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ECONOMIC ANALYSIS, ROOT CONTROL, AND BACKWATER FLOW CONTROL AS RELATED TO INFILTRATION/INFLOW CONTROL

Appendices

by

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Grant No. 803151

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16. ABSTRACT A study was conducted to identify and analyze present practices for determining and controlling infiltration and inflow (I/I) and investigate the role of roots and tide or backwater gates in the I/I problem.

It was found through on-site investigations and questionnaires that local authorities were just starting to consider their I/I problems. Roots were found to be a major sewer system problem. Tide gates were found to be considered satisfactory, although generally they receive infrequent maintenance and often do not properly close.

The results of the study are presented in four volumes. The first report (EPA-600/2-77-017a) reviews a sample economic analysis and information concerning root control and tide gates as determined by the study. This volume of appendices to the report contains the literature review, questionnaires used, and field reports on root control and tide gate conditions and practices. The third report (EPA-600/2-77-017c) is a Product and Equipment Guide for I/I detection and control. Information is given and manufacturers listed for six classes: cleaning, internal inspection, rehabilitation, flow measurement, safety, and pipe. The fourth report (EPA-600/2-77-017d) is a Manual of Practice which covers the I/I investigation, sewer system cleaning and rehabilitation, and guides for new construction.

The study updates a similar effort conducted in 1970.

This report and the other three volumes are submitted in fulfillment of Demonstration Grant No. 803151 by the American Public Works Association under the sponsorship of the U.S. Environmental Protection Agency. Work was completed on this report in July 1976.

17 KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sewers, Sanitary sewers, Manholes, Fluid infiltration, Economic analysis, Sewer pipes	Sewer system analysis (conditions), Root control, Tide gates, Joints, Sewer repair, Appurtenances, Rehabilitation and sewer inspection	13B

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The first volume of this study delineates the economic analysis, root control, and backwater flow control aspects of infiltration/inflow control for the user community's ready reference. Its Appendices review the literature published to 1975, the field reports on root control practices, and experiences with tide gates and backwater flow devices. These and the two remaining volumes (I/I Product and Equipment Guide and I/I Manual of Practice) represent a concerted effort to compile needed information for local authorities and consulting engineers on the control and elimination of infiltration/inflow flows to sanitary sewer systems.

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ABSTRACT

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APPENDIX A

LITERATURE ABSTRACTS

1970/1975

Relating to Infiltration/Inflow
and Related Subjects

PART A

Sewer Infiltration Studies

A1. Control of Infiltration in Sewer-Systems Design and Maintenance, Nashville Metropolitan Government and Davidson County, Tenn. Sewerage Services

R. Harrington

Technical Report No. 20, Department of Environment & Water Resources Engineering, Vanderbilt University (1969)

Descriptors: - Infiltration, Sewers, Sewage Disposal, Specifications, Ground Water Movement, Waste Water Treatment, Design Standards Materials Testing.

Nashville (Metro) in new specifications to upgrade previous standards for the design, construction and maintenance of its sanitary sewers. A change in pipe materials, bedding, pre-cast manholes, pre-cast service connections and improved stoppers have reduced infiltration and have provided reduction in the amount of allowable infiltration. (1969)

A2. Infiltration in Sewers,

W. J. Robertson and A. W. Bird,

Australian Civil Eng., Vol. 10. No. 4 Apr 1969

Descriptors: Investigations, Infiltration, Sewers

Extensive investigations by Melbourne where the problems of entry of extraneous water into sewer system was studied, is discussed, wet-weather infiltration factors are enumerated.

A3. Reduction of Groundwater Infiltration into Sewers by Zone Pumping at Meridian, Idaho,

Hoffman and Fiske, Boise, Idaho,

Federal Water Pollution Control Administration, Water Pollution Control Research Series DASR-9, 1969

Washington, D. C.

Descriptors: Infiltration

Identifiers: Volume reduction, Surcharging, Zone pumping, Groundwater Infiltration

In Meridian, Idaho, an investigation was made to determine whether the lowering of the groundwater table by zone-pumping was practical and economical. It was concluded that this was not economically feasible when compared to other corrective measures.

A4. Report to the City of Flint, Michigan on Sanitary and Storm Sewer Systems, 1969,
Metcalf and Eddy, Boston, Mass.
Descriptors: Sanitary Engineering, Sewers, Sewerage, Flow separation, Infiltration, Drainage Systems, Drainage Practices, Drainage Engineering Urbanization, Municipal Wastes, Pollution Abatement, Storm Runoff, Water Pollution Control, Sewage Treatment, Treatment Facilities, Flood Protection, Flood Plan Zoning, Construction Costs, Future Planning
Identifiers: Combined Sewer Separation, Sanitary Sewers, Basement Flooding

In Flint, Mich., Metcalf & Eddy investigated the problem of basement flooding, river pollution and future potential stormwater discharges. Sewer separation was recommended, together with enactment of legislation to prohibit future connections to the sanitary sewer system from foundation drains or other sources of surface or groundwater. An I/I survey was recommended. (1969)

A5. Sewerage Practice in the Gulf Coast Area,
J. K. Mayer, E. Steimle, & F. W. MacDonald,
Tulane University, New Orleans, La.
Public Works Vol. 101, No. 8 Aug. 1970
Descriptors: Sewers, Survey, Sanitary Sewers, Length, Materials, Infiltration, Flows, Saturated Soils, Water Table
Identifiers: Combined Sewers
Seventy-one municipalities and sewer districts, spanning the coast from Florida to Texas, were questioned as to types and length of sewers, materials of construction, type of bedding infiltration experience, soil description, depth of water table, and average flows and treatment used.

An analysis of the data collected was made for the purpose, if possible to establish correlations among the factors; this was not possible because of the scattering of the data.

A6. Storm Water Pollution, New Orleans, La., New Orleans Sewerage and Water Board, Final Report June 1970

Descriptors: Pollutant Identification, Water Pollution, Path of Pollution, Water Pollution Control, Pollution Abatement, Leakage, Storm Drains, Drains, Drainage Systems. Sewers, Municipal Wastes, Inflow, Sewerage, On-site Investigation, Lakes, Water Quality Control, Inspection, On-Site Tests, Repairing, Infiltration, Dye Testing, Cracking, Pumping Plants, Design Standards, Installation

Identifiers: Storm Water Pollution, Sewer Leakage, Cross Flow, Televised Inspections, House Sewers, Cross Connections, Sewer Inspections.

The New Orleans Sewerage and Water Board as part of a pollution study, examined leakage between 8-inch diameter sewers and storm sewers at open joints, fractures and house connections, by T.V. camera and by conducting infiltration tests. It was found that the major source of pollution arose from accidental cross-flows between sanitary sewer house connections and storm sewers at points of crossing. These cross-flows resulted from broken or cracked pipe and joints in both systems. Settlement pressure generated by the overlying storm sewer on the house connection was the principal culprit.

A7. Storm Water Pollution, New Orleans, La. New Orleans Sewerage & Water Board Supplementary Report June 1970

Descriptors: Repairing, Sewers, Leakage, Inflows, Water Pollution Control, Pollution Abatement, Drainage Systems, Storm Drains, Municipal Wastes, Sewerage, Pumping Plants, Disinfection Chlorination, Water Quality Control, Water Waste Treatment, Path of Pollutants, Lakes, Infiltration

Identifiers: Sewer repairs, leakage repairs, Pipe repairs, Sewer repair costs, Stormwater Pollution, Sewer Inspection, Sewer Leakage, House Sewers, T.V. Inspection.

Following the publication of a report in 1967 (USEPA Water Pollution Control Research Series, Report 11022 EFF 12/70), an evaluation of repairs made to correct 47 major leaks and defects was prepared. Upon completion, exfiltration tests were made indicating the existence of excessive leakage. This was attributed to unrepaired house sewer connections. The following actions are now planned or underway - relining existing sewer connection pipes with flexible thin plastic pipes, new sewer line construction to relieve overloaded pumping stations and installation of disinfection equipment at sewage pumping stations.

A8. Infiltration in Separate Sanitary Sewers
Riddle Engineering, Inc. - Kansas City, Mo.
Journal, W.P.C.F. Vol. 42, No. 9, Sept. 1970.
Descriptors: Infiltration, Sewers Costs, Runoff Maintenance, Repairing Storm Runoff Construction, Waste Water Treatment
Identifiers: Detection Methods

A survey was conducted by Riddle Engineering, Inc. in western Missouri and eastern Kansas in connection with the proposed elimination of infiltration and stormwater in the sewage systems of 49 abatement facilities in the area. Location of storm water inlets was established by low pressure air testing. The smoke testing program allowed visual identification of roof leaders, street inlets, broken pipes, ruptured manholes, and other drains. Infiltration and its correction was regarded as a separate problem.

A9. Engineering Investigation of Sewer Overflow Problem in Roanoke, Va.
Hayes, Seay, Maltern & Maltern, Roanoke, Va.
USEPA Water Pollution Control Research Series - 11024 DMS 05/70.
Descriptors: Sewers, Infiltration, Overflow, Water Pollution Control, Surveys, Computer Programs, Storm Runoff, Flow Measurement, Rainfall-run-off relationship, Sampling, Construction Costs.
Identifiers: Sewer infiltration, Sanitary Sewers

An engineering investigation of the sewer overflow problem was carried out in Roanoke, Va. in 1970. About 25% of the separate sanitary sewerage was studied covering the amounts of infiltration for various storm intensities and durations and the amounts of sewage overflow. The results were analyzed by computer to determine magnitudes and frequencies of overflows. The results were used to develop an optimum design to reduce sewer overflows.

A10. Storm Water Problems and Control in Sanitary Sewers, Oakland & Berkeley, Ca., Metcalf & Eddy, Inc., Boston, Mass.
USEPA Water Quality Office, Report No. 11024 EQG 03/71.

Descriptors: Infiltration, On-site Investigations, Infiltration Rates, Sewerage, Combined sewers, Separated Sewers, Computer Models, Urban Drainage, Storm Runoff, Storm Water, California Water Pollution Sources, Bays, Estimated Costs.
Identifiers: San Francisco Bay, Sanitary Sewers, Combined Sewer Overflows, Flow Routing Program.

Metcalf & Eddy conducted an engineering investigation on stormwater infiltration with sanitary sewers and associated problems in the East Bay Municipal Utility District (including Oakland, Berkeley, Ca., et al) in 1971. Ratios of infiltration to rainfall in the study subareas ranged from 0.01 to 0.14, Ratio of peak wet weather flow to average dry weather flows ranged from 2.1 to 9.1. About 11% of the rainfall entered the sanitary sewer system. 30.6% of the infiltration is contributed by 4% of study area that has combined sewers. Problems associated with infiltration:

(1) Pollution of San Francisco Bay
(2) Operational difficulties at Sewage Treatment Plant
(3) Danger to public health, property damage and nuisance.

Recommendations for most feasible combination of remedial measures cover:

(1) Treatment Plant improvements
(2) Separation of remaining combined sewers
(3) Partial treatment of overflows
(4) Sewer improvements

Costs between 42 and 94 million dollars, estimated time for implementation, 7 years.

A11. Pollution Control Starts in Collection System
Black & Veatch - Kansas City, Mo.

J. O. Schmidt

Water Pollution Control Federation Session 15, No. 3, Oct. 6, 1971

Descriptors. Sewers, Infiltration, Drainage Water, Waste Water Treatment, Maintenance Monitoring, Specifications, Construction Materials, Overflow

Identifiers: Wastewater by-passing, Collection systems, T.V. inspections.

Black & Veatch Consulting Engineers, Kansas City, Mo. state in a review of the infiltration problem that extraneous flows into sanitary sewers has been tolerated and controlled by by-passing which is no longer acceptable for reasons of increased wastewater flows and increased downstream use.

Three basic remedial measures are:

1. Reduce extraneous water entering sanitary sewers by flow monitoring, repair and replacement using improved methods and materials, and by continuous inspection, particularly of house connections.
2. Prevent the entrance of extraneous water in 8 new sewers by use of new and improved construction materials and methods including T.V. inspection.
3. Treat overflows that cannot be avoided.

A12. Pollution Control in Sewers

Black & Veatch Consulting Engineers, Kansas City, Mo.

John O. Schmidt

J. Water Pollution Control Federation, July, 1972.

Descriptors: Sewers, Infiltration, Water Quality Control: U. S.: wet weather periods, overflows, sewer design

In a further article, Black & Veatch (Schmidt) states that in areas where homes are constructed with basements and footing drains, large inflows of extraneous water into sanitary sewers cannot be avoided. In older systems, the house service sewer contributes the major portion of infiltration. Exacting specifications and rigorous inspection in the construction of large sewers will ensure "tight" sewers, but similar results for house service connections depend upon whether cities are willing and able to employ such measures. Billings, Montana achieved significant infiltration reduction by a serious campaign, but there is a practical limit as to how much infiltration can be reduced and after this point has been reached, overflows may still occur.

A13. Ground Water Infiltration and Internal Sealing of Sanitary Sewers
Montgomery County Sanitary Dept., Dayton, Ohio
Water Pollution Control Research Series, No. 11020 DHQ June, 1972
Descriptors: Water Pollution Control, Sewers, Sewerage, Joints (Connections), Leakage, Infiltration, Inflow, Seepage, Infiltration rates, Pipe Flows, Storm Water, Storm Runoff, Groundwater movement, Ohio., Peak Discharge, On-site investigations, Inspection
Identifiers: Montgomery Co., Ohio, Sealing Sanitary Sewers, illicit sewer connections, Televised sewer inspection.

A study was conducted on Ground Water Infiltration & Internal sealing of Sanitary Sewers by Montgomery County Sanitary Department, Dayton, Ohio, involving joint sealing and T.V. inspection. Pressure grouting of small main line sewers was undertaken with minimal flow reduction resulting therefrom. Infiltration from extraneous storm water, illegal connections and basement underdrains out-weigh the leaky joints contribution to the problem.

A14. Construction of Wastewater Facilities, Hot Springs, Ark., W.P.C. - Ark. K 305, Draft Environmental Impact Statement
E.P.A. Air and Water Programs, Dallas, Tex., ELR 5042, July 28, 1972
Descriptors: Environmental surveys, Wastewater, Land Use, Construction Improvement, Water Treatment, Sewers, Pollution, Outfall sewers, Waste Treatment
Identifiers: Environmental impact statements, Lift Stations, Waste Water Transportation

In an environmental impact report on the proposed construction of wastewater Facilities in Hot Springs, Arkansas, a detailed presentation of the adverse and beneficial environmental effects are included. The work involved sanitary sewer interceptors, lift stations, outfall lines and an advanced wastewater treatment process.

A15. Sewer Bedding and Infiltration

Gulf Coast Area

Tulane University, New Orleans, La.

John K. Mayer, Frank W. MacDonald and Stephen E. Steimle

U.S.E.P.A. Water Pollution Control Research Series, EPA 11022 D.E.I.

May, 1972

Descriptors: Sanitary Sewers, Ground Water, Construction materials, Sanitary Engineering, Cost estimates, Maintenance

Identifiers: New Orleans, La., Gulf Coast Regions (U.S.)

In the Gulf Coast Region (U.S.) ground water infiltration studies were undertaken in 1962/63 and again in 1970 by research staff of Tulane University, New Orleans, La. Infiltration measurements in the systems ranged from zero to 111,000 gals/inch-diameter/mile/day. Where decreases in infiltration had occurred this was attributed to soil and grease clogging the breaks which was confirmed by subsequent T.V. inspection. High infiltration rates were attributed to poor construction methods on main sewers and house connections. It was pointed out that many locations of the U. S. Southern Coast along the Gulf of Mexico experience higher infiltration rates and greater maintenance difficulties with sanitary sewers than other sections of the country.

A16. Process Design Manual for Upgrading Existing Wastewater Treatment Plants

United States Environmental Protection Agency, Washington, D. C., Technology Transfer, Oct., 1974.

Descriptors: Investigations, Flow equalization, Infiltration, Inflow, Upgrading, Trickling Filters, Activation Sewage Plants, Clarifiers, Effluent Polishing, Pre & Post Airation, Disinfection, Sludge Treatment and processing.

Identifiers: Wastewater Treatment Plants upgrading

In October, 1974, the E.P.A. published a Process Design Manual for Upgrading existing Wastewater Treatment Plants. These upgrading procedures may be applied ahead of a plant and include infiltration and inflow and flow reduction and equalization. Excessive infiltration/inflow is regarded as a likely possibility when influent BOD and S. S. concentrations are consistently below 150 mg/l. Major causes of infiltration given as leaky manholes, faulty lateral connections, leaky pipe joints. Excessive inflows attributed to illegal downspouts, footer drains, cross connections with storm sewers, and surface runoff into the top of illogically placed manholes.

Typical testing and inspection techniques given as 1. Smoke Testing, 2. Hydrostatic testing, 3. Air testing, 4. Closed circuit T.V., 5. Photographic methods.

The most common remedial techniques are given as:

1. Internal or external pressure grouting with chemical sealants.
2. Manhole grouting
3. Replacing, elevating and/or sealing of manhole covers
4. Replacements of severely damaged sewer sections or service connections
5. Insertion of sewer liners
6. Removal or plugging of illegal inflow connections such as downspouts on footer drains

Reported costs for inspection and repair of sewers vary widely in response to sewer age, construction materials and methods, accessibility of sewers, sewer size and soil conditions. Estimates vary from $5.00/foot to $20.00/foot.

A17. Urban Runoff Pollution Control, State of the art

Richard Field and John A. Lager

J. Env. Eng. Div. A.S.C.E., New York, Vol. 101 No. EE1 Feb., 1975

Descriptors: Bacteria, Combined sewers, Cost Analysis, Cost Effectiveness, Disinfection, Drainage, Environmental Effects; Environmental Engineering, Flood Control, Hydrology Overflows, Rainfall/Runoff, Sewage Treatment, Storage Tanks, Storms, Storm Sewers, Surface water Runoff, Waste Treatment, Wastewater, Water Pollution, Water Resources.

Combined sewers major sources of pollutı

affects water quality. Three principal types of discharge (1) Combined sewer overflows, (2) storm drainage in separate systems, (3) overflows (bypasses) from infiltrated sanitary sewers. Current approaches to problem involves control of overflows, treatment and combination of both. Control may involve maximization of treatment with existing facilities, control of infiltration and inflow, surface sanitation and management and flow regulation and storage. The following were evaluated - high rate screening and microstraining, ultra high rate filtration, dissolved air flotation, physical/chemical treatment, and modified biological processes. The swirl concentrator which originated in the U. K. and was further developed by the A.P.W.A. and E.P.A. has been highly developed. High rate disinfection methods have been applied. Integrated use of controls and equipment are promising.

A18. The Pressure Sewer: A New Alternative to Gravity Sewers
I. G. Carcich, L. J. Hetling, R. P. Farrell
Civil Engineering, A.S.C.E. May, 1974.
Descriptors: Gravity sewers, Pressure Sewers, Grinder Pumps, Infiltration Elimination, Pressure Sewer Wastewater Characteristics, Economics
Identifiers: Albany, N. Y., E.P.A. Demonstration Project - pressure sewers and grinder pumps vs. gravity sewers

The article describes the Albany E.P.A. Demonstration Project - where 12 new homes were equipped with both conventional gravity sewers and a grinder pump-pressure system. Systems originated with the late Prof. Gordon M. Fair of Harvard University with his suggestion of a pressure sewer within a sewer with the combined sewer being used exclusively for stormwater to eliminate the costly construction of a new separate sanitary sewer system. The key to a pressure sewer system is the relatively recent development of the grinder pump. The pump is described and its performance evaluated. It is suggested that the pressure sewer pipe must be sized considering the anticipated flow and yet large enough to avoid excessive function losses which could overload the pumps. It should be small enough to ensure a minimum daily velocity of 2 ft/sec thus controlling deposition of settleable solids. In Albany pressure sewer waste was 100% stronger on a concentration basis than conventional sewage, but contained 50% less contaminants on a gr./capita/day basis. Sewage volume was 2/3 lower (on a per capita basis) than the conventional sewers primarily because of elimination of infiltration and other extraneous flows such as downspouts and foundation drainage. The grinder pump is said to have little effect on the efficiency of treatment at the Sewage Treatment Plant. The E.P.A. are participating in other demonstration projects on the pressure sewer and the grinder pump at

Phoenixville, Pa. and Grandview Lake (Columbus) Indiana. Pressure sewers have been built without government aid at Saratoga, N. Y. and Clifton Park, N. Y. The grinder pump was developed by the G. E. Company, under a sub-contract from A.S.C.E. and is now manufactured by Environment/One Corp.

A19. Sewer Pipe - Infiltration is the Issue
Civil Engineering, - A.S.C.E., New York, N. Y., July, 1974
Virginia Fairweather

Descriptors: Infiltration-Inflow, Sewer Systems, Environment, Regulations, Funding, Sewer Cleaning, Inspection, Guidelines, Cost, Grouting, Joints (flexibility), Gasketing

Identifiers: E.P.A. requirements re I/I studies for Federal Funding for new Sewage Treatment - Separate sewerage - Infiltration and Inflow.

Infiltration/Inflow excess increasing in importance in the sewer design, construction and maintenance and rehabilitation field. E.P.A. now requires I/I studies to determine whether infiltration/inflow is excessive in an existing system before application for Federal Funds will be considered. Three phases have been set up by E.P.A.

1. Preliminary infiltration/inflow analysis (If it costs more to treat, than to eliminate I/I it is considered excessive) (E.P.A. Criterion)
2. A sewer system evaluation survey involving precise identification of I/I sources and determination of costs to correct each defined source.
3. Sewer Rehabilitation and/or construction or expansion of treatment plant.

Controversy has arisen over these regulations. Defenders say the amendments to the Act were a good thing as I/I specifications were vague and few were concerned, and again that prior to the amendment, new funds available for new treatment plants were only encouraging the building of bigger plants rather than minimizing flow. Critics say that designing for an I/I rate under 250 gals/in-mile/day cannot be justified by the resulting saving of the treatment plant. Others feel that depositions of suspended solids in the sewer will result if system becomes relatively "bottle tight" and that flushing may be required to avoid septic reactions-gas and odors. Some E.P.A. officials state that inflow is usually cheaper and easier to remove, and that it isn't cost-effective to take out all infiltration. Therefore the E.P.A. criterion is cost by which excessive I/I is determined and E.P.A. has not set a maximum infiltration rate. Infiltration studies can be either in-house or consultant oriented. Both methods have been accepted by E.P.A. It is noted that Florida has had great concern about infiltration because of high ground water levels and rapid population growth. Much early work in TV inspection and chemical grouting methods. E.P.A. guidelines estimate that a 5 phase sewer evaluation (physical survey, rainfall situation, preparatory cleaning, internal inspection and survey report) should cost between 65c and 95¢ per ft. Grouting a typical sewer joint might cost $40.00 while sealing a typical sewer reach might cost $270 - $470. Having determined infiltration sources, (assuming that inflows are often easy to correct) possible rehabilitation methods are:

(a) Dig up and replace defective pipe
(b) Insert plastic liners
(c) Carry out chemical grouting

Method (c) is the most commonly used, plastic liners being relatively new and used when a reach of pipe is badly deteriorated and grouting not economically feasible.

Methods of grouting in conjunction with TV inspection are described. Two chemical grouts are commonly employed (1) AM 9 - American Cyanamid Corp. (also used under the names Q-Seal & PWG), and (2) The 3M Companies elastomeric sewer grouting compound. AM 9 is a mixture of acrylamide monomers and a chemical catalyst and initiator. It is pumped through hoses into the sewer section under repair and works by penetrating waste in the joint and migrating out of the pipe to stabilize the soil around the outside. A gel forms in the joint and the soil, forming a waterproof diaper around the pipe preventing further infiltration.

A new grout produced by the 3M Companies is an elastomeric grouting compound. It is catalyzed with water, expands up to 10 times and forms a new rubber-like gasket right in the leaky joint. It does not penetrate surrounding soil. It is believed that 3M excels in areas that are very dry as the grout will not shrink in the absence of moisture. AM 9's soil stabilization property is a plus in sandy or shifting soil where it stops the leak and helps prevent future differential settlement. In new design, minimization of infiltration is paramount and joint flexibility is of prime importance avoiding sheared joints and connections. Proprietary connecting systems are described involving custom drilling of concrete sewer structures with special fittings. Other systems have gaskets and seals cast integrally into the manhole. One new method involved the use of a fiberglass reinforced polyester socket and a urethane spigot sealing ring.

A20. Considerations for Analysis of Infiltration/Inflow

David J. Cesareo and Richard Field

U. E. Environmental Protection Agency, Edison, N. J.

Before 1974 International Public Works Congress and Equipment Show - Toronto, Canada September, 1974. In APWA Reporter, Vol 42, No. 7 July 1975.

Descriptors: Flow Analysis, Pollution Control, Infiltration, Inflow, Preventative Sewer Maintenance and Construction, Cost Factors, Ordinances and Regulations, Survey, Sewer Rehabilitation, Evaluation of Cost Estimates, Hypothetical I/I Cost Evaluation, Surge Facilities, Grouting Practices.

Identifiers:

This paper is comprehensive and detailed in scope. The work of U.S.E.P.A. and the A.P.W.A. is described. It is postulated that all sewers act as combined sewers to some degree and that the usual amount of Infiltration and Inflow still exhibit overflows and by-passes under wet-weather flow conditions. Infiltration (and exfiltration) often produce local washout of soil bedding around defective pipes or joints resulting in sewer line blockage and increased grit handling, often followed by failure of the sewer barrel with resulting pavement cave-in. No such effects attributable to inflow connections. In infiltration direct relationship exists between entry of sewer flows through defective pipe, service connections and joints and intrusion of water seeking tree roots. Result: Blocked sewers due to root intrusion and worsening of cracks and defective joints and connections. No such relationship at points of inflow.

Once infiltrated and inflow waters combine, they are not readily distinguishable from each other - net effect of presence is robbed sewer system capacities and usurped capabilities of system facilities such as pumping, treatment and regulation overflow structures. Prevention of excessive infiltration depends on effective design and allowances, choice of materials and diligent inspection and testing to ensure compliance with specifications. Correction of excessive infiltration requires a proper engineering survey and evaluation to determine presence and extent of problem, cost-effective engineering evaluation and elimination of flows by repair and replacement. Prevent of excessive inflow requires setting and enforcing strict sewer use ordinances.

A discussion of economic factors is given urging cost benefit evaluation rather than emphasis on adverse effects of surcharged sewers.

A discussion of the Federal Water Pollution Control Amendments of 1972 is included and suggestions are advanced as to the necessary surveys and studies required to meet the amendments.

A discussion of cost analysis is included and basic guidelines are given such as:

1. A possible excessive infiltration source equals at least 1-3 gpm (1440-4320gpd)
2. A typical 400 ft. manhole reach may contain 3 to 8 possible excessive infiltration sources.
3. Excessive infiltration will occur in less than 50% of the possible sources.
4. Equipment and manpower costs to grout a typical MH reach is approx. $150 (1974 dollars)
5. Grouting a typical sewer joint or infiltration source within a manhole reach costs approx. $40 (1974 dollars)

Average cost for the complete 5 phase evaluation is given at 65¢ to 95¢ per foot for total length of sewer system to be surveyed.

A Hypothetical Infiltration/Inflow Cost evaluation is presented. Certain work carried out locations in the U. S. is documented including the use of surge facilities at Rohnert Park, Calif. The overall impact on water quality should remain an important factor of consideration. Simple elimination of an extraneous inflow source may not always be the best cost-effective engineering choice as its eventual impact on the environment must be considered. References are given.

PART B

Sewer Design

B1. Design and Construction of Sanitary and Storm Sewers, Manual of Practice No. 37, 1969. American Society of Civil Engineers, New York, New York.

This manual covers all aspects of the subject (including mathematical modelling) of the design of both storm and sanitary sewers which represented at the year of publication acceptable current procedures. It covers all phases of investigation, plan and specifications, preparation, contrast documents and construction procedure. It represented the work of a capable expert committee.

A listing of modern papers (1970/4) covering mathematical model design of collection networks is included in the Appendix but for technical reasons and only periphery relationship to the I/I problem they have not been summarized.

PART C

Flow Measurement

C1. Flow Measurement in Gallons per Minute and Sampling in Sewage Systems, Beatie, Russell H., United Industries, Inc., Wichita, Kansas, 1971.
The tract considers:

(1) Force mains

(2) Gravity sewers, open channels or outfall points

Various methods and equipment for measurement or flow and sampling are described.

C2. Development of a Meter for Measurement of Sewer Flow, H. G. Wenzel, Jr., Univ. of Ill., Dept. of Civil Engineering, Urbana, 1973, Water Resources Center Research Report No. 74.
See also Journal of Hyd. Div. A.S.C.E. Vol 101, No. HY1, Jan. 1975.
Descriptors: Pipe Flow, Instrumentation Venturi Meters, Flow Measurement, Discharge Measurement, Urban Drainage, Open Channel Flow, Design Criteria, Performance, Optimization.
Identifiers: Sewer Flow, Flow Meter.

