LANCASTER COUNTY PLANNING COMMISSION

STORM DRAINAGE STUDY

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Lancaster County Planning Commission
Storm Drainage Study

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INTRODUCTION

The growth of Lancaster County in the last few years has changed many of its areas from a principally rural-farm orientation to a commercial-residential nature. This change of land use has an important effect on the amount of storm water runoff resulting from a rainfall. The construction of impervious roof and paved areas and lawn areas have greatly increased the storm water runoff. This increased runoff has not only very seriously overloaded many of the existing drainage facilities, but has also exposed the inadequacy of the storm drainage requirements of many of the municipalities within the County of Lancaster. Although most municipalities have some form of requirements for storm drainage facilities, these are often lacking in specifics, and are generally not worded positively enough to ensure adequate enforcement. Recognizing these factors and the need to reevaluate the requirements for storm drainage facilities, it is the purpose of this study to recommend design criteria which will provide the basis for the design of adequate storm drainage facilities for suburban, urban, industrial, and agricultural areas of the County. In addition, this report provides an inventory of the existing major storm drainage systems within the County and suggests the scope of a future storm sewer report of a more comprehensive nature.

Included within the recommended design criteria for storm drainage facilities are the basic runoff equations for the determination of the volume of runoff, runoff coefficients relative to the various types of surfaces found within the County, and storm intensity duration curves for various frequency storms common to this area. Recommended practice for the requirement and placement of storm drainage facilities is also discussed.

STORM DRAINAGE DESIGN CRITERIA

Justification for the installation of storm drainage facilities of any type is primarily twofold. The first justification is economic in nature by virtue of prevention of damage to property which may result from the effects of the storm runoff; and the second justification is found in the lessening of the inconvenience to both vehicular and pedestrian traffic during and shortly after a rainstorm.

In residential areas, consideration is normally given only to providing sufficient storm drainage facilities to provide for convenience of travel, except in those low lying areas where severe flooding would occur without storm drainage facilities.

In the higher-valued commercial and industrial areas, consideration must not only be given to the convenience of those using these areas but also to the greater property damage which may result from the storm water runoff.

The extent to which storm drainage facilities are provided must be balanced against the extent of the convenience provided and property damage prevented and the cost to provide the storm drainage facilities.

RECOMMENDED STORM DRAINAGE DESIGN METHOD

The methods used to determine the volume of runoff occurring as a result of a rainfall vary in complexity and in approach. The method most widely used throughout the United States is referred to as the "Rational Method" and is suggested for use in the Lancaster County area. As its wide use would suggest, this is a relatively simple method to use, and is based on information such as runoff coefficients and rainfall intensity which is generally available to any designer normally engaged in this type of work. Such information is included later in this report.

The rational method is particularly applicable to smaller drainage areas which would be encountered in the average residential subdivision or commercial-industrial complex. In addition, the Pennsylvania Department of Forests and Waters requires that all drainage facilities which receive water from drainage areas in excess of one-half square mile or 320 acres be approved by the Department of Forests and Waters and be designed in accordance with their criteria. Therefore, any requirements of the Lancaster County Planning Commission would be superceded by the requirements of the Department of Forests and Waters in these cases of larger drainage areas.

The rational method translates rainfall into runoff by the equation $Q = CIA$, in which "Q" is the storm water rate of runoff in cubic feet per second, "A" is the drainage area in acres contributing runoff to the point under design, "I" is the average rainfall intensity in inches per hour for the period of rainfall for the particular frequency storm and "C" is the runoff coefficient or ratio between the expected rate of runoff from the area and the average rate of rainfall on the area.

STORM DESIGN INTENSITY

The study of that part of hydrology which encompasses the behavior of storms cannot be called an exact science because, given a factor such as rainfall, one cannot precisely predict the resulting deposition of water in scientific and mathematical terms. This inability to accurately predict is due primarily to the great complexity of the hydrologic cycle, the lack of accurate observable data, and the almost innumerable combination of hydrologic phenomena that occur in nature. Because of this, the aspects of hydrology that are related to rainfall are generally related in terms of statistical probability; that is, there is a probability that with a given intensity and length, a particular storm will occur once within a given number of years. The more frequent storm will be of lower intensity and the less frequent storm will be of higher intensity. It is accordingly the responsibility of the designer to determine, for the specific locale, the frequency of storms that will best balance the probability of inconvenience and damage against the expected cost of the installation of storm facilities to provide for the runoff from these storms. Since it is sometimes desirable to provide a higher degree of protection for some facilities than others, it is necessary to select the severity of the storm for different facilities.

The records of various storms have been maintained by the United States Weather Bureau for many years. The frequency of various storms of specific length and intensity can be plotted and graphically shown from these records. The graphs for the Lancaster County area are shown on Figure B-1 in the appendix of this report. These intensity-duration-frequency curves have been prepared from information supplied by the United States Weather Bureau. Curves which have been developed on the basis of United States Weather Bureau records for Reading, Philadelphia, and Harrisburg have been adjusted to conform to the conditions found in the Lancaster County area. From the plottings of these storms, it can be predicted that a storm with a specific intensity and length will occur once in a given number of years. In addition, the various combinations of intensity and length are given for storms of various frequencies. Minor or slow-falling precipitation such as drizzle, snow or hail does not occur at a sufficient rate to influence the intensity-duration curves, and is not included in these curves.

The frequency of a storm refers to average interval expected between storms of a specific intensity and duration. This is not to say that exactly five ten-year storms will occur within a fifty year period, and be spaced at uniform intervals. There is merely a statistical probability that five of these storms will occur within the fifty year period; they may, however, be spaced erratically, possibly several of which might occur within the space of one year. It can also be seen from Figure B-1 that for a given storm length the intensity will vary with the frequency of the storm. The less frequent storms will be more severe.

For use in determining the amount of storm water runoff for the usual residential development, a five-year frequency storm is recommended. This provides a reasonable balance between the anticipated damage or inconvenience to the residents and the cost for the installation of the storm facilities. Storms with a frequency of occurrence of once in ten years are recommended for urban areas and for drainage facilities under the major streets, and twenty-five to fifty years storms are recommended for higher value districts and for drainage facilities under major highways.

TIME OF CONCENTRATION

The assumption is made in the rational method that runoff at a point is a function of the average rainfall rate during the time for water to flow from the remotest part of the drainage area to that point. This time for the runoff to flow to the point where the runoff is being estimated is called time of concentration and is the time required for the maximum runoff rate to develop. Also, it is necessary that for the maximum runoff rate to occur, the duration of the storm must be at least equal to the time of concentration, because then every part of the watershed will be contributing simultaneously to the runoff flow. Therefore, the time of concentration is used to determine the storm duration time in the use of the rainfall intensity-duration curves.

There are various graphs, charts and other methods for the calculation of concentration time which take into consideration the slopes, surface covers and condition of the ground. In general, overland flow without the formation of small streams of storm runoff are restricted to about 1,200 feet. Because of variations in ground cover, slope, and topography, the point at which channel flow actually begins can vary considerably, and judgement must be used in determining this hypothetical point. In nearly all cases, this point will occur before the storm water has travelled 1,200 feet. Beyond this, it is generally considered that the flow progresses from a surface overland flow into the channel flow mentioned above with inherent higher velocities. In most cases this is taken into consideration in the graphs and charts used. There are many formulas and charts available for the computation of concentration time, and none is seen to have any great advantage over the others. Table A-1 in the appendix gives average overland flow velocities for various surfaces.

For urban and suburban storm sewers, the time of concentration consists of inlet time, which is the time required for storm runoff to flow over the surface of the ground to the nearest inlet, plus the time of flow in the sewer from that inlet to the point under design. This inlet time consists of the overland flow time required for water to reach established surface drainage channels such as street gutters or natural swales, plus the channel flow time required for water to flow through these channels to the inlet. This time will vary with the surface, slope, nature of the surface cover and distance of surface flow. As is the case of the runoff coefficients, the inlet time is dependent upon not only the nature of the ground and the surface cover, but on the season and the stage of crop growth which might be involved. Consideration must also be given here to the anticipated buildup of undeveloped areas so that the corresponding inlet time may be calculated over the improved surface.

RUNOFF COEFFICIENTS

The runoff coefficient "C" used in the rational formula indicates the degree of imperviousness of the drainage area under study and reflects the percentage of runoff expected from a given amount of total rainfall. As is the case with many factors in design, the greatest exercise of judgement is called for on the part of the designer in establishing the values of "C". Because it is an item on which judgement is required, a range of values for various types of surfaces has been compiled, and are presented in Table A 2 and in the recommended storm drainage requirements for the Lancaster County Planning Commission found later in this report.

Although its use in the formula implies a fixed ratio for any given drainage area, in reality the coefficient represents losses between the amount of rainfall and actual runoff, which may vary for a given drainage area with different climatological or seasonal conditions. These losses include interception by vegetation which is not usually significant for urban and suburban drainage areas, but may have a considerable influence on forested areas. Infiltration into impermeable soils is also a consideration in the determination of the runoff coefficient, and this relates to the ability of the soil to absorb water and percolate it into deeper ground water. This is also affected by variations which include the season, the wetness of the soil at the beginning of the storm, the amount and type of ground cover involved, and the type of soil.

