUBDRAINS

The most common applications of subdrains are under fill embankments and along storm drain conduits in watercourses. A standard subdrain usually consists of a filter blanket and perforated pipe (or equivalent) in a narrow trench backfilled with filter sand and drainage material. The types of conduits acceptable for use as subdrains are perforated pipes of corrugated metal (galvanized and asphalt coated), concrete, asbestos cement, vitrified clay, and a semicircular conduit of galvanized steel and corrugated metal cover. The material for filter blankets and other filters shall generally conform to the requirements shown on Figure G 635.

An embankment subdrain is installed along the flow line of natural watercourse (or swale) and its tributaries under all fills. The minimum pipe size shall be 6" for lengths up to 500' and 8" for lengths exceeding 500'. The grade should not be flatter than 0.5%. Outlets into the storm drain conduit should be provided at intervals not exceeding 1000'. The subdrain should be laid with the perforations downward.

The use of subdrains along storm drain conduits shall be considered whenever test borings indicate the presence of groundwater. These subdrains increase the bearing capacity of the subgrade and decrease the hydrostatic pressure on the conduit. The basic considerations which determine subdrain requirements are the type of soil, type and location of the storm drain conduit, and groundwater conditions.

A distinction must be drawn between flow of free water as in sandy soils and capillary action as in clayey soils. When a storm drain is located where groundwater naturally concentrates, heavy flow should be anticipated and subdrain pipes are usually required (Conditions II and III, Figure G 635). When a storm drain is located in wet clayey soil, which is practically non-percolating, weep holes in cast-in-place conduits or open joints in RC pipes are usually sufficient (Condition I, Figure G 635). A sand and gravel blanket is often used in a soft trench subgrade such as silt or clay which are moist from capillary action. To prevent blanket washout, cut-off walls with drainage outlets should be provided along the alignment. Additional soil testing and recommendations may be requested (if required) from the Geology and Soils Engineering Section, Street Opening and Widening Division.

Pipe subdrains may be slab or heel drains according to their location at the storm drain conduit.(see Figure G 635). These drains are 6" or 8" perforated pipes with the perforations downward. The subdrain is backfilled with a washed concrete sand filter 16" wide, extending from the base to the top of the storm drain conduit with a minimum depth of 2' below the ground surface to block surface drainage. The subdrains run parallel to the storm drain conduit in continuous reaches of 200 feet with a 3' gap separating the reaches. Branch outlets go into the storm drain conduit at 25' intervals or at closer intervals in areas of heavy groundwater flow. A slab drain with a low-flow channel is generally used where groundwater conditions are severe.

It may be more economical to consider groundwater pressures in the structural design of the storm drain conduit than to use subdrain pipes. This depends on the depth of cover over the storm drain conduit, its weight, and the elevation of the water table. When a storm drain conduit is too light to resist the uplift force of groundwater, which is often the case with a trapezoidal channel in a watercourse, subdrains must be used. The designer should consult the Structural Engineering Division to evaluate
the structural design for groundwater conditions and weight to resist uplift.

G 636 FLAPGATES

A flapgate is a water-pressure-operated automatic gate that allows water outflow from a conduit but prevents backflow into the conduit. It is usually installed in a pipe or box outlet at which the water level is periodically higher than the area drained but allows drainage during other periods.

Whenever the designer considers using a flapgate, he must carefully investigate the actual conditions under which it must operate. Bronze seats and fittings should be used for flapgates subject to salt water. The operating head of water must be considered in selecting the proper flapgate. See the manufacturer's recommendations for the proper installation of flapgates.

A storm drain lateral which is flapgated into the main line must be set back from the main stream of flow for free operation of the flapgate. This requires a spur larger than the lateral in which to install the flapgate. Such an installation and its applications are given in Figure G 636.

G 637 STREET CULVERTS

A street culvert is a shallow single- or multiple-barrel reinforced concrete box (or pipe) inletting and outletting through the curb. Its purpose is to convey street runoff underground across an intersection, thus making possible intersection design without cross-gutters. The culvert is also used to convey runoff under railroad tracks and to drain cul-de-sac streets and other locations where a shallow drainage structure is required. A street culvert is usually designed for low flow and as a temporary solution for a drainage problem until a storm drain is constructed.

