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EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS  
**DEPARTMENT OF ENVIRONMENTAL PROTECTION**  
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# **Guidelines for Performing Infiltration/Inflow Analyses And Sewer System Evaluation Survey**

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One Winter Street, Boston, Massachusetts

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INTRODUCTION

Extraneous water from infiltration/inflow sources reduces the capacity and capability of sewer systems and treatment facilities to transport and treat domestic and industrial wastewaters. Infiltration occurs when existing sewer lines undergo material and joint degradation and deterioration as well as when sewer lines are poorly designed and constructed. Inflow normally occurs when rainfall enters the sewer system through direct connections such as roof leaders, yard drains, catch basins, sump pumps, manhole covers and frame seals or indirect connections with storm sewers. The elimination of infiltration/inflow by sewer system rehabilitation and an on-going operation and maintenance program to identify these areas is essential to protect the enormous investment in sewers and wastewater treatment facilities made by cities, towns and the Commonwealth as well as for the protection of the environment.

Chapter 275 of the Acts of 1989 as amended by Chapter 203 of Acts of 1992 established the state revolving fund program in Massachusetts contemplated by Title VI of the Clean Water Act (the “CWA”) and created the Massachusetts Water Pollution Abatement Trust (the “Trust”) to implement the program. The Trust is authorized under the Act to make loans to local governmental units to finance the costs of eligible water pollution abatement projects. In order to receive a loan, a potential borrower must file an Application for Financial Assistance with the Department of Environmental Protection (DEP), Bureau of Municipal Facilities (Bureau). Once DEP has approved the Application, it will forward a Project Approval Certificate to the Trust. The Trust is then authorized to execute the loan, subject to the availability of funds and subject to review by DEP and the Trust of financial information contained in the Application and development of terms and conditions for the loan.

Guidelines have been developed to assist cities, towns, and districts for performing these projects.

## II.

### PURPOSE

The intent of these guidelines is to aid communities in performing infiltration/inflow analysis, present a systematic approach for conducting evaluations and provide a source of information to assist the applicants in fulfilling the requirements under the act.

The guidelines are mandatory for those communities who wish financial assistance. They are also recommended for any community that intends to perform infiltration/inflow work on its own without financial assistance.

It is not intended that these guidelines supersede the infiltration/inflow regulations of the Federal Construction Grants Program pursuant to section 201 of the Clean Water Act, (see 40 CFR 35.2120).

### III.

### DEFINITIONS

Building Service Connection – where a building service lateral connects to the public sewer; typically made using a wye or tee, with a chimney for deep public sewers.

Building Service Lateral - the pipe from a building to the public sewer.

Combined Sewer - a sewer intended to serve as both a sanitary and a storm sewer.

Defect - a point source of infiltration/inflow.

Dyed Water Flooding - It is a detection technique in which dyed water is introduced into catch basins previously smoke tested in order to confirm direct connections or indirect connections between storm drains and sanitary sewers.

Dyed Water Testing - It is a detection technique in which dyed water is introduced into the suspected private sources of inflow (downspouts, area drains, driveway drains, etc.) in order to confirm their direct connections to the sanitary sewers.

Dyed Water Tracing - It is a technique in which a confirmed inflow source is located through inspection with a color T.V. camera.

Excessive Infiltration/Inflow - the quantities of infiltration/inflow which are less costly to remove by sewer system rehabilitation than to transport and treat at the receiving facility, when both capital costs of increased sewerage facilities capacity and resulting operating costs are included.

Groundwater Migration - the tendency of groundwater to move from a rehabilitated defect to another defect.

Infiltration - Water other than wastewater that enters a sewer system (including sewer service connections and foundation drains) from the ground through means which include, but are not limited to, defective pipes, pipe joints, connections, or manholes. Infiltration does not include, and is distinguished from inflow.

Infiltration/Inflow - the quantity of water from both infiltration and inflow without distinguishing the source.

Infiltration/Inflow Rehabilitation - Construction associated with the removal of infiltration and inflow from abatement facilities.

Inflow - Water other than sanitary flow that enters a sewer system (including sewer service connections) from sources which include, but are not limited to, roof leaders, cellar drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, catch basins, cooling towers, storm waters, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

Internal Inspection - the inspection of conduits (previously cleaned) by physical, photographic and/or television (TV) methods.

Key Manhole - the manhole through which the entire flow from a sub-system passes.

Preparatory Cleaning - the adequate cleaning of sewers previously identified as potential sources of excessive infiltration/inflow prior to internal inspection.

Private Infiltration/Inflow Source - an infiltration/inflow source emanating from private property and discharging to the public sewers.

Public Infiltration/Inflow Source - an infiltration/inflow source emanating from public property and discharging to the public sewers.

Sanitary Sewer - a sewer intended to carry only sanitary flow.

Sanitary Flow - Sanitary flow is defined as the component of wastewater which includes domestic, commercial, institutional, and industrial sewage and specifically excludes infiltration/inflow.

Sewer Segment - a length of sewer from one manhole to another, also called "sewer reach".

Sewer Facilities - All facilities for collecting, pumping, treating, and disposing of sewerage.

SRF - State Revolving Fund.

Storm Sewer - a sewer intended to carry only storm water, surface runoff, street wash water and drainage.

Storm Water - all water running off from the surface of a drainage area after a period of rain.

Subsystem - an individual drainage basin that is part of a collection system; sizes typically range from 10,000 LF to 30,000 LF, (not including building service laterals). However, the goal is to strive to subdivide the collection system into 20,000 LF subsystems.

Suspect Inflow Source - a possible source of inflow which did not smoke during smoke testing, generally located on private property.

Visually Estimated Infiltration/Inflow - the rate of infiltration/inflow observed during internal inspection, and estimated at the time.

Wastewater Flow - Sanitary flow which includes infiltration and inflow.

Please refer to attached SRF Regulations for other definitions.

PURPOSE

The infiltration/inflow analysis is performed to demonstrate the non-existence or possible existence of excessive infiltration/inflow in each sewer system tributary to the treatment works. Through a systematic investigation of the sewer system, the analysis should identify the presence, flow rate, and type of infiltration/inflow conditions which exist in the sewer system. The systematic investigation should include the following: description of existing wastewater collection system; estimates of average residential, industrial, commercial and institution wastewater flows; (which are used for general background but, not usually necessary for I/I determinations) groundwater levels; continuous flow monitoring and in some cases flow isolation monitoring; determination of infiltration and inflow rates; and recommendations for further investigation when appropriate.

If the infiltration/inflow analysis demonstrates the existence or possible existence of excessive infiltration/inflow, a detailed plan for a sewer system evaluation survey shall be included in the analysis. The plan shall outline the tasks to be performed in the survey and their estimated costs. The following tasks are generally included in the analysis phase and the recommended methodologies are described in detail.

1. INVENTORY OF EXISTING CONDITIONSPURPOSE

The purpose of the inventory of existing conditions is to gather information on the sewerage system so as to better understand the specifics of that system and thereby develop the flow gauging program. The inventory is the first major work task in an I/I Analysis, and should be performed prior to any significant field investigations.

METHODOLOGY

Inventory sources of information including;

- Past engineering studies.

- Maps of both wastewater and storm sewer systems.

- Interviews with people familiar with the system.

- Maintenance record.

- Treatment plant and pumping station flow records.

- Historical USGS groundwater data, as well as any available groundwater level information collected for the current season during which field investigations are performed, should be studied to relate the general groundwater conditions to the individual project conditions.

Based upon a review of these sources, it is possible to establish:

- Type of sewerage system (separate or combined).
- Drainage patterns.
- Number and frequency of occurrence of overflows, bypasses, and surcharging.
- Type and age of sewer lines and manholes.
- Condition of existing facilities.
- Previous problems, I/I investigations, and rehabilitation in the system.

The inventory of conditions should include a physical survey of the collection system which is being evaluated during the I/I investigations. The Physical survey is conducted to isolate I/I problem areas, select flow gauging (continuous and instantaneous) sites, and provide a basis for a preliminary assessment of the general physical (structural and operational) condition of the collection system. At a minimum, the following tasks are to be performed during the inventory of conditions:

- Inspection of a representative number of manholes (10 percent of the total number of manholes within the collection system).

- Selection of continuous and instantaneous flow gauging manholes.

- Determination of gauging area boundaries for continuous and instantaneous gauging areas.

- Measure groundwater levels (as evidenced by wet rings and/or leakage) within all manholes inspected during the inventory of conditions. (Refer to section IV-3 for Groundwater monitoring procedures)

- Identify problem areas.

At the completion of the physical survey, a letter report will be prepared and submitted to the Bureau for review. The letter report will document all problems observed, present a preliminary assessment of the condition of the collection system, the location of proposed gauging manholes, groundwater monitoring sites and observed groundwater data, preliminary results of the ongoing or postpone flow monitoring based upon groundwater levels observed during field inspections. Authorization to proceed or postpone flow monitoring will be issued by the Bureau within 48 hours following submittal of the letter report. This "Letter Report" should be a brief statement (no more than two or three pages) summarizing the site conditions and noting major departures from the original scope of work. A site map showing the location of the key manholes and subsystem boundaries should accompany the "Letter Report." At this point in the project development it may be advisable to hold a meeting with Bureau personnel to discuss the overall plan of the project.

Both the groundwater monitoring and flow gauging programs can now be more accurately developed. Initial assumptions on subsystems and metering locations can be modified, as required.

## 1.1 INITIAL FLOW MONITORING

Initial flow monitoring will be conducted at the onset of the project at select key locations as necessary to determine overall system flow quantities and infiltration trends. It is recommended that approximately no less than 70% of the total flow be captured with the least number of meters depending on system characteristics. The flow monitors at the initial flow monitoring locations will remain in operation throughout the duration of the infiltration identification field work.

## 1.2 LIMITED MANHOLE INSPECTION

### PURPOSE

In the course of selecting key manholes for the installation of continuous flow recording meters one or more manholes per subsystem must be entered. Inspection of additional manholes to the extent of 10% of the total system under study is to be conducted to ascertain the general physical condition of manholes and sewers for the purpose of the I/I Analysis report, to verify sewer system configurations and meter area boundaries, and to investigate and determine groundwater levels.

### METHODOLOGY

The number of manholes inspected will vary from study-to-study but should be 10% of the total system under study at a minimum. During this part of the “Inventory of Existing conditions”, it is not necessary to enter the manhole and perform a complete inspection, except for those manholes selected for flow monitoring and groundwater monitoring. However, those manholes partially inspected must be fully inspected as described in the “Extensive Manhole Inspection” Section V-4, at the time that the complete extensive manhole inspection is conducted in the 80% inflow area, and in areas exhibiting excessive infiltration, over 4,000 gpd/idm. Partially inspected manholes located in areas falling outside of the two categories stated above may also be completely inspected if deemed advisable consistent with sound engineering practice.

The term ‘limited’ refers to the quantity of manholes (10% of the total) and not to the thoroughness of the inspection. The intent of the limited inspection is to primarily obtain an initial overall perspective of the condition of the system. However, the option to perform a complete inspection of the manholes at this time is also open if it is deemed desirable due to work scheduling or other project management considerations.

For those manholes to be entered and completely inspected refer to Section V-4 “Extensive Manhole Inspection” under “Methodology” items 1 through 9, and visual pipe inspection items 1 through 8. Record all pertinent information in an inspection form. (see sample copy in appendix)

## 2. SEWER FLOW MONITORING

### PURPOSE

The purpose of sewer flow monitoring is to collect accurate, current information on the flow characteristics of the study area. The information provided by flow monitoring will aid in locating those areas that have excessive infiltration/inflow and determine if they warrant further investigation. This task should be accomplished at the earliest possible stage in order to minimize the survey costs.

It should be emphasized that the flow monitoring data provides the basis for determining the need for and location of areas where additional, costly field work should be performed. As such, the need to assure flow data accuracy using sound field data collection and field calibration methods, accurate calculation methods, and appropriate analysis procedures cannot be over-stated.

### 2.1 CONTINUOUS METERING METHODOLOGY

The objective of continuous flow monitoring is to obtain information necessary to accurately analyze the gauging tributary areas for infiltration during high groundwater periods and for rainfall related inflow during wet weather periods. Continuous metering shall be conducted for a minimum of ten consecutive weeks, typically between March 1 and June 30.

However, if it is determined that groundwater levels are sufficient, and if approval is received from Bureau personnel, the flow monitoring program may begin prior to March 1 and/or extend beyond June 30.

Continuous monitors shall be installed at an interval of approximately one monitor for every 20,000 linear feet of sanitary sewer.

There are three acceptable methods of continuous flow monitoring, depending on existing field conditions. The methods are, in order of preference:

1. The use of a primary device such as a weir or a flume in conjunction with a continuous depth sensing device.
2. The use of a continuous monitoring device incorporating a velocity sensor combined with a depth sensor.

3. The use of a continuous depth sensor in conjunction with depth and velocity rating curves developed from a number of instantaneous flow depth and velocity measurements over a wide range of depths.

**METHOD 1**      The first and most preferred method is the use of a primary device such as a weir or flume in conjunction with a continuous depth sensing device. This method is particularly applicable to sites with smaller diameter pipe in the eight inch to fifteen inch diameter range. This method addresses concerns relating to backwater effects, sediment, slope variations, turbulence, etc., but may not be suitable for large diameter pipe or steep grade locations.

Care should be taken to assure that potential flow rates do not exceed the capacity of the primary device. Care should also be taken to assure that the primary device does not act as a hydraulic restriction causing surcharging.

**METHOD 2**      The second most preferred method is the use of a continuous monitoring device incorporating a velocity sensor combined with a depth sensor. This method is particularly useful in situations where large diameter pipes exist with significant flow depths.

Care should be taken, however, to assure that the depth and velocity sensing probes are sufficiently submerged during minimum flow depth periods to assure proper operation.

**METHOD 3**      The third most preferred method may be utilized when weirs or other hydraulic aids and/or continuous depth and velocity devices cannot be used due to flow quantity or other physical constraints. Depth and velocity rating curves may be developed from a number of instantaneous flow, depth and velocity readings over a wide range of depths. Monitoring may then be done with a continuous depth recorder. This method is particularly useful in smaller diameter pipes or in larger diameter pipes with little depth or flow.

It should be noted that the Manning formula for flow calculation using depth only sensors will not be used as the principal method since it is dependent on the slope, and coefficient of roughness; parameters which cannot be adequately estimated for old pipe without intimate knowledge of the existing conditions. In addition, the use of pump station records should not be used as the principal method because of the possibility of time lags or event masking due to wet wells. Approval of this method should be sought from the Bureau and properly justified prior to conducting flow calculations on this basis.

When using either Method #2 or Method #3, accurate determination of the cross sectional area of the flow being measured is mandatory. The dimensions of circular pipe should be measured to verify diameter and determine if a true circular cross section exists. If it is determined that a circular cross section does not exist, or if the meter site is placed in known non-circular cross section pipe, it is recommended that field measurements be taken using a sound method such as that described in Appendix B.

Care must be taken to accurately measure the configuration of any debris and include the information into cross-sectional area derivation.

When using either Method #2 or Method #3, the need for accurate determination of the average (mean) velocity of the cross-sectional area of flow being measured cannot be overstated. The recommended method of determining the average (mean) velocity will vary depending on the pipe size and depth of flow. The methods which are described in the Exhibits Section are considered preferred methods.

In all cases, determination of average (mean) velocity of the cross-sectional area of flow should be performed over a wide range of flow depths that occur at the meter site. A correlation should be established between the sensed velocities and the field measured mean velocity at each given flow depth using a method similar to that described in Appendix A.

When calculating flow rates using the recorded data, the sensed (continuously recorded) velocities should then be adjusted based on the observed correlation. If poor or inconsistent correlation is found, a stage/velocity calibration curve should be developed and incorporated into the appropriate flow calculation program, using the sensed velocities only to determine when surcharge conditions or backwater condition exist.

Care must be taken to assure that instances of velocity probe fouling are not misinterpreted as backwater or standing flow conditions.

Care should also be taken to continuously review calculated flow rates at each flow monitoring location to assure that upstream and downstream flows balance properly. Any discrepancies should be addressed as early in the monitoring program as possible.

## 2.2 AVERAGE LOW GROUNDWATER INFILTRATION

In order to establish average low groundwater infiltration, the flow monitors installed during the initial flow monitoring program will remain in operation until at least August 30. If it is determined that groundwater levels have not sufficiently receded, the flow monitors will remain in operation until sufficient low groundwater, minimum infiltration conditions exist. Rainfall monitoring should also continue during the extended flow monitoring period.

However, rain data may not necessarily be required in 15 minute increments. Additional rain data sources may be considered for this phase of the rainfall monitoring to supplement on site measurements. Other sources of precipitation data are enumerated in Section IV-4.

The average low groundwater infiltration as determined by this method along with the high groundwater infiltration (see IV-5.1 “Flow Data Analysis” subheading “Peak Infiltration”) shall be used for calculating the average annual infiltration in order to perform the cost effective analysis described in V-9.