The retention of storm water in surface depressions is another consideration which influences the value of "C". The first rainfall from a storm would fill many of the depressions which are present on essentially all surfaces. As the length of the storm progresses, these depressions are filled, and thus are not nearly as important a consideration for longer storms. This is also the case with infiltration into the soil, since the storm progresses, the voids in the soil become filled and absorb less and less water. Since it is the five and ten-year frequency storms which are normally used in storm runoff calculations for urban and suburban areas, some of the variations such as surface depressions and soil infiltration are not as critical as they would be in longer storms. The range of coefficients given in this report generally relate to values which would correspond to the variations which could reasonably be expected to occur.

Consideration should be given to the determination of "C" factors for presently undeveloped drainage areas which will cause an increase in runoff when fully developed in the future. Although an area may now be only woodland or pastureland, consideration should be given to the future when this land may well become a residential, commercial, or industrial development. Although it may appear an unnecessary burden on the developer of the land, it is pointed out that once the storm drainage facilities are installed, there is little probability that these will be removed and replaced within the next few years to account for increased runoff. Thus, any storm drainage facilities to be installed must be considered with respect to anticipated usage of the tributary drainage land areas. For this reason, it is recommended that the future land use maps of the individual municipalities be used as a guide to the determination of runoff coefficients to be used by the developers.

Since there is little possibility that overall runoff coefficients would fall below 0.30 after most of the land is developed in the future, it is recommended that this be used as a minimum value in the computation of the runoff for all areas except permanent parks and cemeteries.

GUTTER FLOW AND INLET LOCATION

Once the runoff from a storm has reached the gutters of the streets, the problem is when and where to place the inlets to collect the water. The normal curb height for urban areas using the standard straight curb is approximately six inches. However, in suburban areas where rolled curbs are generally in use, the curb height is approximately four inches. With resurfacing in later years, this could be very easily reduced to three inches of less. Accordingly, since curbs should carry the storm water without overflowing to the grass areas and without overflowing into the center of the travelled part of the roadway, the depth of storm water in gutters should be restricted to three inches. Using the universally accepted Manning equation, the capacities of the gutters have to be calculated for various slopes. A graph using this equation has been prepared with the capacities shown for various depths of flow in gutters, and is included as Figure B-2 in the appendix of this report.

Having determined the capacity of the gutter at a given slope of street, the problem becomes one of determining the placement and size of the storm inlets. Several drawings have been included in the appendix of this report showing the various conditions which can be expected on streets and at intersections within a development. As stated above, inlets should be provided when the depth of flow in a gutter exceeds three inches. Inlets should also be provided at abrupt changes in the vertical or horizontal direction of storm sewers, and where required to drain low spots in a street. Inlets should be provided on both sides of the street at low spots so that it is not necessary to force the flow of water across the crown of the street.

Although it is generally felt that all storm water should be prevented from flowing across streets before being collected, it must also be recognized that reasonableness should be used in determining the requirements for inlet locations. Accordingly, it is recommended that storm water which has not reached the depth of three inches along the gutter be permitted to flow across the intersection at a cross street, since traffic would have to stop at that point and would be encountering the water at relatively low speeds. On through streets where the traffic would be moving without stopping, it is recommended that this depth along the gutter be limited to one inch. This would permit a relatively small amount of water to flow across the street, and once it has spread out at the intersection the depth would even be less than 1 inch. It is also felt that water which has reached the required depth for an inlet along the gutter be permitted to flow around the radius of an intersection and be picked up at an inlet on the other radius point. These conditions are shown on Figures B-4 through B-7 in the appendix. This may cause some minor inconvenience to pedestrians trying to use the sidewalks. Since most developments will be in suburban rather than urban areas, however, it is felt that there will be little foot traffic during rainstorms, and such minor inconveniences should be permitted. This is generally done now in the

Lancaster County area and has worked out satisfactorily. The placement of the inlets should be along the gutter line as shown on Figure B-3 in the appendix and should not be permitted on the curved part of the curbing.

Although there are many types and sizes of inlets and varying capacities, it is suggested for standardization and ready supply that the Pennsylvania Department of Highways Standard 2' x 4' and 2' x 6' inlets be utilized. These are of good hydraulic design and are generally available to all contractors with little delay. Their capacities are such that only at extreme street grades will the gutter capacities exceed the hydraulic capacity of the inlets. The efficiency of the inlet can be increased by depressing the grating 1 to 2 inches below the elevation of the gutter.

In addition to the proper design of a storm water collection system, consideration must be given to the point of discharge of storm water. In the cases of new subdivisions, the flow is invariably conveyed to an existing natural drainage swale on an adjoining property. The problem now arises that with a storm water collection system, the storm water volumes are increased by the change of character of the intercepting drainage surface and are also concentrated at the point of discharge. This concentration of flow gives rise to possible erosion of the natural channel or swale and possible legal recourse by the adjoining property owner.

Erosion velocities, or velocities above which erosion takes place, vary widely, depending upon the characteristics of the channel material, depth of flow in the channel, and the velocity distribution. Maximum permissible velocities are presented in Table A-3 in the appendix of this report for common channel materials.

Two of the most common methods avialable to control the erosive potential of high velocity storm sewer discharges are energy dissipation and flow distribution. Both methods simply decrease the velocity of the flow below the point at which erosion takes place. Energy dissipation is accomplished by providing turbulence to the flow of water. Kinetic energy from the velocity of the water is dissipated by this turbulence.

Relieved of its energy, the water is slowed to a velocity below that which would cause scour of the channel material. This can be accomplished using a precast concrete structure available from precast manufacturers; or, as an alternate, properly placed riprap of suitable size could accomplish the same result. Flow distribution can be accomplished by using a precast structure which increases the width of the stream of storm water. The resulting increased area of flow thus reduces the velocity below that which causes scour. Flared end sections avialable for corrugated metal pipe can provide for a reduction in stream velocity, and are a method of flow distribution. Energy dissipation is the preferred of the two methods noted above for control of erosion. References 8, 9, and 10 contain additional information relative to the design of erosion control devices.

RECOMMENDED STORM DRAINAGE REQUIREMENTS

The following summary of storm drainage requirements is based upon the foregoing discussion, and can be used as the Lancaster County Planning Commission storm drainage requirements in its Subdivision Regulations:

1. Storm drainage facilities shall be provided where desirable or necessary in order to drain low points along streets, to intercept storm runoff along streets at reasonable intervals, and to permit the unimpeded flow of storm runoff along natural water courses. Such facilities shall consist of inlets, manholes, pipes, headwalls, and other facilities necessary for the collection and transportation of storm runoff.

2. The following criteria shall be used in determining the extent of the design required for storm drainage facilities in residential developments:

    a. For drainage areas of less than 2 acres, the flow normally can be carried in gutters of minimum slope.

    b. For drainage areas over 2 acres, the drainage facilities shall be designed by a Registered Engineer in accordance with the criteria included herein.

       Drainage facilities for drainage areas in excess of 1/2 square mile (320 acres) shall conform to the requirements of, and be approved by the Pennsylvania Department of Forests and Waters.

       In the case of non-residential development, the storm drainage plan shall be prepared by a Registered Engineer.

3. The method used in calculating runoff shall be the Rational Formula Q = CIA, in which "Q" is the storm flow in cubic feet per second, "C" is a coefficient indicating the degree of imperviousness of the drainage area, "I" is the intensity of rainfall in inches per hour for the particular frequency of storm used, and "A" is the drainage area in acres.

   Coefficients "C" used for the calculation of runoff shall be based on the anticipated ultimate use of the land as outlined in the officially designated future land use plan for the municipality involved or in the absence of such a plan on values assigned by the Lancaster County Planning Commission. Except for cemeteries, golf courses, and publicly owned park areas, a minimum value of "C" to be used for composite areas shall be 0.30. Other suggested "C" values to be used are as follows:

Type of Surface	Normal Range	Recommended Values[1]
Pavements, concrete or bituminous concrete	0.75-0.95	0.90
Pavements, bituminous macadam or surface-treated gravel	0.65-0.80	0.75
Pavements, gravel, macadam, etc.	0.25-0.60	0.50
Sandy soil, cultivated or light growth	0.15-0.30	0.30
Sandy soil, woods, or heavy brush	0.15-0.30	0.30
Clay soil, bare or light growth	0.35-0.75	0.50
Clay soil, woods or heavy growth	0.25-0.60	0.40
City business sections	0.60-0.80	0.70
Dense residential sections	0.50-0.70	0.60
Suburban, normal residential areas	0.35-0.60	0.35
Rural areas, parks, golf courses	0.15-0.30	0.25

[1]Use of lower values must be fully justified.

