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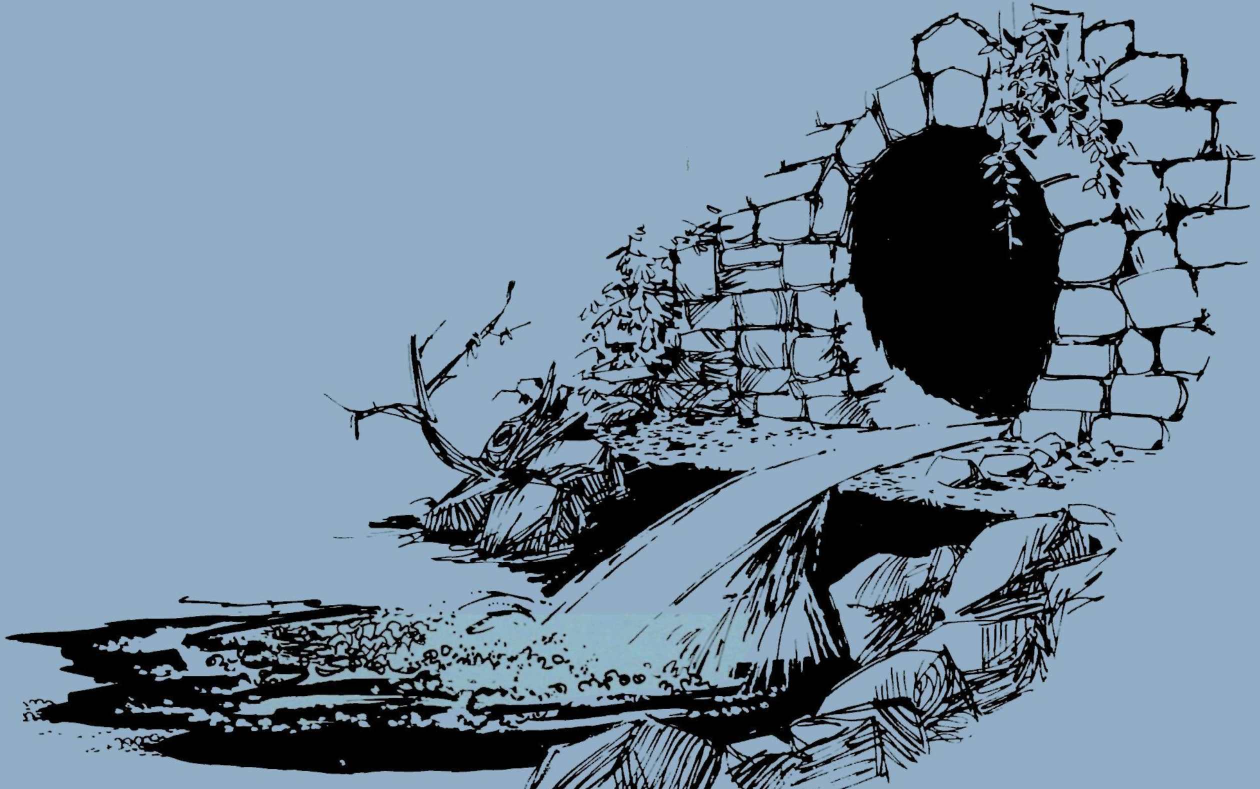
Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems

A Manual of Practice



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PREVENTION AND CORRECTION OF EXCESSIVE INFILTRATION AND INFLOW INTO SEWER SYSTEMS

Manual of Practice

by the

AMERICAN PUBLIC WORKS ASSOCIATION

For the

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE
&

THIRTY-NINE LOCAL GOVERNMENTAL JURISDICTIONS

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ABSTRACT

As a result of a national study of the sources and prevention of infiltration and inflow, a Manual of Practice was proposed. The Manual is intended to serve as a guide to local officials in evaluating their construction practices, conducting surveys to determine the extent and location of infiltration and inflow, the making of economic analyses of the cost of excessive infiltration/inflow waters; and instituting corrective action.

Excerpts from sewer control legislation are given as well as information on air and exfiltration testing.

This Manual of Practice was prepared for the Environmental Protection Agency in partial fulfillment of Contract 14-12-550. The study was also supported by thirty-nine public agencies. A companion document, "Control of Infiltration and Inflow Into Sewer Systems", was also prepared.

Key Words: INFILTRATION, INFLOW, INVESTIGATION, CONSTRUCTION, LEGISLATION, TESTING, ECONOMICS.

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INTRODUCTORY STATEMENT: THE INFILTRATION AND INFLOW PROBLEM AND ITS PREVENTION AND CONTROL

THE PROBLEM

A serious problem results from excessive infiltration into sewers from ground water sources, and high inflow rates into sewer systems through direct connections from sources other than those which sewer conduits are intended to serve. The hydraulic and sanitary effects of these extraneous flows are of particular importance now because urban growth generally requires all available sewer capacities to handle present flows and serve future expansion. The pollutional effects of by-passed and spilled and under-treated waste water flows caused by infiltration and inflow are paradoxical at a time when higher degrees of treatment are being demanded to protect the nation's water resources.

The effects of these extraneous waters are of primary importance in separate sanitary sewers. These intrusion waters pirate greater proportions of the relatively smaller sanitary lines than of combined sewers and storm sewers. When sanitary sewers become surcharged and produce flooding of street and road areas and back-flooding into properties, the spilled flows are a serious sanitary hazard. Similarly, when by-passing of pumping stations, sanitary relief and interceptor lines, and sewage treatment processes occur because of excessive infiltration-inflow volumes, the waste waters discharged to receiving waters have great pollutional potential.

In combined sewers, such intruded waters offer less threat of surcharging and back-flooding during dry weather flows, but the hazard of local overloading during storm periods should not be discounted. Unnecessary and over-long overflows at combined sewer regulator stations introduce pollutional waste waters into receiving waters. (The effects of overflows were investigated and reported upon by the American Public Works Association for the then Federal Water Pollution Control Administration, Department of the Interior, and participating local jurisdictions in a project covering "Problems of Combined Sewer Facilities and Overflows – 1967").

The effects of infiltration, and inflow are alike, except for two specific conditions. Infiltration, and its counterpart – exfiltration – often produce local washout of soil bedding around defective pipe or joints, followed by actual failure of the sewer barrel or cave-in of roadways and pavements and loss of nearby utilities and utility vaults. No such effects are attributable to inflow connections. In infiltration, a direct relationship exists between the entry of sewer flows through defective pipe and joints and the intrusion of water seeking tree roots through the same cracks or openings. No such relationship exists in the case of points of inflow into sewer systems. The clogging of sewers with intruded sand, clay, or gravel at points of infiltration is a specific infiltration effect not duplicated in the phenomenon of inflow.

When infiltration waters and inflow waters become commingled within sewer systems they are not readily distinguishable from each other. The net effect of their presence is the same: robbed sewer system capacities and usurped capabilities of system facilities such as pumping, treatment, and regulator-overflow structures. What is different about these two types of extraneous waste waters is their source.

This difference is borne out by the definitions of "infiltration" and "inflow" chosen as guidelines for the study of this problem in 1969-70 by the American Public Works Association Research Foundation for the Federal Water Quality Administration and 39 participating local jurisdictions in the United States and Canada. For a clear understanding of the purposes of this Manual of Practice (which is the end-product of the national investigation of the infiltration and inflow problem), it is essential to restate these basic definitions:

> **"INFILTRATION"** covers the volume of ground water entering sewers and building sewer connection from the soil, through defective joints, broken or cracked pipe, improper connections, manhole walls, etc.
>
> **"INFLOW"** covers the volume of any kinds of water discharged into sewer lines from such sources as roof leaders; cellar and yard area drains; foundation drains; commercial and industrial so-called "clean water" discharges; drains from springs and swampy areas; etc. It does not include, and is distinguished from, "infiltration."
>
> **"INFILTRATION/INFLOW"** is the volume of both infiltration water and inflow water found in existing sewer systems, where the indistinguishability of the two components of extraneous waters makes it impossible to

ascertain the amounts of both or either.

These basic definitions serve two purposes – to define the difference between the two extraneous water flows, and to show that the difference relates to sources, rather than characteristics, of such flows. Definitions of other words and phrases used in this Manual of Practice are contained in the Glossary of Pertinent Terms, Section 8.

Infiltration results from soil conditions in which sewer lines are laid; the quality of materials and construction workmanship; ground water levels; precipitation and percolation of surface waters; waters retained in the interstices of surrounding soils, and the stability of pipe and joints and appurtenant sewer structures after periods of service.

Inflow is the result of deliberately planned or expediently devised connections of sources of extraneous waste water into sewer systems. These connections serve to dispose of unwanted storm water or other drainage water and wastes into a convenient drain conduit. They are interpreted, in terms of this Manual, to include the deliberate or accidental draining of low-lying or flooded areas into sewer systems through manhole covers.

Infiltration and inflow conditions have two characteristics in common, in that each problem is divided into two parts: prevention of excessive extraneous flows, and correction of conditions already imposed on existing sewer systems.

In the case of infiltration, prevention of excessive entries into new sewer systems depends on effective design; choice of effective materials of sewer construction; imposition of rigid specifications limiting infiltration allowances; and alert and unremitting inspection and testing of construction projects to assure tightness of sewers and minimization of infiltration waters.

Correction of infiltration conditions in existing sewer systems involves evaluation and interpretation of sewage flow conditions to determine the presence and extent of excessive extraneous water flows from sewer system sources, the location and gauging of such infiltration flows, and the elimination of these flows by various corrective, repair and replacement methods.

In the case of inflow onditions, the problem is similarly two-faceted: prevention and cure. Prevention of excessive inflow volumes is a matter of regulating sewer uses and enforcement of such precepts and codes by means of vigilant surveys and surveillance methods. Correction of existing inflow conditions involves location of points of inflow connections; determination of their legitimacy or illicit nature; evaluation of the responsibility for correction of such conditions; establishment of inflow control policies where none have been in effect; institution of corrective policies and measures, backed up by investigative and enforcement procedures to make such policies potent.

THE NEED FOR GUIDELINES: THE MANUAL OF PRACTICE

Control of infiltration and inflow in all future sewer construction work, and the search for and correction of excessive intrusion of excessive flows of extraneous waters into existing sewer systems, is an essential part of sewer system management.

Past practices often have been based on inadequate technical policies, usually devoid of substantiating data on causes and effects of infiltration and inflow conditions. There has been a dearth of standardization of such practices; the policy of "standardization" has been limited to a follow-the-leader attitude of accepting and using the criteria of others without consideration of their applicability to present-day materials and methodologies.

In fairness to the great advances made in the manufacture of pipe and joint materials, a review of practices is long overdue. This Manual has been prepared to provide a stimulus to improve practices in the design, construction and operation-maintenance of sewer systems.

One word of clarification and caution is necessary. This Manual is designed as a compilation of practices in the subjects outlined, in terms of their applicability to the actual conditions under which specific new sewer system projects are to be constructed or existing systems are to be operated and maintained. In short, what is offered here are *general guidelines* for better practices – pointing the way to improvements in control of infiltration and inflow, sewer service, and water quality control. It is hoped that the guidelines contained in this Manual will result in the eventual development of so-called "standards of practice," with the understanding that each project, each sewer system, must be designed, equipped, constructed, and operated to meet specific local conditions.

SECTION 2

DESIGN STANDARDS AND NEW CONSTRUCTION METHODS FOR THE CONTROL OF INFILTRATION IN SEWER SYSTEMS

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DESIGN STANDARDS AND NEW CONSTRUCTION METHODS FOR THE CONTROL OF INFILTRATION IN SEWER SYSTEMS

2.1 BASIC FACTORS

The initial area of concern in reducing or eliminating infiltration involves the production of a pipe system and appurtenances which are water-tight and do not permit ground water leakage. The realization of this objective begins during design; but, in truth, a number of preliminary activities are necessary to provide vital background information before any design decisions are made.

This section proposes a logical, orderly approach to the entire problem of producing an infiltration-free sewer in the first instance, and one that will resist deterioration in service due to improper design, workmanship, or maintenance practices. Not every detailed step which would be used in good sewer design practice will be delineated. The emphasis is on those factors in design and construction that are particularly involved with infiltration control. Any criteria which affect the installation of a sound and well-built system will aid in reducing infiltration, but there are many considerations of hydraulic and structural significance that may have little bearing on infiltration control.

References will be made to appropriate published manuals on general sewer design and construction techniques in lieu of any attempt to assemble repetitive material that could be voluminous and not totally applicable to infiltration control.

It is appropriate to point out at the outset that the first step in producing infiltration-free sewers may be the selection of a qualified and experienced civil engineer. Even the larger communities or agencies may not have sufficient personnel to execute the field survey and design activities required to produce plans and specifications for extensive sewer system construction. Small subdivision systems often are engineered by a consultant for the private owner, subject to agency approvals. The choice of a consultant may involve the most important decision of the project.

A number of professional societies and groups have published manuals and guides on how to select consultants and set appropriate fees. They include:

- American Society of Civil Engineers
- National Society of Professional Engineers – Salary and Fee Guide
- Consulting Engineers Council – Selecting a Consultant

2.2 PREDESIGN INVESTIGATIONS

2.2.1 Soil and Ground Water Investigations:

Soil and ground water conditions must be considered if the design for a proposed sewer system is to avoid infiltration. Section 3.7.1 describes in detail effects of poor soil conditions.

The types of surveys and tests needed to obtain the necessary information include:

a. Reconnaissance

Reconnaissance is the gathering of available information on soils and groundwater conditions. For small projects, it may supply all the necessary information for proper design. For major projects, it will serve as a basis for a more thorough subsurface investigation, and may provide information on the feasibility of alternate locations for a proposed sewer system.

Geological maps, aerial photographs, flood records, and the results of previous subsurface investigations performed in the general vicinity of proposed construction might be available in the municipal engineer's office, libraries, universities and utility companies.

Telephone calls or visits to builders familiar with the area, municipal personnel, and local residents often yield useful information or will point out potential trouble areas.

The above information will give direction and add to the effectiveness of a personal site review. Investigation of construction excavations, watercourses, high-water marks, lowland wet areas, types of vegetation, and rock outcrops furnish additional important information regarding soil and ground water conditions.

b. Types of Subsurface Investigations

Subsurface investigations are performed to obtain information more directly related to the proper design of the proposed sewer.

Test pits of 10 to 15 feet in depth, depending on the type of backhoe used, will economically provide information on rock and soil types, layering and compactness, safe soil slopes, and ground water level, and they will permit soil and ground water sampling.

Probing consists of driving a rod through the depth of soft or loose soils, with or without provision for obtaining soil samples. Probes are usually used as a supplement to more reliable methods of investigation.

Auger borings may be advanced either by hand or by power equipment. Hand auger borings are limited in depth. Auger borings produce information on soil type and (under certain conditions), on ground water. The "hollowstem auger," however, can supply information similar to that outlined under machine borings.

Machine borings produce the same information as the machine augers. In addition, they are a means to obtain undisturbed samples and rock core samples, and can be used as ground water observation wells.

Geophysical exploration methods are used for very large projects to supplement the more direct methods listed above. They include seismic and electrical refraction surveys and require highly specialized personnel. The same applies to aerial photographic interpretations.

Ground water readings can be obtained in conjunction with the above methods of exploration, but generally are limited to the time of investigation. To observe ground water fluctuations over periods of time, cased machine borings can be used for observation wells. A perforated tubing is placed in the cased hole and sealed to eliminate surface water entrance. Ground water readings can then be made periodically to monitor ground water level variations. Existing manholes also can be used as ground water observation wells by drilling through the bottom of the manhole and installing a pipe perforated below the manhole base and extended above maximum anticipated height of water level. The system must be sealed at the manhole bottom to avoid infiltration if the ground water level rises above the manhole base.

Advice and assistance from qualified soil engineers and ground water experts should be sought in connection wtih sizeable jobs or where anticipated exploration methods warrant such expertise.

c. Types of Laboratory Tests

Three general types of laboratory tests can be performed: soil classification tests, soil performance tests, and ground water analysis.

Classification tests, such as sieve and hydrometer analysis, provide information on the physical characteristics of the soils. Results of the tests are useful in distinguishing (1) if a material is suitable as backfill or bedding; (2) if it will produce problems associated with dewatering as they pertain to pumping of the fines, subsequent settlements, and evaluation of ground water flow. Also the tests serve as a basis for determining which performance tests are needed to aid the design.

Performance tests provide information for predicting the behavior of the soil under additional loads, such as embankments to be constructed next to or over a sewer installation. Such loads could cause differential settlements of the sewer, with subsequent cracking and infiltration. Permeability tests results are used to assess the rate of ground water flow in connection with infiltration problems.

Chemical ground water analysis, particularly tests for the acidity of the water, is important in pipe material selection.

d. Types of In-Situ Tests Available

Simple field classification tests are available to determine if soils encountered are similar to those anticipated. Also, in-situ field density tests are used to monitor compaction. The most common methods are the Sand Cone Method and the Rubber Balloon Method.

2.2.2 Soil Clasification

In order to identify a specific soil and relate its properties to the aspects of infiltration, it is necessary to have some knowledge of soil classification. For instance, a "Brown coarse SAND, little medium Gravel" will indicate high permeability and, therefore, excellent ground water flow characteristics, while a "Silty CLAY" with its low permeability will impede ground water flow for all practical purposes.

The suitability of soil for bedding or backfill purposes and the need for specific types of trench sheeting and dewatering methods become apparent with the proper classification of a soil type.

Numerous soil classification systems are in use throughout the United States. Soils are generally classified as cohesionless or cohesive. Cohesionless soils refer to boulders, gravels, sands, and silts or any combination thereof. Cohesive soils are those containing clay and exhibiting plasticity.

A soil description should contain the color of the material and the relative proportions of the particle sizes present in the soil. Standard proportion terms are used in conjunction with classification descriptions.

Soil identification and classification thus entail an evaluation of the relative percentages of various soil particles. Cohesionless soils classification involves determining the predominate particle sizes, that is, the major component representing more than half the soil. Mentions of the remainder, the minor components, then forms the soil classification.

2.2.3 Analysis of Existing System

Except in the case of a totally new sewer system, designers of new sewers plan at some point to connect to an existing system, trunk line, or treatment plant. Too often, a careful analysis of the older sections is neglected. This may be because of time limitations or fee limitations, or because the importance of preplanning inspection and evaluation was overlooked or no funds were made available for such preliminary studies. This should be corrected in the interest of improved sewer practices. Preplanning investigations should be separately funded and completed prior to design. At this time preplaning inspection cannot be funded from Federal or state construction grants. Local funds expended for this purpose may result in lower construction costs and better utilization of existing facilities.

The haphazard juncture of different parts of the system over the years can result in poor hydraulic characteristics which are not discovered until an overall systems analysis is made to correct infiltration and flooding problems. Most of these bottlenecks never would have occurred if proper preliminary investigations had been made before new sewer extensions were connected. Although they are not a cause of infiltration, they magnify the effects and multiply the damage and destruction. Too often, land subdivision sewer extensions are approved with only a cursory examination of the adjacent trunk capacity and the treatment plant at the end of the sewer system. The condition and capacity of the intervening system frequently are overlooked.

The connections of additional contributions to an already overloaded system may be against the public interest and welfare. The adoption of a program of infiltration and inflow detection and correction, as outlined in Sections 3 and 4 of this Manual, may be necessary before acceptance of sewer extensions. In some areas the state water pollution control agencies have forced a halt to new home and building construction until existing systems are corrected.

The following items should be covered in the analysis of the existing system when performed by the municipal engineer or consultant or required from the developer's consultant on new subdivisions:

1. Identification of the route of flow for the added contribution from point of connection to existing sewer system to the point of ultimate treatment and disposal.
2. Selection of key manholes along the route where major junctions or merging of flows occur.
3. Opening of key manholes, observing flow and general condition and taking invert and pavement elevations.
4. Performing hydraulic analysis of route of flow to determine present capacity and the effect of new contributions from a sewer extension.

Upon receipt and review of the preceding information, the engineer in charge of the sewer system should make a determination of acceptance or rejection of the sewer extensions. Such decisions should be made before extensive design is performed. In decisions on boosting capacity, the officials also should be involved – studies on the existing system, making corrections, and removing bottlenecks. These efforts are described more completely in Section 3. Consideration of any existing system is mentioned at this juncture mainly because it is so often overlooked and the effects of existing infiltration and inflow may well influence new design and construction.

2.3 PIPE AND JOINTING MATERIALS AND PRACTICES

2.3.1 Types of Sewer Pipe to Control Infiltration

Improvements in pipe material ensure that the designer can provide proper materials to meet rigid infiltration allowances. The basic question of water tightness of pipe material may not be a matter of concern as much as problems of structural integrity and strength of waste water character, or of local soil or gradient conditions which would make one material better suited than another, or preferable under certain special installation conditions.

There are several common pipe characteristics which affect a pipe's performance. These are ability to:

1. Withstand handling during transport to the job site, unloading, and laying;
2. Withstand the effects of corrosion from hydrogen sulfide and resultant acid formation as well as industrial chemicals; and
3. Withstand physical action of cleaning equipment, such as saws, jets, and abrasion from cables where circumlinear lines are used.

In such cases or situations, pipe materials are chosen for reasons other than their relative resistance to infiltration.

The design of sewer lines which will be operated

TABLE 2.3.1

STANDARD SPECIFICATIONS FOR SELECTED SEWER PIPES

NAME	STANDARD
Asbestos-Cement Non Pressure Sewer Pipe	ASTM C 428-70
Asbestos-Cement Non Pressure Small Diameter Pipe	ASTM C 644-69
Asbestos-Cement Pipe, Standard Methods of Testing	ASTM C 500-70
Concrete Sewer, Storm Drain & Culvert Pipe	ASTM C 14
Concrete Culvert, Storm Drain & Sewer Pipe, Reinforced	ASTM C 76
Concrete Sewer & Culvert Pipe, Joints for Concrete Pipe using flexible, watertight Rubber Gaskets	ASTM C 443
Corrugated Metal Pipe	AASHO M-36 & Federal Specification WWP-4059
Rubber Rings for Asbestos-Cement Pipe	ASTM D-1869-66
Solid Wall Plastic Pipe	ASTM D-2751, & D-2729
Truss Pipe	ASTM D-2686
Vitrified Clay Pipe	ASTM C-425

under pressure also must be evaluated. The pressures to be used may effectively determine the type of pipe which must be used.

The types of sewer pipe now in use are listed alphabetically and briefly described below:

Asbestos-Cement sewer pipe is manufactured from asbestos fiber, portland cement and silica, and is divided into seven strength classes which are designated for pipe sizes ranging from 6-inch diameter up to 42-inch diameter. Types of pipe specified depend on the usage intended.

Type I – for use where moderately aggressive waste water and soil of moderate sulfate content are expected to come in contact with the pipe.

Type II – for use where highly aggressive water or water and soil of high sulfate content, or both, is expected to come in contact with the pipe.

Type III – for use where contact with aggressive water and sulfate is not expected.

Asbestos-cement pipe is in common usage in many cities. Its particular advantages include reduced number of joints due to longer laying lengths and its relatively light weight. It is often used for pressure sewers.

Cast Iron or Ductile Iron is utilized primarily in building drain lines or laterals. However, it's also specified where poor sewer foundation conditions exist, such as in stream crossings; where a high water table may require a very tight joint, or when the sewage will be under pressure, as in a force main.

Concrete sewer pipe presently is in common usage for new construction of sewers, storm drains, and culverts. Non-reinforced concrete pipe is available in sizes ranging from 4 to 24 inches in diameter; reinforced concrete pipe is used for sewers 12 to 156 or more inches in diameter. One of the advantages of concrete pipe is the relative ease of providing the required strength in a wide range of lengths. A variety of jointing methods are available, depending on the tightness required and the operating pressures involved.

Fiber Glass pipe has not been used extensively for sewer service in the United States and Canada. It has been limited to special application such as industrial waste drain lines. It reportedly is used more widely in European practice. However, if recent technical developments can be coupled with production efficiencies and lower cost, this material may find wider application. Fiber glass pipe is made with polyester or epoxy resin and fiber glass material for reinforcemnt. Other types of pipe are made with a sand filler; these are available with bell and spigot joints and "O" ring gaskets. Types of fiber glass pipe joints include mechanical and chemical welded joints.

Plastic Sewer pipe use in sewer construction has been limited to date, but plastic pipe can provide essentially water-tight construction. Types of pipe presently in use in sanitary sewer lines include PVC (polyvinylchloride) and ABS (acrylonitrile-butadiene-styrene). One type of plastic pipe that has received recent attention is the so-called composite "truss" type. Joints are obtained by use of a sleeve-type coupling and chemical solvent welds consisting of ABS in methyl-ethyl-ketone. Recent

European practice has been to use plastic pipe of exrremely long lengths without joints, in some cases extruding the pipe on the jobe site to avoid shipping problems.

Steel pipe is used for both gravity and force main construction. Two types exist. Smooth wall welded seam pipe with combinations of cement mortar and coal tar coatings and linings and a variety of tight jointing methods is used in pressure applications. Corrugated galvanized steel with combinations of asbestos bonding, coatings, pavings and smooth lining and mechanical gasketed or "O" ring joints is used in gravity sewer construction.

Vitrified Clay pipe is resistant to corrosion from acids and alkalis and resists erosion and scour. It is built in short laying lengths and therefore requires more joints which can be subject to infiltration. However, in the past few years application has been made of a resiliant, flexible joint to clay pipe with reported reduction of infiltration.

Table 2.3.1, Standard Specifications for Selected Sewer Pipes Contains references to the American Society for Testing and Materials (ASTM) specifications and American Association of State Highway Officials (AASHO) standard specifications for various types of sewer pipe.

2.3.2 Sewer Jointing to Control Infiltration

So important is the effectiveness of sewer joints for the control of infiltration that, axiomatically, no sewer system is better than its joints. A good joint must be water-tight, root penetration-tight, resistant to the effects of soil and sewage, long-lasting, and flexible.

Up to 30 years ago, cement mortar commonly was used to make sewer pipe joints. As attention was given to prevention of infiltration and root intrusion into sanitary sewers, it became evident that mortar was not a good material for this service. Such joints were subject to shrinking and cracking; they were rigid and tended to break loose from pipe bells and spigots; they swelled because of hydrogen sulfide action and caused the rupture of pipes; they were the cause of root intrusion. To overcome these defects, various forms of asphaltic compound joints came into use. Some are hot-poured and others are pre-cast. While these materials have desired characteristics, they also require care and skill in application to assure water-tightness.

Finally the compression-type gasket was developed. It was first used on asbestos-cement pipe, and then was found suitable for vitrified clay by casting of a plastic ring on the spigot of the pipe and a plastic lining on the bell of the pipe. Compression-type gaskets were also made applicable to concrete pipe. Manufacturers of plain and vitrified clay pipes have developed a resilient or rubber-like sleeve clamp for the pipe end in the form of a non-corrosive metal band which makes a good joint for plain end pipe.

The following types of joints are used in sewer pipe service:

Cement Mortar is not recommended today. The joints are rigid and tend to crack with any movement or displacement of the pipe, including back-filling operations.

Asphaltic or Bituminous joints have been and are being used to overcome the objection to the rigidity and failure of cement mortar joints. The water-tightness of this type of joint will be affected if such a joint compound shrinks away from the sides of sewer pipe. In addition, the cementing with chemical adhesives or solvents must be carried out with care to achieve an adequate long-lasting seal.

Polyvinylchloride (PVC) and Polyurethane sewer joints are in common usage with clay sewer pipe. PVC, first utilized in the 1950's is cast both on the spigot and in the bell of the pipe. Experience has shown that because of dimensional changes of the material a good water-tight seal cannot be assured with PVC. Polyurethane has been found satisfactory because of its high resilience. Clay pipe manufacturers now provide pipe having a polyester compound cast on the spigot and into the bell. A compression gasket is used to make the seal between these surfaces, as the spigot end is pushed into place inside the bell.

Compression Gasket joints have been in use for over 30 years. Gasket components may consist of natural rubber, synthetic rubber or various other elastomeric materials. Compression-type joints are used on asbestos cement pipe, cast iron pipe, concrete pipe, vitrified clay pipe, and certain types of composite plastic pipe. Demonstrations have shown these to be the most effective seals against infiltration into sewers; at the same time they provide for deflection.

On most types of pipe the joint surfaces are formed by the basic pipe material. These pipes use a separate rubber gasket which acts as the sole sealing element.

With vitrified clay pipe the joint surfaces are formed by molding elastomeric material on the ends of the pipe. This molded material may act as the compression seal or may be used in conjunction with a rubber ring gasket.

Chemical Weld joints are used to join certain types of plastic pipes and fiber glass pipes. This type of joint has been reported to provide a water-tight seal. However, neither plastic nor fiber glass pipe has been used extensively, or for sufficient time to demonstrate the longevity of this type of joint. As mentioned under bituminous joints, some of the early bituminous pre-cast welded in-the-field joints, which used a solvent to effect the bonding of the pre-cast bituminous material, required care in installation to provide a complete seal throughout the circumference of the joint.

Field practice indicates that the forming of a joint at the bottom of a sewer trench is not performed under the most ideal conditions; jointing under such in-the-wet and often difficult-to-see circumstances does not lend itself to precise and careful workmanship. A type of joint which need only be assembled in the trench, rather than formed under such adverse conditions, would offer a desired characteristic to prevent infiltration.

2.3.3 Effect of Subsurface and Ground Water Conditions on the Selection of Pipe Joints

All soils, with the exception of soft organic materials, will safely support a sewer installation as long as no additional loads are being added. The required strength of the pipe therefore is based on the weight of the soil above the pipe and the method of backfilling the trench. Under these conditions the choice of joint type should not necessarily be influenced by the soild type.

Immediate or future additional loads on the pipe-supporting soils, however, can create considerable differential settlements, resulting in structural failure of pipes and joints and cause infiltration or exfiltration depending on ground water level. Examples of such loads are roadway embankments next to or over the sewer line and heavy foundations. A special case is sewer lines constructed in man-made fill which are placed on compressible soils. Such fills, increasingly used in the reclamation of swamps and coastal land as well as over solid waste disposal areas, can settle for many decades. Most differential settling problems have arisen from improper bedding and failure to replace inadequate subgrade materials.

The magnitude of such settlements, varying from fractions of an inch to several feet, defies standard solutions and requires extensive soils explorations, testing, and expert evaluation. Low magnitude settlements can sometimes, but only after careful study, be handled by the proper selection of pipe strength and flexibility and the use of joints which permit a certain amount of alignment change without distress or loss of seal. The selection of the joint may also be based on its shear transmitting capability as differential settlement causes shear to be transmitted through the joint.

A chemical analysis of ground water is mandatory where the sewer will be installed at or below ground water or in rock or tight clay because the trench may act as an aquifer. The proper selection of pipe materials and joints depends on these tests and will prevent deterioration of the system and subsequent infiltration.

2.4. DESIGN CRITERIA FOR NEW SEWERS

2.4.1 Type of System

There are many existing combined sewer systems. Recent surveys, however, have indicated there is no significant amount of new combined sewer construction. In combined sewer systems, infiltration and inflow tend to cause more frequent and prolonged combined sewer overflows. Such flows in a separate sanitary system may make the system inadequate and, in effect cause it to simulate the role of a combined sewer since it carries so much ground water admixed with sanitary sewage.

It is assumed that the ultimate goal of every sewer administrator is to design, construct, and maintain his sanitary system in a way that will subject as little excess water as possible and feasible. The cost and inconvenience of parallelling existing lines and building larger treatment plants are more than adequate justification for providing tight sewer systems. Over and above such economic considerations, many jurisdictions and industrial wastes producers are being ordered to cease pollution which may be induced or aggravated by excessive infiltration. The aim, therefore, is to realize the ultimate capabilities of the sewer construction materials available.

2.4.2 Design Allowance for Infiltration/Inflow

A review of current practice in the use of infiltration design allowances by design engineers has revealed the need for standardization of terms and units used in this field. This allowance is made in the form of volume per unit of time and is added to the design flows of domestic sewage and industrial wastes. The total of all such flows at their peak is used to establish pipe and waste water treatment plant unit sizes.

The peak design flow is the maximum daily rate of flow resulting from highest usage during certain hours of the day, days of the week, and weeks of the year. It is based on the principle that at some specific moment water and waste water flows will be at peak volume because of the accumulation or combination of maximum usage conditions. But it may never actually occur. A number of state water pollution control agencies stipulate peak design flow as a specific volume or quantity per capita. The following tabulation, Table 2.4.2, lists design flows required by some states and provinces.

Other jurisdictions have developed peak rate curves. Figure 2.4.2.1 is the rate chart used by Washington, D. C.

Peak design flows must be examined carefully by the design engineer to avoid the excessive impact and importance of infiltration/inflow volumes. There has been too great a tendency on the part of designers and their design standards, as illustrated by Table 2.4.2 to lump all extraneous flows into some vague

TABLE 2.4.2

DESIGN FLOWS
DESIGNATED BY STATE REGULATIONS

Alberta

1) Maximum hourly flow = average daily x $\left(1 + \frac{14}{4 + P^{0.5}}\right)$

when P = population in thousands, range of maximum hourly flow is from 2 to 4 times average daily

2) Per capita average daily flow = 100 gallons.

Illinois

1) Laterals and sub mains — 400 gallons per capita per day.
2) Main, trunk and outfall sewers — 250 gallons per capita per day.
3) Per capita average daily flow = 100 gallons.

New Jersey

1) Sewers designed to carry at least twice the estimated average design flow when flowing half full.
2) Per capita average daily flow = 100 gallons.

New Hampshire

1) All sanitary sewers shall be designed to carry at least four times the estimated average design flow when full.
2) Interceptors shall be designed to carry at least two and one-half the average design flow when full.
3) Per capita average daily flow = 100 gallons.

Oklahoma

1) Laterals and submain sewers designed for 400 gallons per capita per day when running full.
2) Main, trunk, interceptor and outfall sewers shall have capacity of at least 250 gallons per capita per day when running full.
3) Per capita average daily flow = 100 gallons.
4) The 100-gallons-per-capita-per-day figure is assumed to cover normal infiltration, but an additional allowance should be made where conditions are especially unfavorable. This figure likewise is considered sufficient to cover flow from cellar floor drains, but is not sufficient to provide any allowance for flow from foundation drains, roof leaders, or unpolluted cooling water, which should not be discharged to sanitary sewer systems.

Oregon

1) Because usually it is impossible to exclude all ground water infiltration, it is recommended that the capacity of sanitary sewers when flowing full be equivalent to at least 300 gallons per capita per day and preferably 350 gallons per capita per day on the basis of total estimated future population. Trunk and interceptor sewers should in general have capacities equal to at least 250 gallons per capita per day.

Pennsylvania

1) Laterals and submain sewers — 400 gallons per capita per day. Main, trunk and outfall sewers — 250 gallons per capita per day.
2) Per capita average daily flow = 100 gallons.

Tennessee

1) Laterals and submain sewers — 400 gallons per capita per day. Main, trunk and outfall sewers — 250 gallons per capita per day.
2) Per capita average daily flow = 100 gallons.

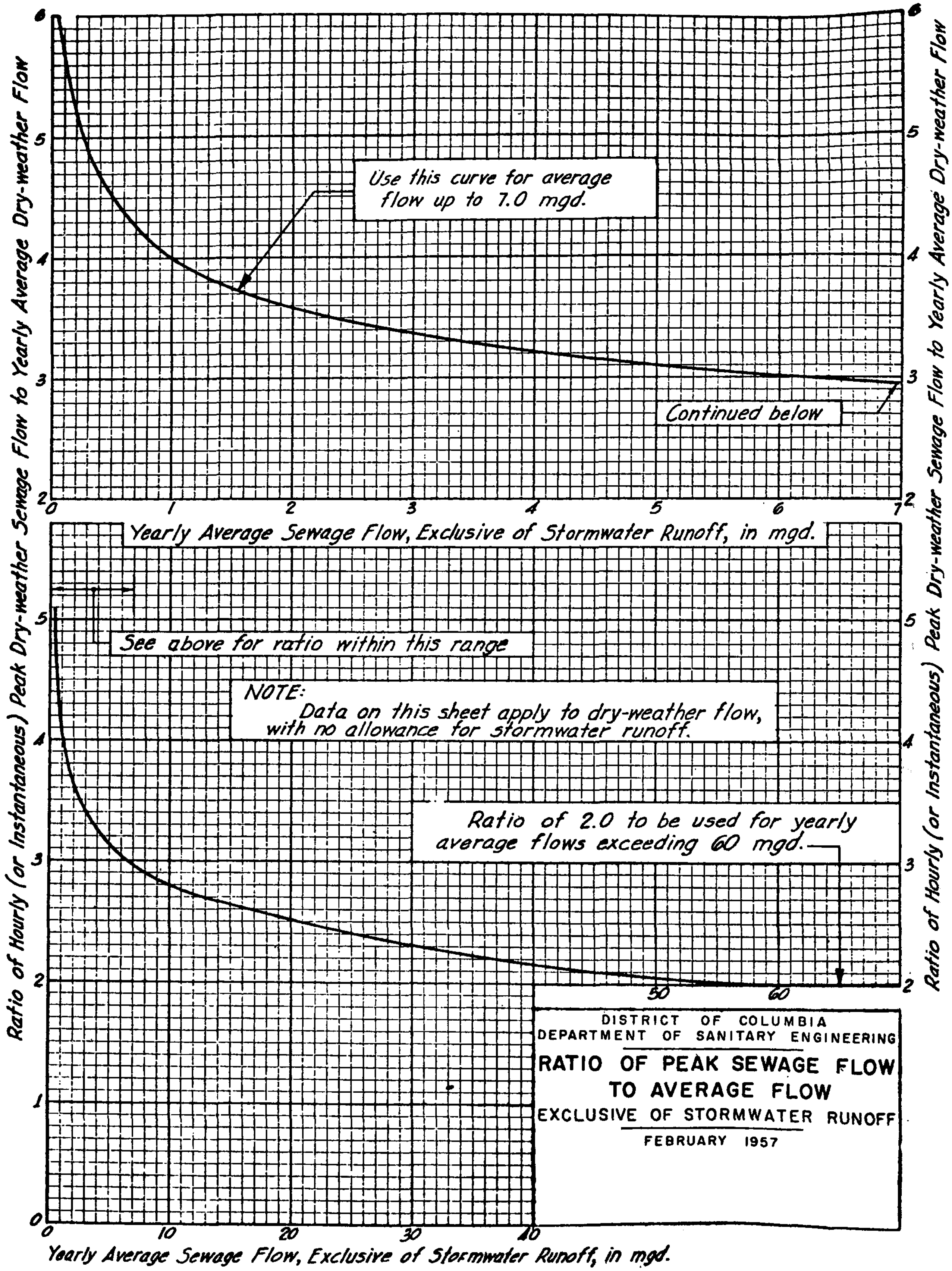
Texas

1) Laterals and minor sewers shall be designed, when flowing full, assuming flows equivalent to four times average daily flow. Main trunk, interceptor, and outfall sewers shall be designed when flowing full, assuming flows of 2.5 times the average daily flow.
2) Per capita average daily flow = 100 gallons.

Utah

1) Laterals and submain sewers — 400 gallons per capita per day. Main, trunk and outfall sewers — 250 gallons per capita per day.
2) Per capita average daily flow = 100 gallons.

FIGURE 2.4.2.1



DISTRICT OF COLUMBIA
DEPARTMENT OF SANITARY ENGINEERING

RATIO OF PEAK SEWAGE FLOW TO AVERAGE FLOW

EXCLUSIVE OF STORMWATER RUNOFF

FEBRUARY 1957

multiplier for an assumed average daily flow. Actual infiltration and inflow can vary tremendously from jurisdiction to jurisdiction, e.g., from a minimal 10 percent of sanitary flow to 100 to 200 percent. Each designer must evaluate the conditions existing in his area and not simply use a convenient and unsubstantiated design allowance. Without careful examination of local conditions and the establishment of realistic design criteria, the system may be seriously over- or under-designed. In the first case public funds are being wasted; in the second, overload problems will plague the system. The design engineer must never abdicate his responsibility to produce a workable design for his project based on thorough examination of all conditions present. No reference manual can delineate all of the situations he will encounter.

As previously discussed, the ideal goal in sewer system and waste water management is to prevent the entry of all waters which do not require treatment and thereby keep associated sewer system costs at a minimum and reduce environmental pollution. Ideally, there should be little need for design allowances in such a perfect system. In practice, however, there always will be at least a small increment of infiltration which it is usually not economically feasible to find and correct. The fact that it is not usually economical to either locate or eliminate *all* infiltrations is important; this must be recognized in the early planning stages.

In addition, since a design allowance covers both infiltration and inflow, a considerable variation of inflow can be effected, depending on the effectiveness and permissiveness of local jurisdictional control with respect to sewer-use ordinances and their enforcement.

In the past some sewer designers have used such flow units as gallons or cubic feet per acre per day. However, this terminology was based on the old concept of storm and combined sewer design. Since an attempt now is being made to eliminate or minimize all excess water intrusions, allowances for them should be keyed to actual flow records or estimates from sources of flow such as per capita or per dwelling unit. Sometimes infiltration/inflow rates are assumed as a percentage of the per capita flow, as indicated by water use and recognized standards. Such determinations may be adequate for overall systems planning but are not sufficient for detailed final design.

An accurate estimate of infiltration/inflow allowances should be divided into two basic components:

a. **Infiltration Component**
Since infiltration is related to tightness of pipe and manholes, any design allowance should be correlated with the maximum allowable construction infiltration allowances. While the full discussion of construction allowances is contained later in this section, it is sufficient to note that any amounts of permitted infiltration must be recognized in the design. In effect, then, the construction infiltration allowance on the project, *including building sewers,* becomes the infiltration component of the design allowance.

b. **Inflow Component**
Where a new sewer system is being designed in a jurisdiction that forbids the introduction of any ground, storm, or clean waters and where enforcement is complete and effective, there would be no inflow component. Such a system is difficult to achieve; and to do it the following inflow sources would have to be prohibited and enforced:
   1. Roof downspouts,
   2. Foundation drains,
   3. Basement drains,
   4. Basement sumps and or capped clean-outs,
   5. Sump pumps,
   6. Areaway drains,
   7. Driveway drains,
   8. Yard drains,
   9. Street drains, and
   10. Perforated manhole covers in areas of potential flooding.

Since initial achievement and continued realization of such restrictions are not completely realistic, the inflow component must be varied and tailored to fit the individual local situation. In terms of an average per capita sanitary contribution of 100 gallons per day, an inflow component of five gallons per capita per day might be chosen.

