SANITARY SEWER OVERFLOW (SSO) NEEDS REPORT

MAY 2000

Prepared for:

United States Environmental Protection Agency
Office of Water, Office of Wastewater Management

Prepared by:

Parsons Engineering Science, Inc.
Metcalf and Eddy
Limno-Tech, Inc.

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ACRONYM LIST

Acronym	Term
AMSA	Association of Metropolitan Sewerage Agencies
ASIWPCA	Association of State and Interstate Water Pollution Control Administrators
CDC	Centers for Disease Control
CERF	Civil Engineering Research Foundation
COI	"Cost of Illness" Estimates
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DOI	Department of Interior
I/I	Infiltration / Inflow
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
O&M	Operation and Maintenance
POTW	Publicly Owned Treatment Works
RDI/I	Rainfall Dependent Infiltration and Inflow
RIA	Regulatory Impact Analysis
SIC	Standard Industrial Classification
SRF	State Revolving Fund
SSCS	Sanitary Sewer Collection System
SSO	Sanitary Sewer Overflow
STORM	Storage, Treatment, Overflow, Runoff Model
UI	Urban Institute
WPCF	Water Pollution Control Federation
WTP	Willingness-To-Pay
WWTP	Wastewater Treatment Plant

SECTION ONE

OVERVIEW

1.1 INTRODUCTION

A properly functioning wastewater collection and treatment system is a key element in the infrastructure of any municipality. Effective wastewater systems are widely acknowledged as among the most important factors responsible for the general level of good health enjoyed in the United States.

Wastewater collection systems are intended to remove wastewater from homes and other buildings and convey it for proper treatment and disposal. If functioning properly, they remove from daily life any concern for adverse health effects from sewage. However, when a system is not functioning properly, it can pose risks to public health and the environment, and adversely impact the overall quality of life.

Sanitary sewer overflows (SSOs) that result in a discharge to water of the United States are prohibited under the Clean Water Act. However, efforts to address sanitary sewer collection systems (SSCSs) and SSOs under the National Pollutant Discharge Elimination System (NPDES) program, and by other State and local initiatives, have varied from state to state. Differences in program emphasis and approach, along with other factors, have contributed to significant variance in collection system performance. In response to concerns that there is a need for greater national clarity and consistency, EPA has conducted an in-depth analysis of SSCSs, SSOs and associated NPDES program implemention issues, and an analysis of the municipalities' financial needs in the area of SSO abatement.

1.2 PROJECT OBJECTIVES

This project is primarily intended to provide estimates of the national costs, or "needs", associated with improving existing SSCSs to achieve compliance with existing Clean Water Act (CWA) requirements. Cost estimates in this report address both the capital costs needed to correct the effects of deferred reinvestment in the system, and the costs needed to provide adequate capacity, management, operation, and maintenance of SSCSs.

A cost model has been developed to provide a reasonable national cost estimates of collection system needs associated with increasing SSCS capcity to handle peak flows that occur during wet weather conditions. The cost model should not be applied at the local level to individual sewer systems. In addition, estimates of improved management, operation, and maintenance were made.

On May 29, 1999, President Clinton directed EPA to: "Improve protection of public health at our nation's beaches by developing, within one year, a strong national regulation to prevent the over 40,000 annual sanitary sewer overflows from contaminating our nation's beaches and jeopardizing the health of our nation's families." In response, EPA is developing a notice of proposed rulemaking (NPRM) to clarify and expand NPDES permit requirements for municipal sanitary sewer collection systems and SSOs.

The costs estimated in this report are distinct from, and do not reflect, the costs associated with the NPRM. The analysis of the costs and benefits of clarified regulations for SSOs is set forth in the Economic Analysis accompanying the NPRM. This Needs report is limited to identifying the existing deficiencies with collection system infrastructure reinvestment (capital costs) and maintenance, and the costs to be incurred from correcting these deficiencies. The cost estimates in this study are associated with longstanding reinvestment needs that have not been addressed to date Estimates of Benefits to be gained from correcting these existing deficiencies are provided in []. The costs associated with today's rulemaking are discussed separately in Section VII of the Preamble to the NPRM.

This report also includes a summary of the national perspective on the current status of the conditions of sanitary sewer collection systems, the conditions contributing to, and the effects of SSOs.

1.3 BACKGROUND

A sewer system is typically one of the largest infrastructure investments made by local governments. About 148 million people in the United States are served by over 19,000 municipal separate sanitary sewer collection systems. These separate sewer systems consist of between approximately 3 billion linear feet of municipally-owned pipe that conveys sanitary sewage to local and regional wastewater treatment facilities.

Additionally, nearly 42 million people are served by approximately 900 combined sewer systems. Needs estimates to address CSOs and combined sewer systems are not included in this analysis.

1.3.1 What are SSOs? - Overview

For the purpose of this report, SSOs are an overflow, spill, release or diversion of wastewater from a sanitary sewer collection system. SSOs include:

(A) Overflows or releases of wastewater that reach waters of the United States;
(B) Overflows or releases of wastewater that do not reach waters of the U.S.;
(C) Wastewater backups into buildings that are caused by blockages or flow conditions in a sanitary sewer other than a building lateral. Wastewater backups into buildings caused by a blockage or other malfunction of a building lateral that is privately owned is not a sanitary sewer overflow.

Wastewater backups into buildings caused by a blockage or other malfunction of a building lateral would be excluded from the definition of SSOs because such backups generally are not considered to be the responsibility of the municipality that owns and operates a municipal sanitary sewer collection system.

1.3.2 Conditions Contributing to SSOs—Overview

SSO points can occur in a variety of locations in an individual collection system, depending on the system's characteristics. SSO points may occur from a manhole or a pump station, be directed to a receiving water through an overflow pipe, or result in basement flooding.

SSOs are caused by various conditions. For the purposes of this discussion, major causes of SSOs are grouped into the following general categories:

- Peak flows that exceed system capacity
- Blockages
- Structural, mechanical, or electrical failure

These categories are not exclusive ecause SSOs can be caused by a complex combination of factors. For example, partial blockages caused by debris, sediment, oil and grease, or roots can reduce the effective capacity of a pipe and cause an overflow during peak flow conditions. The causes of SSOs are discussed further in Section 3.

1.3.3 Relationship to Treatment Plant Performance

The highest rate of wastewater flow to treatment plants typically occurs during large wet weather events. High rate flows that exceed the design capacity of a treatment plant can make the treatment facilities inoperable. For example, wet weather flows in excess of the design capacity of a secondary treatment plant can wash out the biological mass necessary for treatment. To avoid damaging treatment facilities, dilute flows in excess of a plant's capacity are sometimes bypassed around the plant. Reducing peak flows in the collection system or providing storage in the collection system can reduce situations where flows exceed treatment plant capacity, thereby improving treatment plant performance.

1.3.4 Effects of SSOs—Overview

SSOs release untreated sewage which may present a health and environmental risk and impair the enjoyment of receiving waters. The health and environmental risks attributed to SSOs depend on multiple factors, including location and season (which determine the potential for public exposure), frequency, volume, the amount, concentration, and type of pollutants present in the discharge, and the uses, conditions, and characteristics of the receiving waters.

Bacteria, virus, and other pathogens typically present in SSOs pose the most immediate health risks to those who come in contact with SSOs in roadways, drainage ditches, and through basement flooding. In addition to pathogens, SSOs typically contain metals, synthetic chemicals, nutrients, pesticides, and oils that can be detrimental to the health of humans and wildlife.

As a result, the quality and uses of waters of the United States can be affected by SSOs, resulting in the closure of beaches and recreational areas, increased health risks during exposure to surface waters (for example, to children wading in creeks), restrictions or prohibitions on fishing and shellfish harvesting, and increased risks to drinking water sources. For example, in 1995, U.S. beaches were closed or had advisories issued against swimming more than 3,500 times, most frequently as a result of high levels of bacteria from SSOs and other sewage overflows (NRDC, 1996). SSOs are also unsightly and can cause offensive odors which detract from the enjoyment of parks and other open spaces.

These limitations to the use and enjoyment of water bodies also cause adverse economic impacts SSOs can impose a financial liability for a community by leading to enforcement actions that inhibit potential development through moratoriums on sewer connections SSOs may also result in negative public relations that have an detrimental financial impact on a community. The effects of SSOs are discussed further in Section 6.

1.3.5 SSO Planning and Abatement

The reduction or elimination of SSOs can entail a variety of activities including:

- Sewer system cleaning and maintenance to remove restrictions
- Reducing I/I through system rehabilitation
- Upgrading sewer, pump station, or POTW capacity and/or reliability

Abatement of SSOs is discussed in greater detail in Section 3.

1.3.6 Eliminating SSOs—Goals and Realities

This report estimates financial needs for reducing collection system infrastructure deficiencies to very low levels in accordance with existing control objectives of minimizing SSOs. The complete elimination (zero overflows) of SSOs nationally is not considered a realistic option. On a national basis, collection systems could not feasibly be designed or operated to achieve this level of control. Several factors preclude a collection system from being completely free from overflows:

Environmental Considerations: When designing a collection system, engineers make assumptions about the amount of I/I that enters the collection system through leaky joints and cracks and other unavoidable structural defects. While in principle, sewers could be designed to account for every possible condition, this approach is not feasible. Oversizing of pipes for rare storms would result in flowrates during dry weather inadequate to carry solids, resulting in deposition and potential blockages.

Natural Disasters: Widespread flooding, extreme storms, hurricanes, earthquakes, tornadoes, localized subsidence, and other natural events can cause SSOs. Designing a collection system to completely withstand these forces of nature under all potential circumstances is not feasible.

Blockages: Because of the extensive reach and dendritic pattern of sewer systems, opportunties for blockages are ubiquitous and cannot be anticipated or prevented on an ongoing basis. Roots from trees affect the structural integrity of sewer pipes, and frequently lead to blockages and SSOs. In addition, acts of vandalism, accidental releases into the system of sewer-blocking materials, and other events can lead to SSOs, even when all reasonable measures have been taken to eliminate them.

The results portrayed in this report for control levels approaching the zero overflow level of control are only to illustrate how costs would increase with incremental levels of control. Readers should not conclude that at some level of expenditure, the complete elimination of SSOs under all conditions could be a reality.

1.4 DEFINITIONS OF KEY CONCEPTS

This section provides definitions and a brief discussion of some important concepts used in this report. A number of SSO-related concepts can sometimes be interpreted in different ways.

1.4.1 Baseflows, Infiltration and Inflow

Flows in sanitary sewer collection systems can be described in terms of major components such as baseflow (or dry weather flow), inflow, and infiltration. "Baseflow" describes the wastewater that a sanitary sewer system is intended to convey and includes wastewater from residences and commercial, institutional, and industrial establishments. Sanitary sewers are not installed to collect large volumes of infiltration and inflow (I/I), although I/I enters sanitary sewers because they are not watertight. For sanitary sewers that receive significant levels of I/I, the highest rate of wastewater flow typically occurs during wet weather conditions Figure 1 shows how flows in a sewer system with significant I/I can respond to a wet weather event.

Inflow generally refers to water other than wastewater — typically precipitation like rain or snowmelt — that enters a sewer system through a direct connection to the sewer.[1] Inflow connections to sanitary sewers generally are not supposed to be authorized. Many inflow connections are the result of third parties' "tapping" into a sanitary sewer line without the knowledge or consent of the municipal sewerage authority. Other inflow sources were legal connections at the time of installation. The volume of inflow in a sanitary sewer typically depends on the magnitude and duration of storm events (or related phenomena, such as snow melt), as well as other variables. Therefore inflow is often characterized by a rapid increase in volume that occurs during and immediately after a storm event.

Infiltration generally refers to other water that enters a sewer system through defects in the sewer.[2] Infiltration can be long-term seepage of water into a sewer system from the water table. In some systems, however, the flow characteristics of infiltration can resemble those of inflow — i.e., there is a rapid increase in flow during and immediately after a rainfall event, due, for example, to rapidly rising ground water. This phenomenon is sometimes referred to as rainfall-induced infiltration (RII).

1.4.2 Avoidable vs. Unavoidable SSOs

Even well-operated sanitary sewer collection systems can experience occasional SSOs. Their occurrence can be minimized through proper design, construction, operation, maintenance, and management. For the purpose of this report, SSOs are considered avoidable if they would have been prevented by properly designed and constructed system components, adequate collection system components, and appropriate preventive maintenance, operation, and oversight. Unavoidable SSOs are those that occur due to factors beyond the reasonable control of the operator, provided that the collection system is properly designed, constructed, operated, maintained, and managed.

Examples of unavoidable SSOs include:

- Discharges from constructed emergency overflow structures caused by exceptional acts of nature, such as widespread flooding, that can result in collection system flows that exceed approved collection system capacity in systems where the operator has taken all feasible steps to prevent the SSO.
- Discharges from uncontrolled locations (e.g., manholes, basement backups) caused by exceptional acts of nature, such as major storms and widespread flooding, that can result in collection system flows that exceed approved collection system capacity in systems where the operator has taken all feasible steps to prevent the SSO.

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[1] Inflow is defined in EPA's Construction Grants regulations at 40 CFR 35 2005(b)(21) as water other than wastewater that enters a sewer system (including sewer service connections) from sources such as, but not limited to, roof leaders, cellar drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, catch basins, cooling towers, storm waters, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration. Other, non-regulatory definitions of inflow found in the technical literature are similar to this with some variation as whether specific sources are included

[2] Infiltration is currently defined in EPA's Construction Grants regulations at 40 CFR 35 2005(b)(20) as water other than wastewater that enters a sewer system (including sewer service connections and foundation drains) from the ground through such means as defective pipes, pipe joints, connections, or manholes Infiltration does not include, and is distinguished from, inflow Other, non-regulatory definitions of infiltration found in the technical literature are similar to this with some variation as whether specific sources are included.

- Third-party actions, such as vandalism or sewer breaks caused by an independent entity's actions, that could not be reasonably prevented. This would not include the addition of wastewater, infiltration, or inflow to the collection system by a user or customer municipality.
- Some blockages that cannot be avoided by reasonable measures.
- Sudden unforeseeable structural, mechanical, or electrical failure that could not be avoided by reasonable measures such as providing adequate backup equipment.

1.4.3 Rainfall Events that Cause Overflows

Wet weather SSOs may occur at different discrete locations throughout a sewer system in areas affected by excessively high flows. For the purposes of the capital cost model used in this report, when multiple SSO caused by a single rainfall event occur in the same collection system, they will be counted as one SSO.

Therefore, the estimated number of annual rainfall events that cause overflows for a system is the number of rain events during which SSOs are expected to occur, regardless of the total number of individual locations for the SSOs.

1.4.4 Wastewater Collection Systems

In this report, EPA refers to a municipality that owns and operates treatment plants which receive from the collection system of other municipal entities as a "regional system owner/operator." Regional municipal collection system owner/operators who provide wastewater treatment often only operate a relatively small portion of the collection system (e.g., major interceptors, collector sewers in certain areas).

Municipal satellite collection systems discharge to a regional collection system that is owned and operated by an entity that is different from the owner and operator of the satellite system. Operators of municipal satellite collection systems typically do not operate a treatment plant for some or all drainage areas, but instead rely on the operator of the regional collection system to provide wastewater treatment and discharge the resulting effluent.

Portions of the collection system that are not directly owned by a regional municipal operator include:

Municipal satellite collection systems - Some regional collection systems accept flows from municipal satellite collection systems that are owned and operated by a different municipal entity

Non-Municipal collection systems - Private satellite collection systems are associated with a wide range of entities such as some trailer parks, residential subdivisions, apartment complexes, commercial complexes such as shopping centers, industrial parks, college campuses, and military facilities.

Non-municipally owned building laterals - Non-municipally owned sewers make up a high percentage of the total sewer length of most sanitary sewer collection systems. Some portion or the entire length of lateral connections to buildings are generally owned by the building owner. Building laterals may feed into non-municipally owned satellite collection systems which convey wastewaters to a municipal collection system.

1.4.5 Market Externalities

SSOs persist in some communities despite the increasingly acknowledged adverse impacts they have on individual residents. Where these problems have not been adequately addressed, continuing SSOs may be thought as a market failure. There may be no market incentive for individuals contributing to the problem to contribute to its solution For example, homeowners whose downspouts or sump pumps are connected to the sanitary sewer may not be the homeowners in whose basement the backups occur. If the majority of homeowners are satisfied with the service provided by the local publicly owned treatment works (POTW), they may vote down a proposed sewer rate increase. A community, therefore, might not be able to raise sufficient public support to increase service to improve the conditions for the minority of homeowners that have problems. Because the costs of increased sewer rehabilitation would be borne by all residents, but the benefit (e.g., avoided basement backups) may accrue to a minority, the local government might not be able to justify to its citizens the costs to correct SSOs.

In the case of environmental quality, an additional problem is the public nature of this "good." Environmental quality is a 'public good' because it is predominantly nonexcludable and nonrival. Individuals who willingly pay for reduced pollution cannot exclude others who have not paid from also enjoying the benefits of a less-polluted environment. Because individuals tend to utilize but not assume ownership of many environmental amenities, they may not be willing to invest adequate resources in their protection. In the absence of government intervention, the free market will not provide public goods, such as a cleaner environment from the reduced occurrence of SSOs, at the optimal quantities and qualities desired by the majority of the general public and as required by health and environmental legislation.