### 3. GROUNDWATER MONITORING

#### PURPOSE

The purpose of groundwater monitoring is to obtain current groundwater data throughout the collection system for relating gauged flow rates and infiltration to groundwater levels. Existing groundwater conditions in the vicinity of the sewer are determined to ensure that optimum conditions exist for the type of investigation being performed (i.e., flow isolation/high groundwater, TV inspection/high groundwater, smoke testing/low groundwater). Data documenting the seasonal fluctuations in the groundwater level is also gathered.

Most sources of infiltration are impacted by variations in groundwater levels. For this reason, the determination of infiltration quantities in the sewer system should be based on the wastewater flow data collected during high groundwater periods. When reporting peak infiltration rates, a comparison of current groundwater observations to historical groundwater data should be made. The results of this comparison should be considered when analyzing the infiltration data collected during the study.

#### METHODOLOGY

General groundwater information can be obtained from a number of sources which may include the following:

- State Water Resources Agencies
- U.S. Geological Survey
- Local or County Water Conservation Districts
- Groundwater users, including municipalities, water companies and individuals
- Local construction companies or contractors.

Two types of groundwater level measurement gauges are acceptable. These include measurement of wet-ring or highest level of condensation within manholes, and piezometers. In all cases, wet-ring measurements alone should be adequate.

When conducting the inventory of conditions, groundwater level information should be collected during manhole inspections. Groundwater monitoring sites should be selected and reported to the Bureau in the Inventory of Conditions letter report. No less than two monitoring sites are to be selected per subsystem (based on 20,000 LF each subsystem) for monitoring during the field program. In cases where subsystems are less than 10,000 LF, groupings of subsystems may be satisfactory. In cases where subsystems are larger than 20,000 LF the general goal is to have one groundwater monitoring manhole at approximately 10,000 LF intervals. To supplement this information, piezometers can be installed. Bureau approval must be obtained for installation of these types of groundwater level measurement gauges. At each groundwater monitoring site, groundwater data should be collected at least biweekly during the flow monitoring program.

During limited manhole inspections, all manholes inspected will be investigated for signs of groundwater leakage. Rates of leakage and/or wet ring heights of groundwater above the manhole inverts will be noted for those selected as groundwater monitoring sites. The initial observations will be used as references to determine the fluctuation of groundwater levels during the field work. Manholes which indicated groundwater will be monitored on a biweekly basis at a minimum and more frequently as necessary within a subsystem when additional infiltration identification field work is being conducted within that subsystem.

If no indications of groundwater are observed during limited manhole inspection within a subsystem, the use of piezometric tubes installed through manhole walls shall be used to monitor the groundwater level at a select manhole within the subsystem. The piezometric tubes should be checked at the same frequency as the manholes identified during the limited manhole inspection. The level of the water, the condition of the tube, seal, and manhole should be noted. Any action taken during the visit, and weather conditions should also be noted.

#### 4. RAINFALL MONITORING

##### PURPOSE

The purpose of rainfall monitoring is to obtain data to compare variations in gauged flow rates to rainfall intensity, total volume and rate per event, and duration per event for the purpose of identifying inflow and its components. Rainfall data is collected specific to the study area, to enable inflow rates to be determined during different storm events for conversion to a standard storm event.

##### METHODOLOGY

Since rainfall data vary from one location to another, rainfall recording devices shall be used within the study area to obtain data.

Rainfall data can be obtained from tipping buckets or continuous weighing rain gauges. Charts that record rainfall for several events and a totalizer that provides a check against recorded data is useful. Less sophisticated devices such as graduated cylinders may also be appropriate to provide crude, supplemental information in some cases.

Preferably one continuous recording tipping bucket rain gauge shall be located for every five to ten square miles of the study area. Consideration should also be given to climatological anomalies within the overall study area to determine placement and number of rain gauges as well as area of control ascribed to each gauge. Rain gauges shall be capable of 15 minute precision and be accurate to within 0.01 inches of rainfall.

In addition to the rainfall data collected within the study area, other less site-specific data should be obtained and evaluated. Sources of precipitation data are the National Oceanic and Atmospheric Administration (NOAA), airports, state weather observers, local radio and TV weather stations, electronic media weather observers, other public works and research agencies and private citizens. Another useful publication containing daily precipitation quantities from NOAA stations is Climatological Data, which is published monthly for each state.

Use of data collected from rainfall monitoring stations run by others is acceptable, providing that the type and the location of that equipment is suitable.

## 5. FLOW DATA ANALYSIS

### PURPOSE

A proper flow data analysis will evaluate the information obtained from continuous flow monitoring and other supplemental data in order to categorize the wastewater flow into its various components; sanitary flow, infiltration, and inflow. This analysis requires engineering judgement and consideration of seasonal impacts to the collection system being studied. This includes consideration of whether free flow or restricted flow conditions exist and adjustment of inflow to the designated standard design storm. Following the quantification of each wastewater component, accepted engineering principles and noted guidelines are used to make recommendations for further study to identify infiltration and inflow sources.

### 5.1 COMPONENTS OF WASTEWATER FLOW

Wastewater Flow– Wastewater flow is comprised of Sanitary flow, Infiltration and Inflow. A description of these components follows:

Sanitary Flow- Sanitary flow is defined as the component of wastewater which includes domestic, commercial, institutional, and industrial sewage and specifically excludes infiltration/inflow. Sanitary flow does not include year-round (permanent) infiltration. Sanitary flow is generally expected to exhibit a diurnal flow pattern which, typically, is reproduced each weekday and may exhibit a somewhat different flow pattern on weekends.

- 5.1.2 Infiltration – Infiltration is defined as the component of wastewater which is extraneous water entering the sewer system from the ground through sources such as defective pipes, pipe joints, connections, and manhole walls. Some quantity of infiltration is generally expected to be present in wastewater flow throughout the year. Because infiltration is directly influenced by groundwater fluctuations, the volume of infiltration entering a sewer system is generally expected to fluctuate from season to season with typically larger volumes anticipated in the spring and smaller volumes anticipated in the summer.

Sewer systems physically located in or near coastal areas may be subject to tidal infiltration. Separate components of infiltration are detailed below.

“Peak Infiltration Rate” is defined as the average of the minimum flow rate observed over a period of several days, during high (or “peak”) groundwater conditions which usually occur in early spring after snow melt and/or soil thaw, and generally measured during low flow conditions – midnight to 6:00 A.M.

“Minimum Infiltration Rate” is defined as the average daily minimum flow rate MGD determined over a period of several days, during low (or “minimum”) groundwater conditions.

“Annual Average Infiltration” is defined as the average daily infiltration rate (MGD) determined over the entire calendar year.

“Total Annual Infiltration” is defined as the total infiltration volume (gallons or MG) over the entire calendar year.

“Tidal Infiltration Volume” is defined as the increase in infiltration which may occur when the groundwater table is temporarily elevated due to the impact of high tide. In cases where it is not possible to distinguish tidal infiltration from tidal inflow, the combination may be reported as tidal I/I.

- 5.1.3 Inflow – Inflow is defined as the component of wastewater which is extraneous water discharged into a sewer system from sources such as sump pumps, roof leaders, cellar/foundation drains, surface drains, drains from springs and swampy areas, manhole covers, catch basins, cross-connections from storm drains, cooling water discharges, leaking tide gates, and other inlets. Inflow differs from infiltration in that it is the result of direct

connections of extraneous flow sources into the collection system and, generally, is not linked to fluctuations in the groundwater table. The methodology used to quantify inflow (detailed below) does not allow for the independent quantification of rainfall-induced infiltration; therefore, the quantification of inflow also is likely to include some portion of rainfall-induced infiltration.

Inflow is largely the result of wet weather (stormwater) influenced on the sewer system. During dry weather, the quantity of inflow is generally expected to approach zero. During storm events, inflow may rapidly impact the sewer system causing the wastewater flow to increase. The increase in wastewater flow due to inflow may terminate a short time after the storm event or it may influence the sewer system for a prolonged period depending on the type of inflow sources which exist in the system. It is not uncommon for inflow to elevate wastewater flows for a number of days. Sewer systems physically located in or near coastal areas may also be subject to tidal inflow. Separate components of inflow are detailed below and are identified on Figure 4, appended.

“Total Inflow volume” is defined as the total volume (MG) of inflow generated from a single storm event including both direct and delayed inflow. Total inflow is the area between the storm event hydrograph and the dry weather hydrograph.

“Direct Inflow Volume” is defined as the portion of total inflow which is generated from direct connections to the collection system such as catch basins, roof leaders, manhole covers, etc. These inflow sources allow stormwater runoff to rapidly impact the collection system and produce an inflow hydrograph which sharply increases soon after the start of the storm and decreases swiftly upon conclusion of the rainfall event. Direct inflow is the area between the storm event hydrograph and the dry weather hydrograph beginning at the initial divergence of the curves and ending at a time following the conclusion of the storm when the majority of inflow is expected to be produced from delayed inflow sources.

“Delayed Inflow volume” is defined as the portion of total inflow which is generated from indirect connections to the collection system or connections which produce inflow after a significant time delay from the beginning of a storm. Delayed inflow sources include: sump pumps, foundation drains, indirect sewer/drain cross-connections, etc. Through the analysis of metering data, rainfall-induced infiltration can not be distinguished from delayed inflow and, therefore, by definition, is included as part of delayed inflow. Delayed inflow sources exert a gradual stormwater impact on the collection system and produce an inflow hydrograph which decreases gradually upon conclusion of the rainfall event, and after peak inflow caused by direct connections. Delayed inflow is the area between the storm event hydrograph and the dry weather hydrograph beginning at the conclusion of direct inflow and ending at a time when the storm event hydrograph and the dry weather hydrograph converge.

“Rainfall-Induced Infiltration Volume” is defined as the short-term increase in infiltration which is the direct result of stormwater percolation into the ground and through collection system defects in pipes, joints, connections, or manhole walls which lie near or are readily reached from the ground surface. Rainfall-induced infiltration (RII) may also be commonly referred to as “rainfall dependent infiltration (RDI)” or “rainfall dependent I/I (RDI/I)” By definition, rainfall-induced infiltration is a portion of delayed inflow.

“Peak Inflow Rate” is defined as the largest inflow rate (mgd) determined over a one hour period which is generated from a single storm event. The peak inflow rate is the largest rate difference between the storm event hydrograph and the dry weather hydrograph.

“Total Annual Inflow Volume” is defined as the total inflow volume (MG) determined over the entire calendar year.

“Annual Average Inflow Rate” is defined as the average daily inflow rate (MGD) determined over the entire calendar year. It may be estimated by subtracting the average daily dry weather wastewater flow from the average daily total wastewater flow.

“Tidal Inflow” is defined as seawater entering the sewer system through direct connections such as leaking tide gates and defects in manholes located in salt marshes or other areas subject to tidal influence. In cases where it is not possible to distinguish tidal inflow from tidal infiltration, the combination may be reported as tidal I/I.

## 5.2 METHODOLOGY FOR ESTIMATING SANITARY FLOW

The sanitary flow component of the total wastewater flow is generally determined through two independent methods of analysis; water consumption and flow meter data. In the first method, water consumption records can be analyzed and apportioned, based on sewer population, and industrial, commercial, and institutional usage, for each metered subsystem to estimate the anticipated sanitary flow expected to be measured by the wastewater flow meter.

The second method is an analysis of wastewater flow meter data which has not been influenced by a rainfall event (i.e. metered data from a dry weather period). During a dry weather period, sanitary flow can be estimated by subtracting the infiltration portion of the nighttime minimum flow from the average daily wastewater flow which was recorded on the same dry weather day. The methodology for calculating the infiltration portion of the nighttime minimum flow is explained below.

### 5.3 METHODOLOGY FOR ESTIMATING INFILTRATION

To determine infiltration, wastewater flow meter data should be examined to identify periods of dry weather (generally at least three to five days without a storm event). During selected dry weather periods, nighttime minimum flows should be analyzed to estimate “peak”, “minimum”, and “annual average” infiltration rates. These should be reported in both gpd and gpd/idm units for each subsystem.

The nighttime minimum flow represents a period of minimal sanitary flow; therefore, a high percentage of the nighttime minimum flow may be attributed to groundwater infiltration. A portion of the nighttime minimum flow may also be attributed to sanitary flow from 24-hour industrial/commercial operations, institutional flows, and/or some small amount of domestic flow. The portion of the nighttime minimum flow which can be attributed to sanitary flow may be estimated through a combination of the following: (1) a detailed survey of nighttime large industrial, commercial, or institutional water users, and (2) an estimate, based on engineering judgement, of the expected percentage of the nighttime minimum flow which may be attributable to domestic flow contributions. The percentage of the nighttime minimum flow which may be attributable to domestic flow contributions is likely to be a small portion. Each individual subsystem should be analyzed to determine the quantity of flow to be deducted. The portion of the nighttime minimum flow attributed to sanitary flow must be subtracted from the total nighttime minimum flow to calculate an infiltration rate.

During high (or “peak”) groundwater conditions, which usually occur in early spring after snow melt and/or soil thaw, the minimum nighttime flows will be at their highest level. During this period, the peak infiltration rate is quantified by taking the average, over several days, during dry weather conditions of the portion of the minimum nighttime flows estimated to be infiltration.

During low (or “minimum”) groundwater conditions, which usually occur in late summer after a prolonged period of minimal rainfall, the minimum nighttime flows will be at their lowest level. During this period, the minimum infiltration rate is quantified by taking the average, over several days, of the portion of the minimum nighttime flows estimated to be infiltration.

The annual average infiltration rate can be calculated directly by analyzing metered flow data for an entire year. However, if metered flow data exists for only a portion of the year, it may be estimated by calculating a weighted average of peak infiltration (for a representative number of high infiltration months) and minimum infiltration (for a representative number of low infiltration months).

A separate analysis must be performed to identify the presence of tidal infiltration. During a dry weather period, nighttime minimum flows corresponding to a high tide should be compared to nighttime minimum flows corresponding to a low tide. Due to the tide cycle, this analysis can be performed on minimum nighttime flow data which occurs about one week apart. This time period is sufficiently short to insure that seasonal fluctuations in infiltration can be largely disregarded. If a significant flow increase is detected during the high tide period, it may be attributed to tidal infiltration, tidal inflow, or tidal I/I. Care should be exercised when selecting the high tide period for use in this analysis. The elevation of each high tide varies and an extreme high tide elevation is likely to produce a large volume of tidal infiltration than a moderate high tide elevation.

#### 5.4 METHODOLOGY FOR ESTIMATING INFLOW

Flow meter data and rainfall data should be analyzed to identify periods of wet weather when inflow may be expected to occur. Flow meter data during the wet weather period (generally over several days) should be compared to flow meter data during a selected dry weather period (usually a period immediately preceding the storm) provided this period is representative of similar groundwater conditions. The rate and volume of inflow tributary to a subsystem can be computed by subtracting the dry weather flow data from the wet weather flow data. This analysis is represented graphically in Figures 2, 3 and 4.

For each significant storm event during the flow monitoring period, both the peak inflow rate and the total inflow volume should be calculated and reported. The total inflow volume should also be apportioned into an estimated direct inflow volume and an estimated delayed inflow volume.

The peak inflow rate, as illustrated in Figure 4, is the largest rate difference, determined over a one hour period, between the storm event hydrograph and the dry weather hydrograph. The peak inflow rate should be reported in gpd or mgd for each subsystem metered, for surcharge conditions see section 5.7.

The total inflow volume, as illustrated in Figure 4, is the area between the storm event hydrograph and dry weather hydrograph. Total inflow can be apportioned into two components: direct inflow and delayed inflow. Direct inflow is the portion of the inflow hydrograph which rapidly increases soon after the start of the storm and decreases swiftly upon conclusion of the rainfall event. Direct inflow begins at the initial divergence of the storm event and dry weather hydrographs and ends at a time following the conclusion of the storm approximately equal to the inflow response time of the subsystem. The inflow response time of the subsystem can be estimated as being the time differential between initiation of the storm event and the increase in the observed flow. Delayed inflow is the portion of the inflow hydrograph which decreases gradually upon conclusion of the rainfall event and after the peak inflow caused by direct connections. Delayed inflow is the area between the

storm event hydrograph and the dry weather hydrograph beginning at the conclusion of direct inflow (as defined above) and ending at a time when the storm event hydrograph and the dry weather hydrograph converge. It is expected that a portion of the delayed inflow may include rainfall-induced infiltration. In some cases, a second storm will impact the flow data prior to the time when the initial storm event hydrograph and the dry weather hydrograph converge. If this occurs, the expected delayed inflow hydrograph may be extrapolated from the flow data collected prior to the second storm. Total, direct, and delayed inflow volumes should be reported in gallons or million gallons for each subsystem metered.

A separate analysis must be performed to identify the presence of tidal inflow. During a dry weather period, nighttime minimum flows corresponding to a high tide should be compared to nighttime minimum flows corresponding to a low tide. Due to the tide cycle, this analysis can be performed on minimum nighttime flow data which occurs about one week apart. This time period is sufficiently short to insure that seasonal fluctuations in infiltration can be generally disregarded. If a significant flow increase is detected during the high tide period, it may be attributed to tidal inflow, tidal infiltration, or tidal I/I. The elevation of each high tide varies and an extreme high tide elevation is likely to produce a larger volume of tidal inflow than a moderate high tide elevation.