When local regulations permit connections of "clean water" to the separate sanitary system and cannot be tightened by any amount of logic and persuasion used to convince local officials, the design engineer should develop inflow or storm water allowance curves for the system. These curves result from studies of permitted inflow in terms of paved areas per dwelling unit or per person and in consideration of a certain maximum storm toleration. Figure 2.4.2.2 is an intensity-duration frequency curve developed by the Washington, D. C., Sanitary

INTENSITY - DURATION - FREQUENCY RAINFALL CURVES

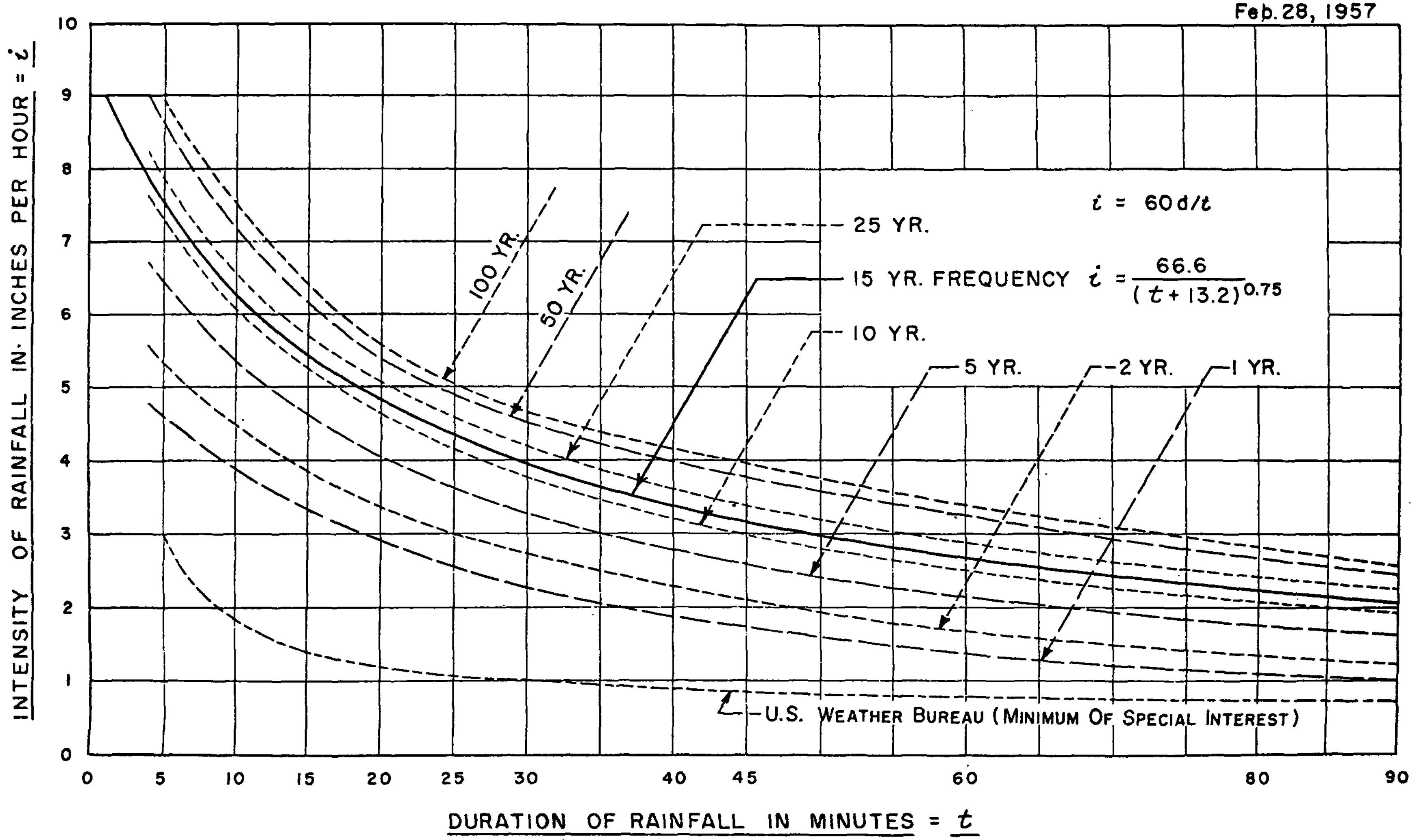


FIGURE 2.4.2.2

Engineering Department, which has selected the 15-year storm as the design storm. Figure 2.4.2.3, also from Washington, D. C., shows the storm water allowance curves for this storm falling on various acreage areas with varying population densities. These represent an attempt to correlate lot or plot area with population. A straight-forward use of infiltration or inflow criteria on strictly an area basis becomes meaningless when population development or potential development is ignored.

The Washington, D. C., charts are useful as an illustration of the concept of inflow component allowances. However, they also incorporate a flat 700-gallons-per-acre-per-day figure representing yearly average flow of ground water infiltration. Such an assumption does not take into account varying lengths of pipe, population densities, and types of buildings. Four hundred people per acre in high-rise apartments would produce considerably less infiltration potential than 400 people in 100 single-family homes on one-half acre lots. However, in a combined system such as in Washington, D. C., which also permits outside areaway drains, the infiltration load is less significant.

The following examples illustrate the use of design infiltration/inflow allowances and the varying impact on resultant flows. These may or may not apply to conditions existent in other jurisdictions. A basic design assumption is that infiltration and inflow represent additional volume, over and above the peak domestic flow of four times the average daily flow.

Table 2.4.2.1

Illustration of Design Infiltration/Inflow Allowance Calculations

Assumed Conditions:

Area - 1200 acres
Population Density - 20 persons per acre
Total population - 24,000
Separate Sanitary System -
  4-inch building sewers - 36 miles
  8-inch street laterals - 24 miles
  10-inch sub-trunks - 6 miles
  12-inch trunk - 6 miles
Average daily per capita sanitary contribution - 80 gallons
Peak design flow - 4 times average daily flow

Example 1 - Tight System with No Permitted Inflow

Additional assumptions -
  Construction Infiltration Allowance = 100 gpimd
  Maximum Inflow = 5 gallons/capita/day
Infiltration Component =
  400 gpmd x 36 miles = 14,400 gal/day
  800 gpmd x 24 miles = 19,200 gal/day
  1000 gpmd x 6 miles = 6000 gal/day
  1200 gpmd x 6 miles = 7200 gal/day
Total Infiltration Component = 46,800 gal/day
Inflow Component = 5 gpcd x 24,000 = 120,000 gal/day
Total Infiltration/Inflow = 166,800 gal/day
Peak Design Flow = 80 gpcd x 24,000 x 4 = 7,680,000 gal/day
Total peak Design Flow = 7,846,800 gal/day

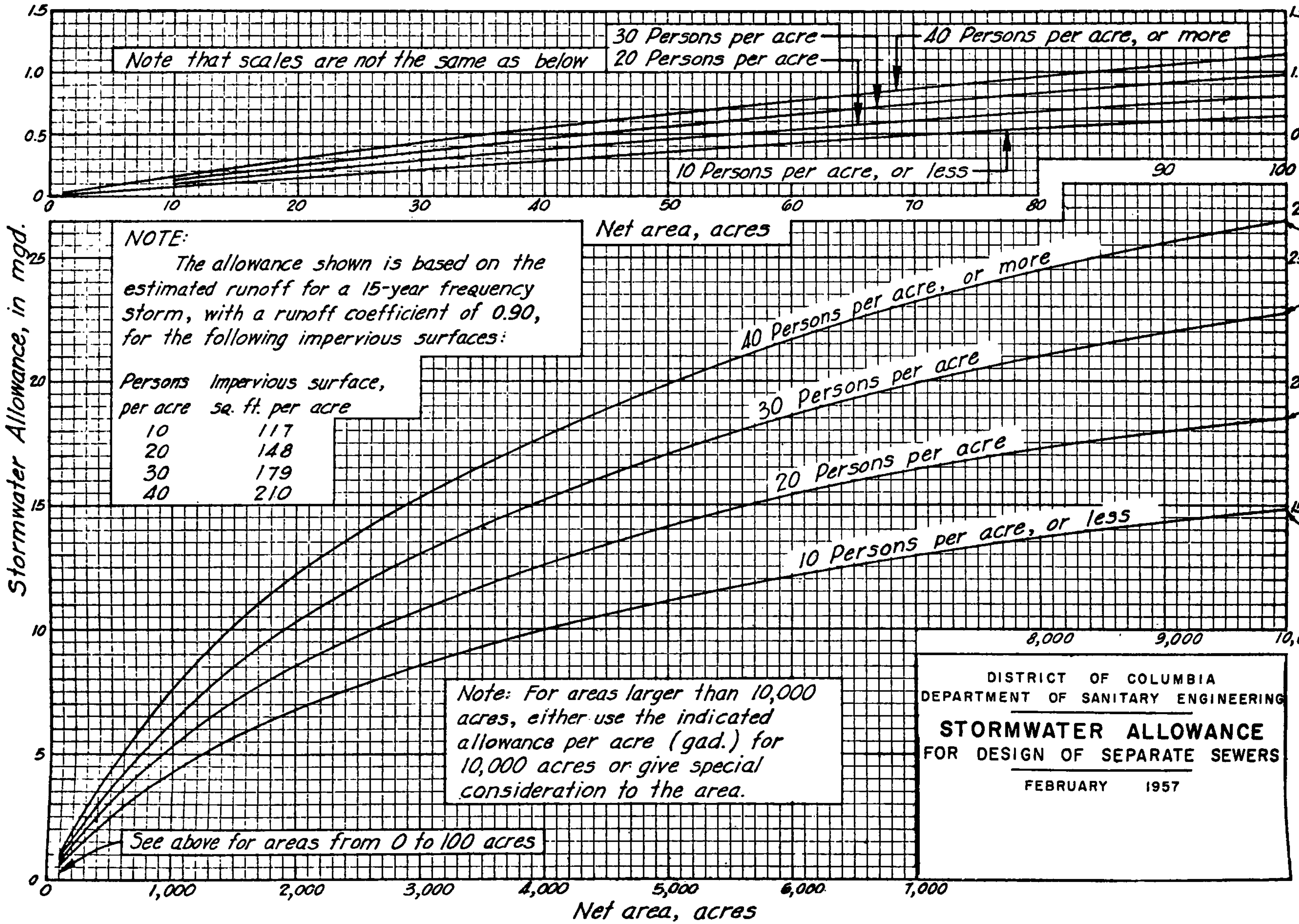
Table 2.4.2.2

System Slightly Less Tight and Some Areaway Drains Permitted

Additional assumptions -
  Construction Infiltration Allowance = 500 gpimd
  Inflow Calculated from Washington, D. C., Stormwater Allowance Curve, Figure 2.4.2.3
Infiltration Component -
  2000 gpmd x 36 miles = 72,000 gal/day
  4000 gpmd x 24 miles = 96,000 gal/day
  5000 gpmd x 6 miles = 30,000 gal/day
  6000 gpmd x 6 miles = 36,000 gal/day
Total Infiltration Component =234,000 gal/day
Inflow Component (from figure 2.4.2.3 = 6,000,000 gal/day
Total Infiltration/Inflow = 6,234,000 gal/day
Peak Design Flow = 80 gpcd x 24,000 x 4 = 7,680,000 gal/day
Total Peak Domestic Design Flow = 13,914,000 gal/day

The two preceding examples not only illustrate the methods for arriving at peak design flows; they also show how in the same theoretical design area seemingly small variations in design criteria can effect great differences in flows and pipe sizes.

In Example 2, the increase in allowable construction allowance – from 100 to 500 gallons per mile per day per inch diameter – raises the total infiltration from 1 to 5 percent of the sanitary flow. In terms of actual volumes the 500-inch-gallon allowance, which is prevalent at this time, would permit a maximum of 85.50 million gallons of



Note that scales are not the same as below
30 Persons per acre
20 Persons per acre
40 Persons per acre, or more
10 Persons per acre, or less
mgd.
Net area, acres
NOTE:
The allowance shown is based on the estimated runoff for a 15-year frequency storm, with a runoff coefficient of 0.90, for the following impervious surfaces:
Persons per acre | Impervious surface, sq. ft. per acre
10 | 117
20 | 148
30 | 179
40 | 210
Stormwater Allowance, in mgd.
40 Persons per acre, or more
30 Persons per acre
20 Persons per acre
10 Persons per acre, or less
2,660 gad.
2,270 gad.
1,860 gad.
1,480 gad.
Note: For areas larger than 10,000 acres, either use the indicated allowance per acre (gad.) for 10,000 acres or give special consideration to the area.
See above for areas from 0 to 100 acres
Net area, acres
DISTRICT OF COLUMBIA
DEPARTMENT OF SANITARY ENGINEERING
STORMWATER ALLOWANCE
FOR DESIGN OF SEPARATE SEWERS
FEBRUARY 1957

FIGURE 2.4.2.3

extraneous water per year.

The most striking change in extraneous water flow occurs in the inflow component of Example 2 utilizing the Washington, D. C., design curves for storm water (inflow) into separate sanitary sewers. In this case the inflow alone is 6 mgd which almost equals the peak sanitary design flow and dwarfs the infiltration component even in its increased condition.

These illustrative examples are over-simplified in order to emphasize the impact of differing design and construction allowances. In actual practice pipe sizes would be varied according to the design flows in a slightly more involved procedure.

2.4.3 Manhole and Cover Design

Brick and block manhole construction methods no longer are applicable, becuase of the reduced availability of skilled masons in the sewer construction field and the vulnerability of mortar joints to corrosion and leakage. Precast manholes, properly joined with rubber gaskets or sealing compounds, have alleviated the problem. In recent years the development of custom-made precast manholes with pipe stubs already cast in place has reduced the problem of shearing and damage of connecting pipes. They have also reduced the leakage difficulties associated with breaking into a precast manhole to insert the pipe line and then making an adequate water-tight seal around the pipe. The use of flexible connectors at all joints adjacent to manholes reduce the possibility of differential settlement of the manhole and the shearing of the connecting pipes.

The design of the joint between the precast manhole sections and brick courses used to reach grade, and the joint between the manhole ring and the balance of the structure should be given special attention. The details of these joints are seldom given by designers, although if water follows the trench, or the street sub-grade considerable hydrostatic forces may be present and infiltration will occur.

The bedding and foundation beneath a manhole also is a vital part of preliminary investigation and design. All parts of the sewer system must maintain their integrity and proper inter-relationship to sustain a tight system.

Manhole cover design is attracting more serious attention in view of evidence that even small perforations can produce sizeable contributions of extraneous inflow. It has been estimated that a single 1-inch hole in a manhole top covered with 6 inches of water may admit 11,520 gallons per day; this exceeds the infiltration or the inflow components in Example 1 of sub-section 2.4.2. Obviously, manholes that are in areas subject to flooding should have solid, sealed covers. Such covers, however, often prevent adequate ventilation of the manhole and sewer, posing danger to maintenance employees. Thus, the design of sections requiring sealed covers should be given special care. Maintenance employees should check all manholes for hazardous gasses prior to entering.

2.4.4 Practical and Maintainable Design

Recent investigations into sewer design problems have revealed a serious lack of understanding and communication between design engineers and maintenance personnel. There are many sewer maintenance superintendents who are struggling with problems caused not only by inadequate hydraulic design but also by impossible physical structures with extended lengths of pipe, omitted manholes, curved lines on difficult radii, and inaccessable chambers. Such maintenance problems result in inadequate maintenance and unauthorized overflows, and usually prevent rapid and adequate infiltration and inflow surveys.

The sewer system cannot be buried and forgotten. Every effort must be expended to guarantee its maximum useable and economic life.

2.5 CONSTRUCTION METHODS AND INSPECTION

2.5.1 Construction Considerations

The most critical factor relative to the prevention of infiltration in new sewers is the act of construction. All of the currently manufactured pipes and joints are capable of being assembled into sewer systems with minimal infiltration. This capability must be coupled with good workmanship and adequate inspection. The following items represent some of the more important factors which relate to infiltration control:

2.5.1.1 Construction Contract Documents Related to Soils and Ground Water

Soils and ground water information used in the design must be made available to the construction contractor. These data are required to evaluate the need for or the design of sheeting, dewatering, borrow material, and a number of other considerations which influence the estimate of his costs. Since the nature of soils and location of ground water anticipated is of prime importance for sewer work, all subsurface information obtained should form a part of the contract documents. Each subsurface exploration should be clearly located on an overall site plan since the data obtained from the exploration is directly applicable to that particular area. Care should be taken to avoid possible misinterpretation or misrepresentation. For example, ground water table elevation should be accompanied with the date of such observation; soil and rock profiles developed from subsurface explorations should reflect extrapolation between investigation locations and present the conditions most likely to prevail. The widely used exculpatory notes which in effect say, "We are not responsible for any information supplied to you, Mr. Contractor", may not be acceptable in a court of law and may result in higher bid prices due to the contrator's uncertainty as to what he will encounter.

2.5.1.2 Trenching and Excavation Methods

Trenches should be made as narrow as possible but wide enough to permit proper laying of pipe, inspection of joints, and consolidation of backfill. Depending on the type of soil, space available, ground water level, length of time the excavation is to remain open, and depth of excavation, the slopes are constructed as steeply as they will stand without caving. In some areas a minimum slope of 1:1 is specified or the placing of shoring in a vertical trench is required. For deep excavations, particularly below ground water table, the excavation should be braced or sheeted to provide safe working conditions.

Construction should be accomplished in dry conditions and thus, if water is encountered in the excavation, dewatering should be done by sump pumping, use of well points, or deep wells.

2.5.1.3 Bedding and Backfill

Trench excavation is done by hand or by machines, depending on location and magnitude of excavation necessary. For most trenching work, excavation by machine is more economical and efficient. Machines particularly adapted to sewer trench excavation are continuous bucket excavators, overhead cableway or track excavators, power shovels or backhoes and boom and bucket excavators. Figure 2.5.1.3, Bedding for 84-Inch Interceptor, is a photograph of the bedding prepared for an 84-inch concrete pipe laid on a curvilinear alignment.

Depending on ground water location, types of soil, depth of excavation, available space and length of time the excavation is to remain open, it may be necessary to install sheeting or bracing to prevent caving of the banks and prevent or retard entrance of ground water into the trench.

2.5.1.4 Backfill and Bedding Material

Backfill directly around the sewer pipe should be selected material. Compactable material should be used around flexible pipe. The remainder of the backfill generally is governed by the type of material initially excavated. Figure 2.5.1.4, Placement of Rock Bed, is a photograph of the placement of rock bedding for a large (72-inch) interceptor. Frozen earth, rubbish, old timber, and similar materials should be avoided where permanent finished surfaces are desired because they decompose or soften and cause settlement. Differential settlements can lead to ground water infiltration because of cracking of the sewer or opening of the joints.

Depending primarily on the location of the sewer and the anticipated development of the area, specifications may require a specific gradation for backfill material as well as definite compaction requirements. In this case, the proposed fill must be laboratory-tested to determine its gradation and compactive characteristics.

In some instances materials with high void ratios (such as trap rock or clam shells) produce a water course around the pipe. It is extremely important that pipe installation and inspection be carefully performed to preclude heavy infiltration from this aquifer.

Bedding material is that which forms the foundation for the sewer. It may be original ground, concrete, sand, or gravel, depending on the nature of the soils present. Improper or non-uniform bedding can result in settlements which subsequently cause infiltration.

Specific information for backfilling and bedding of various types of pipe are available from individual pipe companies or associations.

It is obvious that the installation of backfill and bedding can affect the infiltration characteristics of the pipe. ASTM, ASCE and other references contain installation practice instructions which, when applied, will help produce tight pipes.

2.5.1.5 Compaction Techniques

Regardless of location, the most critical area with respect to compaction is directly around the sewer pipe. The backfill is placed and packed by hand under and around the pipe being compacted by light hand tampers. As backfilling is continued to original surface level, compaction is achieved by machines. The entire trench width must be compacted. Depending on the size of excavation to be filled, compacting equipment will range from hand operated

FIGURE 2.5.1.3

BEDDING FOR 84-INCH INTERCEPTOR

Courtesy: United States Concrete Pipe Co.

FIGURE 2.5.1.4

Courtesy: United States Concrete Pipe Co.

compactors to large rollers.

2.5.1.6 Dewatering Techniques

Excavation can be dewatered by sump pumping, a well point system, deep wells, or soil solidification. Pumping from sump pits is most widely used for shallow excavations when the quantity of water is small and the water table need not be lowered any great distance. Well point systems and deep wells are more complex and should be designed by an engineer. It should be pointed out that in any wellpointing procedure caution should be exercised in assuming that the ground water table will be restored after construction at the same rate or in an equal period of time that it took to draw the water down. This procedure will prevent any sudden "surge" of water which could conceivably exert enough force to cause disruption of new construction.

2.5.1.7 Construction Inspection and Testing of Soils, Bedding and Backfill

Infiltration of groundwater into a proposed sewer system can be minimized by proper construction procedures, rigid inspection of materials and methods of installation, and performance of soil and ground water tests. To elaborate:

a. **Field Inspection of Excavation, Bedding and Backfill**
   Construction procedures and materials should be inspected for conformance with project plans and specifications. Rigid inspection is mandatory.

b. **Field Soil Tests**
   Field soil testing is used in conjunction with controlled backfill. When specifications require backfill to be compacted to a high percentage of maximum density, in-situ field density tests are performed to determine if such compaction is achieved. The most common means of field density testing are the Sand Cone Method and Rubber Balloon Method, both yielding a field density to be compared with laboratory maximum density in order to monitor degree of compaction.

c. **Laboratory Testing**
   For projects specifying a particular gradation requirement for trench backfill or bedding, the proposed material should be subjected to a sieve and/or hydrometer analysis. Further, a compaction test should be performed if specifications call for a required degree of compaction.

2.5.2 Construction Infiltration Allowance

One of the most effective ways to control infiltration, and at the same time measure the quality and condition of the new system, is to establish a maximum infiltration rate. A national survey of agencies and consultants revealed that although the most commonly used allowance is 500 gallons per mile per day per inch of sewer diameter (inch-gallons), there is a definite trend in the direction of lower limits. Pipe manufacturers consistently claim that the rates of 250 gallons per mile per day per inch diameter or less are readily attainable.

In 1950 the Clay Pipe Engineering Manual recommended a construction infiltration allowance of 1500 inch-gallons. The 1968 edition recommends no more than 500 inch-gallons, indicating the improved techniques now available. The Water Supply and Pollution Control Commission of New Hampshire places a 300 inch-gallon maximum on infiltration.

In 1965 a survey by Public Works magazine revealed that 50 percent of cities surveyed used the 500 inch-gallons allowance, but even at that time 40 percent used lower rates and 15 percent were actually specifying a low allowance of 100 inch-gallons. A survey concluded in 1970 revealed allowances as low as 50 inch-gallons with a few "zero" allowances reported. Anotherrecent fact-finding survey, carried out by the New York State Health Department, Division of Pure Waters, indicated that 80 percent of responding consulting engineers in the state believed the 500 inch-gallon standard should be lowered; 30 percent of those favoring reduction recommended an allowance of 200 inch-gallons. Twenty-five percent suggested 100 inch-gallons; 28 percent, a 250 inch-gallon allowance.

It is apparent that a maximum construction infiltration allowance for all types of pipe of 200 gallons per mile per day per inch of diameter (inch-gallons) can be obtained without additional construction cost. The economic benefits, cost-benefit ratio, should be determined for requiring lower construction infiltration rates.

Manholes are subject to infiltration leakage over and above the inflow component entering sewers through cover perforations. Although the contribution is recognized, actual construction allowances are not always utilized. The Clay Pipe Engineering Manual states that manholes should be tested for leakage and that this infiltration amount should be deducted from any infiltration tests of the pipe section. The exfiltration leakage allowance specified by the State of New Hampshire is 1 gallon per day per vertical foot of depth. It stipulates, also, there shall be no visible leakage due to infiltration where the ground water table is high.

2.5.3 Inspection of Construction

The importance of adequate inspection during construction cannot be overemphasized. Material, time, and money usually can be saved by supplying a fully trained inspector for all phases of sewer construction projects. Deliberate malpractices and unintentional mistakes can result in contravention of the designer's intent and jurisdiction's desire to provide a sewer system of dependability and long life.

An alert inspector pays dividends by requiring strict adherence to job standards, but he should not assume so active a role in the project that he preempts the supervisory direction of the contractor. If the contractor does not have adequate supervision on the job, the inspector should report this to the contracting authority and the project should be suspended until such supervisory personnel are available. The inspector and the field engineer logically may be asked to interpret specifications, but they cannot assume direction of, or responsibility for, the contractor's forces. If too many questions arise about the plans and specifications, the design engineer should visit the site and reassess the adequacy of these documents. The need for this type of job contacts affirms the need for the design engineer, whether employed by the jurisdiction or by a consulting engineering firm, to keep in touch with the project during construction. The inspector should not be expected to make engineering design decisions.

The inspector should have basic responsibilities for adherence to specifications; the accounting or verification of quantities of material supplied, and time spent on the project. He should be provided with a log book and whatever other forms are necessary to produce an adequate record of all activities of the contractor's forces. He should observe and record weather conditions and all other occurrences and conditions that affect the quality of workmanship. It is not necessary that the inspector be a licensed professional engineer, but he should report to a professional engineer who should appear on the job frequently enough to answer all questions of the inspector or contractor. The consulting engineer or the municipal design engineer should recognize that construction is the ultimate realization of his plans. He should be well represented during this crucial period.

During the course of interviews the best inspectors were often described as retired contractors or former job superintendents who provide maximum practical experience and knowledge. They are familiar with all of the "tricks of the trade," both good and bad. They speak the language of the workers and engender respect because they know what they are talking about.

2.6 TESTING FOR ACCEPTANCE

Testing and inspection are at times confused and considered to overlap; however, it should be made very clear that these are two separate quality-control functions. Each may depend on the other but neither can substitute for the other. Although many engineers depend on criteria other than resistance to infiltration as the main factor in controlling the design and construction of sewers, the chief method of guaranteeing a properly installed and workman-like job has been the use of what can be described as infiltration tests. Even though infiltration may not be considered a prime factor in design, it still is considered the most effective measure of the quality of sewer installation and conformity with job specifications. The owner should provide the testing services and such services should not be a part of the contractor's contractual responsibilities. An alternative to this procedure could be the inclusion of the method or methods to be used as a bid item in order to provide a basis for reimbursement for the performance of such sewers by the contractor.

A number of testing methods were reported, including the following:

2.6.1 Infiltration Testing

The infiltration test is the most obvious method of determining the tightness of the sewer. If a sewer line has been laid under the ground water table, it is obvious that any clear water flowing through the pipes prior to any house connections represents true infiltration. Despite the fact that a large percentage of sanitary sewers are laid below ground water table, either in wet or dry seasons, there always is a question as to what effect this will have on infiltration rates, since the head of water above the pipe will have a great bearing on the quantity of water intruding into the conduit due to pipe and joint defects. Infiltration tests consist simply of measuring, through use of weirs, the amount of flow in a sewer before any building connections are made.

Unfortunately, this test has been used in many cases where there are great lengths of pipe involved; under these circumstances it is impossible to draw firm conclusions as to compliance with specifications in any specific manhole-to-manhole section. As a matter of fact, using an allowance of 500 gallons per inch of sewer diameter per mile per day, a nominal 300-foot manhole-to-manhole section would yield an infiltration quantity of less than 0.106 gallons per minute, which is hardly measurable. Infiltration testing, therefore, has been utilized mainly on relatively long sections of sewer lines; even in these cases the test is open to considerable question.

The infiltration test never should be used in dry ground, since it is applicable only when the static head is above the crown of the pipe at the upper manhole. In some instances the flooding of the sewer trench, usually associated with the puddling of back-fill, has been used to simulate a high ground water condition. This synthetic condition may not offer a real simulation of the actual immersion of a sewer line in ground water.

Another disadvantage of the infiltration test, since it involves such small quantities, is that a very large section of a sewer project must be completed before any meaningful test can be made. This means that a number of manhole sections with broken pipes and infiltration rates considerably over the allowance could be included in the long stretch of pipe tested; the effects of such defective conduit could be masked by the sections of the system which are water-tight. Thus, the defective sections may never be detected and located for corrective action. It must be concluded that actual infiltration testing by flow-gauging have to be ruled out as an adequate method for approving new construction, except under favorable circumstances.

2.6.2 Exfiltration Testing

The reverse of measuring actual infiltration is to fill a pipe with water and observe the loss of water during a specified test period. This exfiltration method is far more positive since it involves subjecting the pipe system and the manholes to an actual pressure test. However, the presence of ground water outside of the pipe, the effect of slopes, size of pipe, and other factors will affect the validity of this test. Gravity sewer pipe is not expected to be a pressure system. Cases have been reported where the surcharging of new sewer lines for testing purposes has resulted in fractured pipes and manhole sections not designed for the pressure head developed during the test period. Unfortunately, the pressure effects of a head of water in an upper manhole can produce destructive results in lower sections of the sewer because of the effect on downstream bulkheads, house connections, "hookups," and even sewer joints. However, during the testing of manhole-to-manhole sections, the exfiltration test has fewer hazards, though it cannot locate small fluctuations in sewer leakage.

This test should be used mainly in dry areas where the ground water level is below the crown of the pipe. Development of correlations of heads, sizes of pipe, slope, and other factors must be considered prior to exfiltration testing. Attention should be given to the presence of house service plugs in exfiltration test programs. The elevation of such plugs will have a bearing on exfiltration heads, and the test head must exceed the highest house service elevation.

The ability to use the exfiltration procedure on small sections of pipe allows a very sensitive test, since the water pressure in the section of pipe under test can be related to the water level in the hydrostatic tube inserted in the plug or in the manhole. There is no specific correlation between the water exfiltration test and infiltration which covers all sewer system conditions. It may be assumed that there is some, but an unknown direct relationship between exfiltration quantities and the infiltration to which the sewer will be exposed but if exfiltration is to be the test method, there is a need for dependable hydraulic criteria which will clearly establish this relationship.

ASTM C-425 established as a guideline that when there is more than 2 feet of head, 10 percent should be added for each 2 feet of additional head to correlate exfiltration to infiltration.

A disadvantage of exfiltration testing with water lies in the problem of finding enough water to fill the sewer section and then disposing of it after the test is completed. Water is a precious commodity in some regions during certain seasons of the year, and may not be readily available for testing purposes. In addition, the disposal of the large amounts of water used in exfiltration testing or in creating high water levels in a trench may produce undesirable construction conditions. Appendix 10, Examples of Specifications for Exfiltration Testing of Gravity Sewers, lists several specifications which might be used.

2.6.3 Air Testing

In the last few years air testing has been developed to a point where it appears to be highly promising as a method for determining sewer-construction tightness. Its advantages include the fact that the air is readily available and will cause no problems with the construction process or in the trench. Air testing provides the inspector and contractor a monitor of the construction workmanship as the installation proceeds.

Air testing is carried out by plugging both ends of the sewer in adjacent manholes and pumping a certain amount of low-pressure air into the sewer section under observation. The pressure attained is usually within the range of 2 to 5 pounds per square inch. Air testing normally is limited to pipe under 24 inches in diameter. Above this size, special air testing provisions are required such as testing only the individual joint.

Research work and actual field experience have demonstrated that the maintenance of such pressures for certain periods of time are a positive indication of the water-tightness of the sewer section. This test method requires the use of a compressor and sealing equipment. There is need for an acceptable correlation between air testing and true infiltration, and for correction of air-testing data for existing ground water conditions. It is essential to establish an accurate measure of the static ground water table at each manhole before the test can be made and properly evaluated. Air testing is being used because it offers a quick and easy method for evaluating new sewer sections for acceptance. This test does not determine the tightness of manholes which must be tested separately, nor does it indicate differences such as misalignment and small cracks and failures that may be compacted from the outside with a tight soil and would thereby pass the air test and yet be deficient in structural integrity.

Appendix 9 contains typical specifications for low pressure air testing of sewers for infiltration control.

2.6.4 Still Photography

Photography, including colorslides, stereo-photos, etc., can provide a record of the condition of new sewer lines. Its use is primarily for new construction, since line conditions generally allow an adequate view of defects as is true with TV inspecting. It serves as an aid to the inspector by providing a record of sewer construction workmanship. It may reveal faulty joints or broken pipe.

2.6.5 TV Testing

Television testing is a misnomer since television is, more accurately, a method for observing the condition of the interior of sewer pipes. For new pipes, television detects cracks and other defects not detected by other means of testing because the defect had been packed with clay during backfilling. Efforts have been made with some success to estimate actual infiltration flows observed in television studies. TV is also useful in the detection and eventual correction of infiltration problems in existing sewer systems. After building sewers have been connected, and the sewer system is in use, infiltration, exfiltration, and air testing cannot be used. TV appears to have the following advantages:

a. Instantaneous viewing is permissable. If a sewer line, new or old, cannot be viewed, this is immediately discernable. Where lines are restricted, causing sand or other debris to cover the lens of the camera, flooded dips in the lines, misalignments, and other such deficiencies can be determined immediately.
b. "Development of Pictures" is not necessary. Therefore, there is no delay in making a decision especially where time is of the essence.
c. Several people can "view the line" together on the spot. In addition it is possible to take video recordings off the screen in order that permanent records can be made by means of a Polaroid or a 35-milimeter camera. Sound recordings onto the video tape are made at the time of recording to specifically identify the place, the time and the conditions found. This saves unnecessary narration or eliminates later questions as to areas or conditions.
d. With the use of TV it is possible to limit picture records to specific defects and those areas that typify the general condition of pipe free from defects.
e. TV provides the only means by which moving water can be observed. In addition, water of infiltration from house services that are noted to be running, can be properly evaluated by TV viewing. When a house service is noted to be running, a check of the building itself is possible to determine whether the flow is, in fact, domestic flow or water of infiltration. TV has certain

disadvantages:

a. Operation of the equipment requires a highly qualified electronic technician.
b. Evaluation of TV reports, especially in the case of infiltration studies, requires the services of a skilled or specialized professional engineer if optimum results of the study are to be achieved.

2.6.6 Smoke Testing

Smoke is not an acceptable method of detecting infiltration points. However, it has been used by some of the surveyed communities, and a number of engineers feel it is effective in locating sewer cracks, defective joints, and direct connection of a sanitary sewer to a storm sewer. In this case, a smoke generating unit is placed in a manhole with a blower, and the smoke can be observed coming out of the soil wherever there is a leak. It would appear to be a method that has limited application on lines that are seriously damaged or have been installed very poorly. Smoke tests are useful in locating sources of inflow waters which enter sewer systems through pipe connections which are not trapped such as roof downspouts. Where a high-water table is present, the smoke will be absorbed by the overlying water.

2.6.7 Visual Observations

In large size sewer lines, and also by the use of certain types of mirrors and lights in smaller sewers, it is possible to inspect visually certain pipe lines. Except in the case of large size pipe it would appear that other methods of inspection are more productive. In any case, this is not a quantitative test of sewer conditions.

2.6.8 Conditions For Acceptance Tests

Another aspect of testing is the final acceptance of a sewer line after construction. It is almost a universally accepted fact, although not always so practiced, that new sewer construction should be tested and accepted in as short sections as feasible. It becomes extremely difficult to assign responsibility for correction of new sewer lines if building connections have been installed since tests can not be made properly after these connections. In addition, the crucial role of the building sewer must be taken into consideration; the sewer contractor cannot be held liable for any inadequacies of plumbing contractors who usually lay at least part of the building connection line. If new sewer lines are tested section by section and before connections are made for final acceptance, the sewer contractor can be held responsible for excessive infiltration rates which are found and evaluated by effective methods of testing.

2.7 CORRECTIVE MEASURES

Testing prior to acceptance may indicate that sections of the system do not meet the required infiltration standards. The decision then must be made as to whether or not the defective sections must be excavated and replaced or repaired, or whether internal sealing will be allowed. Where the defects are not extensive, internal sealing generally will tighten up the pipe to meet specifications. Excavation, on the other hand, often results in the breaking of adjacent joints.

The feeling that an internally sealed pipe is "less than new" has led to the replacement of defective sections. However, a realistic evaluation of the costs, problems, and possible additional effects on the pipe may indicate that the project specifications should require or allow the contractor the option of such sealing for minor defects when in the opinion of the inspecting engineer there are no structural deficiencies in the barrel of the pipe. Internal pipe grouting can be a permanent solution if the technique is applied in accordance with engineering principles that consider the type of soil being grouted and the nature of the defects being evaluated.

2.8 BUILDING SEWER STANDARDS

2.8.1 Jurisdiction and Control

Building sewers are the means of connecting in-structure plumbing and drainage lines to street sewers. They are the link between the production and sources of sewage, commercial wastes, industrial process waters, and the facilities provided by local government for the removal and treatment of waste waters. Building service conduits, which act as the bridge for the gap between the structures served and the sewers which perform this service, represent a vital gap in regulation and control. The portion of the building sewer beween the structure and the property line constitutes one part of the connection, while the portion between the property line and the public sewer in the street line completes the connection.

Reference is made to these two portions of building sewers because separate parts have been constructed and connected under the control and supervision of separate governmental agencies. The connection to the building plumbing and drain system that extends to the property line often is interpreted as an extension of the structure facilities, is ordinarily installed under plumbing or building code regulations, and tested and approved by plumbing officials or building inspectors. The section of the building sewer between the property line and the street sewer, including the connection thereto, usually is installed under sewer rules and inspection; approval is within the purview of public works or sewer officials.

One exception to this rule of split authority often occurs in the case of industrial wastes connections. Because of the effect of such wastes on sewer structures and treatment facilities, the entire length of these building sewers may be supervised by sewer officials. This procedure gives them better control of such connections and the introduction of wastes, when ruled to be amenable to sewer transportation and treatment.

Building sewers play a vital role in the overall infiltration and inflow volumes carried by separate sanitary and combined sewer systems. This split in authority impedes total control over building sewer construction, testing and acceptance under present circumstances when unified action is most needed. Contributing to potential entry of infiltration water into sewer systems are the relatively short lengths of house sewer run, the multiplicity of these lines in any given stretch of collection sewers in heavily built-up urban areas, and the fact that each connection line has two physical connection points – one at the building line and the other at the junction with the public sewer. One control agency should supervise the building sewer as a single source of infiltration.

2.8.2 Codes, Construction and Testing

Regulations governing building sewers are often contained in building or plumbing codes. They represent a considerable range of interest and control. Many codes make no reference to foundation drain connections, although many make the distinction between the building sewer and the building storm sewer. A number of codes still permit various area drains to be connected to the building sewer.

Most plumbing codes permit a wide range of materials to be used, although some of the most recent ones are more restrictive. A few codes require the building sewer to be tested usually by holding a 10-foot head of water for 15 minutes with no allowable leakage. Air testing is mentioned as a test procedure, mainly on the interior system although the building sewer also can be tested. Smoke tests also can be used as the pipe lies in the trench before backfilling and connection to the lateral. Small defects are then readily apparent.

Because of the potential severity of the infiltration and inflow contribution of building sewers, they should be constructed of top quality, water-tight materials with thorough inspection and testing. The physical connection to the street lateral sewer should be performed by the sewer agency or department crews after careful training and inspection.

Section 4 of this Manual gives specimen portions of sewer-use ordinances that relate to prohibitions of certain types of building connections and stipulate the types of wastes which must be excluded from public sewers. Other code excerpts involving industrial process wastes and commercial operations wastes are contained in Section 9 of this Manual.

SECTION 3

CORRECTION OF INFILTRATION CONDITIONS

SECTION 3

CORRECTION OF INFILTRATION CONDITIONS, EXISTING SYSTEMS

The correction of infiltration involves a lengthy, systematic approach or plan of action. The haphazard deployment of investigative devices and sealing equipment is ineffectual and extremely costly. Interwoven with correction is maintenance. Preventive Maintenance that restores the full capacity of the pipe will permit the sewer to take the full capacity for which it was designed, including infiltration waters, and will, therefore, reduce the rate of surcharge in upstream manholes.

There must be an orderly plan of approach when investigating infiltration conditions. Excessive infiltration is occurring and when it is determined where visual inspection is needed, sewer cleaning is an important consideration because of the cost and time involved. It is impossible to run a camera through a sewer that has restricted flow due to sand deposits or other debris. Cleaning serves to produce the maximum available carrying capacity in the sewer pipe. Sewer cleaning will dictate the rate at which inspection can be accomplished in accordance with the availability and capability of the sewer cleaning crews. The following general procedure for the inspection of infiltration conditions is an adaptation of a program developed by American Pipe Services, Minneapolis, Minnesota.

3.1 OBJECTIVES

The first step in analyzing the extraneous water problem is to define that problem as clearly as possible. Before retaining consultants and sewer service organizations, the public works director should review and evaluate such questions as:

1. In what condition is the system?
   a. How can this be determined?
   b. What will it cost to determine the condition?
2. Is there an infiltration/inflow problem?
   a. How large is it?
   b. What is its effect?
3. What will it cost to identify and correct?
4. Is adequate preventative maintenance being performed?
5. Are state agencies forcing action?
6. Is correction an economically justified procedure?

He may not have all the answers but it is essential that he know the questions.

The goals and objections usually can be outlined as an effort to:

1. Determine the need for a sewer system analysis;
2. Establish an effective sewer maintenance program;
3. Determine and project minimum and optimum needs for equipment and manpower;
4. Determine if infiltration is a significant problem; and
5. Correlate cleaning and inspection with any contemplated street paving program.

When the public works official has identified and evaluated the problem, he may look for guidance from a qualified consulting engineering firm, supplemented by competent sewer service organizations if he does not have adequate manpower and equipment.

3.2 IDENTIFY SYSTEM

3.2.1 Plot Maps

The first request by a consultant or infiltration analyst will be for detailed maps of the sewer system. Only in rare instances are all such maps available. Even in jurisdictions that take pride in maintaining excellent records, the existing maps often will be found inaccurate as to utility locations because as-built records never were made or kept in past practices.

It is imperative that the existing sewer maps be completely checked in the field for verification of line, grade, and sizes. Future studies and corrective action will be rendered difficult and expensive unless adequate attention is given at the very outset of operations. Such mapping also is essential for routine preventive maintenance programs.

Scales, types of maps, and information must be tailored to each community or area. If the public works department or sewer agency does not possess such maps or if there are no personnel available to produce them, a consultant or a separate land surveying firm may be engaged for this vital step.

3.2.2 Identify Drainage Systems

Maps should be analyzed to develop a series of small drainage areas or "mini-systems." Key manholes should be selected for each "mini-system" through which the total "mini-system" flow enters the trunks or the next area. A theoretical office analysis of key manholes should be made to identify the sections and manholes that are bottlenecks. This operation requires that true invert elevations and pipe sizes be known so that hydraulic computations can be made. At this point some feeling for the scope of the problem can be gained.

3.3 IDENTIFY SCOPE OF INFILTRATION

3.3.1 Flow Measurements

In conjunction with the identification of drainage systems, actual dry-weather and wet-weather flow measurements should be made at key manholes. A series of such measurements may extend over many months of observation during daily periods of low domestic and industrial flow.