An experimental and analytical study sought to determine the geometry of a Venturi type flow meter for sewer flow measurement which consisted of a pipe constriction producing critical flow under open channel conditions and which acts as a conventional Venturi type under full flow. A description of its construction is given together with head loss characteristics and experimental rating curves for both conditions (of flow).

C3. Developments in Sewer Monitoring Equipment and Techniques, Galliers, R. and King, M. V., J. Inst. Munic. Eng. (Great Britain) Vol. 97, No. 1, Jan. 1970.
The paper described modern equipment and techniques developed by Birmingham, England to gain knowledge of the flows in the corporation's sewers. It has application in control of trade effluent discharge, in design of sewers and river channels and the effect of storm overflows in rivers.

C4. Sewage or Highly Sediment-Laden Water Discharge Measurement with Reference to Pollution Flux Determination, Le Frou, C., Houille Blanche, Vol. 24, No. 5, 1969.

This is a French language paper describing the use of the dilution method with radioactive tracers and velocity measurement by electromagnetic pick up. A comparison is made of approx. discharge measurements by current meter or electromagnetic pick up at various points in the velocity field and dilution method with chemical tracers to results of their application and to continuous discharge record.

C5. Velocity Measurements in Sewers Vital to Design and Maintenance, Curtis, L. W. Consulting Engineers, Cleveland, Ohio, Water and Sewage Works, Vol. 116, No. 4, April, 1969.

Surveys and trends of several methods during major sewerage system study concluded that salt-concentration method of measuring velocity was best suited to determine discharge-depth relationship (rating curve) for a number of sewers. It will also give indication of condition of sewer. It was established that no ratio exists applied to surface velocity measurements that will give accurate average velocities in pipe.

C6. Simple Method for Wastewater Flow Measurement,

Shah, J. B., Oakland County, Dept. of Public Works, Pontiac, Michigan, J. Water Pollution Control Federation, Vol. 45, No. 5, May, 1973.

Use is made of a 90 degree V notch weir and a portable liquid level meter. A curve relating average lead to true total weekly flow was developed. Figures compared favorably with totalized flow readings from an electromagnetic flow meter.

C7. An assessment of Automatic Sewer Flow Samplers,

Shelley, P. E. and Kirkpatrick, G. A. Jr., Hydrospace-Challenger, Inc., Rockville, MD., Government Printing Office, Washington, D. C., EP 1 23/2: 73-261 (EPA R2-73-261).

Descriptors: Sewers, Samplers, Sewage Samplers, Automatic Control Equipment, Combined Sewers, Storm Sewers, Design Assessments, Surface Water Runoff, Reviews, Sampling.

Characteristics of storm and combined sewer flows are reviewed along with purposes for and requirements of a sampling program. Automatic sampling equipment's desirable characteristics and problem areas are discussed. Compendium of 60 models of commercially available and custom designed automatic samplers is given along with descriptions and characteristic suitabilities of same. Review of field experience is covered along with a state of the art with regard to automatic sampler technology. Design guides are given for development of a new, improved automatic sampler for use in storm and combined sewers.

PART D

New Pipe Materials

D1. Whats New in Water and Sewer Pipe,
K.A. Godfrey, Jr., Civil Engineering--American Society of Civil Engineers, New York, Oct. 1970, p. 46-51.

Descriptors: Pipes, Seepage, Linings, Sewers, Water Supply, Epoxy Resins, Plastics, Joints, Asbestos--Cement, Asphalt, Concrete.

Identifiers: Dallas, Texas, Galveston, Texas, Modesto, California.

10" drain pipe has been placed by a moving form casting non-reinforced concrete pipe at a rate of 30 feet per hour. Forty-two miles of PVC pipe (diameters 2" to 6") laid in Texas using Badger Equipment introduced in USA in 1970. Also in Texas Truss Pipe (ABS plastic in diameters 8" to 15" with an specification for infiltration allowance of 100 gals/inch pipe diameter per day with 10 ft. head) is being laid. 8000 ft. of 8" and 10" concrete pipe has been relined in Texas with 6" and 8" polyethylene Uni-Pipe which was cheaper than cleaning and mechanically applied relining. The pipes are heat butt-welded, P.V.C. couplings have been used to join pipes of different dimensions.

In Modesto, California 5500 feet of 24 inch concrete has been lined with an 18" Techite Liner jacked through the entire length of the pipe from one jacking pit.

D2. Heat Shrinkable Tubing as Sewer Pipe Joints,
The Western Co., Richardson, Tex., Environmental Protection Agency, Washington, EPA Program 11024 FLY 06/71.

Descriptors: Joints, Sewers, Sewerage, Pipelines, Joint Costs, Material Testing, Watertight, Infiltration Pipelines, Conduits, Construction Costs, Prototype Tests, Inflow, Costs Analysis.

Identifiers: Polyolefin, Heat Shrinkiner Tubing, Waterproof Joints.

Preliminary Tests of Heat Shrinkable Tubing (H.S.T.) as used in electronic and aerospace industries showed promise in coupling commercial sewer pipe. Lab studies of joints and tubing covering (1) characteristics & (2) operational and economic feasibility were conducted under program. Small scale and full scale tests using 8" commercial sewer pipe indicated that a polyolefin with a polymeric base hot melt adhesive produced the most durable waterlight joints and were superior to existing pipe joining mechanisms. Costs of H.S.T. joints compare favorably with conventional joints considering both material and installation costs. No significant departure from current installation procedures is involved and the H.S.T. joint is equally acceptable to repair and install commercial pipes and joints. Further development and in-use demonstration is recommended.

D-3. Plastic Pipe Applications,
Water and Sewage Works, Vol. 117, No. 4, April, 1970, p. 115-117.

Descriptors: Plastic Pipes, Installation Water Distribution, Sewers, Sewage Treatment, Industrial Plants, Temperature, Pressure, Costs Waste Water Treatments.

Identifiers: Thermoplastics

A review is presented of current developments and future trends in use of plastic piping in water, sewage and industrial waste systems. Economic considerations may be limiting factor on use of plastic pipe larger than 4" diameter unless other factors such as corrosion govern. Fiberglass reinforced thermoplastics have doubled or tripled pressure ratings without substantial increase in costs. Limiting factors in extensive use of plastic pipe in sewer mains were volume manufacturing constraints in 8" to 18" sizes and highly specialized nature of installing requiring on-the-job supervision. Lack also of adequate standards are noted.

D-4. Impregnation of Concrete Pipe,
Southwest Research Institute, San Antonio, Texas, Environmental Protection Agency, Washington, D.C., E.P.A. 11024 - E.Q.E., June, 1971.

Descriptors: Concrete Pipe, Impregnating Corrosion Prevention, Sewers, Permeability, Polymers, Cold Tar, Linseed Oil, Sulfur, Urea, Formaldehyde, Exposure.

Program undertaken to investigate methods of increasing corrosion resistance, strength and decreasing the permeability of concrete used in sewer lines by impregnation the pipe with low cost resins such as asphalt, cold tars, linseed oil, sulfur, urea,formaldehyde, et al. Methods to accomplish, materials, application techniques,test results and economics are presented.

D-5. Glass Polymer Composites,
Atomic Energy Commission, Washington, D.C., Patent Application 276 211; 28 July, 1972, Government owned available for licensing.

Descriptors: Glass Particle Composites, Filled Thermoplastics, Sewer Pipes, Filled Molding Materials Polymethyl Methacrylate Manufacturing.

Identifiers: PAT-CL-106.

Glass polymer composite described. Method of preparation described consisting of crushed glass in a mixture of sizes to obtain minimum void volume impregnated with monomer polymerized in place. Sewer pipe has been made from this material.

D-6. PVC (Polyvinyl Chloride) Sewer Pipe,
Clayton, Bob, Continental Oil Co., Wilton, Connecticut.

Descriptors: Sewers, Pipes, Polyvinyl Chloride.

The advantages of PVC sewer pipe are discussed. Pipe is intruded uniformly to a very close tolerance, is flexible and has an increased capacity to withstand effects of underground loading. Material specifications, design criteria, installation and corrosion resistance are considered.

D7. Large Diameter Polyethylene Force Mains Installed Quickly,
Lash, Rodney, W., Public Works, Vol. 105, No. 1, January, 1974.

General benefits are described from the use of P.E. pipe as a sewer force main with reassuring earth load tests at Utah State University instead of the use of a conventional gravity sewer.

PART E

Pipe Maintenance And Repair

E1. Polyethylene Pipe Slipped into Defective Sanitary Sewer,
Harlan, T. S. and Allman, W. B.,
Civil Engineering, Vol. 43, No. 6, June, 1973, American
Society of Civil Engineers, New York, N. Y.

Descriptors: Ground Water Pollution, Infiltration Sewers, Pipe Lines, Polymers, Polyethylene Pipe.

Public Demands for pollution abatement focussed attention on sewage collection systems suffering from infiltration of ground water and infiltration of raw sewage. Procedures are available for insertion of polyethylene pipe into old sewer mains and for connection of service lines. Renewal is stated to require 50% of time required to excavate and lay new pipe. Traffic disruption is minimized and costs range from 20% to 80% of former conventional methods.

E2. Inhibit Sewer-Root Growth With a Soil Fumigant,
Anonymous, American City Magazine, March, 1973.

Descriptors: Sewers, Disinfectants, Compound Herbicides, Solid, Plants Growth

Two methods of stoping root intrusions into sewer systems are recorded. Dichlorbenil giving the line a soak treatment is said to be effective; another method applying a foam root inhibitor is also said to be effective. The former is marketed under the name, "Vaporooter Plus," the latter under "Sanofoam Vaporooter."

E3. Inspection and Maintenance of Sewers via TV and Internal
Grouting Equipment, Heranon, Joe,
Water, (Temple, Texas), Vol. 54, No. 3, June, 1972.

Descriptors: Sewers, Economics, Telecommunications, Monitoring Systems, Television, Sewer Inspection Systems, Grouting.

Where TV closed circuit is used for sewer inspection, repair work can be carried out concurrently immediately following the inspection. TV inspection shows up grade changes, damaged sections or leaking joints in the line and also infiltration points. A description of the electrical components of Halliburton County's (Okla.) Telespection (a) system and comparison telegrout system is given. System is said to be effective and economic.

(See also--Effective Use of TV Inspection on Sealing Can Save Money Herndon, J. and Lenahan. T. before 44th Conference of Water Pollution Control Federation, Oct. 6, 1971).

E4. Sewer Maintenance Methods,
Bay, James, W., Spokane (Wash.) Public Works Department, Before 44th Annual Conference of Water Pollution Control Federation, San Francisco, California, Oct. 6, 1971.

Descriptors: Sewerage, Sewage Systems, Operation and Maintenance, Cleaning, Repairing, Equipment, Personnel Management, Waste Water Treatment.

Identifiers: Blockages, Rodding, Balling, Spokane, Wash.

The paper outlines practices in Spokane. The flexible steel rod is the most universal tool for sewer maintenance being used in a continuous form for removal of roots and other large objects. Balling is the primary method for removal of sand and gravel. Used alternately in Spokane, they have produced excellent results. Frequency of each use is one (1) year. It is suggested that even with most modern methods such as TV, inspection personnel is the all important factor.

E5. Sewer Maintenance Costs,
Santry, I. W. Jr., Dallas, Texas, Before the 44th Annual Conference of the Water Pollution Control Federation, San Francisco, California, Oct. 6, 1971.

Descriptors: Sewers, Operation and Maintenance, Data Collections, Stop Logs, Personnel, Cleaning Inspection, Repairing, Storm Runoff, Infiltration, Manholes, Protective Linings, Plastic, Replacement Costs, Cost Analysis, Water Pollution Control, Operating and Maintenance Costs.

Record keeping operations are deemed to be an all important factor in municipal public works in order to form rational decisions for repair or replacement of previous installations. Such parameters are length of service, costs of maintenance, ease of repair, evaluation of materials and workmanship. Analysis of data showed that repairs on both mains and services reflected about the same percentages for labor material equipment and administration.

E6. The First Thing First is Preventative Maintenance,
Tedesco, J. J., Department of Public Works, Paramus, N. J., Public Works, Vol. 101, No. 1, January, 1970.

Descriptors: Waste Water Treatment, Sewers Maintenance, Cleaning, Legislation, Data Collection, Economics, Scheduling.

Recommends that preventative maintenance commence with the completion of the sewer system. Describes the length and size of the sewer mains in Paramus. First item purchased after completion was a Sewerroder providing main line maintenance at a rate of 3000 ft. per day. The machine handled satisfactorily sheeting, debris, bricks and rocks. Other equipment acquired from time to time to give a reasonably complete line of sewer maintenance equipment following which a schedule of preventative maintenance was established.

E7. Improved Sealants for Infiltration Control,
Anonymous, Federal Water Pollution Control Administration,
Washington, D. C., Research Series WP 20-18, June, 1969.

Descriptors: Sewage, Water Infiltration, Sealants, Control Methods.

A research was undertaken to develop new, more effective sealants for sewer line leaks. Objective was achieved and results of all equipment and materials investigated and/or tested or compared are presented. Weaknesses of rejected materials were noted. Specific properties of acceptable materials were ascertained and identified. Cost effectiveness of new sealant materials was compared with presently available materials. Several sealants were demonstrated to be able to effect strong permanent repairs with no significant cost increase. Some present sealer application equipment can be modified for use with new materials. New equipment designs are described and recommended.

E8. Polyethylene Pipe Inserted into Deteriorating Sewer Line,
E. I. duPont deNemours, Washington, D. C.,
Water and Sewage Works, November, 1971.

Descriptors: Sewers, Pipelines, Municipal Wastes.

Identifiers: Pasadena, Texas

4000 ft. of 12" polyethylene pipe was inserted in a deteriorating sewer line in Pasadena. Du Pont Aldyl D polyethelene pipe in 38 Ft. lengths (weight 245 lbs/length) were butt fused together at the job site and pulled through the old concrete pipe with a 3/8" cable pulled by winch truck. Line replacement costs were said to be reduced by 80%.

E9. Fiberglass Reinforced Pipe Supports Failing Sewer,
Water and Sewage Works, October, 1971.

Descriptors: Pipe, Fiberglass, Kansas Flextran.

209 feet of 31" x 41" sewer failed in Kansas City, Kansas allowing rubble to fall into the invert with the sewage flow being impeded.

It was decided to insert a 24 inch diameter Johns-Manville flexible fiberglass reinforced polyester resin pipe with an integral bell and spigot end and known under the trade name of Flextran. The pipe was selected for reasons of high design flow, resistance to acids and other corrosives and thin wall section. The annular voids were filled for support.

E10. Plastic Relining of Small-Diameter Pipe,
Bremner, Raymond, M.,
Journal San. Eng. Div. American Society of Civil Engineers 96 (SAZ) April, 1970.

Descriptors: Sewers, Maintenance and Repair Plastic Relining, Toronto, Ontario, Water Pollution Control.

The insertion of a high density plastic pipes through existing sewer lines, the extension of all line drains into the new plastic pipe and the grouting of the annular space between the liner and the old sewer was successfully accomplished at Toronto. The method has several advantages (a) minimum amount of excavations and disturbance to travelled portion of roadway (b) less expensive (c) three times faster than conventional open cut methods (d) improves hydraulic capacity (e) extends useful life. Plastic relining is regarded as a significant development in making best use of funds for maintenance and restoration of existing sewerage systems.

E11. Making Sewer Cleaning Scientific,
Harwick, J. J., Bureau of Street and Sewer Maintenance, Milwaukee, Wisconsin,
American City Magazine, Vol. 89, No. 4, April, 1974.

Milwaukee has developed a capacity index and a performance factor for the rationalization of Sewer Cleaning.

E12. Sewer Grouting Cures Plant Overload Problem,
Kenmet, R., Hunter, U. S. Dept. of Commerce, Oklahoma City, Oklahoma,
Public Works, Vol. 104, No. 7, July, 1973.

The paper describes the use of TV inspections to evaluate the extent of overload in the sewer system and subsequent grouting in a small Oklahoma town.

E13. New Tight Fit-Insertion of a Plastic Liner in a 42 Inch Sewer,
Anonymous, Houston, Texas
Public Works, Vol. 104, No. 6, July, 1973.

A 36" plastic pipe was inserted in a 42" concrete sewer at Houston, Texas. To facilitate movement of the plastic liner through the concrete sewer the plastic pipe ends were equipped with casters mounted as a removable frame. Assembled string of pipe sections was pulled through the old sewer using a nose cone and cable.

E14. Sewer Problems? Push A New Pipe Through the Old.
Anonymous, Sacramento, C lifornia,
Western Contractor, Vol. 47, No. 3, March, 1972.

A ½ mile of 40 year old sewer was modernized in 5 working days by pushing a pipe having a suitable constant outside diameter and structurals able to withstand thrusting loads required for installation.

(See also--Pipe Liners Restore Aging Sewers, Behrens, Harry G., Division of Water and Sewers, Sacramento, California, American City, Vol. 87, No. 12, December, 1972).

E15. Recommendations for Installing PVC Gravity Sewer Piping,
Durazo, Ray, Plastic Pipe Institute
Public Works, Vol. 105, No. 4, April, 1974.

Describes recommended practice for installing single wall thermoplastic sewer pipe in open trenches based on design requirements for flexible pipe. Proper control of installation procedures are also described.

E16. Sewer Within A Sewer Saves City $400,000.
Nester, Andrew W.,
American City Magazine, Vol. 89, No. 2, February, 1974.

A cast-in-place concrete elliptical combined sewer 60" high and 40" wide and having 38 sanitary connections entering from the top along the route was utilized by placing a 14" sanitary sewer line in the invert of the old pipe. The sanitary connections were tied into the new pipe and the line covered with covered with concrete.

E17. New Approach to Saving A Trunk Sewer,
Cessna, J. C.,
Water and Wastes Engineering, Vol. 7, No. 2, Feb., 1970.

The article describes the repair of a trunk sewer by threading a fiberglass pipe inside the existing pipe line. The pipe used was a composite of polyester resin and sand mortar reinforced by continuous fiberglass filaments. The existing concrete pipe was exposed down to the springline and an 8" concrete shelf was poured along each site of the pipe line. It was jacked into place.

E18. We Kept the Sewer in Service,
Foster, J. D. and Tooley, J. T., East Bay Municipal Utility District, Oakland, California, American City Magazine, Vol. 84, No. 11, November. 1969.

An interceptor sewer showing structural failure was reinforced by pulling in 20 ft. sections of "Techite" reinforced plastic mortar pipe. The interceptor lay 10 feet under a heavily trafficked street near the waterfront.

E19. Surveying, Sealing Save Sewers,
Kosova, H., Video Pipe Grouting Co., Chicago, Illinois, Water and Wastes Engineering, Vol. 8, No. 8, August, 1971.

Three infiltration projects carried out in New York City under special conditions using TV and internal chemical grouting are described.

E20. TV Inspection and Chemical Grouting of Sanitary Sewer Lines,
Gundy, B. C.,
Air Force Civil Engineering, Vol. 12, No. 1, February, 1971.

An investigation of methods to control and repair sanitary sewer lines indicated that a chemical grout method was promising. The method had been used in mines and basements to bar water infiltration and as a barrier in leaking earth dams. After the line has been cleaned a TV camera is used with a headlight and skids mounted in tandem about 3 ft. ahead of the packer, facing it. A receiving camera is set up in a panel truck and the viewer in contact with the cable winch operation by telephone directs the movement of the equipment. The packer is a pipe like unit with an inflatable rubber sleeve at each end.

E21. Chemical Control of Tree Roots in Sewer Lines,
Ahrens, J., Leonard, O. A., and Townley, N. R.,
Journal Water Pollution Federation, Vol. 42, No. 9, September, 1970., Sacremento

Studies were made of herbicides that would selectively kill tree roots in sewer lines by flooding. Metham and Dichlobenil were used with and without a surfactant. Toxicity was found to be only a minor problem. A one hour flood treatment with various combinations of the chemicals killed all roots extending a short distance outside the joints.

E22. Plastic Liner Repairs Leaking Sewer,
Johnson, L. D., San Mateo, California,
Public Works, Vol. 101, No. 6, June, 1970.

Descriptors: Sewers, Outlets, Infiltration Linings, Plastic, Tubes, Flexibility, Water Pollution Control, California.

Identifiers: Inverted siphon, San Mateo, California.

An inverted siphon crossing a slough as part of a 54 inch sewer outfall was equipped with a flexible section of pipe due to adverse soil conditions. Inspection showed that the section had broken in one place near one bank of the waterway and infiltration could not be controlled. It was decided to line the section of the pipe with a plastic tube. Specifications provided for a P.V.C. sheet sandwich reinforced with polyester fabric. The liner was constructed in one continuous tube to fit the 54 inch line over the length of the siphon. The deflated plastic tube was manually pulled through the siphon by divers and fixed at both ends by steel circumferential hoops. The tube was inflated by filling it with water which forced the infiltration water out of the pipe. As at June 1970 the outfall trunk sewer had been in operation for 3 months and no leaks in the siphon had been noted. The unique solution saved both time and money.

PART F

Pipe Testing

F1. Testing New Sewer Pipe Installations,
Roy Edwin Ranseier and Associates, Berkeley, California,
Journal, Water Pollution Control Federation, Vol. 44, No. 4,
April, 1972.

Descriptors: Sewerage, Watertight Construction Joints, On-site Tests, Infiltration, Leakage Porosity, Orifices, Pipes, Flow Rates, Head Loss, Specifications Repairing, Sealants.

Identifiers: Air testing, Water Testing.

As deterioration is continuous in nature in sewer lines, construction should approach excellence. Air testing is therefore both a useful and accurate method testing for leakage following construction and afterward.

Sufficient correlation now exists among specifications to warrant a standard specification for pipe soundness. Pipes however, have varying porosities and by a change of one number in a specification this variation can be met.

No correlation between the air test and the water test has been found, because the surface tension of water determines some of the flow characteristics through increasingly smaller orifices.

F4. Smoke Testing in Halifax's Sewer Lines,
McDonald, R. Basil,
Water Pollution Control (Canada, Don Mills Ont.), Vol. 111, No. 6,
June, 1973.

Descriptors: Sewerage, Inflow, Infiltration, Leakage, Smoke Testing, Joints.

Identifiers: Smoke Testing, Halifax, Canada.

Method of locating sources of infiltration and illegal (inflow) storm connections to the sanitary sewers using smoke testing is described.

F5. Advances in Sewer System Testing,
Chase, Silliam J. and Berschauer, Walter
Public Works, Vol. 103, No. 5, May, 1972.

The article discusses the significant elements in flow in design of sewer systems with emphasis on the development and application of low pressure air testing.

F6. Infiltration Measure in Sanitary Sewers by Dye-Dilution Method, S. A. Smith and L. G. Kepple, Clare A. Hill and Associates, Redding, California, Water and Sewage Works, Vol. 119, No. 1, January, 1972.

Study indicates dye-dilution technique can be used to measure sewage flows and evaluate groundwater infiltration in a municipal collection system. Speed of readings at points along line enabling comparison is costable.

APPENDIX B

SURVEY OF ROOT CONTROL PROGRAM
QUESTIONNAIRE AND RESPONSES

APWA Research Foundation
Survey of Root Control Program

Name of Authority ______________________________

Mailing Address ______________________________

Person Supplying Information ____________________ Tel. No ____________

	Separate Sanitary	Combined
A. Population served	________	________
Miles collector sewers	________	________
Miles interceptor sewers	________	________

B. Are roots a problem in your sewer system? (Yes/no) ____________

C. Relative maintenance problem of

cause	% of total	cause	% of total
grease	______	material dumped into manholes	______
sand	______	other ____________	______
roots	______	____________	______
deteriorated lines	______	____________	______

D. Is a root control program conducted (Yes)____ (No) ____ If yes number of

1. digups per year due to roots ________
2. stoppages per year where roots are involved ________
3. miles of sewer cleaned per year for root control ________ mi.
4. percent of system subjected to root intrusion ________
5. percent of system requiring maintenance per year because of root intrusion ________
6. Maximum frequency for cleaning due to roots ________
7. Have chemicals been used to control roots (Yes) ____ (No) ______ If yes
   a. chemicals used (name) ______________________________
      Supplier ______________________________
   b. were results favorable (Yes) ______ (No) ______
   c. Comments ______________________________
      ____
8. relative importance of root intrusion problems

Separate Sanitary	Problem (Yes/No)	Combined	Problem (Yes/No)
Collector	________	Collector	________
Interceptor	________	Interceptor	________
House lateral	________	House lateral	________

Storm	Problem (Yes/No)
Collector	________
Interceptor	________

9. Describe nature of maintenance program
   Rodding ______________
   Chemicals. Foaming__________ Dumping in manhole __________ Sealant with root control ____
   Ball ______________
   Baskets ______________
   Other (list) ____

   Are you satisfied with these maintenance techniques? Yes __________ No ____________
   If no, why not? ____

E. Of collector sewers affected with root intrusions
   1. size of sewer affected

	approximate miles in system	% affected
6 in.	______	______
8-12 in.	______	______
15-24 in.	______	______
over 24 in.	______	______

   2. depth of the sewer affected

	% of portion of sewer with root intrusion
1-5 ft	______
5-8 ft	______
8-12 ft	______
over 12 ft	______

F. Type of trees or bushes which cause majority of problem in your area
   1. ____
   2. ____
   3. ____
   4. ____
   5. ____

G. Point of intrusion of roots

point	% of problem	point	% of problem
a. joints	______	d. Y on collector	______
b. breaks	______	e. other	______
c. house laterals	______		

H Does your authority maintain

	(Yes/No)
1. The Y	______
2. The house lateral to property line	______
3. The house lateral to the building	______

I. Age of sewers and type of joint where root intrusion is a problem

	sewer material	year laid	type of joint
1.	______	______	______
2.	______	______	______
3.	______	______	______
4.	______	______	______

J. Sewer Sealing

1 Has sewer sealing been used to control infiltration (Yes) ______ (No) ______

2. If yes, has sealing (reduced) ______ (increased) ______ (had no effect) ______ on root intrusion

3. Has root intrusion affected the chemically sealed joints (Yes) ______ (No) ______

4. Has the sealing method been modified as a result of roots (Yes) ______ (No) ______

If yes, please explain ______

5. Have roots caused pipe bells to crack (Yes) ______ (No) ______

6. Have roots caused an infiltration problem (Yes) ______ (No) ______

K. Is there a relationship between

1. Depth of ground water and extent of root intrusion in your system (Yes) ______ (No) ______

If yes, explain ______

2. Types of soil and extent of root intrusion (Yes) ______ (No) ______

If yes, explain ______

L Do you believe that there are infiltration problems in your sewer system (Yes) ______ (No) ______

If yes, please explain ______

PLEASE RETURN TO

Richard H Sullivan
APWA Research Foundation
1313 East 60th Street
Chicago, Illinois 60637

City of Los Angeles, California
Date: April 22, 1975

Person Interviewed. Ray Jellison

The Sewer Maintenance Division maintains 6,000 miles of sanitary sewers and 1,200 miles of storm drains. Root problems are found in about 20 percent of the system including hillside lots, rear yard easements, and streets. Many of the sewers with problems are relatively shallow and have been subjected to ground movement (earthquakes).

A mild inflow problem has been identified (2 X DWF). The groundwater table is low enough that infiltration is not a problem

The City maintains only the house "y."

Grease is the major problem with sand and roots next. About 300 grease stoppages per year are recorded.

The maintenance program has been with mechanical rodders Due to budget cuts, these machines are now only used for emergencies. Trouble locations are now hand rodded

The herbicidal root control program was started in 1974. Less than 50 miles have been treated. Treatment is conducted October through March. Two to three thousand dollars have been used for chemicals annually.

Initial work in Los Angeles was done by flooding, following the Sacramento County experience. However, with the development of the foam equipment, foaming is being used exclusively. Few accidents occurred using flooding However, steep grades made it impossible to treat many trouble areas. Five accidents involving foam getting into houses occurred last year.

The preliminary testing of herbicidal control indicated that treated sections will be free of roots for one to ten years – with an average of five. Treated areas appear to have less than 10 percent regrowth and root intrusion problems have not been found in interceptor sewers or storm drains.

The majority (80 percent) of the sewers with root intrusion problems is between 1.5 and 3 m (5 and 10 ft.) deep. The three major problem trees are:

1 Eucalyptus

2. Palms

3. Pine

The majority of the root intrusion has been identified as originating in the house lateral.

The maintenance program is handled by eight district yards and one citywide special crew Each district has.

1 inspection crew which handles partial stoppages in the manhole or from grease;

1 hydro cleaner crew.

The citywide crew has a bucket machine for cleaning large lines. The crew also has backhoes and other heavy equipment. A television crew also is available.