A box culvert has a minimum height of 4" and a minimum inside width of 2'. The grade is whatever is attainable with a minimum grade of 0.002 feet per foot. The culvert location should be clear of surface and sub-surface obstructions. Street lights and traffic lights have location priority over culverts; therefore, the designer must coordinate his design with these departments. The culvert inlet should have a 9" curb face with a warped gutter. The culvert outlet should have an 8" curb face.

Culverts using small-diameter pipes are occasionally employed to keep dry-weather flow out of intersections. Pipe culverts may be gravity flow or inverted siphons, depending on the fall available across the intersection. These culverts are temporary construction and require more maintenance than normal.

All culverts must be cleaned periodically for proper operation. Therefore, upon completion of Construction, the designer shall transmit a copy of the culvert plans to Sewer Maintenance Division, Bureau of Sanitation, thereby notifying them that maintenance should be scheduled.

G 638 OUTLET CHAMBERS

An outlet chamber conveys flow from a bench drain or lot drain, through the sidewalk or parkway area into the street gutter. The standard plan Outlet Chamber No. 4 is typical of single or multiple box sections of 4' width or less. The reinforced concrete top slab of the outlet chamber may be replaced with a removable galvanized diamond steel plate as per Standard Plan Sidewalk Culvert-Steel Plate Top to increase the depth of the structure.

An outlet chamber should have a minimum cross-sectional area equal to the inletting conduit. The minimum grade of the outlet chamber shall be 0.002 feet per foot. The maximum allowable outlet velocity shall be 7 ft./sec. to avoid cross-street flow. The outlet should have a 30^{o} to 60^{o} angle from the curb line facing downstream to prevent deposits of silt and debris in the street. The standard curb face at the outlet is 8"

G 639 SMALL CURB OUTLETS

A small curb outlet is one which conveys runoff from a private roof or surface area through the parkway and curb into the street gutter. The drain usually consists of acceptable 4" pipe or rectangular conduit. Since this drain is intended for small areas, on]y two pipes or equivalent conduit per outlet should be allowed. A large area should use outlet chambers. Loading conditions (particularly under driveways) must be considered. No open channel shall be allowed through a curb in an improved street area.

Small curb outlets must not be removed or plugged by storm drain construction. Those which interfere must be relocated or connected to the storm drain. It is generally preferable to outlet a reconstructed curb outlet into a catch basin whenever feasible. (See Sections 2-14 and 3-7 of Standard Plan Notice to *Contractors-Comprehensive.)*

G 640 APPURTENANT CONSTRUCTION

G 641 SUPPORTS, RELOCATIONS, AND REMOVALS

Every effort is made in selecting a storm drain alignment to avoid substructures; therefore, those substructures still interfering must be either relocated or removed. An economic study should be made of those substructures within the trench and other substructures parallel to and one foot or less clear of the trench to determine if they should be relocated or supported. Whenever it is practical, any parallel substructure which has had its lateral support removed by the trench should be supported in place. (See Section 3-20 of Standard Plan Notice to Contractors-Comprehensive.) The interfering portions of abandoned sewers and storm drains are removed and sealed as per Subsection 306-3.1 of the Standard Specifications. For ownership and responsibility of relocating utilities, see Subsection G 364.1. For the method of removal and relocation of utilities, see Section 5 of the Standard Specifications.

Existing sewer and storm drain pipes across trenches shall be supported in accordance with the standard plan Supporting Pipes Across Trenches. Interfering sewer house connections shall be remodeled in accordance with the standard plan *Remodeling Details for House Connection Sewers.*

G 642 CONCRETE BLANKETS AND ENCASEMENTS

Concrete blankets and encasements are usually used to protect existing sewer pipes from damage during construction and from surcharge loading. Existing storm drain pipes (or boxes) must be reviewed and designed by the Structural Engineering Division for additional protection (if required) from a change in loading either from a reduction in cover by grading, an increase in cover by fill, or lack of clearance for proper bedding of the proposed storm drain conduit.

The storm drain designer is responsible for transmitting the proposed plans to the Structural Engineering Divisions (or sections) for review and design (see Section G 362). To this end, a sewer pipe shall Require review and protection whenever it lies within 18" below a proposed storm drain conduit. A concrete blanket as per Standard Plan is usually used over the sewer pipe for clearances of 6" to 18" below the proposed storm drain conduit. For clearances of less than 6" below or above the proposed storm drain conduit, a concrete encasement as per Standard Plan is generally used.