The flow in the sewers can be obtained by various methods:

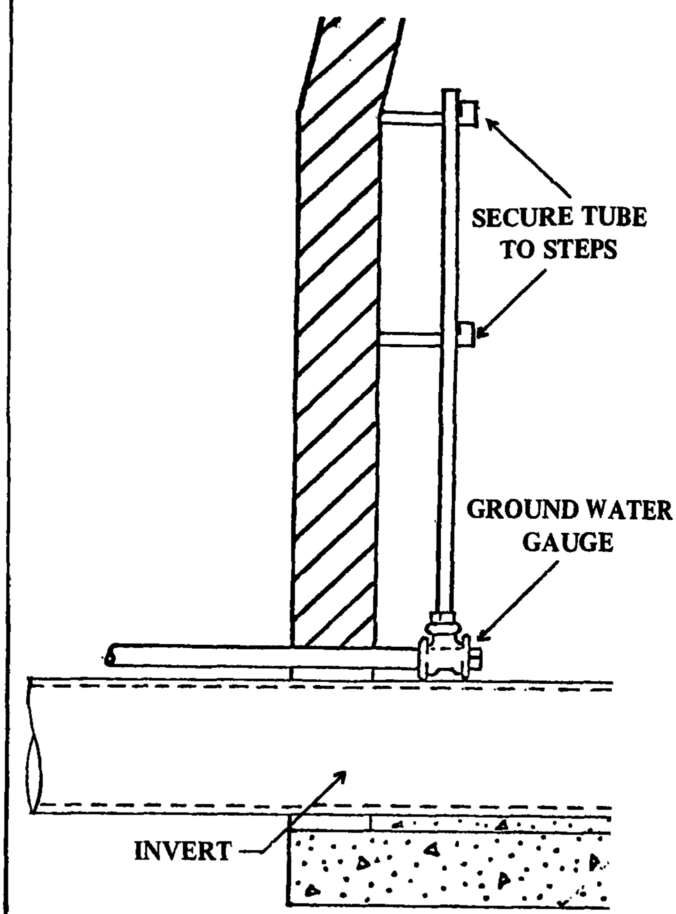
1. Measure depth and obtain velocity by timing floating material, appearances of dye, conductivity of injected salt solutions, radioactive tracers, or mechanical velocity measuring devices.
2. Utilize various types and shapes of calibrated measuring devices such as V-notch and sutro weirs and orifices.
3. Use electronic flow recorders that can transmit records to distant points.
4. Utilize photograpic installations that will automatically record levels of water behind weirs.
5. Install float-actuated devices that can record depths of flow.
6. Evaluate pumping records at all pumping stations, lift stations and treatment plants.
7. Make flow measurements at major metering installations such as Parshall flumes, venturi devices and wet well float meters at treatment plants.

Ground water elevations also should be obtained from ground water gauges installed in manholes where wet ground conditions are suspected. These gauges are like glass water level gauges in boilers, are permanently placed by inserting a pipe with elbow through the manhole wall, sealing it carefully, and attaching a visible plastic viewing tube with a calibrated scale behind it. Figure 3.3, Ground Water Gauge, shows a gauge in place. Water rises in the plastic tube to the height of the ground water outside of the manhole.

Ground water elevation is extremely important in planning an infiltration study. Unless the ground water elevation is higher than the sewer pipe, little actual infiltration – other than during storms – can be expected. Thus, gauging and inspection should be carried out on those sections located under the

FIGURE 3.3

GROUND WATER GAUGE



Courtesy of American Pipe Services Minneapolis, Minnesota

ground water table.

Ground water gauges should be inspected weekly for an extended period, such as an entire year, to determine seasonal variations. Inspection and gauging then can be planned for maximum conditions.

The amount of infiltration flow as observed within a pipe often can be judged when the head is known.

All of this information should be collected carefully, along with rainfall records for the area, and evaluated in terms of variations of dry-weather to wet-weather flows and time relationships to major storms. When compared with the theoretical computations and analysis of the drainage system as outlined in 3.3, a clear picture of the actual situation can be developed.

3.3.2 Rainfall Simulation

If the infiltration/inflow problem has been identified as rain-connected and the system is supposedly separate, a rainfall simulation in the *storm sewers* can help pinpoint the source. In this simulation study, storm sewers that are adjacent to sanitary sewers are plugged and filled with dyed water. If this water shows up in the sanitary sewer, there is serious infiltration or a direct inflow connection between the two systems. Further investigations, as described in Section 4, can be used to identify inflow.

The preceding step has illustrated a basic factor in such surveys – which is the identification of, and distinction between, infiltration and inflow. Although this section of the manual is devoted to the infiltration component, it should be emphasized that inflow is of equal or greater significance in some systems. For that reason it is suggested that when extraneous water flows are shown to be immediately sensitive to rainfall, an inflow investigation be made as described in Section 4.

3.4 PHYSICAL SURVEY OF SEWER SYSTEMS

In conducting a complete physical and lamping survey of the entire sewer system, every manhole is entered and sewers are examined visually for degree and nature of deposition, flows, pipe condition, etc. Manholes also are examined. Mirror and periscope devices can facilitate viewing lines, but it is imperative that someone physically enter each manhole. Very little information can be obtained by peering into even a shallow one. The proper safety checks for combustible gas, oxygen deficiency, etc., must be carried out prior to entry into any manhole.

If the static ground water gauges have not been installed, they should be placed during the lamping survey.

Smoke tests used in the inflow study also may reveal infiltration sources under low ground water conditions.

It should be emphasized that proper forms for recording field data, experienced survey personnel, and means for recording results on a visual plot map are essential for subsequent evaluation. If local staff personnel are not available, the consultant or the professional survey team can perform these duties and produce the data as well as analyzing them.

3.4.1 Effects of Poor Soil Conditions

Sewers constructed in poor soils may be subjected to settlement that will tend to open the joints or cause cracking of pipe, with subsequent infiltration or exfiltration. Because such settlement takes place over long periods of time and is accelerated as new construction in the vicinity of the pipe creates additional loads on the soils below the sewer, the failure of the sewer installation can occur after many years of satisfactory performance. This indicates that, as increased infiltration has been noted and poor soils conditions prevail, new construction along or above the pipe is subject to suspicion and investigation.

Man-made fill should be considered as poor soil unless the fill was placed under rigid construction control. This is especially true where fill has been placed on soft materials such as clay, swamp, tree roots, or debris.

An abrupt change of foundation conditions is often the cause of cracking. Pipes connected to deep manholes, the latter founded on harder material than the pipes, can spell trouble. A pumping station on pile foundation, with the sewer and adjacent manholes laid in soft soils, always is cause for suspicion.

Elimination of infiltration due to the above sources usually will require complete reconstruction of the affected portion of the system and should be based on a revised design. This design must include elimination of future settlements or the choice of pipe and joint type as well as use of pipe cradles and other means that will permit settlement without failure of the sewer system.

3.4.2 Effects of Ground Water Conditions

If the ground water level is at or above the sewer installation, the ground water can affect infiltration in two basic ways: attack on the pipe or joint materials, and an increase in the rate of infiltration once openings in the system have occurred for a variety of reasons, not necessarily connected with ground water.

Chemicals in the ground water, such as sulfates and organic acids, will attack certain pipe and joint materials. The rate of attack depends on the rate of flow through the ground and the resistance of the sewer materials to the attack.

The presence of ground water may induce electrolytic corrosion of metal pipes by stray currents. Correction depends on the degree and type of deterioration, and could involve replacement with different materials, external coatings, and cathodic protection.

Ground water has a very pronounced effect on infiltration after a sewer system has lost its water-tightness for any reason. Given a certain number and size of openings in a portion of the pipe system, infiltration will be influenced by the flow of ground water through the surrounding soils, the distance between the pipe and top of ground water surface (head), and the composition of the soils.

For soils of high permeability, such as gravel and clean sand which permit a high rate of ground water flow, the openings in the sewer will determine the rate of infiltration, together with the ground water head which dictates the hydrostatic pressure. Conversely, soils of low permeability such as clay may retard the rate of ground water entry through openings in the sewer; for example, a dense clay may seal openings and reduce or eliminate the effect of the hydrostatic pressure of the ground water at sewer level. The silt content of the soil can have a dual effect on infiltration; it influences the permeability but it can also increase the amount of solids entering the sewer lines with the ground water.

Trench backfill and bedding materials different from the in-situ soils should be taken into account in the above described considerations. Trench backfill can act as a ground water barrier or, on the other hand, as an artificially created undergound stream.

3.5 ECONOMIC AND FEASIBILITY STUDY

Equaling in importance the identification of infiltration is the evaluation of costs and benefits. Although frequently there are overriding health and environmental reasons for correcting infiltration, exfiltration and inflow, there may be situations in which the jurisdiction or agency has a choice between either accepting the extraneous flows and treating them, or eliminating them. Each choice has an associated cost and requires a careful analysis prior to any policy decision. Section 5 provides a detailed economic analysis that most communities can apply in arriving at meaningful conclusions.

The public works engineering staff or the consulting engineer should make this economic evaluation in conjunction with a review of existing design features that would indicate the system's adequacy. The current market value of the system also should be weighed to illustrate the magnitude of the investment which must be protected.

At this stage in the survey, fiscal decisions can be made to proceed with correction programs only if found economically and technically feasible. By this time, cost estimates can be developed for the subsequent correctional stages.

Generally, the pre-investigation will delineate those sections of the system where high ground water elevations, high flows, and defective pipe conditions indicate the possibility of more than average infiltration flows. Analysis at this point will enable the identification of the areas with the most infiltration and the drainage areas with less infiltration where the economics of the corrective actions dictate.

3.6 SEWER CLEANING

3.6.1 Initial Cleaning

A planned sewer cleaning program is essential for the following reasons:

1. Full capacities and self-scouring velocities are restored.
2. The difficult areas to clean are discovered. Areas indicating possible breaks, offset joints, restrictions, and poor house taps may require photography or television inspection.
3. The most economical method and frequency of cleaning can be established. This will permit more realistic annual budgeting.
4. Individual flow readings by weir or recorders will be more accurate in clean sewers.
5. Clean sewers are a necessary prerequisite for any television inspection program and correction sealing procedures.

Through past experience it has been found that many municipalities are not equipped or experienced enough to clean sewers adequately in preparation for inspection by closed-circuit television or sealing by pressure injection of sealants. Closed-circuit TV is used basically to inspect the pipe line to determine whether or not there are any structural failures, misalignment, or points of infiltration. In this phase, small amounts of debris left in the bottom of the line, such as sand, stone, or sewage solids, may not interfere with a good inspection except in pipe of less than 10 inches in diameter. However, initial cleaning preparatory to inspection should be done more thoroughly than for routine maintenance. A full diameter gage or "full gauge squeegee" should be passed through the sewer to insure optimum cleanliness.

Where repairs are going to be made by means of internal pressure injection, it is also important that all such deposits be removed. Two basic problems that will result from debris left in the line are (1) the damage that would be done to the inflatable ends of the sealing machine or packing device, and (2) inability of inflatable ends to create the perfect seal required during the pumping period of sealants and for pulling the sealing device through the line.

It is desirable to have little or no flow within the sewer lines during the inspection or pressure sealing. In most cases it is not possible to achieve this condition. It has been found that flow depths of one-third of the pipe or less are tolerable in the performance of these services. It should be understood that inspections under submerged conditions will give questionable results.

3.6.2 Sewer Cleaning Plan

OBJECTIVE:

Sewer pipe cleaning in preparation for television, photography or internal injection

PRE-CLEANING INSPECTION:

Determine condition of pipe to be cleaned and type of equipment to be used.

CLEANING EQUIPMENT:

The equipment can include, but not be limited to:

1. Rodding Machine – sectional rodding machine with 36-inch, 39-inch or 48-inch sectional rods either 5/16-inch or 3/8-inch diameter – hydraulically or mechanically powered.
2. Rodding Machine – continuous rodding machine with a minimum of ;375 diameter rod.
3. Bucket Machine – 10.5 hp up to 100 hp; buckets 6 inches up to any size for cleaning round or square box sewers.
4. High Velocity Water Machine – air or water-cooled power plant; sewer cleaning hose 3/4-inch minimum with operating pressure up to 1500 psi; maximum pressure at the pump.
5. Hydraulically Propelled Devices or Cleaning Tools – with or without harness.

CLEANING OPERATION:

The actual cleaning operation and the type of equipment selected generally is determined by the size and condition of the pipe to be cleaned. Ordinary conditions in most cases may require the use of more than one type of equipment or a combination of more than one piece or type of equipment. These can include, but not be limited to, the following:

1. Rodding machines, either sectional or continuous, can be used to clean the pipe in preparation for final inspection prior to grouting; however, under severe cleaning requirements they are used primarily to thread the sewer or pipe line for cleaning operations and use of bucket machines.
   There are many tools that can be attached to the front of the rod which will effectively remove debris, such as heavy conglomerates of grease, root intrusions, etc. The rodding machine also can be used to pull such cleaning tools as a stiff wire brush or swab, to clean light debris from within sewer lines. It should be noted that with those two tools, a tag line connected to a bucket machine should be used in order to pull the swab or brush back if adverse conditions are encountered.
   It is necessary that in the above type of cleaning methods a head of water, like that which could be furnished by a fire hydrant, should be used to help propel the solids within the sewer line to the downstream manhole.
2. Bucket machines provide a positive means of cleaning pipe. Their operation allows a positive connection of cable from one manhole to the other, with applicable power to pull a bucket loaded with sand or gravel back to the manhole for dumping on the street, into a container, or truck bed (if a truck loader machine is used). This method of cleaning removes solid materials such as sand, gravel, and roots, and renders the pipe clean for sealing if followed up with a stiff wire brush and swab or squeegee.
   It is important that final cleaning tools be as close to pipe size as possible to obtain the necessary results preparatory to a good grouting job.
   It also is necessary that a sufficient amount of flushing water be available during the final cleaning operation, to scour and flush the pipe.
3. The high velocity or hydraulic pipe cleaning machine is mobile and provides a fast and, under most conditions, effective cleaning. Operation of this machine with a specially designed cleaning nozzle will produce a cleaning or scouring action from streams of water directed to strike the inside wall of the pipe under high velocity. As a result of the jet action from the rearward orifices, the cleaning nozzle and hose is propelled forward. As the hose and nozzle is pulled back to the manhole, the high velocity spray produces a hydraulic rake effect bringing the debris back to the manhole. Care is necessary in using hydraulic cleaning equipment. In sandy soil where the sewer may be defective. creation of voids may cause collapse of the pipe.
4. Hydraulically propelled cleaning tools are placed in the pipe with the proper tolerances between the outside diameter of the device and the inside diameter of pipe. Water is put

into the manhole or sewage is allowed to build up behind the ball to produce a head of pressure moving the device down the sewer line and allowing some water to escape. With the rush of water, turbulence is created to cause sand or solid materials to go into suspension, thereby moving down the line. Caution must be used in the operation of these devices because the water pressure created behind the ball can affect bad joints in the pipe. The pressure may in some cases damage private property because of water entering basements through house laterals.

CLEANING EXAMPLE:

A 12-inch line with severe sand, gravel, and root intrusion will require the use of bucket machines and flushing equipment or a high water velocity machine. In some cases where roots are the main problem, a rodding machine with a saw or auger-type cutter may be required, with a follow-up wire brush tool to clean the pipe. In every case a swab-type tool incorporating a rubber disc to clean or wipe the pipe to the full pipe diameter can be used to free the inside pipe wall completely from any obstruction. This is not only important to effect the proper application of the sealants; it will prevent possible damage to the inflated rubber ends of the sealing machine or packing device and create the perfect seal required during the pumping period of the sealants.

3.7 TELEVISION AND PHOTOGRAPHIC INSPECTION

As a result of the findings of the previous stages, the best utilization of television or photographic inspection can now be determined. Arbitrary use of these techniques without pre-planning and budget review is not recommended. The most economical results are not achieved on a random basis. These techniques are useless when flows in the sewer exceed one-third of the depth.

The following are some of the more pertinent factors associated with TV and photography:

3.7.1 Reasons for Inspection

a. As part of a planned sewer system restoration as outlined in the previous stages.
b. As assurance of sound underground facilities prior to a "permanent surface" type paving program.
c. For the inspection of new construction prior to final acceptance.
d. To determine deficiencies in "troubled areas".
e. To pinpoint the cause, source, and magnitude of infiltration problems.

3.7.2 Methods of Inspection

a. Draw the camera through the sewer and record deficiencies on forms, polaroid pictures, stereo slides, video tape, and/or movie film. Take shots of adjacent "typical" sound pipe for comparison purposes so that the degree of the deficiencies may be ascertained. Locate pertinent features.
b. Record results of the study and draft final report.
c. Summarize and analyze, and recommend corrective measures.

3.7.3 Testing and Sealing

A variation of the above mentioned method is to use television and a testing device. Upon visual inspection of a potentially leaky joint, the testing device is pulled over the joint and a pressurized test made. If the test indicates defects, sealing is accomplished immediately. The cost of this method may be high, although the cost of two setups, one for inspection and then for sealing should be evaluated.

This method of "grouting as you go" does not allow an economic and engineering analysis of the optims which are available such as replacement of the sewer or sealing only those defects which allow major contributory flows.

3.7.4 Results of Inspection

a. Location of sources and magnitude of infiltration.
b. Location and extent of structural deficiencies.
c. Accurate location of wyes, taps, manholes, lampholes, surreptitious connections of any kind, cross-connections to the storm sewer, and any other physical features of consequence:

3.7.5 Benefits of Inspection

a. Provides the information necessary for the drafting of a sewer system map or the updating of an existing one.
b. Enables the engineer to recommend the redesign, reconstruction, rehabilitation, repair, or replacement of any specific part or parts of the system.
c. Provides a permanent written and pictorial record of the system which can be utilized at any time.

3.8 RESTORATION OF THE SEWER SYSTEM

Based on the results and recommendations of the inspection report, sound budgeting and planning for the restoration of the system can now be achieved. The engineer can now appropriately decide how to correct the structural deficiencies and eliminate the infiltration. The following is a suggested approach:

3.8.1 Structural Deficiencies

a. Take into consideration the age, type, and depth of the pipe and the severity and extent of the damage.
b. Depending on the engineering and economic evaluations, either repair the pipe on a partial basis or replace the entire section between manholes. (The economic evaluation must include the cost of repair of the roadway surface.)
c. Isolated or minor damage may be tolerable or corrected at nominal cost.
d. It is obvious pavements should not be placed over damaged or defective pipe. Remember that marginal damage could become severe before the life of the pavement expires.

3.8.2 Infiltration

a. In a structurally sound pipe, most infiltration can be eliminated by the internal injection of sealants. This method of repair precludes excavation. Frequently this internal sealing is performed simultaneously with internal testing, as described in 3.10.3.
b. Weigh the cost of sealing against the cost of treating this extraneous water.
c. Think in terms of the hydraulic load placed on the collection system and on the treatment plant. If, during periods of high static head, the treatment plant must be by-passed, compute the cost of plant expansion to handle these peak loads.
d. Consider the fact that small leaks may become larger with the passage of time and/or increase in static head.
e. Compare grouting costs with partial and total replacement costs.
f. Define those sources of infiltration that could be considered livable.

3.8.3 Correction Alternates

a. Replacement of broken sections.
b. Insertion of sleeves or liners.
c. Internal sealing with gels or slurries.
d. External sealing by soil injection grouting.

3.8.4 Building Sewers

An internal grouting method for eliminating waters of infiltration from building sewers has been devised. A pilot project recently completed by American Pipe ervices indicates how sealing may be accomplished if economically desirable.

The first step in the process was to identify the building sewers that were leaking by the use of closed circuit television in the mains. It must be determined whether observed flows are from domestic usage, footing drain tile discharge or as a result of exfiltration from a flooded storm sewer and subsequent infiltration into the building sewer which crosses under the storm sewer.

Domestic usage can be determined by a check of the house at the time of TV inspection to make sure no water is being used and that there are no cooling waters or cistern over-flows discharging to the system.

Footing drain tile contribution can be eliminated from consideration by knowing what the elevation of the ground water table is in the study area. This is done through the use of groundwater gages installed in the sanitary manholes nearby. If the groundwater table is higher than the footing drain tile a check for building sewer infiltration should not be initiated until the groundwater subsides.

If the discharge from the building sewer can be directly attributable to rainfall connected infiltration as a result of flooding storm sewers, internal grouting can be used if an economic analyses indicates a favorable cost-benefit ratio. There must be enough infiltration, either joint leaks and/or building sewer leaks, in a specific run of pipe to make the cost of both camera and packer in the line at the same time worthwhile.

If the economic analyses indicates the advisibility of sealing, the camera-packer tandem is placed in the street sewer with the camera pulled into a position such that it can view the building sewer discharge. Simultaneously, the adjacent storm sewer is re-flodded. When the infiltrating water appears in the sewer a technician is sent into the connecting house basement where he inserts a small inflatable bag into the service cleanout and pushes it all the way out to the main where the camera can view it. It is then retracted toward the house in two foot increments being inflated and deflated at each increment. Initial inflations will stop the water from getting to the main, but eventually the bag will be retracted to a point where the full-flow infiltration will again be evident. At this point the bag is left inflated in the building sewer. Then the grouting "packer" in the main is positioned with its anular opening over the house service connection and inflated. Grout is pumped into the building sewer until sufficient pressures have been reached. The catalyst is triggered and the grout gels. At this point the "packer" is deflated and moved away from the building sewer and the bag in the building sewer itself if deflated and removed. A domestic type sewer cleaning machine is employed through the house sewer cleanout to remove the gel from the line and the sealing process is complete.

The cost range for this procedure has been found to vary from $200 to $500 per house service, depending on the number of services per manhole setup and the amount of chemical used. It also has been found that it is not economically justified to seal building sewers when the infiltration flow is less than 10 gpm. In some areas replacement of the building sewer may be more economical than internal sealing.

3.9 TREATMENT PLANT DESIGN CRITERIA

Besides the obvious advantages of restoring needed capacities and reducing costs and pollution, the final study goal of the complete restoration program is the more accurate estimate of hydraulic loading for future plant design. The design criteria will be tempered by the knowledge that nominal and predictable amounts of extraneous clean water can now be anticipated.

The accomplishments and benefits of pursuing a logical, orderly program for infiltration/inflow correction can be listed as follows:

1. The sewer systems can now be reasonably maintained, usually at lower unit costs. Annual budget needs can be accurately and realistically projected.
2. Serious structural deficiencies will be corrected.
3. Any subsequent paving programs can be carried out with reasonable assurance that the sewers will not require repair at a later date and can easily be maintained.
4. The waste water treatment plant, lift stations, and other facilities will be of adequate size to serve present and projected needs.
5. Treatment or pumping costs in the future will be reduced as much as possible.
6. Infiltration volumes will be reduced to a minimum.

SECTION 4

METHODS FOR CONTROLLING THE DISCHARGE OF INFLOW WATERS INTO PUBLIC SEWER SYSTEMS

SECTION 4

CONTROLLING DISCHARGE OF INFLOW WATERS

4.1 GENERAL

Discharges of excessive amounts of non-sanitary wastes into public sewers is a costly misuse of such sanitary systems. Included in such extraneous waters are inflows from various sources through deliberately connected pipes and drain lines. Separate sanitary sewer systems are most seriously affected by such inflows. Combined sewers suffer in somewhat lesser degree, and storm sewers are designed for these flows.

Elimination of inflows of such waters, by preventing and correcting direct discharges through pipe connections, is in the best interests of dependable and economical service from sewer networks and appurtenant waste water facilities. Inflow waters which have their sources in urban structures and other practices are not "polluted," in the sense that thay would require prompt removal from the urban environment and subsequent treatment to prevent the degradation of watercourses into which they are discharged. In the case of separate sanitary sewers, the use of carrying capacities to handle such waste waters is unnecessary and costly. For the purpose of providing proper and safe drainage of such waters from private properties, their discharge into storm sewer systems is more appropriate.

National experiences have demonstrated the advisability of following general guidelines for handling the extraneous waters (referred to in this Manual as inflow) in the design, construction, and management of public sanitary sewer systems:

Roof leader connections – excluded.

Foundation and most areaway drain connections – excluded.

Basement drain connections – permissible under certain circumstances.

Residential, industrial, commercial cooling water connections – excluded.

Other so-called "clean waters" – excluded.

Certain industrial-commercial wastes – permissible when controlled and authorized.

It is the purpose of this section of the Manual to set forth general policies and lines of action by jurisdictions for:

1. Determination of causes and effects of inflow waters in sewer systems.
2. Detecting and locating sources of inflows and determining their conformity with jurisdictional regulations.
3. Planning workable and equitable prevention and elimination of such waste water connections, where necessary.
4. Establishment of official sewer-use ordinances, codes and regulations upon which jurisdictional actions can be taken to (1) prevent future inflow connections and (2) eliminate existing inflows detrimental to the capacities and capabilities of sewer systems, pumping and treatment facilities, and other system appurtenances.

4.2 CAUSES, EFFECTS AND CONTROL OF INFLOW

Sections 2 and 3 of this Manual relate to the problems of infiltration. It is necessary here to draw the distinction between the responsibility for actions taken to control infiltration and for similar actions to prevent and eliminate excessive inflow into sewer systems.

The sources of infiltration are generally within the control of the jurisdiction. The causes are the responsibility of the jurisdiction, in terms of design, choice of materials, construction control, operation, and soil and water conditions in which the sewer is laid and functions. The responsibility for decisions in infiltration prevention and correction is totally the jurisdiction's, as is the necessary action to eliminate the detrimental effects of excessive infiltration.

On the other hand – with the exception of inflow through manhole covers – the sources of *inflow* are, for all intents and purposes, from the properties of private individuals and organizations. The causes are their responsibility, except where these have been authorized or condoned by official actions. The responsibility for making decisions on prevention and elimination of inflows may rest with the jurisdiction; but real action will depend on total or at least partial participation and expenditures by property owners.

Inflow control is involved with other distinctions. As a basis for corrective actions, it must be determined if such connections have been made legally or illegally – with approval or condonement on the part of the jurisdiction, or illicitly and surreptitiously. A further distinction must be drawn between the types of sewers into which such inflows intrude, with entry into storm sewers normally acceptable and into combined sewers acceptable under certain conditions.

The overall effects of inflow are much the same as those attributable to excessive infiltration: usurpation of sewer system capacities; local area and private property flooding; surcharging of, and deleterious effects on, pumping and treatment installations; increases in combined sewer overflows, and increased pollutional loadings on receiving waters.

However, there is a distinction between the volumetric and peak effects of inflow and infiltration. It offers opportunities to differentiate between sources of these two types of extraneous water flows in existing sewer systems when the two waste waters are commingled and generally indistinguishable from each other. Inflow volumes increase and decrease more markedly than infiltration flows, except in the case of inflows due to certain industrial and commercial "clean water" discharges.

The sources of actual inflow drainage are similar to infiltration sources: the soil and ground water therein. Inflows occur more rapidly following precipitation conditions due to roof runoff. The imperviousness of roof surfaces simulates urban areas such as roads, streets, parking lots, and other surfaced facilities. Inflows due to areaway and yard drains occur rapidly, and even basement and foundation drains may produce peak flows of inflow waters more rapidly than the slower reaction of sources of infiltration to ground water table changes.

Exclusion of inflow waters from sanitary sewers is general practice, or at least a general goal, in jurisdictions in the United States and Canada. This was the disclosure of the 1969–1970 national investigations and research studies. This general statement is especially true of those systems which have taken cognizance of this problem, have established specific policies, and have taken actions to control the effects of this type of waste water intrusion. It is necessary to draw this distinction because many jurisdictions have established no such policies, enacted no such regulatory practices, or have taken a permissive attitude on inflow connections by overlooking or condoning conditions directly affecting the serviceability of sewer systems and appurtenant facilities.

The case for inflow control is clear. The effects on sewer system management are unmistakable, but no broad policy can cover all circumstances in all local jurisdictions. Inflow conditions are the product of local phenomena and policies. They reflect building practices, including the use of basement or other sub-grade building areas or the adoption of on-slab construction; soil and ground water conditions; precipitation experiences; climate, as it applies to extensive air conditioning, and industrial-commercial developments in any area, followed by the generation of so-called "clean waters" from processing operations. Proof of the interlocking effect of a wide range of jurisdiction conditions on inflow sources and rates is found in the fact that availability of unrestricted amounts of public water supply and the price thereof influences the production of such "clean waters" in industrial and commercial operations.

The upshot of these interlocking effects is that inflows into jurisdictional sewer systems do not occur in a governmental vacuum. They result from policies and practices in other phases of urban life, including not only sewer-use regulations but building code and plumbing code provisions; control of industrial-commercial construction by means of zoning; water supply policies and pricing structures; availability of storm sewer connections, and other factors too varied to enumerate.

Inflow control practices by jurisdictions are affected and influenced by location of storm sewers in relation to property tie-ins, the geology and the terrain of the community, local governmental actions on control of ground water levels by draining and topographic control. All of these factors must be examined and evaluated by each jurisdiction which has not yet established policies on inflow control or taken adequate actions to enforce regulations already in existence.

While this Manual urges the prevention and control of excessive inflow into sewer systems, particularly sanitary sewer facilities, it also stresses the need for local decisions based on all local conditions. Evaluation of all these local factors is the first step in any inflow control program. The burden of proof is to *prove* that inflow is detrimental and that control is a foregone necessity if these adverse effects are to be prevented and corrected. What about the traumatic effect on the public of any sudden decision to eliminate long-standing inflow sources? It dictates that jurisdictions take actions based on this type of evaluation of local conditions and on findings that control needs are indisputable. In some cases, the value of inflow has been advocated by some engineering and operation personnel during prolonged dry periods, on the basis that such extraneous flows inhibit sewer septicity and odor conditions.

These are the general factors involved in the causes, effects, and means of control of the inflow problem. No specific limits can be established for inflow, such as the goals proposed for reduction in infiltration allowances; the factors involved are too indeterminate to permit the setting of determinate guidelines. No built-in limits can be set for allowable inflow, except in terms of broad policies covering certain permissible connections – such as basement drains entering sanitary sewers because of the nature of the waste waters generated by in-structure operations.

Certain sources of inflow can be exempted from prohibitory regulations, such as basement drains and, under certain circumstances, some types of so-called "clean water" discharges. Whether certain exemptions are permitted or not, policies must be firmly set and enforced without favoritism.

4.3 LOCATION AND DETECTION OF SOURCES OF INFLOW

Control of inflow, like control of infiltration, resolves itself into two practices: prevention of new inflows, and correction of existing inflows deemed detrimental to sewer systems and wastes handling and treatment work.

Prevention involves exclusion of inflow connections by edict, and the rejection of any such flows when new structures are built or present building operations modified and their plumbing and drainage lines installed. Correction involves the location of existing sources and their elimination by physical separation of any such connections in accordance with set policies of the jurisdictions.

Elimination of existing inflow connections is not merely a simple procedure of locating these sources and ordering them discontinued. Not only are search and surveillance procedures difficult, but matters of principle are involved:

1. Have such connections been made in violation of existing regulations? In this case no official record of these connections will have been filed, and no record of their nature, size, and location will be available.
2. Have they been made in accordance with authorized actions by the jurisdictions or their agencies? In this case all pertinent information on these drain connections may have been mapped and recorded.
3. Have they been installed in the absence of local prohibitions and/or with uncontrolled permissiveness of public officials? In this case their existence may or may not be recorded and their sources listed in building or plumbing plans, or in other drawings in the possession of property owners.

Locating approved and recorded inflow connections is relatively simple. It involves examination of building connection plans and permits an on-site check of their actual installation and conformity with jurisdictional authorization. If decisions are made to eliminate previously authorized inflows because subsequent effects on sewer systems have been greater than originally anticipated, a careful search may be required to determine if the connections are serving only the purposes intended and authorized. This may involve gauging of inflow volumes and testing of inflow composition. Gauging and testing may require the location of the points where inflow connections are made. This may be directly into the building or "side sewer" at the building line; at some point in the run of the building connection between the structure and the street sewer wye, or through a separate drain line which enters the street sewer independently.

Similar search-and-find procedures can be followed for all inflow connections which have been installed without or in the absence of code requirements but with the provision that all such connections be indicated in applications for plumbing or building permits. The problem in such cases is to make certain that all inflow lines have been recorded and that the sources of inflow waters are known and traceable. This problem points out the importance of prohibiting multiple-property drain connections to a single building sewer line. Such multiple connections make it difficult, if not impossible, to place specific responsibility for excessive inflows on any one of the connected structures.

The problem of locating illicit, surreptitious, and unlisted inflow connections is a more difficult one. It involves painstaking inspections and investigations of all plumbing and drainage lines by expert persons and the tracing of buried lines back to their original sources. Every such source must be held suspect until the point of discharge is located, either by tracing piping plans or by detection methods.

In residential and related types of structures the inflow sources are relatively few and less complicated, but in industrial and commercial buildings they can be more difficult to locate and evaluate.

Each jurisdiction must choose and use its own techniques. This Manual can list only some of the possible procedures:

1. Tracing roof leader connections with dye,

pieces of paper, plastic chips, or confetti; corks of varying colors placed in roof gutters, the colors indicating specifically designated buildings; chemicals such as salt, with tests for chlorides in runoff water; use of safe radioactive tracer materials of short-life character, checked with Geiger counter-type equipment, and other appropriate detection methods. They all involve the observation of sewer lines in the vicinity of the structures being investigated. Observations can be made during storm periods or in flows induced by water discharged onto roofs.

2. Tracing foundation drains by introduction of dyes or chemicals into the ground surface around the building being investigated, or by injection of such tracer materials into the ground at the foundation or footing level. Such procedures must be followed by tests or observations in sewer lines, as suggested in (1).
3. Tracing basement drain connections by locating in-structure sources of such inflow waters and introducing tell-tale materials which can be detected in receiving sewers.
4. Applying tracer materials such as dyes or chemicals, in areaways or areaway drains, and introducing flows into them by hose connections or waiting for storm flows to flush the tell-tale materials into adjoining sewers.
5. Applying tracer chemicals, radioactive tracers, or dyes to industrial and commercial equipment, such as water-using air conditioners, refrigeration units, stack-washing pits, or other wet-processing points where drainage water is suspected of being connected to sewer lines. This must be followed by suitable detection means in street sewers, in manholes or other chambers located on such commercial-industrial property.
6. Application of smoke bomb tests in street sewers, followed by observations of the appearance of smoke plumes at building roofs, in basement and areaways, at industrial and commercial connections or building vents, or from the ground in the area of foundation drains.
7. Actual excavation of building lines suspected of being illicitly connected to public sewers. This must be considered as a last-resort measure in any inflow investigation.

4.4 REMOVAL AND ELIMINATION OF INFLOW CONNECTIONS

Decision on removal and elimination of inflow connections may be based not only on the existence of such connections but also on the amount of inflow volumes contributed to sewer systems. Determination of the volume of inflow is difficult and often impossible. These volumes change with climatic and meteorological conditions, ground water levels, and variations in industrial and commercial "clean water" disposal operations. These factors must be considered when tests are planned and undertaken.

Gauging of inflow volumes can be made, when applicable, by use of the types of procedures described in Section 3 of this Manual, covering correction of infiltration conditions in existing sewers. Points of gauging must be chosen specifically to locate the sources of inflow and pinpoint the structure generating such waste waters.

Methods for removal and elimination of existing inflow connections will depend on local conditions; on whether they were made without specific approval but with permissive failure of jurisdictional officials to provide proper control; on whether they were made illegally in contravention of regulations; on whether other conditions prevailed at the time of their original connection or at the time removal actions were instituted.

In the case of illicit connections, property owners can be ordered to discontinue such lines, and a fair and reasonable period can be set for the necessary corrective action. The cost should be borne by the violator, but there is some responsibility on the part of the jursidiction to suggest and/or provide alternate means of inflow-water disposal. This problem will be compounded if no existing storm sewer system is available to receive drainage or industrial-commercial waste waters which cannot be safely and adequately handled on the site.

While it is inadvisable to offer firm guidelines for such disposal procedures, the following methods have been applied with some success in representative jurisdictions:

1. Discharge of roof leader drainage onto property for seepage into soil. Roof leaders should be extended for an adequate distance beyond building walls to prevent the rapid percolation of such waters into the soil and thence into the ground water table around the foundation, where it adds to the drainage problem from this source. A distance of 5 to 10 feet has been specified in some jurisdictions.

2. Discharge of roof drainage in built-up areas into street gutters.[1] Many jurisdictions prohibit the discharge of roof drainage onto sidewalks or property areas which will drain into public streets and cause pedestrian hazards. In such cases, local regulations often require the piping of roof drainage water under the sidewalk and directly into the gutter area.
3. Discharge of roof drainage, areaway drainage, yard area drainage, or foundation drainage into storm sewers or into surface ditches in rural and suburban areas.
4. Discharge, under certain conditions, of basement drainage into sanitary sewers or combined sewers, rather than storm sewers, in order to prevent pollution of the latter with in-structure waste waters which require treatment.
5. Reclamation and reuse of clean industrial and commercial waters, such as air conditioning and refrigeration cooling waters, and other unpolluted process waters for other on-stream purposes. These steps reduce the water consumption demands of such structures and eliminate large volumes of avoidable inflows into sewer systems.
6. Connection of clean water discharges to storm sewers, or discharge of such unpolluted waters into nearby watercourses.
7. Internal on-stream separation of so-called clean waters produced in industrial and commercial operations, from industrial wastes which can be discharged into sanitary sewers if such wastes are deemed amenable to transportation and treatment with sanitary sewage flows. Once such clean waters are admixed with industrial-commercial wastes which require treatment, they become an inseparable part of the total flow and must be accepted in sanitary sewer systems which admit such industrial wastes.
8. Disposal of industrial-commercial inflow waters with industrial wastes in company-owned treatment facilities, in cases where such installations decide to go it alone in the handling of their wastes.

Under any circumstance, acceptance of industrial or commercial process wastes in public sewer systems must be based on the ability of sewer systems to transport, and treatment works to handle, such wastes without damage to physical structures, impairment of waste treatment processes and facilities, and danger to operational personnel. It is the function of a sewer-use ordinance to stipulate the types of wastes amenable to handling and treatment, on the basis of quality and quantity, and set forth the basis of charging for such sewer service.

These are some of the ways in which a jurisdiction can accomplish the elimination and control of inflow. Since it owns the sewer system, the jurisdiction has ministerial responsibilities and police rights to invoke fair and equitable standards for the acceptance of inflow waters; exclude them if the public interest so dictates, and impose costs for corrective actions. However, the rule of reason must prevail in establishing policies, in imposing costs, and in determining who pays or shares in the cost of corrective actions:

1. If inflow connections have been permitted and it is then found that elimination of these connections is needed to overcome the deleterious effects oulined above in this section and in Section 1 of this Manual, part or all of the costs involved may have to be borne by the jurisdiction.
2. If inflows were allowed by permissive policies of the jurisdiction, either because no prohibitions were enacted or were allowed by nonenforcement policies, part of the cost of elimination may rightly be a charge against the community.
3. If illicit connections were made in violation of known rules or regulations, the total cost of corrective actions should be paid by the property owner, or the builder if the latter can be held responsible.

It is again stressed that decisions must be based on local conditions and pertinent factors. Public support and participation will be needed in all such corrective programs because of the costs and inconveniences involved. Jurisdictions are urged to carry out carefully planned and judiciously executed corrective programs to assure public compliance and cooperation.

Every available means should be used to win friends and influence people. Meetings with individual property owners, citizens' groups, or local improvement organizations should be held to explain the reasons for corrective actions and the public benefits that will result from inflow control. Every communication device should be pressed into service,

[1] Some local codes prohibit the practice, and require connection to the storm drainage system or even the sanitary sewers to reduce problems of erosion or icing of sidewalks.

including radio, television, the press, bulletins and brochures, motion pictures and slide presentations, lectures and face-to-face confrontations.

Samples of informational material used by some jurisdictions for this purpose are contained in Section 9.

Special problems of inflow control – and of infiltration control – confront multi-community, regional, or district sewer systems. A jurisdiction may have police and ministerial control over the use of its sewers by its own residents yet find that it is powerless to regulate sewer uses in communities contributing waste water flows to the system operated by the primary jurisdiction.

In such cases, the incentive for such contributory communities to prevent and eliminate excessive inflows must stress local benefits, in terms of better community sanitation and lower costs of sewer service. The jurisdiction which renders interceptor and treatment service to such satellite communities can:

1. Point out the hazards of local flooding and property damage due to sewer lines surcharged by inflow and infiltration.
2. Impose rules which must be enforced by contributing communities if their wastes are to be accepted and handled by the recipient jurisdiction.
3. Establish charges for handling contributed flows, based on volumes of flow – thereby placing a penalty on uncontrolled intrusion of excessive amounts of extraneous waters.
4. Use any other means for accomplishing inflow control, either voluntary or compulsory, and for bringing the importance of the problem to the officials and residents of contributing communities.

4.5 ESTABLISHMENT OF OFFICIAL POLICIES BY SEWER-USE ORDINANCES AND REGULATIONS

The establishment of sewer-use laws, rules, regulations, or codes of practice must be the basis for enforcement actions. Such regulations remove doubts and indecisions as to jurisdictional policies; apprise builders, developers, and property owners of their rights and responsibilities; guide installers and suppliers of sewer, building, and plumbing facilities in their operations; establish standards for engineering and architectural designers, and assure uniform treatment for all persons and organizations.

Enactment of such ordinances, codes, or regulations is strongly urged. For this reason, this Manual presents excerpts from sewer regulations of representative jurisdictions in the United States and Canada. These excerpts have been chosen from scores of workable ordinances and rules for the purpose of offering guidance to jurisdictions considering enactment of initial regulations and those intending to modify and modernize their practices and policies.

These excerpts have been divided into two parts: (1) quotations from ordinances relating specifically to connection of so-called inflow waters from residential, commercial, and industrial structures, and (2) code terms referring to the discharge of industrial and commercial process wastes which, if amenable and allowable, become an integral part of the sanitary sewage flow of a jurisdiction and, as such, are handled as an admixture component of its total waste water flows.

The excerpts in part 1 are given below, under appropriate headings. The regulations relating to industrial wastes discharges are contained in Section 9 because of their significance to the problems of waste-water discharge and handling from such sources, over and above the inflow waters that must be minimized or totally eliminated.