Values of "I" storm intensity, to be used are as follows (inches per hour):

Time of Flow minutes	Frequency of Storm Years		
	5	10	25
5	5.8	6.5	7.5
10	4.7	5.4	6.2
15	4.0	4.6	5.2
20	3.4	4.0	4.5
25	3.0	3.5	4.0
30	2.7	3.2	3.6
35	2.4	2.9	3.3
40	2.2	2.7	3.1
45	2.1	2.5	2.9
50	2.0	2.3	2.7
55	1.9	2.2	2.6
60	1.7	2.1	2.5

Storm with a frequency of occurrence of once in five years shall be used for residential developments and suburban areas; ten year storms shall be used for urban areas, and for drainage facilities under major streets; twenty-five year storm shall be used for high value districts and for major highways. The time of flow shall be the time which it takes runoff from the furthest point of the drainage area to reach the location of the drainage facility to be designed, and shall include overland flow time plus gutter flow time plus time of flow through pipes, culverts, or natural streams. Overland flow time shall be computed using a generally accepted chart or formula. Suggested runoff velocities are as follows:

Description of Course of Runoff Water	Percent Slope vs. Velocities[1]					
	0-2%	2-4%	4-7%	7-10%	15%	20%
Woodland or Dense Grass	0.2	0.3	0.4	0.4	0.4	0.4
Pasture or Average	0.3	0.4	0.4	0.4	0.5	0.5
Poor Grass	0.4	0.5	0.5	0.6	0.7	0.8
Bare Soil	0.5	0.6	0.7	0.8	0.9	0.9
Paved Areas	0.8	1.0	1.2	1.4	1.6	2.0

[1] Velocities in feet/second.

4. Inlets shall be placed at points of abrupt changes in the horizontal or vertical directions of storm sewers, at points where the flow in gutters exceeds three inches, and at a maximum distance of 600 feet apart. In streets, inlets shall normally be located along the curb line and at or beyond the curb radius points. For the purpose of inlet location at corners, the depth of flow shall be considered for each gutter. At intersections, the depth of flow across through streets shall not exceed one inch. The Manning equation shall be used to calculate the capacities of gutters. Pennsylvania Department of Highways 2′ x 4′ and 2′ x 6′ inlets or equivalents should be used and can be considered to have capacities of 10.0 cfs and 15.0 cfs, respectively. Inlets shall be depressed two inches below the grade of the gutter or ground surface. Manholes may be substituted for inlets at locations where inlets are not required to handle surface runoff.

5. Storm sewers shall have a minimum diameter of 15″ and shall be made of reinforced concrete or corrugated metal. The Manning Equation shall be employed in computing pipe

capacities. Sewers shall be installed on sufficient slopes to provide a minimum velocity of three feet per second when flowing full.

6. Headwalls shall be used where storm runoff enters the storm sewer horizontally from a natural or man-made channel. The capacity of such storm sewers shall be calculated for both steady flow and culvert design. The lower value of the two shall be used to determine the capacity of storm sewer.

7. Open channel flow of storm runoff through residential areas will be permitted only for natural streams with permanent or intermittent flow as denoted by a solid or broken blue line on a U. S. Geologic Survey Map. Such channels shall be designed to handle, without overflowing, the calculated runoff from a storm of 10-year frequency or as required by the Pennsylvania Department of Forests and Waters. The capacities of any modifications to natural channels shall be computed from the Manning Equation. Permissible stream velocities are as follows:

Material	Allowable Velocity Feet per Second
1. Well established grass on good soil	
a. Short pliant bladed grass	5-6
b. Bunch grass-soil exposed	2-4
c. Stiff stemmed grass	2-3
2. Earth without vegetation	
a. Fine sand or silt	1-2
b. Ordinary firm loam	2-3
c. Stiff clay	3-5
d. Clay and gravel	4-5
e. Coarse gravel	4-5
f. Soft shale	5-6
3. Other	
a. Bituminous or cement stabilized channels	6
b. Paved channels	10-15

8. A minimum of a 20-foot wide right-of-way should be provided along all storm sewers not located within public rights-of-way.

EXISTING STORM DRAINAGE SYSTEMS

All of the more densely populated municipalities within Lancaster County have storm drainage systems in varying degrees of adequacy and comprehensiveness. Information relative to the storm drainage systems within these municipalities was investigated to the limited degree permitted by the scope of this report. At present, only two municipalities within the County have combined sanitary and storm sewer systems. These are the City of Lancaster and the Borough of Christiana which discharge into the Conestoga and Octoraro Creeks, respectively. The Borough of Marietta is presently installing a complete sanitary sewer system which will eliminate its combined sanitary and storm sewer system.

The largest storm sewer system within the County of Lancaster is found within the City of Lancaster. The City is divided into three major drainage basins, all of which are at least in part combined sewer systems, with sanitary sewerage and storm water sharing the same sewers. The Water Street District, which serves essentially the south-central portion of the City, terminates at the Engleside Diversion Chamber along the Conestoga Creek. During dry weather, most of the flow to this chamber is conveyed to Lancaster's South Sewage Treatment Plant, located on the New Danville Pike, for treatment. The recently reconstructed diversion chamber receives the sewage and storm water from 120-inch and 96-inch diameter sewers. During rain storms and periods of snow runoff, the chamber diverts that portion of the runoff which the South Sewage Treatment Plant is not capable of treating to the Conestoga Creek. The Northern section of the City is also drained by a combined sewer system The combined flows in excess of the dry weather flows are discharged to the Conestoga Creek with the normal flows being diverted to the Lancaster North Sewage Treatment Plant for treatment.

Similar combined flows are discharged to the Conestoga Creek at the Stevens Avenue Pump Station, Susquehanna Pump Station, and along Abbeyville Road in Lancaster Township.

The outlying areas of the City of Lancaster including the Townships of Manheim, East Lampeter, and Lancaster all have developed storm sewer systems to some degree. These are for the most part fragmented or partial systems, however, with many and severe storm sewer problems still existing.

The remaining municipalities within the County have storm drainage installations which comprise, in most instances, fragmented or partial systems. A summary of all drainage systems is included on Figure B-8, with descriptions given in the "Summary of Existing Storm Sewage Systems".

Elizabethtown and Ephrata possibly have the most advanced and complete systems, with the Boroughs of Columbia, Mount Joy, Millersville, and Lititz also having at least part of their Boroughs provided with reasonably adequate storm sewer systems. In at least a few instances, the reconstruction or new construction of state highways projects has provided the municipalities with a nucleus of storm drainage facilities upon which they can build. These, by their very nature, are also fragmented and incomplete. In many cases, the sole purpose for the installation of storm drainage facilities was to provide drainage for low areas or to provide a channel for streams at low flows to pass under highways or roads. The recent surge of residential and commercial construction within Lancaster County has contributed considerably to the inadequacy of those facilities down-stream from these areas of development as was noted earlier in the report.

The following is a summary of Existing Storm Sewer Systems in Lancaster County: A map of existing storm sewer system is given in the appendix.

1. *City of Lancaster:* Most of the storm sewer systems are combined with the City sanitary sewer system. There are two major storm water diversion chambers: the Engleside Diversion Chamber located at the intersection of Route 272 and Route 324, serving most of the southern half of the City, and overflowing into the Conestoga Creek; and the Clay Street interceptor serving the northeast section of the City and also overflowing into the Conestoga Creek. In addition, smaller combined systems serve parts of the eastern section of the City and overflow to the Conestoga Creek at the Susquehanna and Stevens Avenue Pump Stations. Numerous other storm sewers exist which serve localized areas.

1-A *Areas Immediately Surrounding the City:* Minor storm drainage systems, not necessarily connected to each other, but serving most of the developed areas. Discharges are to the Conestoga, Little Conestoga and to tributaries of these two main streams.

1-B *Outer Fringes of the Metropolitan Area:* Mostly in residential sections and along major highways. Often designed only to relieve specific local drainage problems. Some are very minor systems as part of state highway projects or residential subdivisions. These areas would be classified as having "fragmented" systems.

2. *East Petersburg:* Fragmented storm sewers relieving local drainage problems. Discharge eventually to the Little Conestoga Creek. Has no major systems.

3. *Neffsville (Manheim Township):* Fragmented or localized storm sewers discharging to small streams and runs in the area. Minor storm drainage system as part of School Valley Farms Development.

4. *Willow Street Area:* Served by localized drainage structures which discharge to nearby unnamed streams.

5. *Strasburg Borough:* Series of inlets and drainage pipes along Main Street. No other significant drainage facilities. Discharge is to local unnamed streams.

6. *Quarryville Borough:* Storm sewerage facilities are developed into a minor system which discharges to an unnamed stream near the east end of the Borough.

7. *Christiana Borough:* Has a combined storm and sanitary sewer system normally flowing to the sewage treatment plant. During storm flows will overflow into Pine Creek and Williams Run which merge to form Octoraro Creek. Generally covers most of the Borough.

8. *New Holland Borough:* The central and south portions are served by storm sewers that can be considered as a minor system. The facilities appear to be adequate and discharge is to a tributary of Mill Creek. Other storm sewers on the northern side of the Borough discharge to a tributary of Conestoga Creek.