One 3-man crew has been used for herbicidal root control. The district foreman identifies trouble spots. A hydro cleaner is used prior to TV inspection.

Flooding was accomplished by adding the chemicals to the line by hand and then filling the line with a firehose. One-hour retention was used and only one line at a time was treated.

The foam crew contacts adjacent property owners and monitors the sewer section for the arrival of the foam at the downstream manhole. If after an appropriate time the foam has not arrived, the line is refoamed the following day.

To alleviate backup problems into the house lateral – which often appears to occur at the first connection – a 30.5 m (100 ft.) plastic tube has been used to inject the foam.

For flooding, a one percent solution was used. For foam, a five percent solution is required.

An experiment was conducted using a 10 percent solution and a high pressure spray. Effectiveness was not judged due to limited experimentation. The increased operator care and supervision needed and the inability to adequately control the speed of the pull through the pipe and the amount of solution used were the principal drawbacks

The control program will have $8,000 for chemicals this year. If funds were available, say $80,000 and two crews, full time, an adequate program could be put into effect.

To date, there has been little acceptance by the district crews of the technique, i.e., even after treatment, maintenance schedules are not necessarily revised.

The City of Los Angeles has not instituted a special safety program for the chemical crew. Manholes are entered as needed and special clothing is not provided. Employees are informed of the effect of alcohol after inhaling the Vapom odors, i.e., nausea

A copper sulfate root control program had been attempted for many years, but no tangible benefits were found.

Los Angeles County, Department of Public Works
Date. April 22, 1975

Person Interviewed Gerald M. Cadwell

The Public Works Department is responsible for the maintenance of 3,850 miles of collector sewers. Interceptor sewers are the responsibility of the Sanitary District.

The Department has experimented with Vapom for five years. Early treated sections have been televised and minor root regrowth observed.

The slope of the ground in most areas does not allow flooding to be considered The present method is to insert a 100-foot hose, 3.1 cm (1.25 in.) in diameter, and pump the foam in and pull it back. This will be done from both directions to minimize pressure buildup which would force foam into adjacent residences.

Less than 10 percent of the system has root intrusion. Problem areas affected include back lot easements and lines in desert areas.

The County does not maintain any portion of the house lateral and information is not available as to the extent of the root problem from laterals.

Grease is the primary maintenance problem followed by roots. Groundwater is not a problem anywhere in the system. Over 90 percent of the system is 20 cm (8 in.) in diameter, and 90 percent has been installed since 1945. The minimum pipe depth is 7 5 feet and is seldom deeper than 2.7 m (9 ft.). Root problems exist at all depths.

The primary source of root problems are from

1. Elms
2. Palms
3. Tamaracks
4 Oleanders
5. Pepper trees

The root problems appear at the joint in lines laid before 1964.

<u>Maintenance Practices</u>

The county operates three yards. There is an overall three-man inspection crew which inspects 350-400 miles of sewers each year.

Each yard has three crews as follows·

1 Hydraulic cleaner, three men
1 Rod, three men
1 Construction, three men

One systemwide crew of three to four men is used for chemical control. The fourth man is used when water must be obtained from fire hydrants

Three TV inspection crews also are used

The cost of sewer maintenance averages $2.50 per residence served. A four-day, 40-hour week is used with an estimated 20 percent fuel saving.

Root Control Procedure

For foaming, a plug is placed in the line at the manhole and the foam line passed through it for a set time.

A 200-gallon mix tank is on the truck The initial batch is mixed in the yard and 400 to 600 gallons will be mixed during a day of operations.

Employee safety was evaluated by an environmental control group. They considered:

Disposable coveralls

Hoods

Chemical filter cannister masks

Full-face shields

Taped cuffs on coveralls

It was found that such safety controls are required only during mixing.

Crew members do not enter manholes; all work is accomplished from the surface

At the present rate of application it will require 2.5 years to cover known problem area.

No separate budget has been set for the purchase of chemicals and no set season has been set for such work. The crew, when not working on roots. is used for a rat and roach control.

Sacramento County, Department of Public Works, Sacramento, California
Date: April 21, 1975

Persons Interviewed: Neil Townley
Walter Driggs

Sacramento County was one of the first agencies to develop a root control program using the Stauffer Chemical Company's product, Vapor-rooter, for root control. An extensive testing program was conducted with the assistance of the University of California – Davis. This program has been described in several publications.

Fred Horne, developer of the chemical control system, cites Sacramento County as making the most extensive use of the method, although Los Angeles and Los Angeles County (both covered by separate reports) are also making limited use of the control method.

The County's service area contains approximately 1,500 miles of small-diameter sewers with a connected population of about 280,000. The groundwater table averages 60 feet depth and infiltration is not a problem. The pipe sizes are roughly as follows.

4.5 million feet – 15 cm (6 in.)
1.3 million feet – 20 cm (8 in.)
0.3 million feet – 25.4 cm (10 in.)
0.3 million feet – 30.5 cm (12 in.)
1.0 million feet – larger than 30.5 cm (12 in.)

An extensive preventive maintenance program is carried out, principally by using sewer balls, plus an effective record system and efficient scheduling.

About 600 miles per year of sewer are cleaned, varying in frequency from yearly to every six years, based upon the conditions associated with the sewers in each area.

The maintenance crews are as follows:

4 Balling crews, year round, three-man crew
1 High pressure hydro cleaner, used generally for grease problems, two-man crew
2 Coil-rod crews, year round, two-man crew
1 TV inspection crew, three-man crew
1 Herbicidal control crew, summers, three-man crew

The herbicidal control crew has treated approximately 200 miles of sewers at a rate of 50 miles per year. A two-year cycle is used in areas with heavy root growth. Sewers (house lateral) are also treated to the property line.

In Sacramento County, root problems are generally associated with 15 cm (6 in.) to 20 cm (8 in.) lines. It is rare to find problems in lines of larger than 30.5 cm (1 ft.) Root problems are also generally found in sewers 7 to 15 feet deep, the depth of approximately 70 percent of the system.

Ten percent of the system is from 3 to 7 feet underground, although a minimum depth of 1.8 m (6 ft.) is sought. Fifteen percent of the system is at a depth greater than 15 feet.

In the service area, the main root producing trees and bushes are thought to be

1. Willows
2. Cottonwoods
3. Elms
4. Eucalyptus
5. Oleander

The general point of root entry is at the joint. Ten percent of the root intrusions is estimated to be from faulty house connections and 10 percent from defective joints in the house lateral

The area where root intrusion problems are prevalent is served by sewers approximately 25 years old. Mortar joints and construction and inspection policies could be categorized as being the best practice of that time, but now it can be seen that they were inadequate. For example, asphalt impregnated paper pipe was allowed for use as house laterals. Many house laterals have failed, often crushed by root growth around the pipe.

Some root control work has been done in storm drains, where the general practice was to butt the pipe together without joints. In storm drains, roots are characterized as woody and intruding generally through the bottom of the pipe In sanitary sewers, the roots are generally thread-like and intrude from the top or side of the pipe, although when a joint is dug up, the root is generally found encircling the joint out of reach of any mechanical cleaning equipment.

The root control program was started in 1969. Reinspection of treated lines indicated some remaining root growth but the reduction could not be quantified In recent years a judgment factor has been used to grade the root intrusion problem at each joint. A numerical scale of one to ten is used, which is recorded by the TV inspection crew at the time of inspection. On the basis of such a qualitative scale, it is estimated that 75 percent of the root growth is destroyed by the chemical treatment. Mr. Townley characterizes the situation as "treatment will not eliminate all root growth. Inspection after treatment indicates 50 to 75 percent effective kill of roots present. Our records, for areas of continued treatment, indicate a steady decline of root conditions as opposed to a gradual increase in root growth prior to treatment "

The sections of the sewer system being treated for root intrusion are in the rear easement and generally in hard pan soil.

A generalization can be made that since the sewer trench is the only disturbed ground, homeowners are more apt to dig along the trench for planting and to screen the back of their yards

Herbicidal Treatment

The cost per foot of herbicidal treatment as used by Sacramento County is about $ 0.20. Chemicals are mixed in the corporation yard in a tanker truck. Every effort is used to not display the chemical containers where the public might have access to them to prevent the possibility of adverse public reaction.

The downstream manhole is plugged with an inflatable plug. This is done from the surface and it is felt that there is no need for a workman to enter a manhole. From the upstream manhole, a metered amount of solution is added until the line is just flooded. The mixture is held one hour and then allowed to flow downstream to the next pipe section. Each batch is used four times and one crew can have four batches working with careful planning by the foreman.

Initial set-up time is approximately one-half hour, depending upon access difficulties to the initial upstream manhole.

Notification is not given to abutting property owners.

Total production averages 2,000 to 4,000 feet per day. Herbicidal control is used only during the summer when roots are most active in drawing up nutrients to feed growth. The treatment program begins in mid-June and is continued until September or October.

During the entire program only one tree has been partially (estimated 25 percent) damaged, and a spill on the surface lost a grape vine (which recovered the following year).

The mixing tank has a 3,870 l (1,000 gal.) capacity. Once the chemicals are introduced from their 40-gallon, corrosion-resistant storage tank, a recirculating pump is used to keep the solution well mixed. A 300-foot hose is used to deliver the mixture to the manhole.

The County is spending approximately $26,000 per year for chemicals.

House Laterals

The County has assumed responsibility for the house lateral to the property line Accordingly, cleanouts are required for new construction and are being installed on the balance of the system by County crews as problems develop To control roots, a portable foam unit is used. From the cleanout an inflatable plug is placed on the upstream side and a measured amount of foam is injected into the line. When the foam is in, the plug is pulled and the two-man crew goes to the next line. Twelve to eighteen house laterals are done per day, and approximately 1,000 laterals have been treated to date.

Care must be used to keep the foam from going toward the house as the pressure of the foam will push the water seal out of traps.

General Comments

Roots are considered a primary source of maintenance problems. Grease is second, and large objects inserted in the manhole, third.

In 1956, building specifications were changed to require graded materials to be used for backfill. It is felt that this has allowed water and roots to travel longer distances along trenches and cause more root problems.

When sand is used for backfilling, cracks or poor joints can allow relatively large amounts of sand to enter the pipe.

The sewer balling practices of the County are of interest. A 102-foot plastic pipe section has been set up in which to train new operators. The maximum head allowed in the upstream manhole is 61 cm (2 ft.).

Experience with the hydro cleaner indicates that about 5 gallons of material can be removed per pass.

It was stressed that inasmuch as potentially damaging chemicals are used, an extensive record system is maintained to record the location, date, and amount of chemicals used.

Safety of crews is important. Individuals must be cautioned to avoid contact or breathing fumes. Sacramento County provides clean uniforms which can be worn several days if no spills occur, for all crew members. When chemicals are accidently spilled on clothing, personnel are required to change the contaminated uniform as soon as possible. Experience has taught that contaminated clothing or shoes could produce skin irritation when worn for extended periods after the spill. Personnel are required to wear rubber boots, eliminating the contaminated shoe possibility.

The fumes from the mixture apparently trigger nausea if alcohol is consumed following exposure. Fumes will linger for a few days in lines which have been treated – another reason for the County's requirement that all work be done from the surface. Chemical-type respirators, as well as aprons, are used when mixing of the chemicals is being done and containers handled.

City of St. Petersburg, Florida
Date. August 29, 1975

Person Interviewed. John Monck

The City of St. Petersburg maintains all sewers within the public right-of-way. In St. Petersburg, most sewers are laid in the 3 m (10 ft.) easements along the back of the property line and this is where most of the sewer maintenance problems are found. The city is relatively flat and has a varying groundwater table depending upon the season.

The rear easements are extensively planted, property owners using plant material for screening and as a fence.

If property owners develop sewer problems, they are required to call a private plumber. The private plumber, after checking the house lateral to the edge of the easement and finding that the problem lies in the city portion, calls the city and a maintenance crew is dispatched. The maintenance crew checks the manhole to see if the flow appears normal and if flow is not normal, the line is rodded and a check is made to see if property owner's complaint has been satisfied. If the flow in the sewer is normal and the property owner's complaint has not been taken care of, the city digs in the easement to correct the problem. Of the approximately 200 calls per month, 50-60 percent require dig-up by the city crew. The general point of intrusion is the expander from the cast iron 10-cm (4 in.) to the 15-cm (6 in.) vitrified clay stub.

If stoppage is in the city line, the property owner is reimbursed up to $25 for his plumbing bill. The average cost of city correction per stoppage was $81.50 plus the $25.00 for the plumber in 1973-74.

Approximately a year ago, the city had plotted all stoppages in a one-year's period. Twelve areas of 0.5-mile diameter were conspicuous and a maintenance program has been evolved to systematically treat roots in each area.

Approximately two months ago, the city started a program using Sanifoam in the lines. Two 3-cm (1.25 in.) plastic pipes are inserted approximately 30 m (100 ft.) into the line and the foam turned on. When the foam reaches both ends, the foaming is stopped. Sometimes it is necessary to pull the plastic pipe, foaming along the weir.

A two-man crew is used on foaming and they do not enter manholes Safety equipment includes gloves and rubber aprons. A distinctive feature of the St. Petersburg program is the fact that the personnel involved in the root control program have all received special training in the handling of chemicals for either plant or insect control. Mr Al Noll is directly in charge of the program and recently transferred to the Sewer Division from the Park Department where he was also in charge of chemical application. The lead crew member is a college trained entomologist

For mid-block applications, pump and supplies are carried to the manhole. The city has experimented with a Cushman scooter and trailer for ease of access, and this has been promising.

The root control crew also has duties to control roaches which are found throughout the system. They have found that the Vapom used in the Sanifoam is effective in killing roaches and moves rats out of the area.

The root control crew treats approximately 305 m (1,000 ft.) per day. No formal public relations program is being carried out. Some contact is made with adjacent property owners and a handbill is being developed for delivery before foaming. There have been a few incidences of foam backing into houses, sometimes up the stack, other times into the toilets.

The city has two TV rigs, both of which were constructed from purchased components. TV is being used in conjunction with the root control program to determine the effectiveness of killing the roots

In the experience of the maintenance crews, roots per se do not break the joints, rather, they take advantage of any opening that is available.

Two Rockwell rodding machines are used. Crews are on duty seven days a week, 16 hours a day because of the number of blockages. One hydrocleaner is also used and another is on order. There are five construction crews, two for deep work with six to seven men, two shallow construction crews of five men each, and one minor correction crew of three to four men.

In summary, the preventive maintenance program in St Petersburg is about one year old. Fred Horne has been instrumental in training personnel in the use of Sanifoam. The city is happy with the method and hopes, through the preventive maintenance program, to reduce the number of stoppages experienced each year and reduce the tremendous cost of the stoppage control program

Tide Gates

Two flap gates which are maintained by the city's Streets Department were inspected The flap gates are wood and placed parallel in a canal to protect a lake from salt water intrusion. The flap gates are six years old and manually operated. Metal hinges are used with rubber seats on the concrete frame The installation is rated as generally satisfactory and minimal maintenance has been necessary. The flap gates are opened and closed once each day.

Sewer Lining

The city has two sewer lining projects in the construction phase. One project by Naylor is for seven blocks of 90-cm (3 ft.) pipe and the product is Nipac. The sewer is being lined because of the very fragile condition of the existing reinforced concrete pipe.

The second project appears to be experiencing some problems and this is attributed to the fact that the plastic pipe was not properly protected on the surface and thus, has become out of round, making it difficult to weld the joints.

City and County of Denver, Colorado
Date: August 21, 1975

Persons Interviewed: Messrs. J. Zohn, Don Frederick, and Mike Workman

The Wastewater Management Division of the Public Works Department is responsible for the maintenance of approximately 1,500 miles of collector sewers, serving a population of 1,200,000. Approximately 4 miles of the system is combined which serves only 150-200 acres. Construction will soon be undertaken to correct this situation.

Roots are a problem and approximately 300 miles of the system is checked per year for root infestation. Approximately 30-35 percent of the collector system is subjected to root intrusion, which constitutes an estimated 25 percent of the total maintenance problem. The majority of sewers in Denver are 9-12 feet deep inasmuch as most of the homes have basements.

The city is divided into four maintenance areas, each being assigned a combination television-packer sealer operated by a four-man crew. Two television units with three-man crews are used for system-wide inspection.

The city has used AM-9 for sealing for about five years. Copper sulfate is added to the AM-9 root control, and reinspection of the grouted lines indicates seals are holding with a notable decrease of root problems.

The city has not used other chemicals for the control of roots but has relied upon an extensive maintenance program.

Two years ago a surveillance inspection was accomplished on representative areas of the entire sewer system. Since that time, preventive maintenance activities have been scheduled in the problem areas. Five truck mounted flexible rodding units are used, each with a two-man crew. In addition, five (5) flexible hydrocleaners are used. Prior to 1965, a 25-man crew used hand rods for the total maintenance effort. In 1965 extensive checking was done with Dallas, Los Angeles, Albuquerque, and other major cities to determine the type of equipment which would allow the most efficient maintenance program.

Prior to the PM program, there was an average of 60 backups per month. Now the average is one to two a week. All reports of plugged sewers are followed up with a TV inspection of the line.

The city now feels that they can rod or jet for approximately $0.05 per foot.

The city has an extensive program to assist district personnel. District maintenance personnel who find problems clean the sewer with a hydrocleaner, leave a tag line, and then request TV inspection. On a "next day" basis, the sewer is inspected and a report submitted to Central Management. Copies of the report are filed in a Master Cleaning

File, with the maintenance district, the construction group, and a TV master file. Upon completion of the necessary work by the district or construction crew, the line is reinspected. This procedure continues until TV inspection reveals that the problem has been taken care of.

Maintenance schedules are utilized by district personnel; inspection and flushing of the entire system occurs once per year; rodder and jet cleaning occur about 2–2 1/2 years. This PM program was established three years ago starting at the highest point and working toward the treatment facility. There are also 30, 60, and 90-day schedules for areas with grease problems.

All TV and sealing equipment is of Cues manufacture and all units are radio controlled.

The city has enforcement policies regarding inflow connections

The Sacramento County root rating system of 1 to 9 for intensity of roots is used.

Air testing is used on new sewer lines.

Several modifications have been made to the Cues equipment for the Denver operation. Holes were cut into the rear doors of the vans and trailers in order that they may be closed during the winter. Larger air conditioning units have been installed. In addition, auxiliary fuel tanks and large floodlights for nighttime work have been added. Special floats and lights were designed in order that lines up to 254 cm (100 in.) in diameter can be surveyed.

During TV inspection, if a joint is offset – root intrusion, debris, mineral stains, radial breaks, or flow – the joint will be sealed.

City has not used smoke in detection work.

Sealing specifications require 15 seconds to fill the joint and 30 seconds of additional grout flow to fill the void surrounding the exterior of the pipe Ordinarily grouting is limited to 7.6 l (2 gal.) per joint; however, as much as 15.1 to 22.7 l (4-6 gal.) may be used. The cost of AM-9 to the City and County of Denver is roughly $2.55 per gallon The city finds that up to five joints per 100 yards need sealing under the criteria which the city has established

Shreveport, Louisiana
Date: August 11, 1975

Persons Interviewed: Alfred Pertus, Charles Harrell

The Department of Public Utilities is different from other city government units in that its services are paid for exclusively by the rate structure with no support from the general city income. Moreover rate increases must be approved by a public vote.

At the working level this organization keeps good records of sewer maintenance, specifically stoppages. This data contains address, date, and nature of stoppage. The city is subdivided into quarter sections and for each quarter section a detailed map of mains, collectors, interceptors, wyes, and house services is maintained The sewer maintenance records are kept so that easy reference to the system maps is possible

Although this unit does not maintain the storm drain system, they have strong feelings that root intrusion is a minor (if any) problem there. There was also strong opinion that root intrusion was the definite result of pipe breaks, that is, root intrusion does not cause breaks

City of Austin, Texas
Date August 13, 1975

Persons Contacted. Joe Varga, E M. Wallace

It was indicated pipes installed after 1955-58 have required rehabilitation. This was attributed to a 30.5 to 61 cm (1 to 2 ft.) back loading of crushed gravel around the pipe combined with the use of plastic pipe and expansion joints (begun in 1962-64).

Roots were reported to cause a majority of the problems encountered, although this could not be quantified. The city is opposed to chemical control of roots, claiming that to abate the root problem with chemicals one would necessarily kill ground vegetation.

Austin has recently passed an ordinance similar to Shreveport's regarding maintenance of the house service They estimate 75-90 percent of infiltration comes from the house service. Using a hydrostatic test procedure, the lines are to be tested one at a time. Property owners are to be given 60 days for correction and the line will be re-tested. Non-compliance could result in discontinuing water service.

City of Dallas, Texas
Date. August 14, 1975

Person Contacted: A.E. Bud Holcomb, Manager

The City of Dallas has an exceptionally low water table and hence little need for storm water detention facilities. They have good maps for maintenance purposes. They have lately been installing 10 to 30.5 cm (4 to 12 in.) pipe but system is primarily 10 to 20 cm (4 to 8 in.). Some concrete pipe is failing due to chemical reactions. City responsibility is up to the property line. At the property line, lateral cleanouts are being installed at a cost of approximately $25. Six emergency repair crews are used. This is their only function, making lines serviceable. Lakes with pipe underneath cited as a major source of inflow.

Mr. Holcomb has strong opinions on the nature and causes of root infiltration. He is convinced that the hole must, in all cases, be present before the root can penetrate. The root, once in, will eventually grow to a diameter that will crack the pipe; however, he feels this takes a long enough time to make this aspect of infiltration almost trivial. He also concludes that roots are not a major source of infiltration, but actually inhibit infiltration by "plugging" the hole Once in the pipe the roots will proliferate according to the amount of flow in the pipe. That is, a high flow rate will inhibit the root growth as the roots need to "lay" on top of the nutrients and cannot survive under water.

Thus, Mr. Holcomb concludes that pipe size only seems to determine how well roots thrive in a pipe.

The city can inspect the house services and force property owners to make repairs. The penalty is a fine and/or shut off of water service. A hydrostatic test administered by plumbing inspectors is used to determine soundness. A city ordinance aimed specifically at controlling infiltration from house services is anticipated.

Roots are estimated to cause about 85 percent of the blockages and digups which occur. There are no combined sewer systems by design. Grease was reported to play a major role in reducing flow rates by accumulating on root growths.

Sewer pipes often fail (allowing root intrusion) due to improper methods of backfilling, pipe fatigue, contractors headache ball, and other city units.

The city is using two TV inspection units.

Other general observations offered were as follows. In arid areas the disturbed ground at the pipe location acts as a natural conduit for storm water. This is due to the extreme hardness of the ground surrounding the ditch This is a prime cause of infiltration. Roots are not a single major cause of problems. A large portion of infiltration in Dallas occurs from the house service and conventional methods of sewer rehabilitation will not correct the problem.

City of Fort Worth, Texas
Date: August 15, 1975

Person Contacted: Dalton Field

The city believes that 75 to 90 percent of its infiltration comes from the house connections. They have no control over repairs to the house service and do not believe that the attempts being made by other jurisdictions to correct this situation will be successful There are no designed combination systems.

The city has generally not considered chemical control of roots or sewer grouting because of limited testing units. Chemicals were favorable, but not enough to convince them to spend many resources for this type of control. Roots are not a single major source of problems Sand and grease are more troublesome to this district, but again, these are simply components of the overall sewer maintenance problem

With 1,600 miles of interceptor sewers spread over many miles of sprawling countryside, inspection presents unique problems. These have been solved by using once weekly helicopter patrol.

Each such trip results in at least one requirement for a site visit by a maintenance crew. The effectiveness of this patrol was observed first-hand. Two separate major overflows were discovered.

Records for the entire sewer system and all repairs, maintenance, blockage, etc., are processed with electronic data processing equipment Included are labor and material costs. The reports generated by this system are invaluable for spotting trends in failures, documenting need for major rehabilitations, etc

City of North Little Rock, Arkansas
Date August 25, 1975

Person Contacted· Frank Murphy

The general feeling of the city of North Little Rock is that 70 to 90 percent of infiltration occurs at the house service. The authority maintains only collectors. Y and house service belong to property owner. Present city code requires cast iron for house service. Much fiber and concrete pipe have been used in the past. Plastic pipe has been tried; quality control could not be maintained.

Metropolitan St. Louis Sewer District (MSLSD)
Date: August 26, 1975

Person Contacted: Jack McLaughlin

The MSLSD functions under a state charter with six trustees. Their responsibility includes the collection and treatment of both storm and wastewater. Consequently they have a large combined system.

The district cannot force homeowners to correct existing services. The city feels that as much as 80 percent of infiltration originates in the house service. As to roots and infiltration, they expressed the belief that roots cause infiltration only when a bell is cracked; that simple intrusions would only cause exfiltration. The extent to which root diameter growth would cause infiltration could not be estimated. However, diameter growth is slow.

Chemical control is practiced but with some skepticism. They have purchased several trees and shrubs due to killing. They are not convinced, however, that chemicals will not work. The basic problem is shutting off service and blocking off lines. They are currently experimenting with root control chemicals in grout. The work is being done under contract with CUES.

Buffalo Sewer Authority
Date: September 2, 1975

Persons Contacted: Gilman Leahy, Rocco Missica, Prosper Morgante

Buffalo is one of the oldest cities in America. Its sewer system is equally old and subject to physical defects and limitations.

The population of the city proper is approximately 460,000. It has been larger but is now generally stabilized after a shift of growth to the suburbs. In addition to the city, the Authority handles flows from four other sewer districts. Erie County S D.; West Seneca S.D.; other sections of Erie County and West Seneca Districts. and Lackawanna S.D and other minor S.D. areas. The flow from out-of-city areas is estimated to be 11 mgd.

Note. Some of the information contained in the root survey questionnaire obtained from the Buffalo Sewer Authority by mail prior to the on-site survey, as well as data disclosed during the on-site investigation on September 2, 1975, is at variance with facts contained in a Report on a Comprehensive Sewerage Study conducted by Leonard S. Wegman Co., Consulting Engineers, New York, N.Y , dated December 1973. This study was undertaken to develop a master plan for the correction of sewer system conditions and to alleviate pollution from combined sewer overflow incidents. While no references were made in the study report to root problems, the subject of infiltration/inflow was included in the master plan concept and other factors of sewer system investigation were relevant to the purpose of the APWA root study. To the extent deemed necessary, the basic facts covered by the root study were modified or augmented on the basis of the Wegman report. Of necessity, no extensive recapitulation of the Wegman findings can be included here, nor would such inclusion be of value to the root survey. The Study Report has been obtained by the investigator and will be filed with APWA for record purposes.

Combined sewers in residential areas and in the business district are constructed on both sides of the street – under the sidewalks in the former areas and near the curblines in the latter territory. The location of the lines at these vulnerable points, in terms of tree plantings, adds to the root problem. Where separate sanitary sewers are installed, they are located in the center of the roadway, as a general rule. The combined sewers receive inflow from so-called small curb inlets without any basin collecting sumps and from large catchbasins. The receivers are cleaned by hand dipping; the catchbasins are cleaned by clamshell units.

According to the questionnaire data and the on-site survey, BSA maintains control over house sewer connections but the laterals from the building line to the property line, and from the property line to the street sewer, are the responsiblity of the property owner. Reference is made to the relative shortness of the building sewers in the Buffalo area because of the location of the sewer lines under the sidewalks on both sides of residential streets and near the curb line in business areas. No other details of house sewer responsibility were considered pertinent to the root problem because the sewers themselves are even more susceptible to root intrusion than the building laterals under Buffalo system conditions.

The Root Problem and Its Control

Root intrusion is a problem in the sewer system of the Buffalo Sewer Authority – in both the preponderant combined lines and the smaller footage of separate sanitary lines. The problem affects street sewers of all sizes, laid at all depths. As stated above, the root problem in house sewers was not stressed by BSA officials, and it is assumed from the interviewer's survey and the questionnaire data that the difficulties are centered in street sewers.

The following comments are intended to confirm or supplement the root problem information contained in the questionnaire survey form.

The Authority Sewer System

The Authority sewer system comprises 806 miles of lines. The questionnaire and the on-site survey disclosed that 321 miles of the collector lines are separate sanitary and 485 miles are combined sewers. However, the Wegman report characterizes the system as primarily "combined" as indicated by the following table:

Combined Sewers	91.0%
Combined Relief Sewers	5.5%
Storm Sewers	3.0%
Road Storm Sewers	0.5%

The interviewees stated that the older areas of the city are served by combined sewers and the newer areas by separate sewers.

The sewers are old; three-quarters of the system is over a half-century old with 60 percent constructed prior to 1910 and only 7.8 percent built since 1941. The combined lines are over-large and dry-weather flows are stagnant and produce heavy depositions in the cavernous conduits. Storms produce severe "first flush" concentrations and overflows through more than 70 discharges into the receiving waters. The sewer system is relatively flat.