4.6 SELECTED EXCERPTS FROM SEWER-USE REGULATIONS

4.6.1 Drainage Connections Prohibited

"Storm waters, surface waters, ground waters, roof runoff, subsurface drainage, cooling waters or other uncontaminated waters shall not be admitted into any sanitary sewer but shall be discharged into such sewers as are specifically designated as storm or combined sewers or to a natural outlet." – *Kansas City, Missouri.*

"No person shall discharge, or cause to be discharged, any storm water, surface water, ground water, roof runoff, subsurface drainage, uncontaminated cooling water, or unpolluted industrial process waters to any sanitary sewers." – *Cedar Rapids, Iowa* and *Jacksonville, Florida.*

"No person shall discharge, or cause to be discharged, any storm water, surface water, ground water, roof runoff, subsurface drainage or cooling water, such as from boilers, air conditioning systems and the like, to any sanitary sewer." – *Knoxville, Tennessee.*

"No leaders from roofs and no surface drains for rain water shall be connected to any sanitary sewers." – *Enterprise Public Utility District, Shasta County, California.*

"No person shall make connection of roof downspouts, exterior foundation drains, areaway drains, or other sources of surface runoff or groundwater to a building sewer or building drain which in turn is connected directly or indirectly to a public sanitary sewer." – *Rome, New York.*

"No person shall cause or permit the roof water downspouts of any building or surface or ground water drains in or about any building, to be connected into, or to remain connected into, and soil, pipe, drain, or lateral sewer tributary to any sanitary sewer of the city, or shall cause or permit any other physical condition to exist in, on or about any building, or in the yard around any building whereby either the roof water or surface water, from or about such building is caused or permitted to flow into any soil, pipe, drain or lateral tributary to any sanitary sewer of the City." – *Akron, Ohio.*

"It shall be unlawful for any person to discharge the contents of a swimming pool into a sanitary sewer." – *Enterprise Public Utility District, Shasta County, California.*

4.6.2 Methods and Points of Disposal Specified

"Storm water, cooling water and all other unpolluted waters shall be discharged to such sewers as are specifically designated as combined sewers or storm sewers, or to a natural outlet approved by the City Engineer." – *Jacksonville, Florida.*

"Storm water and all other unpolluted drainage shall be discharged to such sewers as are specifically designated by the City as combined sewers or storm sewers. Cooling water may be discharged with approval of the City to a storm sewer, combined sewer or natural outlet." – *Knoxville, Tennessee.*

"Storm water and all other unpolluted drainage shall be discharged to such sewers as are specifically designated as combined sewers or storm sewers, or to a natural outlet approved by the Water Pollution Control Superintendent. Industrial cooling water or unpolluted process waters may be discharged, on approval of the Superintendent, to a storm sewer, combined sewer, or natural outlet." – *Cedar Rapids, Iowa.*

"No person shall suffer any particular drain from any building or land of which he is the owner or occupant to leak or be out of repair; and no person shall, except in accordance with a permit from the Commissioner of Public Works, enter or attempt to enter a particular drain into a public drain or sewer." – *Boston, Massachusetts.*

"Rain water from roofs or other approved areas exposed to rain water may be drained into the storm drainage system, or the combined sanitary and storm water drainage, but shall not drain into any sewer intended for sanitary sewage only. Rainwater from roofs or other approved areas exposed to rainwater may drain into a public street gutter, provided that such gutter is paved and runs to a catch basin connected to a public storm drain, and provided further that such drainage has the approval of the City Engineer or other public authority having jurisdiction over public streets or public storm drains." – *Burlingame, California.*

"Paved areas, yards, courts, courtyards, public garage drainage areas and all other areas not having natural drainage, and building roofs as required by the Irving Building Code, shall be drained into the storm sewer systems where such systems are available; otherwise, they shall be drained to a lawful place of disposal approved by the City Engineer. When rain water from any roof is conducted underneath the sidewalk to the street curb, the pipes under the sidewalk shall be of cast iron with an area equal to twice that of the downspout or a concrete trough may be used which shall be fitted with a cast iron cover held in place with non-corrodible screws and such covers shall be made preferably in one piece and shall be set flush with the surface of the sidewalk. Storm water shall not be drained into sewers intended for sanitary sewage except by special permission of the Chief Plumbing Inspector." – *Irving, Texas.*

"For residences, multiple residences, churches, schools, hotels, motels, industrial and commercial buildings, planned developments, hospitals and all similar installation and appurtenances thereto: Storm plumbing outlets, downspouts, parking lot drainage, footing drains, and unpolluted water must be connected to any storm drain existing on the same side of the centerline of the abutting street and within 60 feet of a side property line. In the event a natural outlet is available abutting the property, it may be used for storm water disposal. In the event neither of the two above outlets are available, storm water may be disposed of in dry wells or by draining the water to the street gutter, but storm water shall not be directed over the surface of a public sidewalk or walkway. The method for their being connected to a combined sewer when there is no accessible storm drain: downspouts, storm plumbing outlets, parking lot drainage, unpolluted water and footing drains must be carried in a side sewer pipe separate from the sanitary side sewer pipe to the property line, as designated by the City Engineer, and shall be joined with the sanitary side sewer at that point and then connected to the combined sewer, provided that the City Engineer may permit or require storm drainage to discharge upon the surface of a public place or into a natural outlet or dry wells, even though a combined sewer is accessible, when it is planned to provide a storm relief sewer in the vicinity of said combined sewer." - *Seattle, Washington.*

"The sanitary and storm drainage systems of a building shall be entirely separate except where only a combined sewer is available." – *Metropolitan Toronto, Ontario.*

"It shall be unlawful for any person to connect or cause to be connected, any drain carrying, or to carry, any toilet, sink, basement, septic tank, cesspool, industrial waste, or any fixture or device discharging polluting substances to any storm water drain in the City." – *Rockford, Illinois.*

"No person, other than a municipality having such right by contract with the county, shall make or cause to be made any connection or attachment to any county sewer facility, nor shall any person maintain, use or cause or permit any such connection or attachment to be maintained or used without having obtained a permit therefore from the Commissioner of Public Works." – *Nassau County, New York.*

4.6.3 Existing Inflow Connections Eliminated

"All existing connections between rainspout drains on all residential dwellings and commercial buildings in the City of Transcona which are connected to the sanitary sewer system shall be disconnected on or before the effective date of this by-law." – *Transcona, Manitoba*

4.6.4 Protection from Damage

Protection of sewer facilities is usually accorded special attention, apart from general penalty provisions.

"It shall be unlawful for any person to maliciously, willfully, or negligently break, damage, destroy, uncover, deface or tamper with any structure, appurtenance, or equipment which is a part of the municipal sewage works." – *Santa Cruz, California.*

"No person shall maliciously, willfully, or negligently break, damage, destroy, uncover, deface, or tamper with any structure, appurtenance or equipment which is a part of the sewage works. Any person violating this provision shall be guilty of disorderly conduct." – *Oklahoma City, Oklahoma.*

"No unauthorized person shall maliciously, willfully, or negligently break, damage, destroy, uncover, deface, or tamper with any structure, appurtenance, or equipment which is a part of the sewage works. Any person violating this provision shall be subject to immediate arrest under charge of disorderly conduct." – *Rome, New York.*

4.6.5 Penalties for Violations of Regulations

"Any person found to be violating any provision of this ordinance except Article VI, ("Protection from Damage") shall be served by the city with written notice stating the nature of the violation and providing a reasonable time limit for the satisfactory correction thereof. The offender shall, within the period of time stated in such notice, permanently cease all violations. Any person who shall continue any violation beyond the time limit shall be guilty of a misdemeanor, and on conviction thereof shall be fined in the amount not exceeding $200.00 for each violation. Each day in which any such violation shall continue shall be deemed a separate offense. Any person violating any of the provisions of this ordinance shall become liable to the city for any expense, loss, or damage occasioned the city by reason of such violation." – *Rome, New York.*

"Any person found to be violating any provisions of this or any other ordinance, rule or regulation of the District, except Section 10.1 hereof ("Protection from Damage") shall be served by the District Inspector or other authorized person with written notice stating the nature of the violation and providing a reasonable time limit for the satisfactory correction thereof. Said time limit shall not be less than two nor more than seven working days. The offender shall, within the period of time stated in such notice, permanently cease all violations. All persons shall be held strictly responsible for any and all acts of agents or employees done under the provisions of this or any other ordinance, rule or regulation of the District. Upon being notified by the District Inspector of any defect arising in any sewer or of any violation of the ordinances, rules or regulations of the District, the person or persons having charge of said work shall immediately correct the same." – *Enterprise Public Utility District, Shasta County, California.*

"Any person who shall violate any provision of this Ordinance shall be served by the City with a written notice stating the nature of the violation and providing a maximum of ten days of grace; provided, however, that in case of serious danger to public health, or potential damage to the sewer system, a forthwith notice to cease the violation may be served, which notice shall have immediate effect. Any person who shall violate any provision of this ordinance shall, upon conviction of such violation, be punished by a fine of not to exceed One Hundred ($100.00) Dollars, or by imprisonment for a period of not to exceed ninety (90) days, or by both such fine and imprisonment, in the discretion of the Court. Each day in which any such violation shall continue shall be deemed a separate offense." – *Wyoming, Michigan.*

"Any person violating any provision of this ordinance, or who shall fail to do any act he is required to do under the provisions of this ordinance, shall, upon conviction, be punished by a fine not exceeding $500.00 or imprisonment not exceeding six months, or by both such fine and imprisonment. Each day any violation of this ordinance shall continue shall constitute a separate offense." – *Salem, Oregon.*

"(1) The owner of any commercial or industrial establishment found to be violating any provisions of this ordinance shall be notified in writing by the director, stating the nature of the violation and providing a reasonable time limit for the correction thereof. The owner of such establishment shall permanently cease all violations within the period of time stated in the notice, and shall certify to the director that the corrections have been accomplished. (2) The owner of any commercial or industrial establishment found to be violating any provision of this ordinance who shall continue such violation beyond the time limit provided in paragraph one, above, shall be guilty of a misdemeanor, and upon conviction thereof shall be fined in an amount not exceeding Two Hundred Dollars ($200.00) for each violation. Each day in which such violation shall continue shall be deemed a separate offense. (3) In cases of repeated violations, the director may revoke the permit for the discharge of wastes into the sewer system, and effect the discontinuation of water or sewer service, or both. (4) Any person violating any of the provisions of this ordinance shall become liable to the city for any expense incurred as a result of such violation." – *Kansas City, Missouri.*

4.6.6 Inspectors' Right of Entry

Many ordinances assert the city's right of inspection, plus entry onto premises for the purpose. The timing, objectives, and circumstances of the inspectional visits may be differently regulated; but possession of proper identification and credentials is almost universally required of the inspector:

"Any duly authorized representative of the City, bearing proper credentials and identification shall be permitted to enter upon all properties for the purpose of inspection, observation, measurement, sampling and testing, in accordance with the provisions of these regulations." – *Jefferson City, Missouri.*

"Authorized representatives of the City of Yakima are hereby empowered to, at all reasonable times, enter and inspect all buildings and premises for the purposes of ascertaining whether the provisions of this chapter are being violated." – *Yakima, Washington.*

"That the Superintendent or any member of his department so authorized by him may enter into and upon any lands and premises for the purpose of inspecting the sewer connections and any pipe or other apparatus or thing connected therewith, particularly rain downspouts." – *Transcona, Manitoba.*

"The City Engineer and other duly authorized employees of the City bearing proper credentials and identification shall be permitted at all reasonable hours to enter upon all properties for the purpose of inspection, observation, measurement, sampling and testing, in accordance with the provisions of this Ordinance." – *Wyoming, Michigan.*

"The officers, officials, servants, employees and workmen of the City shall have the right at all reasonable times to enter upon any land to which this section applies, to inspect the works installed thereon and generally for the purpose of ascertaining whether the provisions of the said subsection are being compiled with." – *Yorktown, Saskatchewan.*

"The officers, inspectors and any duly authorized employee of the District shall carry evidence establishing his position as such and upon exhibiting the proper identification shall be permitted during reasonable hours to enter in and upon any and all buildings, industrial facilities and properties for the purpose of inspection, reinspection, observations, measurements, sampling, testing or otherwise performing such duties as may be necessary in the enforcement of the provisions of the ordinances, rules or regulations of the District." – *Enterprise Public Utility District, Shasta County, California.*

"The Engineer in Charge and other duly authorized employees of the City bearing proper credentials and identification shall be permitted to enter all properties for the purposes of inspection, observation, measurement, sampling and testing in accordance with the provisions of this ordinance. The Engineer in Charge or his representatives shall have no authority to inquire into any processes including metallurgical, chemical, oil refining, ceramic, paper, or other industries beyond that point having a direct bearing on the kind and source of discharge to the sewers or waterways or facilities for waste treatment. While performing the necessary work on private properties referred to above, the Engineer in Charge or duly authorized employees of the City shall observe all safety rules applicable to the premises established by the company and the company shall be held harmless for injury or death to the City employees and the City shall indemnify the company against loss or damage to its property by City employees and against liability claims and demands for personal injury or property damage asserted against the company and growing out of the gauging and sampling operation, except as such may be caused by negligence or failure of the company to maintain safe conditions. The Engineer in Charge and other duly authorized employees of the City bearing proper credentials and identification shall be permitted to enter all private properties through which the city holds a duly negotiated easement for the purposes of, but not limited to, inspection, observation, measurement, sampling, repair, and maintenance of any portion of the sewage works lying within said easement. All entry and subsequent work, if any, on said easement, shall be done in full accordance with the terms of the duly negotiated easement pertaining to the private property involved." – *Knoxville, Tennessee.*

4.6.7 Testing for Sewer Infiltration

"No house connections will be permitted until sections of sewers are completed between completed manholes and inspected for infiltration and other tests which the City Inspector deems necessary." – *New Britain, Connecticut.*

"The inspection shall include a test to determine that the side sewer is of tight construction and does not allow infiltration or exfiltration of water. Specifications for such a test shall be included in the rules and regulations (the City Engineer may make) referred to in Section 35 of this ordinance." – *Seattle, Washington.*

"Infiltration testing shall take place when the natural ground water table is above the crown of the higher end of the test section. The maximum allowable limit for infiltration shall be four-tenths (0.4) gallon per hour per inch of internal diameter per 100 feet of length with no allowance for external hydrostatic head." – *Anchorage, Alaska.*

"If, in the construction of a section of sewer between any two structures, excessive ground water is encountered, the test for leakage shall not be used, but instead the end of the sewer at the upper structure shall be closed sufficiently to prevent the entrance of water, and the pumping of the ground water shall be discontinued for at least three days after which the section shall be tested for infiltration. The infiltration, as measured by the amount of water intercepted at the structure below the plugged end of the sewer, shall not exceed 0.1 gallon per minute per inch of nominal diameter of pipe per 1,000 feet of length of sewer being tested. If the sewer main being tested contains laterals, the allowable leakage shall not exceed 0.2 gallon per minute per inch of nominal diameter per 1,000 feet of length of sewer main being tested. The length of laterals shall not be used in computing the length of sewer main being tested." – *Escondido, California.*

SECTION 5

ECONOMIC GUIDELINES

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ECONOMIC GUIDELINES

5.1 THE ECONOMIC FACTORS INVOLVED

When excessive amounts of infiltration and inflow waters enter sanitary or combined sewer systems, the immediate effects are "physical." As important as these physical effects on the capacities and capabilities of sewer conduits, pumping facilities, treatment works and regulator-overflow structures may be, the full impact of such extraneous waters cannot be known until the "financial" factors are computed and evaluated.

The evaluation of the economic factors of infiltration and inflow has been given little attention because of the unavailability of rational fiscal guidelines that will permit the computation of the tangible costs of handling excessive amounts of extraneous waters and balancing these costs against the cost of constructing relatively infiltration-free sewer systems in the future and of financing projects to correct infiltration and inflow conditions in existing systems.

This Manual outlines a rational approach to the economic factors involved in surcharged sewer systems and over-taxed waste water handling, treatment and disposal works. It stresses the two factorial effects of excessive infiltration and inflow: "sanitation" and "cents." These include, but are not limited to, the following:

1. Increased size and cost of new sewers if excessive infiltration and inflow are permitted;
2. Need for construction of relief or supplementary collection and interception sewers, at dates prior to those originally estimated as the economic life of existing sewers;
3. Operation and maintenance costs for handling local sewer surcharges, clean-up of flooded areas, and damages to flooded private properties;
4. Increased operation and maintenance costs for pumping excess flows;
5. Cost of repairing pavement cave-ins and wash-outs of subsurface utilities caused by infiltration and exfiltration;
6. Cost of removing soil and debris and tree roots entering sewers through defective sewer pipes and joints;
7. Cost of excessive wear on pumping station equipment and power requirements;
8. Increased operation and maintenance costs at waste water treatment plants;
9. Need for increases in treatment capacity because systems are overloaded with excessive infiltration and inflow volumes, and
10. Regulating agencies will no longer tolerate the bypassing of flows from sewers or waste water treatment plants.

The hidden costs of infiltration-inflow usurpation of system capacities and capabilities generally have been overlooked when jurisdictional officials are planning corrective action. Even the readily computable costs of such extraneous water intrusion into systems seldom have been evaluated and properly interpreted in terms of the economics of urban services.

Where preventive measures have been taken to reduce infiltration in new sewer systems, designers and utility officials have been concerned about any added cost of projects covered by specifications for tighter systems. Little consideration has been given to immediate and long-range savings that might accrue in terms of reduced size of new sewer lines and longer service life of such systems.

If and when correction of infiltration in existing overtaxed sewer systems has been considered or undertaken, the main concern has been the out-of-pocket or bond investment for sealing or replacing defective sewer structures. Little thought has been given to the comparative economics of costs vs. the benefits to be derived in sewer system service and in the pumping and treatment of waste waters. Few jurisdictions actually have evaluated the volumes of flow due to infiltration and inflow and the marked economic effect of these extraneous flows.

Emphasis has always been on the adverse effects of surcharged sewers on the public which uses thoroughfares and on property owners inconvenienced and injured by the back-flooding of overtaxed sewers into their properties. Sanitation and convenience thus have been considered to the exclusion of the dollar cost of such flooding conditions.

No meaningful evaluation of this problem, in all of its ramifications and implications, can be made without taking up the costs of such intruded flows and the capital investments required to eliminate or alleviate the difficulties previously mentioned. Otherwise no rational relationship between costs and benefits can be developed.

For this reason a guideline approach to an economic evaluation g of these problems is offered. It is based on a theoretical community "profile" for two different size jurisdictions, under two different conditions. In this sense, it is a *sample* of an economic concept because there is no such thing as an average community and an average sewer system. Each jurisdiction has its own character; its sewer system and treatment and disposal facilities are individualized.

The cost assumptions and other factors used in the guideline may or may not reflect conditions in any individual jurisdictional system. Each community has its own cost experiences, its own sewer system needs, its own pumping and treatment requirements, and other factors than those outlined.

Such local "known" factors can be used to replace the arbitrarily chosen physical and economic assumptions used in the sample analysis. The value of the guideline is that it illustrates a method whereby the costs and benefits of infiltration and inflow, and of their prevention and correction, can be determined. Admittedly, such economic analyses may be subject to errors, but any such computations will be an improvement over past practices of disregarding the economics of sewer services in an era when all urban functions deserve such evaluations.

5.2 GUIDELINE FOR ECONOMIC EVALUATION

5.2.1 General

The first step in an economic analysis of the infiltration and inflow problem in any jurisdiction is to tabulate the so-called "community profile" in terms of pertinent sewer service factors. Table 5.2.1 shows the community profiles chosen as the basis of the analysis for two jurisdictions. Population sizes of 100,000 and 250,000 were chosen because there are numerous communities of these sizes in the United States. A key explanation of terms and data sources will enable jurisdictional officials and consulting engineers to prepare specific profiles for any communities under consideration.

5.2.2 Collection System

The capital or construction costs of a sewer system show wide variations among cities. Differences in topography and climate are two of the several reasons. The sewer pipe and manhole costs presented in this analysis reflect approximate values from several midwestern areas. It was assumed that the presented values include all costs, such as landscaping and street cut repairs, and other phases of construction and reconstruction. Not included in this analysis were the costs of sewage pumping stations. Table 5.2.2 shows the assumed unit capital costs by pipe size, and for manholes. Operation and maintenance costs, including overhead for collection systems, are arbitrarily estimated at 1 percent of capital costs.

Also included in the costs for a collection system are estimates for emergency repairs resulting from street cave-ins, and for pumping and clean-up due to wet-weather flooding of local areas. The inclusion of these costs is justified because sewer infiltration

TABLE 5.2.1
COMMUNITY PROFILE

Population	100,000	250,000
1. Area (acres)	12,000	28,000
2. Density (persons/acre)	8.3	8.9
3. Housing Units (3.5 persons/unit)	28,570	71,430
4. Housing Structures (75% of units)	21,430	53,570
5. Mfg. Establishments	112	333
6. Business Establishments	1,470	3,900
7. Business Structures (75% of est.)	1,100	2.900
8. All Structure Connections (ft./structure)	60	60
9. Diameter (inches)	6	6
10. House Connections (feet)	1,285,800	3,214,200
11. Mfg. Connections (feet)	6,720	19,980
12. Business Connections (feet)	66,000	174,000
TOTAL 6 inch		
Building Sewer Connections	1,358,520	3,408,180
Municipal System		
13. Sewer Miles/Acre	.022	.021
14. Total Sewer Miles	264	588
15. Pipe Size as Percent of Total System (feet)		
6 in. to 8 in. @ 75%	1,045,440	2,328,480
10 in. to 12 in. @ 14%	195,149	434,650
15 in. to 18 in. @ 6%	83,635	186,278
21 in. to 27 in. @ 4%	55,757	124,186
30 in. to 42 in @ 1%	13,939	31,046
Total Length of Sewer Sys.	1,393,920	3,104,640
16. Manholes	3,485	7,762

KEY – TABLE 5.2.1

1. *Area* – Average sewered area of cities in these population ranges. Taken from a survey summary prepared by APWA for a study on combined sewer overflows. *Problems of Combined Sewer Facilities and Overflows 1967.* Federal Water Pollution Control Administration, U. S. Dept. of the Interior; December, 1967.
2. *Density* – Based on average area and population by city size, from overflow report summary (Ibid).
3. *Housing Units* – Average for all SMSA's in 1960. *1960 Census of Housing,* Bureau of the Census, U. S. Dept. of Commerce.
4. *Housing Structures* – Average for all SMSA's in 1960 (Ibid).
5. *Manufacturing Establishments* – Based on average number for appropriate SMSA size. Each establishment assumed to occupy separate structures. *1963 Census of Manufacturers.* Bureau of the Census, U.S. Dept. of Commerce.
6. *Other Business Establishments* – Based on average number of retail and service establishments by appropriate SMSA size. *1963 Census of Business.* Bureau of the Census, U. S. Dept. of Commerce.
7. *Other Business Structures* – Assumed to be 75 percent of business establishments.

8/9. All connecting sewers were assumed to be 6-inch vitrified clay pipe with a length of 60 feet between the structure and the municipal sewer

10. Presented in feet. Number of structures times 60 feet.
11. Presented in feet. Number of structures times 60 feet.
12. Presented in feet. Number of structures times 60 feet.
13. *Sewer Miles/Acre* – Based on overflow survey cited in (1), above.
14. *Total Sewer Miles* – Sewer miles/acre, times average area.
15. *Pipe Size and Percent of System* – Average sizes as percent of system based on U. S. totals estimated by BSDA. Picton, Walter L.; "2.7 Billion Feet of Sewer Pipe Will Serve Communities by 1975." *Wastes Engineering.* November, 1959
16. *Manholes* – One manhole for each 400 feet of municipal sewers. Merritt, Frederick S. Ed. *Standard Handbook for Civil Engineers.* New York: McGraw-Hill Book Co. 1968.

TABLE 5.2.2
UNIT CAPITAL COSTS OF SEWAGE COLLECTION SYSTEM

Unit	UNIT Capital Cost
Pipe:	
6 inch Building Connections	$ 6.00/l. ft.
6 & 8 inch Municipal Sewers	10.00/l. ft.
10 & 12 inch	12.00/l. ft.
15 & 18 inch	20.00/l. ft.
21 to 27 inch	30.00/l. ft.
30 to 42 inch	40.00/l. ft.
Manholes	300.00 each

Source: Bid prices supplied by Streater Division, Clow Corporation for new systems

contributes to street substructure undermining and erosion and wet-weather flooding due to surcharged sewers.

The cost figures for repairs and cleanup are arbitrary; they are presented to illustrate typical costs directly attributable to infiltration and inflow. Any jurisdiction can substitute its own cost experiences in making a similar analysis.

The costs for emergency street repairs have been assumed as $10,000 per 100 miles of sewer per year. Pumping and clean-up due to flooding also is estimated at $10,000 per 100 miles of sewer per year.

5.2.3 Treatment Plant

The plant chosen for this model is one providing three stages of waste water treatment. The costs presented are those for an activated sludge primary-secondary system and an activated carbon tertiary treatment system.

The capital costs of primary and secondary treatment are based on a study conducted by the U. S. Public Health Service in 1963.[1] The cost of tertiary treatment has been estimated at 100 percent of the costs of primary-secondary treatment.[2] Plant operating and maintenance costs are based on a study

[1] Modern Sewage Treatment Plants – How Much Do They Cost? Public Health Service, Division of Water Supply and Pollution Control. U. S. Department of Health, Education and Welfare, Washington, D.C., 1964.

[2] Cost and Performance Estimates For Tertiary Waste Water Treating Processes. Federal Water Pollution Control Administration, U. S. Department of the Interior, Cincinnati, Ohio, June, 1969.

carried out by P. P. Rowan, K. L. Jenkins and D. H. Howells of the Public Health Service.[3] The operating costs of tertiary treatment are again assumed to be 100 percent of primary-secondary treatment.

The capital costs of primary and secondary facilities were computed on a per-capita basis. These were converted to gallons per day by assuming an average flow of 100 gallons per day, per person. For each of the two city sizes presented (100,000 and 250,000 population) two plant sizes are shown. The first is based on a 100 gallons/capita flow and the second includes a 70 percent industrial population equivalent.[4] Operation and maintenance costs also were computed on a per-capita basis. Regardless of the sources of flow to the plant, the analysis gives a basis for making decisions as to effect of the volume on increased plant costs.

5.2.4 Capital Costs

As stated previously, the capital costs were based on a Public Health Service study. Data on activated sludge plants were available from 133 construction projects in all parts of the country. The included projects represented design populations up to 100,000. The expected costs were estimated by regression analysis from the formula:

$$\log 10y = 3.6533024 - 0.2782395 \log X$$

y = expected per capita cost

X = design population (r = –0.73)

(r = coefficient of correlation)

The resulting values represent contract construction costs. Not included are engineering, legal and administrative costs. Also not included are land acquisition costs. The study points out that the non-construction costs, exclusive of land, could add 20 percent to the expected costs. These costs have been added, as has 10 percent for land acquisition. All study capital costs were stated in 1957-59 dollars. Those presented herein were inflated to 1967 levels using the FWQA treatment plant U. S. cost index (1967 = 120.28).

Annual capital costs are based on an average useful life of 25 years[5] and a 5-percent interest rate, despite the fact that present rates on municipal bonds are considerably higher.

It should be noted that the projects included in the Public Health Service study were limited to those with design populations of 100,000 or less. Therefore, the values obtained for plants of over 10-mgd capacity may or may not reflect the actual costs of larger treatment facilities. The lack of applicable cost data for larger plants necessitated the extension of the cost curve beyond the sample range. However, the resulting values appear reasonable and are presented for illustrative purposes only.

5.2.5 Operating Costs

Plant operation and maintenance costs also are based on a Public Health Service survey. Included in this were operating and maintenance costs for 60 activated sludge treatment facilities. In this study the valid design population range is up to 200,000. As before, extension of the curve may or may not accurately reflect these costs for larger plants. The expected values were estimated from the formula:

$$\log Y = 1/(-0.50927) + 0.13791 \log X$$

y = the expected annual per capita cost x 10

X = population served x 0.01 (No r is given)

All costs were stated in 1957-59 dollars. They have been inflated to the 1967 level by use of the OBE-IPD of state and local government purchases of goods and services (1967 = 133.3). Included in the operation and maintenance costs are all costs other than central administration and capital maintenance.

Figure 5.2.5 shows the capital and operating costs of treatment from the formulas above. The figures have been adjusted and inflated to 1967 price levels. Table 5.2.5.1. shows the various treatment costs for the four plant sizes. All figures are per million gallons of daily design flow.

Tables 5.2.5.2. and 5.2.5.4. summarize the total direct costs of sewage collection and treatment. The annual capital costs for the collection system were computed by using a 20-year life and 5-percent interest rate. The 20-year life reflects an accepted practice of bonding sewage construction costs. The collection system itself may have a useful life of from 50 to 100 years, but can be paid for in about 20 years.

Figures 5.2.5.3 and 5.2.5.5 show the various annual collection and treatment costs as a percentage of the total direct annual municipal costs.

Table 5.2.5.6 presents the various system costs as a cost per unit. From these figures, estimates of the costs of infiltration and inflow can be illustrated. As discussed earlier, the costs of pumping stations have

[3] Rowan, P.P.; Jenkins, K.L; Howells, D. H., "Estimating Sewage Treatment Plant Operation and Maintenance Costs." Journal of the Water Pollution Control Federation, Vol. 23; February, 1961.

[4] This is the average proportion, for the areas surveyed, of industrial waste population equivalent to total population from the APWA overflow study survey, Problems of Combined Sewer Facilities and Overflows, 1967. Federal Water Pollution Control Administation, U. S. Department of the Interior, December, 1967, p. 69.

[5] Keefer, C. E., "Estimating the Life of Sewage Treatment Facilities," Public Works. Vol. 93 July 1962, pp. 79-82.

TABLE 5.2.5.1

UNIT TREATMENT PLANT COSTS PER MGD (1967 PRICE LEVEL)

Population	100,000		250,000	
Average Plant Size	10 mgd	17 mgd	25 mgd	42.5 mgd
Capital Costs				
Primary & Secondary Treatment				
Total Capital Costs/mgd	$290,389	$ 250,538	$ 224,976	$ 194,176
Annual Capital Costs/mgd	20,604	17,776	15,962	13,777
Tertiary Treatment				
Total Capital Costs/mgd	290,389	250,538	224,976	194,176
Annual Capital Costs/mgd	20,604	17,776	15,962	13,777
Total Treatment Capital Costs/mgd	$580,778	$ 501,076	$ 449,952	$ 388,352
Total Annual Capital Costs/mgd	41,208	35,552	31,924	27,554
Annual Operation & Maintenance Costs				
Primary & Secondary Treatment/mgd	$ 16,129	$ 14,930	$ 13,997	$ 13,063
Tertiary Treatment/mgd	16,129	14,930	13,997	13,063
Total O & M Costs/mgd	$ 32,258	$ 29,860	$ 27,994	$ 26,126
Total Annual Treatment Costs/mgd	$ 73,466	$ 65,412	$ 59,918	$ 53,680
Total Annual Treatment Cost	$734,660	$1,192,544	$1,497,950	$2,281,400

discussed earlier, the costs of pumping stations have not been included in this analysis.

5.3 INFILTRATION AND INFLOW COSTS

To illustrate these costs, an example is presented using the cost data from the 100,000-population city.

In this case it is assumed that 10 gallons per capita per day is ground water infiltration and inflow. Initially, the relevant costs are those that will vary with changes in flow. When considering costs over a short period of time, the capital costs are not variable and should not be considered.

For a city with a population of 100,000, infiltration is assumed to add 1 mgd to the total flow. For the municipality, the costs attributable to this infiltration would be a portion of the 0 & M costs of collection and treatment. From Table 5.2.5.6 the costs of 1000 gpd are $10.44 for collection and $29.86 for treatment. At 1 mgd, the total annual cost of infiltration/inflow would be about $40,000.

To this, the annual costs of emergency street repairs and wet-weather basement flooding must be added, inasmuch as the elimination of infiltration and inflow will end these occurrences. The costs of both emergency street repairs and flooding each have been estimated at $10,000 per 100 miles of sewer per year. A city of 100,000 people has approximately 264 miles of sewer (Table 5.2.1). Therefore, the annual cost of street repairs and flooding damage would be about $53,000.

The total avoidable costs of O & M and emergency repairs and flooding will be approximately $93,000 per year.

5.4 COSTS VS. BENEFITS EVALUATION

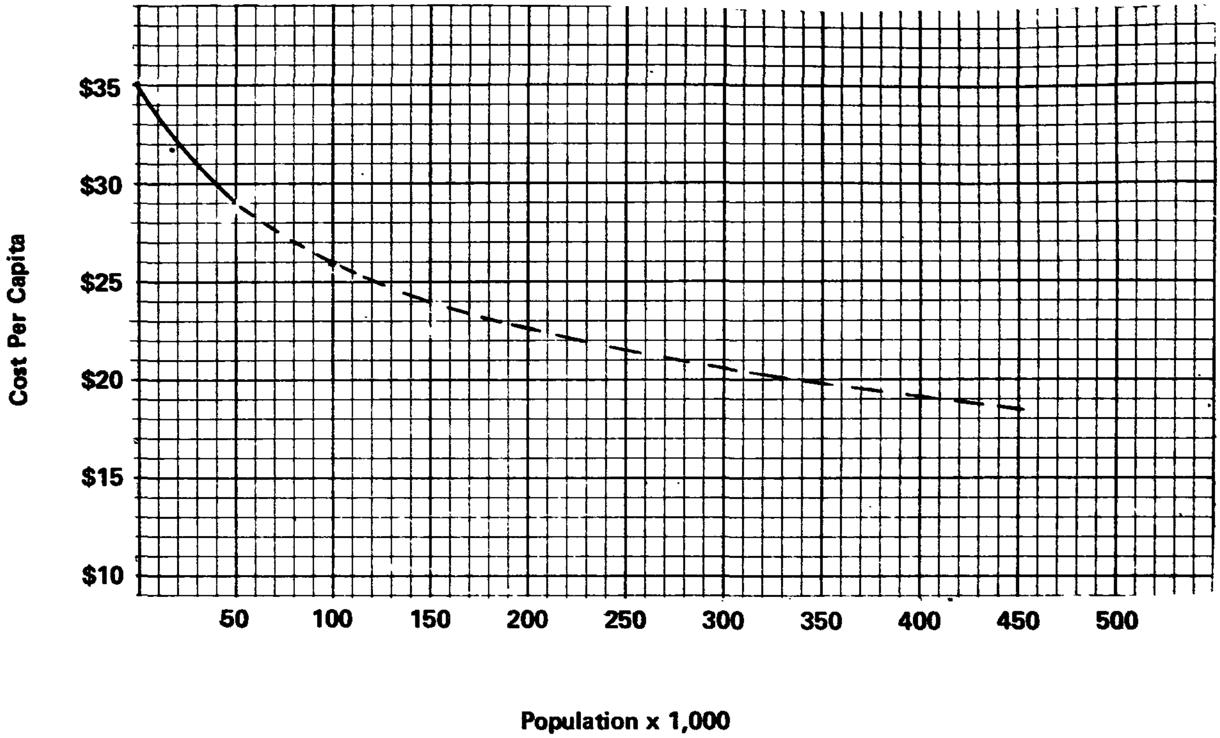
It must now be determined if this annual saving is great enough to offset the cost of eliminating infiltration and inflow. By assuming that correction costs will be capitalized at 5 percent for 20 years, the break-even point can be determined. That is, what capital investment with a 20-year payback period at 5 percent will have an annual capital cost of $93,000? The investment would be approximately $1,160,000.

The 20-year payback may or may not represent the true useful life of the capital expenditure. Should the useful life be longer, the savings also will be realized for the longer period. This would raise the break-even points. Also not reflected is the trend toward increasing unit costs. Any increases would permit a higher break-even point.

However, for illustration purposes, the $1,160,000 figure will be used. An investment up to $1,160,000 to eliminate infiltration and inflow costing $93,000 per year in avoidable costs will result

FIGURE 5.2.5

TOTAL CAPITAL COST – PRIMARY & SECONDARY TREATMENT
(1967 Dollars)



ANNUAL OPERATION & MAINTENANCE COSTS
PRIMARY & SECONDARY
(1967 Dollars)

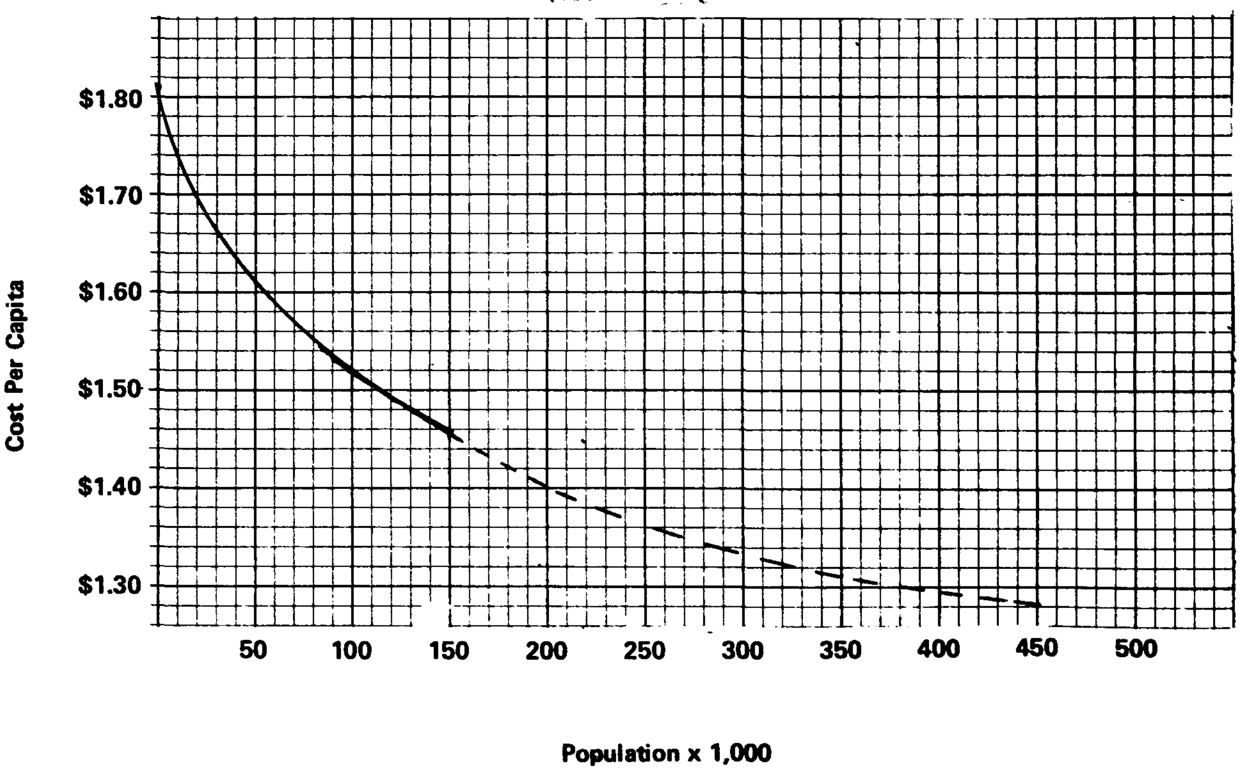


TABLE 5.2.5.2

TOTAL SYSTEM COSTS
100,000 POPULATION

Collection	Unit	Unit Capital Cost $	Total Capital Cost $	Annual Capital Cost $	Total Annual O & M Cost $	Total Annual Cost $
Private Connections	1,358,520 ft.	6.00/ft.	8,151,120	654,070	81,511	735,581
Municipal System						
6 & 8 Inch Pipe	1,045,440 ft.	10.00/ft.	10,454,400	–	–	–
10 & 12 Inch Pipe	195,149 ft.	12.00/ft.	2,341,788	–	–	–
15 & 18 Inch Pipe	83,635 ft.	20.00/ft.	1,672,700	–	–	–
21 to 27 Inch Pipe	55,757 ft.	30.00/ft.	1,672,710	–	–	–
30 to 42 Inch Pipe	13,939 ft.	40.00/ft.	557,560	–	–	–
Total Municipal Sewer Pipe			16,699,158	1,339,991	166,992	1,506,983
Manholes	3,485	300.00 ea.	1,045,500	83,894	10,455	94,349
Treatment:						
Primary & Secondary	17 mgd	250,538/mgd	4,259,146	302,192	253,810	556,002
Tertiary	17 mgd	250,538/mgd	4,259,146	302,192	253,810	556,002
Total Treatment	–	–	8,518,292	604,384	507,620	1,112,004
Total Municipal Collection & Treatment	–	–	26,262,950	2,028,269	685,067	2,713,336
Total System	–	–	34,414,070	2,682,339	766,578	3,448,917

FIGURE 5.2.5.3

ANNUAL MUNICIPAL COLLECTION & TREATMENT COSTS
AS PERCENT OF TOTAL ANNUAL MUNICIPAL COSTS

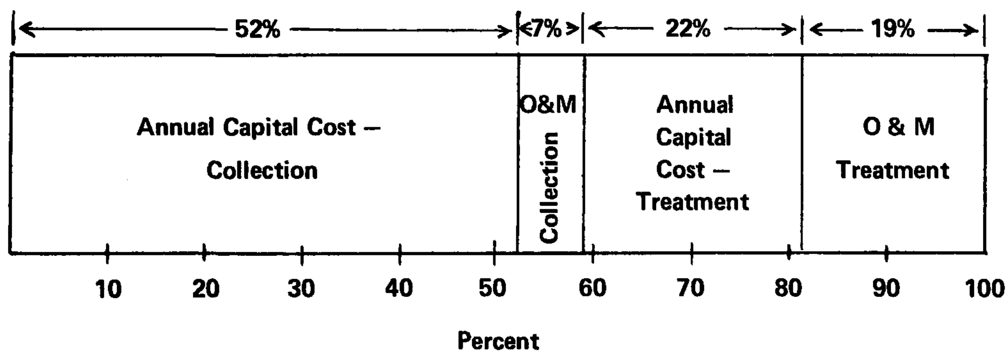


TABLE 5.2.5.4

TOTAL SYSTEM COSTS
250,000 POPULATION

	Unit	Unit Capital Cost	Total Capital Cost	Annual Capital Cost	Total Annual O & M Cost	Total Annual Cost
Collection						
Private Connections	3,408,180 ft.	6.00/ft.	20,449,080	1,640,896	204,491	1,845,380
Municipal System						
6 & 8 Inch Pipe	2,328,480 ft.	10.00/ft.	23,284,800	–	–	–
10 & 12 Inch Pipe	434,650 ft.	12.00/ft.	5,215,800	–	–	–
15 & 18 Inch Pipe	186,278 ft.	20.00/ft.	3,725,560	–	–	–
21 to 27 Inch Pipe	124,186 ft.	30.00/ft.	3,725,580	–	–	–
30 to 42 Inch Pipe	31,046 ft.	40.00/ft.	1,241,840	–	–	–
Total Municipal			37,193,580	2,984,524	371,936	3,356,460
Manholes	7,762	300.00 ea.	2,328,600	186,854	23,286	210,140
Treatment:						
Primary & Secondary	42.5 mgd	194,176/mgd	8,252,480	585,523	555,178	1,140,701
Tertiary	42.5 mgd	194,176/mgd	8,252,480	585,523	555,178	1,140,701
Total Treatment	–	–	16,504,960	1,171,046	1,110,356	2,281,402
Total Municipal – Collection & Treatment	–	–	56,027,140	4,342,424	1,505,578	5,848,002
Total System	–	–	76,476,220	5,983,320	1,710,069	7,693,389

FIGURE 5.2.5.5

ANNUAL MUNICIPAL COLLECTION & TREATMENT COSTS
AS PERCENT OF TOTAL ANNUAL MUNICIPAL COSTS

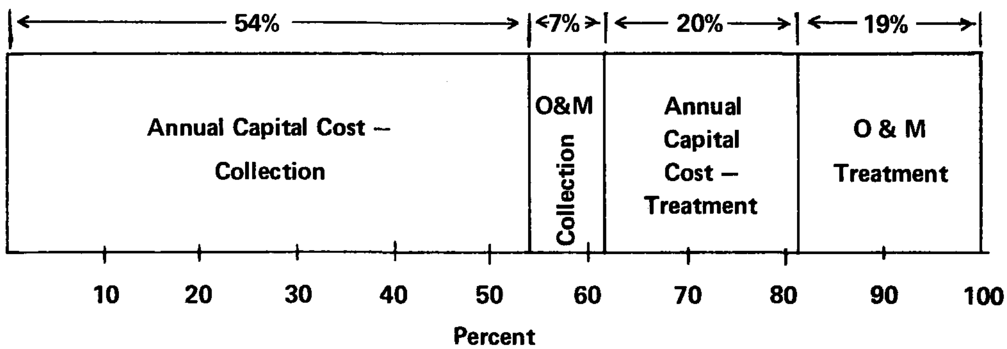


TABLE 5.2.5.6

PER CAPITA AND PER 1000 GPD COSTS MUNICIPAL SYSTEM

	Population	
	100,000 (17 mgd)	250,000 (42.5 mgd)
Per Capita Cost – Municipal System		
Total Capital – Collection	$ 177.45	$158.09
Annual Capital – Collection	14.24	12.69
Annual O. & M. – Collection	1.77	1.58
Total Capital – Treatment	$ 85.18	$ 66.02
Annual Capital – Treatment	6.04	4.68
Annual O. & M. – Treatment	5.08	4.44
Annual Cost Per 1000 Gallon Daily Flow – Municipal System		
Total Capital – Collection	$1,043.80	$929.93
Annual Capital – Collection	83.76	74.62
Annual O. & M. – Collection	10.44	9.30
Total Capital – Treatment	$ 501.08	$388.35
Annual Capital – Treatment	35.55	27.55
Annual O. & M. – Treatment	29.86	26.13
Cost Per 1000 Gallons		
Capital – Collection	$ 0.2295	$ 0.2044
O. & M. – Collection	0.0286	0.0255
Capital – Treatment	$ 0.0974	$ 0.0755
O. & M. – Treatment	0.0818	0.0716

in a net saving to the community. For example: If the investment necessary is $1,000,000, and this is amortized at 5 percent for 20 years, the annual cost would be approximately $80,000. The annual infiltration and inflow cost of $93,000, less the annual cost of its elimination, would result in a net savings of $13,000 per year.

