SECTION 6
DESIGN OF ENCLOSED STORM DRAINAGE SYSTEMS

6.01 GENERAL

All storm drains shall be designed by the application of the Manning Equation either directly or through appropriate charts or nomographs. In the preparation of hydraulic designs, a thorough investigation shall be made of all existing structures and their performance on the waterway in question.

The design of a storm drainage system should be governed by the following six conditions:

1. The system must accommodate all surface runoff resulting from the selected design storm without serious damage to physical facilities or substantial interruption of normal traffic.

2. Runoff resulting from storms exceeding the design storm must be anticipated and disposed of with minimum damage to physical facilities and minimum interruption of normal traffic.

3. The storm drainage system must have a maximum reliability of operation.

4. The construction costs of the system must be reasonable with relationship to the importance of the facilities it protects.

5. The storm drainage system must require minimum maintenance and must be accessible for maintenance operations.

6. The storm drainage system must be adaptable to future expansion with minimum additional cost.

An example of the design of a storm drainage system is outlined in Paragraphs 6.03 and 6.04. The design theory has been presented in the preceding sections with corresponding tables and graphs of information.

6.02 PRELIMINARY DESIGN CONSIDERATIONS

A. Prepare a drainage map of the entire area to be drained by proposed improvements. Contour maps serve as excellent drainage area maps when supplemented by field reconnaissance.

B. Make a tentative layout of the proposed storm drainge system, locating all inlets, manholes, mains, laterals, ditches, culverts, etc.

C. Outline the drainage area for each inlet in accordance with present and future street development.

D. Indicate on each drainage area the code identification number, the size of area, the direction of surface run-off by small arrows, and the coefficient of runoff for the area.

E. Show all existing underground utilities.

F. Establish design rainfall frequency.

G. Establish minimum inlet time of concentration.

H. Establish the typical cross section of each street.

I. Establish permissible spread of water on all streets within the drainage area.

J. Include A. through I. with plans submitted to the Engineering Department for review. The drainage map submitted shall be suitable for permanent filing in the Engineering Department and shall be a good quality reproducible.

6.03 INLET SYSTEM

Determining the size and location of inlets is largely a trial and error procedure. Using criteria outlined in sections 2, 3 and 4 of this manual, the following steps will serve as a guide to the procedure to be used.

A. Beginning at the upstream end of the project drainage basin, outline a trial subarea and calculate the runoff from it.

B. Compare the calculated runoff to allowable street capacity. If the calculated runoff is greater than the allowable street capacity reduce the size of the trial subarea. If the calculated runoff is less than street capacity, increase the size of the trial subarea. Repeat this procedure until the calculated runoff equals the allowable street capacity. This is the first point at which a portion of the flow must be removed from the street. The percentage of flow to be removed will depend on street capacities versus runoff entering the street downstream.

C. Record the drainage area, time of concentration, runoff coefficient and calculated runoff for the subarea. This information shall be recorded on the plans or in tabular form convenient for review.

D. If an inlet is to be used to remove water from the street, size the inlet (inlets) and record the inlet size, amount of intercepted flow, and amount of flow carried over (by-passing the inlet).

E. Continue the above procedure for other subareas until a complete system of inlets has been established. Remember to account for carry-over from one inlet to the next.

F. After a complete system of inlets has been established, modification should be made to accommodate special situations such as point sources of large quantities of runoff, and variation of street alignments and grades.

G. Record information as in C. and D. for all inlets.

H. After the inlets have been located and sized the inlet pipes can be designed.

I. Inlet pipes are sized to carry the volume of water intercepted by the inlet. Inlet pipe capacities may be controlled by the gradient available, or by entry condition into the pipe at the inlet. Inlet pipe sizes should be determined for both conditions and the larger size thus determined used.

6.04 STORM SEWER SYSTEM

After the computation of the quantity of storm runoff entering each inlet, the storm sewer system required to carry off the runoff is designed. It should be borne in mind that the quantity of flow to be carried by any particular section of the storm sewer system is not the sum of the inlet design quantities of all inlets above that section of the system, but is less than the straight total. This situation is due to the fact that as the time of concentration increases the rainfall intensity decreases.

A. Storm Sewer Pipe

The ground line profile is now used in conjunction with the previous runoff calculations. The elevation of the hydraulic gradient is arbitrarily established approximately two feet (2') below the ground surface. When this tentative gradient is set and the design discharge is determined, a Manning flow chart may be used to determine the pipe size and velocity.

It is probable that the tentative gradient will have to be adjusted at this point since the intersection of the discharge and the slope on the chart will likely occur between standard pipe sizes. The smaller pipe should be used if the design discharge and corresponding slope does not result in an encroachment on the two foot (2') criteria below the ground surface. If there is encroachment, use the larger pipe which will establish a capacity somewhat in excess of the design discharge. Velocities can be read directly from a Manning Flow Chart based on a given discharge, pipe size and gradient slope.

B. Junctions, Inlets and Manholes

A. Determine the hydraulic gradient elevations at the upstream end and downstream end of the pipe section in question. The elevation of the hydraulic gradient of the upstream end of pipe is equal to the elevation of the downstream (hydraulic gradient) plus the product of the length of pipe and the pipe gradient.

B. Determine the velocity of flow for incoming pipe (main line) at junction, inlet or manhole at design point.

C. Determine the velocity of flow for outgoing pipe (main line) at junction, inlet or manhole at design point.

D. Compute velocity head for outgoing velocity (main line) at junction, inlet, or manhole at design point.

E. Compute velocity head for incoming velocity (main line) at junction, inlet, or manhole at design point.

F. Determine head loss coefficient "k" at junction, inlet, or manhole at design point from Tables 5-4, 5-5, 5-6 or Figures 5-10, 5-11.

G. Compute head loss at junction, inlet, or manhole.

$$h_j = K_j \left(\frac{v_2^2 - v_1^2}{2g} \right)$$

H. Compute hydraulic gradient at upstream end of junction as if junction were not there.

I. Add head loss to hydraulic gradient elevation determined to obtain hydraulic gradient elevation at upstream end of junction.

All information shall be recorded on the plans or in tabular form convenient for review.