Trunk sewers built before 1930 were of brick, stone, or segmented block. Since 1930 these trunks have been constructed of reinforced concrete. Street sewers are mostly vitrified clay with mortar joints; newer lines – the limited footage recently installed – are made with newer joints such as O-ring slipseal types. The poor joints in the major part of the system contribute to heavy I/I and to the root problem. Approximately half of the Authority sewers are laid under the groundwater table; the rest are above the groundwater table at least during part of the year. The Authority has no authority over sewers in the sewer districts they serve.

- Sewer maintenance problems are caused primarily by root growths – 50 percent, grease formations are responsible for 20 percent of maintenance work; sand deposits, 20 percent; and industrial wastes materials, 10 percent.
- Sewer dig-ups for root control amount to only five, plus or minus, per year; dig-ups are limited to sewer sections which cannot be cleared by regular root-cutting operations.

• Approximately 80 percent of the sewer system is subject to root intrusions; from 40 to 50 miles of sewer are de-rooted each year. This represents about one-third of the 80 percent of the total mileage of BSA sewers; average root cleaning cycles are once every three years, but certain areas that are known to have heavy rooting are serviced more frequently – often on a six-month interval basis.

• Rodding is the usual method of root removal, using auger equipment and bucket scrapers. A so-called "screw machine" is used when regular rodding with usual tools does not do the job. The first pass for threading a cleaning cable through an affected line is carried out with flat slat "sticks" which are joined with wirebinding into the length necessary to pass from manhole to manhole. The wires are discarded after joints are broken; some slats are joined into lengths of two or three and left intact from job to job if the truck can handle them. The slats in use are old and frayed, but they work effectively. They have the advantage of being flexible and floatable. Rodding is done with hand winches or with power take-off units on the service trucks; slats are 3 m (10 ft.) long.

• BSA has not owned a high-pressure jetting unit but the first one was delivered to the Authority during the interviewer's visit to the service yard and offices. No vacuum units are used for removing debris and roots from manholes; hand dipping or bucketing is the method used

• BSA reported reasonably satisfactory root removal by these means. The methods used must be characterized as "routine," no novel procedures are utilized. A plastic-canvas diaphragm scraper – 25 years old – is used, sans rotation.

• Collectors are affected by roots at all depths from 15 cm (6 in.) to over 60 cm (24 in.) The greatest footage of sewers lies in the 20 cm (8 in) to 30 5 cm (1 ft) size (500 mi.). BSA reported that the 80 percent affected factor applies to all sizes of sewers. Long sections of root mats are often removed from lines, particularly from the smaller lines.

• Four sewer maintenance crews of five men each are in service Four crews of five men each are used for storm receiver basin cleaning and two crews of three men each service the lesser number of large catchbasins. Three complaint crews of two men each answer complaints and perform any emergency work they can handle. Root removal is considered a part of the routine sewer cleaning program except in cases where complaints are specifically due to root formations. It can be seen from the average frequency of root cleaning that a full-scale preventive maintenance program is not used throughout the entire system. Attention is given to complaint areas and sewer sections that are known to be heavily root-infested.

• BSA reports that it uses a form of chemical control, but it is not a sophisticated procedure using flooding or foaming in the newer sense of the chemical control procedure. A material called "SAN-FAX" labelled as "containing Penetrex" and producing "synergized exothermic action" is used. The investigator asked to see the material and found that its main ingredient is NaOH, supported with "biodegradable surfactants." It must depend on caustic action.

BSA has used this material in about 10 percent of its sytem where rooting is heaviest. About 25 lb. are dumped into a manhole for a treatment; the sewer is not plugged or flooded – solution occurs with normal sewage flow. It was reported that the treatment seems to stunt the roots and cause them to disintegrate. The chemical applications are limited to once in the spring and once in the fall, when root growths are most active. Root growth was reported to be minimal during the tree growing season. The investigator did not see a treatment or the results thereof. BSA reported that chemical treatment doubles the length of time between root stoppages in the affected areas. The material is obtained from the Du Bois Chemical Co., Buffalo. It was characterized by BSA as "expensive," thus limiting its use to most-needed areas.

Tree-Planting Policies

The relationship between tree growths and root problems is obvious, especially due to the location of sewers under sidewalks and in close proximity to curb-side plantings and the age of the sewer system, with poor joints in many areas. The major problems with roots are attributed, in order, to maples, elms and poplars. Roots affect sewers at all depths, especially in areas when lines are not continuously inundated in the groundwater. Buffalo offers innovation in tree plantings: Plantings are made by the City Forestry Department; property owners must get permits to plant between the sidewalk and the curb line. A city ordinance may be involved in this regulation. Unfortunately, little contact exists between the Forestry agency and BSA in the choice of plantings.

Roots are considered a cause of joint infiltration, due to crushing action by the root growth. While the root problem is characterized as a street sewer phenomenon in Buffalo, a large percentage of roots do enter house laterals – 40 percent of the total root problem – and gain entry to the street sewers via the laterals, particularly because the street sewer is located close to the tree line and the house sewers are shorter in length because of the sewer location.

Charlotte-Mecklenburg Utility Dept., Charlotte, N.C.
Date August 28, 1975

Persons Interviewed Lee Dukes, R. D. Campbell, David Duncan

The Charlotte-Mecklenburg Utility Department serves the City of Charlotte and the sewered portion of Mecklenburg County. The Utility Department is responsible for sanitary sewers; the Charlotte Department of Public Works provides storm sewer service. The overall population served by the Utility sewer system is approximately 300,000. The city-county Utility Department was created on January 17, 1972, by agreement between Charlotte and Mecklenburg County, consummated by the two separate legislative bodies. Other joint services had been established prior to the Utility Department agreement; other joint functions for the city and county area are contemplated

The Charlotte-Mecklenburg Sewer System

The Utility's service area is sewered on the separate sanitary system basis, with storm sewer service provided by the City of Charlotte within its own area A total of 1,082 miles of collector sewers and 200 miles of interceptor sewers are included in the Utility's system.

Sanitary sewers are predominantly vitrified clay Three "eras" of sewer construction were defined From 1927 to 1958, sewers were laid with jute and mortar joints; from 1958 to approximately 1961, bitumastic joints were used; from 1961 to date, compression joints of the "O-ring" type have been used.

The groundwater table is relatively low in the service area and most sewers are laid above the table level. The soil is relatively dense and of clayey nature. This soil condition is poor for the widespread use of septic tanks in the county area which is not yet served by sanitary sewers. New jointing methods have overcome adverse conditions in the newer sewer lines. This is especially true for realty subdivisions in the county where developers installed private sewers which have since been taken over by the city, and now the Utility. Those private sewers were not originally inspected by the city or county; in some cases, poor backfill practices resulted in damaged pipe. Maintenance by developers was poor to non-existent.

In some annexed areas, private sewer lines were abandoned and new lines were laid and connected to interceptor and treatment facilities. Many septic tanks are still in service. While the Charlotte-Mecklenburg sanitary sewer system is characterized as almost universally vitrified clay, lines of 46 cm (18 in.) and larger size are of concrete. A limited number of cast iron sections are in service.

Building Sewers and Connection Policies

The above information on street sewers is included in this root survey report because of the relationship between construction and general installation data and root intrusion problems. The same relationship exists between root problems and house sewer installations, and connection to street sewers.

House sewers are usually 10 cm (4 in.) in size Approximately 1.5 m (5 ft) of cast iron soil line is carried from the building line to the house sewer line. House sewers are normally vitrified clay. The property owner is responsible for the house line to the property line, with the Utility responsible from the property line to the street sewer and for the street sewer connection. The property owner reimburses the Utility for its costs in connection with building sewer work and making the connection to the street sewer.

Because of troubles caused by poor building sewer connections to street sewers due to intrusion of stubs into the sewer lines, broken sewer lines at connection points and root intrusion through defective tap connections, the Utility has invoked new methods of making connections. In the older connections, plumbers or contractors broke out a hole in the street sewer, laid a hub over the joint and cemented the juncture closed. This produced a poor connection Joints in older house sewers were poorly made and resulted in root and infiltration intrusion.

In the new procedure, excellent, tight taps are being provided. No wye or tee connections are laid in the street sewer during construction because the Utility has found that these connectors were seldom located and used when a house lateral connection was made Each connection is now made via a diamond-drill hole cut into the street sewer by the Utility forces The hole is just undersize for the 10 cm (4 in.) house line and the connection is made with a "Rimrock" ABS plastic sewer tap saddle, a cast aluminum or cast iron saddle arrangement. The joint is made up with an epoxy sealant "sewer tap joint compound" made by Smith & Loveless. The new connections produce no impedences in the street sewer when cleaning equipment is passed through the line; infiltration is eliminated; and root intrusion is controlled. Any house sewer connection over 12.5 cm (5 in.) in size must be made via a manhole. No wye or tee connections will be permitted in the future. Plumbers or owners are refused permission to make the taps. The city bills the owner for $3 for making the tap and an average of $310 (1975) for providing the building sewer on a paved street and $85 on an unpaved street.

The Utility estimates that there are over 3,000 illicit sewer connections in the service area, for which no fees have been paid. It expects to locate 2,000 such connections by means of a program of smoke testing and dye testing. Most of the illicit connections are located in newly annexed areas

Roots are a problem in the CMUD system but no unusual procedures have been instituted to prevent, control or modify the cause conditions, over and above a routine sewer cleaning program which uses standard rodding and cutting techniques. No chemical root control procedures have been tried in the past due to costs and the opinion that such treatment has not been demonstrated to be effective under the conditions found in the CMUD system. The Utility will undertake chemical control if the APWA study demonstrates the effectiveness of this practice elsewhere in the U.S. The Utility mentioned the hazards of chemical control to crews and property owners.

The only chemical used in sewer work has been a caustic compound utilized by dumping into manholes on an occasional basis for grease control.

Some 40 percent of sewer maintenance work is attributed to root intrusion, with grease formations - 10 percent; sand and sludge - 20 percent; deteriorated lines - 10 percent; and material dumped into manholes - 20 percent. The questionnaire data were confirmed during the on-site survey: 26 digups per year; 200 root stoppages per year; 310 miles of sewers cleaned per year for root control; 50 percent of the CMUD system subject to root intrusions. If half of the 1,282 miles of sewers is subject to root intrusion, cleaning of 310 miles per year for root control would represent the servicing of approximately 60 percent of the root-infestation mileage per year, or approximately an 18-month coverage schedule. The opinion was expressed that a yearly average coverage would be more advantageous.

This schedule represents a system average; actually, the Utility knows the points of greatest root intrusion and schedules the frequency of root removal to meet the actual intrusion conditions. Sewer root cleaning operations are both routine-on-schedule and subject-to-complaints of sewer stoppages by property owners.

The major root problems are experienced in the older parts of the service area where trees are older, root structures more widespread and old sewer joints not tight. While the CMUD system is not subject to widespread infiltration problems, due primarily to low groundwater levels. root problems are affected by age of sewers, tightness of joints and other related factors.

Root intrusion is heavy in house connections, due to poor joints in old lines. Poor house connection practices, as described above in the discussion on tapping practices, have produced heavy rooting at these points, with roots then following the house connection into the street sewer. The new tap methods will alleviate this condition.

It is anomalous that annexed areas and private developer-sewered sections have been less subject to root infestations than older lines in the City of Charlotte. This condition, despite the poorer sewer construction practices in the recently annexed areas, is attributed to the absence of old tree plantings in the newer developments, by the CMUD officials.

Most of the CMUD sewer system is sized from 20 to 30 5 cm (8 to 12 in.), with 35 percent of these sizes affected by roots. Of the 1,282 miles of lines, only 125 miles are sized from 38 to 61 cm (15 to 24 in.), and approximately 25 percent of these lines are root-affected. Reinforced concrete lines, used for sewers over 38 cm (15 in.) in size, represent only 75 miles and roots are no problem therein.

No sewers in the CMUD area have only 30.5 cm (1 ft.) cover and very few have a 61 cm (2 ft) cover. Lines laid with 91-151 cm (3 to 5 ft.) cover represent about about 20 percent of the root intrusion problem. Most sewers are laid with cover of 1.5 m (5 ft.) to 2.4 m (8 ft.); 70 percent of these lines are subject to root problems. Below 2.4 m (8 ft.) of cover root problems are less prevalent, only 10 percent of such lines are subject to root intrusion. The opinion was expressed that sewers laid below the water table, under all-season conditions, are not subject to root intrusion because structures are not seeking water from such sources.

The clayey nature of the Charlotte area soil does not impede root growth. The relationship between infiltration and root intrusions is obvious, despite the fact that, due to deep groundwater table levels, infiltration is less widespread than root intrusion problems. In the opinion of CMUD officials, the entry of roots into open joints or cracks can cause crushing of pipe due to the pressure of growth. Crushing of concrete walls and walks was quoted as proof of the breaking power of roots.

Root Removal Practices

Reference has been made to the fact that no chemical control of root growths has ever been tried in the CMUD system. Five rodding machines are in service – the same number used in the City of Charlotte before the city-county agency was created and the service area enlarged. However, four additional hydraulic jetting units have been acquired, with approximately two attributed to the enlarged service area. Crews were reported to be 5 men. Five units are in service on Wednesday, Thursday and Friday; four on Monday and Tuesday; and one on Saturdays and Sundays. Rodders are the "backbone" of the sewer maintenance program. Rodders are equipped with "corkscrew" tools and with bucket devices, etc.

Five high-velocity hydraulic sewer cleaners are in service, of two makes. These units are manned by crews of three men. They are used to augment the work of the rodders, or operate separately to flush debris from the lines.

CMUD officials expressed lack of complete satisfaction with the present sewer maintenance program. Root control is viewed as expensive, root growths are not completely removed at the crown of the sewer and they grow back rapidly Some areas of the service territory, where root intrusion is heavy, should be cleaned at bi-monthly intervals while other areas can be serviced as infrequently as 18 months or longer. Roots enter the CMUD sewers near the crown or the upper circle of the pipe. The investigator made reference to the possible value of chemical control to meet this criticism for current practice.

As a result of discussions of the tree growth relationship with the root problem during the course of the interviews, a communication dated 9/22/75 was received by the investigator, listing the type of trees and shrubs in the Charlotte-Mecklenburg area and indicating their relative rooting significance. They are:

1 Willows
2. Privet Hedge
3. Maples
4 Poplars
5 Elms
6. Oaks (all types)
7 Junipers

City of Chesapeake, Virginia
Date. August 29, 1975

Persons Contacted· W. R. Hood, W. T. Catlett, Jr., William M. Patrick, Hugh M. Jones, L. L. Paul

The Public Utilities Department serves approximately 50,000 persons of the 100,000 population in the far-flung city area which are connected to the sanitary sewer system. Some half of the homes are not now served by the sewer system. They use private septic tanks and in many cases get their water from on-property wells. Some two-thirds of the city land is rural in nature because of the great expanse of the community's official area.

Chesapeake is a part of the Norfolk metro complex. Chesapeake was created in 1963; prior to that date the area was part of the City of South Norfolk and Norfolk County. Local sanitary districts in Norfolk County owned separate sewer systems, which Chesapeake took over in 1963, when it assumed the outstanding capital debts of the sewer districts.

The city is located on generally flat terrain. The groundwater table is relatively high and the level is affected by tide action in the Bay, producing an unusual stratification of fresh and saline water in the soil The soil is sandy and mud-structured, producing what was described by the new construction foreman as "running sand." This condition contributes to frequent street cave-ins when sewer leaks or infiltration occur, due to the poor support for sewer pipe lines.

The Chesapeake Sewer System

The city is served by separate sanitary sewers, operated by the Utilities Department. Storm sewers are the responsibility of the Public Works Department. The city owns no interceptor sewers, except for pumping station force mains, and no treatment facilities The city, like the other communities in the metro complex, discharges its wastewater into the system of the Hampton Roads Sanitation Commission, a subdivision of the State created in about 1948 to provide water pollution control facilities for the area. The nine Commissioners are named by the Governor. The city maintains 70 pumping stations or lift stations to deliver flows to the Hampton Roads interceptors.

The city operates approximately 300 miles of collector sewers. Many of the sewers are old, having been taken over from local sewer districts. Some construction is poor, with poor joints. Old concrete pipe, installed during WPA days, has deteriorated due to sulphating in the saline tide-induced groundwater, and is being replaced as needed.

Building Sewers and Connection Policies

House sewers are of special significance because of the official opinion that the greatest amount of root growth takes place in these lines and subsequently produces problems in street sewers. House sewers are mostly of 10 cm (4 in) size, laid with vitrified clay pipe. The average length of house sewer laterals ranges from 10.7 m (35 ft.) to 15 2 m (50 ft.). Property lines in areas without curbs are about 9.1 m (30 ft.) from the centerline of the street; where curbs are installed, the property line is approximately 2.4 m (8 ft) inside the curb line, the owner being responsible from the property line to the building wall A clean-out is installed in the house lateral at the property line

The present policy requires the property owner to obtain a permit for installation of the house lateral from the Permit Department of the city, which carries out its own inspection service. The plumber installs the lateral to the clean-out, including the clean-out If the clean-out is not installed by the property owner, the city makes this installation at its own cost. The city lays the lateral to the street sewer and makes the sewer connection. Connections are either by pre-installed wyes or tees, or the city drills the sewer with a diamond saw and installs the connection with a special saddle arrangement. The new system has reduced root intrusion at this point and at joints which were previously poorly made and provided entry for root growths. Joints are mortared, with steel bands that are left in place. For plastic lines, joints are made up with plastic cement. Compression ring-type joints are used on street sewers.

Because of the root problem induced by poor lateral connections to the street sewer system, the city is correcting such points in existing laterals and tightening up on inspections in new lateral connections. The city requires a one-year guarantee for plumbing work on laterals and has invoked the guarantee to require the relaying of poor work.

Sewer Root Problems and Corrective Actions

According to the Public Utilities officials, the major root conditions in the system occur in house laterals and root growths in street sewers often have their source in building sewers. Street sewer stoppages are often caused by the pushing of "bundles" of roots out of house laterals into the sewer lines by plumbers and drain cleaners.

Public Utilities responds to all property owner complaints of sewer stoppages. It checks the sewer line first and if the sewer is clear, it "snakes" out the house lateral from the clean-out to the street sewer – the portion for which the city assumes responsibility. If the line is still clogged, the owner must clear his portion of the house sewer. One case was quoted: A stoppage complaint was investigated, where a plumber had cleaned the lateral to the clean-out without clearing any stoppage. City forces found that the plumber had pushed the root mat into the city's portion of the lateral The city obtained a release from the property owner to enter his section of the lateral and then cleaned the rest of the house sewer. No charge was made for the city's services but it informed the owner that the stoppage had been in his part of the lateral and that his plumber had dislodged the mass and pushed it into the city's line.

Primarily, root control work is carried out with small rodding equipment using augers and bucket equipment as required. No chemical control has been used. Stoppage complaints are the main cause of root cleaning but if crews have the time they do carry out some routine root control work on a preventive maintenance basis. From 300 to 400 complaints are received per year, varying from no complaints per day to six or more.

Complaints are handled by use of a high-velocity flusher, with a catcher device located downstream from the entry manhole. If flushing does not clear the line, rodding is carried out. If rodding is required in house laterals – the portion from the clean-out to the street sewer – a hand cable-type rodder is used. In street sewers, a heavy cutting auger is used, dubbed "grandma" by the sewer crews. If this cutter does not clear the line, dig-up operations are used by separate construction crew personnel. Preventive maintenance, when applied, is limited to areas which are known to have root infestations in sewer lines.

Infiltration is high in Chesapeake due to high groundwater and old sewer lines. The frequency of pavement cave-ins, mentioned above, is induced by washouts of running sand soils at points of sewer or joint failures. In the light of the high infiltration conditions, the investigator questioned the minimal occurences of root problems in street sewers. Utility officials conjectured that high groundwater, year-round, and submergence of sewer lines discouraged root intrusion into sewers; the saline water condition in the ground was assumed to discourage root growth. Roots in house laterals were attributed to shallower lines and closeness to trees and shrubs. A majority of buildings have no basements in Chesapeake and house laterals are laid at shallow depths

Root growths are known to be heavier during the dry season; this is pointed out as confirming the reason for the absence of heavy root conditions in street sewers that are normally laid under the groundwater table. Again, it is stressed that the Chesapeake root problem is centered in house laterals, rather than in street sewers, but this does not mean that street sewers are free of rooting conditions.

The root experiences outlined in the mail questionnaire form received from Chesapeake prior to the on-site survey demonstrate the minimal problem in street sewers. Of the 400, more or less, stoppages experienced during the year, officials attribute most cases to lateral roots which either enter the street sewer or are pushed into the sewer by plumbing clean-out operations. Of the 50 dig-ups per year reported in the questionnaire response, most were described as occuring at lateral clean-out locations. Only 5 miles of street sewers out of the total system's 300 miles of collectors are cleaned for root control per year, or under two percent of the footage. In areas where root growths are known to be more troublesome, frequency of cleaning was reported to be 18 months.

The root problem is attributed totally to joint conditions, especially in house laterals and older sewer connections. Joints in vitrified clay sewers date back some 50 years, starting with cement mortar joints, then to bituminous joints, and now o-ring compression slipjoints. Old fiber sewers, laid during WW II, were flattened and damaged by sewer cleaning operations. Concrete sewers laid in the WPA era have experienced deterioration, as described above, and have been replaced where needed.

Infiltration/Inflow Conditions

The Chesapeake system is not subject to inflow from property sources because of the absence of basements, foundation drains and cellar sumps Roof leaders are not considered a problem Inundated manholes are a factor, but the city uses manhole frames with "dust covers" laid under the manhole covers and this may reduce inflow, expecially when the inside cover becomes sealed with street dirt

Tree Conditions

The survey disclosed that trees, especially in house lateral areas, are the cause of root problems Elms are considered the most troublesome, followed by maples, gum trees and a type known as "quick myrtle."

City of Madison, Wisconsin
Date: August 26, 1975

The 168,000 citizens of Madison, Wisconsin are served by a separate 814 km (506 mi.) sanitary sewer system. The system also includes 11,500 manholes, 10 km (6 mi.) of force main and 23 lift stations. Sanitary sewer sizes range from 10 to 91 cm (4 to 36 in.). The Madison Metropolitan Sewerage District provides wastewater treatment services for the area and also installs and maintains the major interceptor system.

Maintenance Program

More than 90 percent of the system is built with vitrified clay pipe at depths ranging from 2.4 to 3.6 m (8 to 12 ft.). The oldest sewers were installed about 1905.

The Engineering Division receives between 700 and 800 calls annually reporting sewer backups. Two-thirds of these calls are found to be caused by problems with service connections and one-third are caused by sewer main stoppages. The cause of each main stoppage is reported and tabulations made of annual totals. The attached tabulation shows causes for sewage backups for 1974 and a portion of 1975 Grease and roots cause most of the backups. It is often difficult to classify which is the basic cause of the stoppage. City personnel clean service connections only if requested and paid for by the property owner.

About 108 km (67 mi.) of the 814 km (506 mi.) system has been listed for special attention. Fifteen percent of the 108 km (67 mi) system is cleaned quarterly and the remainder twice annually. Root growth is a major problem in all but about two of the 108 km (67 mi.).

The remaining 707 km (439 mi.) not included in the special program are cleaned as time permits. The present cleaning cycle is at about a three-year interval, but attempts are being made to reduce the time interval to less than two years.

The city utilizes three rodding crews and two hydraulic jet crews to clean the system. For the past six years city crews cleaned an average of 404 km (250 mi.) of sewer per year. This represents less than half of the system since portions are cleaned two or more times. It is expected that the cleaning program can be expanded with the recent purchase of a new hydraulic sewer cleaner and the replacement of an old rodding machine.

Control of Roots

The most severe root problems are caused by Sugar Maples and the American Elm Willow, Poplar, Oak and Ash trees also cause problems of varying degrees. Sewers in excess of 1.8 m (6 ft.) deep usually have less root problem than shallow sewers. Most root growth consists of a mass of hairline roots entering the upper half of sewer joints It is believed that roots seek moist air rather than water.

Most of the root areas are cut with augers or saws attached to the power rodders. The hydraulic jet is also used with a cutting attachment. This operation was observed in the field. The operator was cutting upstream using about 84 kgf/cm^2 (1,200 psi) pressure. The small roots cut from the sewer were caught by a screen at the downstream manhole and removed from the system. The crew foreman thought that roots from Willow trees were the most troublesome and stated that root growth was especially bad during dry years. He further stated that Elm roots continued to grow in sewers at least one year after the tree is cut down.

Madison has used chemicals to control root growth only to a very limited extent. About 10 years ago chemicals were used in one line but the experiment was unsuccessful since high flows prevented holding of chemicals in the line. During the past few years the city has used chemicals on occasion to clean service laterals. The chemical, San Fax, has been found to be especially effective in cleaning grease from lines Only about 114 liters (30 gal.) of chemicals have been used during the past 8 years.

The City Engineer listed six areas of concern relating to the expanded use of chemicals for root control.

1. Excessive cost
2. Possibility of chemicals backing into basements through service connections
3. Possible adverse effects on treatment plant processes
4. Possible adverse effects on effluent in receiving waters
5. Damage to above ground vegetation
6. Unknown effect on PVC main and services

Televising and Sealing of Joints

The City of Madison owns its own television equipment and routinely televises all new contract work. Problems are detected and identified in most but not all installations. Typical problems include broken or cracked pipe and deposits of rocks or gravel. Sewers are required to meet infiltration requirements of 186 l/cm/km/d (200 gal/in/m/day).

The television equipment is also used as a maintenance aid. If a jet machine washes out excess sand or broken pieces of pipe, the section is then televised to locate and evaluate the problem. Wyes, tees and service connections are also located when required for design or maintenance considerations.

The equipment is used occasionally as a check on routine cleaning work and to locate sources of Infiltration/Inflow

The City's equipment does not have pressure grouting capability. In 1973, the city contracted for the grouting of 133 joints in various sized sewers. The project cost $25,000 or about $188 per joint. It is believed that reduced treatment costs more than offset the cost of sealing. There were very few trees in the sealing area thus the effect on root growth is unknown.

During 1974 city crews televised 24 7 km (81,000 ft.) of sewers. Records indicate that the cost of televising was $0.72 per m ($0.22 per ft.) and the cost of advance cleaning was $0.56 per m ($0.17 per ft.) Upon examination it was found that several cost times were not included. However, the cost relationships should be relatively accurate.

MADISON, WISCONSIN
SANITARY SEWER MAIN BACKUP CAUSES
1975 MAIN BACKUPS

JANUARY 1, 1975 TO AUGUST 20, 1975

Item	Occurrences	Percentages
Rocks	2	1
Grease	36	22
Unknown	25	15
Roots	36	22
Paper	8	5
Rags	1	1
Storm infiltration	51	31
Manhole Plug	5	3
	164	

1974 MAIN BACKUPS

Rocks	6	3
Grease	88	38
Unknown	41	18
Roots	61	27
Paper	13	6
Rags	3	1
Storm infiltration	2	1
Manhole Plug	12	5
Grit	3	1
	229	

City of Milwaukee, Wisconsin
Date: September 2, 1975

The City of Milwaukee maintains about 1,231 km (765 mi.) of sanitary sewers, and 893 km (555 mi.) of combined sewers as well as the 1,497 km (930 mi.) of underground storm sewers which serve substantially all the separately sewered areas. A separate agency, the Metropolitan Sewerage Commission, installs and maintains interceptor sewers and also provides wastewater treatment services for nearly all of Milwaukee County.

Sewer Cleaning Technique

The variety of problems encountered in the maintenance of a large sewerage system requires the use of several cleaning methods. Accordingly the city utilizes four basic types of equipment. The following tabulation shows statistics relating to each type of equipment for the 1974 calendar year.

Cleaning Method	Number of Crews	Crew Size	Average Production m/day (ft/day)	Annual Production 305 m(1000 ft)	Cost of [b] Cleaning/m (Cleaning/ft)
Jet	2[a]	2	914-1,219 (3,000-4,000)	1,207	0.14 (0.04)
Sewer Ball	2	5[c]	914-1,219 (3,000-4,000)	1,549	0.18 (0 055)
Rodder				982	0.3 (0.08)
Sectional	1	3	610 (2,000)	480	
Continuous	1	2	610 (2,000)	502	
Bucket Machine	4[d]	3	76-91 (250-300)	212	2.23 (0.684)

(a) Will soon have a third crew.

(b) Figures do not include full equipment or fringe benefit costs Actual total costs are about 30-35% higher.

(c) May change to 4-man crews.

(d) May reduce to two or three crews within one year.

City personnel have coded the sewerage system according to the need for or difficulty of cleaning and assigned appropriate cleaning equipment to designated areas. A total of sixteen schedules are maintained for the four types of cleaning equipment in each of four districts. Some of the large sewers are not coded and are cleaned only occasionally or when complaints are received. The least troublesome areas, with sewer sizes up to 30 cm (12 in.) are cleaned by use of a sewer ball. Personnel state that it would be desirable to clean on an 18 month schedule; however, the present cycle is somewhat in excess of two years.