It is uncertain if total infiltration and inflow to a total system of the size described could be corrected for $1,160,000. However, there may be relatively short sections within the system accounting for a large portion of the extraneous flow. In such cases, investment in correction may result in an appreciable net savings.

In addition to possible variable cost savings, future capital system expenditures to meet increasing demand may be reduced or postponed. If either or both the collection and treatment plant are operating at or near capacity, a reduced flow would eliminate the need for immediate construction to increase system capacity.

A case may arise where a city finds it necessary to extend service to a new subdivision or a new satellite urban area, or to a formerly unsewered area within its jurisdiction. Here the choice could be between expansion of treatment and interceptor capacity and the reduction of present flow.

The cost data from Table 5.2.5.6 will permit the determination of the low cost alternative. For simplification, assume that the increased demand will be 1 mgd and that any increments to plant capacity will be made at constant costs.

To expand collection and treatment facilities to handle 1 mgd, a capital expense of $1,544,880 would be required [Table 5.2.5.6 ($1,043.80 + 501.08) x 1000].

The annual capital cost of this investment would be approximately $119,000 [Table 5.2.5.6: (83.76 + 35.55) x 1000]. For comparison, the annual costs of O & M ($40,000) and street repair and flooding ($53,000) must be added. Therefore these three cost factors are the annual avoidable costs accruing from the correction of infiltration and inflow. This is how much a city could spend on the correction of infiltration and inflow to reduce the daily flow by 1 mgd, and save money by doing so.

In the above example, the total annual cost of the capacity expansion alternative is $212,000. Assume again a 20-year payback at 5 percent for the cost of correcting infiltration and inflow. In this case the break-even point will be about $2,640,000. Any investment for infiltration and inflow reduction resulting in a reduced flow of 1 mgd and costing less than $2,640,000 will produce a net savings to the community.

The examples cited above are admittedly over-simplifications. However, they do serve to point out the need for more comprehensive examinations of both the present and future costs of any capital investment decision. A lower initial cost is not always the least expensive way to achieve a desired objective.

Before the true costs of alternatives can be determined, all inputs must be outlined and stated in compatible terms. The figures presented herein show the required inputs for two moderate-size cities. They may serve as yardsticks for comparison with like-size communities. However, the major value of this analysis is in the illustration of the total system cost considerations needed when making an investment decision. Each jurisdiction can evaluate its own fiscal policies by using data relating to its own sewer costs, sewage flows, treatment processes, infiltration and inflow corrective measures, local bond-financing practices and other factors considered in the analysis presented above.

Jurisdictional officials and consultants are reminded that the decision to undertake infiltration and inflow correction may have to be based on local sanitation and water pollution control factors such as a no bypass policy, over and above the economic considerations.

SECTION 6

TRENDS AND DEVELOPMENTS

SECTION 6

TRENDS AND DEVELOPMENTS

6.1 INTENSIFICATION OF THE PROBLEM

Today's recognition of the infiltration and inflow problem springs from urban growth and the essential role which sewer system capacities and wastes handling facility efficiencies play in environmental sanitation and water pollution control. The 2,942 million feet of sewers now in service represent an investment generally estimated to be upwards of $50 billion. It is predicted that an additional 1,240 million feet of public sewers must be installed in the next decade, and 649 million feet of new sewers will be needed to replace inadequate lines now in service. These additions and replacements will represent a further investment of some $20 billion.

It would be inexcusable to shorten the service life of existing sewer systems by allowing extraneous waters that do not require collection and treatment to usurp capacities required for present and future flows. This Manual has offered guidelines for evaluating the dollar value of infiltration and inflow in terms of their effects on sewer systems and waste-water treatment facilities.

Every 100 gallons per day of unnecessary infiltration and inflow removed from an existing system, or prevented from entering a new system, provides capacity for a new urban resident or for an industrial wastes equivalent unit in an expanding urban era. On the basis of causes, sources, and effects of infiltration and inflow in its own system, each jurisdiction must evaluate its problem on the basis of its own conditions, its own cost factors, and its own policies.

6.2 IMPROVEMENTS IN PIPE AND JOINT PRODUCTS

Improvements have been made by manufacturers through research and development of improved sewer pipe and sewer jointing materials. Effective choice and use of these products is the keystone to better control of infiltration. Still further progress in pipe and jointing methods can be anticipated in the next few years. Designers, contractors, and jurisdictional administrators must maintain close contact with manufacturers to keep informed on product progress. Cooperation between sewer officials and those who serve them, and manufacturers, will stimulate greater product developments which can assist in the reduction and elimination of infiltration.

6.3 TIGHTENING INFILTRATION ALLOWANCES

A quarter-century ago many sewers were built under specifications which permitted infiltration rates as high as 1,000 gallons per day per mile of length per inch of pipe diameter. These are the sewers which are still in service in many jurisdictions at the outset of the 1970's. The common infiltration rate in present practice is sharply reduced from the earlier specification allowances, judging from the findings of the national investigatory project recently completed by the American Public Works Association for the Federal Water Quality Administration and participating jurisdictions. The general use of the 500 gpd/mile/inch of pipe diameter was given impetus by the adoption of this criterion by the so-called "Ten States Standards" nearly two decades ago.

Better pipe products – and particularly the development and application of better jointing materials and methods for these new pipe types with proper construction and rigid inspection – offer unmistakable opportunities for markedly lower infiltration allowances in all future construction work. Better equipment and tighter control of construction methods can produce approaches to watertight sewers; examples of this type of sewer construction already are in service. It is physically possible and economically feasible to limit infiltration allowances to 200 gallons per day per mile of sewer per inch of pipe diameter, a level which can be specified and conformed to without any appreciable increase in construction costs.

6.4 CONSTRUCTION AND INSPECTION IMPROVEMENTS

The best pipe and jointing material in the world cannot assure a watertight sewer job. Construction methods must make the proper use of such materials, because no sewer job is any better than its construction quality. The sewers of the future must be laid in dry trench, on proper bedding, with good backfill and compaction methods, and under conditions that will assure physical stability while the line is in service. Joints must be made carefully.

Every sewer job must be inspected adequately to assure adherence to construction specifications. Alert inspection is as important as proper materials and construction methods. Modern methods of inspection and testing to determine the tightness of sewer lines, from section to section, are available. They must be applied in every sewer construction project.

6.5 ELIMINATION OF INFILTRATION IN EXISTING SEWERS

The total problem of infiltration cannot be solved by even the best design and construction practices for new sewer systems. The greater footages of sewers now in service – antedating today's better pipe, joint materials, and construction methods – allow excessive infiltration which must be eliminated or minimized to overcome the usurpation of sewer capacities and the capacities of pumping, treatment, and disposal facilities.

Jurisdictions affected by infiltration must carry out surveys to locate sources of such extraneous waters, determine their volumes, and correct defects in sewer pipe, joints, manholes, and other appurtenant structures.

6.6 IMPROVEMENTS IN INSPECTION, TESTING AND SEALING PRACTICES

Survey procedures must be planned carefully and executed expertly. Lines must be cleaned prior to internal inspection or sealing. Inspection methods and devices of great sophistication can assist in visual observation. Closed-circuit television equipment, photographic devices, physical observation facilities, and other internal inspection systems are available to jurisdictional agencies. Commercial firms with wide experience and highly specialized equipment can carry out the multiple functions of infiltration inspection-location-correction and be retained for this purpose.

Effective and economical methods for correcting points of defect in sewer systems include methods for internal sealing of pipe and joints with chemical compounds and physical grouting materials. Other sealing methods are applicable by means of external corrective procedures. The present capabilities of such sealant methods will be increased by further research and development. The use of such infiltration control methods will increase. Physical replacement of defective sewer pipe and joints will remain a workable procedure, but in areas of urban densities such reconstruction methods may result in disruption of traffic and impediments to other public services. Success has been reported in lining larger sewers, especially those constructed of brick.

6.7 IMPROVEMENT IN BUILDING SEWER CONSTRUCTION PRACTICES

Infiltration through building sewer connections must be recognized as a serious problem. Future infiltration from such sources must be eliminated by improved construction, inspection, and approval practices. Every jurisdiction must examine its present regulations for such construction, and evaluate the effectiveness of the agency or agencies now charged with regulating these connection-line installations.

What if supervisory control of building sewer connections is divided between (1) multiple agencies, such as building and plumbing officials for the section between the building and the property line, and (2) sewer, engineering, or public works officials for the section between the property line and the street sewer, together with connection thereto? In that case, consideration should be given to consolidating total authority in a single agency or to planned cooperation and coordination of multiple-agency actions.

Improved building sewer construction will involve more rigid regulations, stronger enforcement and inspection practices, and more effective testing of such lines before approval. The choice of available pipe and jointing materials should be made on the basis of local needs and conditions. Connections of building sewers to dissimilar materials should be made with an approved fitting.

Poor conditions of existing building sewer connections are the cause of a large percentage of the total infiltration flows being handled by sewer systems. Efforts should be made to locate and evaluate such infiltration sources. Programs of correction should be instituted, where this is feasible, with the use of sealing methods similar to those utilized for public sewer rehabilitation programs. Excavation and replacement of defective building sewers may be required despite its costliness and inconvenience to the public.

Building sewers should not be connected to street sewers by any means other than through a suitable wye fitting. Other connections can cause obstructions in the street sewer or result in connections that are not tight. All wye-connections installed on sewers prior to building connections must be capped or plugged to prevent infiltration. All abandoned building connection stubs must be sealed to prevent open sources of infiltration.

6.8 PREVENTION AND ELIMINATION OF INFLOWS IN SEWER SYSTEMS

Inflows into sanitary sewers must be eliminated to the greatest possible extent. All future connections to sewer systems should be regulated by sewer-use ordinances or other legislative edicts. Existing inflow connections should be eliminated, to the greatest extent possible and feasible, by surveys to locate sources, followed by corrective actions that will be equitable to property owners and made acceptable to them by carefully planned and executed public information and educational procedures. Costs of such corrections should be allocated on the basis of responsibility for originally installed inflow lines.

The importance of a well-planned public relations program cannot be overstressed; endorsement of the inflow control program by both the elected officials and the public is essential. Inflow control affects individual property owners, and correctional action may cause a great deal of inconvenience as well as cost; but the eventual benefits make such efforts worthwhile.

6.9 SUMMARY

Guidelines have been given for the control of infiltration and inflow conditions. Each jurisdiction must determine its own policies and practices, using these indicators as to what can be accomplished by new criteria and actions.

The control of infiltration and inflow is not merely an academic exercise in urban planning and development. It can be translated into the public services purpose: **service to the public.** The fact that investments in control of extraneous water flows in overtaxed systems can be economically rewarding is further reason why all jurisdictions should investigate their problems and take necessary actions to protect the capacities and capabilities of their sanitary facilities.

SECTION 7

ACKNOWLEDGEMENTS

SECTION 7

ACKNOWLEDGEMENTS

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SECTION 8

GLOSSARY OF PERTINENT TERMS

SECTION 8

GLOSSARY OF PERTINENT TERMS

Efforts to attain better levels of infiltration and inflow control must be based on a uniform understanding of the "language" of the field. In fact, one of the findings of the national investigation of this problem of extraneous water intrusion into sewer systems was that there has been no "standardization" of nomenclature among jurisdictional authorities, state and provincial agencies and those who serve and supply the sewer system field. Out of this "babel" of misconceptions of intent and purpose has come misinterpretations of community-to-community data and a confused inability to arrive at better sewer system practices.

To assist in the interpretation of the findings of the national investigations, a Glossary of Terms is included in the report of which this Manual is an integral part. To make this Manual document a self-contained guide to better practices, the following clarification of the meaning of pertinent terms is provided.

Areaway A paved surface, serving as an entry area to a basement or sub-surface portion of a building, which is provided with some form of drainage device that may be connected to a sewer line.

Building Sewer The conduit which connects building waste water sources to the public or street sewer, including lines serving homes, public buildings, commercial establishments, and industry structures. In this report, the building sewer is referred to in two sections: (1) The section between the building line and the property line, frequently specified and supervised by plumbing or housing officials, and (2) the section between the property line and the street sewer, including the connection thereto, frequently specified and supervised by sewer, public works or engineering officials. (Referred to, also, as house sewer, and building connection.)

By-pass A pipe line which diverts waste water flows away from, or around, pumping or treatment facilities – or by-passes such facilities – in order to limit the flows delivered to such facilities and to prevent surcharging or adversely affecting their operation or performance.

Cellar Drain A pipe or series of pipes which collect waste waters which leak, seep, or flow into subgrade parts of structures and discharge them into a building sewer, or by other means dispose of such waste waters into sanitary, combined or storm sewers. (Referred to, also, as "basement drain.")

Clean Waters Waste waters from commercial or industrial operations which are uncontaminated, do not need, and could not benefit from waste water treatment processes, and which for sanitary purposes do not require disposal into public sewers, particularly separate sanitary sewers.

Collector Sewer A sewer located in the public way which collects the waste waters discharged through building sewers and conducts such flows into larger interceptor sewers and pumping and treatment works. (Referred to also as "street sewer.")

Compression Gasket A device which can be made of several materials in a variety of cross-sections, which serves to secure a tight seal between two pipe sections (frequently referred to as "o" ring.)

Exfiltration The leakage or discharge of flows being carried by sewers out into the ground through leaks in pipes, joints, manholes or other sewer system structures; the reverse of "infiltration."

Foundation Drain A pipe or series of pipes which collects ground water from the foundation or footing of structures and discharges these waters into sanitary, combined or storm sewers, or to other points of disposal, for the purpose of draining unwanted waters away from such structures.

Grouting The cementing together of loose particles of soil in such a manner that the soil so grouted becomes a solid mass which is impervious to water.

Inch-Gallons A designation for the commonly used expression, referring to units of infiltration allowances. The full expression is gallons per inch of diameter per mile of pipe per day.

Infiltration The discharge of ground waters into sewers, through defects in pipe lines, joints, manholes or other sewer structures.

Inflow The discharge of any kinds of water into sewer lines from such sources as roof leaders, cellar, and yard-area drains, foundation drains, commercial and industrial so-called "clean water" discharges, drains from springs and swampy areas, etc. It does not include "infiltration" and is distinguished from such waste water discharges, as previously defined.

Infiltration/Inflow A combination of infiltration and inflow waste water volumes in sewer lines, with no way to distinguish either of the two basic sources, and with the same effect of usurping the capacities of sewer systems and other sewer system facilities.

Infiltration Allowances The amount of infiltration anticipated in sewer systems; considered inevitable under sewer construction and sewer service conditions, and authorized and provided for in sewer system capacity design and in sewer construction practice. A distinction is made between "sewer design infiltration allowances" which the designer provides for in structuring the total sewer system and "construction infiltration allowances" permitted in the specifications covering the construction of specific projects and specific sections of the total sewer system.

Interceptor Sewer A sewer which receives the flow from collector sewers and conveys the wastewaters to treatment facilities.

Joints The means of connecting sectional lengths of sewer pipe into a continuous sewer line, using various types of jointing materials with various types of pipe formations that make possible the jointing of the sections of pipe into a continuous collecting sewer line. The number of joints depends on the lengths of the pipe sections used in the specific sewer construction work.

Jurisdiction Any governmental entity, such as city, town, village, county, sewer district, sanitary district or authority, or other multi-community agency which is responsible for and operates sewer systems, pumping facilities, regulator-overflow structures and waste water treatment works.

Overflow A pipe line or conduit device, together with an outlet pipe, which provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regulator device has been allowed the portion of the flow which can be handled by the interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Pipe Sealing A method of correcting leaks or defects which permit infiltration of excessive extraneous waters into sewers, by means of physical or chemical materials, applied by interior or exterior means, and which seals such points of defects and reduces or eliminates such infiltration waters.

Pipe Tests Various methods of testing sewer lines, after construction, and in service, to ascertain whether or not infiltration allowances have been met, and locating the sources of infiltration which exceeds construction specifications. Such tests include: infiltration tests; exfiltration tests; air tests; and other means of locating sources of infiltration in new and existing sewer lines, such as smoke bomb tests.

Precipitation Rainfall or thawing snow and ice which produce storm water runoff from streets, roads, and other impervious surfaces, and which percolate into the soil and augment the ground water, are held in the interstices of the soil, affect the ground water table, or produce inflows into sewer systems.

Regulator A device or apparatus for controlling the quantity of admixtures of sewage and storm water admitted from a combined sewer collector line into an interceptor sewer, or pumping or treatment facilities, thereby determining the amount and quality of the flows discharged through an overflow device to receiving waters or other points of disposal.

Roof Leader A drain or pipe that conducts storm water from the roof of a structure, downward and thence into a sewer for removal from the property, or onto or into the ground for runoff or seepage disposal.

Sewer Inspection Methods for determining the condition of new or existing sewer systems, in terms of infiltration conditions, by visual inspection, closed-circuit television viewing, photographic methods, or other means.

Sewer-Use Ordinance A regulation, code, or ordinance enacted by a jurisdiction to specify the types and volumes of waste waters which can be discharged into sewer systems, the waste waters which cannot be so discharged, and the fees or charges to be imposed for the privilege of discharging those wastes and volumes which are permitted.

State Provincial Water Pollution Control Agency A branch of government which imposes and enforces water quality standards, establishes standards of design for sewer systems and pumping and treatment facilities, and has responsibility for maintaining established water pollution control standards in receiving waters.

The "TWO I's" A phrase adopted for this report, to designate the two factors of infiltration and inflow which affect sewer systems and the other waste water handling facilities evaluated in this project and report.

SECTION 9

APPENDICES

APPENDIX 1
WHY REGULATE THE USE OF YOUR SEWER SYSTEM?

In October 1969, the New York State Department of Health's Division of Pure Waters, Bureau of Water and Waste Water Utilities Management, distributed a memorandum outlining its position on the question: "Why Regulate the Use of Your Sewer System?"

The reasons presented by the State agency are so relevant to the guidelines expressed in this Manual, in Section 4, that the memorandum is included here. Each jurisdiction is urged to evaluate the New York State presentation in terms of its own conditions.

Why are Sewer Use Ordinances Valuable?

1. The objective is to have legal authority to protect life and limb and sewers and wastewater treatment facilities, to minimize overall expense of treatment to the taxpayer, and to prevent unwarranted abuse of the sewerage system.
2. *Protect Sewer System from:*
   (a) damage, deterioration and destruction from discharges of gasoline, fuel oil, cleaning solvents, and paint particles;
   (b) hazardous explosive substances;
   (c) acids or alkaline wastes which eat out joints and cause infiltration;
   (d) ashes, tar, sand, cinders, metal, broken glass, wood, clay and slag which clog sewers;
   (e) grease which adheres to sewers and causes stoppages;
   (f) hazardous wastes, such as sulphur dioxide, hydrogen sulphide and sulphur-oxidizing bacteria which may cause disintegration of some sewers; and
   (g) excessive high-temperature wastes.
3. *Protect Biological Treatment Units* of a waste water facility from:
   (a) excessive acidity or alkalinity harmful to biological waste water treatment processes;
   (b) greases, oil, etc., which cause scum formation; and
   (c) toxic substances such as copper, chromium, lead, zinc, arsenic and nickel which kill off or inhibit biological activity.
4. *Protect Receiving Water Users and Aquatic Life from:*
   (a) poisonous compounds or radioactive wastes which may also pass through waste water utility facilities in dangerous concentrations that are hazardous to human life or injurious to edible fish and/or shellfish;
   (b) high temperature wastes which disturb or destroy natural aquatic life; and
   (c) high or low pH wastes which may interfere with natural aquatic life.

What Are the Problems that Municipalities Face?

1. There has been frequent evidence of cases where municipalities experience trouble from one or more of the above sources. As a result, they are forced to:
   (a) spend considerable sums of money to repair the sewer system; and
   (b) spend sums to repair the damage done to treatment units of the waste water facility. And, municipalities may be sued because of pollution of a body of water caused by inadequately treated discharges.
2. In many cases, industry has made no effort or very little effort to cut down on the volume and/or concentrations of the waste waters until an ordinance is enacted and/or steps are taken to enforce it. Sometimes investigation and action of communities to enforce ordinances has resulted in industry finding out that they have suffered losses in their uncontrolled discharges.
3. When an industry approaches the officials of a community on the discharge of their industrial wastes into the public sewer system, the officials must find out first whether the cost of their handling these wastes will be too high for municipal treatment.
4. Many communities permit runoff from roofs, footing drains, cistern overflows, etc. This adds considerably to the capital cost and

operating expenses and affects operation of waste water facilities.

What are the Rules and Interrelationships?

Article 12 of the Public Health Law (New York State) Reg. 1220, contains a general prohibition against pollution; namely, "It shall be unlawful for any person, directly or indirectly to throw, drain, run or otherwise discharge into such waters, organic or inorganic matter that shall cause or contribute to a condition in contravention of the Standards adopted by the Water Resources Commission pursuant to section one thousand two hundred five of this article." The community is therefore responsible for any violation of standards promulgated by the Water Resources Commission because it allows the condition to exist.

Alternates

Most users of public sewer systems will cooperate, but some willful violators always attempt to take unfair advantage of a municipality and discharge undesirable wastes. A good ordinance fitting the particular needs of the sewerage system which can be properly and promptly enforced by local officials is needed in each community.

Solution

1. Water pollution abatement and prevention is the sole aim of a municipal waste water treatment plant. Therefore, the ordinance must regulate the concentrations and volumes of waste water to the plant to obtain the maximum practical reduction of pollutants.
2. The sewer ordinance should control the concentrations and volumes of waste water to minimize the capital cost and operating expenses of treatment that is paid by taxpayers, both individual and corporate.
3. The sewer ordinance to be effective must provide for *penalties* in case of violations together with procedures for their inspection. It must empower the officials to prohibit the discharge of any wastes at any time which can harm life, limb, structures or property; that is, if necessary, have legal machinery available to take immediate action.
4. In many cases, industry may agree to *pre-treatment* of their wastes, while in others, industry may prefer to pay municipalities for expenses of treatment.
5. *The inability of a waste water treatment plant to effectively process* a new industrial load does not necessarily constitute a permanent banning of industrial load from sewerage system. Provisions may be worked out for altering or extending the plant to handle the load with the industry or industries concerned paying their proper share of construction costs and operation expenses of such modifications which would benefit them.
6. Exclusion of existing roof water, footing drains, cistern overflows, etc., is a difficult problem, but the municipality should not shirk its responsibility for saving the taxpayer's money. One way of speeding up elimination is to charge taxpayers who have connection for continuing the connection.
7. *Cooling and condensing waters* containing no organic matter or reducing gases which are incapable of causing objectionable conditions in an open watercourse, should be segregated from polluted wastes and discharged into storm sewers or to a natural outlet.
8. Under no circumstances should the *responsibility for industrial waste water control* be delegated to an agency or a department which does not have the authority and responsibility for regulating the condition of receiving water.
9. The *ordinance should be flexible* enough to cover all known conditions as well as those which may arise in the future.
10. Pre-treatment of certain wastes which cannot be accepted in sewer systems must be required.

APPENDIX 2

REGULATION OF THE DISCHARGE OF INDUSTRIAL, COMMERCIAL AND OTHER SPECIAL WASTES INTO SEWER SYSTEMS

Sewer-use ordinances or other types of local laws, codes and regulations provide a valuable means for controlling the types of wastes discharges into sewer systems which may be deleterious to sewer lines, detrimental to wastes handling, treatment and disposal works, or hazardous to operation and maintenance personnel involved in these municipal installations.

Section 4 of this Manual contains sample excerpts from representative ordinances relating to the control of sewer connections and discharges of inflow waters into public sewer systems. Research work on sewer-use regulations covering inflow control provided valuable references to the control of industrial, commercial and other special wastes of the nature referred to above.

This special waste material is so closely related to the regulation and control of inflow waters that it is included here as a valuable source of information for jurisdictions which are planning to enact new sewer-use legislation or to improve and modernize their present powers to enforce rules and protect their sewer systems.

The following excerpts are presented under specific categories for ease of reference. They are intended for guidance purposes only, rather than as actual parts of any codes or ordinances to be drafted by any jurisdictions. The applicability of all regulatory items to actual jurisdictional conditions must be judged by local officials who intend to devise such regulations and who will be required to enforce them.

Prohibited Substances – General

General provisions to bar a broad range of substances from the sewers are often included in sewer-use regulations:

Substances which are not amenable to standard wastewater treatment plant processes or may affect the quality of water supplies derived from watercourses receiving solid waste should be prohibited.

"No property owner or sewer user shall be allowed to discharge sewage into the sewer disposal system which shall be deemed deleterious to such system, or which shall endanger the employees, operation or treatment processes of sewage disposal, or which shall cause incrustations or chemically or physically attack so as to corrode or erode the sewer or sewage disposal system or facilities." – *Boise, Idaho*

"No substances which will clog the drains, produce explosive mixtures or injure the pipes or their joints shall be allowed to enter the drainage system or the sewer." – *Boston, Massachusetts*

"It shall be unlawful for any person to disturb, tear up, or injure any public drain or sewer, manhole, or catch basin or other appurtenances connected with any public sewer or cause any public sewer to become clogged by permitting oils, or greases, rags, lime, sodium cyanide, garbage, fruit or vegetable parings, ashes, cinders, poisonous or explosive liquids or gases, household foods, offal, swill, bottles, tin cans, dead or live animals, tree limbs, lawn clippings, rubbish, or any material of any nature whatsoever other than normal domestic sewage to accumulate therein." – *Rockford, Illinois*

"No person shall release or discharge into any of the City's sewers any of the following: (a) animal grease or oil; (b) horse, cattle, sheep or swine manure; (c) solids in particles larger than will go through a quarter-inch screen; (d) oil or petroleum, or wastes therefrom; (e) any acid or alkali waste which may injure or damage any such sewer, the City Sewage System, or its sewage treatment or sewage at such plant; (f) any other deleterious matter, substance or thing, whether liquid or solid, which will injure, damage or pollute any such sewer, the City's Sewage System or it's Sewage Disposal Plant, or interfere with the proper operation of such plant." – *Yorktown, Saskatchewan*

"Under no conditions will the City consider accepting sewage that is detrimental to pipe lines, hazardous because of explosive liquid or gases, or may cause stoppage of the lines. Any customer found allowing any of the above listed types of sewage to enter the system will be subject to paying all costs necessary to stop such flow and remove the objectionable item from the system, and repair it if necessary, as well as all penalties as further outlined.

In the determination of what materials may be harmful and the degree of correction necessary, the City will generally follow the recommendations of the Water Pollution Control Federation." – *St. Petersburg, Florida*

"The following materials shall be excluded from the sewerage system: (a) Gasoline, cleaning solvent, fuel, oil, etc. These are highly inflammable compounds and serious damage due to explosions of these liquids or their vapors have occurred within sewerage systems; (b) Ashes, sand, cinders, rock, etc. These inorganic compounds add excessive solid loading on the sewerage causing unnecessary cleaning and maintenance; (c) Tar, plastics, and other water insoluble viscous materials. These compounds do not break down by bacterial action and add to the solid loading of a sewerage system. (d) Mineral oils, lubricating oils, etc. do not decompose in the normal course of sludge digestion. They cause potential fire hazards throughout the sewerage system, cause excessive cleaning and impose an unnecessary solid loading upon the sludge system. (e) Feathers, hair, rags, etc. These materials cause excessive maintenance throughout the sewerage system. Feathers and hair do not readily digest in sludge digestion processes and create excessive matting on top of the decomposing sludge. (f) Metal, broken glass, shavings, etc. These materials will readily plug up sewer lines, pumps and appurtenant equipment. (g) Unshredded garbage. Large pieces of unshredded garbage cause sewer lines and pumps to clog and excessive maintenance will occur. Garbage ground in domestic and industrial grinders to a size of ¼ inch or less is satisfactory. (h) Wastes which contain or result in the production of toxic, corrosive, explosive and malodorous gases." – *San Diego, California*

Prohibited Substances – Specifics

Numerous types and characteristics of specific wastes ruled inadmissible to sewers are covered in many ordinances. (Where the quoted portion seems more an itemization than an explicit ban it is because the specific item is one of a series following a prohibitory introduction.)

1. Temperature

"Any liquid or vapor having a temperature higher than 150° F." – *Jacksonville, Florida*

"Any liquid or vapor having a temperature higher than 150 degrees F (65 degrees C)." – *Cedar Rapids, Iowa*

"Any liquid or vapor having a temperature higher than 160 degrees F." – *Wilson, North Carolina*

"Any liquid or vapor having a temperature greater than 140 degrees Fahrenheit." – *Salem, Oregon*

"Steam, vapor, and water at a temperature above one hundred and thirty degrees Fahrenheit shall not be discharged into the sewer. The blow-off of boilers, steam exhaust or drip, or hot water from any other source destined to be discharged into a sewer shall be condensed and cooled to one hundred and thirty degrees Fahrenheit in a blow-off tank or other approved device of which the size, arrangement, location, venting and all connections shall be subject to the approval of the Commissioner of Public Works." – *Boston, Massachusetts*

"No person shall discharge into a sewer or storm drain any industrial waste, water, or liquid having a temperature greater than 100 degrees Fahrenheit, except upon written advance permission of the Board of Public Works." – *Los Angeles, California*

"Any liquid or vapor having a temperature higher than 100 degrees Fahrenheit (37 degrees Centrigrade)." – *Knoxville, Tennessee*

2. pH (Hydrogen Ion Concentration)

"Any liquids having a pH lower than 5.5 or higher than 9.0, or having any corrosive property capable of causing damage or hazards to structures, equipment, or personnel of the sewage disposal works." – *Salem, Oregon*

"The pH of industrial wastes shall average between 5.5 to 9.0 daily. The maximum variation on a temporary basis during any twenty-four hour period shall not be less than 5.0 or greater than 10.0." – *San Diego, California*

"Any industrial waste with a hydrogen-ion concentration less than 5.5 (for acidity), or greater than 9.0 (for alkalinity)." – *Los Angeles, California*

"Hydrogen ion concentration (pH) – 4.5 to 9.5." – *Nassau County, New York*

"Any water or waste, acidic or alkaline in reaction, and having corrosive properties capable of causing damage or hazard to structures, equipment and personnel. Free acids and alkalies in such wastes must be neutralized, at all times, within a permissible range of pH between 5.5 and 10.0." – *Jefferson City, Missouri*

"Waters having a pH below 6.0 or above 8.5." – *Yakima, Washington*

"Any waters or wastes having a stabilized pH lower than 6 or higher than 9, or having any other corrosive property capable of causing damage or hazard to structures, equipment, and personnel of the sewage works, provided accumulated pH does not exceed our limits as specified." – *Wilson, North Carolina*

"Wastes having a pH less than 6.0 or greater than 10.0 or otherwise having chemical properties which are hazardous or are capable of causing damage to the sewage works or personnel." – *Kansas City, Missouri*

"Any waters or wastes having pH lower than 6.0 or greater than 10.5 or having any other chemical or corrosive property which are hazardous or capable of causing damage to structures, equipment and personnel of the sewage works." – *Oklahoma City, Oklahoma*

"Wastes having a pH less than 6.5 or greater than 9.75 or otherwise having chemical properties which are hazardous or capable of causing damage to the sewage works or personnel." – *Omaha, Nebraska*

3. **Fats, Oils, Greases**

"Waste water which contains more than one hundred parts per million by weight of fat, oil or grease." – *Seattle, Washington*

"Any water or waste which may contain more than 100 parts per million by weight, of fat, oil, or grease, exclusive of soap." – *Oak Ridge, Tennessee*

"Any water or waste containing fats, wax, grease, or oils, whether emulsified or not, in excess of one hundred (100) mg/l or containing substances which may solidify or become viscous at temperatures between thirty-two (32) and one hundred fifty (150) degrees F (0 and 65°C)." – *Rome, New York*

"Insoluble oils, fats and greases. So-called soluble oils may be admitted to the extent of 100 ppm, provided subsequent dilution in the sewers or treatment plant does not result in separation." – *Kansas City, Missouri*

"Any water or waste containing fats, wax, grease, or oils, whether emulsified or not, in excess of 100 mg/l or containing substances which may solidify or become viscous at temperatures between 32 degrees and 150 degrees F (0 and 65 degrees C)." – *Cedar Rapids, Iowa*

"Any water, or waste containing grease, as follows: (1) floatable grease in excess of 50 parts per million. Grease is an oil, fat, grease. or other ether – soluble matter. Floatable grease is grease which rises to the surface of quiescent sewage or waste or upon dilution of the sewage or waste with fresh or salt water. (2) Dispersed grease, other than soap, in excess of 500 parts per million. Dispersed grease is grease which is not floatable." – *Watsonville, California*

"Any water or waste containing fat, oil, or grease of such character or quantity that unusual attention or expense is incurred." – *Janesville, Wisconsin*

4. **Suspended Solids**

"Suspended Solids – 300 ppm. max." – *Nassau County, New York*

"Industrial wastes having suspended solids in excess of 500 ppm. will be considered individually. If the sewerage system can safely receive said wastes, wastes having higher suspended solids can be allowed." – *San Diego, California*

"Any waters or wastes containing more than 700 parts per million by weight of suspended solids." – *Oak Ridge, Tennessee*

"Liquid waste material in which the suspended solids exceed 1000 parts per million, determined by weight." – *Los Angeles, California*

"Any waters or wastes containing suspended solids of such character and quantity that unusual attention or expense is required to handle such materials at the sewage treatment plant." – *Jacksonville, Florida*

"Any waters or wastes containing suspended solids of such character and quantity that unusual provision, attention or expense is required to handle such materials at the Waste Water Treatment Plant." – *Knoxville, Tennessee*

5. Biochemical Oxygen Demand (BOD)

"The admission into the public sewers of any water or wastes havihg a 5-day BOD (Biochemical Oxygen Demand) greater than 400 parts per million by weight shall be subject to the review and approval of the City Engineer." – *Watsonville, California*

"Any waters or wastes having a Biochemical Oxygen Demand in excess of 500 parts per million by weight." – *Wilson, North Carolina*

Materials which exert or cause . . . unusual BOD, chemical oxygen demand, or chlorine requirements in such quantities as to constitute a significant load on the sewage treatment works." – *Rome, New York*

"Materials which exert or cause . . . unusual BOD, chemical oxygen demand, or chlorine requirements (such as, but not limited to, whey, whole or separated milk, yeast, whole blood, etc.) in such quantities as to constitute a significant load on the sewage treatment works." – *Oklahoma City, Oklahoma*

6. Phenols

"Wastes containing phenolic compounds over .50 ppm expressed as phenol." – *Omaha, Nebraska*

"Wastes containing pheolic compounds over 1.0 ppm expressed as phenol." – *Kansas City, Missouri*

"Any water or wastes that contains phenols in excess of 0.50 parts per million by weight. These limits may be modified if the aggregate of contributions create treatment difficulties or produce a plant effluent discharge to the receiving waters which may be prohibitive." – *Oak Ridge, Tennessee*

7. Gases and Fumes

"Any water or waste that contains more than 10 milligrams per liter of gases such as hydrogen sulphide, sulfur dioxide, or nitrous oxide." – *Jefferson City, Missouri*

"Any waters or wastes containing more than 1.0 parts per million of dissolved sulfides." – *Watsonville, California*

"Any water or wastes containing more than ten parts per million by weight of the following gases: Hydrogen sulphide, sulphur dioxide, or nitrous oxide." – *Knoxville, Tennessee*

"Wastes containing cyanides or compounds capable of liberating hydrocyanic acid gas over 2 ppm expressed as hydrogen cyanide." – *Kansas City, Missouri*

"Any noxious or malodorous gas or substance capable of creating a public nuisance." – *Santa Cruz, California*

8. Flammables

Flammables are generally regulated in the terms first shown below, but generalized provisions are sometimes encountered:

"Gasoline, benzene, naptha, fuel oil or other flammable or explosive liquid, solid or gas." – *Lethbridge, Alberta*

"Any solid, liquid or gas which by reason of its nature and/or quantity could cause fire or explosion." – *Kansas City, Missouri*

"Any petroleum product or other product which, by reason of its nature or quantity may cause a fire or explosion, or in any way be injurious to persons or to the sewers or storm drains or other appurtenances." – *Los Angeles, California*

9. Solid and Viscous Substances

"Any ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastics, wood, paunch manure, or any other solid or viscous substance capable of causing obstruction to the flow in sewers or other interference with the proper operation of the sewerage system." – *Jacksonville, Florida*

"Any ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar plastics, wood, paunch manure, hair and fleshings, entrails, lime slurry, lime residues, chemical residues, paint residues, cannery waste bulk solids, or any other solid or viscous substance capable of causing obstruction to the flow in sewers, or other interference with the proper operation of the sewer system or sewage treatment facilities." – *Jefferson City, Missouri*

"Any solid or viscous material which could cause an obstruction to flow in the sewers or in any way interfere with the treatment process. Examples of such materials include, but are not limited to, ashes, wax, paraffin, cinders, sand, mud, straw, shavings, metal, glass, rags, lint, feathers, tars, plastics, wood and sawdust, paunch manure, hair and fleshings, entrails, lime slurrys, beer and distillery slops, grain processing wastes, grinding compounds, acetylene generation sludge, chemical residues, acid residues, and food processing bulk solids." – *Kansas City, Missouri*

"Industrial wastes having a viscosity exceeding 1.10 poises (absolute Viscosity) upon discharge or after acidification (pH below 5.5), or alkalization (pH above 8.5.)" – *Nassau County, New York*

"Paunch manure or intestinal contents from horses, cattle, sheep or swine; hog bristles; pigs' hooves or toenails; animal intestines or stomach casings; bones; hides or parts thereof; animal fat or flesh in particles larger than will pass through a quarter inch screen; manure of any kind; poultry entrails, heads, feet or feathers; eggshells; fleshing and hair resulting from tanning operations." – *Lethbridge, Alberta*

"Any waters or wastes containing strong acid iron pickling wastes, or concentrated plating solutions whether neutralized or not." – *Rome, New York*

"Septic tank sludge, except that such sludge may be discharged into selected treatment plants at locations designated for this purpose by the director." – *Kansas City, Missouri*

Scavenger wastes shall mean putrid or offensive matter, the contents of all privies, septic tanks and cesspools. . . . Scavenger wastes will be admitted into the sewerage system only by approval of the City Engineer and subject to the payment of fees or charges fixed by the City Commission." – *Jacksonville, Florida.*

10. Toxic Substances and Chemicals

"Any waters or wastes containing a toxic or poisonous substance in sufficient quality to injure or interfere with any sewage treatment process, constitute a hazard to humans or animals, or create any hazard in the receiving waters of the Plant." – *Watsonville, California*

"Any waters or wastes containing toxic or poisonous solids, liquids, or gases in sufficient quantity, either singly or by interaction with other wastes, to injure or interfere with any sewage treatment process, constitute a hazard to humans or animals, create a public nuisance, or create any hazard in the receiving waters of the sewage treatment plant, including but not limited to cyanides in excess of two (2) mg/l as CN in the wastes as discharged to the public sewer." – *Oklahoma City, Oklahoma*

"Any waters or wastes containing strong acid iron pickling wastes, or concentrated plating solutions whether neutralized or not." – *Cedar Rapids, Iowa*

"Waters and wastes containing metallic ions such as copper, zinc, and chromium. Such wastes shall be subject to the control of the City as to volume and concentration of wastes from individual establishments." – *Jefferson City, Missouri*

"Any waters or wastes containing strong acid iron pickling wastes, or concentrated plating solutions whether neutralized or not. Any waters or wastes containing iron, chromium, copper, zinc, and similar objectionable or toxic substances; or wastes exerting an excessive chlorine requirement, to such a degree that any such material received in the composite sewage at the sewage treatment works exceeds the limits established by the Commissioner for such materials." – *Rome, New York*

"Any waters or wastes containing a toxic or poisonous substance in sufficient quantity to injure or interfere with any sewage treatment process, constitute a hazard to humans, or animals or create any hazard in the receiving waters or storm water overflows or the effluent of a Waste Water Treatment Plant. Materials such as copper, zinc, chromium, and similar toxic substance shall be limited to the following average quantities in the sewage as it arrives at the Treatment Plant and at no time shall the hourly concentration at the Waste Water Treatment Plant exceed three (3) times the average concentration: Iron as FE-15 parts per million; Chromium as Cr. (hexavalent)-5 parts per million; Copper as Cu-3 parts per million; Zinc as Zn-2 parts per million; and with contributions from individual establishments subject to control in volume and concentration by the City." – *Knoxville, Tennessee*

"The term 'objectionable waste' shall mean: . . . (b) Any chemicals or chemical compounds of the following nature or characteristics, or having similarly objectionable characteristics: alcohols; arsenic and arsenicals; cresols; formaldehyde; iodine; manganese; cyanide and other metal plating wastes; mercury and mercurials; phenols and their derivatives; silver and silver compounds; sulfanamides; toxic dyes (organic or mineral); zinc; all strong oxidizing agents such as chromates, dichromates, permanganates, peroxide, and the like." – *Nassau County, New York*