## 5.5 DESIGN STORM RECURRENCE INTERVAL AND DURATION

The total inflow volume produced by a storm event is a function of the rainfall volume (inches of rainfall over the subsystem), the intensity (inches of rainfall per hour), and the duration (hours).

A storm recurrence interval is defined as the storm which, based on historical records, will occur on the average of once within the stated recurrence interval. All flow monitoring data and resultant projected inflow volumes shall be based on the one-year recurrence interval storm.

Storm duration is defined as the length of time from the initiation of the storm even to the conclusion of the storm event. All flow monitoring data and resultant projected inflow volumes shall be based on the six-hour duration storm. The one-year, six-hour storm produces approximately 1.72 inches of rainfall in the Boston area, with peak intensity of 0.87 inches per hour and an average intensity of 0.29 inches per hour. The standard storm hyetograph is shown in Figure 1 of the Exhibits.

## 5.6 DETERMINATION OF RAINFALL/INFLOW VOLUME RELATIONSHIP

Total inflow volume shall be established for all long duration storm events having at least six consecutive hours with an average of approximately 0.20 inches per hour (approximately 1.2 inches within the six consecutive hour period). Storms less than six hour duration may also be used for inflow

analysis provided that an average intensity of 0.20 inches per hour for the entire storm is achieved, and that inflow response is readily noticeable. For each storm event, the total inflow volume (gallons) metered in each subsystem shall be correlated to total rainfall (inches) produced from the storm. This analysis shall be performed graphically as depicted in Figure 5 in the Appendix. The total inches of rainfall will be designated as the X-axis and the gallons of total inflow attributed to a storm will be designated as the Y-axis.

The graph produced by the rainfall/inflow volume relationship data developed for several storms can be used to estimate the inflow volume expected to be produced from a one-year, six-hour storm event (total rainfall of 1.72 inches in Boston). A linear regression can be performed (or alternatively a smooth curve fit) on the points of the graph. Then, using the one-year, six-hour storm rainfall volume on the X-axis and the derived rainfall/inflow volume relationship (graphed line or curve) the inflow volume expected from the one-year, six-hour storm can be read off the Y-axis.

In some instances it may be advisable to eliminate some rainfall/inflow volume relationship data from the design storm analysis if a reasonable explanation exists as to why the data should not be used. Examples of instances which may produce questionable results include: unusually dry antecedent conditions, storm events occurring very close to one another, storms unusually short in duration with high rainfall intensity, collection system surcharging or overflows, etc.

If data is available for only one storm event, despite the recording of flow monitoring data for the prescribed minimum 10 week period, then total inflow volume for the standard design storm may still be estimated by assuming: (1) a linear relationship between total inflow volume and inches of rainfall and (2) the line passes through the origin of the graph. This would result in extrapolating total inflow volume from the storm of record to the design storm based on the ratio of total inflow volume/inches of rainfall. Other techniques for correlating total inflow volume with rainfall will be evaluated by the Bureau on a case-by-case basis.

## 5.7 CONSIDERATION OF FREE FLOW VERSUS RESTRICTED FLOW

In portions of collection systems with significant inflow problems or with limited reserve capacity, the sewers may surcharge and/or overflow for some period of time during a storm event. If surcharging and/or overflows are known to occur or have been documented during the inventory of existing conditions phase of the project, this condition should be considered when estimating the design storm inflow volume through the regression analysis. During storm events, some combination of the following three flow conditions may exist:

#### Free Flow (Stage 1)

This condition generally occurs during the early part of the storm event before the design capacity of the sewer is reached or during storms of lower rainfall intensity. Stage 1 is the condition where the rainfall/inflow volume evaluation is made using a regression analysis technique for several storm events.

#### Restricted Flow (Stage 2)

As rainfall intensity increases, collection system flows increase to the maximum flow capable of being reliably metered in the system. In a Stage 2 condition, the system is operating under surcharge or what can be described as a restricted state. Caution should be exercised when using the rainfall/inflow volume evaluation under storm events which cause restricted flow in the system. The total inflow volume may be approximately correct but the attenuation of flow may result in a smaller direct inflow volume and a larger delayed inflow volume being estimated. Engineering judgement should be used in the analysis under a restricted flow condition.

#### Restricted Flow (Stage 3)

With increasing rainfall intensity the collection system conveys no more wastewater flow than in a Stage 2 condition but experiences and increase in the hydraulic gradient until the system overflows. The rainfall/inflow volume evaluation should probably not be made for storm events which cause significant overflows or, if used, some estimate of the overflow quantity which was unmetered should be added to the estimated inflow volume.

### 5.8 RECOMMENDATIONS FOR FURTHER STUDY TO IDENTIFY INFILTRATION SOURCES

At the completion of the flow data analysis portion of an I/I Analysis (or earlier, see single season two phase gauging), an extensive manhole inspection and flow isolation program can be recommended for all subsystems exhibiting an infiltration rate equal to or greater than 4,000 gpd/idm. Further work on subsystems with a lesser rate can be justified on a case-by-case basis.

The recommendation for performing TV inspection on a small percentage of the collection system (without first performing an extensive manhole inspection and flow isolation program) should be considered. This recommendation should only be made for major interceptors or the community's largest or most critical sewers.

The results of these analyses and recommendations will be presented to the Bureau, and the decision on future work will be made mutually between the community, consultant and the Bureau.

### RECOMMENDATIONS FOR FURTHER STUDY TO IDENTIFY INFLOW SOURCES

At the completion of the flow data analysis portion of an I/I Analysis, the inflow estimated to be produced from the standard one-year, six-hour design storm will be used to rank all subsystems from high to low on the basis of the following: (1) volume of total inflow, (2) volume of direct inflow, and (3) volume of delayed inflow. On a first-cut basis, evaluate performing an SSES in the highest priority subsystems which account for not less than 80 percent of the total system inflow volume (including private sources). The 80 percent rule-of-thumb should be used as a minimum threshold; it is recommended that all subsystems influenced by inflow be considered for further evaluation to identify the inflow sources.

Subsystem which contain a high volume of direct inflow should be targeted for smoke testing and other inflow detection techniques aimed at identification of direct connections to the collection system. Subsystems which contain a high volume of delayed inflow should be targeted for house-to-house inspections (to identify sump pump connections) and other inflow detection techniques aimed at identification of indirect connections or connections which produce inflow after a significant time delay from the beginning of a storm. A significant portion of the delayed inflow volume may be generated by rainfall-induced infiltration (RII). SSES techniques for identification and removal of RII are typically less effective than those aimed at identification and removal of direct inflow. On a case-by-case basis, SSES efforts aimed at the identification of RII in subsystems should be justified and recommended as a lower priority than those aimed at identification and removal of other inflow sources.

Subsystems which exhibit a high peak inflow rate should be evaluated to determine if local surcharging and local overflows exist. It is possible that a large peak inflow rate in a subsystem may not create a significant town-wide or regional impact. However, a large inflow peak rate may create a severe local impact (environmental and/or public health hazard) and, therefore, should be evaluated.

Subsystems which contain tidal inflow should be targeted for physical inspections, with dyed water testing at tide gates during high tide events, and other inflow detection techniques aimed at identification of defects allowing seawater to enter the collection system.

The results of these analyses and recommendations will be presented to the Bureau, and the decision on future work will be made mutually between the community, consultant and Bureau.

## 6. SINGLE SEASON TWO PHASE GAUGING

### PURPOSE

The single season two-phase gauging program allows an optional approach to progress through an I/I study overview and into an SSES program in a single season. This approach saves one year's time and eliminates the problem of collecting I/I data in one season and comparing it to SSES data collected in a second season.

### METHODOLOGY

Prior to the installation of gauges, prepare maps, identify subsystems, calculate inch-miles, and field verify gauge locations.

Generally, up to the first four weeks of a ten week gauging program will be devoted to identify those sewer subsystems which demonstrates that an SSES program is warranted.

When sufficient dry weather high groundwater data from the initial four weeks gauging program has been collected, a preliminary analysis principally for infiltration shall be performed to select areas for further study (SSES phase I flow isolation during high groundwater conditions) based on the 4,000 gpd/idm rule. Flow isolation for areas less than 4,000 gpd/idm may also be selected based on a cost-effective analysis.

A letter report to the Bureau shall be submitted, documenting the preliminary analysis, recommending areas for further study, flow isolation, and requesting approval to commence with the next phase.

Upon receiving approval to proceed, flow isolation should begin (see section V-3), and continuous monitoring of sewer flow in these areas should continue in order to supplement the data gathered during flow isolation. If sufficient wet weather data was not obtained during the initial four week gauging period, continuous monitoring should continue in all study areas to identify inflow.

If upon completion of the flow isolation data collection the 4,000 gpd/idm rule is not used to determine TV inspection eligibility, then a cost effective analysis shall be performed to identify sewer reaches recommended for internal TV inspection (see Section V-9). The sewer reaches shall be prioritized based on the ratio of the cost of transporting and treating the flow to the estimated rehabilitation cost.

Results of both phases shall be incorporated into a final report. This will contain recommendations for both infiltration and inflow source rehabilitation.

7. SINGLE SEASON TWO PHASE GAUGING AND TV INSPECTION APPROACH

PURPOSE

This approach follows the same steps mentioned in the single season two phase gauging program, but in addition, TV inspection may be performed in the same season instead of performing it in the following spring. This approach saves one year's time and eliminates the problem of collecting flow data in one season and comparing it to TV data collected in a second season. This approach is the most preferred method, followed by the single season two phase gauging approach.

METHODOLOGY

If groundwater levels remain high after flow isolation, TV inspection may be performed on manhole reaches as soon as flow isolation rates have been determined to exceed 4,000 gpd/idm.

The charts in the Exhibits (Figures 6,7,8) can be used to arrive at a quick decision to select the eligible reaches for TV inspection given the following parameters: flow isolation rate, length of reach, and pipe diameter.

The following formula is used for calculating eligible flows to perform TV inspection as shown graphically in Figures 6,7,8.

$$\text{Flow (gpd)} > \frac{4,000 \times \text{Reach Length (L.F.)} \times \text{Pipe Diameter (in.)}}{5,280.00}$$

Other methods to determine the eligibility for TV inspection may be used provided prior approval is received from the Bureau. A cost effective analysis may also be used to determine eligibility for TV inspection.

A letter report, similar to the flow isolation letter report, should be submitted to DEP requesting approval to proceed with TV inspection of the eligible reaches. A verbal approval can be issued in order to save time in this process.

INFILTRATION FLOW BALANCING ON SEGMENT BY SEGMENT BASIS

The measured flow isolation rate will be compared to the estimated rates observed during TV inspection. In cases where the flow isolation rate is higher than the total of the estimated TV rates, the engineer can assign flow rates to the various defects observed during the TV inspection, taking into consideration the severity of each defect and using the best engineering judgement. The observed plus the assigned flows should match the measured flow isolation rate, unless there are obvious large defects that should be considered on an individual basis.

## 8. PREPARATION OF REPORT

The I/I analysis report must clearly and concisely summarize the findings and recommendations of the field investigations and data analysis. The following information must be included:

All reports should contain an “Executive Summary” highlighting all tasks performed, a subsection of conclusions and recommendations and approximate costs. It should also have summary tables and estimates of quantities of extraneous flows.

Description of existing wastewater treatment and collection systems.

Description of problems (overflows, bypasses, surcharging, etc.) within the system. Note past studies and rehabilitation work.

Sewer map delineating subsystems, gauging locations, sewer size, etc.

Summarize gauging results. Show how wet weather flows were determined (adjustment to design storm, separate infiltration from base flow).

Summarize all information in tabular form (see Tables 1 through 6 in the Exhibits section).

A cost-effective analysis (if applicable).

Recommendations – list proposed Phase I SSES work, including estimated cost and schedule.

Appendices – Include such items as limited manhole inspection sheets, previous reports, photo documentation, and other pertinent information, as deemed appropriate.

PURPOSE

The sewer system evaluation survey is performed to determine the specific location, estimated flow rate, method of rehabilitation and cost of rehabilitation versus cost of transportation and treatment for each defined source of infiltration/inflow. The sewer system evaluation survey is intended to confirm the general overall findings of the infiltration/inflow analysis and to develop firm conclusions as to the presence of location, and degree of excessive or nonexcessive infiltration/inflow.

The sewer system evaluation survey is performed in two phases. The tasks associated with Phase 1 of the sewer system evaluation survey are presented below and discussed in detail in this section while the tasks associated with Phase 2 are discussed in Section VI.

1. GROUNDWATER MONITORING (See Section IV-3 of I/I Analysis Section, and follow procedures that pertain to flow isolation areas).
  2. RAINFALL MONITORING (See Section IV-4 of I/I Analysis Section)
  3. FLOW MONITORING (See Section IV-2 of I/I Analysis Section for Continuous Metering Methodology)
- 3.1 FLOW ISOLATION GAUGING METHODOLOGY

Areas identified and approved for flow isolation shall be subject to the following:

In small areas (less than 40 manholes) flow isolation gauging may be conducted without simultaneous continuous monitoring.

Flow isolation shall be conducted on a manhole reach by manhole reach basis during dry weather between the hours of 12:00 A.M. and 6:00 A.M.. Manhole reach flow isolation results will be addressed in groups totaling approximately 1,000 LF for analysis purposes in justifying follow-up television inspection if the CEA approach is used.

Special consideration will be made for any situations throughout the study area where the sewer line crosses under rivers, streams, lakes, marshlands or any other water courses or bodies of water. In such cases, it will be considered standard procedure to flow isolate these line sections whether or not they are located in areas designated for further study.

Flow isolation gauging shall incorporate the use of portable precalibrated weirs, or flow depth measurements in conjunction with flow velocity measurements. It is recommended that upstream flow be plugged when possible.

Observed infiltration from manholes should be noted at the time of flow isolation and deducted from line section measurements. The observed infiltration from manholes should be reported on the manhole inspection logs.

A manhole number system shall be developed to identify collection system locations.

Photo documents of field observations shall supplement field data.

NOTE: Manual instantaneous flow measurements shall be used during flow isolation, to calibrate continuous metering equipment, to supplement continuous flow monitoring data, and to develop data from small areas where no continuous monitoring is performed.

#### 4. EXTENSIVE MANHOLE INSPECTION

##### PURPOSE

Manhole inspection and subsequent line lamping is a task to determine the actual physical conditions of the sewer system. The data generated from the inspection will be valuable for the identification of infiltration/inflow sources. In addition, it is useful to verify sewer line configurations and subsystem boundaries. It also provides a factual base for the establishment of a preparatory cleaning program for internal inspection and a routine sewer maintenance program.

##### METHODOLOGY

The manhole inspections and line lamping is usually performed during the high groundwater period, because groundwater associated infiltration/inflow sources can be easily detected. All the manholes and sewer lines in the subsystems determined to contain infiltration in excess of 4,000 gpd/idm, and in inflow areas which account for 80% of the total inflow based on the I/I Analysis should be included in the inspection. Each manhole should be entered. If possible, the inspection should take place during off peak hours when wastewater flows are low and not under surcharge conditions.

Manhole inspection should include gathering the following information. This information is most readily and accurately reported if forms are developed for the field crew to use.

1. Identify the manhole, either by its number or by street and house number;

- (a) Manhole cover type, number of holes in cover, whether cover is subject to ponding. Estimate the area and depth of ponding so that an approximate rate of inflow can be ascribed to this defect if applicable. The following should also be noted: holes in the manhole cover and size of holes, condition of the surrounding ground or street condition, cracks in the pavement that could be pathways of inflow.
  - (b) Condition and number of manhole grade adjustments and manhole frame.
- 2. Cracks or breaks in the walls, shelf or invert.
  - 3. Infiltration at any place, should be estimated in gallons per minute; (Table 7 of the appendix shows the approximate flow rates that can be assigned to the various defects noted. A sample manhole inspection form is also included in the appendix for reference.) If an infiltration source was observed to be leaking at a greater rate during flow isolation than during the time of manhole inspection, then the higher observed rate should be reported on the manhole inspection form.
  - 4. Joints between barrel sections should be tight;
  - 5. Construction materials and conditions;
  - 6. Manhole depth;
  - 7. High water mark;
  - 8. Groundwater level at the manhole, if discernible; and
  - 9. Condition of corbel.

After the manhole inspection is complete, the influent and effluent sewer lines connected to the manhole must be inspected. This can be done by lamping with either a high intensity spot light or a flashlight. The following information should be recorded.

- 1. Laying length, size and type of pipe;
- 2. Offsets or misalignment of any part;
- 3. Protruding taps;
- 4. Root intrusion;
- 5. Visible infiltration/inflow sources, should be estimated in gallons per minute;

6. Type and depth of debris in pipes;
7. Sluggish flow or wastewater backing up into the manhole; and
8. Condition of pipe or corrosion.

5. SMOKE TESTING

PURPOSE

Smoke testing can identify locations of stormwater/groundwater entry into the sanitary sewer system. Direct connections including downspouts, area drains, driveway drains, stairwell drains, patio drains, and storm sewer inlets or ditches can be confirmed with smoke testing. Indirect connections from storm sewers or ditches which require I/I to pass through soil seams can also be identified with smoke testing.