1.5 STRUCTURE OF REPORT

This report is divided into two sections: 1) an overview of operating characteristics of sanitary sewer collection systems; and 2) national estimates of SSO abatement costs, or Needs. A national estimate of SSO abatement benefits is provided as a separate document. The report begins with a review of existing knowledge about the status of the nation's sanitary sewer systems in Section 2. The section describes the extent and condition of sanitary sewers nationwide and the occurrence of SSOs. Various national studies and specific case studies are reviewed to draw conclusions about the extent of SSO problems. Case study information is presented in Appendix A. Appendix B contains additional information on the value of sewer systems in the United States.

Section 3 contains a more detailed description of the actual contributing factors and potential solutions for both dry and wet weather SSO problems based on the information developed in Section 2. Section 3 includes a discussion of some of the characteristics of sanitary sewer systems that make them susceptible to SSOs. The section also includes a discussion of SSO abatement factors, such as sanitary sewer system management, operation and maintenance (MOM), and their potential role in reducing SSOs and extending the useful life of a system.

Section 4 outlines efforts to determine the general costs of SSO control through the review of data contained in the U.S. EPA 1996 Clean Water Needs Survey (CWNS) database, existing national surveys, and information gathered by state water pollution control agencies. Through the general information gathered from these data sources, a cost estimating methodology was developed and tested using existing data from the various sources, brought into consistent December 1998 dollars. The development of the cost estimating model, input parameters, and model test results are described in Section 4, with further information provided in Appendices C, D, E, and F. Section 4 also describes the MOM cost estimate.

The results of the cost model are then presented and analyzed in Section 5. Section 5 contains a discussion of the wet weather and MOM costs developed, the calibration costs associated with specific communities, and an analysis of the results.

A References Section follows Section 5 and contains a list of the references cited in the report. For sources cited in the appendices, references have been included directly in the relevant appendix.

SECTION TWO

OPERATING CHARACTERISTICS OF SANITARY SEWER COLLECTION SYSTEMS

2.1 INTRODUCTION

A sanitary sewer collection system is typically one of the largest infrastructure investments that must be operated and maintained by municipal governments. These systems represent a major public health investment. Approximately 148 million people are served by approximately 3 billion linear feet or 500,000 miles of municipally owned sanitary sewer pipe. An EPA estimate places the asset value of this resource at $950 billion to $2.3 trillion. These sanitary sewer collection systems have been constructed over a number of years, dating back to the early 1900s in some communities. Existing systems are upgraded and expanded and new systems are added to the network continuously.

This chapter discusses the performance of sanitary sewer collection systems and the prevalence of SSOs. Performance data from both national surveys and case studies are provided to give an understanding of the existing condition of the nation's sanitary sewer collection systems.

2.2 PERFORMANCE OF SANITARY SEWER COLLECTION SYSTEMS

2.2.1 Overview

Enough information is available to make the following generalizations about sanitary sewer collection systems in the United States:

- Sanitary sewers are an extensive part of the nation's municipal infrastructure.
- Sanitary sewer systems experience periodic failures.
- Collection system performance varies significantly from system to system.
- A significant number of systems have SSO problems, particularly in wet weather.
- NPDES requirements for sanitary sewer collection systems are inconsistently applied.
- Information on sanitary sewer collection systems and SSOs is limited.

These generalizations are supported by several major studies and national surveys (listed in Table 2-1) that provide information on the existing condition of sanitary sewer systems and the extent and nature of SSO problems. These surveys present extensive information on sanitary sewer systems including:

- Sewer system failure and backup rates
- SSO occurrences and locations
- Overflow volume relative to POTW flows
- SSO receiving water type
- Relative expense associated with sewer system evaluations
- Relative success of rehabilitation programs
- Maintenance expenditures associated with various O&M practices

Additional information is available from a number of communities that have addressed their SSO problems. The surveys and case studies provide an understanding of the extent of SSO problems and the need for a national SSO policy to address these problems

The following sections discuss each of the above generalizations, drawing on information from the national surveys and case studies. (For information on the individual case studies, see Appendix A.)

2.2.2 Sanitary Sewers Are an Extensive Part of the Nation's Municipal Infrastructure

The National Council on Public Works Improvement estimates that wastewater treatment and collection systems represent about 13 percent of the total infrastructure value in the United States (NCDWI, 1988). The total replacement value of sewage collection systems in the United States can be estimated at $950 billion to $2.3 trillion (See Appendix B). The collection system of a single large municipality can represent an investment worth billions of dollars.

The U.S.EPA 1996 Clean Water Needs Survey ("Clean Water Needs Survey" or CWNS) database identifies more than 19,000 municipal sanitary sewer collection systems. These systems serve an estimated 148 million people and are comprised of an estimated 500,000 miles of municipally owned sanitary sewers in the United States. Table 2-2 provides the distribution of system size based on the 1996 Needs Survey data. A relatively few larger systems serve a significant percentage of the population, while there are a great number of smaller systems. Of the more than 19,000 systems, about 4,000 are satellite collection systems that do not treat their own wastewater but rather discharge to a regional collection system that is owned by a different entity.

Privately owned sewers make up a high percentage of the total sewer length of most sanitary sewer collection systems. Private satellite collection systems can be associated with trailer parks, some residential subdivisions, apartment complexes, commercial complexes such as shopping centers, industrial parks, college campuses, and military facilities. Additionally, building laterals are generally owned by the building owner, including single family residences.

ASIWPCA estimates that about 25,000 privately owned collection systems which treat their wastewater with their own plant have been issued NPDES permits. The number of privately owned collection systems that discharge their wastewater to municipal collection system cannot be estimated at this time.

2.2.3 Sanitary Sewer Systems Experience Periodic Failures

A 1984 study of urban infrastructure indicated that on average, there are about 825 sewer backups and 140 sewer breaks every year for every 1,000 miles of sewer. A system of 1,000 miles of sewer serves about 250,000 people (UI).

Sewer backup rates are highest in the northeast and economically distressed cities. System backups are generally higher in communities with the oldest sewer systems, both because of materials in use at the time and because of deterioration. Sewer break rates are highest in the South and West, and are particularly associated with large, growing cities (UI).

Table 2-1. Major Studies on U.S. Sanitary Sewer Collection Systems[1]

Author/Conducting Agency	Reference	Respondents	Date
Association of Metropolitan Sewerage Agencies (AMSA)	Unpublished survey conducted by AMSA	79 member municipalities	1994
Association of State and Interstate Water Pollution Control Administrators (ASIWPCA)	Association of State Interstate Pollution Control Administrators (ASIWPCA), 1997 *Sanitary Sewer Overflow ASIWPCA Membership Survey Results Final Technical Report* Washington, DC	34 States (data for 38,950 wastewater collection systems)	1996
Urban Institute (UI)	Guide to Managing Urban Capital Series Volume 3 Guide to Benchmarks of Urban Capital Condition	62 cities	1984
Water Pollution Control Federation (WPCF)	N/A	1,003 treatment plants	1989
U S EPA Region VI	N/A	734 municipalities	1991
U S EPA Clean Water Needs Survey	1996 Clean Water Needs Survey Report to Congress	53 states and territories	1996
U S EPA Clean Water Needs Survey Special Questions	Sanitary Sewer Characterization Questionnaire	377 municipalities	1996
CA Comparison Study	N/A	6 municipalities	1991
California State University	Arbour, R., and Kerri, K *Collection Systems Methods for Evaluating and Improving Performance*. Prepared for EPA Office of Water.	13 municipalities	1997
Charlotte-Mecklenberg Utilities	Thorton, J and Schoeps, N *Benchmarking of Wastewater Collection Agencies*	18 municipalities	1995
Civil Engineering Research Foundation (CERF)	N/A	345 municipalities	1994
Faria and Larson	Faria, M , and Larson, J , *The Advantages, Difficulties, and Results of Benchmarking,* Presented at the California Water Environment Association	8 municipalities	1996
Hansen Information Technologies	Hansen, C , *Industry Best Practices for Managing Wastewater Collection Systems,* Collection Systems Rehabilitation and O&M, Water Environment Federation	50 municipalities	1997
Knott and Singleterry	*City of Portland Sewer Collection System Maintenance Management Plan,* Presented at the National Conference on SSOs	5 municipalities	1995
Dallas Water Utilities	Stalnaker, R. and Rigsby, M , *Evaluating the Effectiveness of Wastewater Collection System Maintenance,* In Water Engineering and Management	13 cities	1997
Louisiana Tech University	Malik, O , Pumphrey, N D , and Roberts, F.L , *Sanitary Sewers State of the Practice*, Infrastructure Condition Assessment· Art, Science, and Practice, ed M Saito ASCE New York.	121 municipalities	1997
American Society of Civil Engineers (ASCE)	Black and Veatch *Optimization of Collection System Maintenance Frequencies and System Performance.* Prepared for the EPA Office of Water under a cooperative agreement with ASCE	42 municipalities	1998
Water Environment Research Foundation (WERF)	*Benchmarking Wastewater Operations-Collection, Treatment, and Biosolids Management*, Project 96-CTS-5	53 municipalities	1997
U S EPA–Rainfall Induced Infiltration Study	*Rainfall Induced Infiltration into Sewer Systems - Report to Congress*, EPA Office of Water Washington DC	10 case studies	1990

[1] Sources (in order listed above) AMSA (1994), ASIWPCA (1996), Peterson, et al (1984), WPCF (1989), U S EPA Region VI (1991), U S EPA (1994a), U S EPA (1996a), SAIC (1991), Arbour and Kerri (1997), Charlotte (1995), CERF (1994), Faria and Larson (1996), Hansen (1997), Knott and Singleterry (1995), Stalnaker and Rigsby (1997), Malik, Pumphrey, and Roberts (1997), Water Environment Research Foundation (1997), ASCE (1998), and U S EPA (1990a)

Table 2-2. Service Population Distribution of Sanitary Sewer Systems in the United States – 1996[1]

Population Range	Estimated Number of Systems	Estimated Total Population Served by the Systems	Portion of Total No. of Systems	Portion of Total Service Population
Under 10,000	16,359	29,000,000	85.9%	19.6%
10,000 - 24,999	1,632	25,300,000	8.6%	17.1%
25,000 - 49,999	604	21,100,000	3.2%	14.2%
Sum Small Communities <50,000	18,595	75,400,000	97.7%	50.9%
50,000 - 249,999	396	40,800,000	2.1%	27.6%
250,000 - 499,999	30	11,100,000	<0.1%	7.5%
500,000 - 999,999	15	10,800,000	<0.1%	7.3%
Over 1,000,000	4	9,900,000	<0.1%	6.7%
TOTAL	19,040	148,000,000	—	—

NOTE: Data are from the 1996 EPA Clean Water Needs Survey data base. Data does not include approximately 900 combined sewer systems for 1996.

1. U.S. EPA, 1997.

CERF estimates that approximately 75% of the nation's sanitary sewer systems function at 50% of capacity or less. In addition, they estimated that sewer pipeline stoppages and collapses are increasing at a rate of approximately 3% per year. Roots cause over 50% of the stoppages, while a combination of roots, corrosion, soil movements and inadequate construction are the cause of most structural failures (CERF).

The State of Oklahoma has an extensive database on SSO occurrences. Over a two-year period, 350 of the 513 municipal sanitary sewer collection systems in the State reported at least one SSO. The Clean Water Needs Survey classifies 85% of the systems in the State as small community facilities of less than 10,000 population. About half of the SSOs occurred in 11 municipalities that reported over 100 SSOs each. An additional 43 municipalities reported 25 to 100 SSOs each. The database was used to develop a statewide estimate of 79 SSOs/yr/1,000 miles of sewer.

Case studies of four large municipal collection systems with extensive records on their SSOs provide information on the occurrence of different types of sanitary sewer system failures and resulting SSOs (excluding basement overflows) The results from four of these case studies are summarized in Table 2-3.

Table 2-3. Data on SSOs from Four Large Municipalities that Track SSO Information

Parameter	City/Region			
	Louisville	**Oakland**	**Charlotte**	**MD Suburbs/ Washington, DC**
Miles of sewers maintained	1,534	1,500	2,445	4,600
Reporting period	1993–94	1993–94	1983–93	1990–94
Type of failure				
Blockages-O&G/roots/solids*	7	300	---	---
Hydraulic capacity exceeded	0	0	180	---
Pump station failures	25	0	4	---
Sewer breaks	12	600	---	---
Rainfall induced I/I	115	18	---	---
Total SSOs/yr	165	---	359	234**
Total SSOs/yr/1,000 miles	**110**	---	**147**	**51**

Note: --- = Data not available

* O&G = oil and grease.

** Data do not include basement backups. MD Suburbs/Washington, DC reported an average of 592 basement backups per year, caused by either a problem outside the property line or a sewer main surcharge

2.2.4 Collection System Performance Varies Significantly From System to System

A comparison study done by the city of Charlotte, NC in 1995 gathered data from 18 municipal wastewater collection agencies on the size and extent of the systems and system performance. Even when adjusted for system size differences and related factors, the data collected for the study showed wide variances in system performance. For example, the number of main blockages per 100,000 population ranged from 1 to 1,807, with a median value of 24 main blockages per 100,000 population. The variance may come from differences in system characteristics not considered in the study, such as system age and design and soil conditions.

A 1984 Urban Institute study, reporting on a survey of 62 cities, found a wide range in system performance, with a few cities reporting annual rates of more than 3,000 sewer backups and 550 sewer breaks for every 1,000 miles of sewer. At the other end of the spectrum, a few municipalities reported under 60 sewer backups and under 10 sewer breaks per year for every 1,000 miles of sewer. The report indicated that cities in the South and West reported the highest rates of breaks.

In the 1984 Urban Institute study, local officials attributed high rates of sewer breaks and backups to a variety of factors: the materials, construction methods, and technology in practice at the date of installation, the location of pipe in trouble-prone areas, the size of pipes (smaller pipes back up and break more frequently), local soil conditions, and maintenance practices.

A 1991 EPA study compared overflows estimated to be over 1,000 gallons in six California municipalities. The results, summarized in Table 2-4, showed significant variation in performance across systems.

A review of 10 case studies by EPA in 1990 found that peak wet weather flow ranged from 3.5 to 20 times the average dry weather flow.

Table 2-4. Comparisons of SSOs Over 1,000 Gallons in Six Municipalities in California[1]

Agency	Time Period	Months	Monthly Average No. of Overflows Over 1,000 Gallons/ 1,000 Miles of Sewer	Monthly Average Overflow Volume Gallons/1,000 Miles of Sewer
City of San Diego	1/87 – 5/90	41	7.5	123,000
City of Los Angeles	1/87 – 5/90	41	0.1	37,000
Los Angeles County	2/87 – 5/90	38	0.3	3,000
County Sanitation District of Los Angeles County	2/87 – 5/90	38	0.3	11,000
County Sanitation District of Orange County	5/87 – 5/90	37	0.6	51,000
Central Contra Costa Sanitary District	1/87 – 5/90	41	0.3	10,000

Note: Sanitation District sewers do not include small diameter collector sewers (street sewers) serving local agencies.

1 SAIC, 1991

2.2.5 A Significant Number of Systems Have SSO Problems

In 1996, states estimated that 29 percent of municipal sanitary sewer collection systems experience wet weather SSOs, and 25 percent of POTWs served by sanitary sewer collection systems experience some degree of treatment problem during wet weather (ASIWPCA).

- Of the 79 large municipalities responding to AMSA's 1994 survey, 65 percent have SSOs in wet weather.
- States reported that 31 percent of municipal systems have at least an occasional dry weather SSO. The estimated number of dry weather SSOs annually is 1,962 for the 25 states providing this information (ASIWPCA).
- In a 1989 WPCF survey, 1,003 POTWs identified facility performance problems. I/I was the most frequently cited problem, with 85 percent of the facilities reporting I/I as a problem. I/I was cited as a major problem by 41 percent of the facilities (32 percent as a periodic problem and 9 percent as a continuous problem).
- In 1991, EPA Region VI's MWPP program identified I/I as the major source of noncompliance and determined that wet weather SSOs and bypasses due to I/I were occurring in more than 50 percent of the 734 municipalities participating in the program.

2.2.6 NPDES Requirements for Sanitary Sewer Collection Systems Are Inconsistently Applied

Different NPDES authorities have historically provided different emphasis on oversight of sanitary sewer collection systems. In addition, some of the key NPDES regulatory provisions addressing sanitary sewer collection systems are unclear, and different NPDES authorities have provided different interpretations regarding their applicability to SSOs. Some examples of inconsistent application are.