"The following chemical substances shall not exceed the specific listed concentrations in Mg/l: . . . Arsenic, 0.10; Barium, 1.0; Cadmium, 0.10; Chloride, 300.0; Chromium trivalent (Cr. + 3), 2.00; Chromium, hexavalent (Cr. + 6), 0.20; Copper, 0.50; cyanide, 0.20; (Cr. + 3), 2.00; Fluoride, 3.00; Lead, 0.10; Methylene Blue Active Substances, 1.0; Nitrate nitrogen, 20.0; Phenols, 0.20; Selenium, 0.10; Silver, 0.10; Sulfate, 200.0; Zinc, 5.0; Other Constituents – shall not contain other substances which are or may become injurious or detrimental to the sewage system." – *Janesville, Wisconsin*

11. Colored Materials

"Any waters or wastes having an objectionable color which is not removable in the existing sewage treatment plant processes." – *Wilson, North Carolina*

"Concentrated dye wastes or other wastes which are either highly colored or could become highly colored by reacting with other wastes." – *Kansas City, Missouri*

"Blood in sufficient quantities so as to cause discoloration of . . . effluent." – *Omaha, Nebraska*

12. Radioactive Wastes

"Any radioactive waste in an amount greater than recommended by local or state public health agencies." – *Watsonville, California*

"Any radioactive wastes or isotopes of such half-life or concentration as may exceed limits established by the Superintendent in compliance with applicable state or federal regulations." – *Cedar Rapids, Iowa*

"Pretreated wastes shall conform to the following minimum standards: Radioactive wastes – Not to exceed 1,000 micro micro-curies, in the known absence of Strontium 90 and alpha emitters." – *Janesville, Wisconsin*

"Radioactive material: Any institution or industry using radioactive material or fission products must be registered with the City Engineer as well as such other control agencies as the law requires. The active elements and their local concentration permitted to be discharged into the sewers shall be based upon the latest knowledge available to this technology." – *Jacksonville, Florida*

"The introduction of radioactive wastes into the city sewers shall be permitted only if a special permit is obtained prior to introducing such wastes. While each case will be decided on its own merits, in general, decisions will be in accordance with the principles laid down in the Atomic Energy Acto of 1954

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"No person shall discharge or cause to be discharged any radioactive wastes into any public sewers or appurtenances thereof, except where: (a) The person is authorized to use radioactive materials by the Atomic Energy Commission or other governmental agency empowered to regulate the use of radioactive materials; (b) The waste is discharged in strict conformity with current Atomic Energy Commission recommendations for safe disposal of radioactive wastes; (c) The person discharging the radioactive wastes assumes full responsibility for any injury to personnel or damage to the sewerage system that may result from such discharge and submits evidence satisfactory to the Director of Public Works that he has assumed this responsibility. Any person discharging a radioactive waste to a public sewer in accordance with the provisions of the preceding paragraph shall submit to the Director of Public Works such reports as the Director may deem necessary. If any radioactive material is accidentally discharged into any public sewer, the person responsible shall: (1) Immediately notify the Director of Public Works. (2) Render such technical or other assistance to the Department of Public Works within his power to prevent the sewerage system from becoming contaminated with radioactivity; and (d) The person has secured a permit from the Director of Public Works to discharge radioactive materials into the public sewers." – *Santa Cruz, California*

13. Garbage and Garbage Grinders

"Garbage that has not been properly shredded." – *Seattle, Washington*

"Any garbage that has not been properly shredded. Properly shredded garbage shall mean the wastes from the preparation, cooking and dispensing of food that has been shredded to such degree that all particles will be carried freely under the flow conditions normally prevailing in public sewers, with no particle greater than one-half inch in any dimension." – *Enterprise Public Utility District, Shasta County, California*

"Any garbage that has not been ground or shredded." – *Salem, Oregon*

"The term 'minced garbage' shall mean food waste resulting from the normal occupancy of any residential building, no particle of which shall have any dimension greater than one-half inch. Such 'minced garbage' shall not be deemed an 'objectionable waste'." – *Nassau County, New York*

"The installation and operation of any garbage grinder equipped with a motor of three-fourths (3/4) horsepower or greater shall be subject to the review and approval of the Director of Public Works/City Engineer." – *Oklahoma City, Oklahoma*

"Garbage, fruits, vegetables, animal or other solid kitchen waste materials from individual dwelling units resulting from the preparation of any food or drink may be admitted to the sanitary sewer if first passed through a mechanically operated grinder so designed: (a) that it will operate with cold water flowing into the grinder and through the sink drain line in such manner as to congeal and aerate the solid and liquid greases within the grinding unit; (b) that it shall discharge wastes at a reasonably uniform rate in fluid form, which shall flow readily through an approved trap, drain line or soil line in a manner which prevents clogging or stoppage of the drain line; (c) that it shall be of such construction and have such operating characteristics that not more than five percent by weight of all material discharged from it shall have any dimension larger than one-fourth inch, and no particle shall be greater than one-half inch in any dimension; (d) that it shall be self-scouring, with no fouling surfaces to cause objectionable odors; (e) that it shall be free from electrical or mechanical hazards and shall adequately protect the user against injury during operation; (f) that the installation shall be free from cross-connection to any water pipe; (g) that the entire installation shall comply in all particulars with the provisions of the plumbing and electrical codes of the City. The final decision as to the sufficiency of the design to meet these requirements shall rest with the Director of Public Works." – *Santa Cruz, California*

"Under no circumstances will the discharge of garbage or refuse whether shredded or unshredded be permitted into the sewer system. The installation of 'Garbage Grinders' for the purpose of grinding or shredding garbage into the sewer system is expressly prohibited." – *Jacksonville, Florida*

"Household garbage grinders, garbage disposal units, or garburetors, of any nature or kind shall not be affixed to any plumbing or other fixture or otherwise used so that the waste therefrom is discharged into either the sanitary or storm sewer or open ditch or watercourse, provided however, that should any household garbage grinder, garbage disposal unit or garburetors installed and in use within the City on the date of the enactment of this By-law, become worn out and in need of replacement, they shall not be so replaced." – *Kamloops, British Columbia*

14. Installation of Interceptors

"All wastes discharged into the industrial wastes sewer shall be adequately screened by a twenty mesh or finer screen before discharge. An additional screen, with openings not to exceed one-fourth inch square, shall be installed in a fixed position so that all material must pass through said screen immediately before entrance into sewers." – *Yakima, Washington*

"Grease, oil and sand interceptors shall be provided on private property for all garages, gasoline service stations and vehicle and equipment washing establishments; interceptors will be required for other types of businesses when in the opinion of the Director, they are necessary for the proper handling of liquid waste containing grease in excessive amounts, or any flammable wastes, sand and other harmful ingredients, except that such interceptors shall not be required for private living quarters or dwelling units. All interceptors shall be of a type and capacity approved by the Director and shall be so located as to be readily and easily accessible for cleaning and inspection. Where installed, all grease, oil and sand interceptors shall be maintained by the occupant at his expense in continuously efficient operation at all times." – *Lethbridge, Alberta*

"Screen type interceptors, in addition to other required interceptors, may be required for handling industrial waste." – *Santa Cruz, California*

"Grease and oil interceptors shall be constructed of impervious materials capable of withstanding abrupt and extreme changes in temperature. They shall be of substantial construction, water tight, and equipped with easily removable covers which, when bolted in place, shall be gas tight and water tight." – *Wyoming, Michigan (and Knoxville, Tennessee)*

"(a) An interceptor shall be so designed that it will not become airbound and be so located as to be readily accessible for cleaning; (b) a grease or oil interceptor shall be of sufficient capacity to intercept all grease or oil likely to flow into it under normal conditions; (c) the interceptor for motor vehicle wash floors shall have a capacity sufficient to retain the sand or grit reaching the interceptor during any ten-hour period, but in no case shall it be less than four feet long, two feet six inches wide and two feet deep, measured from the floor of the interceptor to the invert of the overflow." – *Metropolitan Winnipeg, Manitoba*

Rate Structures for Sewer Service

Where sewer service charges are levied upon all connected properties, special charges or surcharges are often assessed against contributors of "problem" wastes.

"Industrial rates shall be based on the following unit charges; (1) Industrial Schedule – $23.83 per million gallons, (2) Biochemical oxygen demand (BOD) – 0.0035 per pound, (3) Suspended solids – 0.0056 per pound. Unit charges are to be applied against the total monthly measured quantities of flow, biochemical oxygen demand and suspended solids from each industry, using the calendar month at which the maximum biochemical oxygen demand load occurs at the industry. The resultant monthly charge is applied uniformly each month over the calendar year." – *Salem, Oregon*

"*Industrial and Commercial Surcharge.* All persons, firms, corporations or institutions discharging wastes into the public sewers, shall be subject to a surcharge, in addition to any other sewer service charge, if their sewage has a concentration greater than "normal" concentrations. The amount of surcharge shall reflect the cost incurred by the City in removing the excess B.O.D. and suspended solids. (1) *Computation of Surcharge.* The excess pounds of Biochemical Oxygen Demand (B.O.D.) and suspended solids (S. S.) will be computed by multiplying the flow volume in million gallons per day (M.G.D.) by the constant 8.345 and then multiplying the product by the difference between the persons' concentration in ppm by weight. This product will then be multiplied by the number of days in the billing period to determine the surcharge. (2) *Rates of Surcharge.* The rates of surcharge for each of the aforementioned constituents will be at the prevailing rate at the time. Said prevailing rate at the time is as follows: (a) For Biochemical Oxygen Demand (B.O.D.) $0.01 per pound. (b) For Suspended Solids (S.S.) $0.01 per pound." – *Janesville, Wisconsin*

"When the suspended solids content or the B.O.D. of a waste exceeds the maximum concentration of these components in normal sewage, a surcharge, in addition to the normal sewer charge, shall be levied and established by either of the formulae hereinafter set forth, but in no event shall said surcharge be less than $1.00 per month. The surcharge shall be computed by using formulae as outlined below, providing that the surcharge shall be limited to the maximum amount established by either of the following formulae:

"S (ss) = .0000625 x Va x $ .014 x (SS-400), which shall signify that the amount of the surcharge of the suspended solids basis shall equal the factor of .0000625 for converting parts per million by weight to pounds per cubic foot multiplied by the volume of sewage in cubic feet multiplied by $ .014, the estimated cost for treatment of one pound of suspended solids in raw sewage, multiplied by the concentration of suspended solids in the waste in parts per million by weight minus 400, with the minimum charge to be $1.00, or

"S.(B.O.D.) = .0000625 x Va x .0075 x (B.O.D.-300), which shall signify that the amount of the surcharge on the B.O.D. basis shall equal the factor of .0000625 for converting parts per million by weight to pounds per cubic foot, multiplied by the volume of sewage in cubic feet, multiplied by the concentration of B.O.D. (biochemical oxygen demand of the waste) in parts per million by weight minus 300, with the minimum charge to be $1.00.

"The symbols, letters or figures employed in the aforesaid formulae signify the following: Va = volume of sewage in cubic feet, S (ss) = amount of surcharge on suspended solids basis, S (B.O.D.) = amount of surcharge on biochemical oxygen demand basis,

.0000625 = factor for converting parts per million by weight to pounds per cubic feet, SS = concentration of suspended solids in the waste in parts per million by weight, BOD = biochemical oxygen demand by the waste as defined in .... this ordinance. Determination of the suspended solids and BOD concentration shall be made in accordance with standard laboratory methods." – *Kansas City, Missouri.*

"A surcharge (is) established herein, in addition to the charge now or hereafter fixed for 'Normal Sewage'. The basis of the surcharge shall be determined on each of three constituents of the water or wastes: (a) total suspended solids as herein provided; (b) BOD five (5) days at 20 degree centigrade where applicable as outlined elsewhere in this section; (c) recoverable grease and as herein provided. When anyone or all of the total suspended solids, BOD and recoverable grease of a water or wastes accepted for admission to the city sewage works exceeds the values of these constituents for 'normal' sewage, the excess concentration in each case shall be evaluated volumetrically in terms of 'Normal' sewage and be subject to surcharge on the volume derived in accordance with the following:

$$Sv = \frac{(Sw - 2500)}{2500} \times .90 \times F \times 133690$$

Sv = F ((Sw – 2500) 48) Suspended Solids

$$Sv = \frac{(Bw - 2000)}{2000} \times .85 \times F \times 133690$$

Sv = F ((Bw – 200) x57) BOD

Sv = (Gw – 833) x .70 x F x 133690

Sv = F ((Gw – 833) 112) Grease

Note: Where Sv is the derived volume of wastes in cubic feet subject to surcharge, Sw is pounds per million gallons of suspended solids from the wastes as discharged, 2500 is the pounds per million gallons of suspended solids in the 'Normal' Sewage, Bw is pounds per million gallons of B.O.D. in the wastes as discharged, 2000 is the pounds per million gallons of B.O.D., in 'Normal' Sewage, Gw is the pounds per million gallons of grease from the wastes as discharged, 833 is the pounds per million gallons of grease in 'Normal' Sewage, 0.90 is factor allowance for 90% degree of purification of suspended solids, 0.85 is factor allowance for 70% degree of purification of grease, F is the flow expressed in million gallons of the waste discharge, and 133,690 is equal to the factor to convert million gallons to cubic feet.

The equivalent volume of 'normal' sewage as derived from the excess above the normal strength of any water and waste shall be subject to a surcharge for the volume of equivalent 'normal' sewage as computed from the formula for the Papillion Creek Plant Service Area at the flat rate of $ .0175 for each one hundred cubic feet on the highest single value applicable to the contributing wastes as above computed." – *Omaha, Nebraska*

APPENDIX 3

MILWAUKEE, WISCONSIN, IN-DEPTH STUDY OF SEWER CLEANING PRACTICES[1]

Prior to 1965, the City of Milwaukee's sewer cleaning operations were carried out purely on a reactive-type basis geared to complaints and random inspections.

Late in 1964, a study was made of the city's experience with clogged sewers. All locations where the city had experienced obstructed sewers during the ten-year period from 1955 through 1964 were tabulated and coded for the cause of the obstruction, such as grease, roots, rags, etc.

These incidences of system failures were plotted on a city map. Those areas of the city having a group or cluster of incidences were programmed for regular and periodic cleaning. The frequency of cleaning was dependent upon the suspected causes for the clogged sewers. This was the city's first real attempt to establish a planned, preventative maintenance program for the cleaning of its local sewers.

As a result of this program, the incidences of clogged sewers decreased in these "programmed" areas, but new locations were springing up and property owners' increasing awareness of the possibility of collecting damages caused by these clogged sewers was apparent from the increasing number of claims being filed against the city. Apparently, an increase in the acceptable standard for cleaning sewers was needed – but by how much? How many crews and what kind were needed? How many miles of sewers were now being cleaned by each crew and how effective were the techniques being used? How many additional miles of sewers should be added to the existing program? What type, or methods, of cleaning should be phased out and what new sewer cleaning techniques should we add?

To answer these questions, the Bureau of Street and Sewer Maintenance, in 1968, began a comprehensive study of its sewer cleaning program, methods, and techniques.

The study was divided into two separate phases of investigation. The first was comprised of a block-by-block analysis of every foot of sewer in the city's sewer system. The second phase consisted of sending out questionnaires to 136 major cities in the United States. The date and information gathered was assembled, analyzed, and included in a final study report. Conclusions and recommendations for improving Milwaukee's sewer cleaning operation was the final step in this study. The following excerpts from the Milwaukee report are included in this Manual because of the correlation between sewer cleaning and infiltration conditions:

OBJECTIVES

WHY CLEAN SEWERS?

Most municipalities have a multi-million dollar investment in their sewer systems. It is designed to furnish a collection network for sewage, a by-product of their industries, businesses, and residential properties.

The service that a sewer system provides is most often measured in terms of "capacity" to carry sewage. The amount of flow that a sewer is capable of handling is directly in proportion to the *square* of the pipe's diameter.

In the 1968 issue of the "American Public Works Manual", is found the following statement regarding the need for regular maintenance. "When a sewer is constructed, capacity is purchased. With use, this capacity is reduced and can only be restored by regular maintenance."

Without regular cleaning, the capacity of a sewer can be drastically affected and reduced below originally designed requirements.

Any obstruction, or collection of debris, inside the pipe, such as grease and roots, will reduce this capacity. For example, the efficiency of a 12-inch diameter sewer will be reduced by 75 percent of its originally designed capacity if a three-inch layer of grease, roots, or other debris, is permitted to accumulate around the circumference of the pipe. A sewer cleaning program that permits a 75 percent decrease in the capacity of a sewer is substandard. (The effect of sewer clogging on infiltration is self-evident.)

Water use in the past decade has changed considerably. There is a greater use of garbage disposals, automatic washers, air conditioning units, etc., that has radically changed the per capita water use formula. This has increased the flow in the sewer above that amount originally anticipated in the earlier

[1] Abstracted from a report by Milwaukee's Department of Public Works, entitled, *Sewer Cleaning, A Determination of Needs and Methods*

a sewer system very often affects another portion of the system upstream; i.e., a loss of effectiveness in one section of a system can be hydraulically reflected upstream to a relatively clean portion of sewer.

The principal reasons for establishing an effective sewer *cleaning operation* are based upon two premises: Maintenance of the sewer system's efficiency; and the savings that result from a preventive maintenance program.

A clean sewer assures continuous service and reduces the chance of surcharging and resulting backwater problems. The monies saved by anticipating problems, and eliminating the cause before the problem occurs, has been proven worthwhile in dealing with other maintenance problems, such as surface sealing.

This philosophy can be applied to the maintenance of sewers. By determining the critical areas involved, and establishing a sewer cleaning program that will give reasonable assurances that the system will perform in an acceptable manner, more work can be done by each crew and the efficiency of the sewer system increased.

The objectives of this sewer cleaning study are as follows:

1. Determine the recommended level of sewer cleaning that will give reasonable assurances that the City of Milwaukee's sewer system will function effectively.
2. Compare the City of Milwaukee's present sewer cleaning capability with the recommended level of sewer cleaning and determine if additional crews are required to provide an efficiently operating sewer system.
3. Evaluate present methods of cleaning sewers and determine relative effectiveness of each type of cleaning.
4. Compare the City of Milwaukee's sewer cleaning capability with those of other cities and seek guidelines for improving present cleaning services.

METHODS AND PROCEDURES

This study is divided into two phases.

The first phase offers a critical evaluation of the City of Milwaukee's sewer cleaning techniques and concerns itself with the first two objectives outlined above.

The procedure used in the first phase consisted of interviews and meetings between each of five District Sewer Supervisors and the Assistant Superintendent of Sewer Maintenance.

Each block of sewer in all five Districts was studied. The District Sewer Supervisor was asked to describe any special problems that he might have encountered with that particular section of sewer. In addition, he was asked the following pertinent questions.

1. Do you clean this section of sewer now? If so, what sewer cleaning method do you use? How frequently do you clean this section? How long does this cleaning operation take? How many lineal feet are you cleaning?
2. Assume that you were asked to provide your department with *reasonable* assurances that this section of sewer will provide efficient and reliable service, what would be your recommendation on the type and frequency of sewer cleaning required?

In answering these questions, each Supervisor was asked to consider the following factors:

(a) His experience and knowledge of this area with respect to special problems consisting of unusual waste from abutting properties; to include industrial plants, restaurants, and schools, root penetration from extensive tree population, high density housing developments, etc.
(b) Age of sewer
(c) Type of sewer
(d) Size of sewer
(e) Length of sewer
(f) Street traffic conditions encountered
(g) The Department's records of complaints and service.

The second phase concerns the third and fourth objectives and consists of an evaluation of what other cities are doing in the cleaning of their sewers and a comparison with Milwaukee's present cleaning program. The procedures used in the second phase of this Study consisted of the preparation and mailing of a questionnaire to 136 municipalities in the United States.

An attempt was made to sample most major cities in the United States and obtain opinions and information from various sections having the greatest variety of geographic and climatic conditions. An attempt was made to obtain a greater number of samples from the northeastern section of the country. This permits the City of Milwaukee maximum opportunity to compare its sewer cleaning operations

TABLE 1

MILWAUKEE STUDY
CURRENT SEWER CLEANING OPERATIONS

District	Bucket Lin. Ft.	Bucket Crews Used	Rodder Lin. Ft.	Rodder Crews Used	Wayne Ball Lin. Ft.	Wayne Ball Crews Used	Flushing Lin. Ft.	Flushing Crews Used	Total
1	2,600	1	0	0	0	0	175,000	1	177,600
2	43,150	.5	58,230	.5	410,920	.5	0	4	512,300
3	197,890	2.5	96,420	.5	138,905	.5	9	0	433,285
4	14,320	.5	523,360	1	1,320	0	6,120	0	545,120
5	25,350	1	163,000	0	111,050	.5	4,400	0	303,800
Total	283,310		841,010		662,195		185,590		1,972,105
1967-68 Dept. Avg. Per Crew	300,000	5.5	600,000	2.0	700,000	1.5	200,000		

TABLE 2

MILWAUKEE STUDY
SEWER CLEANING REQUIREMENTS
RECOMMENDED BY SUPERVISORS

District	Bucket Lin. Ft.	Bucket Crews Used	Rodder Lin. Ft.	Rodder Crews Used	Wayne Ball Lin. Ft.	Wayne Ball Crews Used	Flushing Lin. Ft.	Flushing Crews Used	Total Lin. Ft.
1	651,630	9.50	0	0	0	0	282,800	1	934,430
2	235,000	3.80	133,950	0.363	1,129,300	2.56	800	0	1,499,050
3	450,580	7.75	95,770	0.236	264,435	0.524	24,105	0	834,890
4	294,350	4.40	540,720	1.33	639,700	1.56	6,120	0	1,480,890
5	144,015	1.25	191,685	0.228	497,300	1.0	4,400	0	837,400
Total	1,775,575	26.70	962,125	2.157	2,530,735	5.6444	318,250	1	5,586,660

with other cities under similar geographic and climatic conditions. A total of 88 cities responded to this questionnaire.

ANALYSIS OF RESULTS

FIRST PHASE

The first phase of this study was designed to provide information and data concerning the first two objectives. Each supervisor was asked to give thoughtful and critical consideration to his existing cleaning techniques and problems. What were his problems? Was he satisfied with the methods used and the results?

A summary of the results obtained in this phase is shown in Tables 1 and 2. Table 1 is the current operations, while Table 2 depicts the recommended level of operations that will provide "reasonable assurances" that the sewer system will function efficiently. The difference, between the "current operations" and the "recommended level of operations", represents the additional work capability required to meet the supervisors' recommended level of sewer cleaning.

The supervisors' recommendations propose an increase of 18 bucket crews and 3½ wayne ball crews. This represents an expansion of approximately 300 percent in the present cleaning program at an estimated annual cost of $500,000.

SECOND PHASE

The second phase of this Study was designed to gather information and data concerning the third and fourth objectives. This phase involves the evaluation of the relative merits of various methods for cleaning sewers. The questionnaire was intended to help in the evaluation and provide a means of comparing the City of Milwaukee's capability with those of other cities.

From the information reported relating to miles of sewers, and relating to cleaning methods, each municipality's relative ability to clean sewers was computed. The relationship between a city's ability to clean sewers and the total miles of sewers in its system is defined as the "Capacity Index[1]", i.e. –

Capacity Index = Total Miles Cleaned ÷ Total Miles in System x 100

The Capacity Index was tabulated for each reporting municipality. The Capacity Index and the Total System Mileage was plotted to produce Figure 1.

The City of Milwaukee has 2,150 miles in its sewer system and operates near the 350 mile work line with a Capacity Index of 16.2. The recommended increase for the City of Milwaukee, as shown in Table 3, amounts to a shift from the 350 mile line to a point above the 1,000 mile line with a potential Capacity Index of 51.5.

The principal factors determining a municipality's position in the Capacity Index curve is believed to be the following:

1. *Velocity of Flow.* (Design Requirements) This factor will determine the self-cleaning characteristics of a sewer.
2. *Type of Sewer.* (Sanitary, Combined, and Storm)
3. *Nature and Character of the Municipality.* The number and type of industrial complexes, or commercial developments. will affect the type of cleaning problems encountered; i.e., what is the economy based upon – industry, commerce, tourist trade, etc?

[1] For the capacity index to have meaning it must be determined that:
a. all reporting agencies have used the same definition of a clean sewer – that is that a full guage squeegee has been passed through the line, and
b. that all sewers have the relatively same degree of deposition.

TABLE 3

MILWAUKEE STUDY
DATA ANALYSIS OF QUESTIONNAIRE
Number of Cities Reporting = 88

CAPACITY INDEX ANALYSIS

Average index of all Cities reporting = 34.9
Average index of all Cities reporting cleaning footage = 40.4
Average index of all Cities with total system above 2,000 miles = 10.61
Average index of all Cities with total system above 1,000 miles = 18.65
Average index of all Cities with total system above 500 miles = 29.3

Average system mileage of all Cities reporting (index above 100%) = 312
Average system mileage of all Cities reporting (index above 50%) = 428
Average system mileage of all Cities reporting (index above 25%) = 558
Average system mileage of all Cities reporting (index above 20%) = 551
Average system mileage of all Cities reporting (index above 16.2%) = 668
Average system mileage of all Cities reporting (index below 16.2%) = 1507
Average system mileage of all Cities reporting (index below 10%) = 1781
Average system mileage of all Cities reporting (index below 5%) = 2346
Total number of Cities reporting Combined Sewers = 39
Mileage:

High 2600	**Low 2**	**Average 494**

Total number of Citiés reporting Combined Sewers only = 7

Mileage:

High 1500	**Low 50**	**Average 438**

4. *Citizen Demands and Resulting Pressure Groups.* In Milwaukee, the level of citizen demands vary, even between neighborhoods or wards. The difference in citizen demands could be even greater between major cities.

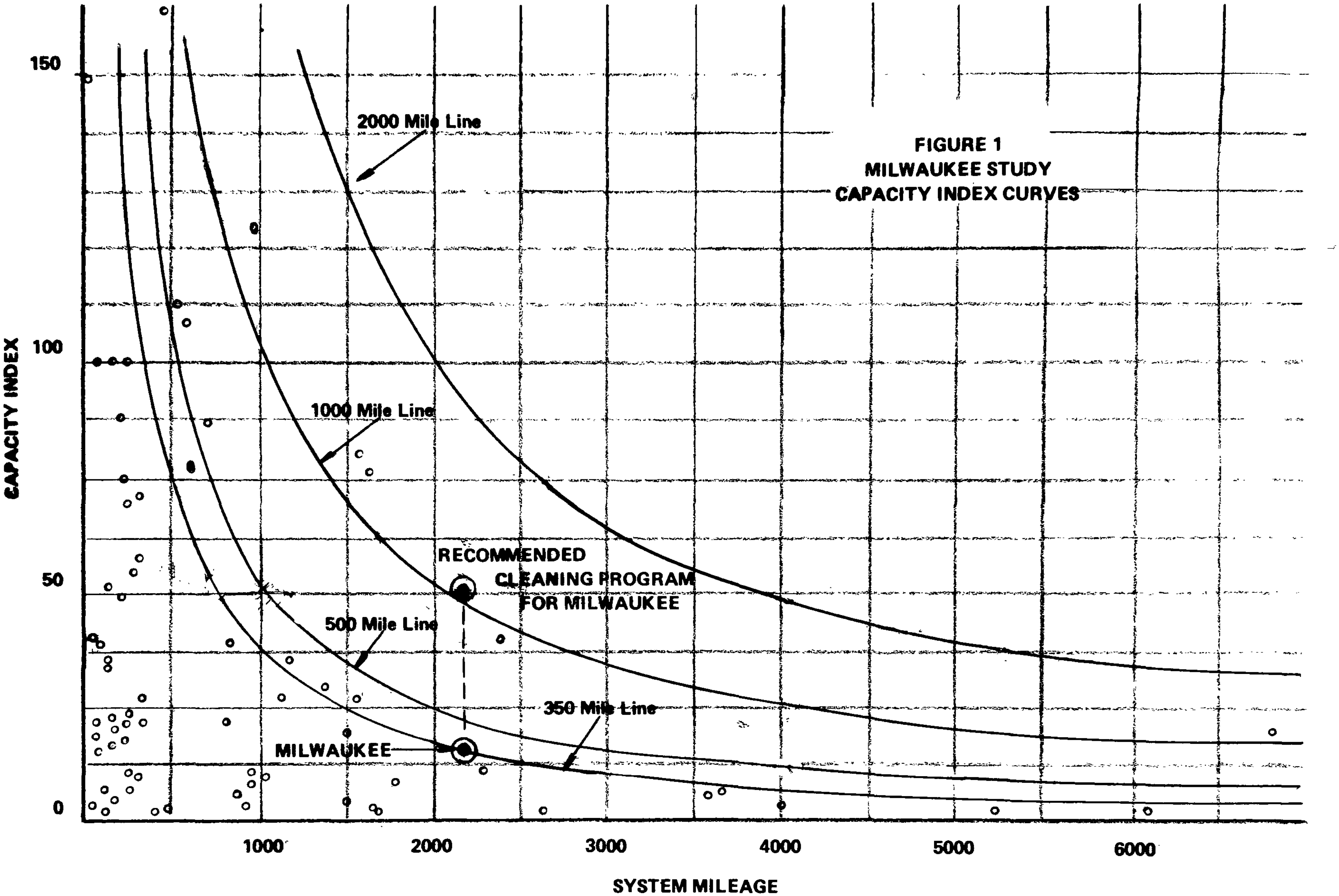


FIGURE 1
MILWAUKEE STUDY
CAPACITY INDEX CURVES

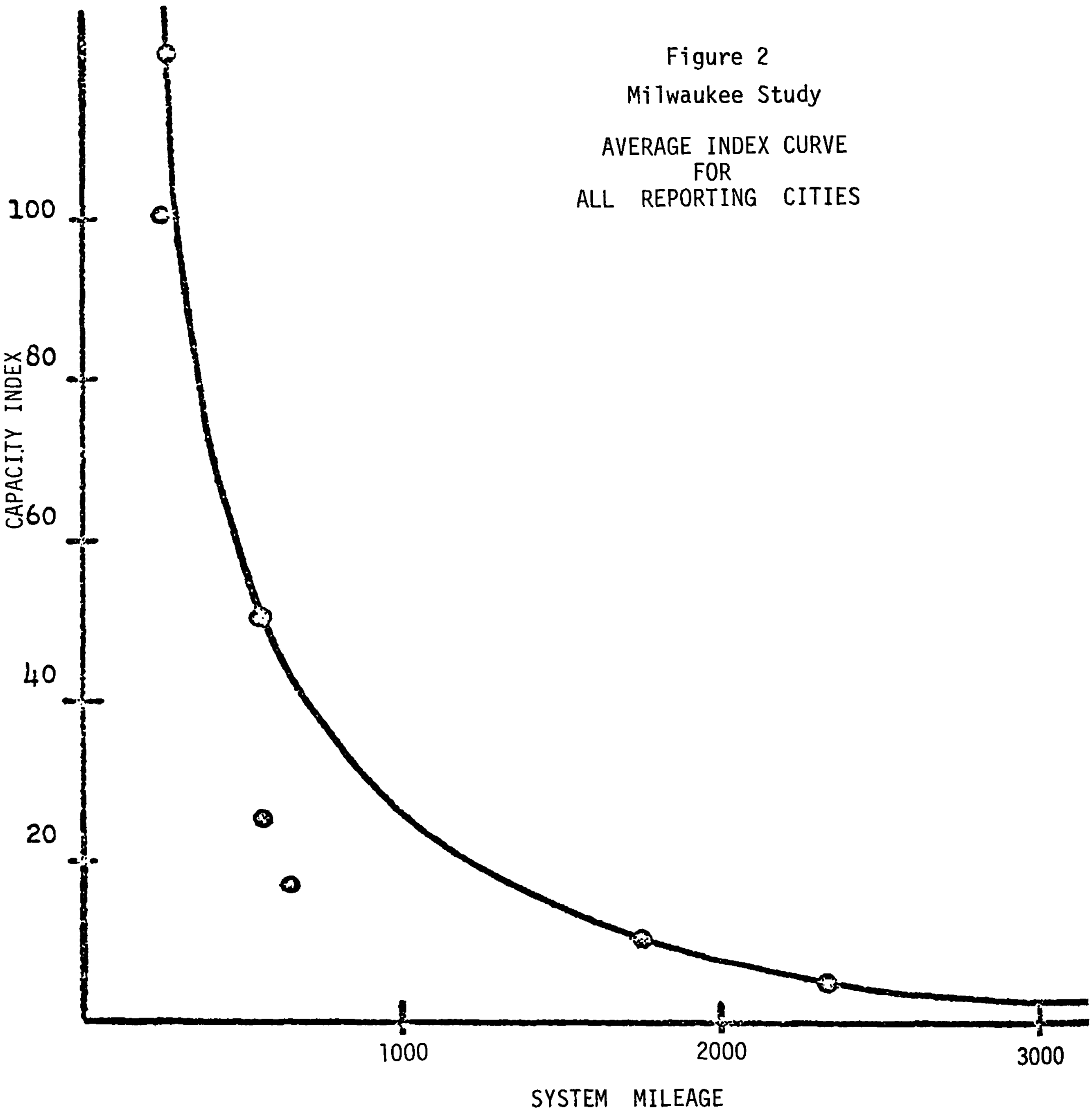


Figure 2

Milwaukee Study

AVERAGE INDEX CURVE
FOR
ALL REPORTING CITIES

TABLE 4
MILWAUKEE STUDY
DOMINANT CLEANING PROBLEMS FOR REPORTING CITIES

Cleaning Problem:	Grease	Roots	Sand	Gravel	Sludge	Industrial Waste
No. Cities Reporting	65	74	49	24	35	11

Preference Tabulation from Survey

Problem	Bucket		Rodder		Wayne Ball		Hyd. Jet		Flushing		Chemicals	
	New Sewers	Old Sewers	New Sewers	Old Sewers	New Sewers	Old Sewers	New Sewers	Old Sewers	New Sewers	Old Sewers	New Sewers	Old Sewers
Grease	17	25	40	36	6	7	32	21	24	22	25	23
Roots	23	28	71	72	4	1	6	6	10	13	15	25
Sludge	16	19	15	20	9	7	24	22	39	38	14	16
Sand & Gravel	49	53	5	9	18	16	26	21	23	24	2	3
ndustrial Naste	18	20	12	12	6	5	16	12	16	16	10	8

5. *Climate and Topography of Land.* The elevation above sea level, and the chemical and physical structure of the soil, can affect the design and construction of the sewers. This can, also, mean a difference in the maintenance problems encountered.
6. *Efficiency of Present Cleaning Operations.* The type of cleaning used may be obsolete or poorly planned. In addition, the municipality might be only responding to emergencies and not be capable of implementing a Preventive Program.
7. *Tax Limitations.* The ability of the municipality to pay the cost for a better and more efficient cleaning operation.

In addition to establishing the "Capacity Index" for sewer systems responding to the national questionnaire survey, and comparing these indexes with its own operations, the city computed and plotted the so-called "Performance Factor"[2] for each responding municipality and compared this factor with the national average. The "Performance Factor" was defined as:

$$P.F. = \frac{\text{Total miles cleaned/type/yr.}}{\text{No. of crews}} = \text{ft./crew/day}$$

The city also summarized the sewer clogging problems reported by responding systems, and evaluated the effectiveness of sewer cleaning method. These data are included in this excerpted report. (Table 4, Dominant Cleaning Problems for Reporting Cities)

The *Bucket Method* is slow and most costly. but offers a solution to almost all difficult sewer cleaning problems.

The *Rodder Method* is very mobile at a relatively low cost, but the final cleaning results are not as reliable.

The *Wayne Ball Method* has a high production rate and removes a high percentage of debris from the sewers.

The *Hydraulic Jet Method* has a high production rate, is very mobile, but could leave a high percentage of debris in the sewers.

The sewer *Flushing Method* is the cheapest, but it leaves a high percentage of debris in the sewers and the final cleaning results are not reliable.

The use of *Chemicals* is a relatively new method, and may be effective where grease deposits are a problem.

[2] For the performance factor to have meaning it must be determined that all agencies have used the same definition of cleaning; that is that a full gauge squeegee has been passed through the sewer.

APPENDIX 4

SEWER CONNECTION REQUIREMENTS
OAKLAND COUNTY DEPARTMENT OF PUBLIC WORKS
PONTIAC, MICHIGAN

OAKLAND COUNTY DEPARTMENT OF PUBLIC WORKS
PONTIAC, MICHIGAN

SEWER HOUSE LEADS: Sewer connection requirements

1. ALL WORK TO BE PERFORMED UNDER O. CO. D.P.W. INSPECTION.
2. NOTIFY WATER AND SEWAGE MAINTENANCE, 24 HOURS IN ADVANCE OF WORK.
3. NO SANITARY SEWER WILL BE USED FOR A CLEAN OUT OR A DEWATERING OUTLET.
4. ALL WORK IS TO BE PERFORMED IN THE BEST TRADE PRACTICES.
5. THE TYPE OF PIPE IN THE GROUND, USED FOR A HOUSE LEAD, WILL BE CARRIED ALL THE WAY TO THE HOUSE UNLESS A FACTORY MADE D.P.W. APPROVED ADAPTER IS USED TO CONVERT TO ANOTHER TYPE OF PIPE.

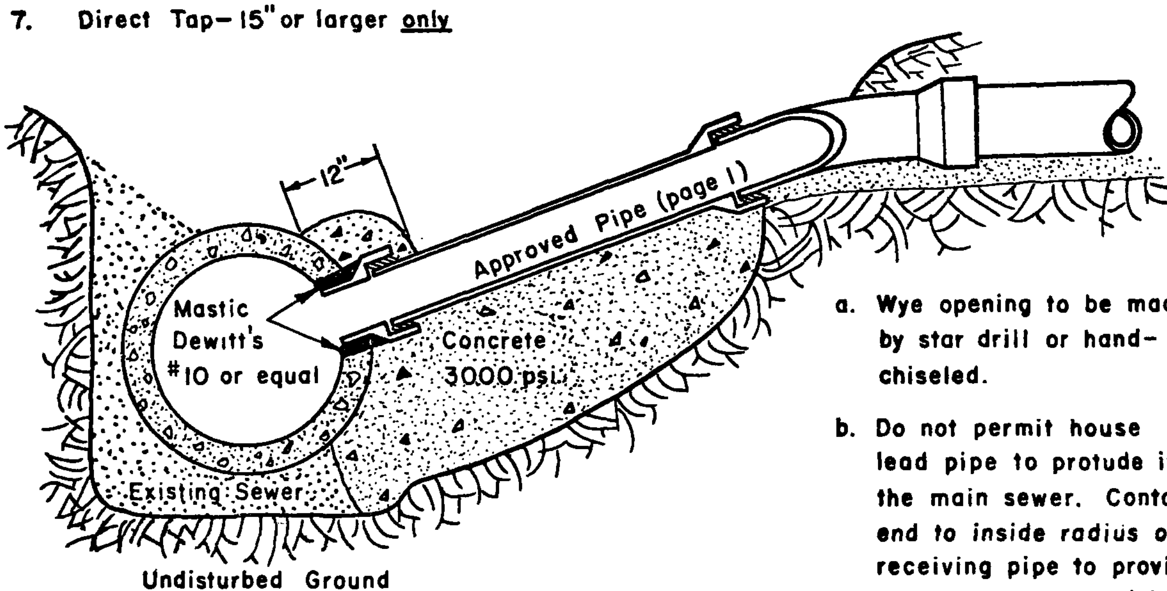
   example: "TYLOX" PIPE TO "WEDGE LOCK" PIPE USE A FACTORY MADE D.P.W. APPROVED "TYLOX SPIGOT" TO "WEDGE LOCK BELL", CONVERSION ADAPTER.

6. **APPROVED PIPE FOR HOUSE LEADS:** FULL DIAMETER, SIX INCH (6 in.)
   A. VITRIFIED CLAY PIPE – NCPI – ER 4 – 67 – EXTRA STRENGTH
      (1) ASTM C – 425 - 60T (TYPE I)
         (a) "AMVIT" .... AMERICAN VITRIFIED PRODUCTS CO.
         (b) "UNILOX" .... U.S.CONCRETE PIPE CO.
         (c) "WEDGE LOCK" .... CLAY PIPE ASSOCIATION JOINT
      (2) ASTM C – 425 – 60T (TYPE III)
         (a) "LOXON" .... LARSON PIPE CO.
         (b) " 'O' RING" .... CLAY PIPE ASSOCIATION JOINT
         (c) "TYLOX" .... U. S. CONCRETE PIPE CO.
   B. ASBESTOS – CEMENT (AC) PIPE – CLASS 2400 (TYPE III)
      (1) "FLUID-TITE" .... KEASBEY-MATTISON CO.
      (2) "RING-TITE" .... JOHNS MANVILLE CO.
      (3) "WELD-TITE" .... FLINTTITE CO.
   C. CAST IRON PIPE – SERVICE WEIGHT
      (1) "LEAD JOINT" .... (HOT POURED AND COMPACTED)
      (2) "TY-SEAL" .... TYLER PIPE CO.
   D. CONVERSION JOINT SEALER; VITRIFIED PIPE TO CAST IRON PIPE, FOUR (4 in.) INCH
      (1) POLYVINYL CHLORIDE (PVC) DONUTS OR EQUAL .... FERNCO JOINT SEALER CO.
      (2) MASTIC DONUTS (SEE NINE (9) BELOW. STANDARD
7. DIRECT TAP. SEE PAGE 2
8. "SPRINGING IN" PIPE AND WYE, SEE PAGE 2

OAKLAND COUNTY D.P.W.
PONTIAC, MICHIGAN

Direct House Lead Connections to Main Sewers

7. Direct Tap– 15" or larger <u>only</u>



a. Wye opening to be made by star drill or hand-chiseled.

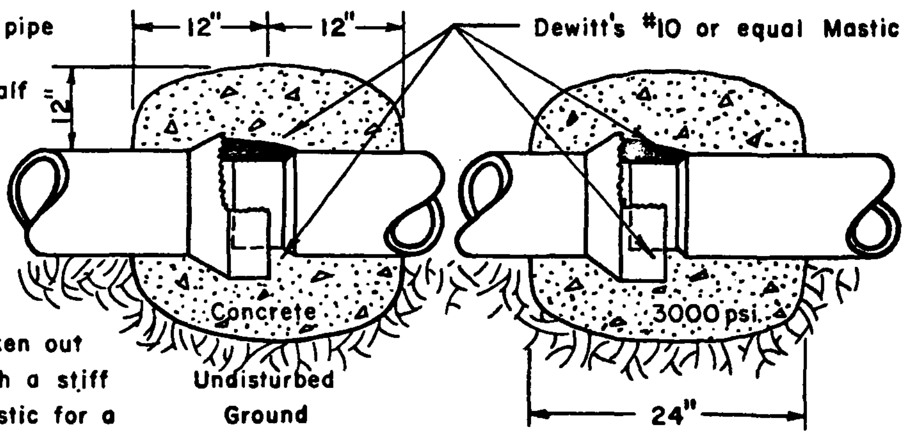
b. Do not permit house lead pipe to protude in the main sewer. Contour end to inside radius of receiving pipe to provide smoothest possible joint.