METHODOLOGY

Smoke testing shall be conducted between July 1 to November 15, during periods of low groundwater and with sufficient time having elapsed from the previous rain event. However, if it is determined that adequate field conditions exist, and if approval is received from the Bureau, smoke testing may be extended beyond November 15. No testing should be conducted unless groundwater is below the pipe and the ground is not frozen. Prior to initiating smoke testing, property owners, police and fire officials should be notified.

Once smoke testing has been initiated and subsequently stopped because of rain, re-initiation of testing shall not occur until conditions are suitable. A “test segment” which was previously tested and had one or more indirect” sources with smoke transfer through soil seams may be used as an indication that suitable low groundwater and dry soil conditions have returned. Regional groundwater wells and manhole groundwater monitors may also be used as guidance for area wide groundwater levels.

In most cases smoke testing shall be conducted using a single blower technique with smoke being introduced at the smoke blower. The maximum allowable “Setup” length shall be no more than two manhole reaches. Field crews will ascertain that adequate smoke coverage has been obtained by observing smoke concentrations and observing smoke travel using house plumbing vents along the setup. Smoke will continue to be introduced into the setup until adequate smoke coverage has been obtained. In the event that smoke does not travel the entire reach, the setup will be reversed by setting the blower on the opposite manhole of the setup and re-introducing smoke. Since this situation may be caused by a line sag, grease or debris buildup, collapsed pipe, or other obstruction, it should be documented as a potential maintenance problem area.

Both the upstream and downstream manholes shall be restricted during the smoke testing to concentrate the smoke within the test section.

Restrictions may be accomplished with sandbags, cones or air plugs.

In situations where heavier smoke concentrations are required, the dual blower technique may be used with a smoke blower placed on both the upstream and downstream manholes with smoke generated at each blower. The maximum set-up length in this situation will typically be one manhole reach, or 300 LF if the manhole reaches are abnormally short.

“Suspect” inflow sources, which may be expected to be connected to the sanitary sewer, shall be recorded along with confirmed sources which actually smoked. These suspect sources may include driveway drains, stairwell drains, window well drains, patio and area drains, and downspouts piped underground, or the foundation, and warrant follow-up dye water testing.

Care shall be taken to inspect the property around all buildings and property for both smoking sources. In situations where heavy smoke is exiting a source, and it can be determined and documented through observation that the source is directly connected to the sanitary sewer, further rainfall simulation may not be necessary. In all other situations where it can not be unquestionably determined if a source is directly connected to the sanitary sewer, further rainfall simulation is required.

## 6. RAINFALL SIMULATION

### PURPOSE

Rainfall simulation is used to identify/confirm inflow sources to the sanitary sewer system. Dyed water flooding can identify both direct connections (catch basins) to the sanitary sewer as well as indirect connections between storm sewers or storm ditches and the sanitary sewer. It can also be utilized in conjunction with flow measurements to quantify the inflow from each of the identified sources. Rainfall simulation shall be conducted between July 1 to November 15. However, if it is determined that adequate field conditions exist, and if approval is received from the Bureau, the rainfall simulation may be extended beyond November 15.

If the infiltration/inflow analysis demonstrates that major inflow problems occur during periods of intense rainfall, a controlled systematic check of all storm sewers that parallel or cross the sanitary sewer system and/or house services should be initiated.

## 6.1 DYED WATER TESTING

Inflow sources including downspouts, area drains, patio drains, window well drains, stairwell drains and driveway drains may not always be detected with smoke testing due to trapped building service laterals or clogged drains.

Suspect sources should be recorded during smoke testing and/or during house-to-house surveys for subsequent dyed water testing. Verified simple defects such as roof leaders and drains may be rehabilitated prior to the house-to-house inspection.

Testing of these sources without plugging can detect whether the sources are connected to the sanitary sewer.

Care should always be taken when working with dyed water on private property. Clogged drains should be cleared where possible and clear water should be injected into the drain prior to the use of dye to ensure that the drain being tested will take water.

Dyed water testing should not be conducted where temperatures are expected to be near or below freezing.

## 6.2 DYED WATER FLOODING

Dyed water flooding of storm sewers and/or storm ditches can detect line segments where there are either direct or indirect connections between the storm sewer and sanitary sewer system.

Direct connections between storm sewers and sanitary sewers are normally detected with smoke testing and may be confirmed with dyed water tracing (see Section VI-3 Dyed Water Tracing).

Indirect cross connections between storm sewers and sanitary sewers are normally identified with smoke testing and subsequently confirmed with dyed water flooding. Storm sewers are normally plugged and filled with dyed water. Fire hydrants are normally used as the water source. A waiting period of at least one hour after initiation of flooding should be used before the test is considered negative. Flow measurements in the sanitary sewer shall be checked both before and after dyed water flooding to estimate the magnitude of the flow rate from the cross connection between the storm sewer and the sanitary sewer.

Dyed water flooding should be followed by dyed water flooding in conjunction with television inspection (Referred to as “dyed water tracing”) to identify the exact location(s) of the indirect cross connection(s).

After completion of dyed water flooding, and dyed water tracing, inflow balancing should be performed. If the majority of the inflow has been identified from direct connections the flooding of possible indirect connections may not be necessary. A cost effective analysis shall then be performed to determine if the indirect connections shall be dyed water traced.

## 7. INTERNAL BUILDING INSPECTIONS

### PURPOSE

Internal building inspections or house-to-house inspection to visually identify private inflow sources in the 80% inflow area are performed to establish whether property owners within a study area are in compliance (or noncompliance) with local sewer ordinances pertaining to infiltration and inflow sources.

### 7.1 METHODOLOGY FOR CONDUCTING HOUSE-TO-HOUSE SURVEYS

Each homeowner should be notified in some way that the inspectors are coming and what they will be looking for. The degree of public notification effort should be determined on a case-by-case basis depending on the requirements of the municipalities, public safety officials, and governing bodies. A notification program utilizing newspapers, radio, or telephone, and/or door-to-door leafleting can increase public awareness. Included in the program should be the overall goals to improve homeowner cooperation.

Inspectors should be appropriately dressed and carry a letter of authorization and photo identification from the municipality. They should also carry a copy of the section of the town regulations which address the inspection powers of the municipality.

Before beginning inspection anywhere on the property, the inspector should introduce him/herself to the owner or tenant of the building and explain what he/she will be doing, and ask permission to begin the investigation.

The investigation should cover the entire property indoors and outdoors.

Outside the building(s) the inspector should look for and make notes of any:

yard drains, patio drains, driveway, sidewalk or stairwell drains, roof downspouts leading underground, and window well drains.

Inside of the buildings the inspector should look for and make note of any:

sump pumps  
floor drains  
roof leader or foundation drain pipes coming in from outside and  
remove sewer cleanout caps

It should be noted if any of these potential sources connect directly to the building's sewer service. If it is not evident where a potential source of inflow drains to, then the owner should be consulted and the explanation should be verified through dyed water tracings if feasible. Sump pumps with unconfirmed discharge locations shall be recorded as unconfirmed sump pumps.

If available, the smoke testing results should be cross checked with the field findings during internal building inspections. If a property owner will not allow an inspection, the inspector should not confront them but should develop a list of addresses to be dealt with on a legal basis later by the municipality.

A list should be kept of owners who are not at home. A second call back should be made at a different time of the day or on a weekend. Call backs should be continued until a minimum of approximately eighty percent of the buildings have been entered.

8. FLOW DATA ANALYSIS (See Section IV-5)

9. COST EFFECTIVENESS ANALYSIS FOR CLOSED CIRCUIT TELEVISION

PURPOSE

A cost-effectiveness analysis (C/E/A) shall be performed as part of any SSES to demonstrate that the Infiltration/Inflow (I/I) entering the system is excessive. I/I is defined as being excessive if the costs for the correction of I/I conditions are less than the costs for transportation and treatment of these flows. For the purpose of this program, Infiltration rates above 4,000 gpd/idm are considered to be excessive. Thus the initial cost effective breakpoint for recommending closed circuit T.V. inspection shall be those line groupings with infiltration rates greater than 4,000 gpd/idm. When infiltration rates less than 4,000 gpd/idm are expected to be excessive a separate C/E/A must be performed for each pipe reach to justify performing closed circuit television inspection.

9.1 GENERAL METHODOLOGY

Transport and treatment cost is the sum of the capital cost relating to sizing sewerage facilities, plus the operation and maintenance cost.

The planning period shall be 20 years, and the discount rate to be used will be determined by the Bureau at the beginning of each fiscal year. The monetary costs to be considered must include the present worth or equivalent annual value of all flow-related capital and operation/maintenance costs. Sunk costs and SSES study costs, are not to be included in the C/E/A, nor do building service connections need to be considered at this time. Costs to be considered include, but are not limited to:

Construction costs, operation/maintenance costs, such as power, chemicals, etc.

Labor costs when labor is expended to address flow related problems.

## 9.2 METHODOLOGY FOR TELEVISION INSPECTION JUSTIFICATION

Based on the Phase 1 SSES measured infiltration flows for the individual sewer segments and manholes, a C/E/A shall be performed on unit lengths of sewer of  $\pm 1,000'$ , including manholes. The intention of using unit sewer lengths  $\pm 1,000'$  is to compensate for groundwater migration. In arranging the individual sewer segments into unit lengths of  $\pm 1,000'$  individual segments cannot be used more than once; i.e. 1,000' segments cannot overlap.

Assume 50% maximum infiltration removal in each 1,000' segment and use test and seal rehabilitation costs for typical sewers (unless conflicting information is known) for the entire segment length and appropriate rehabilitation costs for manhole defects.

Example:

- Given (a) sewer length = 1,000'
- (b) T&T cost @ \$0.50/GPD  
(adjusted to single multiplier to prorate and combine peak inflow with average infiltration on a weighted basis)
- (c) test and seal rehab @ \$5/LF,

the minimum removable infiltration flow required to qualify for SSES Phase 2 televising is:

$$(1,000 \text{ LF} \times \$5.00/\text{LF} / (\$0.50/\text{GPD})) = 10,000 \text{ GPD}$$

### INFILTRATION MIGRATION

Defined as groundwater infiltration to the sanitary sewer which moves from rehabilitated to non-rehabilitated sources.

Rehabilitation of infiltration sources frequently raises in-trench groundwater elevations which can cause unrehabilitated defects to leak at greater rates than before rehabilitation or cause previously non-leaking sources to start leaking (i.e. service laterals).

Migration does occur over a finite distance, and dissipates as in-trench groundwater dissipates to the soil outside of the sewer trench.

## MECHANISMS FOR ADDRESSING INFILTRATION MIGRATION

Televise sewers for infiltration in “clusters” to avoid “shotgun” rehabilitation. This will minimize remaining infiltration from a large number of leaking sources.

A rehabilitation program to minimize groundwater migration effects should be designed by performing a cost-effectiveness analysis on a system-wide basis as opposed to the traditional point source approach.

### 10. PREPARATION OF REPORT

The report on the Phase I SSES must clearly and concisely summarize the findings and recommendations of the field investigations and data analysis. The following information must be included:

All reports should contain an “Executive Summary” highlighting all tasks performed, a subsection of conclusions and recommendations and approximate costs. It should also have summary tables and estimates of quantities of extraneous wastewater.

Description of existing wastewater treatment and collection system.

Description of problems (overflows, bypasses, etc.) within the system. Note past studies and rehabilitation work.

Delineation of subsystems, gauging locations, sewer size, etc.

Outline gauging/internal inspection program.

Summarize gauging results. Show how wet weather flows were determined (adjustment to design storm, separate infiltration from base flow). Include rain fall hourly intensity graphs.

Cost-effectiveness Analysis – demonstrate how transportation and treatment costs are derived and present in a tabular form. (See Tables 3 & 6 in the Exhibits)

Recommendations – list proposed Phase II SSES including cost and schedule. The SSES should include an outline of a sewer system maintenance program.

Appendix – include such items as manhole inspection sheets, internal inspection logs, smoke test and dye water flooding logs and other pertinent information, as deemed appropriate.

If TV inspection for dyed water tracing is not necessary to determine inflow sources then a final report on inflow can be developed utilizing the procedures contained in Section VI-6.

## VI.

### PHASE 2 SEWER SYSTEM EVALUATION SURVEY

1. GROUNDWATER MONITORING (See Section IV-3 of Analysis Section)
2. TV FOR INFILTRATION

#### PURPOSE

TV inspection is utilized to pinpoint the exact location (s) of extraneous water entering the sewer system. This live inspection will provide valuable data which can be constructively used for analytical purposes. In addition a permanent visual record can be made for subsequent review.

#### 2.1 METHODOLOGY FOR T.V. INSPECTION FOR INFILTRATION

Televising for infiltration sources shall be conducted only during high groundwater conditions, between March 1 and June 30. However, if it is determined that groundwater levels are sufficient, and if approval is received from the Bureau, the T.V. inspection may begin prior to March 1 and/or extend beyond June 30.

Nighttime flow gauging shall be conducted immediately prior to television inspection. The preferred gauging method is to plug and weir one sewer segment (manhole to manhole) at a time.

These flows along with the flows observed during TV inspection are to be used in the cost effectiveness analysis for pipeline rehabilitation. Flows observed during TV inspection should be used to aid in estimating the infiltration contribution for each infiltration source observed during the TV inspection program.

If the TV flow is drastically different from the nighttime flow, additional field investigation shall be conducted to account for the difference. For example, where service laterals are observed to be running continuously, inquiry at those houses should be made to ascertain that no water was being used concurrent with televising.

Unless some realistic, documentable method to adjust television inspection observed flows to the design infiltration flow is developed, observed television inspection flows, which may be prorated based on the discussion above, should be used for subsequent cost-effectiveness analysis and projected infiltration removals.

### 3. DYED WATER TRACING

#### PURPOSE

Television inspection in conjunction with dyed water flooding is Dyed Water Tracing, and is intended to identify the exact location(s) of the indirect cross Connection(s) between the storm sewer and sanitary sewer. These specific locations are necessary to develop a rehabilitation program for the line segment.

#### 3.1 METHODOLOGY

Dyed Water Tracing may be conducted at any time of the year where temperatures are above freezing.

In cases where the cross connection(s) between the storm sewer and sanitary sewer are severe enough to surcharge the sanitary sewer, it may be necessary to reduce the head build up in the storm sewer.

Flow measurements shall be taken in the sanitary sewer prior to dye water tracing and during the observation of dyed water in the sanitary sewer to quantify infiltration occurring during the dyed water tracing.

Defects should be noted along with flow rates where dyed water is observed entering the sanitary sewer. Color television inspection equipment will be used to observe the dyed water.

During the dyed water tracing the building service laterals crossing storm sewers and storm ditches are common sources of indirect cross connections and should be carefully observed during the TV inspection.

### 4. INFLOW BALANCING

#### PURPOSE

The purpose of balancing flow aggregation of all identified inflow sources with the total inflow volume established from flow monitoring is:

To ensure that essentially all inflow within a study basin has been identified;

To determine if additional field activities are required to locate inflow sources; and

To ensure that projections for overall inflow elimination by subsystem are achievable by preventing the assignment of an unrealistically high inflow volume to any given inflow source or group of sources.

#### 4.1 METHODOLOGY

Inflow volumes for a collection system tributary to each monitoring location shall be established based on a reference storm event from an approved technique for correlating total inflow to rainfall volume. For purposes of inflow balancing, the reference event shall be a 1-year recurrence interval storm. (See Section IV-5.6)

Inflow sources identified in the study area tributary to a flow monitoring location shall each be assigned an inflow volume at the reference storm event condition using sound engineering judgement.

Guidance for reasonable inflow volume by type of inflow source can be found in Table 7 of the Appendix. Deviations from these inflow values shall be justified.

If the aggregation of all identified inflow sources produce a total inflow volume which is substantially less than the total inflow volume established as a result of flow monitoring, the typical field survey activities including manhole inspections, smoke testing, dye water flooding and building inspection shall be conducted to identify remaining unidentified inflow sources.

A “balance” between total inflow volume from flow monitoring with total inflow volume from inflow source data shall be achieved before proceeding to a final cost-effectiveness analysis.

#### 5. FINAL COST-EFFECTIVENESS ANALYSIS

##### PURPOSE

A separate cost-effectiveness analysis (C/E/A) must be performed for infiltration and inflow as part of an SSES to determine whether the I/I in the system is excessive.

Infiltration/Inflow (I/I) in the system is defined as being excessive if the costs for the correction of I/I conditions are less than the costs for transportation and treatment of these flows.

#### 5.1 METHODOLOGY FOR INFILTRATION REHABILITATION WORK

For SSES Phase 2 infiltration televising, a C/E/A shall be performed to qualify the 1,000’ sewer segments for rehabilitation work to avoid “shotgun” infiltration rehabilitation, which is highly susceptible to groundwater migration. This is contrary to the “classic” approach of analyzing cost-effectiveness strictly on a manhole to manhole sewer line segment unit basis, or even on a single defect unit basis.

Engineering judgement shall be used to estimate the percent infiltration removal based on the observed defects, general pipe condition, percent of infiltration flow from private sources vs. percent of infiltration flow from sources in public right-of-way, etc. For example, test and seal rehabilitation of a cross-country sewer with no service connections might reasonably be expected to result in a high percent removal.

Conversely, a low percent removal might be appropriate where televising showed a high percent of the infiltration flow attributable to house service laterals.