G 643 ANCHOR BLOCKS AND TH RUST B LOCKS

Anchor blocks are used to stabilize pipes on slopes of 3:1 or steeper in accordance with the standard plan Concrete Pipe Anchors. Manholes or similar concrete structures on steep slopes are sufficient to replace one anchor block per structure. Corrugated metal pipe on slopes of 3:1 or steeper may be anchored with steel stakes (approximately 6' long) or corrugated metal bulkheads (metal seep rings-see Figure G 154).

Whenever a force main under pressure changes direction, a thrust is exerted by the pipe against the soil which may be beyond its bearing capacity. To prevent pipe failure from this thrust, a concrete thrust block is constructed between the undisturbed trench and the pipe, thus increasing the pipe bearing area to the capacity the soil can bear. For force mains of 10" or larger operating under a pressure of 15 psi (35 feet of head) or higher, the designer shall refer the design of thrust blocks to the Structural Engineering Division.

G 644 CONCRETE COLLARS AND SEALS

A concrete collar is an expedient which should be used during construction only. A concrete collar should not be used in design or construction whenever beveled pipe and pulled joints can be used. However, concrete collars are required to connect pipes of different sizes or types or where the joint opening exceeds 3/4" for pipes 36" or less in diameter and exceeds 1" for pipes 39" or more in diameter. Concrete collars shall be constructed in accordance with the standard plan Concrete Collar for pipes 66" or less in diameter. Special design is required for concrete collars for pipes of larger diameter.

Whenever an existing pipe is removed or a new pipe is stubbed for future use, the open portion of the pipe must be sealed. For pipe or box conduits with the largest internal dimension of 4' or less, the conduit shall be sealed with an 8" wall of brick and mortar or a 6" concrete wall. For larger openings, special design is required. For the abandonment and sealing of catch basins, manholes, or other structures, see Subsection 306-3 of the Standard Specifications.

G 645 DEBRIS BARRIERS

When designing storm drain inlets in natural watercourses or other undeveloped areas, the designer must consider the problem of debris to assure the proper operation of the inlet. It is neither desirable nor economical to design drains which would pass all the debris; therefore, the debris must be controlled to avoid congestion or even plugging. The cost of damage from flooding which would result from lack of debris control amply justifies the design of adequate debris barriers

The basic kinds of stream burden debris found in this area are floating debris, flowing debris, and detritus. Floating debris consists of limbs, sticks, tumbleweeds, tules, refuse, etc. Flowing debris consists of a mixed fluid mass of fine soils, gravel refuse, etc. Detritus is a bed-load of sand, gravel, and rocks which tend to deposit with a reduction of velocity. Any or all of the above in varying amounts may be found in most watercourses.

The designer should conduct field investigations and evaluate his findings before selecting the type of debris barrier required, if any. Things to look for in the field are the type and amount of loose debris, the type of soil and its susceptibility to erosion, the expected amount and velocity of flow from the natural watercourse, the characteristics of the proposed inlet location, and the probable damage resulting from a partial or total inlet plugging.

The following are situations which may require a debris barrier. The amount and type of debris allowed to pass into the storm drain may be restricted by outlet requirements such as outlets into the street or on a beach area. If a pipe size is decreased downstream of the inlet, the smaller pipe should determine the bar spacing of the debris rack. A decrease in conduit velocity can choke the drain with resulting detritus deposits. An impact type velocity breaker may be impaired by clogged debris.

Debris barriers that have been used effectively in the past are the debris rack, bar grate, debris riser, check dam, pipe and wire revetment, and debris basin (see Section G 634). The debris rack is a line of steel posts or rails spaced at intervals of 12 to 18 inches and placed across the channel upstream of the inlet. It is used to trap floating debris. The bar grate is usually a steel grate of bars inclined from the vertical and placed directly across the inlet to trap floating debris. The debris riser is a vertical pipe open at the top (or with a bar grate) with evenly spaced perforations all around its full height. It is used to trap the flowing debris or mud, for which on-site storage must be provided. It is extended as required according to the height of debris deposits. The check dam is a shallow barrier across the channel upstream of the inlet. A series of check dams, spaced far enough apart to effect a series of fan-shaped steps of alluvial deposits, is used to slow down the stream flow and trap the detritus. For a light amount of all three types of debris, a chain link fence check dam may be used. A pipe and wire revetment filled with brush is also effectively used across natural channels to trap debris and form a basin. However, for a large amount of eroded soil, such as a major watercourse in a hillside area, a permanent debris basin as given in Section G 634 should be provided.