8. "Spring in" wye pipe

a. Break out half of bells as shown;

b. Center the pipe with oakum;

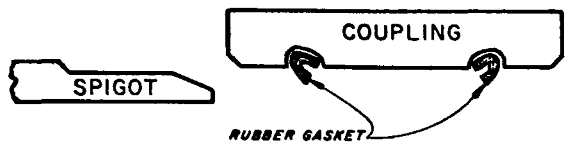
c. Fill the broken out sections with a stiff (summer) mastic for a joint sealer.



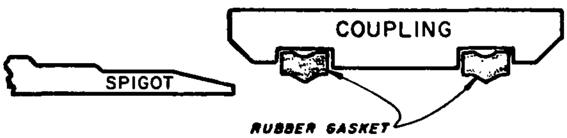
OAKLAND COUNTY D.P.W.
PONTIAC, MICHIGAN

ACCEPTABLE PIPE JOINTS FOR ASBESTOS-CEMENT AND CAST IRON PIPE

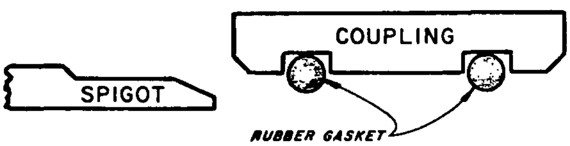
ASBESTOS-CEMENT PIPE



1. ASTM C 428
FLUID-TITE

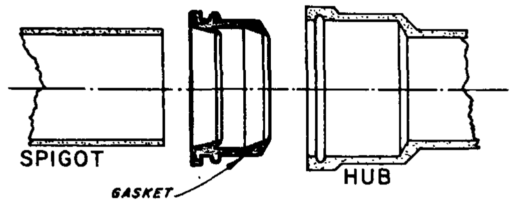


2. ASTM C 428
RING-TITE

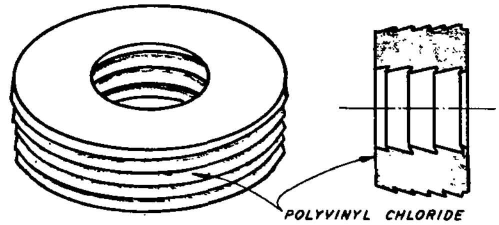


3. ASTM C 428
WELD-TITE

CAST IRON PIPE



1. SERVICE WEIGHT CAST IRON PIPE
TY-SEAL JOINT



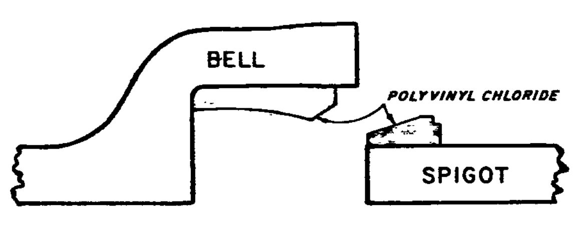
2. CONVERSION JOINT SEALER 6 X 4
FERNCO PVC DONUT

JAN. 1971

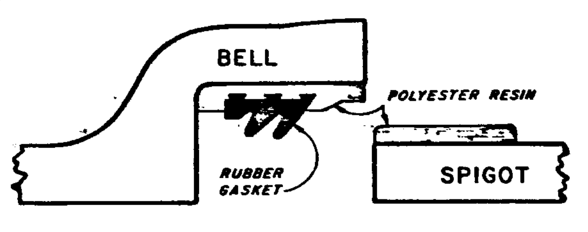
OAKLAND COUNTY DEPARTMENT OF PUBLIC WORKS
PONTIAC, MICHIGAN

ACCEPTABLE PIPE JOINTS FOR VITRIFIED CLAY PIPE

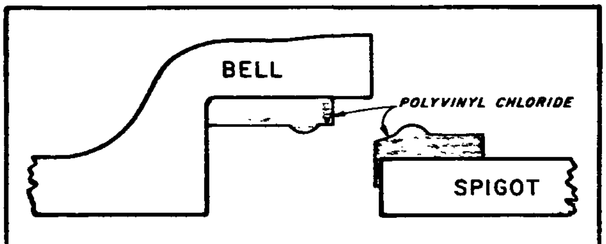
(APPROVED VIT. CLAY PIPE SPEC. N.C.P.I. ER 4-67, EXTRA STR.)



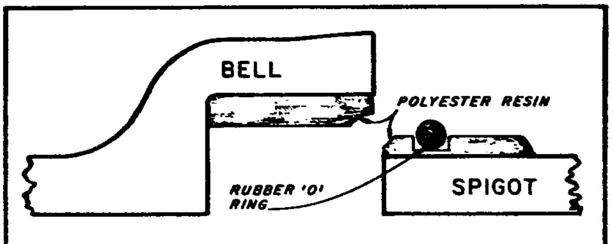
1. ASTM C 425-66T TYPE I
AMVIT



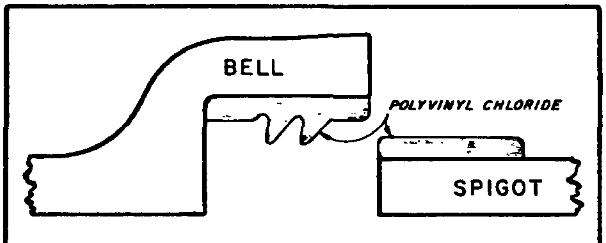
2. ASTM C 425-66T TYPE III
LOXON



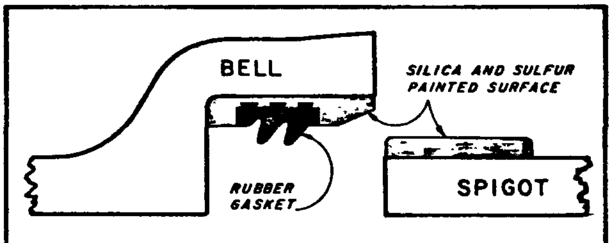
3. ASTM C 425-66T TYPE I
WEDGELOCK



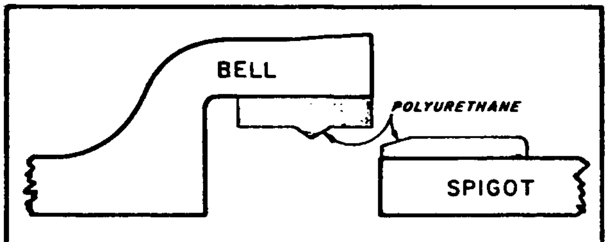
4. ASTM C 425-66T TYPE III
'O'-RING



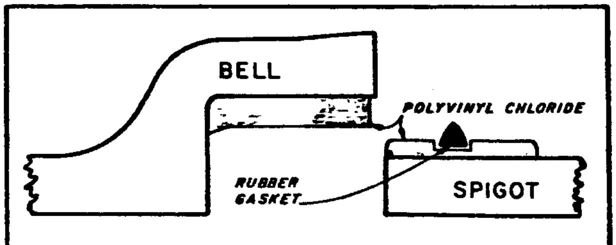
5. ASTM C 425-66T TYPE I
UNILOX



6. ASTM C 425-66T TYPE III
TYLOX



7. ASTM C 425-64 TYPE I
STRE-TITE



8. ASTM C 425-66T TYPE III
AMVIT 'A' RING

OCT. 1970

APPENDIX 5

SAMPLES OF MAINTENANCE REPORT FORMS

Example of Report Form

COMPLAINTS OR REQUEST FOR REPAIRS

JOB NO:

LOCATION

Nature of Complaint:

Received By:	Time:	Date:
From:		
Investigated By:	Time:	Date:
Repairs Requested By:	Time	Date:
Assigned To:	Time	Date:

Action Taken on Complaint or Request:

TIME: DATE COMPLETED: SIGNATURE:

Back

	NO. JOBS	LIN. FT.	SIZE SEWERS	CUBIC YDS. SILT	WATER
BASINS CLEANED					
GRATES CLEANED					
SEWERS CLEANED					
SEWERS EXAMINED					
SEWERS FLUSHED					
TRUNK SEWERS CLEANED					
STREAMS CLEANED					
STREAMS PLAYED					
BASINS SPRAYED					
GARAGE TRAPS INSPECTED					
GARAGE TRAPS CLEANED					
LIGHTS & BARRICADES					
INVESTIGATIONS					
ODORS					
RATS					
MOSQUITOES					
ROACHES					
FLOODING					
BROKEN SEWERS					
OBSTRUCTED SEWERS					
DAMAGED MANHOLES					
BROKEN BASIN TOPS					
OBSTRUCTED BASINS					
BROKEN COVERS					
LOST ARTICLES					
OIL SPILLS					
DYE TEST					

Front

FORM SE-561

MAINTENANCE BRANCH DAILY REPORT

JOB NO.: DATE: / /

UNIT:

LABOR:

EQUIPMENT:

MATERIALS	USED	MATERIALS	USED
BRICK		LUMBER	
BRANCHES		NAILS	
CEMENT		OTHER (SPECIFY)	
CONCRETE SAND			
SCREENED SAND			
PEBBLES			
RED SEWER BRICK			
MANHOLE IRONS			
PIPE VC			
PIPE CONCRETE			
24" COVERS			
30" COVERS			
36" COVERS			
24" FRAMES			
30" FRAMES			
36" FRAMES			
BASIN TOP SIDE			
BASIN TOP CORNER			
JUTE			
LATEX ADDITIVE			
SEWER CLEANER COMP.			
DISINFECTANT			

P-4112

APPENDIX 6

SAMPLE FORM USED TO INSPECT EXISTING SYSTEM BY OPENING MANHOLES

TABLE II

INVESTIGATION OF EXISTING SANITARY SEWERS

SOUNDVIEW AVENUE INTERCEPTOR SEWER AREA

SEWER CONDITIONS OBSERVED

		MANHOLES													PIPES							
STREET NAME	MANHOLE NUMBER	MISSING STEPS	DETERIORATED STEPS	INFILTRATION OBSERVED	RIM OR COVER REPAIRS REQUIRED	MASONRY REPAIRS REQUIRED	WATER FAUCET IN MANHOLE	CLEANING REQUIRED	UTILITY PIPE IN MANHOLE	SEWAGE LEVEL BELOW TOP OF PIPE	SEWAGE LEVEL ABOVE TOP OF PIPE	SEWAGE FLOW STOPPED	CONDITION ADEQUATE	NOT INSPECTED	CLEANING REQUIRED	INFILTRATION OBSERVED	JOINT MISALIGNMENT	BROKEN PIPE	SAG OR HORIZONTAL SWING	CONDITION ADEQUATE	NOT INSPECTED	REMARKS
Tupper Drive	61												x		x		x					
	62				x			x													x	M.H.No. 63, not found.
	63													x							x	
	64												x						x			
	65												x								x	M.H.No. 66, not found.
	66													x							x	
	67												x									
Uncas Rd.	339												x							x		
	338												x						x			
	337												x						x			
	336												x									
Ursula Place	447												x							x		
	448							x														
	246							x							x							
	247							x							x						x	Pipes too full to inspect.
	248							x			x				x						x	
	249							x							x						x	Pipes blocked with sludge.
	250							x							x						x	
	251							x							x						x	M.H.troughs too narrow to permit inspection.
	252	x						x														
	254							x							x						x	Pipes blocked with sludge.
	255							x		x		x			x						x	
	256							x							x		x					
	257							x							x							
	258	x																				
Vantuskirk Ave.	235										x	x			x							
	234							x								x						
	233							x								x						
	232							x														
	326							x							x							
	327												x		x							
	328							x							x							
	329												x		x							M.H.No.330, pulsating flow of soap suds observed.
	330												x		x							
	342							x														

APPENDIX 7

SAMPLE OF LETTERS & FORMS USED TO INVESTIGATE AND CORRECT INFLOW CONDITIONS

1. **SEWER OPERATING COMMITTEE**
102 Witherspoon Street
Princeton, New Jersey
Tel.: 924-3495

Date:

Tests of the sanitary sewer located in your area indicate the following violations and/or deficiencies on your property at

These violations and/or deficiencies must be corrected within thirty days in order to insure your safety and the proper operation of the sanitary system.

Will you please notify this office when the necessary repairs have been completed.

SEWER OPERATING COMMITTEE

ah-300
5/19/67

2. *Washington Suburban Sanitary Commission*
4017 Hamilton Street
Hyattsville, Maryland 20781

RE: Plumbing Violations

Dear

In connection with your property this Commission made an inspection prior to the final approval of the plumbing work performed therein. It is the responsibility of the property owner to be sure that his property in no way violates the Regulations of the Sanitary Commission.

The Commission recently adopted a policy of making another inspection on all properties within the Sanitary District in an effort to eliminate plumbing violations that occur subsequent to the final inspection. The Commission regards a violation of its Plumbing Regulations as a serious matter. The accumulated effect of such violations has created health problems in certain areas as well as increase the operating cost of the Commission.

A recent inspection of your property revealed the following violation:

The Commission realizes that the situation on your property referred to was possibly not created by you or that you may not have been aware of its existence. However, it is one that must be corrected for the welfare of the community.

It is necessary that this condition be corrected as soon as possible and you are therefore allowed fifteen (15) days from the date above to make the necessary changes.

A representative will visit the premises at the end of this time to ascertain if the violation has been eliminated. Your cooperation in eliminating this condition is earnestly solicited.

If you desire to discuss this matter prior to making the correction, will you please come to this office between 8:15 A.M. and 5:00 P.M. on . It may be to your interest to have your builder or seller accompany you at this time.

Yours very truly,

Frank Bliss
Chief Plumbing Inspector

FB/jg

3. *Washington Suburban Sanitary Commission*
4017 Hamilton Street
Hyattsville, Maryland 20781

RE: Illegal Sewer Connection

Dear Sir or Madam:

In connection with a recent study, made by the Commission's Engineers, of the cause of the backing up of sewers in your locality during times of heavy rainfall, it was discovered that your

connected to the sanitary sewer is in excess of the 30 square feet allowed by the W.S.S.C. Plumbing Regulation, which reads as follows:

"608.1 No rain water leaders or other pipes carrying roof, surface or ground water shall be connected to pipes conveying sewage. However, cellar drains in cellars ordinarily dry or not subject to flooding may be connected to the building drain unless expressly disapproved, and paved areas containing not over 30 square feet or horizontal surface entirely unprotected by roof, and not receiving drainage from other surfaces, may be drained to the building sewer or building drain."

This situation on your premises not only contributes to the occasional flooding of some of the cellars (possibly even your own) in the community with the attendant inconvenience and damage, but is a violation of the Plumbing Regulations, adopted for the protection and benefit of this metropolitan area.

The Commission realizes that the situation on your property referred to was quite possibly not created by your or that you may not have been aware of its existence. However, it is one that must be corrected for the welfare of the community.

It is appreciated that it may not be feasible for you to correct the condition mentioned immediately and you are therefore allowed sixty (60) days from the date above to make the necessary changes.

A representative will visit the premises about 10 days before this time to ascertain if the violation has been eliminated.

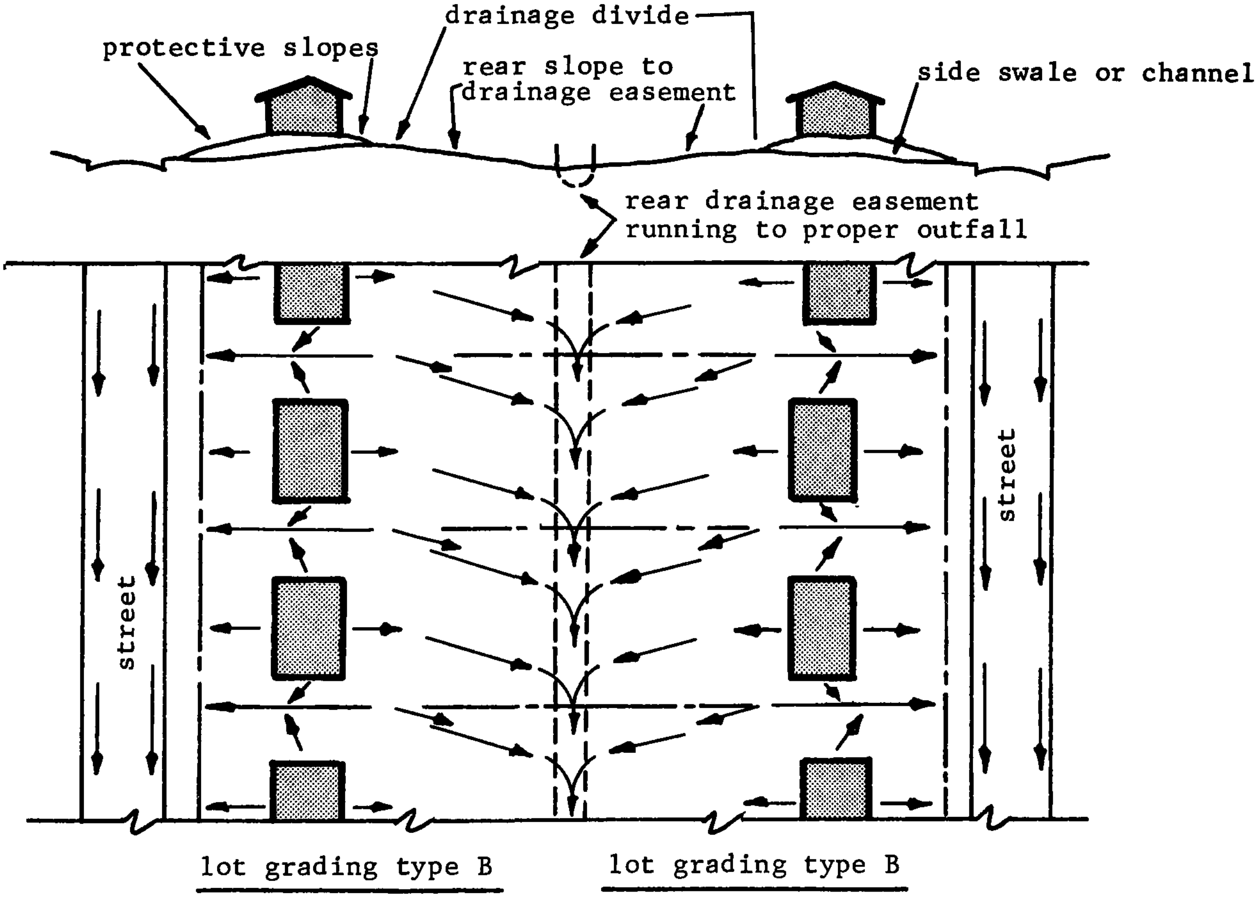
Your cooperation in eliminating the flooding of cellars in your community is earnestly solicited. If you require further information regarding this matter, please call the *PLUMBING DIVISION*, Appleton 7-7700, Ext. 344, before 10:00 A.M., and we will be glad to promptly furnish you with it, if at all possible.

Very truly yours,
Washington Suburban Sanitary Commission

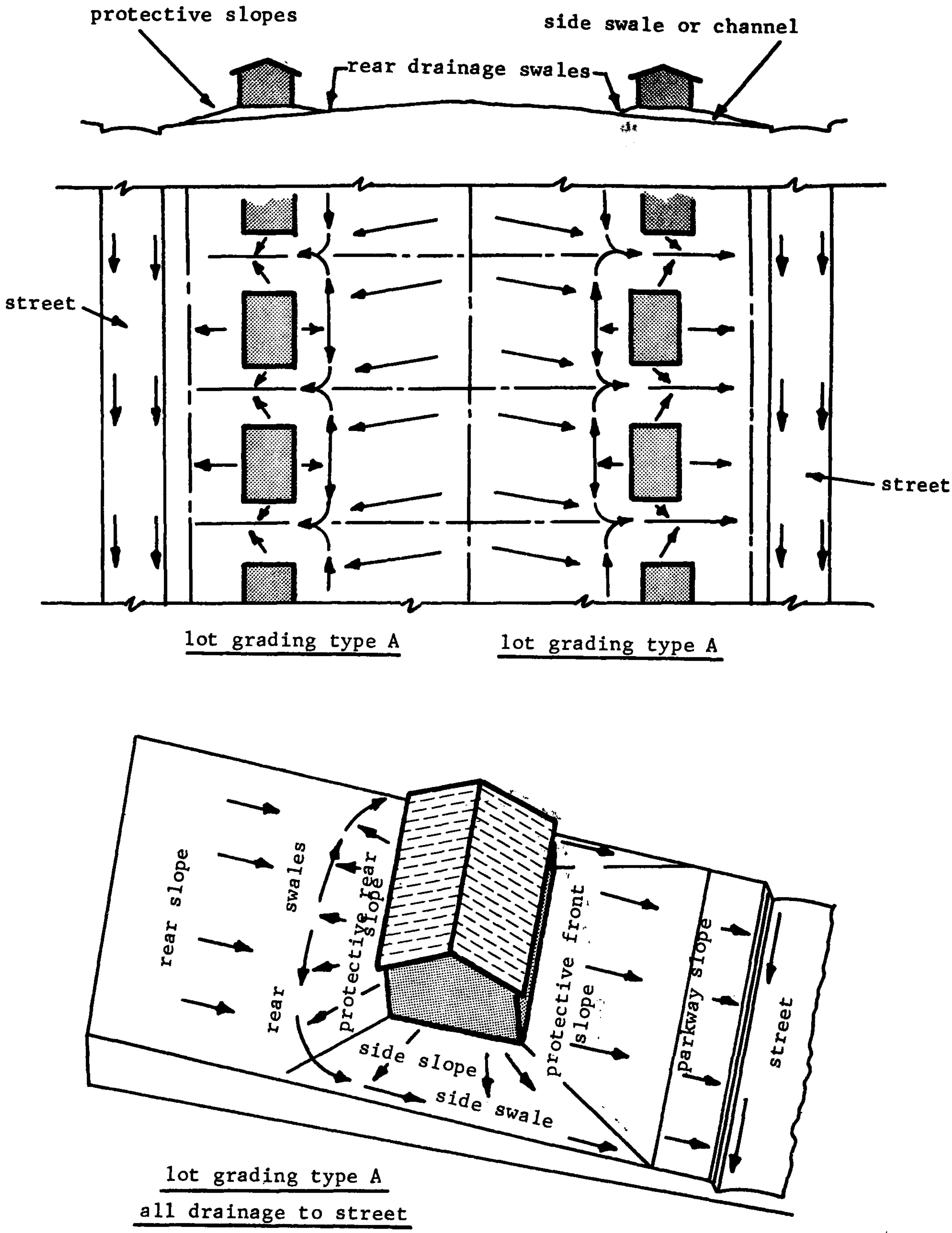
Secretary

APPENDIX 8

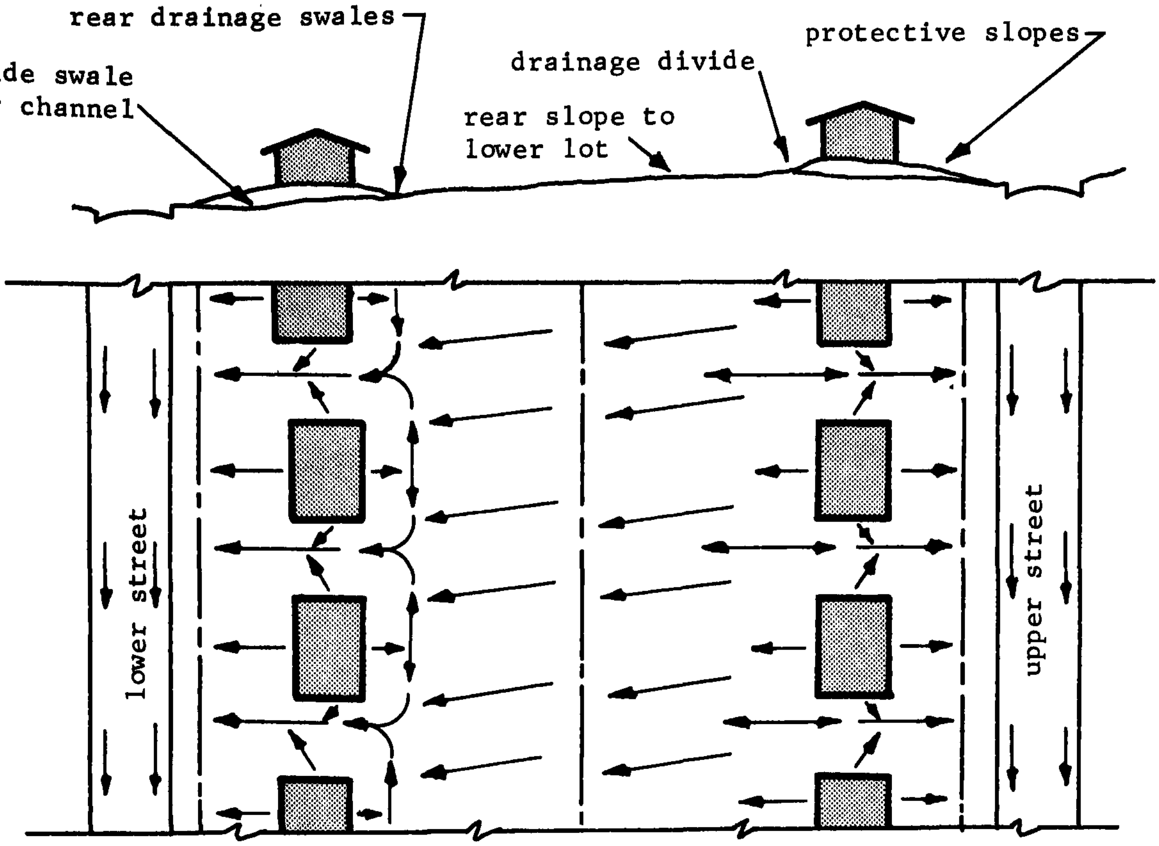
RECOMMENDED LOT GRADING REQUIREMENTS
REPORTED BY
HUBBELL, ROTH & CLARK, CITY ENGINEERS
SOUTHFIELD, MICHIGAN



example 8 block grading type 4, valley along rear lot lines

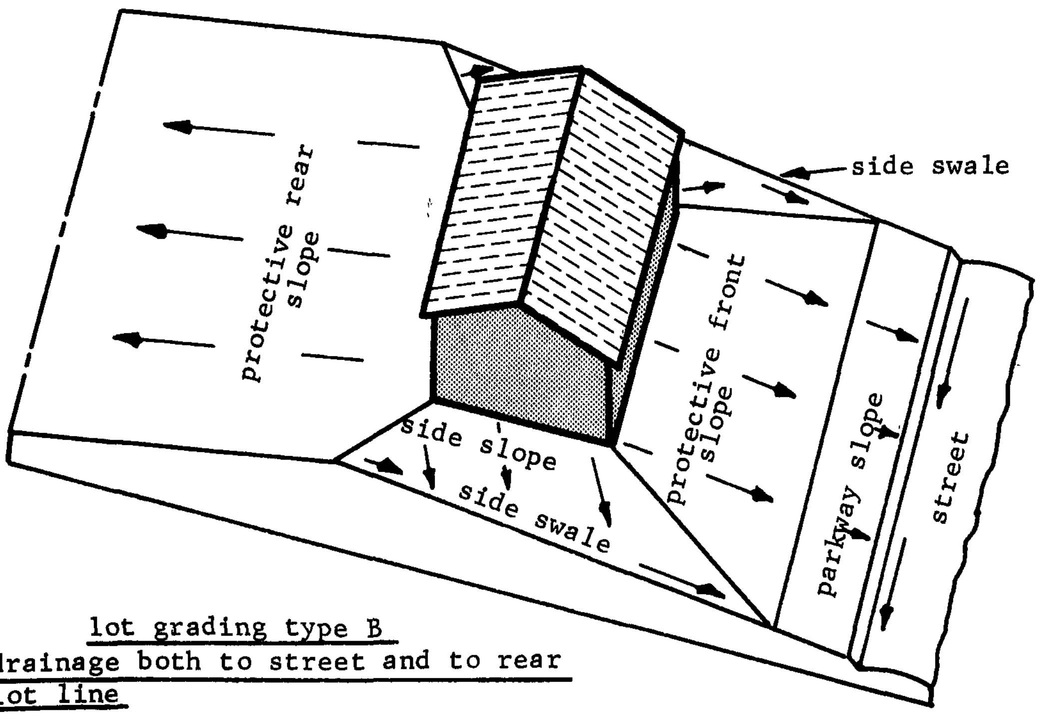


example 8 block grading type 1, ridge along rear lot lines



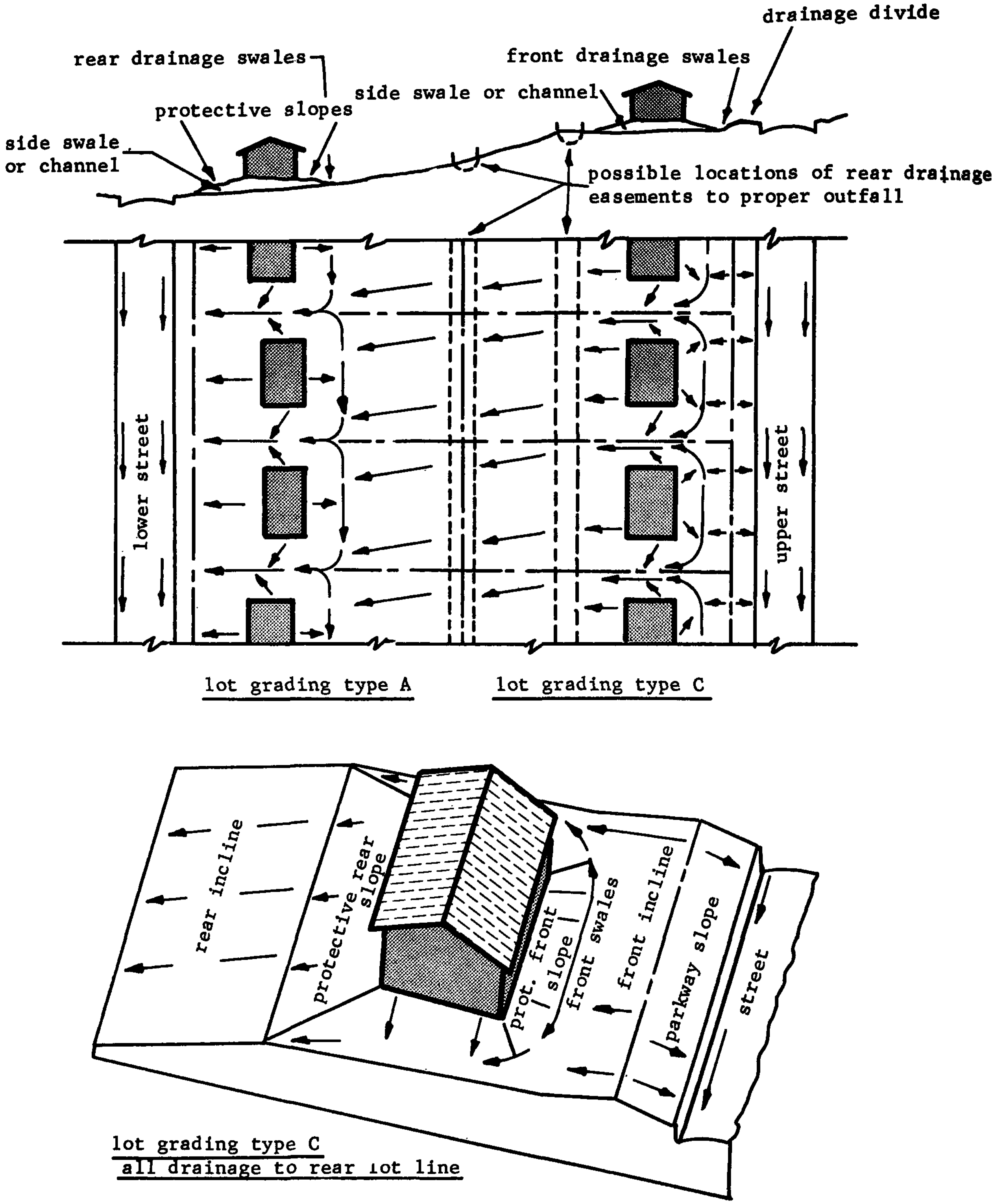
lot grading type A

lot grading type B



lot grading type B
drainage both to street and to rear
lot line

example 8 block grading type 2, gentle cross-slope



example 8 block grading type 3, steep cross-slope

APPENDIX 9

TYPICAL ENGINEERING SPECIFICATIONS FOR LOW-PRESSURE AIR TESTING OF SEWERS FOR INFILTRATION CONTROL

Testing of the tightness of sewers with low-pressure air has become a recognized substitute for the use of water testing methods, to simulate infiltration or exfiltration rates into or out of gravity sewers.

Development of the air-testing procedure in California has been highlighted by work carried out in the 1950's and 1960's by an informal organization in the San Francisco-Oakland Bay Area, composed of sewer utility officials, sanitary engineers and manufacturers. This group, known as the Bay Area Committee on Air- Testing, utilized the same type of coordinated inter-disciplinary knowledge and experience which was the pattern of the studies of infiltration and inflow problems carried out by the American Public Works Association, as described in the Report to the Environmental Protection Agency titled Control of Infiltration and Inflow Into Sewer Systems, a companion document to this Manual of Practice.

Much of the following material on air testing was excerpted from a paper on air-testing experiences at the City of Seattle, Washington, presented by William J. Chase and Harvey W. Duff before the Pacific Northwest Pollution Control Association, November 5, 1965. This paper, in turn, quoted the work of Roy Edwin Ramseier and George C. Riek, on behalf of the Bay Area Committee (ASCE Journal, Vol. 90, Part 1, April 1964).

Description of the Air Test

Test Procedure The low-pressure air test is a test which determines the rate at which air under pressure leaves an isolated section of pipeline. This rate indicates the presence, or absence, of pipe damage. The test procedure, thus far, is described as follows:

1. *Isolate Pipe To Be Tested* The section of pipe to be tested is plugged at each end. The ends of all branches, laterals and wyes which are to be included in the test are plugged. All plugs are carefully braced to prevent slippage and blow-out due to the internal pressure. One of the plugs provided must have an inlet tap, or other provision, for connecting an air hose.

2. *Connect Equipment* Connect one end of an air hose to the plug used for the air inlet. Connect the other end of the hose to the protable air-control equipment. This equipment consists of valves and pressure gauges used to control the rate at which the air flows into the test section and to also provide a means of monitoring the air pressure inside the pipe. Connect an air hose between the compressor, or other source of compressed air, and the control equipment.

3. *Add Air – Supply Air to the Test-Pipe Section* Monitor the air pressure so that the pressure inside the pipe does not exceed 5.0 psig.

4. *Stabilize* When pressure reaches 4.0 psig, throttle the air supply so that the internal pressure is maintained between 4.0 and 3.5 psig for at least 2 minutes. These two minutes allow time for the temperature of the air to come to equilibrium with the temperature of the pipe walls. During this time, check all of the plugs with soap solution to detect any plug leakage. If plugs are found to leak, bleed off the air, tighten the plugs, and begin again by supplying air.

5. *Determine Rate of Air Loss* This step can be performed in two ways: (a) Flowmeter Method. This procedure is used when the rate of air loss is high (greater than 10 c.f.m.). The control equipment includes rotameters or other air-flow measuring devices. Air is supplied to the pipe section at such a rate that the internal pressure is maintained at 3.0 psig. The flow rate is read in cubic feet per minute. The pressure of the metered air is read. The rate of air flow is corrected for pressure and temperature, and is reported in cubic feet per minute of air under standard conditions of pressure and temperature. (Standard pressure is 14.7 psi; standard temperature is 68° F.). (b) Stopwatch Method. This procedure is being used for pipeline inspection on new construction where air losses are usually very small. The control equipment consists of pressure gauges, valves and a pocket stopwatch. After the temperature has been allowed to stabilize for the two-minute period, the air supply is disconnected, and the pressure is allowed to decrease to 3.5 psig. At 3.5 psig the stopwatch is started to determine the time required for the pressure to drop to 2.5 psig. This time required for a loss of 1.0 psi at an average pressure of 3.0 psig can be used to compute the rate of air loss. For a precise calculation of the rate of air loss, the temperature of the air inside the pipe section and the barometric pressure should be determined and reported; however, this refinement has been found unnecessary for the usual acceptance test.

Test Equipment

Plugs Small diameter pipes (4 inch to 12 inch) have been successfully plugged with plumbers' test plugs. The air-supply connection is made by removing the cap from the continuously threaded pipe and substituting the cap from the continuously threaded pipe and substituting a hose-adapter fitting.

Pipes of diameters larger than 12 inch can be plugged by the same plugs used for the water-exfiltration test, with the addition of an air-hose inlet connection.

Safety Braces are required to hold the plugs in place and to prevent the sudden release of the compressed air. Braces are particularly important on plugs 12 inches and greater in diameter. A pressure of 4.0 psig against a 12 inch diameter plug will cause a force of approximately 450 pounds. *The compressed air acts like a spring. Proper precaution must be taken to prevent this spring from propelling the plug from the pipe like a bullet."*

Recommended Air-Test Specification

Discussion

The recommended specification is that based on the data collected by Ramseier and Riek, and which was generally and independently corroborated by City of Seattle work. While some of the other test criteria in use result in a simpler specification, they have, in most cases, somewhat less logic to them per se, or in their development. In specifying a new testing concept, it has been found advantageous in gaining acceptance to be able to show that the test is, in both theory and practice, a logical one.

Fundamentally, the recommended specification is based on an allowable air loss of 0.003 c.f.m. per square foot of internal pipe area. This relates, primarily, to pipe wall porosity. There is also included in the specification, however, a provision that in no case will the allowable air leakage be less than 2 c.f.m. This becomes of some importance on short runs of small pipe (6 in. and 8 in.). It was found by Ramseier and Riek that, using the double plug leak-locating equipment, it is very difficult to specifically locate the particular piece of porous pipe in a buried pipeline which leaks only 2 c.f.m. A crack or poorly-installed joint will result in substantially greater leakage. They concluded that if the leaking pipe could not be readily identified it was not a serious leak, and that it was not reasonable to require its repair.

The recommended specification allows for establishing the rate of air loss from the pipe either by measuring the pressure drop in a given period of time, or by measuring the rate at which air must be added to maintain a constant pressure. Photographs and/or schematic diagrams for equipment to measure either method are shown in the appendix.

Recommended Specification

The owner will furnish all facilities and personnel for conducting the test.

The contractor may desire to make an air test prior to backfilling for his own purposes. However, the acceptance air test shall be made after backfilling has been completed and compacted.

All wyes, tees, or end of side sewer stubs shall be plugged with flexible-joint caps, or acceptable alternate, securely fastened to withstand the internal test pressures. Such plugs or caps shall be readily removable, and their removal shall provide a socket suitable for making a flexible-jointed lateral connection or extension.

Prior to testing for acceptance, the pipe should be cleaned by passing through the pipe a full gauge squeegee. It shall be the responsibility of the contractor to have the pipe clean.

Immediately following the pipe cleaning, the pipe installation shall be tested with low-pressure air. Air shall be slowly supplied to the plugged pipe installation until the internal air pressure reaches 4.0 pounds pe; square inch greater than the average back pressure of any ground water that may submerge the pipe. At least two minutes shall be allowed for temperature stabilization before proceeding further.

The pipe line shall be considered acceptable, when tested at an average pressure of 3.0 pounds per square inch greater than the average back pressure of any ground water that may submerge the pipe, if: (1) the total rate of air loss from any section tested in its entirety between manhole and cleanout structures does not exceed 2.0 cubic feet per minutes, or, (2) the section under test does not lose air at a rate greater than 0.0030 cubic feet per minute per square foot of internal pipe surface.

The requirements of this specification shall be considered satisfied if the time required in seconds for the pressure to decrease from 3.5 to 2.5 pounds per square inch greater than the average back pressure of any ground water that may submerge the pipe is not less than that computed according to the attached page entitled, "Recommended Procedure for

Conducting Acceptance Test."

If the pipe installation fails to meet these requirements, the contractor shall determine at his own expense the source or sources of leakage, and he shall repair (if the extent and type of repairs proposed by the contractor appear reasonable to the engineer) or replace all defective materials or workmanship. The completed pipe installation shall meet the requirements of this test, or the alternative water exfiltration test, before being considered acceptable.

NOTE: It has been found that in many instances clay and concrete sewer pipe must be wetted before an acceptable test can be performed. In as much as under actual field conditions when infiltration would occur, the pipe would wet from ground water, it appears reasonable to allow the contractor at his expense to wet the pipe prior to retesting.

RECOMMENDED PROCEDURE FOR CONDUCTING ACCEPTANCE TEST

1. Clean pipe to be tested by propelling snug fitting inflated rubber ball through the pipe with water.
2. Plug all pipe outlets with suitable test plugs. Brace each plug securely.
3. If the pipe to be tested is submerged in ground water, insert a pipe probe, by boring or jetting, into the backfill material adjacent to the center of the pipe, and determine the pressure in the probe when air passes slowly through it. This is the back pressure due to ground water submergence over the end of the probe. All gauge pressures in the test should be increased by this amount.
4. Add air slowly to the portion of the pipe installation under test until the internal air pressure is raised to 4.0 psig.
5. Check exposed pipe and plugs for abnormal leakage by coating with a soap solution. If any failures are observed, bleed off air and make necessary repairs.
6. After an internal pressure of 4.0 psig is obtained, allow at least two minutes for air temperature to stabilize, adding only the amount of air required to maintain pressure.
7. After the two minute period, disconnect air supply.
8. When pressure decreases to 3.5 psig, start stopwatch. Determine the time in seconds that is required for the internal air pressure to reach 2.5 psig. This time interval should then be compared with the time required by specification as computed below.
9. List size and length of all portions of pipe under test in table similar to one shown here.

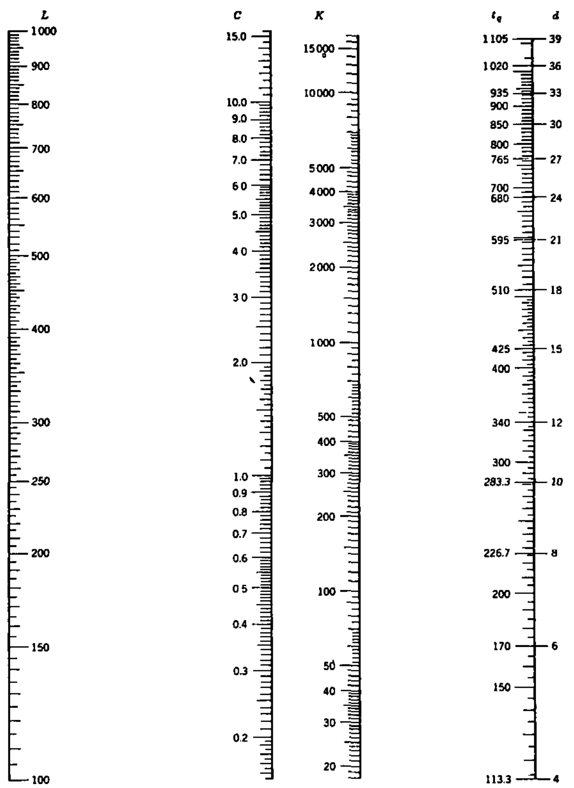
Diameter Inches	Length Feet	$K = .011\ d^2L$	$C = .0003882\ dL$

Total K ________ Total C ________

Time required by specification ________

10. By use of nomograph compute K and C. Use scales d and L, read K and C, and enter these values in the table above.
11. Add all values of K and all values of C for pipe under test.
12. If the total of all C values is less than one, enter the total of all K values into the space for "Time Required by Specification."
13. If the total of all C values is greater than one, divide the total of all K values, by the total of all C values, to get t_q. To make this division with the nomograph, use scales C and K, and read t_q.