9. *Terre-Hill Borough:* Scattered drainage pipes alleviating local problems only. Storm runoff flows in all directions from the center of the town.

10. *Adamstown Borough:* No storm sewers.

11. *Denver Borough:* Localized drainage facilities discharging to the Cocalico Creek.

12. *Ephrata Borough:* Well served by a major system of storm sewers which reaches nearly every part of the community. Discharges to the Cocalico Creek and its tributaries.

13. *Akron Borough:* Limited to localized facilities serving individual drainage problem areas. Newer residential areas are more adequately sewered and all discharges are to the Cocalico Creek or its tributaries.

14. *Lititz Borough:* The Borough of Lititz is well served by a series of minor storm sewer systems and localized facilities. Most discharges are to Lititz Run and its tributaries.

15. *Manheim Borough:* Served by localized drainage facilities which discharge to Chickies Creek. The newer residential sections are served by small systems of storm sewerage.

16. *Landisville:* Partially served by fragmented or localized storm sewers. There are problem drainage areas primarily caused by very level terrain and a high water table. Has no effective drainage systems.

17. *Mount Joy Borough:* Served by localized storm sewers forming minor systems in the west end, and two larger drainage systems in the east part of the Borough. Discharge is to the Little Chickies Creek and to Donegal Creek.

18. *Elizabethtown Borough:* Served by a well defined storm sewer system in all sections of the Borough. Discharges are to the Conoy Creek and its tributaries.

19. *Marietta Borough:* Storm drainage facilities are divided into two parts. The eastern end of the Borough has a fairly well defined minor system and the western part has only localized storm sewers. Storm drainage is discharged to the Susquehanna River.

20. *Columbia Borough:* The part of the Borough north of Route 30 is served by a relatively complete system. The remainder of the Borough has some smaller systems serving specific areas, and other localized installations designed to relieve specific problems. Some storm runoff is carried directly onto streets by deep gutters. Discharges are to Stricklers Run and the Susquehanna River.

21. *Mountville Borough:* Storm sewers are primarily those installed along Route 426. There are other single-purpose installations in the Borough. Runoff is discharged to the west Branch of the Little Conestoga Creek, and to Stricklers Run.

22. *Washington Borough:* Primarily provided by highway drainage along Route 441 and the Penn Central Railroad which runs along the Susquehanna River. Some storm drainage exists in along Route 999. All discharges are to the Susquehanna River.

23. *Millersville Borough:* Isolated pipes or small drainage systems serving local areas. Minor storm sewer system located in the Quaker Hills area. Discharges are eventually to the Conestoga and Little Conestoga Creeks.

A preliminary analysis of the characteristics of the discharge from six storm sewers was made and the results tabulated in Table A-4 appended to this report. Four of the discharges were from combined sewers.

The samples were taken on December 15, 1969 after a minor rainfall. The flow also consisted of the runoff from melting snow. In each case, the major pollutional constituents, the biochemical oxygen demand, and the total suspended solids of the storm water equal or exceed that found in normal untreated domestic sewage.

Although this sampling was not extensive, the results indicate that the storm water does contain a pollutional potential. Further analysis would be required to determine the pollutional effect on the stream.

SCOPE OF FUTURE STORM DRAINAGE STUDY

Primary consideration in a more comprehensive storm drainage study of the County should be given to a determination of the adequacy of existing storm drainage facilities. Such a determination would require both an analysis of the expected discharge at the point of design and an analysis of the capacity of the existing drainage facilities. Although the latter is fairly routine, the former is quite extensive and could require the expenditure of a considerable number of manhours to accomplish. Included in this would be the determination of the drainage area, runoff coefficients, and concentration time for each facility to be analyzed. In addition, unit hydrographs would have to be established for various drainage systems since the sizes of the areas involved extend beyond the limits of accurate use of the rational method. Because of the prohibitive costs which would otherwise occur for the study, the selection of facilities to be analyzed would have to be limited to the larger and more critical areas. A minimum drainage area or some similar criteria would have to be established for each facility to be analyzed in order to precisely specify the limits of the contract for accomplishing this portion of the study.

Relating to the study of the magnitude and location of storm runoff is the extent to which flooding conditions have occurred in the past and may be expected to occur in the future at specific locations. Because it may not be possible or practical to provide for sufficiently large drainage facilities at some locations, an alternate to that solution would be the investigation of the use of flood control measures such as retaining walls to contain the flow, or impounding basins to reduce the magnitude of the peak flow. Consideration in the study should be given to analyzing areas with known flooding problems in order to provide alternate solutions to that of simply providing large storm drainage facilities.

Although the pollutional effects of the two combined sanitary-storm sewer systems in the County are not directly related to the determination of the quantity of storm water at these points, they do effect the quality of water at these locations. As this can, in fact, be a major source of pollution at various times, it is deserving of further study. Since this problem is apparently not the subject of examination in other studies, it is felt necessary and proper to consider it as part of the future storm drainage study. Included in this portion of the study would be the establishment of a relationship between various storm flows and the degree of pollution which results from these flows. Further, methods of flow separation should be determined, and costs estimated for their accomplishment.

Associated somewhat with the pollutional effects of combined sewers is the pollution of streams resulting from the runoff from urban and farm areas. This pollution includes the effects from both chemical and organic fertilizers, herbicides, and insecticides. Again, although this problem is not related to the quantity of storm water, it can very much effect the quality of the receiving streams, and should accordingly be investigated.

Although the determination of the physical limits of flood plains would serve no purpose relative to the quantity of storm water, it is an important tool to the planner in delineating the limits of areas where permanent construction should be prohibited. It would at the same time accurately determine locations suitable for park or recreational areas.

In summary, then, the following list of items is recommended for accomplishment in the preparation of a Comprehensive County-wide Storm Drainage Study, with the list also being able to serve as the scope for an engineering services proposal for that work:

		Probable Cost
1.	Meet with local municipal and Pennsylvania Department of Highway officials to ascertain chronic drainage problem areas and the status of proposed storm drainage improvement programs.	$ 500.00
2.	Prepare an inventory of existing storm drainage facilities which serve a drainage area of 40 acres or more and those facilities serving smaller areas which are creating drainage problems. Inventory shall include existing combined sanitary and storm water sewerage systems and any field measurements required to ascertain sizes, and to ascertain the slopes of critical facilities.	$11,500.00
3.	Determine tributary drainage areas, compute storm flow volumes for five and ten-year frequency storms, determine hydraulic capacity of existing facilities, and determine necessary improvements to adequately carry storm flows for the facilities inventoried.	$12,000.00
4.	Prepare series of 400-scale maps showing existing storm drainage facilities and associated tributary areas. Prepare overlay showing required improvements.	$ 2,500.00

	Probable Cost
5. Analyze existing combined sanitary and storm sewerage systems and suggest methods of separating or treating of the combined flows. Prepare 400-scale maps of combined systems showing proposed schemes for separation or treatment, and give costs for these schemes.	$ 2,200.00
6. Inventory major stream flow obstructions such as dams and bridges and conduct flood routing analyses of selected streams, using flood-of-record flows and projected flood flows to determine the extent of flooding occurring at these locations during flood peaks. Prepare a map showing the extent of flooding during these floods.	$10,700.00
7. Conduct an extended sampling and monitoring of stream quality to determine and compare the affects of agricultural and urban runoff. The chemical analyses shall include determination of biochemical oxygen demand, suspended solids, phosphates, and ammonia in runoff. Correlate stream quality changes with urban and agricultural storm water runoff occurrences along a stream. The period of sampling should be at least a year in duration.	$28,800.00
8. Prepare a report summarizing the information developed through the above steps and through the results of the study, using multicolor graphics.	$ 3,000.00
9. Report reproduction (200 copies).	$ 1,200.00

The estimated cost to prepare the suggested comprehensive report is $75,000. A reduction in the scope of the report would alter this cost.

REFERENCES

1. "Hydrology Handbook", A.S.C.E. Manual No. 28.

2. "Design and Construction of Sanitary and Storm Sewers", A.S.C.E. Manual No. 37.

3. "Rainfall Frequency Atlas of the United States, for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years", U. S. Weather Bureau Technical Paper No. 40, May 1961.

4. "Rainfall Intensity-Duration-Frequency Curves", U. S. Weather Bureau Technical Paper No. 25, December 1955.

5. "Engineering Hydraulics", Edited by Hunter Rouse.

6. Pennsylvania Department of Highways, "Design Manual Part 2, Highway Design".

7. "Data Book for Civil Engineers, Volume I", Elwyne E. Seelye.

8. "Drainage Structures", Highway Research Board Bulletin 286, Washington D. C., 1960.

9. "Handbook of Applied Hydraulics", Davis, McGraw-Hill Book Co., 1969.

10. "Design of Small Dams" - U. S. Bureau of Reclamation, 1960.