Many areas cannot be cleaned with a sewer ball because of offset joints, excessive root growth, or lack of readily accessible water supply. In addition, jets have proven to be the most effective in isolated areas with heavy grease accommodations, and at least nine such areas are cleaned on a monthly schedule.

Jets with cutting tools have been proven to be effective for light root growth. Operators have found, however, that cutting up-grade is slow because of the combined weight of hose, nozzle and cutting tool. In actual practice they generally jet upstream between manhole spans, attach the cutting tool at the upstream manhole, and then pull the nozzle and cutting tool downstream. The tool is then detached, and in heavy growth areas, the span jetted again to flush out root deposits. When it is necessary to use cutting tools, the daily production noted in the previous tabulation is substantially reduced.

Bureau staff reported that operators are reluctant to use a cutting tool with the jet machine because of reduced production and the fear of breaking the cutting tool or locking the nozzle and cutter within the system. Operators also feel that the additional loss of water pressure at the nozzle due to the cutting tool reduces cleaning effectiveness.

Rodding machines are used for cleaning sewers where root growth is more than minimal. In a few isolated instances of extreme root conditions, bucket machines have been used. These are also utilized in sewers with excessive flows, in industrial areas, or where silt deposits are more than nominal. Since rodding machines have proven to be ineffective for cleaning grease deposits, a program is being initiated of jetting sewers after rodding work. Greater overall emphasis is being given to jet machines by the purchase of a third machine and the planned elimination of at least one bucket machine crew.

Sewer Stoppages

The present sewer cleaning program has been in effect only for the past few years. Previous programs were not nearly as comprehensive, were more in response to immediate need rather than as preventive programs, and were not designed to best utilize various equipment capabilities. During the mid-1960s, the city experienced about 160 sewer main stoppages per year. Through the addition of jet machines and the initiation of systematic cleaning practices, the incidences of sewer stoppages have been sharply reduced as shown by the following tabulation.

	Sewer Stoppages
1971	72
1972	62
1973	60
1974	58

About 20 percent of the stoppages are in combined sewers even though the minimum size is 30.5 cm (12 in.). Such stoppages are more often due to debris than to roots or grease.

Root Problems

Virtually all of the root problems in Milwaukee sewers are caused by elm roots from trees planted prior to 1932. About half of the Milwaukee elms have died from Dutch Elm disease and are gradually being replaced by other varieties.

Milwaukee sewers are installed at 2 7 to 3 6 m (9 to 12 ft.) depths to provide gravity drainage from basements Elm roots enter sewers at the upper half of old mortar joints. Staff were not aware of any cases of roots entering sewers with gasket joints, and know of no cases where root growth actually broke a pipe bell.

Field supervisors reported that there are two root growth periods annually – spring and fall. Thus the maximum cleaning effort in heavy root growth areas is at six month intervals

Test of Sewer Cleaning Methods.

In 1974, city personnel conducted a limited investigation of various sewer cleaning techniques. Areas were chosen with known root and grease problems and internally inspected by television prior to cleaning. Four cleaning techniques were then utilized; (1) sewer rodding only, (2) sewer rodding followed by hydraulic cleaning with a jet, (3) hydraulic cleaning only, and (4) hydraulic cleaning with root cutting attachment followed by hydraulic cleaning. The test area was reinspected internally after cleaning.

The test showed that none of the methods removed substantially all of the roots and grease. The jet alone did not remove roots and the rodding machine did not effectively remove grease. Improvements were noted when the root cutter was used in conjunction with the jet nozzle and when the jet was used subsequent to sewer rodding As a consequence of this test, the city is attempting to jet clean all sewers after rodding work is completed.

A copy of a three-page report of these tests, dated April 10, 1975 is attached to this report

Use of Chemicals to Control Roots

The city has no program for use of chemicals to control root growth. On one occasion about three years ago, an equipment supplier attempted to demonstrate the use of foam to control root growth. Foam was inserted at the upstream manhole of a 61 m (200 ft.) span but was not observed at the downstream manhole. Personnel were not sure whether the foam entered the services or whether the equipment malfunctioned.

The sewer was inspected twice at six-month intervals and no effect was noted on root growth

Bureau of Street and Sewer Maintenance
Sewer Maintenance Section
April 10, 1975
Milwaukee, Wisconsin

Test of Sewer Cleaning Methods

In order to maintain an effective sewer cleaning program, a test of certain cleaning methods was performed by City sewer cleaning crews in June of 1974

Test sections were selected in the area between W. Capitol Dr., W Congress St., N. Green Bay Av., and N. 27th St. after Closed Circuit TV (CCTV) examinations of the sanitary sewers. The sewers with roots and/or grease were chosen for cleaning and subsequent re-examination using CCTV

Four cleaning methods were compared·

1. Sewer rodding only
2. Sewer rodding followed by hydraulic cleaning with "Jet"
3. Hydraulic cleaning with "Jet"
4. Hydraulic cleaner (Jet) with root cutter attachment followed by hydraulic cleaning.

The rodder used a new root saw and the jets used new nozzles. All machines were in good operating order. The "Sewer Jet" purchased from Central Engineering did the cleaning in test sections 2 and 3 above and the "Jet" purchased from Conco (O'Brien) cleaned section 4

After cleaning, the sections were re-examined with the CCTV, and Mr. Thurman Hawkins, Sewer Examiner Foreman in charge of the CCTV crew, judged the effectiveness of the cleaning on a rating of 1 to 5 where 1 = very good and 5 = poor. Two ratings were made, for root removal and for grease removal. The judgment was based on a comparison of the before and after examination reports and photographs of the sewers. The amount of flow before and after cleaning was noted on the exam report. If the flow was good prior to cleaning, it will be noted "OK."

The ratings are as follows·

		Rating		
Cleaning Method	Exam. Report File No.	Root Removal	Grease Removal	Flow Improvements
Rodder	Section 1-17439	2	2	OK
	2-17468	3	4	Some
	3-17468	3	4	Some
	Average	2-2/3	3-1/3	
Rodder & Jet	Section 1-17408	3 to 2	3 to 2	Good
	2-17450	2	3 to 2	OK
	Average	2-1/4	2-1/2	

Continued –

Cleaning Method	Exam Report File No.	Rating Root Removal	Grease Removal	Flow Improvements
Jet W/Nozzle	Section 1-17481	4	2	OK
	2-17511	4	2	Good
	Average	4	2	
Jet W/Root cutter and W/Nozzle	Section 1-17413	3	2	Good
	2-17437	3	1	Good
	3-17437	3	2	Good
	Average	3	1-2/3	

Conclusions:

1. None of the methods tested removed all or even substantially all of the roots and grease.
2. Cleaning with the rodder followed by the jet is better than cleaning with rodder alone. The test was too limited to be able to quantify how much "better."
3. Using both the root cutter and the nozzle on the jet provides better cleaning than using only the nozzle Again, it would be difficult to state how much "better."
4. The jet cleaning improved the flow as noted by less depth of flow after cleaning.
5. The jet w/nozzle did not remove roots very well.
6. The rodder does not remove grease in an effective manner.

Recommendations:

1. Schedule sewers now cleaned by rodder only should also be cleaned by jet after cleaning by rodder There are 700,000 lineal feet of sewers now on the annual rodder program plus 60,000 feet on a 6-month program. This would require 55 crew weeks for a jet. This could not be scheduled until a 3rd jet is in service.
2. Sewers now scheduled for cleaning by jet that appear to have substantial tree root growth could be cleaned prior to jet cleaning by either the rodder or by the jet hydraulic root cutter This program would involve up to 330 km (190 mi) of sewers and would require 107 crew weeks to complete The present rodder program requires almost 2 crew years to complete, so any additional rodder cleaning would require extending the cycle on the rodder program or an additional crew. It appears that greater use of the hydrualic root cutters would be the better method at this time.

Patrick W. Hawley, Street & Sewer Maint. Supvr.

City of Seattle, Washington
Date: September 10, 1975

The City of Seattle operates its sewerage function as a sewer utility (enterprise fund) within the City Engineer's Department. All costs attendant to operation and maintenance of the system are financed through user charges. The Municipality of Metropolitan Seattle (Metro) provides wastewater treatment for much of Seattle and also maintains the interceptor system. Interceptors are generally defined as sewers 61 cm (24 in) in diameter or larger which serve a minimum of 2,023 hectares (5,000 acres).

Sewer System Maintenance

The Seattle sewer system includes about 35 km (500 mi.) of separate sanitary sewers and 1,666 km (1,000 mi.) of combined sewers. System maintenance, not including lift stations, is performed by personnel shown in the following tabulation:

	Number of Crews	Total Personnel
District Foremen		2
Patch Crews[a]	5	10
Burket Crews	2	7

[a]Set wyes, castings, investigations, etc

	Number of Crews	Total Personnel
Rodding Crews	4	11
Hydraulic Jet	2	4
TV Survey	1	5
Inspection Crews	1	5
Sewer Repair Crews	1	5
Special Maintenance Helpers		6
		55

The city recently purchased additional television equipment and expects to utilize two television crews soon The two pieces of equipment will be operated by one foreman and six helpers. Video taping capability was included in the specifications but not equipment for internal pressure grouting of joints. The city expects to use television as a maintenance aid and to provide video tapes to the design engineers on sewer systems being considered for replacement

About 20 to 25 percent of the system has been color coded on system maps to indicate areas needing attention by cleaning crews. Root cutting in large sewers is done with buckets and in smaller sewers by rodding machines using straight blades. On a few occasions the crews have tried cutting roots with the hydraulic jet with saw attachment, but this did not prove satisfactory and is not now being used. Crews occasionally do some flushing of the separate sanitary system and also have used a "porcupine" with expandable cutters. The maximum attention given to sewers for root growth is four cuttings per year.

The City of Seattle is very concerned with sewer blockage or system surcharges since they pay claims for damages to basements due to sewage backups. The following tabulation shows the number of recorded backups due to blockage or surcharging during the past three years.

	1972	1973	1974
System Surcharges	140	14	34
Main Blockages	41	37	30

Most of the recorded blockages are due to roots or grease and occur in the separate sanitary systems where sewer sizes are smaller. On at least six occasions the city has paid claims for backups when caused by roots from city trees. In these instances, the city hired a roto-rooter contractor to regularly clean the services In no other case does the city accept maintenance responsibilities for service connections.

Annual rainfall in Seattle is about 89 cm (35 in) so it is believed that the roots in sewers are seeking food rather than moisture. Roots are found to be a problem even in large-sized pipes up to 61- cm (24 in) diameter. Entry is nearly always at a joint near the top of the pipe One case was described where roots substantially filled a 53-cm (21 in) pipe within four years. Willows and poplars are considered to be the worst offenders. The city has had no known case of roots entering a properly constructed gasket joint

Chemical Treatment of Roots

Seattle has had very limited experience with the use of chemicals to control root growth in sewers. City personnel feel that only limited portions of the system can be considered for chemical treatment due to steep grades. Basements would flood if sewers on steep grades are blocked. In addition, it is felt that traditional chemicals will not react properly because of the cold water supply The average temperature of Seattle's potable water is 13°C (55°F) and only increased to 18°C (65°F) during summer months.

In 1967 the city experienced severe root problems in a 46-cm (18 in) line. Copper sulfate crystals, 0.7 kg (1.5 lb) were deposited in a manhole daily for eight weeks. No visible change occurred although the line was not televised. The sewer line was not blocked to surcharge the line during the experiment.

In 1970, personnel televised a sewer line serving homes where basement elevations were high above the sewer. The sewer line was then sandbagged "for a short time" and chemicals were added (DPO). The line was subsequently televised and little change was noted. Another experiment was conducted using San Fax on a dead end line, using hydrant water to fill the line. Again no changes were discerned.

One staff member visited Sacramento County, California, to observe their root control activities and became discouraged with the possibility of chemical control of roots in Seattle. He did not feel that their operation was more than minimally successful and moreover could not be accomplished in Seattle because of cold water and steep grades.

Southwest Suburban Sewer District, Seattle, Washington
Date: September 10, 1975

Person Contacted: Tom Tucker

The Southwest Suburban Sewer District provides wastewater collection and treatment services for unincorporated areas immediately south of Seattle and adjacent to Puget Sound. Three elected commissioners provide policy direction to the agency and 23 staff members perform the operation, maintenance, and allied activities.

The oldest parts of the 290 km (180 mi) sewerage system were constructed about 30 years ago; however, the major portion of the collection system was built in the mid-1950s.

Sewer depths within the district range from 0.9 to 6 m (3 to 20 ft) with the average being 2.4 to 3 m (8-10 ft). Concrete pipe is used for virtually all sewers with mortar joints in sewers laid prior to 1956. Sewers are now laid with O-ring joints and have proven to be trouble-free if properly installed.

Cleaning Practices

Most cleaning work is done with a hydraulic jet with maximum pressure potential of 113 kgf/cm^2 (1,600 psi) A cutting tool is not used with the jet. Staff reported that two neighboring cities had broken cutting tools and felt, to be effective, cameras must be used in conjunction with a jet and root cutting attachment.

District personnel lamp sewers with a 12-volt aircraft landing light before and after jetting as an aid in judging cleaning efficiency. This is felt to be important also in determining the cleaning procedure to be used. If a sewer has substantial deposits of sand or silt, the jet will be inserted in about 15 m (50 ft) increments and withdrawn to wash out deposited material. Different root patterns require different cleaning methods; grease deposits also affect cleaning techniques.

Root Growth in Sewers

Two distinct types of root growth were described. Roots from poplars and willows enter the sewer in lower quadrants (between 5 o'clock and 8 o'clock) and grow longitudinally downstream from point of entry along the bottom of the pipe. Roots often grow in 2.4-to 3-m (8 to 10 ft) lengths and to 1 3 cm (0.5 in) or more in diameter. One root 9 m (30 ft) in length has been found and removed from the system.

Roots from most other trees enter sewers at all areas of the joint and form a "ring" effect but seldom extend downstream more than a minimal distance from the joint. Honey locusts were planted on one street within the district in 1945. The 3-m (10 ft) deep sewer has "ring" effect roots at every joint.

The district installs 15-cm (6 in) house service laterals from the sewer main to the right-of-way line. Private plumbers then extend the service as a 10-cm (4 in) line and often provide a poor connection where pipe sizes change. Property owners often plant laurel hedges along their right-of-way line and roots enter the service lateral through the connection. Many services have been uncovered and found to be full of roots. Also where tap roots have entered these connections, personnel have found several instances where the root expanded and broke the pipe. The field representative being interviewed felt strongly that the pipe was broken by the root and that the pipe was not broken during installation thereby allowing the root to enter. He further stated that poplar roots are the strongest and most likely to break a pipe. He knew of no instances where roots had broken pipe in sewer mains.

Root Removal by Mechanical Means

Pencil-sized tap roots can often be broken by use of a high-pressure jet If successful the entire mass of roots can then be removed. Large tap roots are generally cut with hand rodders by coming in from upstream manholes or by pushing through from downstream to upstream manhole, attaching cutting tools and pulling back to tap root.

A power rodder is used to cut "ring" roots by use of a three-pronged cutting tool, a high R.P.M., and slow retracting speed.

The district experiences about six sewer blockages per year – mostly due to roots from service connections Sewers known to have root problems are cleaned each six months. Prior to acquisition of the hydraulic jet, a systematic cleaning program was not maintained.

Root Removal by Chemical Means

On several occasions the district has controlled root growth through the use of dry chemicals. Staff emphasized that the "heat" chemicals will not function properly when mixed with cold hydrant water. Also tap roots can be controlled more easily by cutting than by use of chemicals.

Chemicals are added to the upstream manhole of the line to be treated until dye is seen at the lower manhole. The line is then plugged and more chemicals are added until line is full of sewage and dye can be seen at the upstream manhole. About 5.4 kg (12 lb) of chemicals are used for an 88 m (290 ft) span of 20 cm (8 in) sewer

Crews hold solution in the sewer line for varying lengths of time, depending upon the relative elevation of basements. Optimum time is 60 minutes. When dyed sewage is released, many hair roots flush out. Also, chemicals have exfiltrated and killed roots adjacent to the sewer. Experience has shown that root growth has been killed for at least five years.

The district has also used copper sulfate to kill roots without surcharging sewers A plastic mesh bag of copper sulfate crystals is hung in a manhole in contact with sewage flow. Crystals are replaced as needed over a several-month period. In one instance about three years ago root growth disappeared and has not re-occurred. This is thought to be an effective method, although time consuming No effect has been noticed at the treatment plant from the use of chemicals to control root growth.

The district does not have an on-going program of controlling root growth through the use of chemicals. However, chemicals will be used in the future where access cannot be provided to the jet machine. "Heat" chemicals will be used if possible, because of grease removal benefits and more immediate correction of root problems

An attorney representing the district has advised the Board of Commissioners of the District that root damage to public sewers or service connections from trees growing on private property are the responsibility of the private property owner. A copy of the 1972 legal opinion is attached.

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January 14, 1972

JAN 17 1972

The Honorable Board of Commissioners
Southwest Suburban Sewer District
15633 Ambaum Boulevard S. W.
Seattle, Washington 98166

OPINION RE: BURDEN OF PAYING COSTS AND
EXPENSES FOR REMOVING ROOTS FROM SEWER PIPE

Gentlemen:

This office has been requested by the Board of Commissioners to furnish an opinion regarding who is to bear the expense when roots grow into sewer pipe, damage is done, and money is expended to cut the roots and repair the pipe. It is the conclusion of this office that the property owner, upon whose property the tree is growing, is responsible for any damage caused by roots which grow into or damage a sewer pipe. This is irrespective of whether it is a side sewer, lateral trunk or a main trunk of the Sewer District, if the tree is growing on land owned by a private property owner. This conclusion is based upon the statutory law on nuisances as codified under Revised Code of Washington 7.48.010 and 7.48.020. These statutes give a person or corporation the right to bring a lawsuit to abate a nuisance and recover damages. Furthermore, the King County Code sets forth clearly at §14.04.300 that it is unlawful to plant a tree within thirty (30) feet of the sewer line. The Code further, at §14.04.310, gives the county authority, through its county health officer, upon failure of a notified property owner to remove the root, to remove the root, repair the damage and place a lien upon the property owner for expense.

RATIONALE

While the common law is in disagreement as to whether a party can recover where there has been invasion of an adjoining property owner's land either by limbs of a tree or roots of a tree, it is fairly clear in Washington, in light of our statutory law of nuisance, R.C.W. 7.48.010, a limb or root of a tree which encroaches the property of another is a nuisance and, if damage is sustained by the other property owner, he can recover against the owner of the tree. The statute sets forth:

> ...an obstruction to the free use of property so as to essentially interfere with the comfortable enjoyment of the life and property, is a nuisance and the subject of an action for damages and other and further relief.

Pursuant to R.C.W. 7.48.020, "Such action may be brought by any person whose property is injuriously affected or whose personal enjoyment is lessened by the nuisance."

Throughout the common law, branches of overhanging trees and roots have been placed in the same category. Quoting from Coke, Litt, Section 4, "From ancient times, it has been a principle of law that the land owner has exclusive right to the space above the surface above his property. To whomsoever the soil belongs, he also owns to the sky and to the depths. The owner of a piece of land owns everything above it and below it to a definite extent." British case law is as follows:

> "Nuisances by an act of commission are committed in defiance of those whom such nuisances injure, and the injured party may abate them, without notice to the person who committed them; but there is no decided case which sanctions the abatement, by an individual, of nuisances from omission, except that of cutting the branches of trees which overhang a public road, or the private property of the person who cuts them. The permitting these branches to extend so far beyond the soil of the owner of the trees, is a most unequivocal act of negligence, which distinguishes this case from most of the other cases that have occurred. The security of lives and property may sometimes require so speedy a remedy as not to allow time to call on the person on whose property the mischief has arisen to remedy it. In such cases an individual would be justified in abating a nuisance from omission without notice. In all other cases of such nuisances, persons should not take the law into their own hands, but follow the advise of Lord Hale, and appeal to a court of justice."

> "Trees whose branches extend over the land of another are not nuisances, except to the extent to which the branches overhang the adjoining land. To that extent they are technical nuisances, and the person over whose land they extend may cut them off, or have his action for damages, if any have been sustained therefrom, and an abatement of the nuisance against the owner or occupant of the land on which they grow, the branches thereof beyond the extent to which they overhang his soil." Wood, Nuisances (3d ed.), §108.

> "It may be understood that any erection upon one man's land, that projects over the land of another, as well a. any tree whose branches thus project, doing actual damage, or anything that interferes with the rights of an adjoining owner, is an actionable nuisance." Wood, Nuisances, §106. Lonsdale v. Nelson, 2 B.&C. 311.

Historically, the question was somewhat in doubt as to whether damage done to an adjacent property owner by an overhanging limb or a root would sustain a cause of action by the party injured. In Washington, in the case of Gostina v. Ryland, 116 Wash. 228 (1920), it was held that an overhanging branch which deposited leaves and needles on the adjacent property was an actionable nuisance, since it deprived the adjacent property owner of his free use and enjoyment of the property. Even though the damages were nominal, there were expenses to the property owner in raking up the leaves and he did have a right of action and could recover monies for damages proven.

It is the law that the adjoining property owner has the right to cut roots off at the property line as they emerge from the other party's property and the same applies for the limbs of a tree. However, the adjoining property owner cannot cut down the tree without an action being brought.

In California, in Shevlin v. Johnston, 205 Pac. 1087 (1922), it was held that roots of a tree are a nuisance and that the adjacent property owner could recover for damages caused to his crops.

SUMMARY AND RECOMMENDATION

The expenses caused by a root of a tree which damages a sewer pipe on property held by the sewer district may be recovered from the property owner upon whose land the tree is growing. Notice should be given to the property owner if and when an obstruction does occur so that he may mitigate his expenses by cutting the roots and repairing the pipe subject to district supervision. However, if he does fail to repair the pipe, then the district has the right to repair its sewer pipe, cut the roots and look to the property owner for reimbursement of the expenses.

We will be happy to discuss any questions raised by this opinion with you.

STERN, GAYLON, NEUBAUER & BRUCKER

By: Robert E. Prince

REP:ss

City of Yakima, Washington
Date: September 8, 1975

Yakima, a city of 46,000, is located in south-central Washington. Although the annual rainfall is only about 20 cm (8 in), the surrounding area is devoted principally to growth of fruit and vegetables. Abundant water is available for irrigation from mountain streams. Most properties within Yakima are served by two water systems – one for potable water and fire protection and the second for lawn sprinkling and irrigation

The city is served by about 322 km (200 mi) of sanitary sewers and 105 km (65 mi) of storm sewers. Since about one-third of the homes in Yakima have basements, sewer depths average about 2.1 to 3 m (7 to 10 ft). About one-half of the sewerage system is in public rights-of-way (streets or alleys) and the remaining half is installed in easements. Soils typical to the area include "hardpan" clay, crumbly shale, gravel, and sandy loam. There is no known solid rock at sewer elevations. Through the years most backfill for sewer trenches has consisted of original materials. About one-third of the sanitary system is below groundwater elevation at least a portion of the year.

Early portions of the sanitary system, dated as early as 1908, were constructed of concrete (60%) and vitrified clay (40%). Recent extensions have been made using PVC, transite, and concrete pipe

Sewer System Maintenance

About 8 km (5 mi) of the 322-km (200 mi) system have been designated for special attention because of root growth or grease deposits. Various portions of these 8 km (5 mi) get weekly, twice monthly, or every three month attention. Water is pumped from a 5,678-l (1,500 gal) tank into a manhole and flow is observed at a downstream manhole. If additional work appears necessary, it is scheduled to be cleaned by a rodding machine or the hydraulic jet.

Normal root growth is cut by use of the rodding machine. City personnel have not used a root cutting attachment on the jet. Several times each year, heavy root growth is found which cannot be cut by normal methods City personnel have devised homemade tools, fitting various size sewers, to cut this growth. These tools consist of steel pipe about 45 cm (18 in) in length with wall thickness of 0.6 or 1 cm (1/8 or 3/8 in.). The ends of pipe are cut into a saw-tooth pattern and hooks are welded to each end of the tool for use in pulling through the system.

Bucket machine cables are attached to each end of the tool and pulled through the system – often after several attempts. Depending on the severity of root growth, the tool is periodically reversed to the original manhole and the cut portion removed. In the event of extremely dense growth, a tool one-half the sewer size is used initially, followed by a tool nearly equal to the inside diameter of the sewer. A three-man crew performs this work

Field personnel report an additional use for this tool. Occasionally protruding service laterals are found which prohibit normal cleaning practices and the use of TV. On many occasions the homemade tool has been used to actually break off the protruding portion of a service. On only one occasion has this resulted in breaking the service outside the main sewer line so that a dig-up was necessary.

The remainder of the 322-km (200 mi) system (except the 8 km (5 mi) given special attention and about one-quarter of the system that is relatively new) is flushed annually and rodded or jetted on about a two-year cycle. During 1974, the city cleaned about 47 km (29 mi) with the jet machine and 76 km (47 mi) with rodding equipment. The jet has been found to be especially successful for cleaning grease. Rodding, jetting, and flushing are each performed with two-men crews.

The city recently purchased its own television equipment without pressure grouting capabilities. Initially the equipment is being used in conjunction with an I/I evaluation of the system. Staff reported that cleaning techniques are being revised as a result of the internal inspections.

The city does not accept responsibility for maintenance of services and experiences about 50 mainline stoppages per year. About 75 percent of the calls regarding sewer blockages are found to be caused by services rather than mains.

Root Growth in Sewers

Historically Yakima has had severe problems with roots in sewers. Sixty percent of the problems are caused by cottonwoods or willows, with willows being the single worst offender. Occasionally problems are encountered with roots from sugar maples, weeping birch, poplars, and even from fruit trees in areas with shallow sewers (less than 1.5 m (5 ft) depth). In one case, asparagus roots blocked a 1.2-m (4 ft) deep sewer in a field which was not being irrigated. Another sewer 2.4-m (8 ft) deep was blocked twice each year by lilac roots. Root problems appear at any time during the year.

Roots enter sewers at open joints of old pipe. A significant portion enter the lower quadrant – no pattern of entry is discernible. Staff do not feel that roots can break a sound sewer pipe.

Roots have also been found in storm sewers, which in Yakima are installed at 0.6 to 2 m (2 to 6 ft) depths. The normal minimum diameter storm sewer is 30 5 cm (12 in.) A few years ago a 30-m (100 ft) length of 66 cm (27 in) storm sewer was found to be virtually full of roots – all but the top 7.5 cm (3 in) Roots from cottonwood and poplar trees were "thumb-sized." After several futile attempts at cleaning by normal methods, the previously described tool was built to fit the 66-cm (27 in) sewer and the 30-m (100 ft) span was cleaned in four hours.

Chemical Treatment of Roots

About 15 years ago Yakima periodically deposited about 0.9 kg (2 lb) of copper sulfate in manholes where root problems were encountered. Staff reported only limited success since they did not block sewer lines and hold the chemicals to get maximum benefit.

Subsequent crews used "hot" chemicals – primarily San Fax. This also was used without ordinary controls – merely dumped into manholes. An entire 19 l (5 gal) was used at one location. Few beneficial results were noted

During the past several years chemicals seldom have been used. For one troublesome sewer span, crews drilled holes 1 m (3 ft) apart to an elevation of 38 cm (15 in.) above the sewer. The ground then was saturated with liquid caustic soda and no problems have since been encountered Trees apparently were not damaged.

Metropolitan Waste Control Commission, St. Paul, Minnesota
Date: September 15-16, 1975

The Metropolitan Council of the Twin Cities Area serves the seven-county metropolitan area of Minneapolis-St. Paul, Minnesota.

The Metropolitan Waste Control Commission consists of nine members – eight appointed by the Metropolitan Council and a chairman appointed by the governor. The commission employs 450 people and provides wastewater treatment and disposal services for the two million people living in the 7,813-sq.-km (3,000 sq. mi) seven-county area. Enabling legislation gives the commission some authority in solid waste matters, but few activities are presently being conducted.

The commission maintains 644 km (400 mi) of interceptor sewers and 19 wastewater treatment plants (formerly 33). The number of plants will continue to be reduced to about 12.

Development of Present Regulator System

System studies in the 1950s and 1960s revealed that numerous combined sewer overflow incidences were occurring at times when trunk and interceptor sewers were operating at less than capacity. Permanent weirs downstream from regulator chambers were being overtopped with resulting combined sewer discharges to the river systems

In April 1966, the district obtained an FWPCA Demonstration Grant for the installation of a "Dispatching System for Control of Combined Sewer Losses" (see 11020 FAQ March, 1971). Regulator modifications were then constructed, and a central computer monitoring and control station installed, as well as rain gauges and river monitoring stations.