- Of the 34 states responding to a 1996 ASIWPCA survey, 28 establish collection system requirements in their discharge permits for treatment facilities Of these 28 States, 24 apply the bypass or similar provisions and 20 apply the upset or similar provisions.
- For municipal collection systems without a treatment plant that convey flow to another system, 2 states issue permits for all such systems, 5 states issue permits for some of these systems, and 26 states do not issue permits for these systems. In states not issuing discharge permits for all such systems, collection systems may be regulated by local entities (10 states), other state measures (17 states), or other means (4 states). In 2 states, such collection systems are not regulated at all (ASIWPCA).
- Wet weather control facilities that provide some level of treatment or flow control prior to discharge are authorized by 13 of the states responding to the ASIWPCA survey. These facilities take various forms and provide varying degrees of treatment.
- Region 6 and states in at least four other EPA Regions (2, 3, 5, and 9) have issued permits for controlled discharges from wet weather facilities. Other states and Regions have not currently decided to allow wet weather facilities.
- Of the 34 states responding to the ASIWPCA survey, no states indicated that they had a policy of always seeking an enforcement action for an SSO. Ten states (out of the 20 providing responses) indicated they had taken no formal enforcement actions related to SSOs during the past 3 years.
- States have different standards that are implemented in varying ways. While 29 of the states responding to the ASIWPCA survey use an allowance to account for extraneous flow entering the collection system, the allowance is calculated in different ways (e.g., volume, use of a peaking factor, portion of I/I deemed cost effective for conveyance and treatment).

In drawing overall conclusions from the survey results, ASIWPCA noted that clarifying national SSO policy expectations and increasing awareness of them among collection system operators, with special attention to satellite systems, is one of the areas that could most benefit from national attention.

2.2.7 Information on Sanitary Sewer Collection Systems and SSOs Is Limited

Although national surveys and studies have collected information on sanitary sewer collection systems and SSOs, national information on the status of collection systems and the extent of SSO problems remains limited and many municipalities are unaware of the overall extent of SSO problems in their own systems:

- In 1994, 40 percent of the municipalities participating in the AMSA survey reported that they did not have information on the annual number of SSOs in their system. Half of the respondents did not know the quantity discharged and 87 percent have not characterized SSO quality.
- States think compliance with NPDES reporting requirements for SSOs is mixed, with poor reporting in some categories. Only 30 percent of the states responding to the ASIWPCA survey estimate that all or nearly all of their municipal permittees comply with SSO reporting requirements, with a corresponding figure of 22 percent of states for their private sector permittees. Further, 18 percent of states thought that less than 50 percent of their municipal permittees are in compliance with SSO reporting requirements, with a corresponding figure of 31 percent of states for their private sector permittees.
- Municipalities have indicated that the lack of available and reliable information, as well as a lack of uniform definitions, have made characterization of their collection systems difficult and inaccurate (UI)

SECTION THREE

CAUSES AND CORRECTION OF SSOs

3.1 INTRODUCTION

This section describes some of the more common factors contributing to SSOs. The role of sewer system capacity, management, operation and maintenance (CMOM) programs in abating SSOs is discussed. The surveys and case studies described in Section 2 indicate that the performance of many of the nation's sanitary sewer collection systems is poor and experience SSOs. Table 1 describes many of the underlying reasons for the poor performance of many of these systems. In summary, these reasons include:

(1) The materials, design, and construction practices historically used in older sewers have contributed to poor sewer performance and deterioration and do not perform to the same level as those today;

(2) An aging infrastructure that has deteriorated with time;

(3) A history of inadequate investment in infrastructure maintenance and repair often associated with an "out-of-sight, out-of-mind" approach;

(4) Collection system performance depends on numerous variables and the location of problems (e.g., roots, debris) may change throughout a system;

(5) Failure to provide capacity to accommodate increased sewage delivery and treatment demand from increasing populations; and

(6) Institutional arrangements relating to the operation of sewers — e.g., almost all building laterals in a municipal systems are privately owned; in many municipal systems, a high percentage of collector sewers are owned by private entities or municipal entities other than the entity operating the major interceptor sewers.

3.2 MAJOR CAUSES OF SSOs

There are many factors responsible for SSOs. These factors can be grouped into three major categories:

- Peak flows that exceed system capacity,
- Blockages
- Structural, mechanical or electrical failures.

These categories are not exclusive as individual SSO events can be caused by a complex combination of factors. For example, partial blockages caused by debris, sediment, oil and grease, or roots can reduce the effective capacity of a pipe and cause an overflow during peak flow conditions.

3.2.1 Capacity Problems

Peak flows in sanitary sewers can result in overflows when the flows exceed the capacity of a component of the collection system. Capacity problems typically arise when:

Table 3-1. Major Underlying Factors That Have Contributed to Poor Sewer Performance and Deterioration

1 Accepted industry design standards often provide inadequate flow capacities for realistic levels of inflow and infiltration

2 Older systems were made of pipes with short lengths and many joints. Manholes were made of brick and mortar. Materials and joints were susceptible to hydrogen sulfide corrosion. Improved materials, such as precast concrete manholes, did not become predominant products until the late 1960s.

3 Collection systems were not installed as designed. Problems are caused by faulty construction, poor inspection, and low-bid shortcuts.

4 Sewers made of "permanent" material are only as permanent as the weakest joints. Earth movement, vibrations from traffic, settling of structures, and construction disturbance require flexible pipe material or joints that can maintain tightness.

5 Corrosion of sewer pipes, from either the trench bedding and backfill or the wastewater being transported by the collection system, was a factor neglected by many design engineers.

6 Not enough scientific knowledge existed or was available to designers about potential damage from plant roots to pipe joints. Root growth is a principal cause of pipe damage that allows infiltration.

7 The "out-of-sight, out-of-mind" nature of the wastewater collection system poses an inherent problem. Many collection systems are maintained by a public works department charged with street, sidewalk, storm drain, and sometimes water utility maintenance. Money is usually spent where the rate-payer can see the results.

8 Negligence and vandalism can be the source of collection system problems. Any material in a sewer will slow the flow and allow other solids to settle.

9 Ditches in which sewers are installed have the bottoms sloping downhill to produce gravity flow. Water that enters a ditch may not easily seep out of the ditch where silt and clay soils have been compacted by heavy excavation equipment. Possible problems include ground-water infiltration into the sewer, flotation of the sewer, and structural failure of the sewer or joint.

10 Poor records on stoppages or complaints from the public can result in an ineffective maintenance program

Source: California State University at Sacramento, 1993.

(1) Actual I/I levels exceed projected levels used in system design. - Actual I/I levels exceed projected levels used in system design - Historically, accepted design standards have often resulted in inadequate capacity for realistic levels of I/I. This due to a combination of factors such as pipe and manhole materials, number of pipe joints, overly optimistic expectations of the ability to remove I/I, inaccurate methods of estimating I/I, and lack of preventive maintenance, many sanitary sewers have experienced I/I levels that were greater than what were originally expected when sized (Merril and Butler, 1994).

(2) The effective capacity of system components is significantly less than the design capacity of those components. - The design capacity of components of the collection system may be lost to partial blockages caused by solid deposits, debris, sediment, grease, or roots. Structural deficiencies (e g., not meeting minimum velocity requirements, structural abnormalities) and inadequate sewer cleaning can contribute to the formation of partial blockages in sewers. In addition, pumps often lose capacity with time. Pump capacity loss can be greatly accelerated by lack of proper maintenance.

(3) Additional hookups that exceed the design of the collection system occur. - Sewers, pump stations, and treatment facilities are typically sized to accommodate projected future growth within reasonable periods. Capacity problems may occur if new hook-ups exceed the allowance for projected growth or if commercial, institutional, or industrial customers increase their wastewater contributions beyond anticipated levels.

Almost all sewer systems exhibit some level of I/I which increases system flows during wet weather, although the amount of I/I can vary significantly from system to system. Historically, industry guidelines for sanitary sewers have required that sewers provide extra capacity for I/I flows which typically has ranged from 2 to 6 times the estimated volume of baseflow in the sewer. However, accepted design standards often provide inadequate capacity for actual levels of I/I. EPA reviewed ten case studies of municipalities with significant I/I problems and found peak wet weather flows that ranged from 3.5 to 20 times the average dry weather flow (U.S. EPA, 1990a).

The amount of I/I entering a sanitary sewer system depends on a complex set of variables, including the magnitude and duration of a particular storm event, surface water height, ground water height, condition of system components (e.g., joints, pipes, laterals, and manhole frames and covers), antecedent soil moisture, size of sewershed, drainage of soils, and the existence of improper connections.[3] The relationship between peak flows and these variables is system-specific and often event-specific. This relationship probably changes with time for a given system as components of the system deteriorate with time, rehabilitation projects are undertaken, and the system expands.

3.2.1.1 System Age and Condition

The age of components in a collection system is one of the most important factors affecting the amount of I/I in a collection system. Much of the nation's sanitary sewer infrastructure is old; some parts of this infrastructure date back over 100 years. A survey of 42 wastewater utilities indicated the age of components of collection systems ranged from new to 117 years, with an average age of 33 years [4] During this time, a wide variety of materials, design and installation practices, and maintenance/repair procedures

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[3] See "*Handbook Sewer System Infrastructure Analysis and Rehabilitation*," EPA, 1991, which indicates that inflow and rainfall-induced infiltration (RII) component flow information is strongly related to the characteristics of the rainfall events occurring during the monitoring period and discusses that infiltration is dependent on rainfall *Rainfall Induced Infiltration into Sewer Systems Report to Congress*, EPA, August 1990 ("EPA guidelines acknowledged that both infiltration and inflow are affected by rainfall"), *Existing Sewer Evaluation & Rehabilitation*, WEF Manual of Practice FD-6, ASCE Manual and Report on Engineering Practice no. 62, 1994 ("In many areas of the U S., the combination of snow melt and rainfall may induce maximum I/I"); *Operation and Maintenance of Wastewater Collection Systems, a Field Study Training Program*, fourth edition, California State University, Sacramento, 1993 ("Precipitation runoff is usually highly correlated with inflow")

[4] *Optimization of Collection System Maintenance Frequencies and System Performance*, American Society of Civil Engineering, 1999

have been used, many of which are inferior to those available today. The age of sewer systems generally varies among communities, and to some degree from one region of the country to another, based on when development occurred. However, the age within a specific system can even vary from one neighborhood to another, and some older cities have probably replaced sections of their sanitary sewer system in especially poor condition in recent years.

The material used in constructing a sewer system is closely related to the age of the system. Older systems are not only more likely to have experienced failure but are typically made of materials commonly in use at the time of installation, with more joints, and less corrosion resistance. The relationship of sewer age, type of jointing, and its likelihood of leakage is shown in Table 3-4. In many older systems, pipe materials are now known to be less durable than previously understood. Many older sewers have had service lives well short of what manufacturers represented. WEF indicates that such has been the case with unlined and unreinforced concrete pipes and earlier versions of reinforced plastic, mortar-lined pipe (WEF, 1999). Older pipes were often manufactured in short lengths with a relatively high number of field-applied joints that have the potential for leakage. Jointing materials used in older pipes have proven to be highly susceptible to degradation with time, leading to leaking joints. Unreinforced concrete and metallic pipe, as well as brick, have also been used for sewer construction. In some areas with warm climates, where concrete and metallic pipe have been installed with shallow grades, the combination of high temperature and solids deposition in the system can lead to hydrogen sulfide generation and corrosion. Also, the lack of reinforcement can increase the likelihood of structural failure leading to major blockages and SSOs.

More recently, pipelines have been manufactured with materials less susceptible to hydrogen sulfide (H_2S) corrosion, such as PVC and HDPE (high-density polyethlyene). Other pipes have been lined or coated to reduce the level of corrosion. In addition, pipes are being manufactured in longer sections, thereby reducing the number of joints and possible entry points for I/I. Vitrified clay pipe produced today is also provided with flexible compression joints that help protect against leakage. Manholes in older systems were typically constructed of brick, which through deterioration with age can contribute to I/I. Since the late 1960s, however, precast concrete manholes with watertight gasketed joints have been the predominant product for sewer manholes. Use of precast concrete manholes can result in significantly fewer entry points for I/I, provided the manholes have been constructed and installed properly.

The condition of a collection system can also depend on the oversight that a municipality provides during the original construction of the system and the historic level of investment made in repairing and maintaining the collection system.

Table 3-2. Relationship Between Sewer Age, Joint Type, and Likelihood of Leakage

System Age (Year of Construction)	Typical Joint Type	Relative Likelihood of Leakage
Pre-1940	Cement	High
1940–1965	Bituminous	Moderate
1965–Present	Rubber Gasket	Low

Ownership patterns often affect the amount of maintenance sewers receive. Typically, private building owners provide little maintenance of building laterals, other than to make sure that the lateral is not severely clogged or causing observable problems like sinkholes. Relatively severe infiltration may occur without any sign at the surface, and even if a building owner was somehow aware of infiltration in a lateral, the owner typically has little incentive to fix it. Municipalities participating in a WEF survey reported a wide range in the percentage of I/I in their systems that came from privately owned building laterals, from very little to 75 percent of the total I/I.[5]

3.2.1.2 Rainfall and Ground-Water Levels

About 70 percent of the over 300 municipalities participating in a recent survey indicated that surface water fluctuations (related to wet weather events) and ground water fluctuations have an effect on I/I in their sanitary sewer collection systems (WEF, 1999). The magnitude and intensity of rainfall directly impacts rainfall-induced I/I entering the system. Communities in regions with higher rainfall amounts and greater rainfall intensity are generally more prone to SSOs than those in regions with little rainfall. During more intense storms, rainfall occurs more quickly and can enter the system at a high rate for a short period of time. This high rate of rainfall-induced I/I can lead to overflows, even if the total volume for the storm is relatively low. Therefore, systems in regions with short, intense storms but relatively little total rainfall may have more SSOs as a result of rainfall-induced I/I than systems with higher total rainfall coming from longer, less intense storms. Foundation drains connected to the sewer system can contribute a significant amount of infiltration during long duration, low intensity storms and multiple storm events.

Elevated ground-water levels during certain times of the year or other climate issues such as frozen ground, freeze-thaw, and shrink-swell potential, can lead to increased infiltration. If the ground is frozen during the rainfall event, the runoff will result in increased stream levels and only groundwater levels under the direct influence of stream levels will be impacted.

3.2.1.3 Soil Type

Soil type (e.g., clay, loam, sand and gravel, rock) level of rainfall-induced infiltration entering the sewer system through leaky pipe joints. Soils with high clay content may provide poor bedding, which can lead to joint separation and increased infiltration. Water that drains into a sewer trench that is surrounded by clay soils may remain in the trench for extended periods extending opportunities for infiltration. Pervious soils, such as sands and gravels, will generally exhibit high ground-water flow, which can lead to increased infiltration through pipe joints and cracks. Soil conductivity levels will also affect corrosion rates. Soil conditions can vary greatly from one community to another and even within the same community.

3.2.2. Blockages

Deposition and blockages may occur from introducing improper materials into sewers, and from introduction of grease, grit, roots, or other debris. The potential for blockages can increase in sewers having flat slopes that reduce flow velocities or other structural defects. A detailed five-year review of backups and overflows in the Washington Suburban Sanitary Commission system (Hannan, 1995) attributed 74 percent of sewer system blockages to foreign material in the system, structural defects causing excessive deposition, or grease and root blockages.

3.2.3. Structural, Mechanical or Electrical Failure

A wide range of structural, mechanical or electrical failures can occur in sanitary sewer collection systems. Examples include cracks or holes in pipes caused by corrosion or external forces and loss of electricity to pump stations. A continuous maintenance effort, including an inspection program, should reduce the occurrence of overflows. Ready access to replacement parts and backup equipment supports rapid response to those SSOs that do occur.

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[5] *Control of Infiltration and Inflow in Private Building Sewer Connections*, WEF, 1999.

3.3 SSO CORRECTION

SSO occurrences can be reduced by effectively implementing comprehensive capacity assurance, management, operation and maintenance (CMOM) programs for collection systems. A comprehensive program is necessary because:

- SSOs are caused by a variety of factors, and a comprehensive set of measures are needed to these factors;
- Collection systems deteriorate with time, and a continuous reinvestment into the system must be made to maintain and/or improve system performance;
- The timing and/or the location of most SSO events is generally unpredictable. Such overflow events can only be prevented by preventative strategies rather than reactive ones.

The complexity and expense associated with a system's CMOM program is specific to the size and complexity of the collection system. Factors such as population growth rate and soil/groundwater conditions can impact the type and level of investment that should be made.