APPENDIX A

Table A-1

Lancaster County Planning Commission

Storm Drainage Study

Recommended Average Velocities
for
Computing Overland Flow Times

Description of Course of Runoff Water	Percent Slope vs. Velocities[1]					
	0-2%	2-4%	4-7%	7-10%	15%	20%
Woodland or Dense Grass	0.2	0.3	0.4	0.4	0.4	0.4
Pasture or Average Grass	0.3	0.4	0.4	0.4	0.5	0.5
Poor Grass	0.4	0.5	0.5	0.6	0.7	0.8
Bare Soil	0.5	0.6	0.7	0.8	0.9	0.9
Paved Areas	0.8	1.0	1.2	1.4	1.6	2.0

[1] Velocities given in feet/second.

Reference: "Data Book for Civil Engineers, Volume I" Elwyne E. Seelye.

Table A-2

Lancaster County Planning Commission

Storm Drainage Study

Recommended Runoff Coefficients

Type of Drainage Area or Surface	Runoff Factor "C" Normal Range	Runoff Factor "C" Recommended Values[1]
Pavements, concrete or bituminous concrete	0.75-0.95	0.90
Pavements, bituminous macadam or surface-treated gravel	0.65-0.80	0.75
Pavements, gravel, macadam, etc.	0.25-0.60	0.50
Sandy soil, cultivated or light growth	0.15-0.30	0.30
Sandy soil, woods, or heavy brush	0.15-0.30	0.30
Clay soil, bare or light growth	0.35-0.75	0.50
Clay soil, woods or heavy growth	0.25-0.60	0.40
City business sections	0.60-0.80	0.70
Dense residential sections	0.50-0.70	0.60
Suburban, normal residential areas	0.35-0.60	0.35
Rural areas, parks, golf courses	0.15-0.30	0.25

[1] Use of lower values should be fully justified.

Reference: Pennsylvania Department of Highways, "Design Manual Part 2, Highway Design".

Table A-3

Lancaster County Planning Commission

Storm Drainage Study

Recommended Allowable Water Velocities
for
Open-Channel Flow

Material	Allowable Velocity Feet per Second
1. Well established grass on good soil	
a. Short pliant bladed grass	5-6
b. Bunch grass-soil exposed	2-4
c. Stiff stemmed grass	2-3
2. Earth without vegetation	
a. Fine sand or silt	1-2
b. Ordinary firm loam	2-3
c. Stiff clay	3-5
d. Clay and gravel	4-5
e. Coarse gravel	4-5
f. Soft shale	5-6
3. Other	
a. Bituminous or cement-stabilized channels	6
b. Paved channels	10-15

Reference: Pennsylvania Department of Highways "Design Manual Part 2, Highway Design".

Table A-4

Lancaster County Planning Commission

Storm Drainage Study

Stormwater Runoff Analysis

Location	Total Suspended Solids mg/L	Biochemical Oxygen Demand mg/L
City of Lancaster		
Orange and Riverside	444	150
Engleside[1]	447	270
Clay Street[1]	170	350
Stevens Avenue[1]	154	420
East Hempfield Township		
Rohrerstown	229	250
Lancaster Township		
Abbeyville Road[1]	163	230
Normal Sanitary Sewage	200	200

[1]Combined Sanitary-Storm Sewer.

APPENDIX B

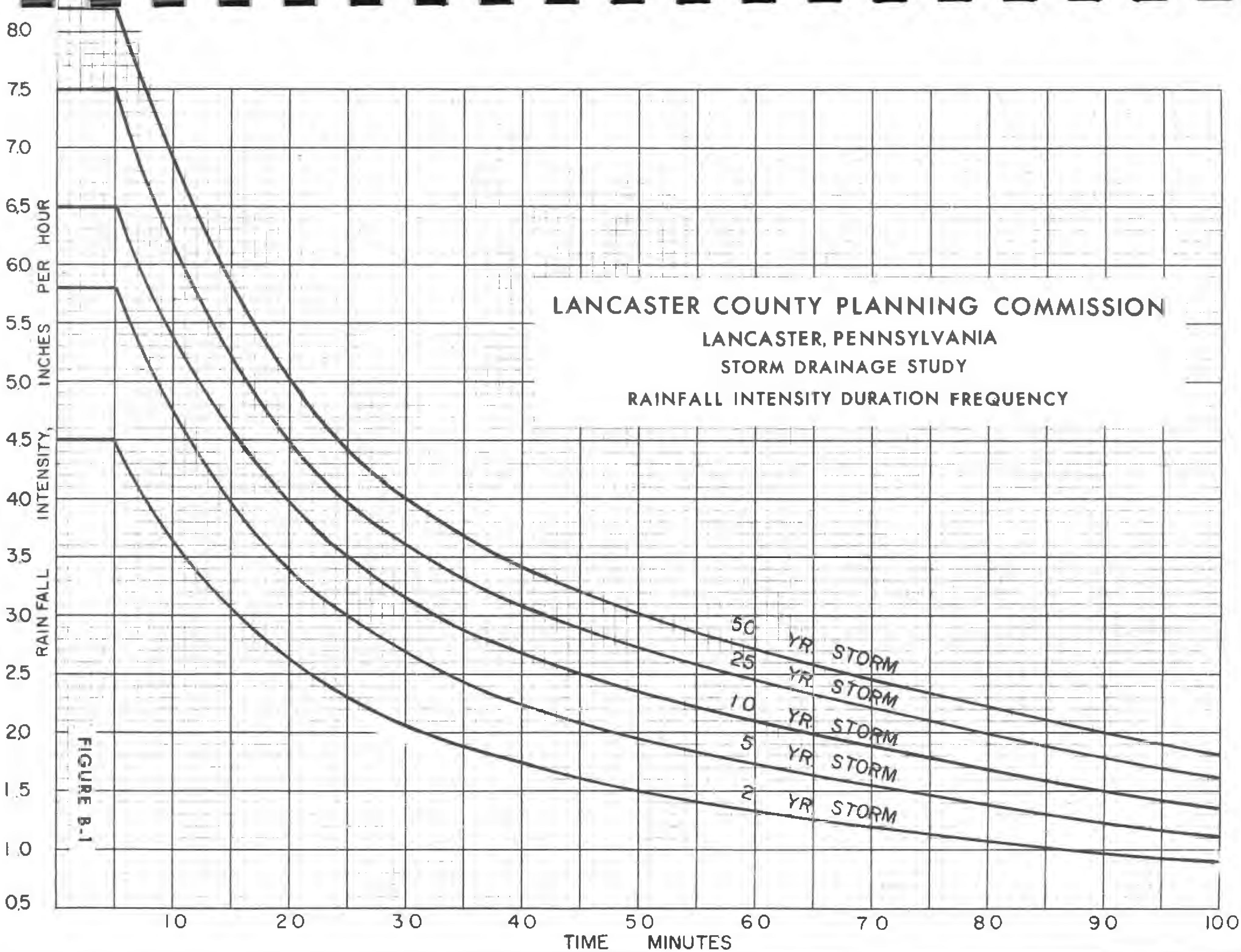
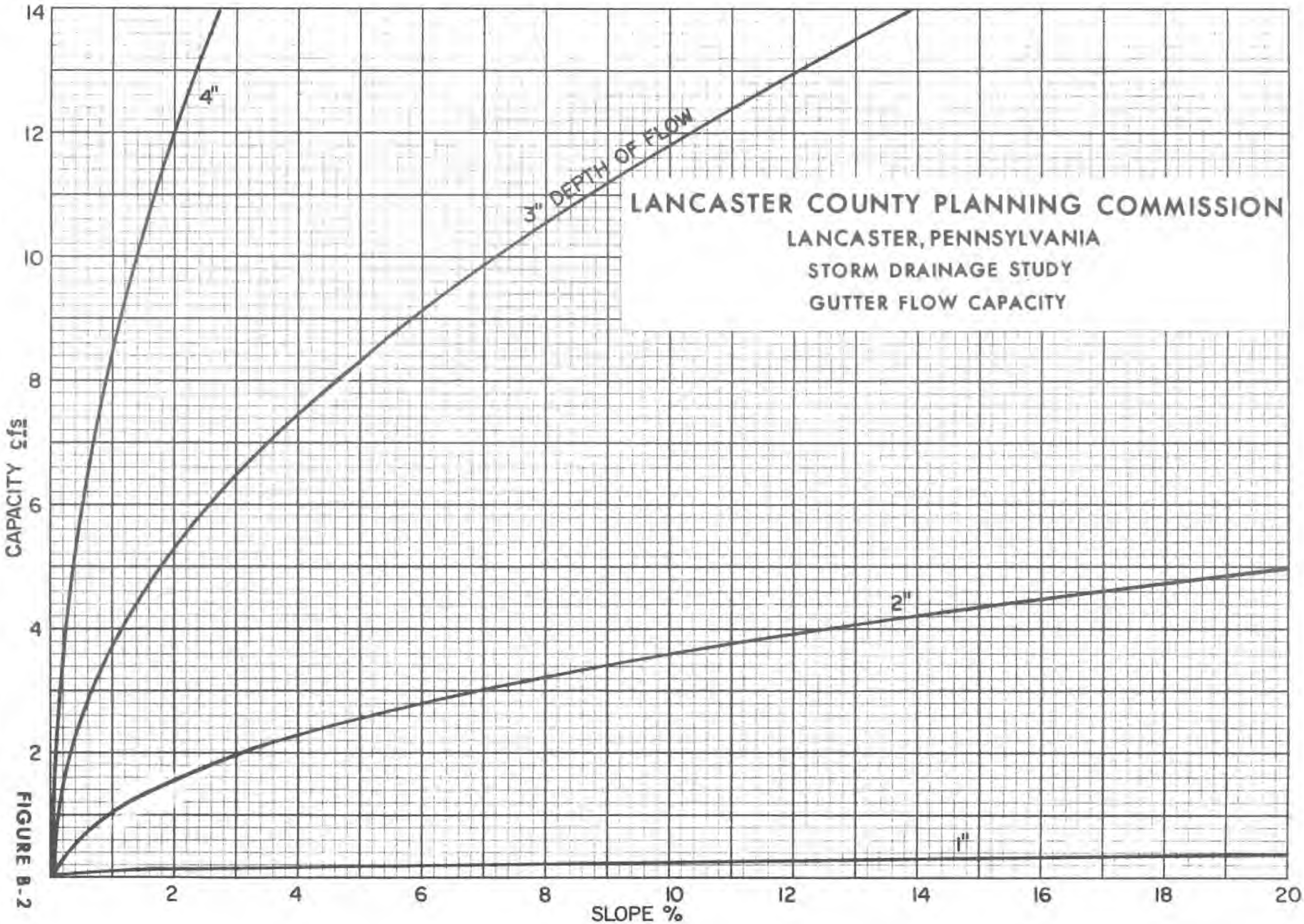