About 90 percent of St. Paul and 40 percent of Minneapolis are served by combined sewers. Sixteen control and monitoring stations were originally constructed. Thirteen were furnished with inflatable Fabridam bags installed in the trunk sewers immediately downstream from the regulator gates. Fifteen bags were installed at the thirteen stations The 16 monitoring stations handle about 80 percent of the combined sewage of the metropolitan area.

Each regulator gate is operated by operating cylinders through a hydraulic power system located in the equipment vault. The gate position is monitored by a potentiometer This underground chamber also contains equipment and controls for inflating and deflating the dams, including an air compressor, pressure switch for deflating the dam, and a water column whose height equals the maximum allowable internal dam pressure 0.14 kgf/cm^2 (2 p.s.i.). This water column was installed as a back-up release device in the event a pressure switch became inoperative. All controls in underground vaults are connected to a central computer station by a telemetry system.

Sewage level sensing devices (bubblers) were installed at all regulator stations and at several locations in intercepting sewers. Three devices were installed at most stations – in the trunk sewer upstream from the regulator gate and downstream below the dam and in the outlet pipe to the interceptor.

Nine rain gauges were installed at various locations in the Twin Cities. Gauges operate through weight measurement with the scale pan movement transmitted mechanically to a potentiometer and to the central computer station through telemetry equipment.

In order to evaluate the effects of combined sewer overflows, five river quality monitors were installed in river areas most affected by overflows. One was installed in the Minneapolis Water Treatment Plant and the remaining four in 2 4 m x 6.7 m (8 ft x 22 ft) two-wheeled trailers. The stations monitor pH, conductivity, oxygen-reduction potential, temperature, chlorides, and dissolved oxygen. Each station is connected to the central computer station by telemetry equipment.

The central computer station monitors sewage elevations in interceptor and trunk sewers, position of regulator gates, air pressure in inflatable bags, rain gauges, and river quality stations. Printouts are available on an hourly basis during dry weather and on a 15-minute basis or more often, during rainfall periods.

The total construction and installation cost of the combined sewer control system was $815,000 and divided as follows:

Computer & Telemetry	$290,000
Regulator Stations	460,000
River Quality Monitors	65,000
TOTAL	$815,000

Operation and Maintenance of the System

Inflatable dams are maintained in full or inflated condition during dry flows and during wet-weather flows until sewage in trunk sewers starts to overflow the dams. Dams then are immediately deflated to prevent damage to fabric No attempt is made to regulate overflows through variable air pressure within the dams

Two benefits are realized through the utilization of the dams. Sewage is stored behind the dams and, for lesser rainfall intensities, overflow incidences are prevented. Secondly, by raising the elevation of the sewage at the regulator gate, more sewage is forced through the gate to the interceptor. Previously, interceptors had been operating during storms at considerably less than full capacity

Minor air leaks occur regularly in bags and are repaired with patching material similar in nature to that used in the repair of inner tubes Bags have been completely ruined – badly torn – at three stations. After replacement, bags at two of the stations were ruined again and not replaced. At these stations sewer grades approaching the bays are about 2 to 3 percent It is presumed that flow velocities are such that inflatable dams cannot be maintained. In these instances the bags were about 1.5 m (5 ft) high in sewers about 2.7 m x 3 m (9 ft x 10 ft). Replacement bags, including attachment materials, cost about $4,000 to $6,000, depending on size, and $1,500 for installation.

The commission budget for 1976 includes an item of $255,000 for regulator system maintenance. About $177,000 is for employee salaries and fringe benefits The staff includes six full-time field men and part-time electrical and pipe fitter personnel. The field crew maintains the 16 regulator stations, dams, and controls; monitors 150 fixed weirs after every storm; and performs some plant maintenance work. About 25 percent of their time is thought to be given to maintenance of regulators. Maintenance at regulator stations includes patching of dams (6 per year), replacing of bubbler tubes damaged by sewage flows, replacing water in standpipes after each use, and repairing telemetry equipment (primarily frequency drifts). Staff reported only occasional minor problems with lines leased from local telephone company.

Evaluation of the Control System

The control system has been successful in eliminating many overflow occurrences. In one test period, overflow occurrences were reduced by 58 percent and hours of overflow were reduced by 88 percent. In one period of seven rainfall events, overflow volumes were reduced by 51 percent.

Although the system is not adjusted for varying rainfall conditions or intensities, rainfall information is valuable for storm modelling and other considerations. River quality monitoring has shown little or no water quality improvement due to reduced overflows, but measurable improvements due to improvements to treatment plants.

The central computer system in fact does not "operate" the system during a storm. No advance preparation of the sewerage system is made when a storm approaches except to be sure that dams are inflated. Regulator gates are open at virtually all times, and dams are deflated by local controls through pressure switches or standpipe blow-offs. The operator of the central system does have the capability, however, of adjusting regulator gates and deflating bags.

APPENDIX C

TIDE GATE SURVEY QUESTIONNAIRE AND RESPONSES

Page No.

TABLE C-1
AGENCIES RESPONDING TO SURVEY

City and County of San Francisco
Denver, Colorado
Pueblo, Colorado
Hartford, Connecticut
Norwich, Connecticut
Savannah, Georgia
Chicago, Illinois
DesPlaines, Illinois
Muncie, Indiana
Council Bluffs, Iowa
DesMoines, Iowa
Owensboro, Kentucky
Portland, Maine
Winnipeg, Manitoba
Boston, Massachusetts
Fall River, Massachusetts
Lynn, Massachusetts
New Bedford, Massachusetts
Springfield, Massachusetts
Bay City, Michigan
Lansing, Michigan
Port Huron, Michigan
Saginaw, Michigan
Troy, Michigan
St. Paul, Minnesota
Kansas City, Missouri
St. Joseph, Missouri
Buffalo, New York
Olean, New York
Wards Island, New York
Cincinnati, Ohio
Cleveland, Ohio
Cuyahoga Heights, Ohio
Lima, Ohio
Toledo, Ohio
Warren, Ohio
Youngstown, Ohio
Toronto, Ontario
Eugene, Oregon
Portland, Oregon
Lancaster, Pennsylvania
Pittsburgh, Pennsylvania
Providence, Rhode Island
Chattanooga, Tennessee
Beaumont, Texas
Richmond, Virginia
Everett, Washington
Seattle, Washington
Huntington, West Virginia
Weirton, West Virginia
Kenosha, Wisconsin
Milwaukee, Wisconsin
Racine, Wisconsin

APWA RESEARCH FOUNDATION
TIDE GATE SURVEY

August 21, 1975

AGENCY ______________________________

PERSON COMPLETING QUESTIONNAIRE.

NAME ______________________ TITLE ______________________

ADDRESS ______________________ CITY ______________________

State/Province ______________ Zip Code ______________ Phone ______________________
(Area Code) (Number)

A. PROBLEMS EXPERIENCED

Has there been:

1. Local system overloading? Yes _____ No _____ If yes, approximate days per year _____days
2. Increased overflows or spills into sewer system? Yes _____ No_____
3. Increasted treatment plant flows? Yes _____ No _____
4. Any effect on treatment plant performance? Yes _____ No _____ If yes, describe ______________________

   ____

   For coastal areas, maximum chloride level _____ppm
5. Increased pumping volumes and bypassing? Yes _____ No _____
6. Amount of additional flow into system due to tide gate problems?

	mgd Max.	Avg.
Pumping	_______	_______
Treatment	_______	_______

7. Describe how presence of backwater is determined?

   ____

   ____

Three general types of tide gates have been listed. Please list information by gate type. If type does not fit, use "Other" and describe under question

B. APPLICATION	**NUMBER BY GATE TYPE** Flap	Pontoon	Side Pivot	Other
1 Number of units used	_______	_______	_______	_______
2. Gate Size:				
Under 24"	_______	_______	_______	_______
24" to 42"	_______	_______	_______	_______
42" to 72"	_______	_______	_______	_______
Over 72"	_______	_______	_______	_______
3. Approximate year first unit installed	_______	_______	_______	_______
Year latest gate installed	_______	_______	_______	_______
Estimated useful life of gate	_______	_______	_______	_______
4. Are design drawings available	_______	_______	_______	_______
Can APWA obtain copies	_______	_______	_______	_______
5. Systems protected:				
Interceptor	_______	_______	_______	_______
Sanitary sewer collector	_______	_______	_______	_______
Combined sewer collector	_______	_______	_______	_______
Storm sewer	_______	_______	_______	_______

Application — Systems protected (Continued)	Flap	Pontoon	Side Pivot	Other
Open stream				
Treatment facility outfalls				
Pump station				
Mechanical Regulator				
6. Water kept out:				
Ocean				
River				
Sanitary storm sewer interconnects				
Other				
7. Are gates installed in tandem? (yes, no)				
C. DESIGN				
1. Material				
Cast iron				
Steel				
Bronze				
Aluminum				
Special alloys (specify)				
Timber (specify)				
Other (specify)				
2. Pivots.				
Single				
Double				
3. Seats:				
Same as body				
Bronze				
Soft (rubber, etc.)				
4 Are power-actuated sluice gates used? (yes, no) If yes, number used.				
5. Are counter weights used? (yes, no)				
D. PERFORMANCE				
1. Performance is				
Good				
Fair				
Poor				
Unacceptable				

Performance (continued)	Flap	Pontoon	Side Pivot	Other
2. Typical gate failure: (check where suitable)				
None	____	____	____	____
Fouled	____	____	____	____
Stuck shut	____	____	____	____
Stuck open	____	____	____	____
Leaks	____	____	____	____
Corroded	____	____	____	____
Broken	____	____	____	____
3 Number of gates no longer maintained due to cost	____	____	____	____
Due to mechanical problems	____	____	____	____
4. Are types of tide gates used suitable for the service required? (yes, no)	____	____	____	____

E. MAINTENANCE

1. Times per year gate is checked or serviced	____	____	____	____
2. Gate is checked or serviced because of:				
Complaint	____	____	____	____
Routine schedule	____	____	____	____
System operating problems	____	____	____	____
Other	____	____	____	____
3 Size crew used to check or service gate (number of men)	____	____	____	____
4 Number of tide gates with remote monitoring control	____	____	____	____

5. Special equipment used ________________________________

____

____

6 Do you have a monitoring or survey system to alert you when any particular gate fails? If yes, describe.

____

____

____

7. If yes, is system effective? Yes _____ No _____

8. Man hours spent in tide gate maintenance last year ________________ mh/yr

9. Funds spent for tide gate maintenance last year ________________ $/yr

F. GATE MANUFACTURE

Manufacturers of gates used — list all used and catalogue numbers if available

Flap. ____

____

____

____

____

Pontoon: ______________________________

____

____

____

____

Side Pivot: ______________________________

____

____

____

____

Other ______________________________

____

____

____

____

6. FUTURE PLANNING

1. Do you now have plans to construct new tide gate installations in the next five (5) years? Yes _____ No _____

   If yes, describe. ______________________________

   ____

   ____

2. Do you have a backwater or reverse flow condition that is not now properly controlled? Yes _____ No _____

   If yes, describe. ______________________________

   ____

   ____

3. If present devices are not suitable, please describe features of a device which would provide more satisfactory service

   ____

   ____

   ____

   ____

   ____

COMMENTS. ______________________________

____

____

____

PLEASE RETURN TO

Richard H. Sullivan, General Manager
American Public Works Association Research Foundation
1313 East 60th Street, Room 345
Chicago, Illinois 60637

City of Cincinnati, Ohio
Date: September 16-17, 1975

Persons Contacted: Jerry Seymour, George Hurddle, Richard Vanderhoof, Arthur Schwer, Ralph Shie

Preliminary information on the Cincinnati system led to the choice of this agency as one of the on-site investigation points in the national survey. It was assumed that a system of backwater gates on the Cincinnati overflows was tied into a telemetry network which alerted the District to gate malfunctions and provided other regulatory recordings of related parts of the sewer system.

The Greater Cincinnati Sewer System

The following information on the Cincinnati sewer system, overflows, backwater gate installations, pumping and lift stations, and the telemetry alert system now limited to pumping stations is taken from the investigator's notes recorded during the two-day survey. Much of the pertinent data requested during the investigation interviews was not available in record form. For example, no official listing of overflows and backwater installations was available.

Telemetry alert equipment was installed on the system's overflow points approximately ten years ago but it failed to achieve its purpose and has been abandoned. Telemetry sensing devices are now limited to pumping station alert operations, with only minor relation to the overflow program and the backwater gate control network, if any.

The backwater gate program in the Greater Cincinnati system is of limited significance in the national survey being conducted by the APWA Research Foundation because of the small number of backwater control installations involved and the minor importance placed in them by the Metropolitan Sewer District

The information contained hereafter is presented with these conditions in mind The on-site survey was, however, of importance to the national study because something can be learned about remote monitoring of sewer system overflows and any relationship, specific or vague, between overflow telemetry and backwater gate operations.

Because of the terrain, pumping of flows is required. A total of some 87 lift stations, many pneumatic and package in type, are in service, together with six so-called permanent pumping stations. The package stations are scheduled to be phased out when the areas served by package treatment plants are sewered and connected to interceptor systems.

The nature of the interceptor systems as combined in function has made it necessary to install over 200 (number not known) overflow-regulator chambers. Regulators in overflow chamber installations vary from Brown & Brown hydraulically operated sluice gates to less sophisticated non-mechanical units. A number of the regulators function on the principle that the sewer connection to the interceptor is small-sized and all flows above the capacity of such lines are diverted to receiving streams. The original estimate during the interview session was that from 50 to 75 Brown & Brown sluice gates are in service. This range indicates the absence of tabulated listings at the time of the survey

Backwater Gates

A small percentage – probably under 10 percent – of the system overflows are provided with backwater gates; of over 50 outlets into Mill Creek, perhaps 10 or 12 are backgated; no backwater gates are installed on the overflows into Muddy Creek.

The minimum number of backwater gates is explainable on the basis that much of the District system provides high-level overflows that are not subject to river level fluctuations.

All backwater gates were reported to be located at the edge of receiving streams, not in separate chambers.

The area streams are protected, more or less, against flood levels by a series of regulating dams.

Most of the backwater gates are of cast iron construction, top-hinged with single pin pivots and two-hinge connections. Officials reported no tandem installations Seats of backwater gates were reported to be the same as the body, with some providing rubber or plastic seats. One steel plate unit was inspected. One timber unit was reported, made of creosoted pine or other standard wood – not special, such as is used in New York City's system.

No specific crew handles backwater gates. The regulator crews which cover all installations on every-other-day schedule do not routinely inspect backwater gates which are normally located at remote points from the actual regulator-overflow chambers If there is evidence of backup of stream water into the chamber, the crews will investigate the condition of the backwater unit. Each regulator-rack-overflow crew covers an area which permits it to contact each location every other day, as stated. The crews clean the racks and perform any other necessary maintenance work There is no system which now records overflow incidents or periods of duration. The monitoring system originally installed for this purpose has been dismantled

The existing backwater gates are old. One unit was installed in 1975, however, on Mill Creek to protect low-lying overflow from back-flooding. The treatment plant outfalls are not backgated Reference was made during the interview to some backwater gating on storm sewer discharges. Some pumping station emergency overflows may be gated.

Telemetering System

Approximately ten years ago (specific date not given), the Metropolitan Sanitary District of Greater Cincinnati installed a telemetering system on its overflows to provide an alert and recording procedure to monitor overflow incidents and duration of such discharges from its sewer system into receiving waters. The sensitive probes in the overflow structures were installed on the crest of overflow dams or other devices, with electronic impulses transmitted by leased telephone wires to a control center located at the Mill Creek Treatment Plant

Operational difficulties were encountered in the system installed by Autocon, Minneapolis-St. Paul, Minnesota, not because of defects in the system but due to problems in the installation chambers. Rather than utilizing a separate probe and alert connection for each chamber, chambers were grouped in many cases and signals received at the control console, indicating that the sensitive probe or probes had been wetted, thus indicating spill to receiving waters, left crews undecided which chamber was reporting difficulty. It then became necessary to check multiple installations to ascertain the surcharge condition being reported by the sensitive telemetering system. In addition, the probes were subject to wetting and signal transmission that was not indicative of overflow conditions The probes reacted to condensation in the chambers, dripping of water and other meaningless conditions. In addition, vandalism damaged parts of the system

Because of these difficulties the system was phased out but the leased wires were continued. Thereafter, the cost of wire leasing was deemed excessive and the whole system was dismantled The system lay dormant until more recently, according to comments during the survey visit, a few units were again activated to see if the system could be made to work effectively. This test proved unsuccessful, according to reports, and the system is now inoperative. A panel showing the old system is on display in the lobby of the administration building at the Mill Creek plant.

A separate telemetry system is now in service on pumping stations, with the central console located in a control room at the Mill Creek plant It monitors three station conditions. Excessively high wet well levels; power failure; and water accumulations in dry wells. The system is by Autocon. It works effectively to indicate the designated failures and to provide a printout of the circumstances.

City of New York, New York
Date. August 21, September 12, 1975

Persons Contacted: Edward Wagner, William Paulmeno

The combined sewer system, coupled with the coastal location of a relatively flat, low-lying island format and the wide tide changes in New York Harbor and its tributary streams and estuaries, underlies the need for tide gate protection of the sewer system. Like other coastal cities, the protective gates on the outfall lines are of true tide gate character, rather than of backwater type.

It is significant that New York's tide gate installations are associated with watershed basin areas tributary to a series of wastewater treatment plants located in various areas of the city. This is so because the installation of tide gates dates back to the first construction of treatment plants to serve low-lying areas of the city. While much of the city's sewer system outlets are affected by tidal actions and require tide gate protection, some areas are sufficiently high to permit combined sewer overflows to discharge into streams that flow into the tide-affected harbor without backwater gate protection It is understood, however, that tidal changes are felt in all waters surrounding the island and peninsula confines of New York and that tides back up waters in the Hudson River some distance to the north of the city.

The relationship between tide gate installations and wastewater treatment in New York City is demonstrated by the fact that the first gates were installed in 1937 in the interceptor system tributary to the Wards Island plant built in 1937. Subsequently, as treatment plants were built, tide gate facilities were installed in such interceptor drainage areas as were affected by tide changes.

Tide Gate Installations

New York City requires a great number of tide gates. The on-site investigation disclosed that approximately 365 gates of various types and sizes are in service A listing of all tide gates was obtained and it is included as a supplement to this report.

The survey questionnaire (the original form of the questionnaire was used during the interview session of August 21, 1975) indicates that approximately 160 flap gates are used in sizes from under 61 cm (2 ft.) to 105 to 180 cm (42-72 in.), with only one of over 180 cm (72 in.) size because of the weight of such a casting Pontoon-type tide gates have been used for the larger sizes – from 105 cm (42 in.) to over 180 cm (72 in.). Timber gates are also installed in the larger applications.

The history of tide gate types, as they applied to New York City applications, was discussed during the interview sessions. Cast iron gates were reported to be the first type developed and they were first used in the city's system. Early version of timber gates dates back to the beginning of the 1930's or prior to that time. Pontoon-type gates of fabricated construction were developed for New York City use in the later 1940s and 1950s.

Experience with these three basic types of tide gates was explored. Cast iron gates have demonstrated long life of materials, with problems limited to hinge breakage and other casting breakage. The cast iron units have resisted corrosion and other deterioration conditions. Pontoon gates have rusted, or tended to deteriorate, after some ten years of service. Original timber gates, built with long-leaf yellow pine, creosoted, with horizontal planking, experienced rotting and they were reported to have had a useful life of approximately ten years. To correct this condition and to enable the city to use timeber gates for its larger-sized installations, a new design was specified Present timber gates are built of "Greenheart" – "Neetanda Rodioe" – imported from British Guiana, not creosoted, and with planks laid vertically. This heavy, resistant timber was reported to be long-lived and to resist the destructive actions of sewage and saline waters which affected the yellow pine material.

Because of maintenance experiences, the city no longer specifies pontoon-type gates in order to avoid short-life and lack of rigidity Gates are now either cast iron for sizes up to approximately 105 cm (42 in.), and timber for larger sizes. Pontoon gates are still in service but a number are in poor condition During the field inspection trip, the investigator saw a pontoon gate with the bottom portion completely rusted away, it was allowing a tide back water flow of an estimated 3 mgd to enter the interceptor at Bruckner Boulevard and Brook Avenue in the Bronx, tributary to the Wards Island grit chamber-pumping station. This installation contained three pontoons of 2 m x 2 m (6 5 x 6.5 ft.) size. This chamber was found to be back-leaking at the rate of 1.3 mgd in 1964, estimated. The chlorides at the grit chamber station were found to be 560 ppm at that time, as compared to a "normal" sanitary sewer chloride content of 120 ppm. Reference is made here to this field survey finding in order to show the effect of pontoon gate deterioration.

The usual location of tide gates is in chambers downstream from regulator chambers. The investigator gained the impression from the interviewees that no shoreline gate installations are in use but some instances of such locations may be included in the far-flung New York City system.

A limited number of backwater gates serve other purpose than to prevent tide inflow into the city's interceptors. The survey disclosed that ten or less interconnects between sanitary sewers and combined or storm sewers exist and that, where necessary, these lines are protected by backwater gate units. In addition, some open streams in the outlying areas enter tidal waters and may be protected by backwater gates The location of such facilities was not disclosed but reference was made during the interview discussions to the existence of such open stream or drainage ditch facilities, with or without gate protection

Tide gates are often installed in parallel, with two or more units protecting the same chamber from tide backups. A limited number of installations were reported to be tandem in nature, with one set of gates backing up another set in case of failure or leakage.

New York City tide gates are designed to provide positive seals between the gate and the seat frames or bases. For cast iron gates, city officials reported that rubber or rubber-like seals are installed on the seat with nothing on the gate castings. For pontoon-type gates, the seal is installed on the movable gate with the seat made of granite blocks, or the reverse procedure is used – with the seal on the seat and dependence made on the gate surface to produce a tight closure. On timber gates, the rubber seal material is usually attached to the timber structure and the seat is made of bronze. Here, too, the sealing procedure may be reversed with the bronze facing installed on the gate proper and the sealing material on the frame

It is evident that the bulk of tide gates in the city system were installed in the interceptors when new treatment plants were constructed. New plants will be limited in the future, with the bulk of the city's treatment facilities involving upgrading and up-sizing existing works. The latest tide gate installations were reported by the interviewees to have been made in 1974 – a flap gate or gates and a timber gate or gates No pontoons have been used since 1960.

Tide Gate Maintenance

Previous reference has been made to the dependability of the three types of tide gates used by the city of New York and to the discontinuance of pontoon-type units and conversion of yellow pine timber to long-lasting "Greenheart" material. Except for the conditions already described, New York City sewer officials characterize gate performance as "good" for flap units of cast iron construction, "good" for new timber gates, and "poor" for the old yellow pine units. Over the years, New York City tide gates have been of Coldwell-Wilcox, Rodney Hunt, Brown & Brown, and McNulty manufacture.

Reference should be made to the paradox involving the growth of marine borers which can affect timber gates. "Limnoria," or marine borers, are more active in clean waters than in polluted waters. Dock structures have been known to deteriorate more frequently in saline water sources which have been improved by adequate wastewater treatment The New York City sewer officials indicated that the shift from yellow pine to "Greenheart" was motivated, in part, by the fact that pollution clean-up might produce greater borer problems for timber that is subject to deterioration.

Gate failures were reported to be due to fouling for all three types of tide gates; sticking or binding of flap and pontoon units; and fouling of timber gates. Corrosion and breaking of hinges and frames were reported for flap and pontoon gates as well as for timber gates. The timber gate reference did not state whether it related to the older units or the new type of design. It was stated that all gates in service are maintained but reference must be made to the investigator's comments about corroded gates and missing gates observed during his field survey.

Regulators and tide gates are serviced by the same crews – five crews of five men each which are responsible for specific drainage areas. The questionnaire describes the type of equipment utilized by the crews; the investigator observed this equipment and its use. The crews seem to be knowledgeable.

Frequency of tide gate inspection and servicing was reported to vary from once monthly to once weekly, depending on specific locations, types of gates, and other maintenance factors. Visits to gate chambers are on a routine basis, supplemented by additional maintenance visits due to complaints. Excessive flows in interceptors, at pumping stations, or at treatment plants result in searches for defective gates in the affected areas. This points out the value of crew assignments to specific interceptor-treatment drainage basins.

It is significant that the system is under daily surveillance for chloride concentrations in incoming wastewater flows. High chlorides indicate poor tide gate closures; they result in check-ups of gate chambers over and above the scheduled routine inspections. The interviewees stated that crews are free to establish their own schedules under present maintenance practice, but that future schedules may be based on computer printout data Regulators may be serviced without similar attention to tide gate chambers.

No monitoring system involving sensitive probes and telemetry alerts is used in the city However, excessive pumping rates are used to alert crews to the probability that tide gate malfunctions exist. This is over and above the known high backwater flows caused by existing gate failures which are known to the crews, such as the chamber inspected by the investigator in the Bronx interceptor sector tributary to the grit chamber station.

Some tide gates are always submerged even during low tide, others are submerged only during high or medium tide conditions. Tide gate costs were estimated to range from $2,500 for small units to $11,000 for units of a size of about 3 m (10 ft) square of timber design. This covers only the gate units; chamber costs could not be obtained.

Detroit Metro Water Department, Detroit, Michigan
Date: August 27-28, 1975

The Detroit Metro Water Department provides water and wastewater services for the city of Detroit and many of its suburbs The Department provides wastewater collection and treatment services for the city of Detroit and transport and treatment services for a few cities in western Wayne County, substantial portions of Oakland County, and a part of Macomb County.

Development of Wastewater System

Virtually 100 percent of the wastewater collection system in Detroit consists of combined sewers, while contribution from adjacent communities is mostly from separate sanitary sewers Until the early 1930s the city sewers led directly into the Detroit and Rouge rivers. At that time a primary wastewater treatment plant was built near the confluence of the two rivers and sewers were built to intercept the river outfalls The plant now provides primary treatment for 34,065,000 m^3 /day (900 mgd), and a new addition provides secondary treatment for 567,750 m^3 /day (150 mgd). Regulator stations were constructed at many connecting points between the interceptor and collector sewers in order to regulate the amount of wet weather flow to be directed to the treatment plant and to river overflows. Backwater gates were installed in the overflows between the regulator chambers and the river outlets – some directly at the outlet. Since river elevations are generally higher than the flow lines of many outlet facilities, these backwater gates were installed to prevent river water from surcharging the collector system, flowing through the regulator chambers and adding to the burden at the treatment plant.

A schematic plan is attached to this report showing the relationship of the regulator chambers and appurtenances, the collector sewer, and the outfall

Dams were also constructed in many of the outfall facilities to prevent river water from entering the collection system Backwater gates have since been constructed in some of the facilities with dams.

Backwater gates in the outfalls of the Detroit system are not utilized to divert system flows nor to increase storage within the system, but merely to protect the system from river inflow.

Plans which accompany this report show the Rouge River Interceptor (one sheet) and the Detroit River Interceptor (two sheets). Each plan shows the type of protection equipment at various overflow points. The legends are not current, however, since many alterations have been made without plan correction. Although conflicting information was received from different sources, it appears that of 76 outfalls to the two rivers, 48 are protected by backwater gates The 48 outfalls are protected by 108 gates. More than half the gates are installed in tandem and many outfalls are multiple outlets with parallel gates.

Design for Backwater Gates

Backwater gates in Detroit have been installed in conformance with the "Specifications for Backwater Gates" (Section 9, five pages) and the plan showing "Timber Backwater Gate Details" all attached to this report The "Schedule of Dimensions" shown on the plan is adjusted for individual projects.

Also attached to this report are the "Plan & Profile" sheet and the "Backwater Gate Structure" sheet for the First Hamilton Relief Sewer Project. The Plan & Profile sheet shows relative locations of the collector sewer, regulator chamber, interceptor sewer, outfall box, and backwater gate chamber. The Backwater Gate Structure sheet shows construction details for the installation of 3 m x 3.7 m (10 ft x 12.2 ft) gates installed in tandem and in twin box configuration. Location and details are also shown for the "stop log" construction which can be used to provide emergency repairs to the gate nearest the river outfall.

Most of the backwater gates in the Detroit system were installed in the early 1930s and in general conformance with present specifications and detailed requirements. Staff were not aware which of the three permitted woods were used nor did they express preferences. No problems have been experienced with the flotation test requirements of Section 9.05.05 and weights have not been needed. Counterbalancing is not required Neoprene seals are used rather than the rubber specified in Section 9.02.07.

All gates are constructed with timbers placed vertically. It is presumed that this reduces costs since the vertical dimension is usually less than the horizontal dimension. In addition, hinge connections at the top of the gate have less of a weakening effect on vertical timbers

If gates are properly installed and maintained, department personnel indicate that they will open with a head differential of about 8 cm (3 in). In periods of extremely high flow, gates have been observed in a nearly horizontal position.