The estimated rehabilitation cost for each 1,000' unit length of sewer, including manholes, shall be based on the appropriate rehabilitation technique required for the infiltration flow sources identified during televising.

The flows used for the C/E/A of each 1,000' segment shall be the flows calculated in the infiltration analysis.

## 5.2 LIFE CYCLE

In Performing a cost effective analysis higher initial cost for repairs may be considered eligible provided a life cycle analysis demonstrates that the higher initial cost is the more economical rehabilitation method in the long run. This analysis may require comparisons of rehabilitation methods with different life expectancies. A study of this type will be evaluated on a case by case basis.

Furthermore, the analysis may require an engineering judgment of the life expectancy of the unit or method composed of various components. The analysis may also be of a single component but used within a certain practice that the life expectancy of the material used only, however long, may lead to unreasonable expectations of longevity that can not be substantiated in actual operational practice. In such cases, comparisons with the historical record of other installations may be helpful in establishing a realistic useful life.

## 5.3 METHODOLOGY FOR INFLOW REHABILITATION WORK

A C/E/A will be required for rehabilitation of inflow sources identified during the SSES study. Rehabilitation cost estimates, source flow estimates, and estimated percent removals must be based on engineering judgment. Where disconnection of discrete sources (such as catch basins, roof leaders, and drains) is evaluated, 100% inflow removal may be used. Inflow sources that are not cost effective can be listed separately and may be recommended for rehabilitation.

6. PREPARATION OF REPORT

The report on the I/I Phase II SSES must clearly and concisely summarize the findings and recommendations of the field investigations and data analysis. The following information must be included:

All reports should contain an “Executive Summary” highlighting all tasks performed, a subsection of conclusions and recommendations and approximate costs. It should also have summary tables and estimates of quantities of extraneous wastewater.

Description of existing wastewater treatment and collection system.

Description of problems (overflows, bypasses, etc.) within the system. Note past studies and rehabilitation work.

Sewer map delineating subsystems, gauging locations, sewer size, etc.

Outline gauging/internal inspection program.

Summarize gauging results. Show how wet weather flows were determined (adjustment to design storm, separate infiltration from base flow). Include rainfall hourly intensity graphs.

Cost-effectiveness Analysis – demonstrate how transportation and treatment costs are derived. Present in a tabular form per subsystem.

Recommendations – list recommended rehabilitation work, including cost and schedule. A final sewer system maintenance program should be presented.

Appendix – Include such items as manhole inspection sheets, internal inspection logs, smoke test and dye water flooding logs and other pertinent information, as deemed appropriate.

The purpose of studying a combined system is to gather information to understand the system and thereby develop the most applicable corrective program. The I/I investigation phase of a combined system may stem from or be part of a CSO study. In a combined system the sewer lines are designed and constructed to serve both as sanitary and as storm sewers.

Because of the different characteristics and purpose of the combined system including their extent in the various Local Government Units (LGU) the study of the combined system may need to be more site specific to better evaluate its problems.

The main tasks associated with an analysis of a combined system are:

- **Inventory of Existing Conditions:** This task is detailed in the I/I analysis section of these guidelines. However, in addition, a most important function of this task is to determine which in fact are combined areas when this information is not readily available. In particular, where the demarcation is not readily evident from adjacent separate areas.
- **Continuous Flow Monitoring:** Generally flow monitoring may be principally directed to quantify infiltration in order to recommend further studies towards the reduction of excessive infiltration. The specific methodologies are also described in other sections.

In some cases it may be desirable to evaluate and quantify inflow, in particular when it is suspected that some areas are the main contributors of inflow. The period of flow monitoring may be of shorter duration compared to an I/I analysis of a separate system. Site specific recommendations in order to best evaluate the system characteristics are encouraged, and the scope of work to analyze the system may need to be more detailed as compared to an analysis of a separate system.

- **Other tasks** will follow from these two above mentioned main tasks and their methodologies are described in their respective sections.

INTERACTION BETWEEN THE REGULATORY BRANCH AND  
THE INFILTRATION/INFLOW PROGRAM

The Department of Environmental Protection, through its Regulatory Branch, is responsible for ensuring compliance with the requirements of the Massachusetts Clean Waters Act (G.L. c.21, ss26-53) and the regulations adopted under 314 CMR CHS 1-9. The Division has authority to enforce the Massachusetts Clean Waters Act in response to violations. Remedies available through either administrative or judicial proceedings include requiring municipalities to undertake specific activities to upgrade the operation and maintenance of sewage system and to submit periodic progress reports on the status of these activities. Quite often, they impose a moratorium on new connections to, or extensions of their sewer system.

Frequently violations occur as a result of Infiltration/Inflow (I/I), which is the introduction of extraneous water into a sewer system. I/I reduces the capacity of sewer lines to accommodate normal flow and impairs the ability of treatment facilities to transport and treat domestic and industrial flows. A systematic approach is necessary to discover and subsequently eliminate these sources.

The Regulatory Branch takes cognizance of the availability of and the requirements of the SRF program in administering its enforcement responsibilities under the Clean Waters Act. By availing themselves of the assistance provided by the SRF, municipalities are able to comply with the directives of an Administrative Order and derive the benefits associated therewith, namely:

- (a) elimination or alleviation of backups or overflows
- (b) promote efficient operation of treatment facilities
- (c) utilize hydraulic capacity for wastewater rather than extraneous flow
- (d) extend the service life of a sewer system
- (e) general benefits to the environment

In summary, the Regulatory Branch and the I/I rehabilitation program share the common goal of obtaining and assuring compliance with the requirements of the Clean Waters Act. To the extent possible, the two programs are administered to complement each other in the pursuit of these goals.

The elimination of infiltration/inflow by sewer system rehabilitation and an on-going operation and maintenance program to identify these areas is essential to protect the enormous investment in sewers and wastewater treatment facilities made by cities, towns, and the Commonwealth as well as for the protection of the environment.

A collection system corrodes, erodes, collapses, clogs, and ultimately deteriorates. Its capacity can be reduced by accumulations or obstructions that are discharged to the system, such as grease, garbage, rags, paper towels and by materials described as disposable by the manufacturer. This also includes any material that may enter at the joints or through breaks in the sewer line itself, such as roots or soil materials. Sanitary sewer capacity is finite, and common sense dictates that it needs to be preserved.

In the past, many municipalities have not provided the quality program for collection system maintenance necessary to protect both the public's health and the sizeable investment in their facilities. Collection system maintenance functions are frequently treated as necessary evil, to be given attention only as emergencies arise. Adequate budgets should be provided for supervision, labor, and equipment.

The execution of a basic plan of routine preventive maintenance designed to preclude interruption of service and to protect capital investment is extremely important. Continuous routine inspection for physical damage to the system to be supplemented by immediate and adequate repair of any damage and elimination of the cause can not be overemphasized.

In order to assure the continued care of the collection system after the I/I Analysis and Sewer System Evaluation Survey have been completed, and approvable operations and maintenance (O&M) program should be drafted and submitted to the Bureau prior to the construction phase.

Acknowledging the importance for communities to have an adequate collection system O&M program, the Department of Environmental Protection through its Bureau has determined that the development of an O&M program is an item eligible for financial assistance. (See Regulations, 310 CMR Sections 41.43 and 41.44)

Please refer to "Guidelines for Performing Operations and Maintenance on Collections Systems" published by the DEP, I/I Rehabilitation Program in August 1989 for detailed descriptions of the various components of an O&M program.

TABLE OF ABBREVIATIONS

|         |                                                                                                  |
|---------|--------------------------------------------------------------------------------------------------|
| AC      | Asbestos-cement pipe                                                                             |
| BMF     | Bureau of Municipal Facilities (“Bureau”)                                                        |
| C/E/A   | Cost-effective analysis                                                                          |
| DEP     | (Massachusetts) Department of Environmental Protection                                           |
| DI      | Ductile iron pipe                                                                                |
| ENR     | Engineering News Record Cost Index                                                               |
| EPA     | Environmental Protection Agency                                                                  |
| gpd     | gallons per day                                                                                  |
| gpd/idm | gallons per day per inch diameter per mile of sewer (does not include building service laterals) |
| gpd/ft  | gallons per day per foot of sewer (does not include service laterals)                            |
| I/I     | Infiltration/inflow                                                                              |
| LF      | linear foot                                                                                      |
| LGU     | Local Government Unit                                                                            |
| MG      | million gallons                                                                                  |
| MGD     | million gallons per day                                                                          |
| MH      | manhole                                                                                          |
| NOAA    | National Oceanic and Atmospheric Administration                                                  |
| O&M     | Operation and maintenance                                                                        |
| PS      | pump station                                                                                     |
| PVC     | Polyvinyl chloride pipe                                                                          |
| RC      | reinforced concrete pipe                                                                         |
| RDI     | Rainfall Dependent Infiltration                                                                  |
| RDI/I   | Rainfall Dependent I/I                                                                           |

|      |                                 |
|------|---------------------------------|
| RII  | Rainfall Induced Infiltration   |
| SRF  | State Revolving Fund            |
| SSES | Sewer System Evaluation Study   |
| T&T  | Transportation and treatment    |
| USGS | United States Geological Survey |
| VC   | Vitrified clay pipe             |

# XI TECHNICAL EXHIBITS

TABLE 1  
I/I ANALYSIS  
SUMMARY TABLE FOR INFILTRATION

| (1)*<br>RANKING | (2)<br>SUBSYSTEM | (3)**<br>SEWER<br>LENGTH<br>Ft. | (4)<br>AVERAGE<br>PIPE<br>in. | (5)<br>PEAK<br>INFILTRATION<br>gpd | (6)<br>INFILTRATION<br>RATE<br>gpd/idm | (7)<br>ELIGIBLE<br>FOR FLOW<br>ISOLATION |
|-----------------|------------------|---------------------------------|-------------------------------|------------------------------------|----------------------------------------|------------------------------------------|
| 1               | F                | 20,000                          | 8                             | 1,288,000                          | 42,504                                 | YES                                      |
| 2               | C                | 22,000                          | 11                            | 833,000                            | 18,175                                 | YES                                      |
| 3               | B                | 18,000                          | 13                            | 700,000                            | 15,800                                 | YES                                      |
| 4               | D                | 23,000                          | 9                             | 500,000                            | 12,750                                 | YES                                      |
| 5               | A                | 19,000                          | 12                            | 400,000                            | 9,263                                  | YES                                      |
| 6               | E                | 21,000                          | 30                            | 835,240                            | 7,000                                  | YES                                      |
| 7               | H                | 20,000                          | 12                            | 190,000                            | 4,180                                  | YES                                      |
| 8               | G                | 24,000                          | 8                             | 100,000                            | 2,750                                  | NO                                       |
| 9               | J                | 18,000                          | 10                            | 60,000                             | 1,760                                  | NO                                       |
| 10              | K                | 19,000                          | 10                            | 40,000                             | 1,112                                  | NO                                       |
| TOTAL           |                  | 204,000                         |                               | 4,946,240                          |                                        |                                          |

- Ranking based on highest Infiltration rate (column 6)

\*\* Exclusive of house services

NOTE: Above figures are used as an example for illustration purpose only.

TABLE 2  
I/I ANALYSIS  
SUMMARY TABLE FOR INFLOW

| (1)*<br>RANKING | (2)<br>SUBSYSTEM | (3)**<br>SEWER<br>LENGTH<br>Ft. | (4)<br>AVG.<br>PIPE<br>DIAM.<br>in. | (5)<br>MEASURED<br>TOTAL INFLOW<br>VOLUME<br>gal | (6)***<br>DESIGN STORM<br>TOTAL INFLOW<br>VOLUME<br>gal | (7)<br>DESIGN STORM<br>TOTAL INFLOW<br>VOLUME<br>gal/idm | (8)<br>%<br>TOTAL<br>INFLOW | (9)<br>COMMULATIVE<br>PERCENT |
|-----------------|------------------|---------------------------------|-------------------------------------|--------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------|-----------------------------|-------------------------------|
| 1               | F                | 20,000                          | 8                                   | 200,000                                          | 400,000                                                 | 13,200                                                   | 31%                         | 31%                           |
| 2               | A                | 19,000                          | 12                                  | 250,000                                          | 500,000                                                 | 11,580                                                   | 28%                         | 59%                           |
| 3               | D                | 23,000                          | 9                                   | 200,000                                          | 400,000                                                 | 10,200                                                   | 24%                         | 83%                           |
| 4               | B                | 18,000                          | 13                                  | 75,000                                           | 150,000                                                 | 3,384                                                    | 8%                          | 91%                           |
| 5               | C                | 22,000                          | 11                                  | 75,000                                           | 150,000                                                 | 3,272                                                    | 8%                          | 99%                           |
| 6               | E                | 21,000                          | 30                                  | 50,000                                           | 100,000                                                 | 83                                                       | 1%                          | 100%                          |
| TOTAL           |                  | 123,000                         |                                     |                                                  | 1,700,000                                               |                                                          |                             |                               |

- Ranking is based on highest Inflow rate (column 7)

\*\* Exclusive of house services

\*\*\* Total rainfall of storm even is assumed to be 0.86 in.  
Design storm peaking factor =  $1.72/0.86 = 2$   
This factor may be used if only one storm occurred.  
In case of more than one storm, figure 5 will be used

NOTE: Above numbers are used as an example for illustration purpose only.

TABLE 3  
SSES PHASE I  
SUMMARY TABLE OF INFILTRATION  
COST EFFECTIVE ANALYSIS FOR TV INSPECTION  
\*\*SUBSYSTEM NO. F

| (1)     | (2)                 | (3)                    | (4)                 | (5)             | (6)                         | (7)                              | (8)                      | (9)                     | (10)              |
|---------|---------------------|------------------------|---------------------|-----------------|-----------------------------|----------------------------------|--------------------------|-------------------------|-------------------|
| RANKING | SEGMENT<br>MH TO MH | SEWER<br>LENGTH<br>Ft, | PIPE<br>DIA.<br>in. | TYPE<br>OF PIPE | PEAK<br>INFILTRATION<br>gpd | REMOVALBE<br>INFILTRATION<br>gpd | T&T<br>COST<br>\$1.5/gpd | REHAB<br>COST<br>\$5/lf | COST<br>EFFECTIVE |
| 1       | 13-15               | 1,000                  | 8                   | VC              | 40,000                      | 20,000                           | 30,000                   | 5,000                   | 6.0               |
| 2       | 17-20               | 1,050                  | 8                   | VC              | 16,000                      | 8,000                            | 12,000                   | 5,250                   | 2.3               |
| 3       | 5-7                 | 1,100                  | 8                   | VC              | 12,000                      | 6,000                            | 9,000                    | 5,500                   | 1.6               |
| 4       | 28-30               | 950                    | 10                  | VC              | 6,800                       | 3,400                            | 5,100                    | 4,750                   | 1.0               |
| 5       | 25-28               | 900                    | 10                  | VC              | 2,667                       | 1,333                            | 2,000                    | 4,500                   | 0.4               |
| 6       | 1-5                 | 1,100                  | 8                   | VC              | 2,000                       | 1,000                            | 1,500                    | 5,500                   | 0.3               |
| TOTAL   |                     |                        |                     |                 |                             |                                  |                          |                         |                   |

\* Rehab cost is based on estimated price of testing and sealing

\*\* One table for each subsystem

NOTE: Above figures are used as an example for illustration purpose only.