LANCASTER COUNTY PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
RAINFALL INTENSITY DURATION FREQUENCY
50 YR. STORM
25 YR. STORM
10 YR. STORM
5 YR. STORM
2 YR. STORM
RAINFALL INTENSITY, INCHES PER HOUR
TIME MINUTES
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
10
20
30
40
50
60
70
80
90
100

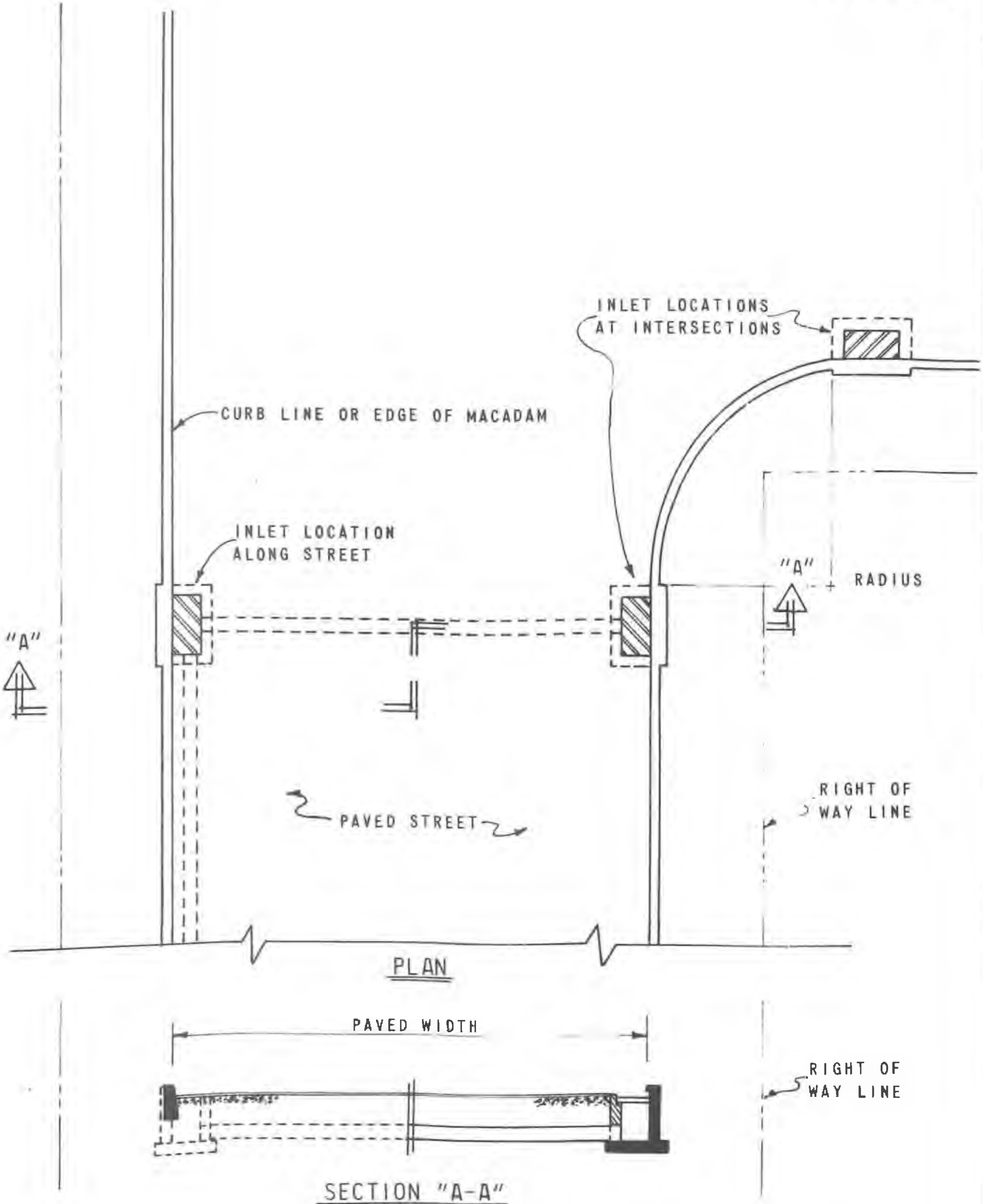
FIGURE B.1



LANCASTER COUNTY PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
GUTTER FLOW CAPACITY
4"
3" DEPTH OF FLOW
2"
1"
CAPACITY cfs
SLOPE %
0
2
4
6
8
10
12
14
16
18
20

FIGURE B-2

FIGURE B-3



SCALE: 1" = 10'-0"