AIR TEST



-NOMOGRAPH FOR THE SOLUTION OF $K = .011d^2L$, $C = .0003882dL$, $t_q = K \div C$

APPENDIX 10

EXAMPLE OF SPECIFICATIONS FOR EXFILTRATION TESTING OF GRAVITY SEWERS

The use of exfiltration testing of sewer pipe to determine the watertightness of construction is widely utilized instead of infiltration tests. To assist sewer system management personnel in evaluating the procedures used by representative jurisdictions for this purpose, the following excerpts of specifications are included here.

1. Example 1

The owner will provide for the conduct of exfiltration tests on the sanitary sewer in the presence of the contractor. Final acceptance of the sewer shall depend upon the satisfactory performance of the sewer under test conditions. The tests shall be performed on pipe between adjacent manholes after the trench has been backfilled.

The test will be performed up to an average maximum hydrostatic head of 10 feet. The exfiltration from the sewer shall not exceed 0.23 gallons per inch of internal diameter per 100 feet of pipe per hour. Head measurement will be made at the flow line elevation of the upstream manhole.

The owner will provide for the necessary watertight hose having a minimum diameter of 3/4 inch. The hose shall be of sufficient length that it can be extended from the nearest hydrant to the downstream manhole of the pipe to be tested. The owner will provide for the necessary control valve, water meter, adapters, and plugs adapted to air and water entry and release and any other equipment that may be necessary to perform the test.

In the event that city water mains are not installed and water available therefrom at the time of the test, the owner will provide water from some other source to make the test.

Procedure

In inspecting exfiltration tests, the following minimum requirements and precautions should be adhered to.

The sewer plug used at the highest end of the sewer shall have a suitable air vent to allow removal of trapped air. The hose between the air vent and the calibrated container shall be of 3/4 inch minimum diameter and a maximum of 10 to 15 feet long. Do not allow the hose to become linked or blocked as this may cause the sewer to be subjected to city water main pressures. To prevent leaks and plug movement during the tests, the sewer plugs should be supported in position by bracing to the opposite wall of the manhole. Do not refill the sewer under test through the calibrated container as this will allow the air to become trapped.

Place the calibrated container at the average height of ten feet above the flow line of the sewer. Check the entire system for leaks in hoses, plugs, calibrated container, etc., while filling through the positive shut off valve. When the water overflows the calibrated container, close the input valve and tests may begin.

Record the elapsed time to empty the container of water and calculate the loss in gallons per hour. If the container has not emptied after 15 minutes, measure the loss and calculate the gallon per hour rate. Take two or more tests at this level. If the test results at the 10 foot average level do not vary more than ten percent, the container can be repositioned at the five foot average level. Take two or more tests at the average five foot level. Open the valve slowly during test runs to avoid building up too high a pressure in the sewer. If more than one section of sewer is to be tested the water used to test the higher section can be saved by placing another sewer plug in the next downstream manhole.

2. Example 2

Vitrified Clay Pipe Unless otherwise specified in the Special Provisions or otherwise directed by the engineer, all vitrified clay pipe installations and laterals adjacent thereto will be tested for leakage. The owner will provide for water and all equipment necessary to make the required tests. The owner, at his discretion, may test only a portion of the lines installed, but in no case will less than twenty-five (25) percent of the lines be tested. In no case will the minimum percentage be allowed unless all sections tested pass the required leakage test the first attempt. All lines will be tested in areas where underground water is or may be encountered.

A section of sewer line shall be prepared for testing by plugging the upper side of the downstream manhole and all openings in the next upstream manhole except the downstream opening. Where grades are slight, two or more sections between manholes may be hydrostatically tested at once. Where grades are steep, the maximum head on any section under test will not exceed ten (10) feet. Branch sewers running from Y-branches on the mains shall be plugged at their upper end if the test head would cause them to overflow.

A section of sewer line prepared as above shall be tested by filling with water to an elevation of four (4) feet above the invert at the midpoint of the test section, or four (4) feet above the existing ground water elevation or one (1) foot above the top of the pipe in the upstream manhole, whichever is greater. The water should be introduced into the test section at least four (4) hours in advance of the official test period to allow the pipe and joint material to become saturated with water. All entrapped air is to be removed from test section prior to performing the test. At the beginning of the test the elevation of the water in the upper manhole shall be carefully measured from a point on the manhole rim. After a period of one (1) hour, or less, with the approval of the engineer, the water elevation shall be measured from the same point on the manhole rim and the loss of water during the test period calculated. If directed by the engineer, enough water shall be precisely measured into the upper manhole to restore the water to the level existing at the beginning of the test, and the amount added shall be used to determine leakage.

Should an initial test show excess leakage in a section of line, it is permissible to draw the water off and test the manhole that contained water. This test shall be made by plugging all the openings in the manhole and filling with water to the same elevation as existed during the test. The leakage from the manhole may be deducted from the total leakage of the test section in arriving at the test leakage. After testing is complete, the manhole shall be waterproofed by grouting and/or painting the interior with sodium silicate or other approved water-proofing agent. If it is necessary or desirable to increase the test head above four (4) feet, the allowable leakage will be increased to allow for the increase in head. Sewer sections showing leakage in excess of that allowed shall be repaired or reconstructed as necessary to reduce the leakage to that specified.

The maximum allowable exfiltration for this test shall be 200 gallons/inch of diameter/mile/day, plus ten percent for each two foot of head over two feet or as indicated in Special Provisions. The contractor's attention is, however, directed to the fact that the stipulation of a maximum allowable leakage shall in no way relieve the contractor of his obligation to correct, stop or otherwise remedy individual leaks in the system due to defective workmanship or material even though such leakage might come within the allowable maximum.

The air test may be substituted for the water test only with specific approval of the engineer. When allowed, the air test shall be conducted in conformance with the requirements and procedures on file in the engineer's office.

Concrete Pipe ,Leakage tests on concrete pipe with cement mortar or other joints, may be specified in the Special Provisions or on the drawings. The testings on these installations will be in accordance with specifications indicated in "Testing of Sewer Lines, Vitrified Clay Pipe," and as directed by the engineer.

3. **Example 3**

The owner will provide an exfiltration test on all sanitary sewers. Final acceptance of the sewer shall depend upon the satisfactory performance of the sewer under test conditions.

The owner will provide the necessary watertight hose having a minimum diameter of 3/4-inch. The hose shall be of sufficient length that it can be extended from the nearest hydrant to the downstream manhole of the pipe to be tested. The owner will provide the necessary one-gallon calibrated container, control valve, water meter, adaptors, and plugs adapted to air and water entry and release and any other equipment that may be necessary to perform the test.

In the event that city water mains are not installed and water available therefrom at the time of the test, the owner will provide water from some other source to make the test.

The test shall be performed on pipe between adjacent manholes after the trench has been backfilled and the pipe cleaned. After filling the line completely, the hose connection from the water source shall be disconnected and the test begun.

The test shall be performed up to a hydrostatic head of ten feet above the average elevation of the sewer line. The exfiltration from the sewer shall not exceed 0.23 gallons per inch of internal diameter per 100 feet of pipe per hour. Head measurement will be made from the flow line elevation of the upstream manhole.

The allowable exfiltration is shown in the table for various pipe sizes.

Where conditions warrant, the owner may perform an infiltration test. The rate of infiltration of water into any sanitary sewer or appurtenance shall not exceed 0.4 gallons per inch diameter per 100 feet of sewer per day. This allowable infiltration, expressed in gallons per hour, is shown in the table for various pipe sizes.

ALLOWABLE LIMITS OF EXFILTRATION

295 Gal/Inch Dia/Mi/Day (at 10 ft. head)

Diameter of Sewer	Maximum Allowable Loss In Gals./Hr./100 Ft. of Pipe
8 in.	1.9
10 in.	2.3
12 in.	2.6
15 in.	3.5
18 in	4.2
21 in.	4.9
24 in.	5.6
27 in.	6.3
30 in.	7.0

ALLOWABLE LIMITS OF INFILTRATION

200 Gay/Inch Dia/Mi/Day

Diameter of Sewer	Infiltration Gals/hr/100 ft.	Diameter of Sewer	Infiltration Gals/hr/100 ft.
Inches	Gallons	Inches	Gallons
8	1.3	54	8.5
10	1.6	60	9.5
12	1.9	66	10.4
15	2.4	72	11.4
18	2.8	78	12.3
21	3.3	84	13.3
24	3.8	90	14.2
27	4.3	96	15.2
30	4.8	102	16.1
36	5.7	108	17.0
42	6.6	114	18.0
48	7.6	120	18.9

Allowable M.H. Infiltration

41 In. Dia. M.H. 0.07 Per Vertical Ft. Per Hr.

48 In. Dia. M.H. 0.08 Per Vertical Ft. Per Hr.

APPENDIX 11

A METHOD FOR GAUGING INFILTRATION FLOW IN SEWER TESTING

(excerpted from literature of Cherne Industrial, Inc.)

The following discussion of the use of a V-notch for gauging the amount of ground water which infiltrates into sewer lines is presented here only for general information. Its inclusion in this Manual is not to be interpreted as any confirmation of the data by the American Public Works Association or the Environmental Protection Agency.

Infiltration testing methods and standards are discussed in detail in Section 2 of this Manual of Practice. Further information on testing procedures can be found in standard text books on sewer construction and testing.

WATER INFILTRATION

Two basic types of equipment are used to determine the actual rate of infiltration. One, the flow meter is used in existing sewers to determine flow through a manhole; the other is the weir. We will devote the majority of this discussion to the weir, since it is the most economical and most widely used measuring device for determining infiltration into newly constructed sewers.

The term, "weir", as it is commonly used, applies to a structure containing a notch with a shape such as a rectangle, a trapazoid, or a triangle (also called a V-notch). Weirs are classified according to the shape of the notch and this discussion will be confined to the most common type, the 90° V-notch, sharp crested, weir. Discharge over this weir is computed by the following formula:

$Q = 3240\ H^{2.5}$ Gallons/Day (H is measured in inches)

This basic formula neglects the velocity of fluid approaching the weir, so that only one measurement need be taken to compute the quantity of water flowing through the weir. This one dimension, "H" is the head of water flowing over the crest. (Note Figure 1)

In Figure 1 the "H" decreases in height as it approaches the weir. This is because the velocity of the fluid increases as it approaches the weir. The "H" reading must be taken at such a point (distance "D" in Figure 1) that the velocity of approach is not a factor. The rule of thumb is that the "H" dimension must be taken at least 18 inches upstream from the crest of the weir or 3 times the height of "H", whichever is greater. This becomes even more complicated, since some V-notch weirs have been modified by their manufacturers so that the reading at the crest of the weir is the actual reading that should be taken. But, in these cases one must be careful not to use the corrected weirs for sizes other than those for which it was designed, otherwise the corrections are useless.

The next consideration in the infiltration test is, "What length of pipe do we check at one time?" Many engineers will specify the total project cannot leak more than a specified number of gallons per inch of diameter per mile of pipe per day, but a single manhole to manhole reach of pipe may be allowed to leak 2 to 3 times this amount. This allows the contractor to average out bad construction over the whole job and is extremely unfair to the buyer and actually unfair to the contractor, since an extremely bad portion of pipe can cause many other pipe sections to apparently fail. The most important thing to consider here is that leakage is a symptom of bad workmanship.

Figures 2 and 3 indicate the details of testing for infiltration in various lengths of sewer lines.

The proper use and reading of the weir is extremely important, both to the contractor and the engineer. To demonstrate this importance, take a typical installation of an 8 inch diameter line, manhole to manhole. It would be about 300 feet long with 8 homes connected to the line by means of 6 inch laterals brought to the property line. It is generally assumed that each lateral will be approximately 20 feet long and suitably capped with a good quality stub seal. Figure 4 is a rough drawing of this setup. We will assume that the infiltration standard is 250 gallons per inch diameter per mile per day, therefore, the allowable infiltration rate for the above installation will be:

$$\frac{250\ \text{GPD}}{5280\ \text{feet}} [(300\ \text{ft.} \times 8\ \text{in.}) + (8\ \text{homes} \times 20\ \text{ft.} \times 6\ \text{in.})] = 160\ \text{Gallons/Day}$$

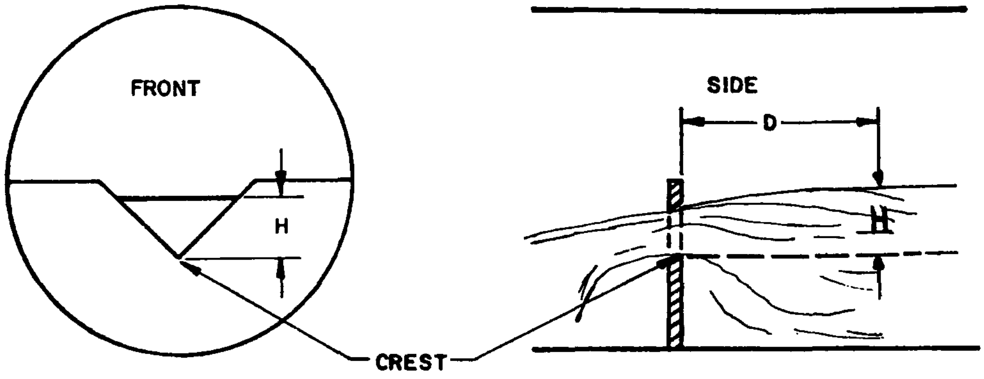


Figure #1

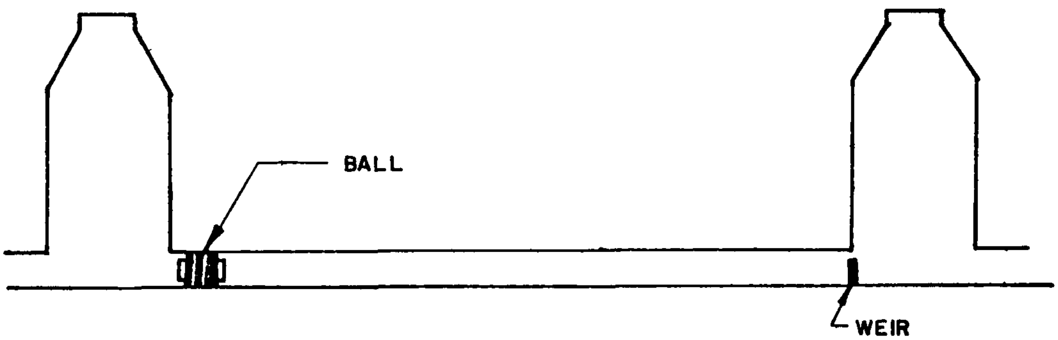


Figure #2

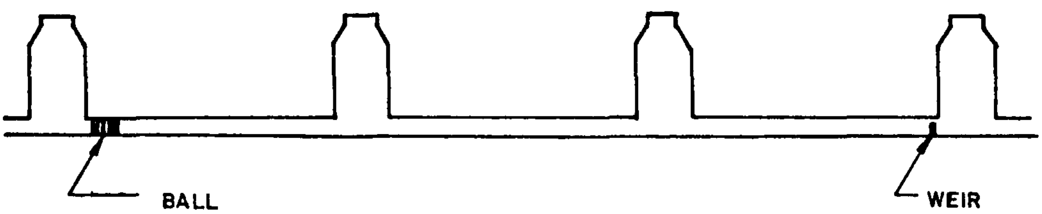


Figure #3

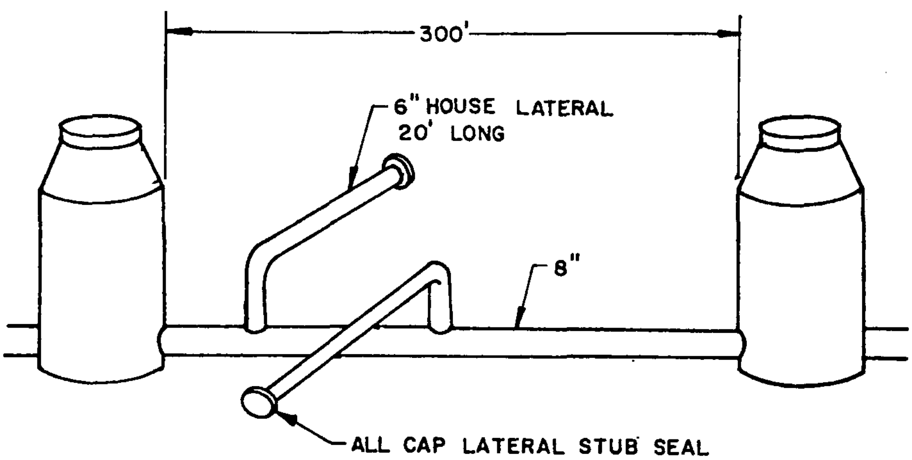


Figure #4

APPENDIX 12

CORRECTION OF INFILTRATION BY MEANS OF GROUTING WITH SEALANTS AND GELS

The following material is presented for general information purposes only. Its inclusion does not constitute any approval of the data offered by manufacturers of products or processes, nor does it represent any endorsement of such materials or methods used for sealant purposes by the American Public Works Association or the Environmental Protection Agency.

Further information can be obtained from he manufacturers and suppliers listed and from others not covered by the data contained in this Appendix.

Grouting is the cementing together of loose particles of soil in such a manner that the soil so grouted becomes a solid mass which is impervious to water. It is not a method of cementing pipes together. The ability of any chemical, or combination of chemicals, to penetrate the soil is directly related to the amount or percent of suspended solids in the grout material used to the void ratio of the soil to be grouted. Grouting technology is an old procedure dating back to the turn of the century.

With the advent of television inspection, soil grouting techniques (especially with the use of sodium silicates and calcium chloride) were attempted in conjunction with internal TV inspection. However, because of the lack of control of the gel time, external piping was required and costs were high. After development of control gel time and reactions, it was possible to utilize internal packing procedures for sewer sealing. American Cyanamid holds the patent for AM-9 and is the major formulator of chemical sealants.

Chemical Grouting with AM-9

American Cyanamid has a policy of "licensing the applying contractor" before agreeing to selling the chemical. Attendance is required at a special grouting school held in their plant in New Jersey. They also check the company who asks to be licensed, as to their professional capabilities, their past experience, the availability of registered engineers, and other factors.

The following data have been excerpted from the "Chemical Grout Field Manual" and other literature of the American Cyanamid Company.

CHEMICAL DATA

Description of AM–9

AM–9 CHEMICAL GROUT is a mixture of two organic monomers – acrylamide and N, N methylenebisacrylamide – in proportions which produce very stiff gels from dilute, aqueous solutions when properly catalyzed. The process by which gelation occurs is a polymerization-crosslinking reaction.

Description of Catalysts

β-Dimethylaminopropionitrile (Catalyst DMAPN). This is a liquid, somewhat caustic, chemical used as an activator for the reaction. The density of Catalyst DMAPN, between 32°F and 104°F, is about 0.86 gm./ml. or 7.1 lb./U.S. gal. There are 529 cubic centimeters per pound of Catalyst DMAPN.

Ammonium Persulfate (AP). Ammonium persulfate is a granular meterial and a very strong oxidizing agent. It is the initiator that triggers the reaction and is therefore the last material to be added. The induction period (gel time) begins with its addition. Generally, it is dissolved in water and added as a 5 to 20 percent solution to the AM–9 solution through a separate pump or by gravity.

Description of Inhibitors

Potassium Ferricyanide (KFe). Potassium ferricyanide is a reddish, granular material which may be used to control the reaction. It behaves as an inhibitor in very small quantities and must be used cautiously for this reason.

Description of Buffers

Buffers are chemicals used to control the pH of the catalyzed AM–9 solution. In rare cases, acidic mixing water will necessitate the use of buffers to bring the solution pH to 8. When ammonium persulfate is used alone for catalysis, buffers will generally be required. Disodium phosphate heptahydrate is recommended. Sodium carbonate may be used in soft water.

Chemical Reactions

The gel is formed by the following two-step process:

Step 1. An aqueous solution of AM–9, containing DMAPN (one component of the catalyst system) and KFe (if required), is prepared.

Step 2. The remaining component of the catalyst system, AP (usually in water), is added to the solution of AM–9 prepared in Step 1. Timing of the induction period (gel time) is started.

Two reactions occur in sequence:

Catalysts → Free Radicals

Free Radicals + AM–9 → Polymer

The first reaction starts almost immediately after the second component of the catalyst system is added to the AM–9 solution. The rate of formation of free radicals and their rate of decomposition is strongly influenced by a number of factors. Control of these by proper selection of the catalyst system and the environment allows a predetermined amount of time to elapse before polymerization of AM–9 occurs. This is known as the induction period or gel time, during which the viscosity of the solution remains almost constant. At the end of the induction period, heat is evolved, and long, flexible, polymer chains are formed. As these chains form, they simultaneously crosslink to form a stiff complex matrix which binds the water into a gel. The gel reaches its maximum strength in a matter of minutes.

Gel Charts

The relationships between gel time and catalyst concentrations, as influenced by inhibitor concentration and temperature, have been determined for a wide range of conditions.

Factors Affecting Gel Time

1. AM–9 CONCENTRATION. Reducing the AM–9 concentration in the range of 15 percent causes a slight increase in gel time.
2. CATALYST CONCENTRATION. Changes in the concentration of one or all components of the catalyst mixture have a very marked effect on the gel times. Too much KFe or too little AP or Catalyst DMAPN will produce weak gels or none at all. The recommended lower limits are 0.4 percent for Catalyst DMAPN[1], 0.25 percent for AP, and the upper limit for KFe is 0.035 percent.[2]
3. TEMPERATURE. The gel times for any catalyst system increase with decreasing temperature and decrease with increasing temperature. A rough rule of thumb is that the gel time is cut in half if the temperature goes up ten degrees Fahrenheit.
4. pH. The pH of the solution, after catalyst addition, may affect the gel time. For best control up to about a one-hour gel time, the pH should be in the range of 7 to 11. Except under very unusual conditions where large amounts of acid are present, Catalyst DMAPN maintains the pH between 8 and 9. Below a solution pH of 6.5, the gel times can become long and indefinite.
5. AIR. AM-9 solutions that are saturated with air gel much slower than those containing no air. In general, allowance must be made for the air that is entrained and dissolved during vigorous mixing.
6. METALS. Certain metals such as iron, copper and copper-containing alloys, have an accelerating effect on the gel time of AM–9 solutions. However, the presence of Catalyst DMAPN in the solution makes it possible to use standard equipment and materials in handling and placing AM–9. Where iron storage tanks are used for AM–9 solutions, they should be painted with aluminum paint to prevent iron rust from entering the injection system. Aluminum, stainless steel, plastic or rubber containers, pipes and valves must be used to handle solutions of AP.
7. MIX WATER. Formation water or water from the local supply may be used in the field depending on which is the more suitable for the application. Some of the factors described in this section may occur in the mix water. Therefore, it is very important to check gel times by carrying out a gel test with the water which will be used in the application.
8. SUNLIGHT. Direct sunlight, due to the ultraviolet rays, sometimes will cause local gelation in tanks containing AM–9 solutions. To avoid this in the field, solution tanks should be covered.
9. INHIBITORS. Most of the ordinary polymerization inhibitors, i.e., hydroquinone, oxygen, ferric ions and sodium nitrite can be used to stop or slow down the gelation of AM–9. These materials, however, cause the formation of weak gels which cannot be improved. KFe, when used in the recommended concentrations, does *not* affect the strength of the final gel. Under special conditions, it may be added repeatedly in small quantities to delay the gelation of a catalyzed solution.
10. HYDROGEN SULFIDE. Hydrogen sulfide has a very complicated effect on the gelation of AM–9. In general, it behaves as an accelerator and may be considered as such under ordinary working conditions.
11. SALTS. The presence of soluble salts, such as

[1] Under special conditions it may be lower.

[2] Under special conditions it may be higher.

sodium chloride, calcium chloride, sulfates and phosphates, has an accelerating effect on the rate of gelation. The amount of acceleration depends on the salt concentration and should be determined by a test in the field. Salts may also have the effect of increasing the gel strength. Certain ones, such as calcium chloride, decrease the rate at which water is lost from gels under dehydrating conditions.

12. FREEZING. The freezing of AM–9 solutions has little effect on their activity. To avoid freezing during application, salt, alcohol or any commercial antifreeze may be added. The effect of these additives on the gel time must be checked.

13. PARTICULATE MATERIALS. Most fine, insoluble materials such as clay, bentonite, etc., slow down the gelation to some extent. If such fillers are used, ...

GROUTING SPECIFICATIONS

The material which follows is suggested by American Cyanamid for inclusion in specifications when it is desired to use AM–9 Chemical Grout. (A "maximum" limit on the amount of chemicals used per size of pipe should not be specified. A range of gallon usage would be preferable. The amount of chemical used is dependent soley on the type of soil to be grouted. The static or hydro-static conditions of the ground water, the approximate volume of chemcial required to assure a permanent, long-lasting seal, and many other factors.)

Materials

Materials shall conform to the requirements listed below. All materials shall be delivered to the site in undamaged, unopened containers bearing the manufacturers original labels.

a. *Chemical Grout.* The chemical grout shall consist of an intimate mixture of dry Acrylamide and dry N, N^1 – Methylenebisacrylamide, in such proportions that dilute aqueous solutions, when properly catalyzed, will form stiff gels.
   The grout must make a true solution at concentrations as high as three pounds per gallon of water.
   The chemical solution shall have the ability to tolerate ground water dilution, and to react in moving water.
   The viscosity of the chemical solution, shall have a viscosity of less than 2 cps, which remains constant until gelation occurs.
   The reaction time shall be controllable from 10 seconds to an hour.
   The reaction shall produce a continuous and irreversible gel at chemical concentrations as low as 0.4 pounds per gallon of water.
b. *Catalyst.* The catalyst for the chemcial grout shall be Ammonium Persulfate. This material shall normally be used in combination with an activator, but it may be used in combination with a buffer for high temperature work.
c. *Activator.* The activator shall be β-Dimethylaminopropionitrile or other suitable compounds.
d. *Inhibitor.* Under some conditions it may be necessary or desirable to control the chemical reaction by inhibition. The inhibitor used shall be Potassium Ferricyanide.

Supervision

The entire chemical grouting operation shall be supervised by a professional engineer experienced with chemical grouts and grouting equipment. Such engineer shall be present whenever grouting is being performed.

Equipment

The chemical grout pumps shall be of a type approved by the manufacturer of the grout, and shall be able to operate continuously at the volumes and pressures required by the job. The pumps shall be capable of proportioning catalysts mechanically, and shall be calibrated prior to use. Materials used for tanks, packers and other equipment shall be compatible with the chemicals.

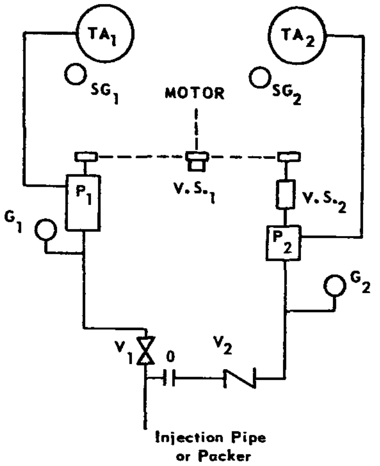
APPLICATION EQUIPMENT

There are three basic types of equipment which have been used to apply AM–9 solutions. These are designated as the proportioning system, the two-solution system and the batch system. Of these the proportioning system is the best and easiest to use, (as described here).

Proportioning System

Flexibility is designed into the proportioning system because it is usually important to vary gel times, pumping rates and pressures over a moderate range during any application. This system allows one man to control all of these factors rapidly and precisely by mechanical means. The need to adjust the compositions or concentrations of solutions during an application is eliminated.

AM–9, Catalyst DMAPN, and KFe (if required) are mixed in TA_1; AP is made up in TA_2. The pump (P_2) is selected to handle a small volume of AP



KEY OF COMPONENT PARTS

TA_1 – Mixing Tank for AM-9 Chemical Grout, Catalyst DMAPN, and KFe.
TA_2 – Mixing Tank for Ammonium Persulfate.
S. G. – Sight Gauges.
P_1 Positive Displacement Pump.
P_2 – Positive Displacement Pump.
$V.S._1$ – Variable Speed Drive.
$V.S._2$ – Variable Speed Drive.
G_1 – Diaphragm Pressure Gauge.
G_2 – Diaphragm Pressure Gauge.
V_1 – Quick Opening Valve.
V_2 – Spring Loaded Check Valve.
O – Orifice.
TA_2 to Injection Pipe should be aluminum, Type 316 stainless steel, rubber or some plastics.
TA_1 through V_1 can be mild steel, aluminum, stainless steel, rubber or plastics.

Proportioning System.

solution (5 to 20 percent AP in solution) relative to the volume of AM–9 solution handled by pump P_1. Thus the flow through P_2 can be varied on the job to produce large changes in gel time without materially changing the concentration of AM–9 in the final mix or the total volume of solution entering the ground. Changes can also be made in total volume pumped without changing the gel time. A typical gel chart for use with field proportioning equipment is shown in Figure 6. The capacity of P_1 is usually about 5 to 15 times that of P_2.

The sizes of all pumps, lines and valves must be chosen according to the pressures and flow rates anticipated. For all applications a separate water source should be available so that water may be pumped through P_1 or another pump to clear the injection points or the formation adjacent to them.

A proportioning system can be constructed to handle a wide variety of pressures. It is also possible to have a low pressure system which can be used to proportion AM–9 and catalyst solutions into the suction side of many standard grouting pumps. The latter then determines the pressures that may be used.

Asphaltic Base Soil Sealing Treatment

The City of Richmond, California used this process on a trial section of sewer in 1962. It was found that infiltration was reduced 50 percent, as shown by the hydrostatic head test.

The treatment compound is an asphaltic base product produced by the Standard Oil Company and was originally used for sealing and soil stabilization of irrigation canals. Before application, the asphaltic compound is diluted with water in proportions of one to a hundred. The treatment is carried out by blocking off a section of sewer and the sealant solution is pumped into this section in exactly the same manner as in carrying out a hydrostatic head test. At the saturation limit, or when the sewer section no longer absorbs sealant, the treatment is considered completed. The sealant is then drawn from the section and reused. The hydrostatic head test is carried out before and after treatment to determine treatment effectiveness.

The lasting quality of this process is not yet known. Its effectiveness in areas of extremely high infiltration is questionable, and more testing is needed. The low cost of this process may make it desirable in cases where partial reduction of flow is sufficient to serve an immediate need.

The City of Richmond is planning to carry out further trials with this process. The product details may be obtained from Mr. P.L. Chapdelaine, Research Engineer, California Research Corporation of the Standard Oil Company, Limited.

Compared to other sealing methods this process is very economical. The cost of the asphaltic compound before dilution is about 50 cents a gallon;

the greatest cost is in the labor involved. No figures are available at present on the basis of cost per lineal foot of sewer treated, but it would depend on the condition of the sewer and the soil conditions around the sewers.

Cement Grouting Process

A process of sealing sewers using cement grout containing certain additives and accelerators, such as calcium chloride, can be utilized as a fairly economical process by properly trained sewer maintenance crews. This method has been used by various agencies, some of which are:

Los Angeles County Sanitation Districts, California

Imperial Beach, California

Menlo Park Sanitary District, California

The necessary equipment is basically simple; operation involves the pulling of a telescopic cable and disc system through the sewer. The discs are metal with a leather or felt perimeter. The term "telescopic" means that there are four or five discs attached to the cable system and spaced about two feet apart. Grout is loaded up between the discs; the head disc is fixed, and as the system is pulled through the pipe, the discs pull and squeeze the sealant into the cracks and leaks in the sewer. Application is repeated as required.

The immediate results after treatment appear to be excellent according to the sources interviewed. Unfortunately, no concrete information was available on tests of durability.

A drawback in this system is that it is necessary to protect side laterals at the street main and lateral connections to prevent grout blockage of the lateral sewers. This might mean excavation. Because of this fact, utilization of this process may be economical only in areas where there are few lateral sewer connections or where the sewers are very shallow in depth and where cost of excavation of lateral connections is low.

The cost of this method lies mostly in the labor involved. As mentioned, this system could be carried out by the sewer maintenance staff. Contractor costs can be expected to run approximately $2.50 per foot of sewer treated.

Other Methods of Sewer Sealing

In addition to the methods of sewer sealing described, other means have been used in American sewer practice. The following information is excerpted from an infiltration study report prepared by W. Long and Associates, Consulting Engineers, Berkeley, California.

This material is presented for information purposes only. Its inclusion in this Manual does not constitute any approval of the data, and/or endorsement of the processes and products described.

Internal Packing Method

A number of major national sewer service companies are experienced in the sealing of sewer system defects by means of both external and internal methods.

The external packing method involves the use of a closed-circuit television unit, a sealing device and related control equipment. The sealing operation begins by introduction of the TV camera and sealing device into the sewer. When a leak comes into view the sealing device is moved into place and by expanding the inflatable ends of the sealing device, the leaking section is isolated. Sealant compounds are pumped into the isolated section under pressures in excess of ground water pressures. The compounds, which have low viscosity, pass through the leakage point and seal the path of leakage and the adjacent soil area. The sealing device is then deflated and the immediate results inspected by the television camera.

The principal chemical used is ordinarily AM–9. The "set" time required for the solution to gel depends on field conditions and is controlled by the quantity of catalyst added to the solution. The gel time may vary from seconds to hours as field conditions demand.

This method has only recently been employed on the West Coast areas (since 1962). Some typical costs in California are given below.

Area	Size-in.	Length-ft.	Total Cost
1. City of Richmond	21, 24	3,000	$4,000
2. Santa Clara County Sanitation District No. 4	8	890	1,400
3. City of Live Oaks	15	4,400	14,000
4. San Pablo Sanitary District	15	3,000	2,400
5. City of Concord	15	4,000	5,000

The average costs in the above list fall in a range of $0.80 to $3.20 per foot. The final cost is generally dependent on the number of seals which must be made per length of sewer.

Because the cost of the process is directly proportional to the number of seals made, it merits consideration in those cases where only a few leaks are present or where the number of sewer joints are less because of longer pipe sections in larger diameter pipes such as trunk sewer lines. The agencies interviewed indicated their interest in continuing to use the system. Many agencies were found to be unfamiliar with the method. Without a planning investigation as described in Section 3 of the Manual of Practice, an agency cannot properly evaluate the desirability of grouting as contrasted to replacement.

Sonoma County, California Asphaltic Treatment Process

The County developed a sewer sealing process which involves impregnating the soil around the outside of the sewer pipe with applications of SC-1 and RS-1 asphalts. These asphalts are applied to the soil about 6 inches above the sewer by an applicator made of 3/4-inch steel pipe with a perforated nipple at the discharge end. The applicator is placed in a hole drilled down to the sewer, and the inlet is connected to the asphalt drum resting on the ground surface. The applicators are spaced 15 feet apart along the center line of the existing sewer. The line is considered sealed when the asphaltic penetration into the sewer ceases. Penetration into the sewer is determined by the color of the sewage at a manhole; carrying asphalt, the sewage is brown-colored.

Considerable success has been reported by the County on this process, with results being recorded at two locations by the County. Recording stations have been located in L.I.D. No. 1 in two manholes, T-71 and I-60, each having a separate drainage area including approximately 5 miles or more of tributary sewers.

Despite this sealing, recent flow records at these two stations indicated flows increased 5 times to the average flow in 2 hours during a moderate rainfall with an intensity of 0.3 inch per hour for 3 hours. However, these flow figures could not be completely attributed to the limitations of the sealing process at this time, due to the fact that neither of the two areas is completely treated to date. Flow records after completion of treatment or repairs should then give the true effectiveness of the process used. It is suggested that detail testing of the treated sections be carried out in order to provide additional information.

Bentenoite

Another common chemical used in bentenoite. Bentenoite is essentially a clay type material mined in various parts of the country. It has a physical property of expanding when wet and contracting when dry. However, because of its high suspended solid content, its use is limited to very pervious soils such as gravel.

Study of "Improved Sealants for Infiltration Control"

The following tabulation of "Preliminary Estimates of the Properties of Grouting Materials," has been excerpted from the report of the Western Company, Richardson, Texas, to the Federal Water Quality Administration, Department of the Interior, June 1969, under Contract No. 14-12-146. The report has been published as Water Pollution Control Research Series, WP-20-18.

Inclusion of this tabulation is for information purpose only. It does not constitute any acceptance of the accuracy of any of the data, or any endorsement of the products listed. The purpose of the research study was an attempt to determine if structural deficiencies could be corrected as well as "welding a new joint together." This is in contrast to the existing concept of grouting, that is, stabilizing the material around the pipe.

PRELIMINARY ESTIMATES OF THE PROPERTIES OF GROUTING MATERIALS ++

Material	Properties: Cost ($) Material	Cost ($) Application	Viscosity	Adhesion	Strength	Shrinkage: Cure	Shrinkage: Environment	Flexibility	Contamination	Pot Life	Remarks
IDEAL MATERIAL			100	100	100	100	100	100	100	100	The ideal material will have a viscosity of water during placement, adhesion equivalent to breakage, strength equal to sewer pipe, no shrinkage, flexible as the sewer pipe, contamination to not affect set or materially affect strength and a pot life which is adjustable.
CEMENT Probable Achievable	1.50/gal	30.00	70	80	100	95	95	60	80	80	By using special additives and formulations, these results are expected.
Concrete (1-2-4) Cement (1-4-0) Cement Mortar(1-1-0)	1.20/ft³ 1.20/ft³ 1.20/ft³	38.50 38.50 38.50	20 30 50	10 20 30	80 85 90	80 85 85	95 95 95	50 50 50	60 60 60	50 50 50	The ratios 1-2-4, 1-4-0, and 1-1-0 refer to the ratios of cement-sand-gravel in the formula.
Pozzolanic	1.00/ft³	38.50	50	35	80	85	95	50	60	60	Volcanic materials which will react with lime to form a cementious material or may be used as additives in cement.
Hydromite Cal-Seal Latex	7.00/gal 5.00/100 lb 1.50/ft³	38.50 38.50 38.50	40 50 50	35 35 35	80 80 80	80 85 85	95 80 95	50 50 50	60 60 60	50 50 50	*Special cement formulations.*
Diesel Oil	1.40/ft³	38.50	50	20	60	80	80	50	80	60	Blend of cement in diesel oil which has a retarding effect until water is added.
Fast-Fix Putty-Fix	1.30/ft³ 1.50/ft³	38.50 38.50	60 40	50 40	95 90	90 85	90 85	50 50	60 60	60 60	Rapid set cements developed by Western for special applications. The formulas can be further improved for sewer pipe grouting use. A number of additives to modify the properties of cement are available.
ASPHALTS Probable Achievable	1.50/gal	30.00	60	30	40	80	90	90	100	40	Limited because of pour point of asphalt in relation to temperature of sewer pipe (200°F vs 60°F). Placement and strength are disadvantages.
SC-70	1.00/gal		60	20	10	80	90	90	100	30	Typical road asphalt diluted with solvent.
S-1	1.00/gal		30	20	20	80	90	90	100	10	Typical road asphalt.
AC-20	1.00/gal		20	20	20	80	90	90	100	10	Special asphalt of the Texas Highway Department.
OA-90	1.00/gal		20	20	20	80	90	90	100	10	200°F pour point asphalt.
OA-55	1.00/gal		20	20	20	80	90	90	100	10	200°F pour point asphalt for pavement crack repair.
GELS Probable Achievable	2.00/gal	30.00	90	20	50	70	40	100+	40	80	Chief gel disadvantages are the strengths and environmental cure characteristics.
AM-9, Penetryn, PWG, Wes Grout and VPG	2.00/gal	38.50	90	10	20	70	10	100+	40	80	Trade names for the acrylamide type or grouting gel.
Terra Firma and Blox-all	2.00/gal	38.50	70	10	30	70	20	100+	40	80	Trade names for the lignosulfate type of gel.
Siroc, Siljel and Formasil	2.00/gal	38.50	70	10	30	70	30	100+	40	80	Trade names for the silicate type of gel. Gel starting materials are basically water soluble and are severely affected if diluted with water or dehydrated.
POLYMERS Probable Achievable	3.50/gal	30.00	85	90	100+	100+	100	100	85	90	Primary disadvantage is cost of materials, however, this is small compared to total cost.
Epoxy plus Herculox, Epo sand or Whiteside	3.00/gal	38.50	40-70	60	60-100	95	100	50-90	40	40	Tradenames for epoxy resin plus amine, acid, anhyhide, etc. as a crosslinking agent.
Urethane HG-10 PC-12	 4.55/gal 4.55/gal	 38.50 38.50	 30-70 50-70	 70 60	 40-90 50-80	 100 100	 100 100	 50-90 40-70	 30+ 30+	 80 80	Prepolymer plus polyol, etc, as a crosslinking agent.
Polyesters	2.50/gal	38.50	30-70	30	60-100+	60	100	50-90	70	80	Unsaturated polyester resin plus vinyl crosslinking agent, styrene. The properties are estimates of anticipated values since there are no known commercial products.

NOTE: An almost unlimited number of materials are available for formula modifications. Each different material in combination with the base polymer material results in a finished product with different properties. Example base chemical suppliers are: Polyesters - American Cyanamic, Chevron, Allied; Hooker, ADM, Dow; Urethane - Union Carbide, Monsanto, DuPont, Glidden; Epoxy - Shell, General Mills, Humble. In addition to the base materials available, other methods exist which permit modification of the properties of the polymers (i.e., fillers, coupling agents, plasticizers, solvents, catalysists).

+ If contaminant is water the Urethane may foam (expand) which may be an advantage.

++ These estimates of the properties of grouting materials were made prior to the beginning of the program. The estimates were based upon general knowledge of the various grouting materials. A number of properties of the grouting materials were selected which were anticipated to be important in their evaluation. An ideal property was assigned a value of 100; the closer the estimated properties approached 100, the better the material property.

BIBLIOGRAPHIC: American Public Works Association, Research Foundation. Prevention and Correction of Excessive Infiltration and Inflow Into Sewer Systems – A Manual of Practice EPA Publication No. 11022 EFF 01/71

ABSTRACT: As a result of a national study of the sources and prevention of infiltration and inflow, a Manual of Practice was proposed. The Manual is intended to serve as a guide to local officials in evaluating their construction practices, conducting surveys to determine the extent and location of infiltration and inflow, the making of economic analyses of the cost of excessive infiltration/inflow waters; and instituting corrective action.

Excerpts from sewer control legislation are given as well as information on air and exfiltration testing.

This Manual of Practice was prepared for the Environmental Protection Agency in partial fulfillment of Contract 14-12-550. The study was also supported by thirty-nine public agencies. A companion document, "Control of Infiltration and Inflow Into Sewer Systems", was also prepared.

KEY WORDS

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