Proximity sensors are mounted slightly above the mid-point on all gates. The portion of the sensor attached to the wall of the outfall is connected to a control box above ground which contains the Quinder tone equipment. This in turn is connected to Systems Control – the centralized station in Department headquarters which monitors the sewerage and water systems through leased telephone lines. When the gate is closed the sensor portion attached to the gate is within about 0.6 cm (0 25 in) of the sensor mounted on the wall. This "completes the circuit" through a magnetic field and the signal to Systems Control indicates the gate is in a closed position. When the gate is open sufficiently to separate the two parts of the sensor by more than 1.3 cm (0.5 in) the signal indicates that the gate is in an open position.

A 1973 installation of four gates (parallel gates in tandem) along with the gate chamber cost $200,000.

Maintenance of Backwater Gates

Maintenance work for all backwater gates, sensing equipment, regulator chambers, and sluice gates is normally performed by one four-man crew. However, for the past year the crew has been reduced to two men plus a part-time employee

Maintenance personnel reported that they attempt to examine each gate and grease the hinges every one or two months when the crew is at its full complement. However, within the past year no such program has been attempted and the crew responds only to emergency calls.

Problems are encountered after every rainfall of sufficient intensity to overflow the system. This had occurred five days before the APWA visit and the crew had been notified by Systems Control of 10 gates where signals indicated that gates were open. Two basic problems regularly occur. debris preventing complete closure of the gates and malfunctioning of sensing devices.

The APWA interviewer, with the maintenance foreman, examined one outfall structure which had three parallel 2.4 m x 3 m (8 ft x 10 ft) gates and an additional three gates in tandem. Two of the gates were listed by Systems Control as "open." Small amounts of debris were deposited at the gate sill preventing complete closure River water, about 10 cm deep and 3 m wide (4 in deep and 10 ft wide), was flowing past the two gates toward the regulator chamber. The foreman, with an ordinary pry-bar, alternately opened and closed the gate by small amounts to allow river water to flush out the debris. When properly closed, only a minimal amount of leakage was observed.

Silt was deposited on the floor of all three outfalls in depths of 7.6 cm to 61 cm (3 in to 24 in). The foreman stated that the outfalls had been cleaned only five months previously at considerable expense. All such deposits must be removed through a 61-cm (2 ft) diameter manhole frame.

Problems with proximity sensors are generally caused by interruption in leased telephone line service or maladjustment of sensing components due to floating debris in the outfall. Location of sensor failure can usually be determined above ground at the control box. Correcting the problem may be more difficult since access to some of the gates is a "monstrous" job. Problems with telephone lines are generally related to storm damage to overhead wires or, all too often, careless linemen or sub-station personnel

The maintenance foreman reported special problems in relation to tandem gates where the outer gate is immediately adjacent to the river. When overflows subside, both gates close at the same time. The water behind the gate nearest the regulator continues to subside, thereby keeping that gate tightly closed. However, the water trapped between the two gates is at the same elevation as the river water, so there is very little head differential between the two sides of the outer gate. This gate then "chatters" or alternately swings open and shut with considerable force. One new gate was destroyed within one year, hinges were broken on another, and seals have been ruined on several such gates Additionally, continuous river currents have twisted some gates so that they cannot properly close.

The river elevations in the Detroit area are at what is thought to be an all-time high. As a consequence, river water is over-flowing outfall dams in several instances and flowing into the interceptor system. The maintenance crew has built several temporary plank dams as extensions of permanent dams, but these are only partially successful. Temporary dams wash out during storm overflows and are not replaced for several days One temporary dam was observed where river water was almost 30.5 cm (1 ft) above the elevation of the permanent dam.

The oldest timber gate in the Detroit system was installed in 1929. The wood is still in good condition. Some warping of timber has been noted on gates exposed to sunlight; however, none has needed replacement. One set of gates has been replaced in order to increase outfall capacity and perhaps three additional gates because of types of structural failure previously described.

System Monitoring and Control

The basic elements of the present monitoring system were installed in 1969. The system includes among other elements, 25 tipping rain gauges, proximity sensors at all backwater gates, pressure indicators at three inflatable dams, and about 200 level sensors located at various points within the collector and interceptor system These elements are all monitored at Systems Control. Nine combined sewer lift stations are also monitored.

Rain gauges are located throughout Wayne County with a few in adjacent counties. Computer printouts show rainfall by five-minute intervals as well as hourly and daily totals. Additional rainfall information is acquired from the Southeastern Michigan Council of Governments

When rain is anticipated or observed on the 201 km (125 mi) range radar screen, collector and interceptor systems are pumped down as much as possible and the three dams inflated at the appropriate time. Overflow incidences have been substantially reduced so that now each of the 76 overflow points discharges an average of about 125 hours per year.

The monitoring system at System Control provides information which is useful for system maintenance, helps in preventing or minimizing overflows, and provides information for a program of stormwater modelling. The system is fully described in a May 1975 U.S. Environmental Protection Agency publication, 670/2-75-020, entitled, "Sewerage System Monitoring and Remote Control." Also a June 1975 U.S.E.P.A. publication, 670/2-75-065, entitled, "Applications of Stormwater Models" relates to the Detroit experience.

Cast Iron Tide Gates

As shown on the attached plan entitled, "Automatic Sewage Regulator," many of the existing regulator stations have cast iron tide gates which allow a surcharged interceptor to overflow into the river outfall. Staff indicate that this has never occurred and the gates receive practically no maintenance.

A few small outfalls are protected by metal tide gates with the largest being 122 cm x 137 cm (48 in x 54 in). Little problem is encountered with these gates. Less debris collects in the smaller sewers due to scouring action. Most of the gates have brass seals although some are neoprene.

Cast iron tide gates also have been installed at some of the pumping stations The hinge pins in at least one such gate must be replaced annually because of instant pressures exerted when pumps are shut off with resulting strong backwater force. The entire Detroit system has about 30-35 metal tide gates.

Gate Manufacturers

The following lists the manufacturers of gates and dams used in the Detroit system.

Timber Gates	Brown & Brown
	Waterman
Cast Iron Gates	Brown & Brown
	Armco
	Rodney Hunt
Inflatable Dams	Firestone
	(Installed by N H. Ibertson & Associates, Burbank, CA)

Specifications for Backwater Gates
Detroit Metro Water Department
August, 1975

SECTION 9 BACKWATER GATES

9.01 General

This section covers the materials, fabrication, installation, and testing of backwater gates.

9.02 Materials

9.02.01 Timber

Timber shall be one of the following grades:

Longleaf Southern Pine, Prime Structural Grade, in accordance with current grading rules of the Southern Pine Association.

Shortleaf Southern Pine, Dense Structural Grade, in accordance with current grading rules of the Southern Pine Association.

Douglas Fir, Dense Select Structural Grade, in accordance with the current grading rules of the West Coast Lumberman's Association.

Timbers shall be air-seasoned. If properly air-seasoned timbers are unobtainable, artificially conditioned timbers may be used when approved by the Engineer. For southern yellow pine the steaming-and-vacuum process of conditioning shall be used and for Douglas Fir the boiling-under vacuum process shall be used.

Timbers shall be sufficiently seasoned so that the part to be penetrated by the preservative shall have enough water removed to make room for the preservative to enter.

Each piece of timber, when delivered to the shop for fabrication, shall bear the guarantee trademark or grade mark of the inspection agency under whose rule the timber was graded.

9.02.02 Creosote

Creosote for wood preserving shall conform to the requirements of the Federal Specification for "Wood Preservative; Creosote-Coal-Tar Solution," TT-W-566.

9.02 Materials (continued)

9.02.03 Metals

Metals shall conform to the requirements of the respective A.S.T.M. Specifications, except as otherwise noted:

Cast Iron - "Gray Iron Castings," A48, Class 30. All castings shall be normalized before machining.

Cast Steel - "Mild to Medium--Strength Carbon-Steel Castings for General Application," A27, Grade U-60-30, Fully Annealed.

Wrought Iron - "Wrought Iron Plates," A42.

Brass - "Naval Brass Rod, Bar, and Shapes," B21, Alloy B.

Aluminum Bronze - "Aluminum Bronze Sand Castings," B148, Alloy 90.

Manganese Bronze - "High-Strength Yellow Brass and High-Strength Leaded Yellow Brass Sand Castings," B147, Alloy 7A.

Stainless Steel - A.I.S.I. Standard Specification, "Stainless Steel No. 304 or 316.

9.02.04 Bolts and Nuts

Bolts and nuts shall be of the material called for on the Drawings. All bolt and nut threads shall conform to the requirements of the American Standards Association Specification B1.1, "Screw Threads for Bolts, Nuts, Machine Screws, and Threaded Parts," free fit, Class 2.

9.02.05 Oil Impregnated Bushings

Oil impregnated bushings shall be "Lubrite," as manufactured by Merriman Brothers, Inc., Boston, Massachusetts; "Oilite," as manufactured by Amplex Division, Chrysler Corporation, Detroit, Michigan; or approved equal.

9.02.06 Grease Fittings

All grease fittings shall be button head type, such as Alemite No. A-1186, or an approved equal.

9.02 Materials (Continued)

9.02.07 Rubber Seals

Rubber seals attached to the upstream face of gates shall have a specific gravity of 1.25 plus or minus .05, durometer reading of 40, plus or minus 5, ultimate tensile strength of 1,800 psi, and ultimate stretch of 500 percent.

9.02.08 Canvas Duck Strip

Canvas duck used as cushion strips between timbers shall be of first quality contton fabric, 28 ounces per square yard of material.

9.02.09 Asphalt

Asphalt shall conform to the requirements of the Federal Specification, "Asphalt; (for) Built-Up Roofing, Waterproofing and Dampproofing," Type III, SS-A-666.

9.02.10 Cast Iron Coatings

Primer coat for coating of cast iron surfaces shall be "bitumastic solution," and finish coat shall be "bitumastic enamel," as manufactured by Koppers Corporation, or an approved equal.

9.03 Shop Fabrication

0.03.01 Gate Fabrication

Shop drawings showing details of fabrication shall be furnished the Engineer and approval obtained in accordance with Article 6 of the General Specifications.

Timber shall be surfaced on all sides and ends, true to the dimensions shown on the Drawings. All bolt holes and countersinks shall be drilled in thier proper location before creosoting. In this operation, due allowance shall be made for the width of the wrought iron carrying bars and the canvas strips. Wood screws or nails may be inserted in creosoted timbers as necessary.

The creosoted timber gate with all its component parts shall then be completely assembled in the shop and checked for its exact size and true plane. The canvas strips between timbers shall be saturated with hot asphalt just before assembly.

9.03 Shop Fabrication (continued)

9.03.02 Creosoting

The timbers shall be coal-tar creosoted to refusal by the "empty-cell" (Lowry and Rueping) process: The general requirements, treatment, and results shall be in accordance with Federal Specification, "Wood Preservation; Treating Practices," TT-W-571."

9.03.03 Hinges

Hinges shall be fabricated and assembled as shown on the Drawings. Hinge links shall be cast steel bushed with bronze. Hinge brackets and blocks shall be bushed with oil-impregnated, self-lubricating, bronze bushings.

9.03.04 Carrying Bars

The wrought iron carrying bars shall be fabricated to the dimensions shown on the Drawings, and shall be accurately drilled to match the tie rod holes on the creosoted timbers and the hinge blocks at the top. They shall be hot asphalt coated and assembled with the timbers while the asphalt is still hot.

9.03.05 Tie Rods

Tie Rods shall be wrought iron bars, fabricated and assembled as shown on the Drawings. The timbers shall be drawn together firmly by tightening the tie rod bolts until all joints are completely closed, the hot asphalt coated carrying bars and canvas strips being in place. Final tightening of the tie rod nuts shall proceed simultaneously with the tightening of the tee bar bolts, the whole assembly being made rigid and the seating face in a true plane.

9.03.06 Tee Bars

Tee bars shall be of cast iron as detailed in the Drawings, drilled to match the corresponding holes in the gate timbers after the tie rod nuts have been tightened. As an alternate railroad rails of section approved by the Engineer may be used.

9.03.07 Wall Anchor Bolts

Wall anchor bolts for the frame shall be wrought iron and for the hinge casting shall be stainless steel or aluminum bronze. All right angled hooks shall be bent cold.

9.03 Shop Fabrication (continued)

9.03.08 Gate Frame

The gate frame shall be cast to the dimensions shown on the Drawing. The seated surface shall be planed to a true plane after normalizing. The frame may be cast as a single piece or as multiple pieces bolted together.

9.03.09 Batten Strips

Stainless steel batten strips of No. 316 metal, 3/16 inch by 1 inch in section, shall secure the rubber seal to the timbers. The strips shall be attached to the timbers by 3-inch No. 16 stainless steel round head wood screws. Care shall be taken that no wood screws are located closer than 1/2 inch from any timber joint. The rubber seals shall center on the seating edge of the cast iron frame.

9.03.10 Lubrication Fixtures

At each hinge pin, provision shall be made for positive lubrication. Button headed grease fittings shall be inserted in drilled and tapped holes located as shown on the Drawings. Fittings shall match grease grooves cut on the inside of the pin bushings. Should any grease tips be located so as to be difficult of access an extension to an accessible location shall be made with flexible high pressure bronze wire tubing.

9.03.11 Metal Coating

One coating of "bitumastic" primer shall be applied to all cast iron surfaces in the shop.

9.04 Installation

9.04.01 Wall Castings

The cast iron frame with its anchor bolts and the anchor bolts for the hinge brackets shall be accurately secured in place in the wall forms and embedded in the concrete pour. A shop template may be used for locating hinge bracket anchor bolts or other means of accurately locating these bolts shall be provided by the Contractor.

The hinge brackets shall be mounted on their anchor bolts so that the upper hinge pins are in perfect alignment.

9.04 Installation (continued)

9.04.02 Timber Gate

The gate when attached to its hinges shall rotate to complete open position without binding at any point. When closed, the rubber seal attached to the gate shall seat uniformly against the frame casting at all points.

9.04.03 Metal Coating

After satisfactory installation, all exposed cast iron surfaces shall be cleaned of loose rust or debris. Any unprimed areas shall be given a coat of "bitumastic solution" as covered in articles 9.02.10 and 9.03.11. All exposed cast iron primed surfaces shall be covered with a finish coat of "bitumastic enamel."

9.04.04 Lubrication

All lubrication tips shall be pressured greased to refusal before the gate is operated.

9.05 Tests

9.05.01 General

The Contractor shall make all arrangements, provide all necessary labor and materials, and make all adjustments for the performance of all tests called for herein. All tests shall be made in the presence of the Engineer.

9.05.02 Defective Work

If inspection or tests disclose defects or noncompliance with the provisions of these Specifications, such defective or improperly constructed work shall be replaced or adjusted, and the tests repeated until compliance with these Specifications is obtained.

9.05.03 Leakage Test

The gates shall be subject to hydrostatic tests, the upstream side being dry, and water on the downstream side of the gates at river level. Under these conditions, leakage around or through any gate shall not exceed 1/10 of a gallon per minute per foot of wetted gate perimeter. No external forces shall be applied to the gate during this test.

9.05 Tests (continued)

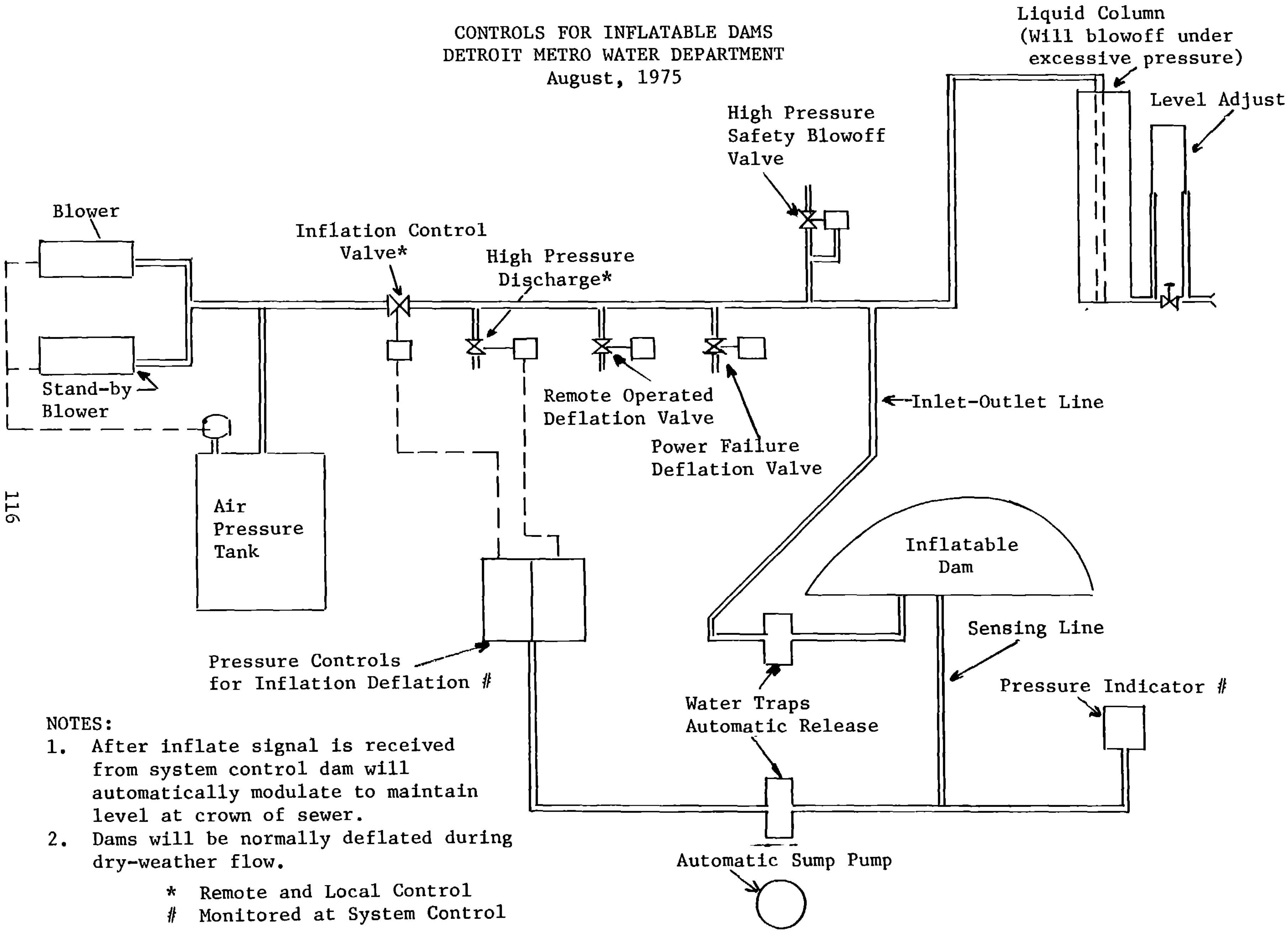
9.05.04 Lifting Test

Under dry conditions on both sides, a pull of 100 pounds exerted simultaneously on each eye bolt shall lift each gate off its seat. With all joints lubricated, the gates shall swing freely in a true arc to wide open without binding.

9.05.05 Flotation Test

Before mounting the gates on the hinge links, the completely assembled gates shall be placed in water. If they float, lead plates shall be attached to the downstream face of the gate by means of screws in order to produce a weight of 65 to 75 pounds per cubic foot of displacement. The lead shall be symmetrically placed and become a permanent part of the gate.

CONTROLS FOR INFLATABLE DAMS
DETROIT METRO WATER DEPARTMENT
August, 1975



NOTES:

1. After inflate signal is received from system control dam will automatically modulate to maintain level at crown of sewer.
2. Dams will be normally deflated during dry-weather flow.

* Remote and Local Control
\# Monitored at System Control

Municipality of Metro Seattle
Seattle, Washington
Date: September 9-10, 1975

Lake Washington, a 40 km (25 mi) long inland fresh water lake, is located near the mid-point of King County, Washington. The city of Seattle encompasses most of the area between Lake Washington and Puget Sound.

During the early and mid-1950s, property owners and citizens groups actively protested the conditions which were leading to the degradation of Lake Washington. Eventually, in 1958, the Municipality of Metropolitan Seattle (Metro) was formed and given authority to conduct specific areawide activities including treatment of wastewater and mass transit. The enabling legislation also authorized Metro to conduct other areawide activities which might be assumed at some future date.

Metro Sewerage System

The Metro sewerage system is now comprised of major intercepting sewers, 20 pumping stations, 16 regulator stations, and 5 wastewater treatment plants. The city of Seattle and other local agencies are responsible for sewage collection and transportation to intercepting sewers. Except for certain construction grants, Metro's activities are financed through user charges collected by local agencies.

The attached "Comprehensive Plan" shows the sewerage service area, the present system, and proposed extensions.

A Computer Augmented Treatment and Disposal (CATAD) system monitors and controls the various components of the system

Metro's operation and maintenance activities are divided into two divisions – Renton and West Point. The Renton Division is responsible for the Renton plant and its contributing interceptor system which collects sewage from the communities along the eastern shore of Lake Washington Virtually the entire service area has separate sanitary sewers

The West Point Division is responsible for the large West Point treatment plant and three smaller plants, all of which discharge into Puget Sound. The service area includes most of the city of Seattle, which generally is served by combined sewers. The city has recently separated sewers in one area of about 728 hectares (1,800 acres) and expects to do some additional separation.

The 16 regulator stations within the system are all located within the combined sewer area managed by the West Point Division Four additional stations are being planned. A typical regulator station is constructed at the intersection of a collector or trunk sewer to receiving waters protected by an outfall gate (tide gate), and a structure housing various controls. Both the regulator and outfall gates are referred to as modulating sluice gates. Sensing devices (bubblers) are located in the trunk sewers to control the outfall gates, in the interceptor sewers to control the regulator gates, and outside the outfall gate to provide tide elevation information. High and low tide elevations in Puget Sound vary regularly by about 3.3 m (11 ft). At times of high tide, the signal from the tide level sensor overrides any other signal calling for the opening of the outfall gate, thereby eliminating the possibility of ocean water entering the interceptor system.

Many regulators are physically located immediately adjacent to Puget Sound. Where regulators are some distance from the receiving water, considerable storage capacity is available in the trunk sewer outfall pipe This is utilized to minimize outfall quantities.

Potentiometers attached to the outfall and regulator gates are connected to equipment in the control structures. Gates and controls are calibrated so that gate movements can be made in one percent increments. This increment of control is felt necessary to eliminate wave occurrences in stored sewage during opening or closing operations.

All control stations are served with standby power capabilities in the event of an electrical failure. Gates are operated by electric motors where emergency outfalls are available if standby equipment is inoperative Four regulator gates are operated hydraulically where no emergency overflow capability exists.

All except one of the control stations are in above ground structures Electrical control problems, presumably due to corrosive gases, have regularly been experienced in the underground structure.

Parts of the Seattle sewerage system were built before 1900. In many of these sewers, flows are diverted with side weirs and thus cannot be regulated.

A schematic plan of a typical regulator station is attached to this report. Construction costs for new regulator stations, including local controls, average about $250,000.

Four flap gates are included within the sewerage system. One gate provides protection for a lift station and three small gates provide emergency relief at regulators. Employees "hope they never work." All are top-hinged, cast iron gates with monel seats. None is furnished with sensing devices to indicate open or closed positions. Specifications for sluice gates and flap valves are attached to this report.

Maintenance of Gates

The Metro Division does not keep separate records showing maintenance costs for the gates within the system.

Very little maintenance work is performed on gates except normal preventive maintenance, which is done regularly on about a three-month cycle. Hydraulic systems are the primary problem requiring more maintenance than electrically operated gates No information was available relative to maintenance of flap gates.

Computer Augmented Treatment & Disposal (CATAD)

The sewerage system of metropolitan Seattle is monitored and controlled through a central computer station and two satellite stations located at the major treatment plants. The central station is equipped with a large central console with two teletype loggers, seven active CRT displays, and numerous controls for monitoring 35 regulator and pumping stations.

CATAD monitors information from the pumping stations and the level sensors in the trunk and interceptor sewers at regulator stations as well as the tide sensors at the outfalls. In addition, the system monitors six tipping-bucket rain gauges located throughout the area. Two additional gauges are planned for installation. Rainfall information is recorded at 1-, 2-, 5-, or 10-minute intervals, depending upon the needs of the system.

the CATAD system, including central and satellite stations and the local control stations, cost $3.1 million, not including the cost of regulators. Annual operating costs approximate $200,000.

During dry weather or periods of normal flow, overflow gates are closed and regulator gates are in a full open position. When a storm approaches, pumping station controls are activated so as to "pump down" the system as much as reasonable possible. As interceptor levels rise, regulator gates gradually close to maintain maximum interceptor flows at pre-set levels. Storage is then provided within the trunk system When the trunk system maximum storage is reached, outfall gates are opened, incrementally, to maintain maximum trunk storage. Tide sensors at outfall gates override the signal to open gates during periods of high tide. In this event, overflows are provided at alternate stations.

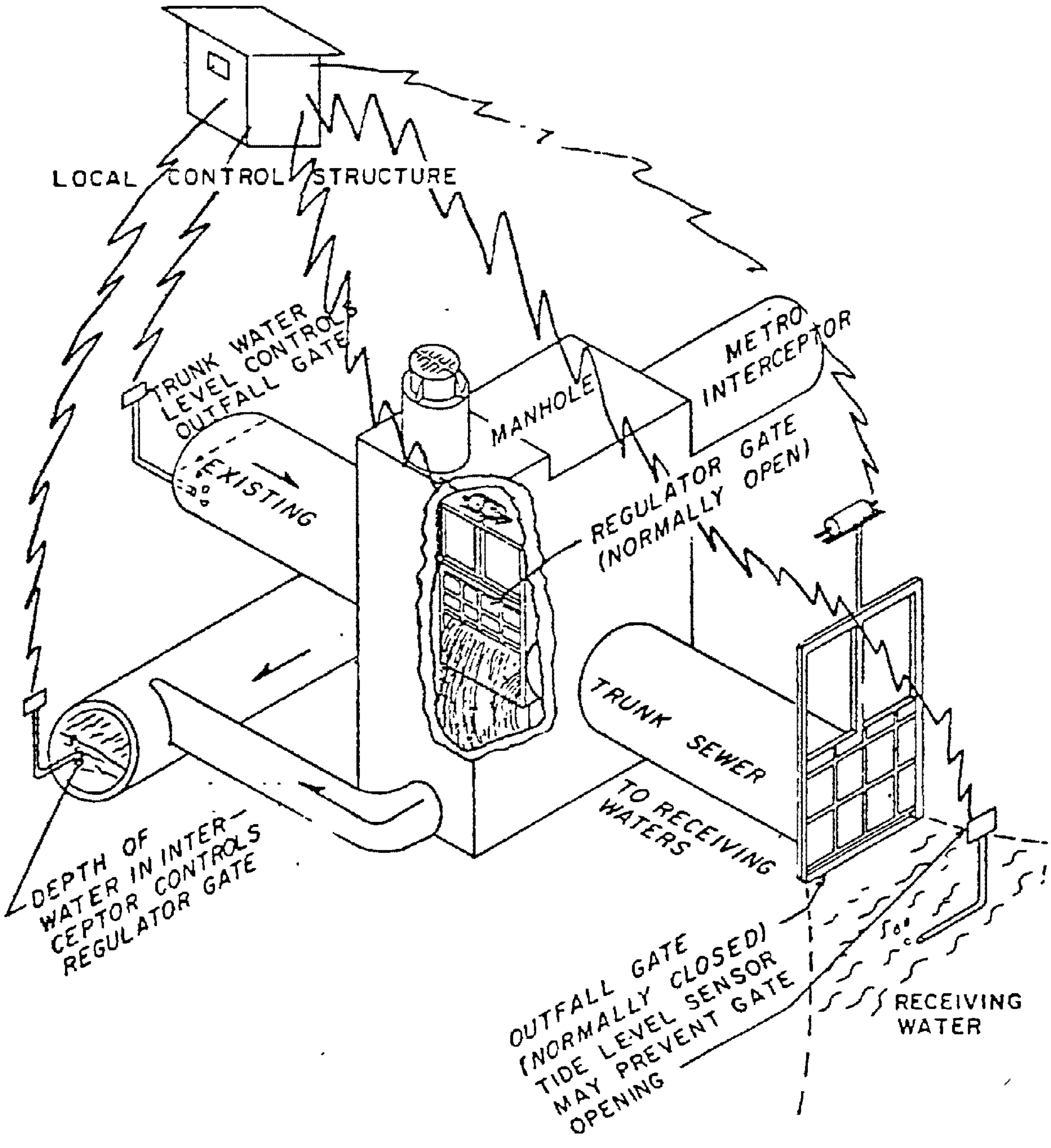
For each regulator station, pre-set elevations for interceptor, trunk, and tidewater are stored within the system.