LANCASTER COUNTY
PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
STREET INLET LOCATION PLAN

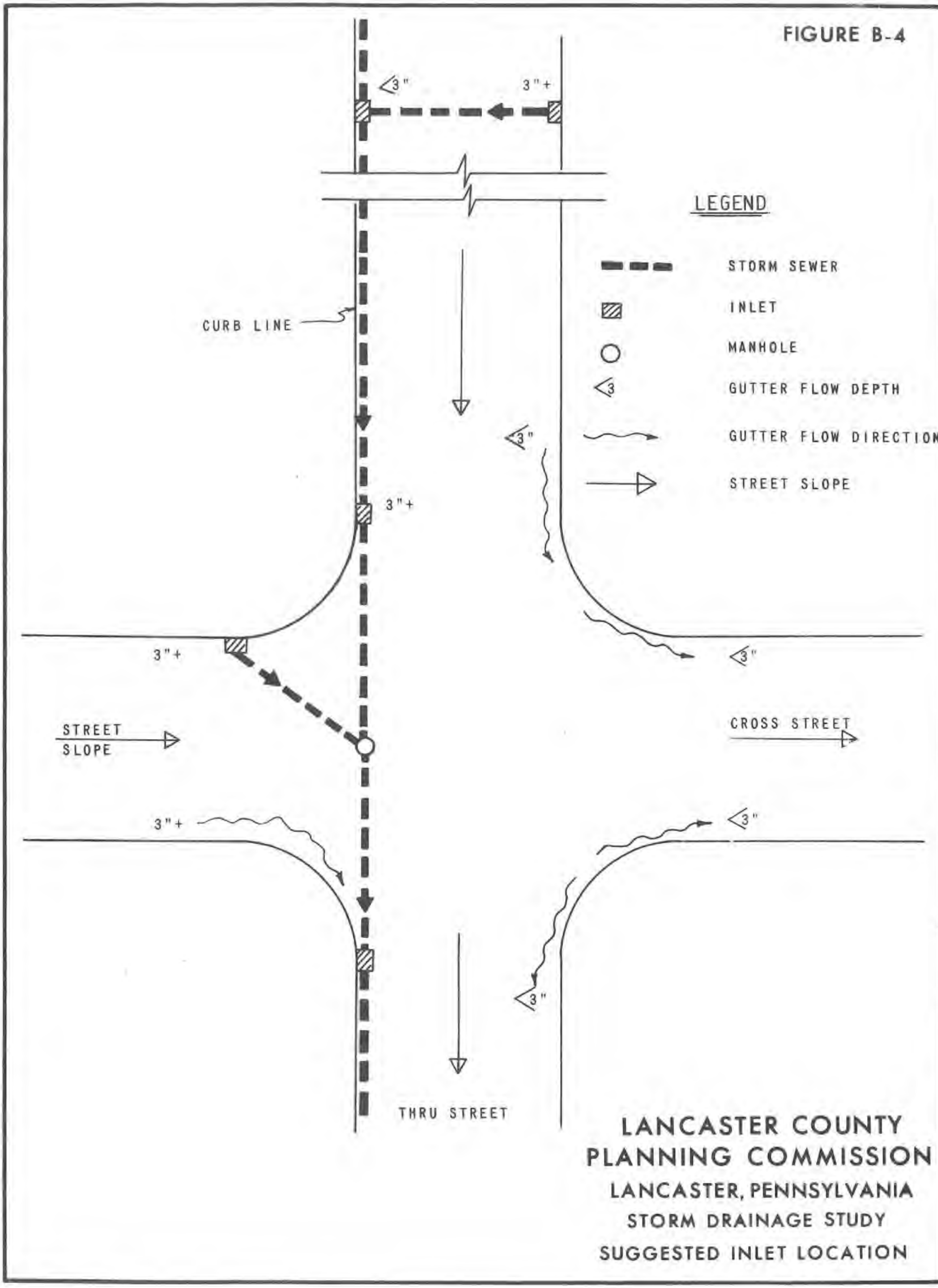
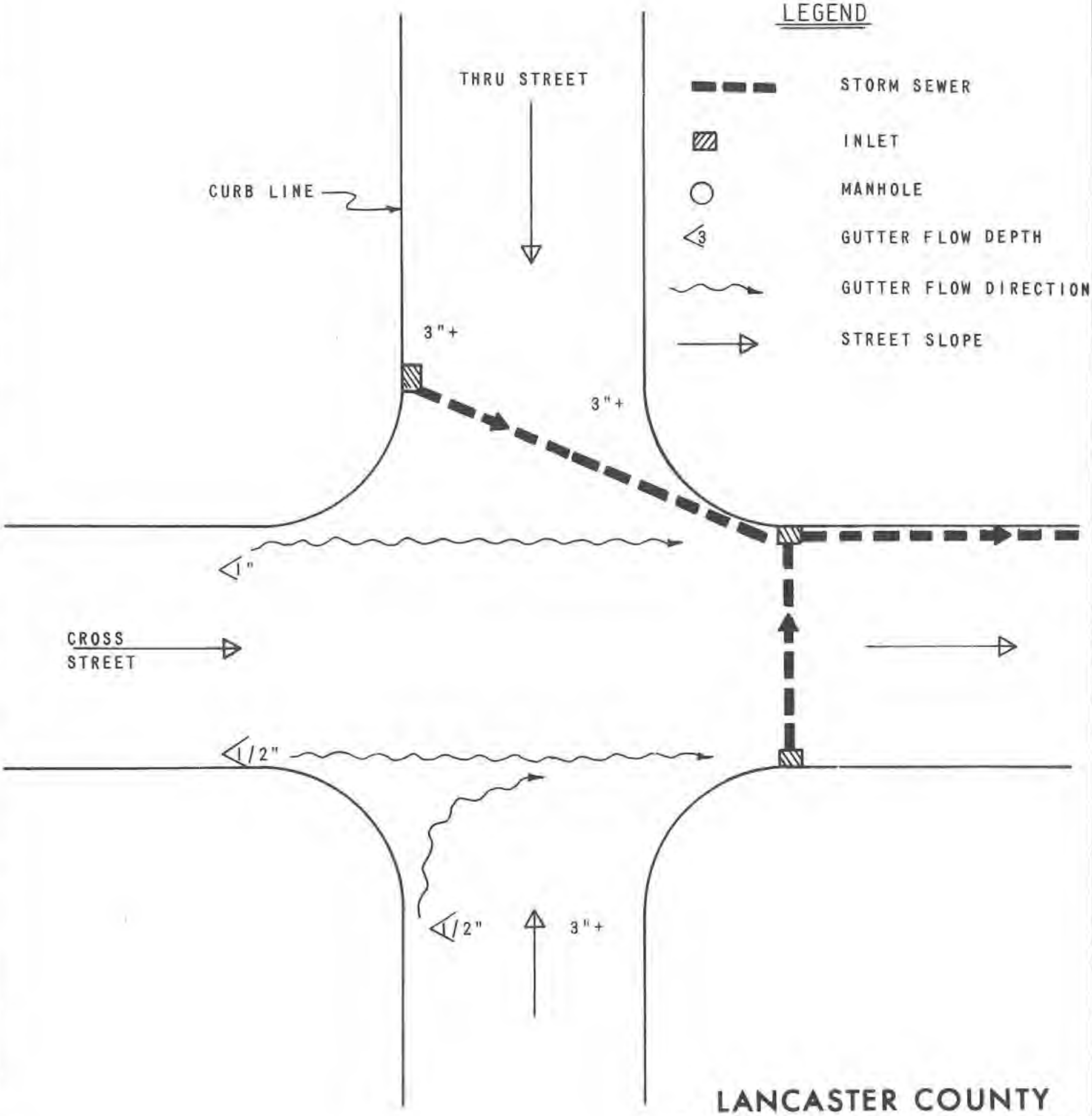


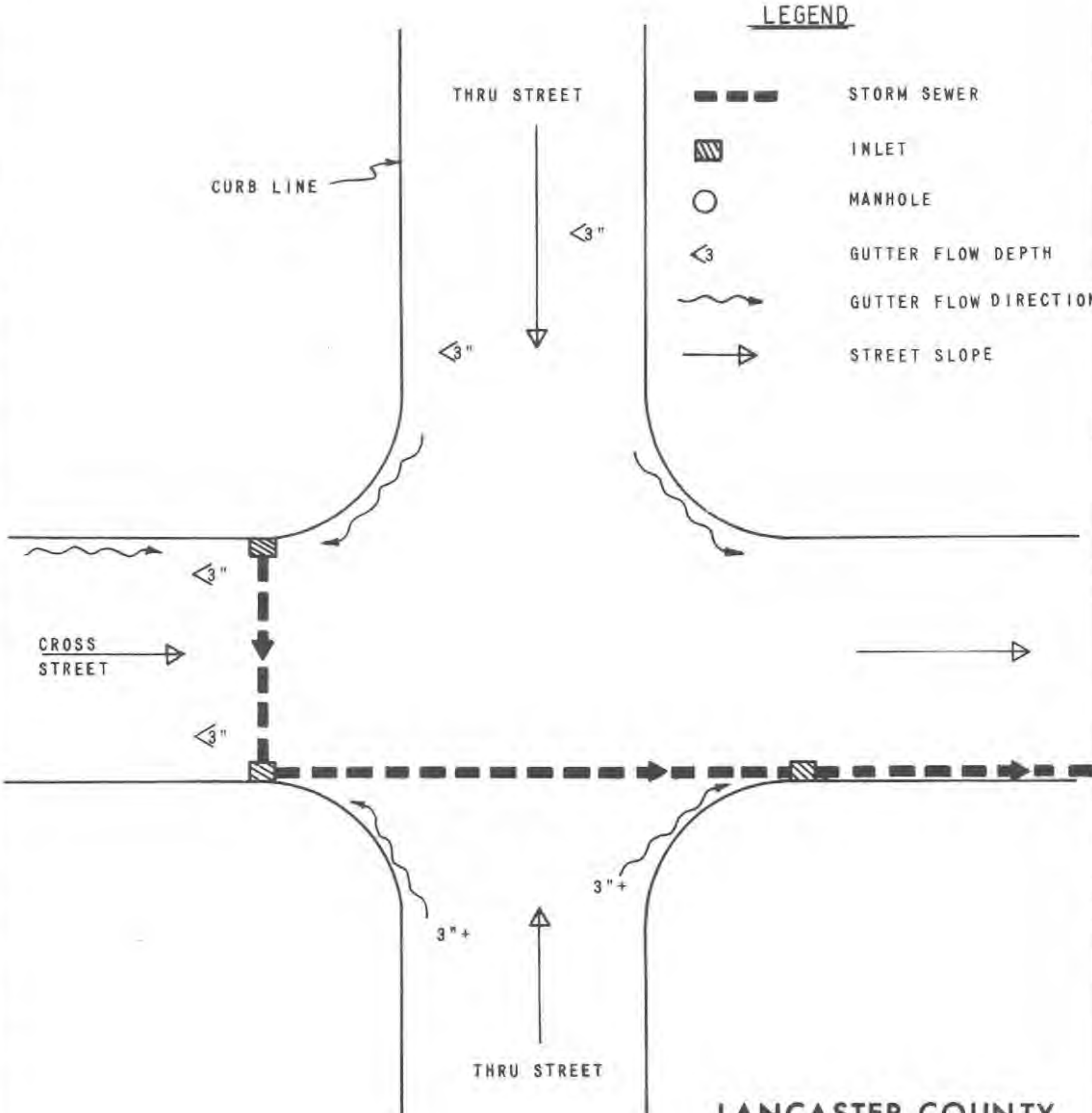
FIGURE B-4
3"
3"+
LEGEND
STORM SEWER
INLET
MANHOLE
GUTTER FLOW DEPTH
GUTTER FLOW DIRECTION
STREET SLOPE
CURB LINE
3"
3"+
3"+
3"
STREET
SLOPE
CROSS STREET
3"+
3"
3"
THRU STREET
LANCASTER COUNTY
PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
SUGGESTED INLET LOCATION