TABLE 4  
SSES PHASE 2  
SUMMARY TABLE OF INFLOW SOURCES  
REHABILITATION METHODS AND COSTS  
(PUBLIC)

| (1)                     | (2)      | (3)                    | (4)                      | (5)                         | (6)                        | (7)         | (8)             | (9)           | (10)              |
|-------------------------|----------|------------------------|--------------------------|-----------------------------|----------------------------|-------------|-----------------|---------------|-------------------|
| INFLOW<br>SOURCE<br>ID# | LOCATION | SOURCE<br>OR<br>DEFECT | DIRECT<br>OR<br>INDIRECT | ESTIMATED<br>IN FLOW<br>gal | REMOVABLE<br>INFLOW<br>gal | T&T<br>COST | REHAB<br>METHOD | REHAB<br>COST | COST<br>EFFECTIVE |
| TOTAL                   |          |                        |                          |                             |                            |             |                 |               |                   |

TABLE 5  
SSES PHASE 2  
SUMMARY TABLE OF INFLOW SOURCES  
REHABILITATION METHODS AND COSTS  
(PRIVATE)

| (1)                     | (2)      | (3)                    | (4)                      | (5)                         | (6)                        | (7)         | (8)             | (9)           | (10)              |
|-------------------------|----------|------------------------|--------------------------|-----------------------------|----------------------------|-------------|-----------------|---------------|-------------------|
| INFLOW<br>SOURCE<br>ID# | LOCATION | SOURCE<br>OR<br>DEFECT | DIRECT<br>OR<br>INDIRECT | ESTIMATED<br>IN FLOW<br>gal | REMOVABLE<br>INFLOW<br>gal | T&T<br>COST | REHAB<br>METHOD | REHAB<br>COST | COST<br>EFFECTIVE |
| TOTAL                   |          |                        |                          |                             |                            |             |                 |               |                   |

TABLE 6  
SSES PHASE 2  
SUMMARY TABLE OF INFILTRATION  
COST EFFECTIVE ANALYSIS FOR REHABILITATION  
\*SUBSYSTEM NO. F

| (1)     | (2)                 | (3)                    | (4)                  | (5)             | (6)                         | (7)                              | (8)                      | (9)               | (10)            | (11)          | (12)              |
|---------|---------------------|------------------------|----------------------|-----------------|-----------------------------|----------------------------------|--------------------------|-------------------|-----------------|---------------|-------------------|
| RANKING | SEGMENT<br>MH TO MH | SEWER<br>LENGTH<br>Ft. | PIPE<br>DIAM.<br>in. | TYPE<br>OF PIPE | PEAK<br>INFILTRATION<br>gpd | REMOVABLE<br>INFILTRATION<br>pgd | T&T<br>COST<br>\$1.5/gpd | TYPE OF<br>DEFECT | REHAB<br>METHOD | REHAB<br>COST | COST<br>EFFECTIVE |
| 1       | 13-15               | 1,000                  | 8                    | VC              | 40,000                      | 20,000                           | 30,000                   | CRACK             | T&S             | 7,000         | 4.3               |
| 2       | 17-20               | 1,050                  | 8                    | VC              | 16,000                      | 8,000                            | 12,000                   | OFFSET JT.        | DIG & REPL.     | 8,000         | 1.5               |
| 3       | 5-7                 | 1,100                  | 8                    | VC              | 12,000                      | 6,000                            | 9,000                    | CRACK             | T&S             | 8,000         | 1.1               |
| 4       | 28-30               | 950                    | 10                   | VC              | 6,800                       | 3,400                            | 5,100                    | CRACK             | DIG & REPL.     | 10,000        | 0.5               |
| TOTAL   |                     |                        |                      |                 |                             |                                  |                          |                   |                 |               |                   |

\* One table for each subsystem

NOTE: Above figures are used as an example for illustration purpose only.



TABLE 7  
SUGGESTED GUIDE FOR FLOW <sup>(1)</sup>

| <u>INFLOW SOURCES</u>                     | <u>AVERAGE INFLOW<br/>RATE (gpm) <sup>(2)</sup></u> | <u>TOTAL INFLOW<br/>VOLUME (gal) <sup>(3)</sup></u> |
|-------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| <u>MANHOLE DEFECTS</u>                    |                                                     |                                                     |
| Ponding Manhole                           | 3.0 <sup>(4)</sup>                                  | 1000 <sup>(5)</sup>                                 |
| Pick or Vent Hole (Per hole)              |                                                     |                                                     |
| Diameter                                  |                                                     |                                                     |
| 1/2"                                      | 1.2 <sup>(6)</sup>                                  | 432 <sup>(7)</sup>                                  |
| 3/4"                                      | 2.7 <sup>(6)</sup>                                  | 1000 <sup>(7)</sup>                                 |
| 1"                                        | 4.8 <sup>(6)</sup>                                  | 1730 <sup>(7)</sup>                                 |
| 1 1/4"                                    | 7.5 <sup>(6)</sup>                                  | 2700 <sup>(7)</sup>                                 |
| Rim Sea                                   | 1.0-5.0                                             |                                                     |
| Corbel Lead or Cracked Frame Seal         | 0.5-1.5                                             |                                                     |
| Broker Frame                              | 1.0-2.0                                             |                                                     |
| <u>MAIN SEWER DEFECTS</u>                 |                                                     |                                                     |
| Cross Connections                         | 5-25                                                |                                                     |
| <u>PRIVATE SECTOR SOURCES</u>             |                                                     |                                                     |
| Later Service, Cleanout or Wye Connection | 0.1-1.0                                             |                                                     |
| Storm Sump Pump to Sanitary Sewer         | 3.0-6.0                                             |                                                     |
| Foundation Drain or Floor Drain           | 3.0-6.0                                             |                                                     |
| Downspout                                 | 3.0 <sup>(4)</sup>                                  | 1000 <sup>(5)</sup>                                 |
| Driveway Drain                            | 3.0 <sup>(4)</sup>                                  | 1000 <sup>(5)</sup>                                 |
| Window Well or Stairway Drain             | 0.5-1.0                                             |                                                     |

## NOTES FOR TABLE 7

- (1) Individual sources may be assigned different rates based on site conditions, and best engineering judgment.
- (2) Based on Average rainfall intensity of 0.29 in/hr (Design Storm). Peak flow rate may be also considered based on peak rainfall intensity of 0.87 in/hr.
- (3) Based on total rainfall intensity of 1.72 in. (Design Storm).
- (4) Flow is calculated by using the rational formula assuming the following:

Area of discharge = 1,100 sq. ft.

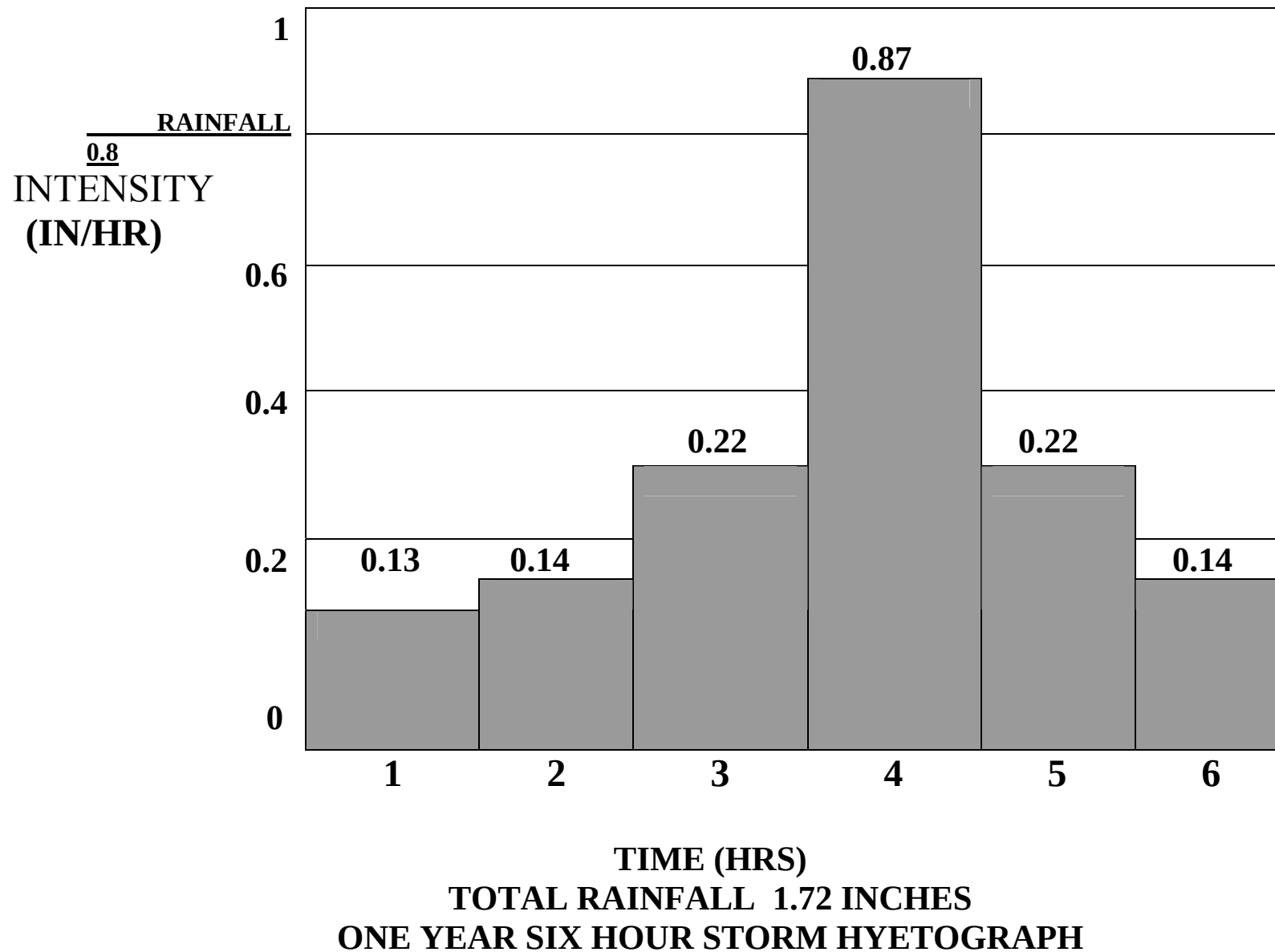
Coef. Of discharge = 0.9

Average rainfall intensity = 0.29 in/hr.

For accurate calculation area of discharge must be measured in the field and coef. of discharge will vary according to the type of soil/pavement.

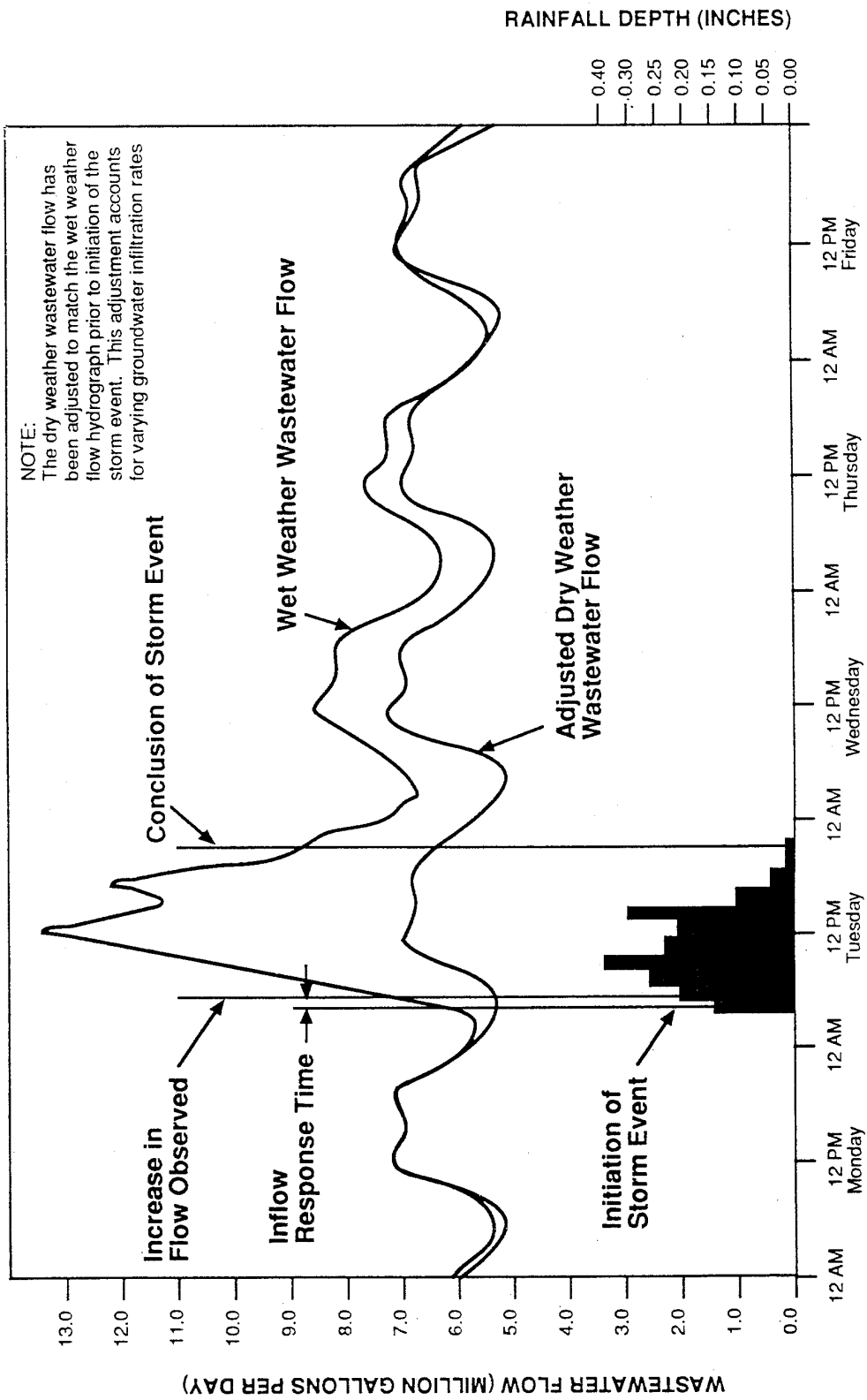
- (5) Estimated volume of inflow is based on the same parameters of the flow rate except the intensity used is the total rainfall of the design storm, which is 1.72" (in).
- (6) Flow rate is per hole and assuming 2" (in) head of rainfall accumulation.
- (7) Estimated volume of inflow is based on a duration of 6 hours of rainfall.