Debris barriers and basins require periodic cleaning and maintenance. Upon completion of construction of debris barriers (or basins), the designer shall notify the Sewer Maintenance Division of the Bureau of Sanitation, so proper maintenance can be scheduled.

G 646 PROTECTION BARRIERS

A protection barrier is a means of preventing people from entering storm drains. This protects the City from liability suits. The barrier may consist of chain link fencing around an inlet or outlet or a grate across the conduit entrance or outlet. A protection barrier is required whenever the inlet or outlet is an attractive nuisance or a particularly hazardous situation. An inlet in a residential area or an outlet near a public beach should be considered a nuisance attractive to minors. A pipe inlet on a steep grade or an outlet inundated by the tide is particularly hazardous.

The type of protection barrier used depends on the size of the inlet or outlet structure and its location. For large closed conduits subject to plugging by debris, the breakaway grate shown in the LACFCD standard drawing Protection Barrier is recommended. For open channels that accept flow from the street or from a natural watercourse containing debris, a breakaway fence is suggested. For smaller conduits, a removable grate of vertical bars spaced at a maximum clear opening of 7" across the inlet or outlet is satisfactory.

G 647 FENCES AND GATES

Fences and fence gates utilized with storm drain projects shall be chain link in accordance with the Standard Specifications. Fencing shall generally be required at the perimeter of rights of way for open channels, drainage basins, pump stations, or any other surface installations deemed hazardous to the public. Fencing is also required at headwalls and endwalls, rectangular channel sidewalls, or other hazardous vertical drops.

Right of way fencing shall be 6 feet high with its centerline normally located 6t' inside the right of way line. Top of wall fencing shall be 4 or 5 feet high with a right of way fence installation and 6 feet high without one. When there is an access road on one side (as shown in Figure G 122), the top of sidewall fence shall be installed on the access road side of the channel only.

Gates shall be installed wherever access is required for maintenance personnel and vehicles. Gates shall be the same height as the adjoining fencing. Personnel gates shall have a minimum width of 3 feet and vehicle gates a minimum width of 10 feet. An opened gate shall not protrude into a roadway or sidewalk area where traffic may be impeded or made hazardous.

G 648 ACCESS ROADS

Access roads provide vehicular access to drainage structures for maintenance or operation by City personnel An access road shall have a mini- mum width of 12 feet, and shall provide either a turn-around or access from both ends of the road. The roadway shall consist of a minimum of 4-inch select material surface (or equivalent) for grades up to 10%, and a minimum of 4-inch AC pavement for grades of 10% or greater. The maximum grade shall be 15%. The turn-around shall consist of either a cul-de-sac with a minimum radius of 30 feet or a "T" equivalent to the minimum alley turning area shown in the standard plan Standard Street Cross Sections. Access roads should be located in a right of way and be completely fenced (see Figure G 122). A soil sterilant should be used on the roadway to abate weed growth.

G 649 RESURFACING AND REMODELING

Whenever storm drains are constructed in City streets, the street improvements must be restored to their former state of usefulness. Pavement removed for the construction of storm drain conduits, warped gutters, or other drainage structures shall generally be replaced in kind (including the base) and thickness with a minimum thickness of 4'> (see Subsection 306-1.12 of the Standard Specifications, and Figure G 624). A Resurfacing Schedule is shown on the title sheet of the construction plans (see section G 722). Trench resurfacing for pipe conduits is included in the cost of the pipe in place.

Generally most remodeling with storm drain work is done on catch basins and gutters. (For remodeling of existing drainage facilities, see Section G 123.) The extent of remodeling should be limited to what is required for proper drainage consistent with design standards and criteria.

Remodeling of street improvements in conjunction with storm drain work must be coordinated with the street design section or Division. If the remodeling is done with a drainage project, the designer prepares a sketch (indicating the location of the drainage project and the street remodeling) and requests the required street details for the most economical solution to the drainage problem, such as grade change or installation of a catch basin. If the remodeling is done with a street project, the designer checks that the drainage facilities conform to the latest standards, such as catch basin top slab and inlets, protection bars, curb height, grating spacing, etc.