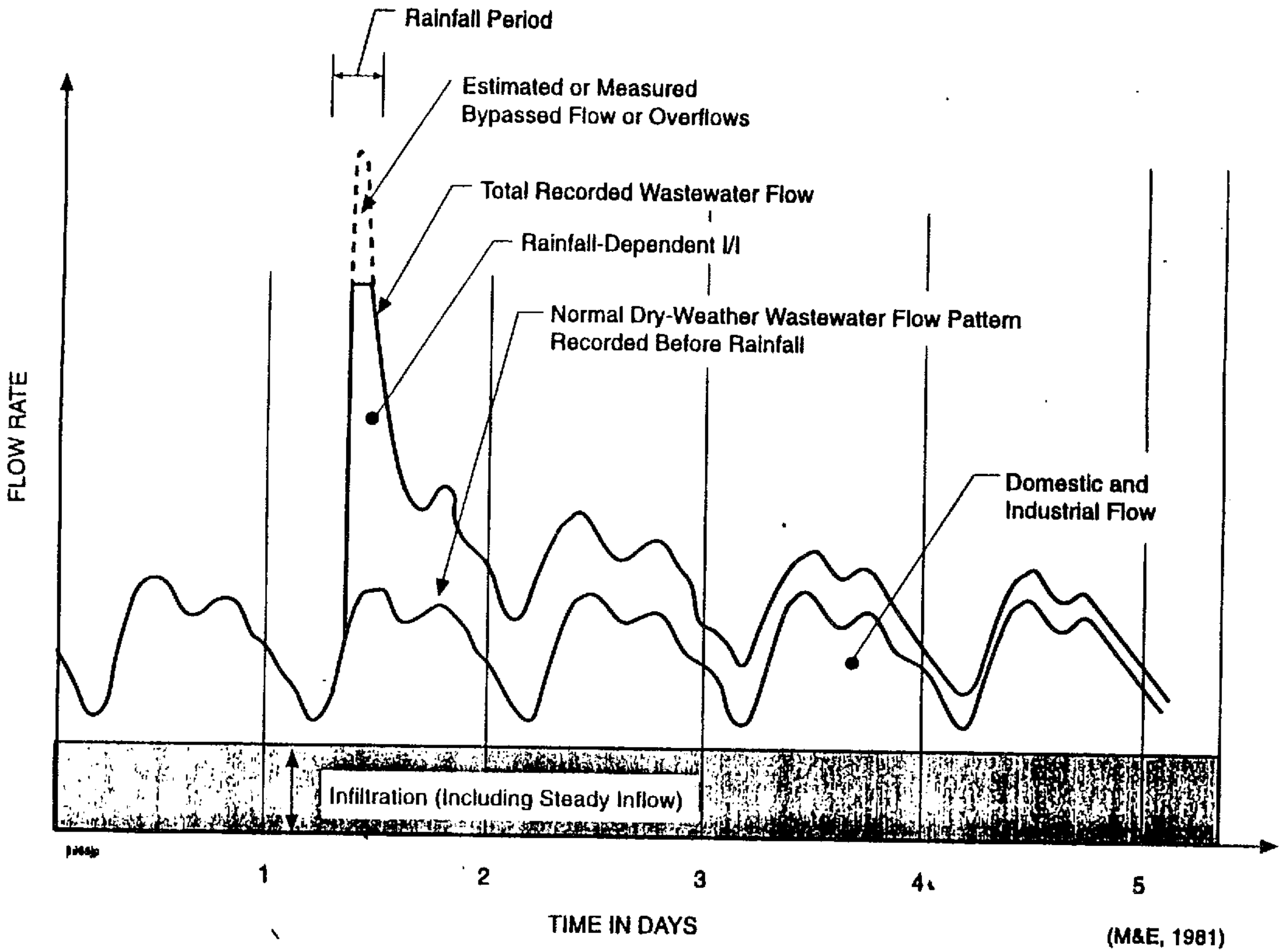
Increased implementation of comprehensive CMOM programs is expected to reduce SSO occurrences with time as:

- Older deteriorated components are either replaced with better performing components or repaired by lining or other means;
- System bottlenecks, such as areas where slopes are too flat or undersized pumps, are fixed;
- Institutional issues, such as ownership, are worked out resulting in more comprehensive application of repair and maintenance activities throughout the collection system;
- The investment in managing, operating and maintaining a collection system is increased; and
- Information management and other targeting procedures improve the efficiency of maintenance and repair activities.

New sewers are generally expected to perform much better and much longer than their older counterparts, due to improved materials and design standards (e.g. greater minimum slope requirements) and enhanced oversight by municipalities in their installation.

3.3.1 Correction of Capacity Related Problems

Capacity problems are typically addressed through a combination of capital improvements that increase design capacity and remove bottlenecks, flow reduction measures and operation and maintenance activities that restore the effective capacity to near the design capacity. The SSO Subcommittee to the Urban Wet Weather Federal Advisory Committee identified the following preferences for activities addressing capacity problems (with most favored listed first):



(M&E, 1981)

Figure 3-1. Reaction of a Typical Sewer System to a Wet Weather Event

- Reducing wet weather peak flows by removing I/I,
- Increasing conveyance capacity,
- Increasing storage capacity; or
- In very limited circumstances, constructing peak excess flow treatment facilities.

3.3.1.1 Infiltration and Inflow Reduction

Infiltration/Inflow (I/I) reduction programs (rehabilitation) are performed to reduce peak flow volumes and the capital costs associated with treating large volumes of nonwastewater. I/I reduction programs typically involve a diagnostic phase to locate specific sources of flow. Flows can then be reduced by removing inflow sources and reducing infiltration through pipeline rehabilitation. Some common pipeline rehabilitation methods include excavation and replacement, chemical grouting, insertion, cured-in-place pipe lining, fold and formed, specialty concrete, liners, and coatings.

The effectiveness of I/I removal efforts is system-specific. Despite the growing number of sewer rehabilitation processes and products, few reports have been available in the litertaure about overall, system effectiveness of I/I removal efforts. In 1973, EPA thought that from 70 to 100 percent of the I/I in a sanitary sewer collection system could be removed through cost-effective sewer system rehabilitation.[6] Later information indicated that sewer rehabilitation is far less effective than had been expected and that even large expenditures for the correction of I/I sometimes produced only a small reduction in infiltration. By 1989, EPA revised its estimate of I/I removal by cost-effective sewer rehabilitation to 40 percent of the estimated infiltration.[7] The Agency also recognized that the correction of excessive infiltration is likely to be unsuccessful in certain circumstances.[8] While the technology and procedures associated with measuring and removing I/I have and continue to improve, the success of specific I/I removal projects depends on an extremely complex set of variables.

Experience with I/I work has highlighted the need to address the following concerns during I/I removal efforts:

- The success of I/I removal efforts can be significantly limited if such efforts do not address private lateral connections to buildings. Many municipalities have hesitated to address private laterals due to institutional and technical problems.

- Peak flows must be correctly characterized. Infiltration may be incorrectly identified as inflow when RII enters the sewer system through defects, but produces a peak flow response similar to that of inflow from direct connections.[9]

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[6] See 54 FR 4225, January 27, 1989.

[7] See "Evaluation of Infiltration/Inflow Program, Final Report," February 1981, U S. EPA, EPA-68-01-4913 The Report notes that many sewer rehabilitation programs eliminated from 0 to 30 percent of I/I flows despite engineer's predictions of 60 to 90 percent I/I removal

[8] See 54 FR 4225, January 27, 1989

[9] See "Rainfall Induced Infiltration into Sewer Systems - Report to Congress," EPA, 1990, 430-90-005

- Ground water migration affects the effectiveness of I/I removal. Correction of a specific infiltration source may not result in a corresponding reduction in the infiltration rate where ground water migration occurs. Traditional approaches to identifying the cost effectiveness of sewer system rehabilitation that evaluate each inflow source or sewer defect on an individual basis may overestimate the amount of flow reduction by failing to account for the migration of water into pipe defects that remain unrepaired.[10]

- Ground water that was precluded from entering main pipes prior to I/I removal efforts can enter the system after major sources of I/I have been repaired.

The relationship between monitored flows and I/I from source defects may overestimate I/I removal. Metering programs may not have accounted for peak flows that bypass the treatment facility or that overflow from the system itself.

3.3.1.2 Increases to Conveyance Capacity or Storage

Additional system capacity can be provided through the construction of a relief sewer or enlarging undersized pipe sections. Another method is to transfer flow from one drainage basin to another. If a pump station has capacity limitations, the capacity can sometimes be increased by adjusting controls, but installation of larger capacity equipment may be required.

Temporary storage of a portion of peak flows can be provide in the collection system. In some cases where large diameter pipelines are used, additional system capacity can be provided by using strategies that provide storage using the existing pipe network. In-system storage, however, requires careful analysis to ensure flooding will not occur and that sediment deposition is not greatly increased, thereby increasing maintenance costs. Additional storage can also be provided by constructing flow equalization basins in the collection system or at the POTW.

3.3.1.3 Peak Excess Flow Treatment Facilities

EPA has identified a limited number of cases where infrequent discharges from peak excess flow treatment facilities (PEFTFs) located in sanitary sewer collection systems have been authorized or approved and issued a permit by an NPDES authority. PEFTFs provide hydraulic relief for a sanitary sewer collection system during extreme wet weather conditions. The objective of such a facility is to protect public health by reducing the probability of uncontrolled, untreated discharges or basement backups by relieving peak flows with treated discharges at controlled locations. Under forthcoming EPA guidance, NPDES permits for discharges from PEFTFs are to require effluent limitations based on secondary treatment or more stringent water quality-based requirement necessary to meet water quality standards PEFTFs that provide less treatment than required to meet permit limitations can be addressed on an interim basis in enforcement actions.

Most PEFTFs provide temporary storage of flow for smaller wet weather events, with stored flows pumped back into the collection system after rain-induced flows decrease. During larger wet weather events, some flows are stored, but flows exceeding the storage capacity are treated and discharged. The sizing of the facility should be based on providing a certain minimum treatment level, meeting water quality standards, and/or reducing the number of overflow events. Typically, wet weather facilities are designed to provide any discharges with removal of floatables, physical/chemical treatment, and disinfection, although some designs call for biological treatment

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[10] See "Rainfall Induced Infiltration into Sewer Systems - Report to Congress," EPA, 1990, 430-90-005

3.3.2 Performance Objectives for Wet-Weather Peak Flow Capacity

The goal a sanitary sewer collection system is to collect and convey wastewater to a treatment facility for proper treatment. However, it may be extremely difficult to ensure that a collection system, which may have built over a 100 year period and can contain thousands of miles of publicly and privately owned pipe, can meet this goal under severe wet weather conditions. Some of the major reasons that addressing these conditions may be difficult are:

- There is significant uncertainty in designing for extreme conditions. These uncertainties are associated with difficulties in predicting the amount of I/I that will enter a system during a extreme storm event, predicting the amount of I/I that can be removed by reduction efforts, and predicting flow dynamics of a stressed system experiencing extreme conditions; changing conditions in the collection system; and uncertainties in measuring flows;

- Limitations on the cost-effectiveness of enlarging system capacity to address the worst conceivable conditions, including the operational difficulties (e.g. increased deposit formation, hydrogen sulfide production) associated with extreme oversizing; and

- Institutional difficulties that arise because of ownership and other issues.

Industry and EPA technical guidance typically does not provide specific criteria for addressing sizing issues that arise in the context of rehabilitation projects. Some industry guidance provides a process for evaluating collection system problems, while other guidance lists factors for consideration in sizing components in a remediation context. For example, the 10-State Standards identifies a number of parameters that should be considered (e.g. design average flows, design maximum flows, design peak hourly flows and design peak instantaneous flows), but doesn't provide criteria for how these parameters are to be applied.

Most States have a formal review process for major municipal sewer rehabilitation projects. While most State regulations or written guidelines do not specify capacity requirements for remediation projects, some States provide guidance on performance objectives for rehabilitation projects. This type of guidance can take various forms, such as a design storm or cost curve analysis. Table 3-3 provides examples of State guidance. These guidelines are generally minimum requirements or otherwise allow for taking into account the potential for a given SSO to discharge into sensitive waters or high exposure areas. Establishing more stringent requirements is consistent with industry practice which recommend that system-specific implementation of measures should reflect the priority given to controlling discharges to sensitive waters and to high exposure areas[11].

Some municipalities develop design rates for their sanitary sewer collection systems during facility planning, master planning or watershed planning activities These design rates can be used to provide a basis for new construction, and rehabilitation hydraulic criteria. The development of design rates is often based on historic performance data that includes flow and I/I projections in a manner that reflects expected targeted seasonal and rain event flow variations (WEF, 1999). Municipalities have used different methods for sizing collection system components in the context of a remediation project, including the use of cost-performance curves to evaluate the relationship of control alternatives, and the use of performance objectives such as

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[11] For example, see *Existing Sewer Evaluation & Rehabilitation*, WEF Manual of Practice FD-6, 1994 for a description of how defining critical sewers can be used to focus maintenance and rehabilitation activities

control of specified design storms. Table 3-4 provides information on sixty communities in 14 States which have developed sanitary sewer remediation programs that identify wet weather performance goals.

Table 3-3 - Summary of State Remediation Objectives

STATE	Design or Performance Criterion for Existing Sewers	Comment
GA	25 year storm	general guideline
IL	- uses cost-curve analysis - wet weather discharge facilities permitted with secondary treatment limitations	experience indicates that 5-year, 1-hour storm usually is sufficient
MA	1-year, 6 hour event	associated with loan program
MI	25-year, 24-hour design	
OR	Bacteria water quality standard provides for no raw sewage discharges for up to the 5-year summer storm and 10-year winter storm	OAR 340.41.120 (13 and 14)
TX	2-year, 24-hour storm	see T30S317
WI	I/I contribution based on 5-year storm - Permittees may bypass if bypass is due to runoff in excess of 10 year, 24 hour rainfall event and other conditions met	Wisc Adm Code NR 205 (k)

3.2.3 Proper Sewer System Management, Operation and Maintenance

EPA believes that the number of SSOs that are caused by blockage or structural, mechanical or electrical failures can be reduced through improved collection system management, operation and maintenance programs (also see ASCE, 1998; WERF, 1996). These programs restore the structural integrity of the system and reduce the potential for blockages. In addition, as discussed above, management, operation and maintenance programs can have a role in controlling capacity related SSOs.

Figure 3-2 shows the results of using different maintenance frequencies on a sanitary sewer system. For this study conducted in Sacramento County, the wastewater collection system was divided into two sections and analyzed to develop a preventive maintenance schedule. One of the sections was cleaned every 1 to 2 years, while the other was cleaned every 3 to 6 years. The portion of the system on a more frequent 1 to 2 year cleaning schedule experienced a noticeable reduction in the number of stoppages (from 384 in 1974 to 107 in 1984). By contrast, the portion of the system cleaned every 3 to 6 years experienced an increase in the number of stoppages over the same time (CSUS, 1991).

This general trend is also evident from the 1984 Urban Institute study. That study collected data from 22 cities on the number of sewer backups per 1,000 miles of sanitary sewers and the percentage of the system cleaned by the city, for each year from 1978 to 1980. The study concluded that "in nearly every case, the cities that clean a high percentage of their sewer systems have lower backup rates. At the same time, the cities with the highest backup rates appear to be doing the least cleaning " (Peterson, 1984).

Table 3-4. Description of Rehabilitation Efforts of 60 Communities

	Community	Population	Existing Treatment Plant Capacity (MGD)	Actual Cost $/household	Ave. Annual Wet Weather Overflows	Annual Frequency of Return Storm	SSO Abatement Goal			Rainfall Intensity (in/hr)
							Return Storm Period (years)	Return Storm Duration (hours)	Rainfall Depth (inches)	
1	Baytown, Texas	70,000	16.2	$771.39		0.025@	>100			
2	Bentonville, Arkansas	17,000	4	$2,700.00		0.025@	>100			
3	Cincinnati, OH	22,724				0.025@	100			
4	Commerce, Texas	10,000	2	$540.00		0.025@	>100			
5	Eureka Springs, Arkansas	1,890	0.7	$4,714.20		0.025@	>100			
6	Friendswood, Texas	31,000	9.25	$130.68		0.025@	>100			
7	Hamilton, Ohio	65,000	24	$623.16		0.025@	>100			
8	Honolulu, HI	687,475				0.025@	100			
9	Jackson, Tennessee	50,000	17	$64.80		0.025@	>100			
10	Little Rock, Arkansas	185,000	51	$437 40		0.025@	>100			
11	Ponca City, Oklahoma	25,000	4	$2,700.00		0.025@	>100			
12	Wayne County, MI	167,939			0.2	0.025@	100			
13	Buena Vista, Michigan	11,000	10	$1,595.43	2	0.04	25	24	3.8	0.16
14	Enid, Oklahoma	47,000	8.5	$1.148.85	2	0.04	25	24	6.5	0.27
15	Frankenmuth, Michigan	4,400	1.8	$4.050.00		0.04	25	24	4	0.17
16	Lancaster, Texas	22,400	3.4	$1,205.28		0.04	25	24	6	0.25
17	Lansing, Michigan	155.000	49	$731.43		0.04	25			
18	Marlette, Michigan	1,900	10	$12,221.01		0.04	25	24		
19	Midland, Michigan	42,000	10	$514.35	3	0.04	25	24		
20	Pine Bluff, Arkansas	63,000	14	$128.52		0.04	25	24	7	0.29
21	King County, Washington	1,100.000	115	$206.28		0.05	20			
22	Covington, Louisiana	10,000	1.8	$270.00	<1	0.1	10	24	8	0.33
23	Fairfield, Ohio	43,000	16	$1,149.12	<1	0.1	10	24		
24	Johnson County, Kansas	340,000	27	$447.12		0.1	10			
25	Kerrville, Texas	18,000	3.5	$750.06	<1	0.1	10	24	6	0.25
26	Monmouth, Oregon	7,700	3.5	$1,402.65		0.1	10*			
27	The Dalles, Oregon	14,000	4.2	$192.78		0.1	10*			
28	Waldport, Oregon	1,750	0.7	$6,942.78		0.1	10*			
29	Addison, IL	17,138				0.2	5			
30	Belvidere, IL	15,193				0.2	5			
31	Benton, Arkansas	17,000	4	$932.85		0.2	5			
32	Crowley, Louisiana	16,000	2.4	$1,181.25	1	0.2	5			
33	Fayetteville, Arkansas	58,000	11.4	$3,072.33		0.2	5			
34	Haltom, Texas	35,000	3.8	$1,002.78		0.2	5	1	2.6	2.60
35	Henryetta, Oklahoma	1,100	0.14	$1,055.43		0.2	5	24	5	0.21
36	Indian Creek, KS	72,000				0.2	5			
37	Mission Township, KS	45,309				0.2	5			
38	Nashville Tennessee	400,000	392**	$3,099.60		0.2	5	24	4.5	0.19
39	Saint Charles, IL	16.935				0.2	5			
40	Tulsa, Oklahoma	360.000	102	$750.60		0.2	5	1		