FIGURE B-5



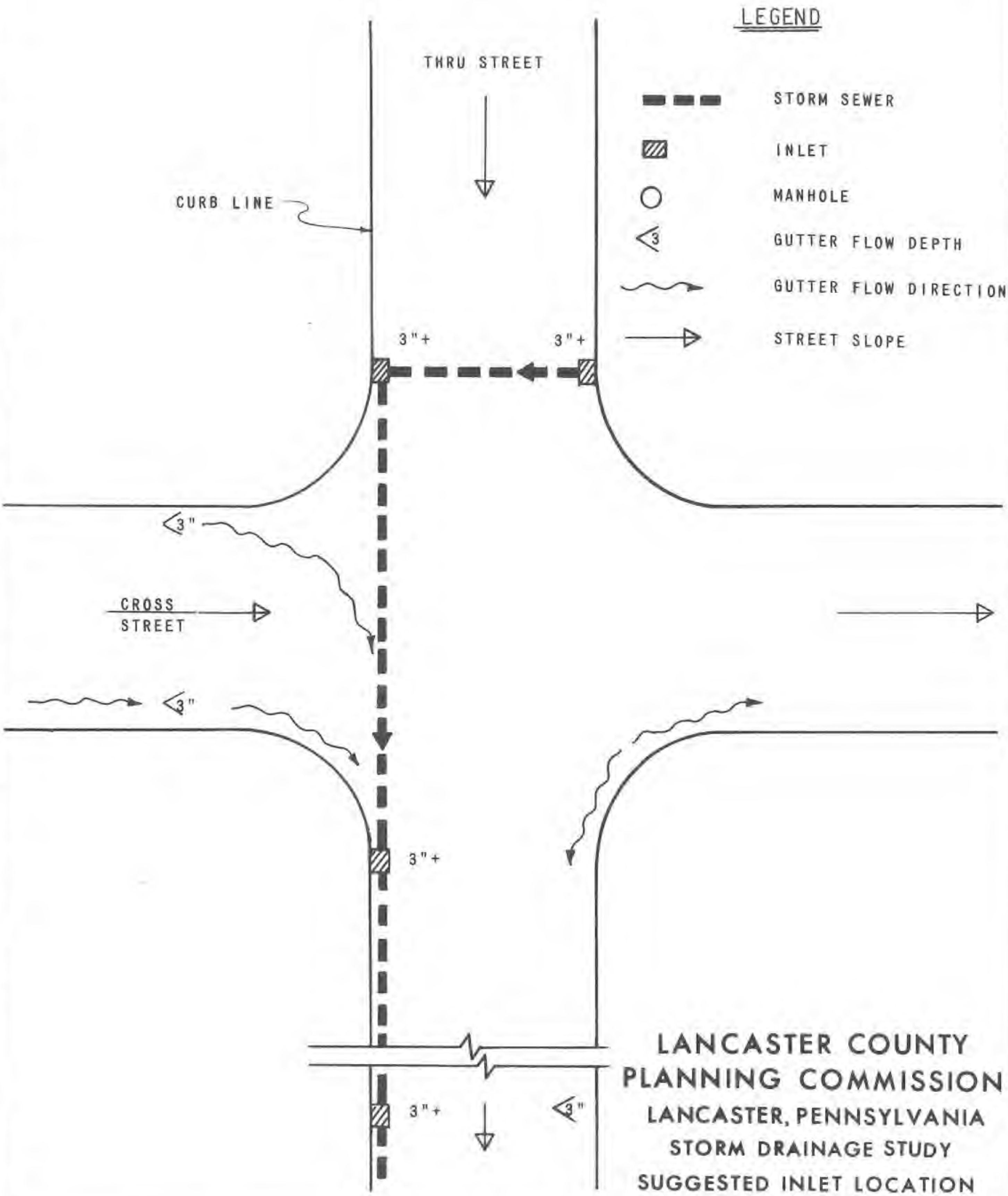
LANCASTER COUNTY
PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
SUGGESTED INLET LOCATION

FIGURE B-6



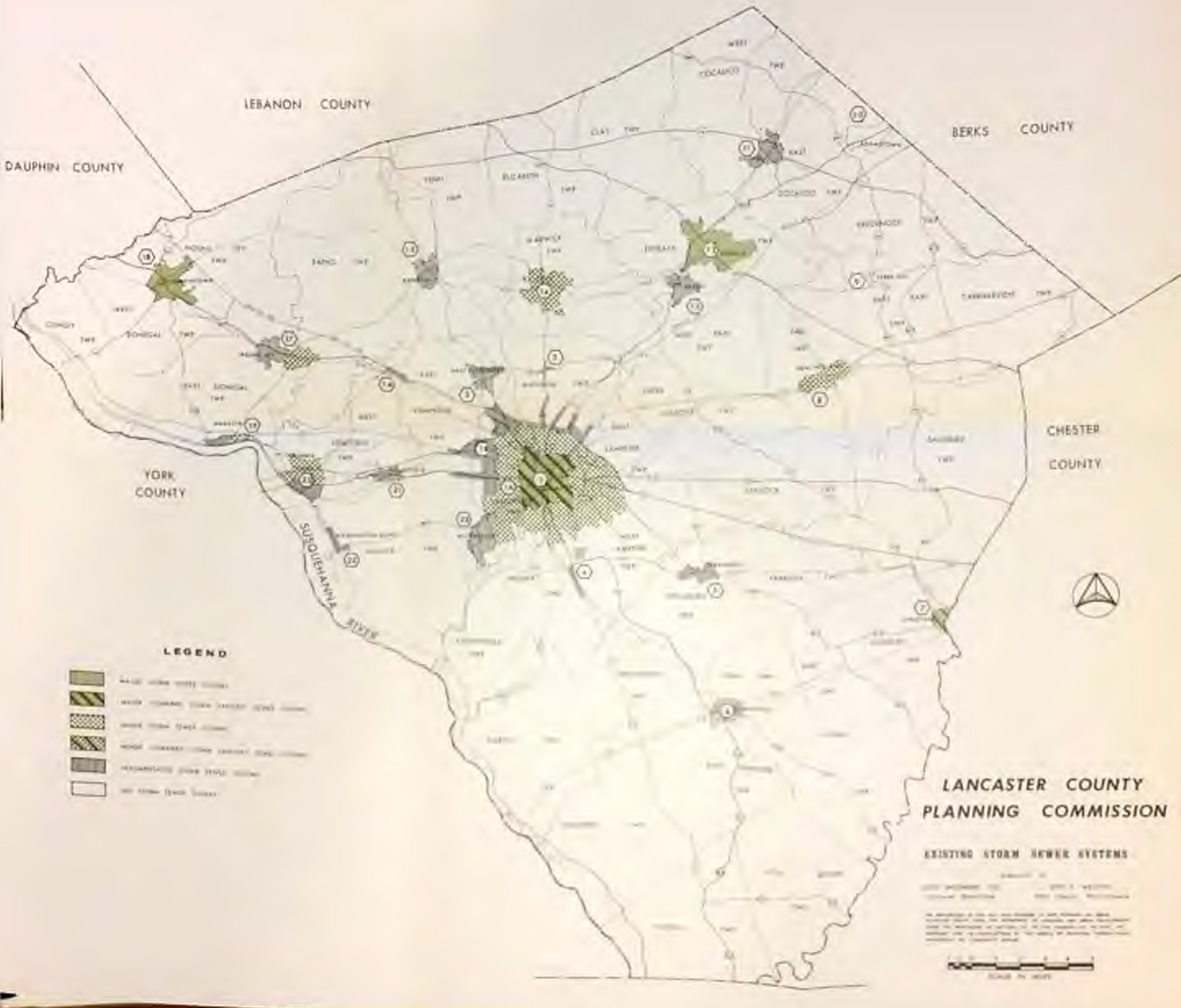
LANCASTER COUNTY
PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
SUGGESTED INLET LOCATION

FIGURE B-7



LANCASTER COUNTY
PLANNING COMMISSION
LANCASTER, PENNSYLVANIA
STORM DRAINAGE STUDY
SUGGESTED INLET LOCATION

APPENDIX C



LEBANON COUNTY
DAUPHIN COUNTY
BERKS COUNTY
CHESTER COUNTY
YORK COUNTY
SUSQUEHANNA RIVER
LEGEND
LANCASTER COUNTY
PLANNING COMMISSION
EXISTING STORM SEWER SYSTEMS