**BASED ON: LOGAN AIRPORT RAINFALL DATA  
JUNE, 1948 – DECEMBER, 1977**

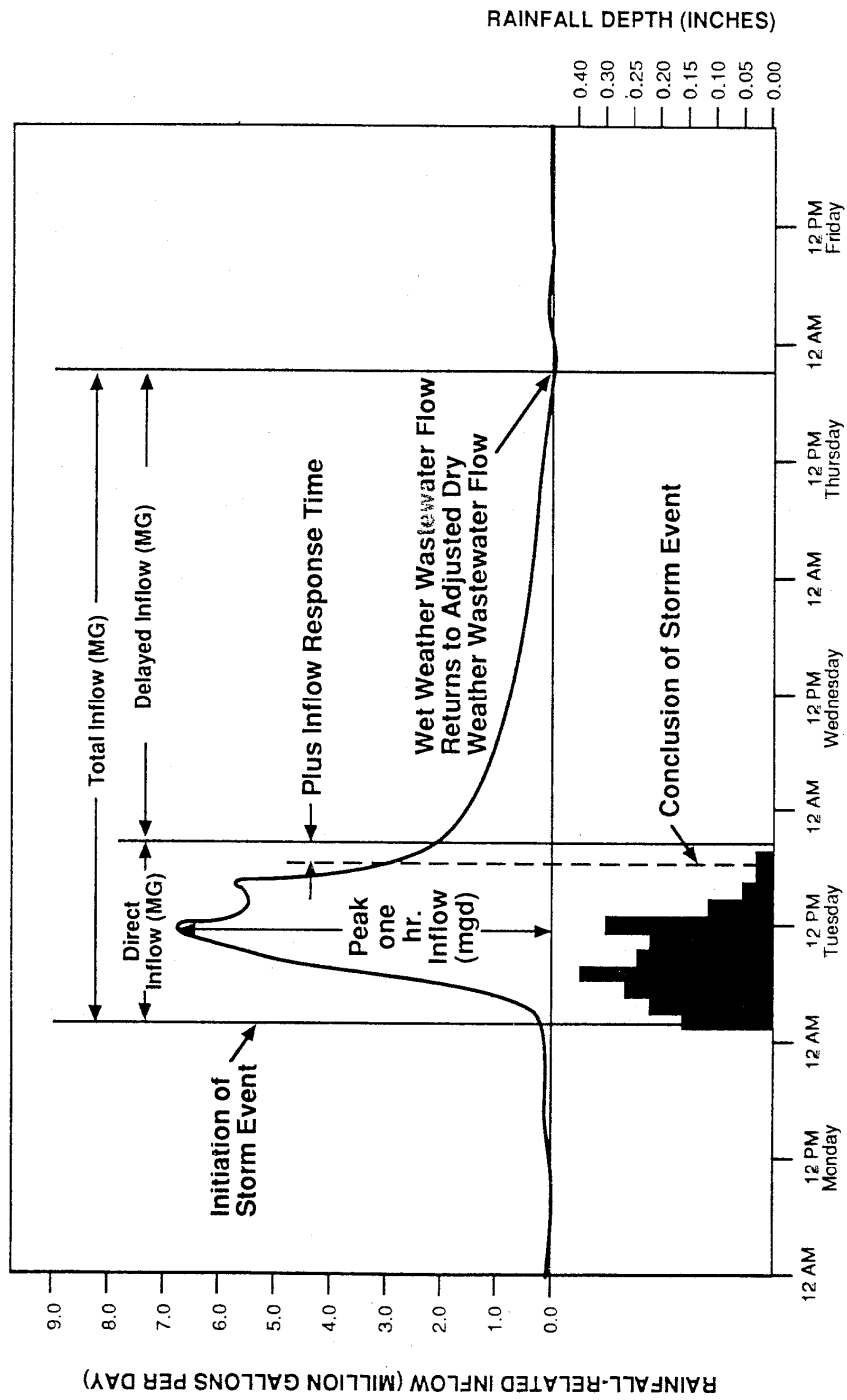


**FIGURE 1**

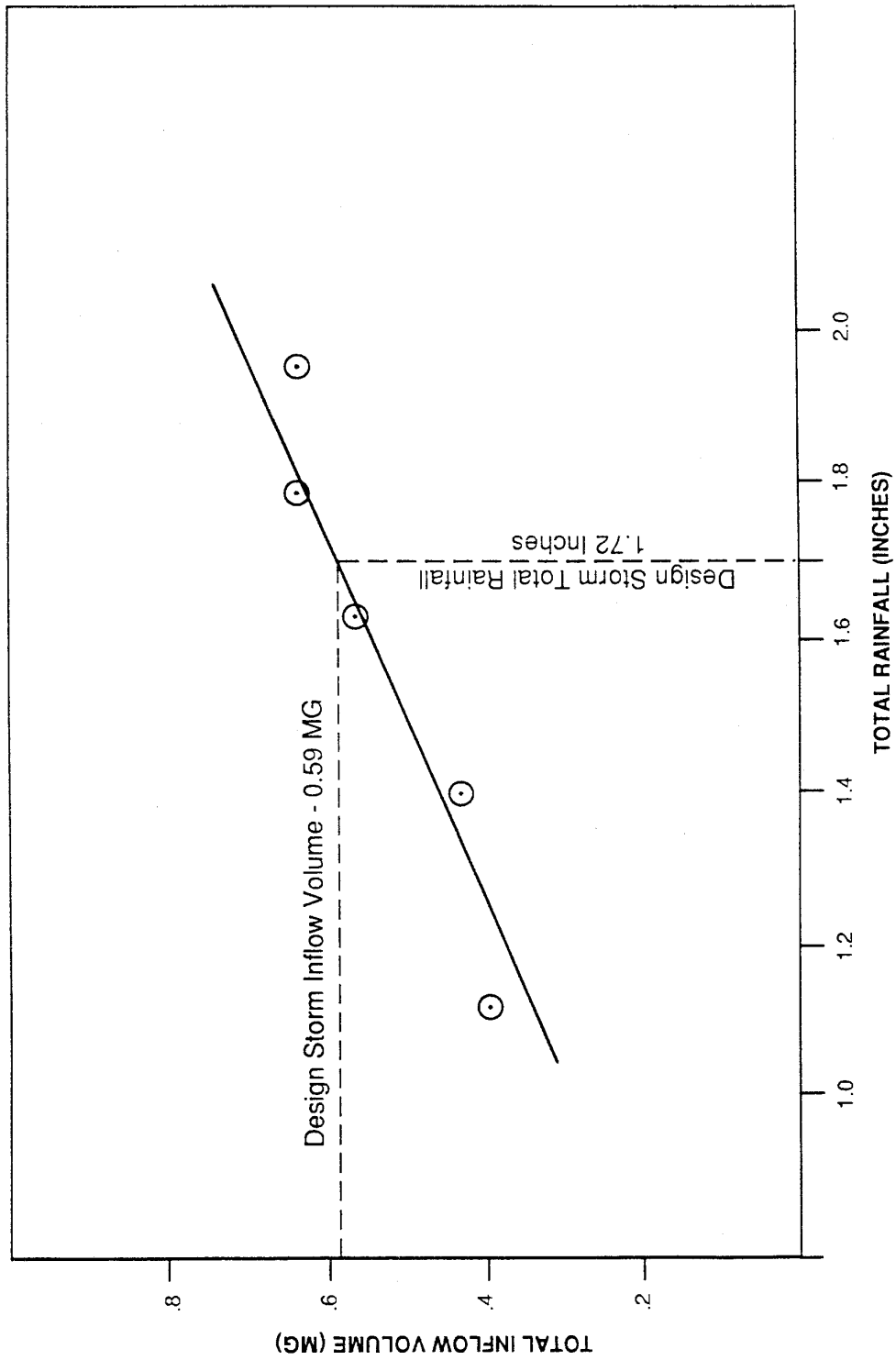




**Figure 3**  
**DRY (ADJUSTED) & WET WEATHER WASTEWATER FLOW**  
**WITH RELATED RAINFALL HYETOGRAPH**



**Figure 4**  
**TOTAL INFLOW HYDROGRAPH CURVE**  
**WITH RELATED RAINFALL HYETOGRAPH**



**Figure 5**  
**TOTAL INFLOW VOLUME TO TOTAL RAINFALL**  
**COMPARISON FOR DESIGN STORM INFLOW ANALYSIS**

TV ANALYSIS  
ELIGIBILITY DETERMINATION

4,000 GPD/IN MILE

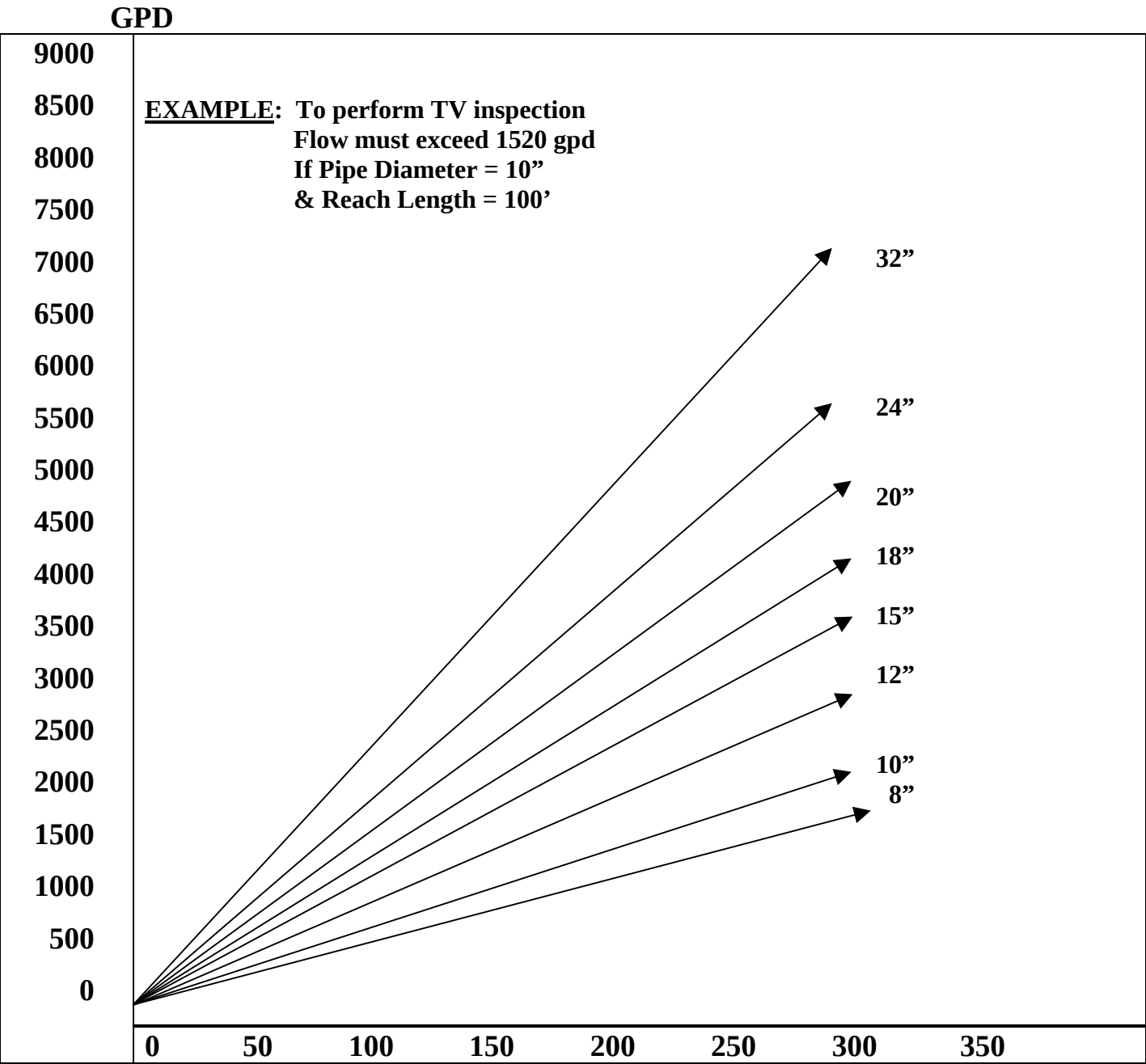
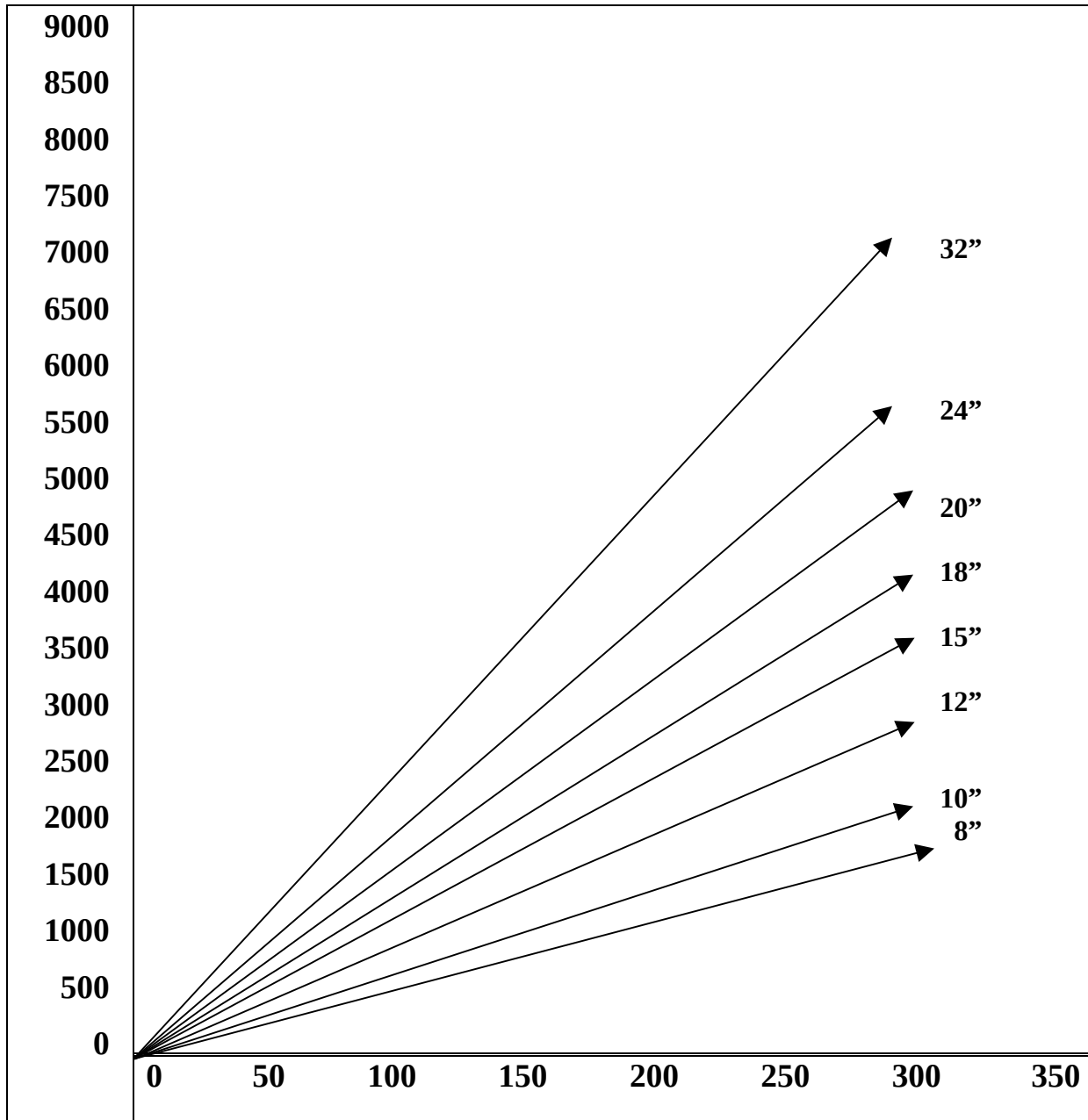


FIGURE 6

# ELIGIBILITY DETERMINATION

4,000 GPD/IN MILE

GPD



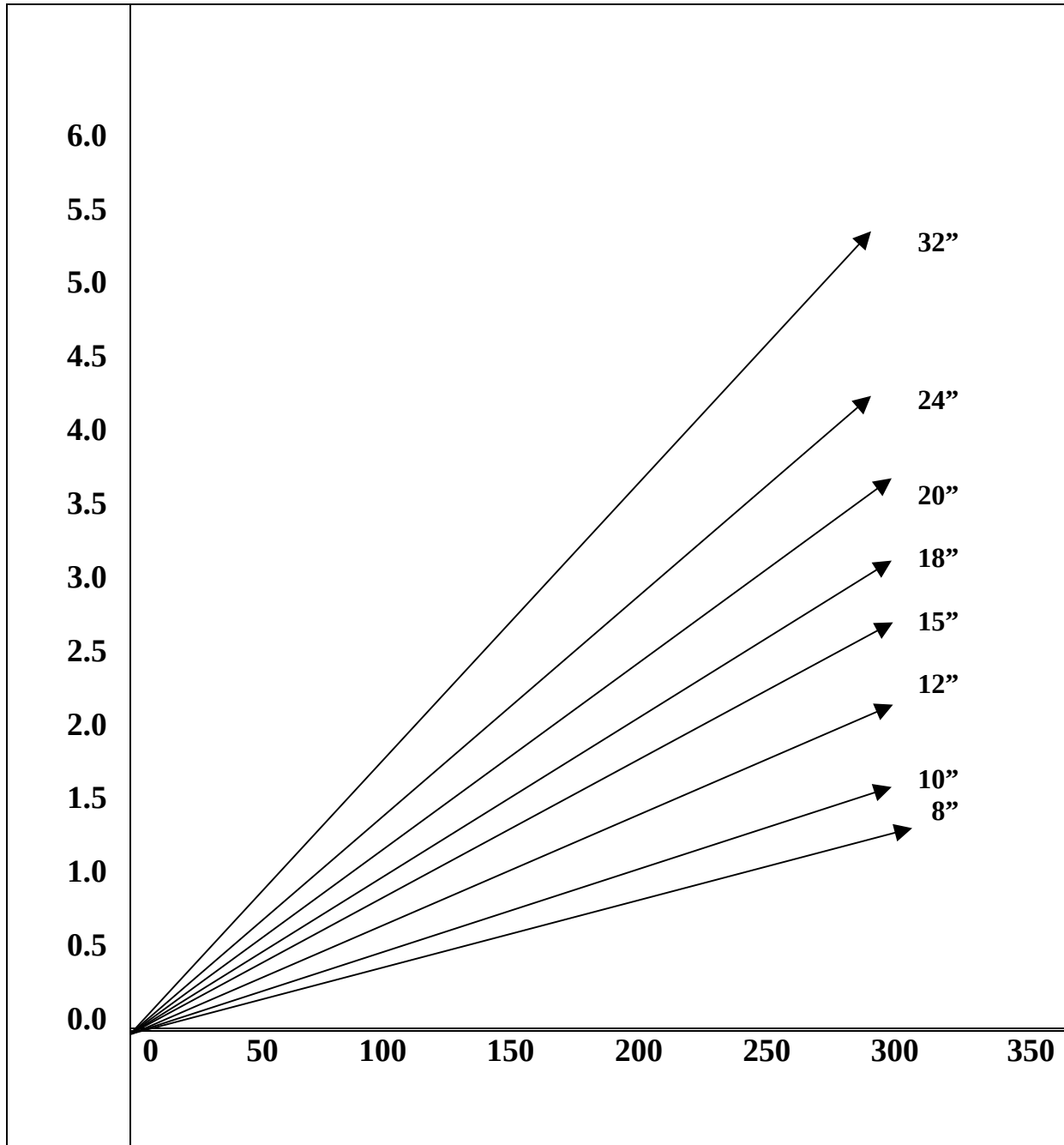
LENGTH OF REACH L.F.

FIGURE 7

TV ANALYSIS  
ELIGIBILITY DETERMINATION

4,000 GPD/IN MILE

GPD



LENGTH OF REACH L.F.