Description of Municipal Rehabilitation Efforts (continued)

Community	Population	Existing Treatment Plant Capacity (MGD)	Actual Cost SSO Program $/household	Ave. Annual Wet Weather Overflows	Annual Frequency of Return Storm	SSO Abatement Goal			
						Return Storm Period (years)	Return Storm Duration (hours)	Rainfall Depth (inches)	Rainfall Intensity (av. in/hr)
41 Turkey Creek, KS	50,404				0.2	5			
42 Elmhurst, IL	42,029				0.33	3			
43 Galveston, Texas	59,000	13.3	$640.71		0.5	2	4	3.5	0.88
44 Greenville, Texas	25,000	3	$1,836.00	1	0.5	2	0.5	1.3	2.60
45 Houston, Texas	1,700,000	250	$1,905.93		0.5	2			
46 New London, CT	40,000				0.5	2			
47 Norman, Oklahoma	80,000	11	$135.00	3	0.5	2	24	3.5	0.15
48 South Houston, Texas	15,000	3	$1,242.00		0.5	2	24	6	0.25
49 Witchita Falls, Texas	103,000	20	$707.67		0.5	2	24	4	0.17
50 Bellingham, Washington	60,000	16	$1,350.00		1	1			
51 Charlotte, NC	338,854				1	1			
52 Edmond, Oklahoma	67,000	6	$181.44		1	1	24	3	0.13
53 Fort Scott, Kansas	8,500	6	$635.31		1	1	24	3	0.13
54 Fort Smith, Arkansas	86,000	20	$3,453.57		1	1	24	3.5	0.15
55 Greenville, SC	125,884				1	1			
56 Idabel, Oklahoma	10,000	3	$675.00		1	1	1	1.5	1.50
57 Jewett City, CT	3,500				1	1			
58 Lexington, Kentucky	240,000	52.3	$156.60		1	1			
59 Vinita, Oklahoma	4,800	1.5	$1,406.16		1	1	1	1.5	1.50
60 Hot Springs, Arkansas	35,000	12	$57.78		1.25	0.8	1	1	1.00
				Average	0.39	11.76			
				Median	0.2	5			
				Mode	0.2	5			

@=Per M&E model, as the goal approaches zero, the highest rainfall in 40 years of historic data is used.

•=Oregon law requires that municipalities have no raw sewage discharges for up to the 5-year summer storm and the 10-year winter storm.

**=In Nashville, approximately 30% if the 392 MGD of WWTP capacity is allocated to flow from combined sewer areas; population and cost statistics are for separate sewer areas only. Shading denotes communities that could not be matched with facility data in the model but they had SSO abatement goals.

▨

Another survey of nine cities and three wastewater districts in Kansas indicated consistently increasing levels of operation and maintenance expenditures beginning in approximately 1970, as shown in Figure 3-3 (Nelson, 1996). The survey indicated that the maintenance needs of the systems generally varied depending on their size, age, accessibility, topography, and city objectives. The preventive maintenance tasks performed in the cities included flow monitoring, manhole inspection, smoke or dye testing, television inspection, and private sewer system inspections. The survey indicated that approximately 50 percent of the sewer length and 68 percent of the manholes in the systems had been inspected in the previous 25 years. The communities also estimated they had rehabilitated 37 percent of their manholes, sewer lines, relief sewers, and private sector connections.

Reviewers of the Kansas survey made the following conclusions:

- Routine inspection and maintenance activities should include manhole inspection, line inspection and testing, and private sewer inspections.
- Sewer systems continuously degrade and this degradation should be managed through proper O&M.
- It was the reviewer's opinion that annual inspection and maintenance frequencies of 6 percent and 10 percent of the system per year, respectively, appear to be cost-effective.

Fayetteville, Arkansas instituted a comprehensive program to improve the performance of its 420-mile collection system beginning in 1990. Data on identified SSO occurrences was reported from 1989 through 1997 and showed a continuous reduction of identified events attributable to implementation of the comprehensive program (see Table 3-5)[12].

Table 3-5. Identified SSO events in Fayetteville, Arkansas

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Number of SSOs identified per year	545	348	216	184	161	123	111	145	103

In a recent survey conducted by the American Society of Civil Engineers (ASCE, November 1998) researchers found that frequency of some maintenance activities has increased over the last two decades The 1984 Urban Institute study found that routine cleaning was conducted on an average of 26 percent of sewer systems annually, although individual cities varied from 100 to 0 percent. Cities that were experiencing poor collection system performance cleaned 10 percent or less of their system annually. In the 1990s, ASCE found that surveyed utilities annually cleaned roughly the same percent of their system as twenty years ago; however, inspection and preventive maintenance activities increased dramatically as shown in Table 3.5.

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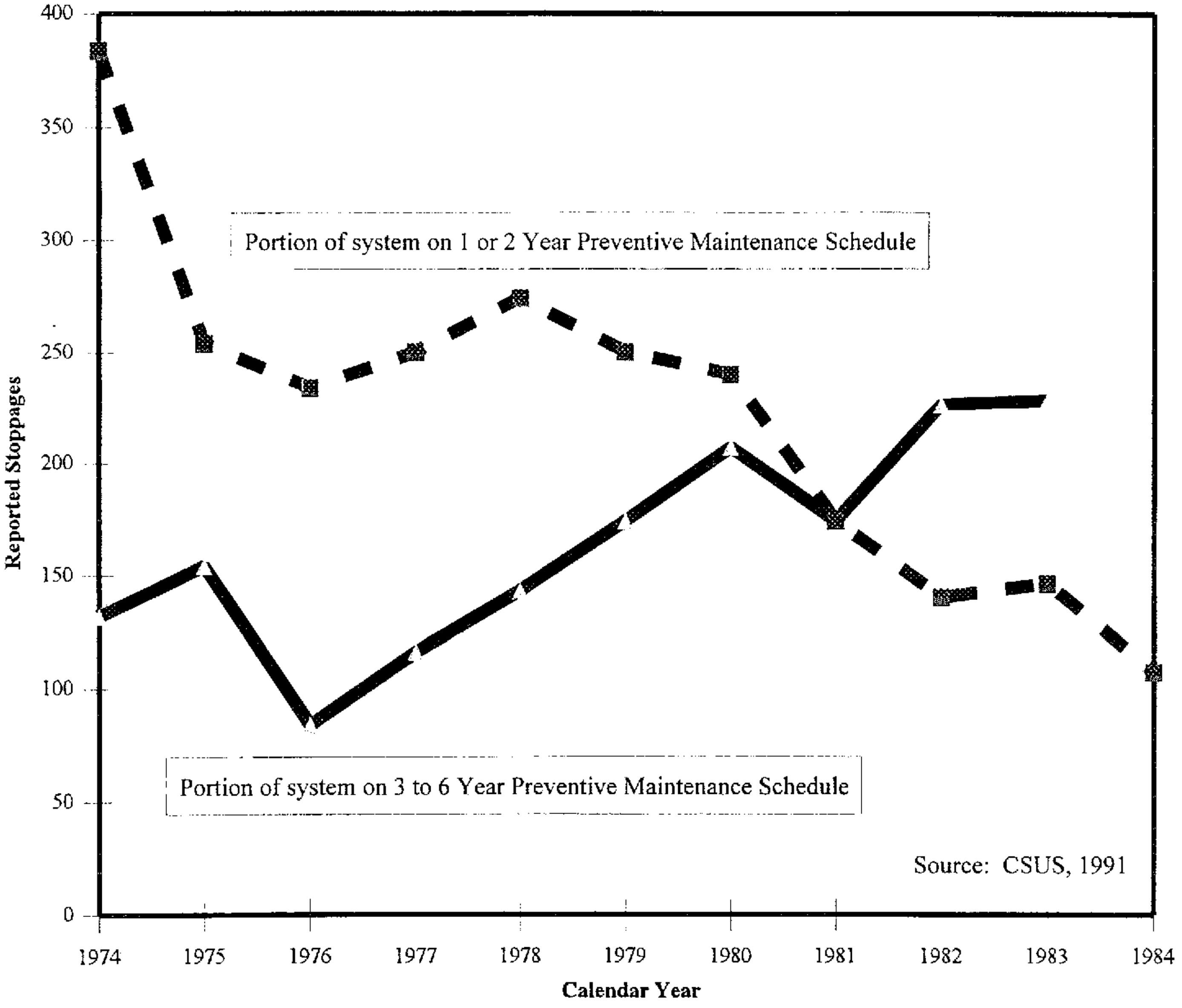
[12] Jurgens, "The Complete SSO Elimination Program," Proceedings of the Water Environment Federation 71st Annual Conference & Exposition



Source: CSUS, 1991

Figure 2. Trends in Number of Stoppages in Sacramento County

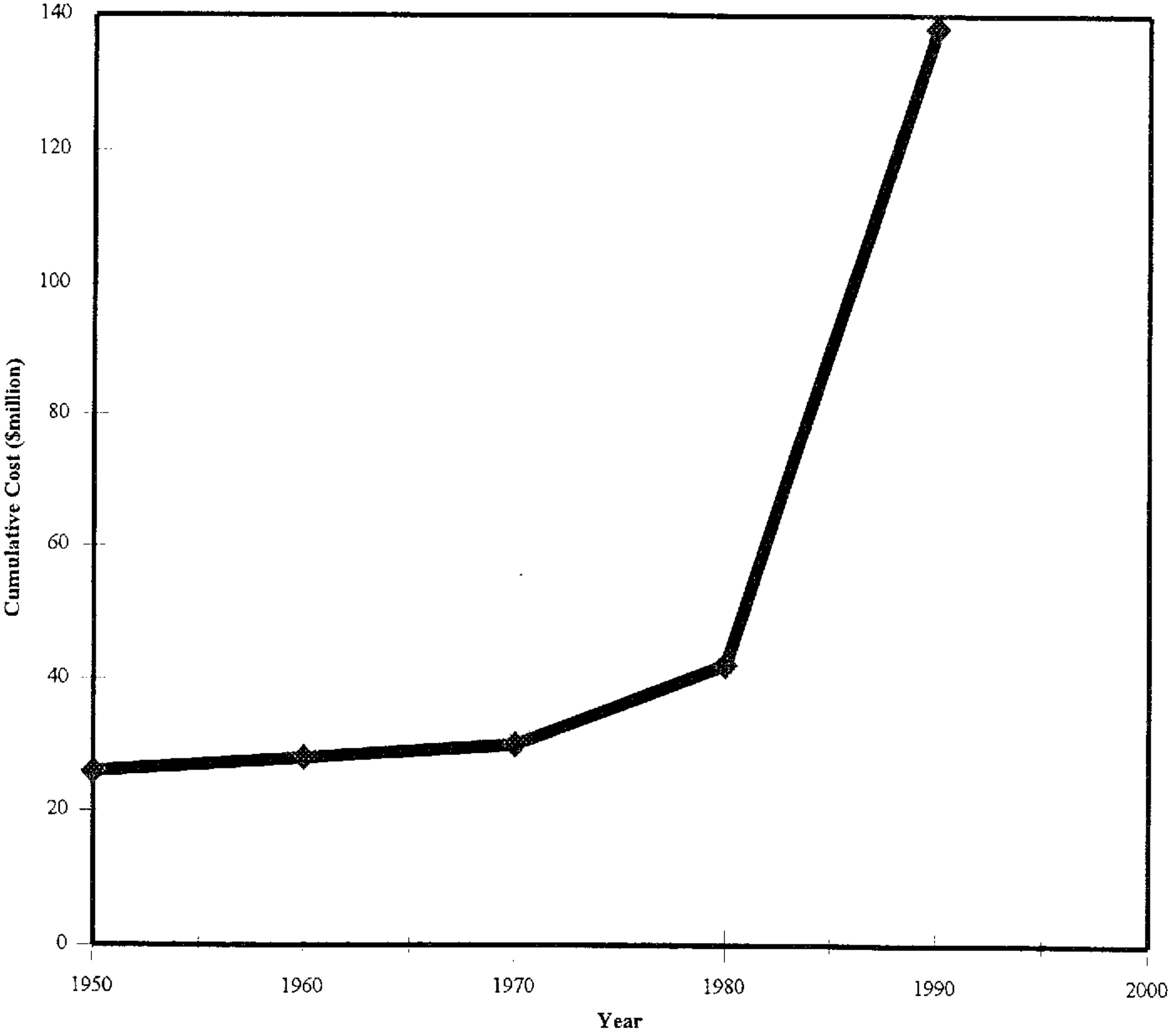


Figure 3-3 O&M Expenditure Trends by 12 Communities
(Costs were adjusted to reflect inflation)

Table 3-6 Changes in Maintenance Activities over 20 Years based upon the ASCE, 1998 Survey Results

(Percent of Collection System per Year)

Maintenance Activity	20 Years Ago	Current (1990-1996)
Flow Monitoring	8%	33%
Manhole Inspection	10%	26%
Smoke/Dye Testing	2%	8%
CCTV	2%	7%
Private Building Inspection	1%	5%

Determining appropriate levels of operation and maintenance activities for sanitary sewer systems is difficult. While more maintenance is better in most circumstances, there are levels of maintenance beyond which the added costs outweigh the benefits of maintenance. Site-specific considerations, such as flat slopes or poor soils, may require some communities to clean and/or inspect the sanitary sewer system more regularly than communities with fewer sewer problems. Only limited data is currently available for quantifying the relationship between preventative maintenance activities to system performance[13].

There is a growing awareness that CMOM activities are an investments in the sanitary sewer system. Proactive collection system managers take holistic approach that include preventive maintenance and utilize principles of capital asset management to protect, maintain and improve the value of the collection system with planned maintenance and rehabilitation based upon the predictive deterioration of the system.

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[13] See "Collection Systems. Methods for Evaluating and Improving Performance", California State University, 1998, "Stopping SSOs Beneficial Maintenance Practices" Charlotte-Mechlenberg, SSO National Conference, EPA, 1995, and "Sanitary Sewer Overflows and Sewer System Maintenance", University of North Carolina at Charlotte, 1998.

SECTION FOUR

SUMMARY OF SSO CONTROL COST METHODOLOGY

4.1 INTRODUCTION

This section outlines the development of the cost estimating methodology for achieving a range of SSO control scenarios in existing sanitary sewer collection systems, shown by the flow chart in Figure 4-1. The main components of the cost estimating model are:

- A hydrologic model
- A series of cost functions
- An optimization routine
- Model input data
- A cost model for SSO treatment facilities
- A system operation and maintenance (O&M) cost model[14]

Beginning with the 1996 Clean Water Needs Survey database and case study information, as described in Sections 2 and 3 and Appendix A, D and E, model input parameters were developed. These data were used as input for the cost estimating model.

This section outlines the development and implementation of the hydrologic model, cost functions, and the optimization routine used to determine the SSO reduction or elimination capital cost for each existing sanitary sewer system, as well as the process for determining increased operation and maintenance costs on a national scale. The model inputs are also discussed, including information from the Clean Water Needs Survey database and additional data sources used in the model. Assumptions made in the development of these model input data and the compilation of sewer system data from the Clean Water Needs Survey database are presented. These model development and implementation steps are described below.

4.2 DEVELOPMENT OF THE CAPITAL COST ESTIMATING MODEL

In developing the SSO cost estimating model, consideration was given to the data available and the level of control achievable under different scenarios. A national policy to address SSOs does not currently exist. Therefore, when determining levels of control to model, a range of assumptions had to be made. The Urban Institute Study (Peterson, 1984) discussed in Section 2 estimated that communities have approximately 827 SSOs annually per 1,000 miles of collection system. Since 1,000 miles of sewer serves about 250,000 people, this translates to over 50 SSOs points per year for an average size community (population of 10,000–25,000) served by a sanitary sewer system.