During a rainfall event, the system can be controlled by any of the three following methods:

1 Remove automatic control by the central terminal under program control of the CATAD System computer.
2. Remote supervisory control through operator-indicated commands at the central terminal;
3. Local automatic control by controllers at the local control stations.

During many overflow events, the system has the capability, generally when operated through supervisory control, of selectivity of overflow locations in order that overflows have the least harmful effect on receiving waters Since completion of the control system, overflows into Lake Washington have been virtually eliminated and overflows into Puget Sound reduced by 95 percent during summer months and 65 percent during winter.

Schematic of Typical Regulator Station
Municipality of Metropolitan Seattle
Seattle, Washington
September, 1975



SPECIFICATIONS FOR SLUICE GATES
AND GATE OPERATING MECHANISMS
MUNICIPALITY OF METROPOLITAN SEATTLE
SEATTLE, WASHINGTON
SEPTEMBER, 1975

C66

C6.03 Sluice Gates and Gate Operating Mechanisms

(1) Scope

Sluice gates and operating mechanisms include two manually operated sluice gates and two electric motor operated sluice gates complete with appurtenances as shown and as specified. Gates and operating devices shall conform with the requirements of AWWA C501 except as specified herein.

(2) Sluice Gates

(a) General. Sluice gates shall be heavy duty, flat framed assembly arranged for mounting on a thimble in concrete. All gates shall be designed to function satisfactorily when subjected to free discharge conditions at any gate opening, partially or fully opened.

Gate equipment numbers, size, design heads, thimble type, manufacturer's model number and type of operator shall be as listed below:

Gate	Size Inches WxH	Design Head Feet to Invert Seating	Unseating	Thimble Type	Rodney Hunt Series	Operator
SG 001	48x48		8.1	Type F	140M	Electric Motor Operated
SG 002	72x48		8.1	Type F	140M	Electric Motor Operated
SG 008	12x18	6.5	6.5	Type F	Reverse Acting 140M	Floor Box
SG 009	6	9.0		Bell & Flange	HY-Q 180M	Floor Box

Motor operated sluce gates shall be suitable for continuous modulating and throttling service with frequent reversals of travel direction. Incremental gate movements under modulating service conditions will range from 1/2 inch to 3 inches at one time. The rate of travel of the gate shall be 3 inches per minute and operational conditions on occasion will require gate movement for the entire stroke without interruption.

(b) Design. Operating forces used for determining the minimum strength of all components and the requirements of the operating devices shall be calculated in the following manner:

1. The force required to unseat the gates in the opening stroke shall be the sume of the guide frictional force (computed using a friction factor of 0.7 and the specified unseating head) and 150 percent of the weight of the gate disc.

2. Operating forces when the gate is in motion and free of its seat shall be determined by the sum of the frictional force (computed using a friction factor of 0.35 and the specified unseating head) and the weight of the disc.

Minimum safety factors for iron and stell shall be not less than 8.0 and 3.5 respectively. Calculations and supporting data shall be furnished to justify the size of all load-bearing components and to justify the design of the operating devices. All calculations shall be found acceptable to the Engineer prior to the construction of any component or assembly of the sluice gates or the operating devices. Calculations will not be required for wall thimbles.

(c) Painting. Gate discs, frames, thimbles and other submerged components shall be shop painted in accordance with Section C13. Operators and other nonsubmerged appurtenances shall be shop primed for field painting.

(d) Wall Thimbles. Wall thimbles shall be of the type shown and specified and shall be formed of ASTM A126, Class B cast iron with the gate mounting face machined flat to form a true bearing surface. Minimum length of thimble shall be 12 inches or as shown on the drawings. Bell and spigot ends of 6-inch gate thimble shall be suitable for connection to extra heavy cast iron drain fittings.

(e) Gates. Gates shall be bronze-mounted cast iron and shall conform to AWWA C501 except as specified herein. Discs, guides and frames shall be ASTM A126, Class B cast iron. Unless otherwise specified, mating surfaces of the disc and frame shall be bronze faced with

ASTM B21 bronze. Seating faces of frames and discs shall be machines with dovetail grooves designed to receive and shall be fitted with ASTM B21 bronze seat facings. All frames shall be of the flat type. Wedges of the adjustable bronze type shall be provided at the sides and at the top and bottom of the disc when required by AWWA C501. Electric motor operated gates shall be designed for modulating service and shall have top and bottom wedges. All bronze castings shall be ASTM B147.

Flush bottom gates shall be sealed at the bottom by a compressible resilient seal mounted on the bottom of the disc or on the bottom of the gate opening. If the resilient seals are to be mounted on the discs, the frames shall be flush with the inverts; if mounted on the bottom of the gate openings, they shall be securely attached to the gate frames and shall be flush with the inverts. In either case, the arrangement shall form an effective seal at the bottom when subjected to differential pressures ranging up to the specified unseating pressures. The material used for the compressible resilient seals shall be suitable for use in normal strength domestic sewage containing above normal amounts of grit and petroleum produts.

(f) Stems, Stem Couplings and Stem Guides. Stems shall be of suitable strength and of ample length for the intended service. Stems shall be of stainless steel, ASTM A276, Type 304, turned straight and true and honed to a smooth finish.

Stem couplings, including keys, pins and threaded parts shall be of stainless steel matching that specified for the stems. Stem couplings shall be of greater strength than the stem.

Stem guides, where required, shall be cast iron, bronze-bushed type mounted on cast iron brackets. They shall be adjustable in two directions and shall be spaced at sufficient intervals to limit the 1/r ration of the stem to 200 or less.

(g) Bolts, Nuts and Fasteners. All anchor, assembly and adjusting bolts, nuts, washers and other fasteners shall be of stainless steel ASTM A276, Type 304 or ASTM A582, Type 303 unless otherwise shown or specified.

(h) Shop Testing. Shop clearance checks and shop performance test, including leakage tests meeting the requirements of subarticle C6.03(2)(i), shall be conducted in accordance with AWWA C501, Section 23. The manufacturer shall furnish a certificate of compliance.

(i) Field Leakage Test. Following gate and operator installation and after all adjustments have been made and the mechanisms properly lubricated, each gate shall be run through one complete opening and costing cycle before starting the leakage test.

Leakage shall not exceed 0.1 gpm per 12 inches of wetted seat perimeter for the specified head. The specified head shall be applied for a minimum of 30 minutes each gate. The head shall be measured from the top surface of the water to the invert of the gate.

The following heads shall be applied to the respective gates during the leakage test:

1. Shop leakage test - the full heads listed in subarticle C6.03(2)(a),

2. Field leakage test - 60 percent of the heads listed in subarticle C6.03(2)(a).

If the leakage exceeds that specified or if the gate and operator are defective in any respect, the gate and operator shall be repaired and corrected before acceptance.

The Contractor shall prepare in writing a detailed statement of the procedure and devices he proposes to use to accomplish the field test. The statement shall include a description of the manner and means provided for measuring the gate leakage and a time schedule for the test. The statement shall be submitted to the Engineer for review and comment. The Contractor shall also arrange for the presence of the gate manufacturer's representative during the field test.

(3) Gate Operating Mechanisms

(a) General. Sluice gate operators include two floor box manual operators and two electric motor-operated floor stand units complete with appurtenances and accessories as shown and specified.

(b) Floor Box Operator (OP008A, OP009A). Floor box operator shall be formed of cast iron and shall be of ample size to accomodate the gate operating nut, lift nut, and thrust bearing operating assembly. The enclosed operating assembly shall be equipped with an easily accessible means of lubrication. The operating nut shall be attached to the lift nut by means of a torque tube of sufficient length to allow the full opening of the gate without stem interference.

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(a) General. Sluice gate operators include two floor box manual operators and two electric motor-operated floor stand units complete with appurtenances and accessories as shown and specified.

(b) Floor Box Operator (OP008A, OP009A). Floor box operator shall be formed of cast iron and shall be of ample size to accomodate the gate operating nut, lift nut, and thrust bearing operating assembly. The enclosed operating assembly shall be equipped with an easily accessible means of lubrication. The operating nut shall be attached to the lift nut by means of a torque tube of sufficient length to allow the full opening of the gate without stem interference.

Operating nuts shall be hexhead type and shall be located and sized so as to provide for easy operation with standard tee wrenches. Each floor box shall be suitable for casting in a concrete floor, shall be provided with a suitable drain, and shall be equipped with a heavey cast iron or steel galvanized after fabrication cover provided with a raised letter "C" on one side and a raised letter "O" on the other side.

Two standard tee wrenches shall be furnished.

(c) Electric Motor Operators (OP001A, OP002A)

1. Gate Operator Motors. Gate operator motors shall be Type IB designed for direct coupling to the gate operator and shall have a cast frame and large cast conduit box. Neoprene gaskets shall be provided between the box and its cover and between the box and the frame. Motors shall be totally enclosed and shall be suitable for severe outdoor exposure and service. The service environment will be one of high relative humidity and complete exposure to wind, rain, sleet, ice, snow, and ambient temperatures indigenous to the area. Totally enclosed motors shall be continuously rated for 70-degree C temperature rise by resistance and shall have a 1.0 service factor. All totally enclosed motors shall be provided with pressure relieving weep and drain holes in the lower part of the stator. Stator windings shall be completely encapsulated with a flexible epoxy compound.

Motor bearings shall be provided with pressure grease fittings and drain plugs. Antifriction type bearings shall be used.

2. Drive Units. Electric motor operators shall be pedestal mounted, multiple gear units as manufactured by the Philadelphia Gear Corporation. Each operator shall have a clutch mechanism which permits manual operation by a handwheel after a small lever has been depressed disengaging the motor from the gear train. In addition, suitable interlocks shall be provided to instantly return the unit to automatic operation and declutch the handwheel when the motor has been re-energized. In addition maximum thrust shall be limited by selecting torque springs to provide not over 120 percent of design thrust as specified in subarticle C6.02(2)(b). Each unit shall be designed for continuous modulating service with a maximum of four reversals per minute, modulating at increments of approximately 1/2 to 3 inches at one time. Rate of travel of each gate shall be 3 inches per minute. Each unit shall be provided with a hammer blow feature to start the gate moving at the beginning of motion in either direction. Transmission of motion to the gate stem by the drive unit shall be accomplished by the use of a nylon nut engaging the threads on the gate stem.

The Contractor is advised that the regular station is designed as an integrated unit, and the size of the standby generation equipment, specified under Article C6.05 has been selected, in part, on the basis of the data presented below. In the event that the motors to be furnished for these units require a larger engine generator unit, the Contractor shall furnish and install the larger unit. All additional costs connected with the increase in the size of the unit and incident to the modi- ation of the design shall be at the Contractor's expense and the change shall be accomplished at no additional expense to the Municipality. Electric motor characteristics upon which the design is based are as follows:

Operator Number	Philadelphia Gear Corp. Model	Motor Full Load* Amps	Motor Locked Rotor* Amps	Enclosure
OP001A	SMBI-15	6.0	31.0	Totally Enclosed
OP002A	SMBI-25	9.0	51.0	Totally Enclosed

*At 230 volts, 3 phase, 60 Hz.

3. Control Devices. A gasketed waterproof cast metal enclosure shall be provided to house all necessary limit switches and gate position transmitter for each unit.

In addition to thelimit switches indicated, torque limiting devices shall be provided for both opening and closing motions.

Each operator shall be equipped with a potentiometric position transmitter connected to a gear-driven shaft. The drive system shall be designed to limit the backlash in the final drive shaft to a maximum of 2 percent. The shaft shall be arranged to rotate 270 degrees for full gate movement. Potentiometers shall be Ohmite Model J0326, 1,000 ohms, as shown.

A gasketed, waterproof, lockable cast metal control station shall be mounted on the pedestal of each operator for connection with the control diagrams shown. The unit shall accept a standard Met lX padlock.

4. Electrical Devices. All circuits shall be factory wired to labeled terminals in the protective enclosure for connection in accordance with the control diagrams shown.

5. Appurtenances. Each unit shall be furnished with an automatic metering type lubricator with one pint minimum oil reservoir. A spare operating nut shall be furnished for each motor operator, labelled with the gate number, and suitably packed in a moisture-proof box.

6. Pedestals. Pedestals shall be of cast iron or fabricated steel, of adequate strength to support the loads.

7. Stem Covers. All gate stems shall have stem covers. Stem covers shall be dustproof and weatherproof and shall be easily removed for gate service and lubrication. The covers shall be of sufficient length to completely cover the stem when the gate is in the open position. Stem covers shall be designed to give visual indication of the gate position. Stem covers shall be fabricated of slotted-steel pipe with removable plastic windows mounted in metal brackets over the slots cut in the pipe, or stem covers may be fabricated of high-strength, rigid, transparent plastic pipe.

SPECIFICATIONS FOR FLAP VALVES
MUNICIPALITY OF METROPOLITAN SEATTLE
SEATTLE, WASHINGTON
SEPTEMBER, 1975

C7.07 Flap Valves - 96 Inch, 48 Inch by 24 Inch

(1) Scope

The 96-inch flap valve and the 48 inch x 24 inch flap valve, each with wall thimble, shall be as shown and specified herein. The valve shall be of a design compatible with the exposure and service and be such as to provide the maximum assurance of satisfactory operation. The exterior of the valves will be subjected to salt water immersion and the interior will be exposed to sewage. The external seating heads referenced to the valve inverts are as follows:

Size Inches	Seating Heads Ft. Min.	Max.	Rodney Hunt Series
96	0	10	FV-AC
48 x 24	0	3	FV-AR

The valve shall remain tightly closed under all tidal conditions. Flap valves and wall thimbles shall be shop painted in accordance with Section C14.

(2) Valve Construction

(a) General. All provisions for testing of materials and the finished product, as set forth in the standards cited herin shall be rigidly observed and certified copies of the results of said tests shall be submitted to the Engineer before the valves are shipped to the jobsite.

Design tensile or compressive stress in any part shall not exceed 20 percent of the material's yield strength as determined by a 0.2 percent offset from the stress-strain diagram as determined in accordance with ASTM E-8 and E-9. Design shear stress shall not exceed 20 percent of the material's maximum shear strength as defined by ASTM E-6.

The Contractor shall submit certified curves showing valve position and discharge rate plotted against the valve head loss coefficient "K" to the Engineer no later than 60 days after receipt of notice to proceed.

(b) Wall Thimble, Frame and Disc. Wall thimble, frame and disc shall be of abrasion-resistant cast iron, ASTM A436. Thimble shall be F section, 8 inches in depth, as manufactured by Rodney Hunt. All surfaces of wall thimble, frame and disc casting shall be ground smooth and shall be free of all flaws, depressions and surface irregularities. Each casting shall be stress relieved after fabrication and all points of stress concentration shall be examined by the use of a dye penetrant similar to Magnaflux "Spotcheck." Examination shall be made in strict accordance with instruction of the dye penetrant manufacturer. All defects detected thereby shall be corrected and certified copies of the results of the examination submitted to the Engineer. Flap valves shall be manufactured with flat frame for mounting on the embedded thimble.

(c) Seats. Seats shall be of monel, of a type specifically selected to be resistant to damage by "wire drawing" due to small leaks when the discs are in the closed position.

All bolts, nuts, studs, etc., used to secure the seats to the frame or disc castings shall be of monel. The seating surfaces shall be machined and ground to true mating surfaces and finished on the order of 25 to 30 micro inches (RMS).

(d) Bearings. Bearings shall be of self-lubricating sleeve type. Bearing material shall be selected to provide a low friction factor. The design of the bearing and materials selected shall be suitable for use when continuously submerged in sewage or salt water.

(e) Valve Trim. Hinge pins, stops, adjusting screws and fasteners including those for securing and mounting the valve on the thimble shall be of monel. Hinge design shall consist of double pivot points for each arm with the rotation at the lower pivot limited and adjustable. The upper hinge post shall be threaded for adjustability with a lock device provided.

(f) Shop Leakage Test. The 48 inch x 24-inch valve shall be tested for leakage in the shop. Leakage shall not exceed 0.4 gallons per minute per 12 inches of wetted valve seat perimeter for a closing test head of 3 feet and 1 foot measured from the valve invert. Three copies of certified test reports shall be forwarded to the Engineer before shipment of the valve.

(3) Acceptance Test

(a) General. After the valves are installed the Contractor shall inspect and adjust the valves and demonstrate that the valves operate freely and in a manner satisfactory to the Engineer.

(b) Leakage Tests. The 96-inch valve shall be field-tested by applying a closing head of 3 feet and 10 feet, measured from the invert of the valve. Test heads shall be applied for one hour each. Leakage shall not exceed 0.4 gallons per minute per 12 inches of wetted valve seat perimeter. Should the leakage be in excess of that specified or the valve found to be defective in any respect, the valve shall be repaired and corrected by the Contractor before acceptance.

Monroe County Public Works Department, Rochester, New York
Date. September 3, 1975

Persons Contacted. Robert Hallenbeck, Emil Zenie, and John Graham

This report explores the applicability of the national survey of tide or backwater gates to the area served by the Monroe County Pure Waters Division and provides information on any facets of this sewer system control program which have any bearing on the current study. Clarification of the record covering such gate installations in the Rochester system is necessarily because of its inclusion in the national study project Although tide or backwater gate installations, as such, are not of any important nature, the on-site survey disclosed practices and problems which deserve recognition in the national study upon which the field visitation was based.

It is necessary, for the record, to state that the Monroe County-Rochester sewer system is not now protected by backwater gates, nor are such facilities now needed. As discussed below, two gate installations dating back to before the turn of the century are no longer serving backwater protection purposes. The system now under the control of the Monroe County Pure Waters agency is now involved in flow monitoring studies which deserve at least passing reference in connection with the on-site survey conducted on September 3, 1975, even though they have no direct relationship with the backwater gate problems covered by the national investigation of state-of-the-art practice.

In addition, studies of the application of swirl separator units to grit removal and primary clarification are being carried out by the Monroe County agency as part of EPA-funded research on combined sewer overflows and pollution control plans for this important area of New York State The on-site surveyor took the opportunity to examine prototype demonstration swirl units at the Pilot Treatment Project in Rochester. Information on this installation, together with photographic prints, is included in this on-site survey report.

The Monroe County Sewer System – General

The Monroe County Pure Waters Division serves the city of Rochester, New York, and contiguous communities in the county The service includes interception of flows from outside city areas and treatment of contributed flows. Collector sewers are the property of these communities and they pay for services rendered. The sewer system of the city of Rochester belongs to the city but has been leased to the county authority for a period of 40 years with the county responsible for operation and maintenance of this sewer system.

A series of treatment plants is operated by the county, or the city, in the various drainage basins Maps of the system and the drainage areas are included as appendices to this report Receiving waters include Lake Ontario, the Genesee River, Irondequoit Bay, Black Creek, Datka Creek, State Barge Canal, and other open waters in the area.

The sewer system of Rochester is old, some of it dating back to as early as 1835 to 1900. For example, sewers in a portion of the city studied by Lozier Engineers, Inc., Rochester, in 1974, as a part of the county agency's clean-up orders from USEPA and New York State Department of Environmental Conservation, were tabulated for age Forty-four percent of the area's sewers was over 73 years old; 75 percent was over 53 years old, and 94 percent was over 33 years old.

The city of Rochester is served predominantly – 75% – by combined sewers and 25 percent separate sanitary sewers Sanitary wastewater goes to the treatment plants, combined flows are regulated with overflows to receiving waters and DWF and a portion of WWF intercepted to the treatment facilities Generally, the outlying areas of the county are served by separate sanitary sewers. The pollution problem, therefore, stems from the city. On December 31, 1974, USEPA issued a permit for the Pinegrove Avenue treatment facilities – NPDES No. NY0028339 – with specific requirements covering pollution control actions on a required time schedule. Overflows from the combined system must be eliminated. A total of 54 overflows and bypasses was listed, the existence of these 54 overflow points was reported during the survey

The Eastman Kodak Company owns and operates its own industrial wastes treatment plant which handles a flow of 25 mgd. This plant has received wide publicity for its effective design and unique efficiency.

Rochester sewers are of various types of construction and materials, depending upon size, age, and other subsurface conditions. For example, the Lozier study report (excerpts of which were obtained by the investigator and are filed with this survey document) stated that 70 percent of the system under study is vitrified clay or "tile;" 10 percent concrete; 9 percent stone; 8 percent brick. and minor portions are made of such materials as tunnel rock, segmented block, corrugated metal, cast iron, and stone-brick

The Lozier study has been quoted because it has a direct bearing on the solution of overflow incidents, elimination or handle of I/I, and other facets of pollution corrections. No references have been found by the writer to backwater gate requirements in the system as a result of perusal of the Lozier report. Monroe County officials made reference to a Lozier statement – not found by the writer – that backwater gates are not required. This is further evidence that Rochester-Monroe County is not a backwater gate area.

Backwater Gates

Two – and only two – backwater gates were ever installed in the combined sewer system of the city of Rochester, both in the same area. One gate chamber was installed at Brooks Avenue and Plymouth; the other at Plymouth and the railroad. They were installed in 1898 at the time that discharge into the Genesee River was subject to wide variations in river levels. At a later time the Corps of Engineers installed a dam at Mt. Morris for flood control purpose and the river levels were stabilized at a height that eliminated backwater action in the two gate chambers. In addition to Mt Morris Dam, the river level is controlled by a dam installed by the Rochester Gas & Electric Co. which regulates the river level for power purposes.

The two overflow chambers – listed as Overflows No 023 and No. 024 – are listed in the attached USEPA NPDES Permit. The record shows overflows of five hours per incident with flows of 1.2 mgd and 2 4 mgd, respectively. The main header at Overflow No. 023 is a 150 cm x 60 cm (5 ft x 2 ft) box, originally provided with two flap gates. The header at No. 024 is composed of two conduits, 60 cm x 135 cm (2 ft x 4 ft-6 in), each conduit with two flap gates, doubled.

The gates are no longer needed for backflow control. Two of the gates were removed recently to increase the flow discharge characteristics of Overflow No 024, as part of a sonic metering installation there to gauge the overflow rates as required by USEPA. The sonic metering arrangement was designed by O'Brien & Gere, Consulting Engineers, Syracuse, New York. In Chamber No. 023, somewhat similar sonic gaging equipment has been installed to monitor overflows, but the flap gates were not removed because they did not impede flow discharges recorded by the meters, which are located sufficiently upstream from the gates to prevent flow interferences.

The sonic meters are unique devices consisting of liquid level meters made by Sonics, coupled with Badger flow meters. Data are telemetered back to the Northwest Quadrant Treatment Plant through a Bristol system and recorded into a computer facility. Sixteen sonic sites are now installed throughout the 50-odd overflows, all more or less telemetry-tie installations. The gates in No. 023 and No. 024 were 30 cm x 30 cm (2 ft x 2 ft). Pictures taken during the on-site survey show the gate openings (gates removed) at Plymouth and Railroad, and the sonic level equipment which locates water levels by bounce-back of sonic waves created at predetermined time intervals. Other pictures show gates in place at Plymouth and Brooks Avenue. The quality of the photos was affected by poor lighting and inadequate working space in the chambers. Their main value is that they show the square flap gates, where still installed, and the clear openings where the gates have been removed.

In summation, it is stated that the backwater gates are not needed. Where still installed, their existence is explained by the difficulty and cost of removal by the Monroe County agency.

House Check Valves

The value of on-site surveys is that investigators have the opportunity to explore phases of the research subject not normally considered as actual parts of the study covered by the interviews. At Monroe County, such a phase of backwater gating was investigated: the required installation of house sewer check valves in parts of the system where house backflooding can occur

The plumbing code of the city of Rochester specifies the use of such "backwater or sewer valves . . . so constructed as to insure a positive mechanical seal and remain closed, except when discharging wastes." The Monroe County Pure Water Division mandates the use of such gates in its service area, including communities outside of the city. The gates are usually 10 cm or 12-1/2 cm (4 in or 5 in) in size, located just inside the basement wall and provided with a clean-out. The types of units required are shown in the catalog sheet from U.S. Pipe obtained by the investigator. Another sheet shows Josam open seat backwater sewer valves and other cellar floor traps and seals.

The county agency reviews all plans for subdivisions in the service area and requires backwater valves wherever it deems it necessary to prevent back-flooding of properties by surcharged street sewers. The units are reported to work effectively but flood wastes may clog the gate seat on occasions. When the authority receives complaints about sewer back-ups, it dispatches crews to investigate the street sewer. If the line is surcharged, sewer cleaning is performed If no sewer stoppages are found, the property owner is advised that his lateral is clogged and/or his backwater gate is unseated. The county offers a lateral cleaning service at a cost of $10, payable at once, successful or not.

Roof leaders enter many house laterals, often behind the check gate, in combined sewer areas. Where separate sanitary sewers are in service, the county requires discharge of roof leaders into storm sewers In new construction, in combined sewer areas and non-residential properties, the county requires the use of holding tanks for roof drainage or a "metered" roof drain, intended to cause the flow to pass through a restricted notch weir which impedes the rate of roof discharge into the sewer system. The existence of many illicit roof leader connections to separate sanitary sewers is suspected by the county agency in suburban areas. Of some 90,000 connections in the city of Rochester, 5,000 were reported to be equipped with back check valves. Of some 30,000 connections elsewhere in the county, 7,000 were reported to be back-gated. In areas where sewers are owned by the local communities, the number of backwater gates may total 10,000. Gates were reported to cost $50,.with installations costing approximately $200. While some of the above information is admittedly vague, its main value is that it demonstrates the widespread practice of requiring the use of backwater sewer line gates

A copy of the applicable part of the Rochester plumbing code is submitted with this report. Reference has been made to the appended sketches of the types of gates required by the code. Responsibility for gate installations belongs to the property owner.

Field Inspections

A field inspection was made of the two backwater chambers, referred to herein as 023 and 024 The pictures were taken during the field trip. The flow monitoring installations were checked, as described in the above report. The sonic level recorders and other telemetry equipment were observed but no inspection was made of the central receiving and computer installation at the Northwest Quadrant Treatment Plant. The chamber equipment, including automatic wastewater samplers, was not in service because rainfall was absent during the field trip. However, recordings of a previous overflow incident were observed. The field trip disclosed some variants from the flap gate data obtained during the interview sessions but this was not of major significance because the principal factor was confirmed by the investigator's observations, namely, that backwater gates are not needed in the Monroe County system and that these facilities have been removed or are inoperative at this time. The number of gates in the two chambers built in 1898 and the details of design are not pertinent.

Swirl Chamber Prototype Installations

The Monroe County Pure Waters Division is involved with an $850,000 demonstration project covering investigations of various types of treatment of combined sewer overflows with which the area system must cope in the very near future. As has been stated, USEPA has issued permits and approved construction of treatment plant extensions and modernization, subject to correction of pollutional discharges of various types on a specific time schedule. The required studies to seek solutions of these pollution problems include the East Side studies by the Lozier firm, the overflow gagings by O'Brien & Gere, and the pilot treatment processes investigations scheduled to be conducted at the demonstration project located adjacent to interceptor-pumping station facilities at Joseph and Ward Streets in Rochester.

The demonstration project is covered by an 80 percent USEPA grant program of $850,000. The building housing various treatment pilot units was started in January 1975, with combined sewer overflows supplied by duplicate pump units of 400 gpm each through a 15-cm (6 in) force main laid on a side bench of a 30-m (10 ft) stone tunnel. The pilot demonstration plant was designed by O'Brien & Gere and the research work will be supervised by the Monroe County agency and the consulting firm.

The installation will investigate the performance of dual media filters, carbon columns, flocculation sedimentation, and dual-disinfection with chlorine and chlorine dioxide. A part of the demonstration project will be devoted to a study of the effectiveness of swirl separators for grit removal and primary clarification of combined sewer overflows, following the general design and operation procedures developed by APWA Research Foundation at the LaSalle Hydraulic Laboratory on behalf of USEPA, recently completed.

Two swirl units have been installed on the flat roof of the pilot building, together with an installation of a sonic-cleaned microscreen manufactured by the FMC Corporation. This microscreen was reported to be the first such installation for the treatment of wastewater. One of the swirl units manufactured by Lancaster Steel Fabricating Co. is three feet in diameter and will be used to confirm the application of this separator principle for grit removal. The design configuration follows the development of the grit swirl unit in the APWA studies. The primary clarification swirl unit is six feet in diameter, also following the design of the APWA studies at the LaSalle Hydraulic Laboratory. The total cost of the two units, exclusive of piping and necessary appurtenances, was reported to be $12,000.

The two units can be operated separately or in series. At the time of the field inspection, no testing had been instituted; delivery was made in August. Metering for flows will be by means of a Fischer & Porter magnetic meter, using two magnetic probes to register velocities through the metering device The swirls were reported to be available for handling raw sewage or combined sewer overflow wastewater.

Photographs were made of the swirl units and the microscreen device. They are submitted with this report.

No Tide Gate Survey questionnaire is filed with this report. Inclusion of the survey would be inappropriate in view of the non-applicability of the questions to the Monroe County Pure Waters Division system conditions. The above report provides the necessary information.

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