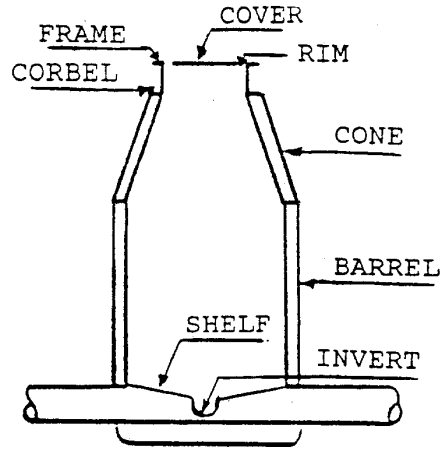
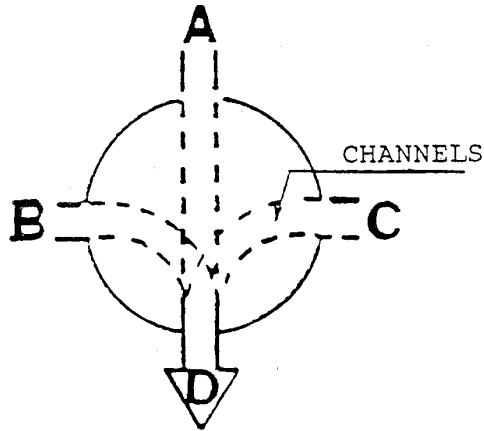
FIGURE 8

# **SAMPLE OF MANHOLE INSPECTION REPORT**

MH NO. \_\_\_\_\_ DATE: \_\_\_\_\_ TIME \_\_\_\_\_ INSPECTOR \_\_\_\_\_

ELEVATION \_\_\_\_\_ DEPTH TO INVERT \_\_\_\_\_ CLEANLINESS \_\_\_\_\_

TYPE CONSTRUCTION \_\_\_\_\_ STREET REFERENCE \_\_\_\_\_



DEFECTS: (Cover, frame, grout, steps, shelf, pipes, or channels)

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_

(USE REVERSE SIDE FOR ADDITIONAL DEFECTS TO BE NOTED.)

| <u>PIPE SIZE</u> | <u>LENGTH</u> | <u>FROM MH#<br/>TO MH#</u> | <u>EST.<br/>FLOW</u> | <u>TYPE OF<br/>FLOW</u> | <u>DEPTH OF<br/>FLOW</u> | <u>VEL. OF<br/>FLOW</u> |
|------------------|---------------|----------------------------|----------------------|-------------------------|--------------------------|-------------------------|
| A. _____         | _____         | _____                      | _____                | _____                   | _____                    | _____                   |
| B. _____         | _____         | _____                      | _____                | _____                   | _____                    | _____                   |
| C. _____         | _____         | _____                      | _____                | _____                   | _____                    | _____                   |
| D. _____         | _____         | _____                      | _____                | _____                   | _____                    | _____                   |

REMARKS:

(Include need for repairs) \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

# SAMPLE OF MANHOLE INSPECTION FORM

1/4 Section Map No. \_\_\_\_\_ Manhole No. \_\_\_\_\_ Inspection Date \_\_\_\_\_

Pipe Size \_\_\_\_\_ Pipe Material \_\_\_\_\_ Manhole Depth \_\_\_\_\_ Crew Leader \_\_\_\_\_

| I. MANHOLE INITIAL INSPECTION                                                                                                      |                                                                         | II. STRUCTURAL INSPECTION                                                                                                 |                                                                         | III. HYDRAULIC INSPECTION                                                                      |                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>A-Location</b><br>1. Roadway<br>2. Gutter<br>3. Pave Alley<br>4. Unpaved Alley<br>5. Easement<br>6. Other _____                 | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>A-Rungs</b><br>1. Serviceable<br>2. Unsafe<br>3. Missing (No.)<br>4. Corroded                                          | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>A-Inflow Indications</b><br>1. Debris on Sides/Rungs<br>2. Debris on Sides/Shelf            | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> |
| <b>B-Manhole Cover</b><br>1. Serviceable<br>2. Damaged<br>3. Displaced<br>4. Missing<br>5. Loose<br>6. Sealed                      | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>B-Cone</b><br>1. Serviceable<br>2. Broken<br>3. Sulfided<br>4. Misaligned<br>5. Leaking/Bad Joints                     | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>B-Surcharge Indications</b><br>1. Grease/Debris on Shelf<br>2. Grease/Debris on Sides/Rungs | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> |
| <b>C-Ring and Frame</b><br>1. Serviceable<br>2. Loose<br>3. Displaced<br>4. Missing Grout<br>5. Needs Raising<br>6. Needs Lowering | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>C-Riser</b><br>1. Serviceable<br>2. Broken<br>3. Sulfided<br>4. Misaligned<br>5. Leaking/Bad Joints                    | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>C-Clarity of Flow</b><br>1. Turbid Sewage Appearance<br>2. Clear Water Appearance           | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> |
| <b>D-Manhole Material</b><br>1. Brick<br>2. Concrete                                                                               | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>D-Shelf</b><br>1. Serviceable<br>2. Broken<br>3. Dirty<br>4. Sulfided<br>5. Bad Base Joint                             | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>D-Flow</b><br>1. Steady<br>2. Pulsing<br>3. Turbulent<br>4. Surcharging<br>5. Sluggish      | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> |
| <b>E-Size MH Cover</b><br>1. 24-inch<br>2. 30-inch                                                                                 | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>E-Channel</b><br>1. Serviceable<br>2. Obstructed<br>3. Sulfided<br>4. Bad Pipe Joint<br>5. Silt<br>6. Poor Struc Cond. | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>E-Flow Depth Compared</b><br>to adjacent manholes<br>1. Same<br>2. Lower<br>3. Higher       | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> |
| <b>F-Manhole Size</b><br>1. 4-foot<br>2. 5-foot                                                                                    | <div style="border: 1px solid black; height: 40px; width: 100%;"></div> | <b>F-Flow Depth</b> _____ inches<br><b>Time</b> _____ AM/PM                                                               |                                                                         |                                                                                                |                                                                         |
| <b>Observation Summary</b> _____                                                                                                   |                                                                         | <b>Foreman II Recommendation &amp; Approval</b> _____                                                                     |                                                                         |                                                                                                |                                                                         |
| <b>Remarks</b> _____                                                                                                               |                                                                         | <b>IV. A-Vermine</b><br>1. Roaches<br>2. Rats<br>3. Other                                                                 |                                                                         |                                                                                                |                                                                         |
| <b>Recommendations</b> _____                                                                                                       |                                                                         | <b>Superior I Approval</b> _____                                                                                          |                                                                         |                                                                                                |                                                                         |

PRIVATE SOURCE INFLOW – HOUSE-TO-HOUSE INSPECTION SURVEY

SUBAREA\_\_\_\_\_ ENTRY PERMITTED\_\_\_\_\_ ENTRY DEFERRED\_\_\_\_\_

NOT HOME ----- ENTRY REFUSED-----

2<sup>ND</sup> ATTEMPT AT ENTRY ALLOWED YES\_\_\_\_\_ NO\_\_\_\_\_

PERSON ALLOWING ENTRY WAS OLDER THAN 18 YES\_\_\_\_\_ NO\_\_\_\_\_

NAME OF PERSON ALLOWING ENTRY\_\_\_\_\_

A. GENERAL PROPERTY INFORMATION

OWNER:\_\_\_\_\_ ADDRESS:\_\_\_\_\_

PHONE:\_\_\_\_\_

B. GENERAL INFORMATION

INSPECTORS:\_\_\_\_\_ DATE/TIME:\_\_\_/\_\_\_/\_\_\_:

C. INTERNAL HOUSE INSPECTION

DOES HOUSE HAVE BASEMENT?\_\_\_\_\_ DOES WATER ENTER BASEMENT\_\_\_\_\_

TYPE OF BASEMENT FLOOR:\_\_\_\_\_

C1. SUMP PUMP INFORMATION

DOES BASEMENT HAVE SUMP PUMP?\_\_\_\_\_ DISCHARGE LOCATION\_\_\_\_\_

HORSEPOWER OF PUMP\_\_\_\_\_ PUMP CAPACITY (gpm)\_\_\_\_\_

FREQUENCY OF PUMP CYCLING:\_\_\_\_\_

IS PUMP ALWAYS ADEQUATE?\_\_\_\_\_

IS SUMP PIPE HARD PIPED? YES\_\_\_\_\_ NO\_\_\_\_\_

C2. FLOW DRAIN INFORMATION

DOES HOUSE HAVE FLOOR DRAINS? YES\_\_\_\_\_ NO\_\_\_\_\_ NUMBER\_\_\_\_\_

FREQUENCY OF USE:\_\_\_\_\_ DISCHARGE LOCATION\_\_\_\_\_

C3. FOUNDATION DRAIN INFORMATION

DOES HOUSE HAVE INTERNAL FOUNDATION DRAIN CONNECTION:

YES \_\_\_\_\_ NO \_\_\_\_\_

FREQUENCY OF USE: \_\_\_\_\_ DISCHARGE LOCATION \_\_\_\_\_

C4. SEWER CONNECTION CLEANOUT

IS THERE A SEWER CONNECTION CLEANOUT? YES \_\_\_\_\_ NO \_\_\_\_\_

ELEVATION OF SEWER CONNECTION CLEANOUT:

ABOVE BASEMENT FLOOR \_\_\_\_\_

BELOW BASEMENT FLOOR \_\_\_\_\_

IS CLEANOUT SEALED? YES \_\_\_\_\_ NO \_\_\_\_\_

C5. LIST OF OTHER INFLOW SOURCES \_\_\_\_\_

D. EXTERNAL HOUSE INSPECTION

D1. DOES HOUSE HAVE ROOF DOWNSPOUTS THAT ENTER THE GROUND?

YES \_\_\_\_\_ NO \_\_\_\_\_

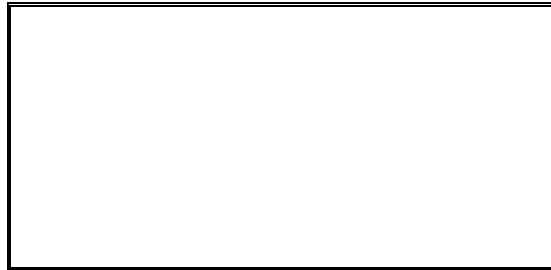
D2. DOES PROPERTY HAVE A DRIVEWAY DRAIN? YES \_\_\_\_\_ NO \_\_\_\_\_

D3. DOES PROPERTY HAVE A YARD DRAIN? YES \_\_\_\_\_ NO \_\_\_\_\_

D4. DOES PROPERTY HAVE A WINDOW WELL DRAIN? YES \_\_\_\_\_ NO \_\_\_\_\_

D5. DOES PROPERTY HAVE OTHERS? YES \_\_\_\_\_ TYPE \_\_\_\_\_ NO \_\_\_\_\_

INDICATE APPROXIMATE LOCATION OF ALL INFLOW SOURCES



FRONT OF HOUSE



## APPENDIX A

### FIELD DETERMINATION OF AVERAGE (MEAN)

#### VELOCITY OF FLOW CROSS-SECTION

When using a flow monitoring method not using a primary device such as a weir or flume, the need for accurate determination of the average (mean) velocity of the cross-sectional area of flow being measured cannot be overstated. The recommended method of determining the average (mean) velocity will vary depending on the pipe size and depth of flow.

In case of flow depths from 2 to 6 inches, the maximum velocity of the flow cross-section should be noted using a portable hand-held velocity probe. The maximum velocity should be multiplied by a factor of 0.9 and the resulting answer should be interpreted as the mean velocity. It should be noted that the use of direct reading velocity probes is not recommended in situations where flow depths are less than 2 inches because of the likelihood of inconsistent data. In those cases, dyed timing procedures or direct weir readings should be attempted. In the case of flow depths above 6 inches, several techniques should be considered on a case-by-case basis. In the case where the velocities appear to be uniform from side-to-side and flow depths are less than 12 inches, a series of velocity measurements along the centerline at 20%, 40% and 80% of the flow depth averaged together, or a single velocity measurement at 40% flow depth may be an acceptable method of determining the average velocity of the flow cross-section.

In the case where velocities appear to be uniform from side-to-side and flow depths are greater than 12 inches, a series of measurements along the centerline of the flow from top to bottom should be taken.

If the velocities are not uniform from side-to-side, and additional series of velocities should be taken on each side of the centerline, the number of additional series being dependent on the width of the flow cross-section. The average velocity is then determined by taking a weighted average of each measured velocity point cross-section in relation to the total flow cross-section.

When using Method #3 where continuous velocity sensors are in use in conjunction with continuous depth sensors, the importance of accurately determining the relationship between the sensed velocity and the average velocity of the flow cross-section cannot be overstated. Average flow cross-section velocities should be collected for the full range of recorded flow depths and compared to the sensed velocities recorded at the time of velocity data collection. The average velocities and corresponding sensed velocities should be plotted versus flow depth to determine the correlation between them.

The sensed (continuously recorded) velocities should then be adjusted during flow computation based on the observed correlation. If poor or inconsistent correlation is found, a stage/velocity calibration curve should be developed and incorporated into the appropriated flow calculation program, using the sensed velocities only to determine when surcharge conditions or backwater conditions exist.

Care must be taken to assure that instances of velocity probe fouling are not misinterpreted as backwater or standing flow conditions.

## APPENDIX B

### FIELD MEASUREMENT OF CROSS-SECTIONAL AREA

#### OF A SEWER LINE USED FOR FLOW MONITORING

When using a flow monitoring method not using a primary device such as a weir or flume, accurate determination of the cross-sectional area of the flow being measured is mandatory. The dimensions of circular pipe should be measured to verify diameter and determine if a true circular cross-section exists. If it is determined that a circular cross-section does not exist, or if the meter site is placed in known non-circular cross-section pipe, it is recommended that field measurements be taken from a centerline reference point to the sides of the pipe at one to two inch intervals from top to bottom. Figure 9 illustrates this procedure. While it is acknowledged that it can be difficult, accurate measurements must be taken from the centerline to the sides of the pipe under the flow line. This difficulty may be alleviated somewhat by performing this work during nighttime minimum flow conditions.

Field notes of the centerline to pipe side measurements should be reduced onto accurate scale drawings. From the drawings, the cross-sectional area for each one inch increment of depth should be determined by a grid system or by a polar planimeter. Incremental cross-sections should then be interpolated between each whole inch measurement to one-tenth of one inch increments. A table of cumulative cross-sectional areas for each one-tenth of one inch increment of depth should then be compiled and the information entered into the appropriate flow calculation computer program in order to evaluate flows at 0.1 inch increments of sensed depths.

Care must be taken to accurately measure the configuration of any debris and include the information into cross-sectional area derivation.

DETERMINING CROSS SECTIONAL  
AREA OF ODD SHAPED PIPE

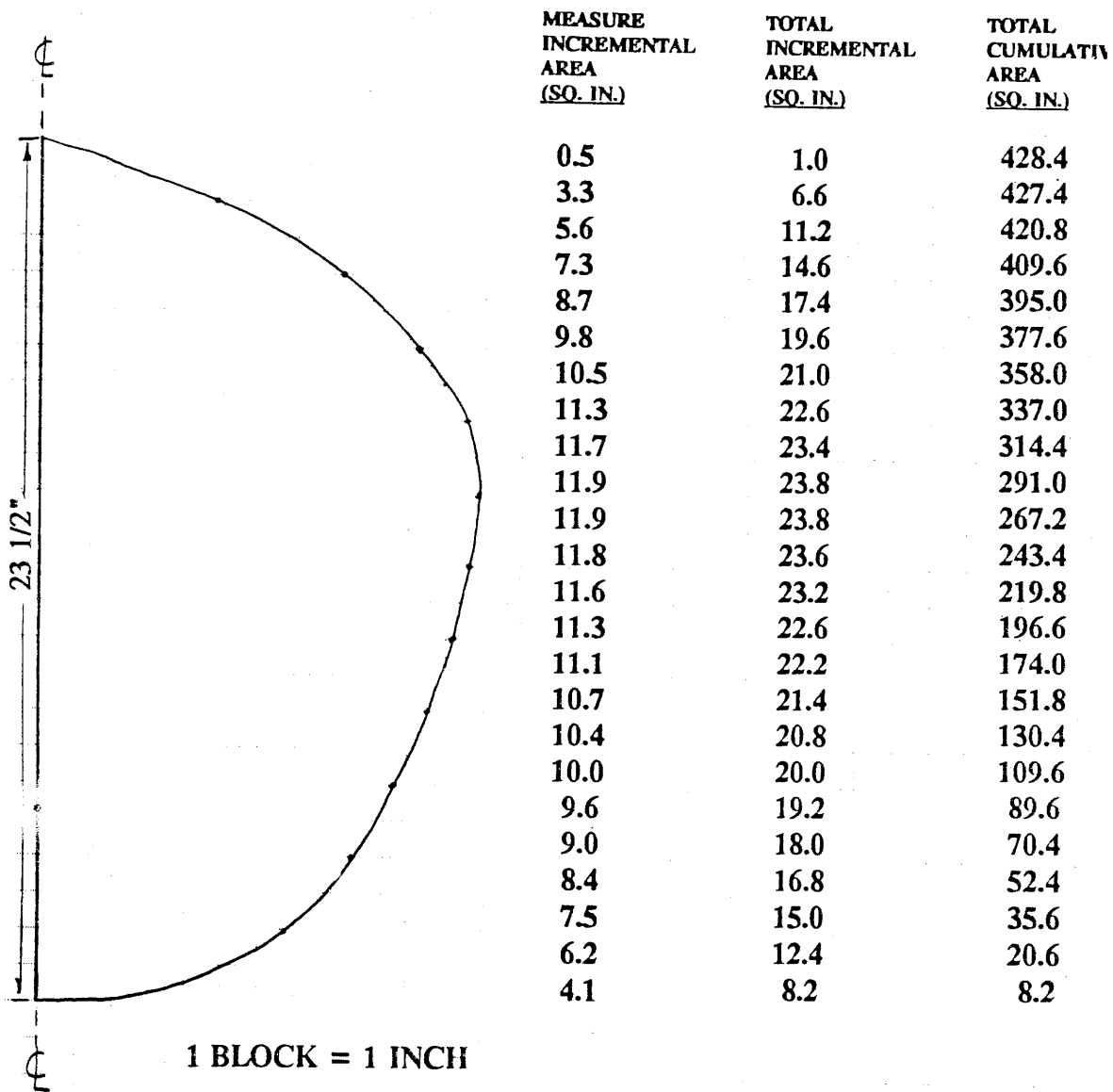


FIGURE 9

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