The SSO reduction levels modeled assumed that the goal would be to eliminate most wet weather capacity-related SSOs from existing separate sanitary sewer systems. The model was developed to estimate the cost of reducing, to various scenario levels, the number of system overflow events per year. (It is important to note again that the term "event" is used to describe rainfall events resulting in at least one overflow for each sanitary sewer system; similarly, the term "SSOs" as used in this report means a system-wide SSO even

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[14] This O&M cost model was further developed since the March 1998 draft of this report

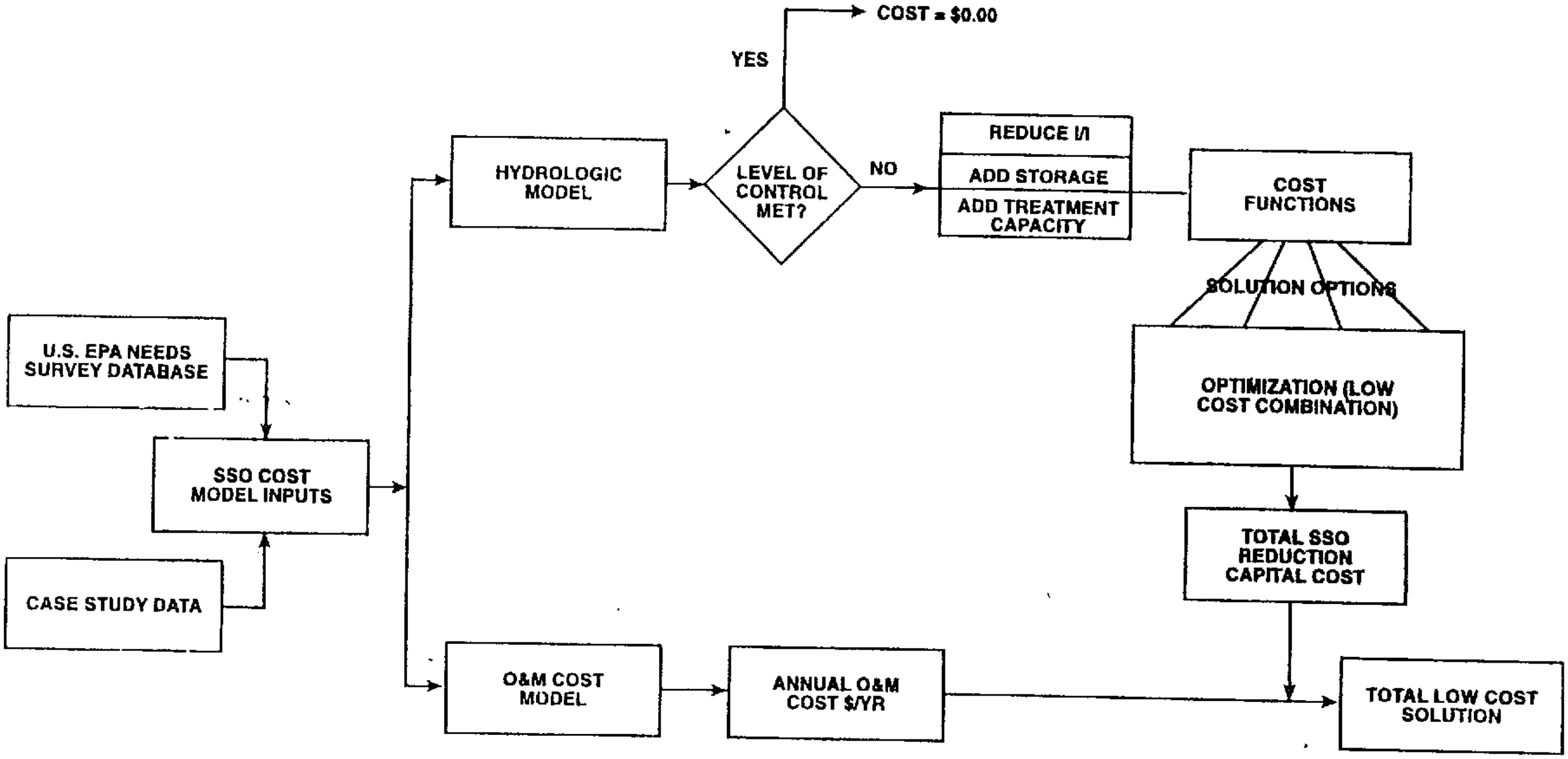


Figure 4-1. Cost Estimating Model Flowchart

except where otherwise noted.) These scenarios include a storm event causing an overflow every 5 years (0.2/yr), every 2 years (0.5/yr), once per year (1.0/yr), and five times per year (5.0).

4.2.1 Model Development

The capital cost estimating methodology consists of three parts: a hydrologic model, a set of cost functions, and an optimization routine. The hydrologic model is used to simulate the effects of wet weather on each separate sanitary sewer system and determine the range of possible combinations of storage, treatment, and I/I reduction that could be used to meet the 0.2, 0.5, 1, and 5 overflow events per year scenario. The output from this hydrologic model is then used, along with the cost functions, to estimate the cost of combinations of additional storage, increased treatment capacity, and I/I reduction (through sewer rehabilitation). This process results in multiple possible combinations of reduced I/I, additional system storage, and increased treatment plant capacity that could meet each of the control levels. The optimization routine is used to determine, for each system, the least-cost combination that would achieve the control objective scenarios. Each of these parts of the model are detailed below.

4.2.1.1 Hydrologic Modeling

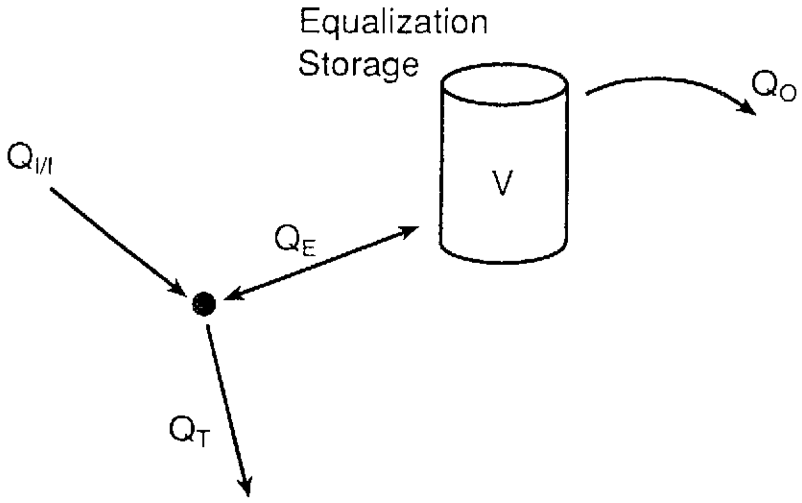
A hydrologic model was used to determine possible combinations of three SSO abatement strategies. increased wet weather treatment capacity at the POTW, additional wet weather storage capacity in the collection system, and sewer system rehabilitation (I/I reduction) to reduce or eliminate SSOs from separate sanitary sewer systems. This model was developed using the Storage, Treatment, Overflow, Runoff Model (STORM), a product of the U.S. Army Corps of Engineers Hydrologic Engineering Center (U.S. ACOE, 1977).

The implementation of this model for separate sewer systems assumes that a percentage of the rainfall enters the system as I/I, based on the I/I coefficient established earlier. This flow, along with the dry weather flow, is either treated at the WWTP, stored in the system, or overflows once the total capacity of the system is exceeded. A schematic depiction of this equalization storage and treatment system, as modeled using STORM, is shown in Figure 4-2.

STORM was used to predict infiltration/inflow ($Q_{I/I}$) based on a modified Rational Formula method and local historical continuous rainfall records for the studied regions obtained from the National Weather Service. For each hourly time step, STORM computes an estimate of the predicted $Q_{I/I}$ at the headworks of the treatment plant. $Q_{I/I}$ is calculated by STORM using the following relationship:

$$Q_{II} = 0.652 \times R \times I \times A \qquad \text{(Equation 4-1)}$$

where: Q_{II} = Inflow/infiltration flows into plant during one hourly time step (MGD)
R = Fraction of rainfall volume that enters the sewer system as I/I and that reaches the treatment plant
I = Average rainfall intensity during one hourly time step (in./hour)
A = Sewered area draining to the plant (acres)
0.652 = Unit conversion factor



$Q_{I/I}$ = Infiltration/Inflow to Plant = Rainfall*I/I*Sewered Area

I/I = I/I Volume Coefficient

Q_E = Flow To/From Equalization Storage = $Q_{I/I}-Q_T$

Q_T = Average Available Wet-Weather Treatment Capacity
(In Excess of Dry-Weather Flows)

Q_O = Overflow from Equalization Storage

V = Flow Equalization Storage Volume

Figure 4-2. STORM Model Storage-Treatment System Schematic

As long as $Q_{I/I}$ does not exceed the assumed wet weather treatment plant capacity (Q_T), then all flow is sent through the plant. If $Q_{I/I}$ exceeds the wet weather treatment capacity of the plant, then the flow is diverted into flow equalization storage at a rate of $Q_E = Q_{I/I} - Q_T$. Once $Q_{I/I}$ falls below the wet weather treatment capacity, then the model returns flow from equalization storage through the plant at a rate of $Q_E = Q_T - Q_{I/I}$.

If the flow equalization storage is full and $Q_{I/I}$ influent to the plant exceeds the plant wet weather capacity, then an "excess flow event" occurs. These excess flows are analogous to SSOs or to partially treated overflows from in-system storage facilities (or flow equalization) in the real systems.

Using the continuous rainfall data for the period of record (not "design storms"), STORM simulates a continuous time series of I/I entering the treatment plant, and tabulates the number of excess flow events and the volume of excess flow that could not be treated at the assumed wet weather treatment rates. Model simulations were performed for varying wet weather treatment rates, R-values, and for varying flow equalization storage volumes.

For purposes of developing a national SSO reduction cost estimate, STORM simulations were performed for five separate sewerage systems to represent typical results from different climatological regions. Rainfall records for Charlotte, North Carolina; Fort Worth, Texas; Wayne County, Michigan; San Jose, California; and Portland, Oregon were used to generate overflow frequency statistics for a range of storage, treatment, and I/I R-values. The use of continuous rainfall data rather than storm frequency measures appropriately reflected intensity measures and antecedent conditions such as soil saturation, which can result in overflows in excess of what an isolated storm might produce. The STORM model was run by one-acre areas within each region so that the results could be unitized with respect to area and extrapolated to other systems.

Data were generated through numerous runs of STORM for each of the five rainfall regions, where R was varied from 0.005 to 0.05 and wet weather treatment capacity varied from 0.00005 mgd/acre to 0.001 mgd/acre. Appendix C presents the final relationships between storage, treatment, and I/I R-values to achieve the overflow objective for each of the five regions. All combinations of storage, treatment, and R-values on these plots are predicted to reduce overflows to the specified frequency.

4.2.1.2 Cost Functions Development

The graphs developed from the STORM model provide various capital cost solutions for reducing wet weather SSOs from existing collection systems in terms of reduced I/I, increased system storage in million gallons/acre, and increased treatment plant capacity in mgd/acre. Therefore, capital cost functions were developed for each of these SSO mitigation options to convert the solutions to a dollar basis. These functions were used in the optimization algorithm to determine which combination of storage, treatment, and reduced I/I R-values would be least costly.

Flow Equalization Storage. Flow equalization facilities offer a means of reducing or eliminating wet weather overflows by storing peak flows in excess of the sewer or treatment plant capacity. Flow equalization can be effective in reducing localized overflows as well as upstream and downstream overflows (by reducing the hydraulic grade line elevation upstream, and by reducing downstream peak flow rates). Flow equalization can be constructed within the sewer system (in-system) or at the wastewater treatment plant. Flow equalization basins sited at plants can also be used for diurnal flow equalization to dampen daily flow fluctuations and improve treatment performance. The following function presents an approximate construction cost curve for a typical off-line flow equalization basin (flow diversion structure, closed concrete equalization basin, wastewater pumping station, and odor control facilities), including costs for excavation and backfill, concrete, mechanical, electrical, instrumentation, piping, and site restoration, but not land acquisition costs (CDM, 1995):

$$COST = 2{,}124{,}900 \times V^{0\,6123}\ ;\ for\ V \le 5\ mg \qquad \text{(Equation 4-2)}$$

$$COST = 1{,}411{,}200 \times V^{0\,9056};\ for\ V \ge 5\ mg$$

where: V = Volume of flow equalization storage (mg)
$COST$ = Construction cost (dollars)

This cost curve reflects costs for new construction (rather than retrofitting existing storage basins) and was developed based on recent experience in planning, design, and construction with sanitary sewer and combined sewer overflow (CSO) flow equalization facilities and historical data gathered by EPA (U.S. EPA, 1993).

Increased Treatment Plant Capacity for Wet Weather. Increased treatment plant capacity for wet weather offers a means of reducing or eliminating wet weather overflows by being able to accommodate at the wastewater treatment plant peak flows due to I/I . Wet weather treatment construction costs were developed using historical data (U.S. EPA, 1978) adjusted to current dollars. The function for secondary treatment was found to be linear with treatment flow rate and was estimated to be approximately $1/gallon of tank volume for conventional treatment. This cost includes an aeration basin, air supply and dissolution equipment and piping, a blower building, flocculator type clarifier, and sludge return and waste pumps. The model was also run with an alternative cost curve derived to simulate preliminary and primary treatment and disinfection. This is discussed in detail in the calibration section of this chapter.

Sanitary Sewer System Rehabilitation. Sewer rehabilitation and inflow source correction can be an effective means of reducing I/I and peak wet weather flows. A comprehensive rehabilitation approach consists of continuous rehabilitation of every foot of sewer to eliminate all defects that could potentially be points of entry of I/I. A comprehensive sewer rehabilitation program is the most expensive type of rehabilitation program because it consists of either replacing, grouting, lining, sealing, or otherwise rehabilitating pipe within the study area.

Sewer rehabilitation construction cost estimates were based on the experience gained from numerous sewer rehabilitation projects. A comprehensive sewer rehabilitation approach aimed at only public sewers (no laterals), as opposed to a point-repair approach, has been found necessary to obtain substantial peak flow reduction to eliminate overflows. Furthermore, experience gained through sewer rehabilitation programs indicates that comprehensive rehabilitation costs $80/lf of rehabilitated sewer, and results in R value reductions on the order of 60 percent. Although actual I/I reductions are system specific and based on numerous variables, this estimate was determined through experience to represent average conditions that may be encountered nationally. Therefore, sewer rehabilitation costs were assumed to be:

$$Rehabilitation\ Cost = \$80/ft \times tsl \times \{1 - [(R_f - (0.4 \times R_o))/(0.4 \times R_o)]\} \qquad \text{(Equation 4-3)}$$

where: tsl = Total system length
R_o = Sanitary sewer collection system's original I/I R-value
R_f = System's post-rehabilitation I/I R-value, $R_o > R_f \ge 0.4 \times R_o$

This equation states that when the final I/I R-value equals half of the original R-value, cost equals the cost to rehabilitate the entire system. Alternatively, if the final R-value equals the system's original R-value, cost equals zero. Meanwhile, if the final R-value lies somewhere in this range, cost is found as a straight-line approximation between these two points.

4.2.1.3 Optimization Routine

As indicated by the figures in Appendix C, there are a number of combinations of storage, treatment, and I/I reduction that will lead to meeting each overflow reduction objective. However, the costs of each solution may vary considerably. The least-cost solution depends on the existing conditions within any given system (e.g., the existing storage capacity, existing treatment plant capacity, and the existing I/I rate). An optimization routine was needed to determine which combination of storage, treatment, and I/I reduction was the least costly for each given system. Incorporation of STORM results into a standard optimization method requires that explicit mathematical functions of the simulation be developed. To represent the STORM results in the optimization routine, the results plotted in Appendix C were fit with mathematical functions of the following form (a different function was used for each R-value represented):

$$STORAGE = CONSTANT \times TREATMENT^{EXPONENT} \qquad \text{(Equation 4-4)}$$

where, storage is the minimum volume of wet weather storage capacity (mg/acre) required to meet the overflow objective for a given treatment rate (mgd/acre) and given R. As the treatment rate increases, less wet weather storage capacity is needed to meet the overflow objective. The constant and the exponent are derived from a linear regression performed on the log transformed data. An example curve-fit is presented in Figure 4-3. These equations are then used with a general optimization routine to determine the least costly solution for each sewer system to meet the overflow frequencies specified. This is performed through a general trial and error optimization that converges to the low-cost solution. The optimization routine is described in Appendix D.

4.3 DEVELOPMENT OF MODEL INPUTS

This subsection briefly describes the parameters used in the SSO abatement cost model, the development of an input data set from the Clean Water Needs Survey database, and the calculation of the final model input data.

4.3.1 Parameters Used By the Model

The model estimates the occurrence of wet weather SSOs and the capital costs associated with controlling wet weather SSOs to various occurrence levels, using available information for separate sewer system communities nationwide. (The model also estimates the national O&M costs associated with levels of O&M required to reduce SSOs, and these results were confirmed against other O&M cost estimating methodologies. However, the role of O&M in optimizing the extent of SSO remediation that could be achieved is not reflected in this capital cost model.)

The major variables included in the capital cost estimating methodology are:

- **Sewered Area** – total area in square miles of the sewershed being modeled. This area is related to the amount of rainfall available to enter the sewer system as I/I, thereby contributing to wet weather overflows. For consistency across sewer systems, most calculations in the cost model are performed on a per acre basis.

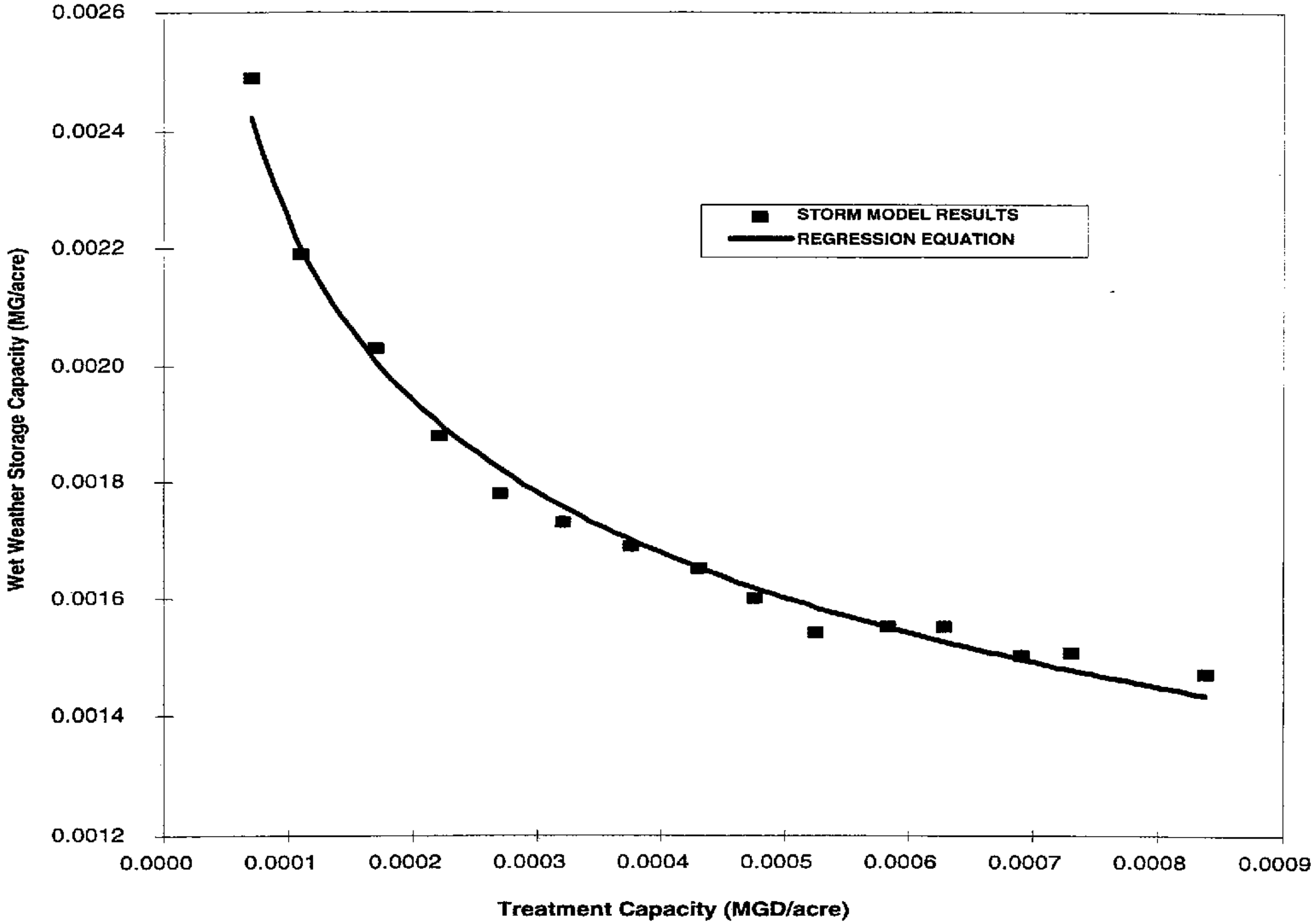


Figure 4-3. Sample Regression Fit to STORM Model Results
Region 3, 1.0 Overflows/Year, I/I Coefficient = 0.025

- **I/I Coefficient** – percent of total rainfall entering the sewer system as I/I during a storm event. It is a system-wide variable that reflects the average of areas of the system with both high and low levels of I/I. It is also an average value over the duration of the storm.
- **Existing System Storage Capacity** – total volume available for storage of wet weather flow in the sewer system.
- **Existing Treatment Plant Capacity** – total additional treatment plant capacity (secondary) of the system available to accommodate I/I. It is the difference between the treatment plant capacity and the average dry weather flow to the system.
- **System Rainfall Characteristics** – rainfall typical for the community being modeled. Five communities were included in the development of this initial cost estimating model. Therefore, the country was divided into five rainfall regions to correspond with the characteristics of these communities.
- **Expected Annual O&M Frequencies and Costs** – estimated frequency for performing various O&M activities, including sewer cleaning, inspection, and simple rehabilitation. The cost of O&M supporting SSO remediation is not reflected in the capital cost model.

The only available source of data that includes all sewered communities nationwide is the Clean Water Needs Survey database. However, this database does not have information available for all of the model input parameters required to run the cost estimating model. Therefore, to calculate the required model inputs, assumptions had to be made based on other sources, such as case studies, information collected through state water pollution control authorities, and existing surveys of SSO problems. In addition, EPA gathered a panel of SSO experts, including sewer district managers, private consultants, and academicians to review the available data and make recommendations for the development of the cost estimating model. The Expert Panel included:

- Mr. Norbert Huang, U.S. EPA
- Mr. Philip M. Hannan, Washington Suburban Sanitary Commission
- Mr. Lawrence P. Jaworski, Montgomery Watson
- Dr. Zhiyi Zhang, University of North Carolina at Charlotte
- Mr. John L. Mancini, John Mancini Consultants
- Mr. Alan J. Hollenbeck, RJN Group
- Mr. Charles W. Fellman, Illinois EPA

Key recommendations made by this expert panel are discussed throughout the model development and calibration descriptions.

The next section outlines the process used to obtain data from the Clean Water Needs Survey database and modify these data to develop a complete list of separate sanitary sewer systems. Section 4.3.3 then discusses the development of model input data, including the methods for calculating the required information and the assumptions made.

4.3.2 Clean Water Needs Survey Database

The Clean Water Needs Survey database contains information on separate and combined sewer systems nationwide. However, these data are not easily reviewed and summarized because of the large number of individual data records, the amount of overlapping information, and the lack of important data elements for some sewer and treatment plant systems. Therefore, pertinent information had to be selected and downloaded from the database to a local computer system, analyzed, and adjusted to eliminate "double counting" of systems, and updated to include data not contained in the system. Figure 4-4 is a flow chart outlining the data manipulation steps, from downloading the data to developing final model inputs.

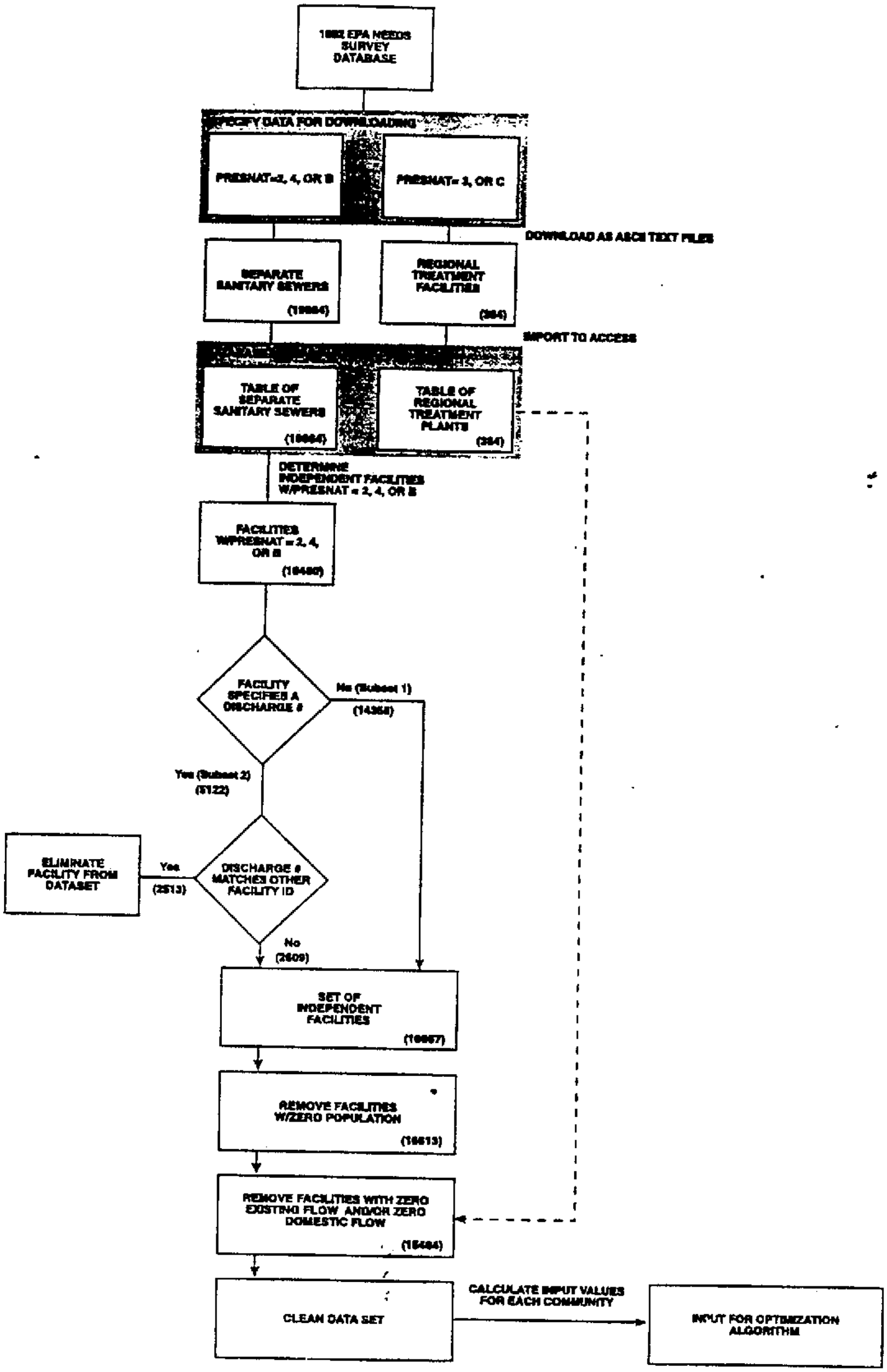


Figure 4-4. Data Collection Flowchart

The model database was formed using data from the 1996 Clean Water Needs Survey. The 1996 Clean Water Needs Survey database contained approximately 19,000 entries for separate sanitary sewers nationwide. This data set from the Clean Water Needs Survey was reduced for model application to account for duplicate entries, zero population or missing population data, and missing flow information. The final data set contained 15,484 separate sanitary sewer systems with a total service population of 130,957,360. A more detailed discussion of this process is provided in Appendices E and F.

4.3.3 Model Input Parameter Calculations

The data set created from the U.S. EPA Needs Survey database included the following information for the 15,484 sanitary sewer and treatment facilities:

- Facility Identification, Name, City, and State
- Present Nature/Type of the Facility (collection system, treatment plant, or regional treatment plant)
- Population Receiving Treatment or Collection
- Total Existing Non-Industrial Flow
- Total Existing Flow (industrial and non-industrial)
- Treatment Plant Capacity.

This information, in conjunction with some data relationships developed from previous Clean Water Needs surveys, provided the background for calculating all the data elements required to implement the cost estimating model. However, some assumptions were required to develop the actual model input data from the information available. This section addresses each of the cost model input parameters, describes the assumptions made in calculating the value for each of the sanitary sewer systems nationwide, and presents changes made based on additional data and the Expert Panel's review.

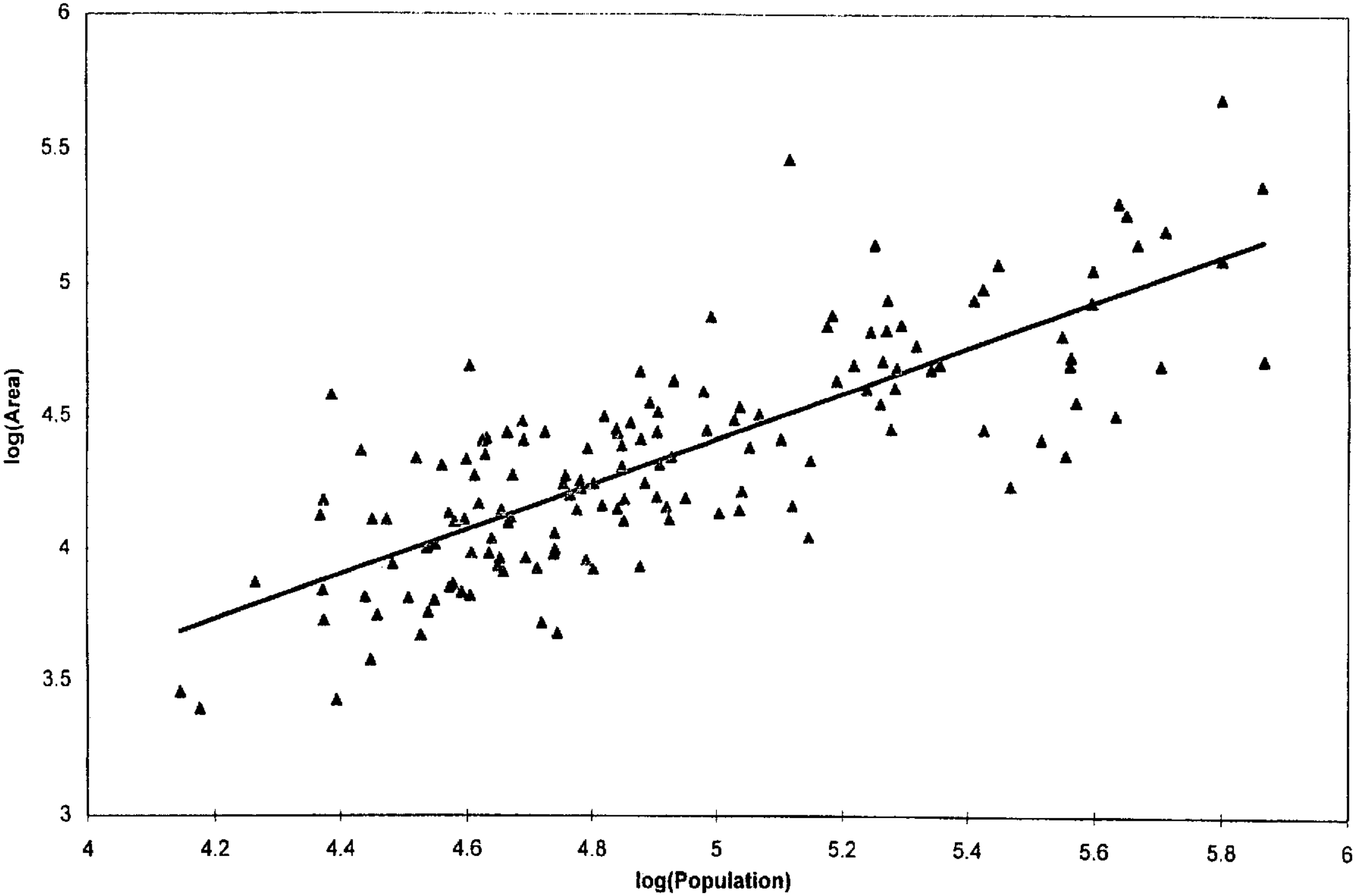
4.3.3.1 Sewered Area

All calculations in the cost model are developed on a per acre basis so that total rainfall volumes can be calculated for the different systems in a common rainfall region. This variable is not available in the Clean Water Needs Survey database. Therefore, a relationship between population and area was developed. To convert population to sewered area, population densities were developed from the State and Metropolitan Area Data Book 1991. Data related to approximately 150 communities throughout the country were gathered and plotted to determine the relationship between sewered area and population densities (see Figure 4-5). The following equation was developed from these data:

$$Log(A) = 0.855 \times Log(Pop) + 0.14 \qquad \text{(Equation 4-5)}$$

where: A = Sewered Area (acres)
Pop = Population

The equation was developed by fitting a line to the plot of the log(Area) versus the log(Population). The best-fit line has a slope of 0.855 and an intercept of 0.14, yielding the above equation. The correlation coefficient for the population density/area relationship is 0.62. This relationship was developed directly from available data for 150 communities throughout the country. Comparisons of the final area calculations with known areas indicated that the relationship was fairly accurate. Therefore, this relationship was not modified during the calibration phase.



Source: State and Metropolitan Area Data Book 1991.

Figure 4-5. Relationship Between Sewered Area (acres) and Populations

4.3.3.2 Infiltration/Inflow (I/I) Coefficient

Because rainfall volumes in sewers are generally much larger than dry weather sanitary flows, even a small difference in the rainfall entering the system could significantly affect the SSO reduction cost. As indicated by the discussion in Section 2, the percent of rainfall entering the sanitary sewer system is dependent on a large number of variables, such as the age of the system, material of construction, ground-water level, soil conditions, and level of inflow. This variable can, therefore, be very difficult to determine, especially for the large number of communities represented by the final data set.

Review of case studies and other information indicated that the percent of rainfall entering the system as I/I (I/I coefficient) is not generally measured. Typically, communities with SSOs or known I/I problems identify specific sub-sewersheds with high levels of I/I. Flow monitoring data are collected in these areas as a first step toward system rehabilitation. The case studies that do identify an I/I coefficient for these sewersheds of concern typically have levels around 15 to 20 percent. This range, however, is representative of I/I coefficients for areas of known I/I problems. The level for an entire community, therefore, would be significantly less because of the influence of the areas without significant I/I.

There are, however, some data related to the peak I/I coefficient for an entire system. These data generally show a peak I/I coefficient ranging from 6 to 10 percent of rainfall. Also, some of the case studies analyzed for the development of the cost estimating model represent another source of information on typical I/I coefficients. The I/I coefficients for these communities ranged from 2.5 to 5.5 percent. These values were judged to represent a more typical range for this variable.

The Clean Water Needs Survey database does not include I/I coefficient data for sewer systems. The only data directly related to I/I coefficient available from the Clean Water Needs Survey database are the flow data for each system. For the purposes of developing the cost estimate, it was assumed that as the average annual per capita dry weather non-industrial flow increases, the I/I coefficient would increase. This assumes that a common level of average annual per capita dry weather non-industrial flow exists in all systems (typically in the range of 60–70 gpcd), and deviations from this are explained by I/I entering the system. Using this relationship, the average annual per capita dry weather non-industrial flow was calculated for each sewer system nationally from available information in the Clean Water Needs Survey database. I/I coefficient values were calculated assuming a constant relationship between I/I coefficient and average per capita flow. The I/I coefficient range was assumed to be from 1.0 to 5.0 percent based on the values found for the case studies investigated. The equation for this relationship is:

$$I/I\ Coefficient\ (\%) = \frac{0.04}{(F_{\max} - F_{\min})} \times (F - F_{Min}) + 0.01 \qquad \text{(Equation 4-6)}$$

where: $I/I\ Coefficient\ (\%)$ = Percent of rainfall entering sanitary sewer system as I/I
F = Average annual per capita non-industrial flow for the facility of concern
F_{max} = Maximum flow for the full set of facilities in the database
F_{min} = Minimum flow for the full set of facilities in the database

The first factor in the equation scales the I/I coefficient based on where the average annual per capita non-industrial flow for a particular facility falls between the minimum and maximum annual per capita non-industrial flows across all the systems in the database. For example, for the system with the lowest average annual per capita non-industrial flow, $F = F_{min}$ so the first factor is zero and the value of *I/I Coefficient* is 0.01. For the system with the highest average annual per capita non-industrial flow, $F = F_{max}$ so the first factor is 0.04 and the value of *I/I Coefficient* is 0.05. Systems with an F value between the lowest and highest would have an *I/I Coefficient* between 0.01 and 0.05. The resulting values were then rounded to the nearest 0.005.

Using the above equation with the data in the Clean Water Needs Survey database resulted in virtually all the sanitary sewer systems having an I/I coefficient of 1 percent. This occurred because a few systems had extremely high per capita non-industrial flows. Therefore, the method of calculation was slightly modified. Typical per capita non-industrial flows would be expected to be in the range of 60 to 70 gpd without the influence of I/I. Therefore, it was assumed that systems with greater than two to three times this typical range (approximately 150–200 gpd) were probably inaccurate and were affecting the distribution. Fewer than 10 percent of the 15,484 systems had per capita flows exceeding this value. For each of these systems, the I/I coefficient was set at the highest value used in the model, 5 percent. Given these conditions, a more realistic distribution of I/I coefficients for the 15,484 systems was obtained.

4.3.3.3 Initial Wet Weather Treatment Plant Capacity

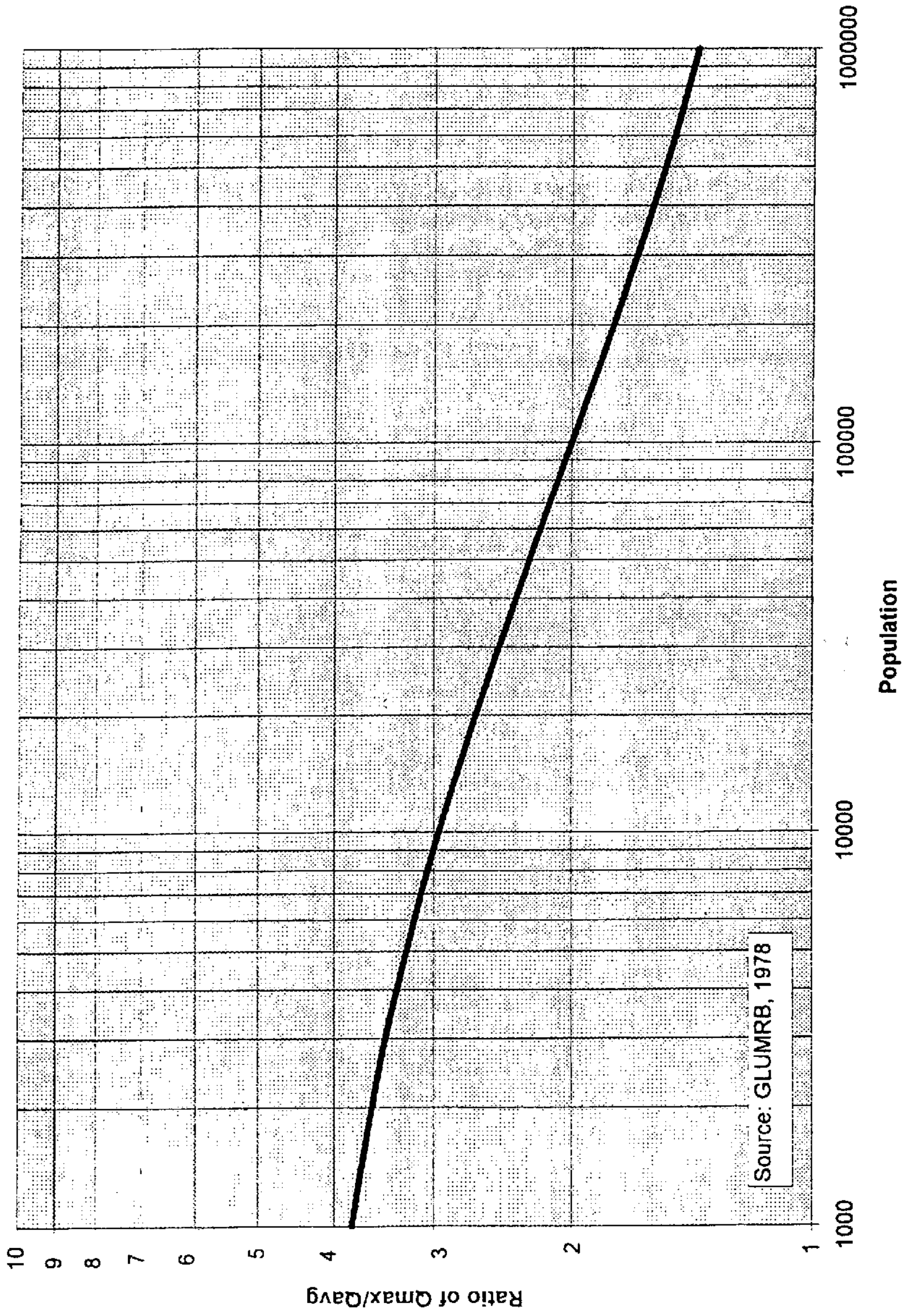
In the cost estimating model, average wet weather treatment plant capacity is the amount of capacity available to accommodate wet weather flow. It is calculated as the difference between the secondary treatment plant capacity and the average annual dry weather flow. The dry weather design capacity is available directly from the Clean Water Needs Survey database. Therefore, the peak capacity had to be calculated assuming a peaking factor for the treatment plants modeled. Also, the total average annual flow listed in the database represents an average that includes both dry weather and wet weather flow. Therefore, an assumption had to be made concerning the ratio of average annual dry weather flow to average annual total flow. No data were available to develop this ratio. However, through experience it is known that on an annual basis the effects of wet weather flow are attenuated by prolonged dry periods. Therefore, it is assumed that the average dry weather flow is approximately 80 percent of the average annual flow.

Also, a peaking factor on the design treatment capacity was used. A variable peaking factor based on population was used. Figure 4-6 shows the design to peak flow rate curve used for the calculation of available treatment capacity. This curve is regularly used in the design of treatment facilities when calculating wet weather treatment capacity. Comparison of the resulting wet weather treatment capacities with known data for calibration communities indicated that this method of calculation was sufficiently accurate. The Expert Panel agreed with the methodology.

4.3.3.4 Initial System Storage Capacity

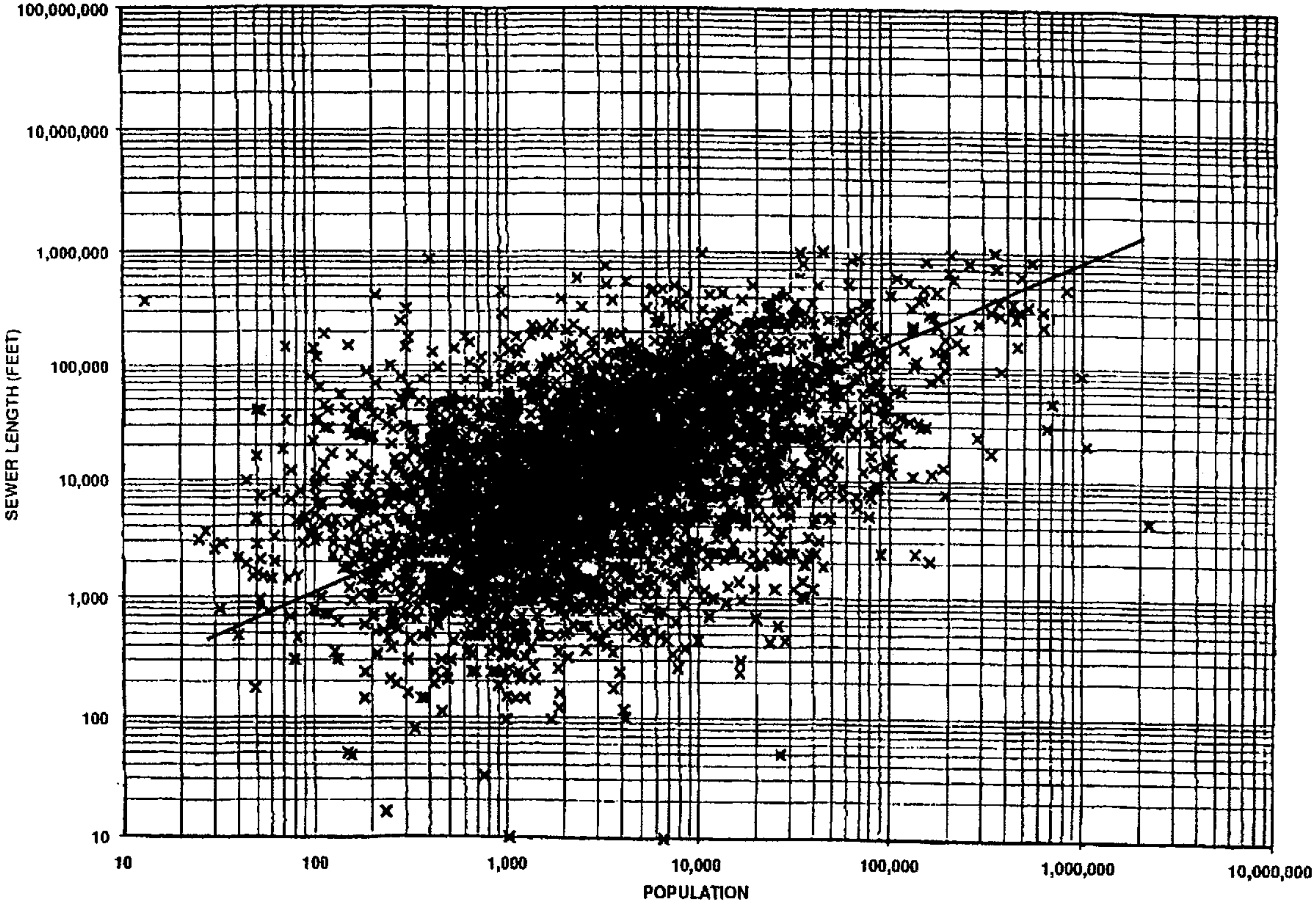
In the cost estimating model, the system storage capacity is defined as the system volume available to store wet weather flow without overflows occurring. The value of this variable for each community depends on the total length of sewers in the system, the average diameter of those sewers, the average amount of the system filled during dry weather, and the amount of remaining volume for storage before overflows occur. These data are not available for all separate sanitary sewer systems being modeled in the cost estimate. Thus, assumptions were developed based on information available in the Clean Water Needs Survey database.

Published data on national sanitary sewer length and diameter were not available at the time the model was developed. Instead, data were collected in the 1984 and 1986 Needs Surveys were used to develop relationships between sewer length and population. Figures 4-7 and 4-8 show how total collector pipe length



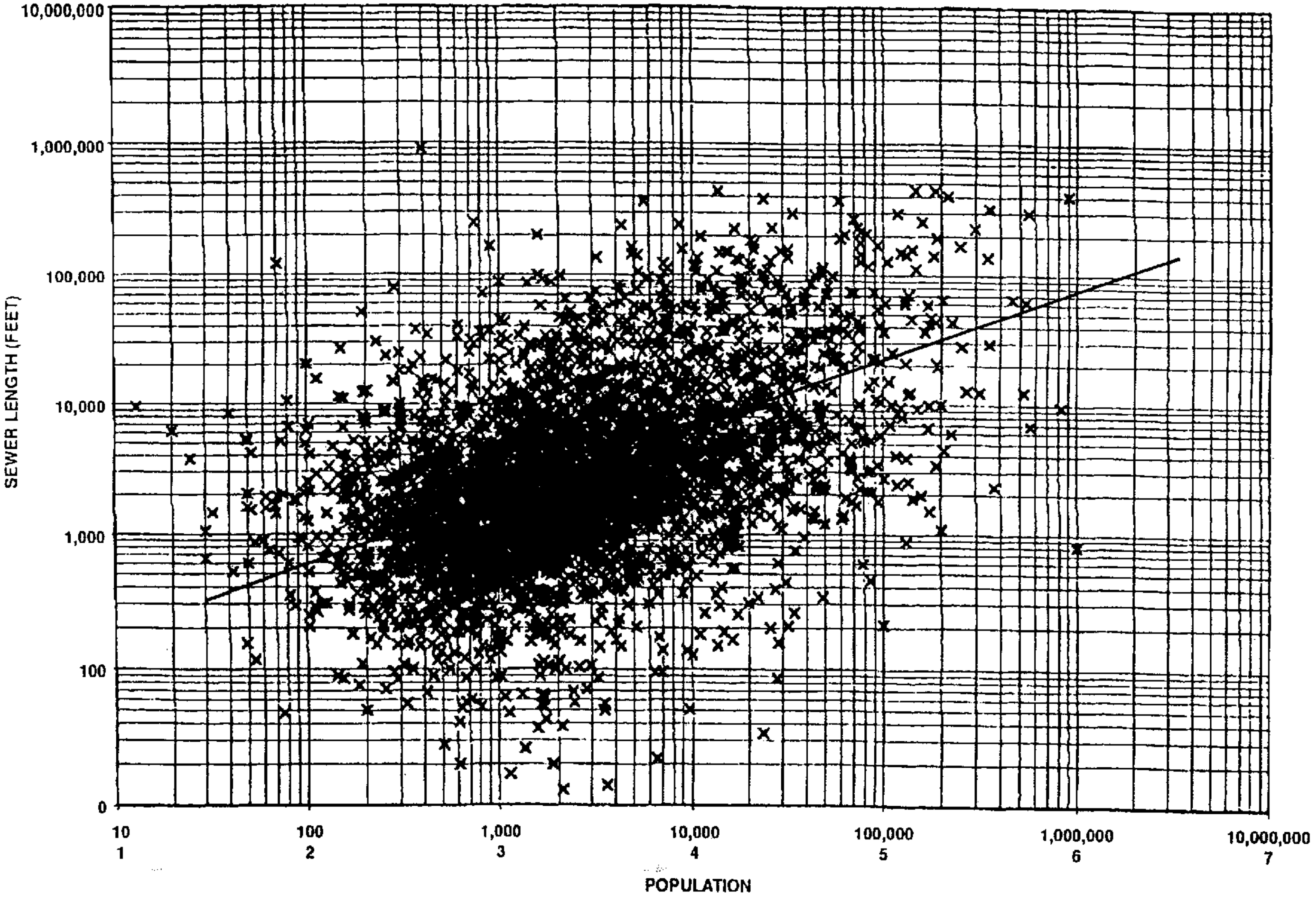
Source: GLUMRB, 1978

Figure 4-6. Ratio of Extreme Flow to Average Flow



Source: Harcum, 1995

Figure 4-7. Collector Sewer Length vs. Present Population Receiving Treatment



Source: Harcum, 1995

Figure 4-8. Interceptor Sewer Length vs. Present Pollution Receiving Treatment

$$Log(L_c) = 0.7Log(Pop) + 1.7 \qquad \text{(Equation 4-7)}$$

and total interceptor pipe length, respectively, are related to population. These plots were used to develop equations relating collector sewer length to population and interceptor sewer length to population by fitting a line to the plot of the log (Sewer length) versus the log (Population) for each plot. The best-fit lines have slopes of 0.7 and 0.51 for the collector and interceptor sewers, respectively, and both have an intercept of 1.7, yielding the equations below:

$$Log(L_i) = 0.51Log(Pop) + 1.7 \qquad \text{(Equation 4-8)}$$

where: L_c = Collector sewer length (ft)
L_i = Interceptor sewer length (ft)
Pop = Population

Since these data from the 1984 and 1986 Needs Surveys were not available for review, it is not known how the data were input to the system and how various individuals interpreted the meaning of collector sewer and interceptor sewer. In addition, the actual data points were not available to perform a direct regression, and the best-fit lines were developed from the graphs.

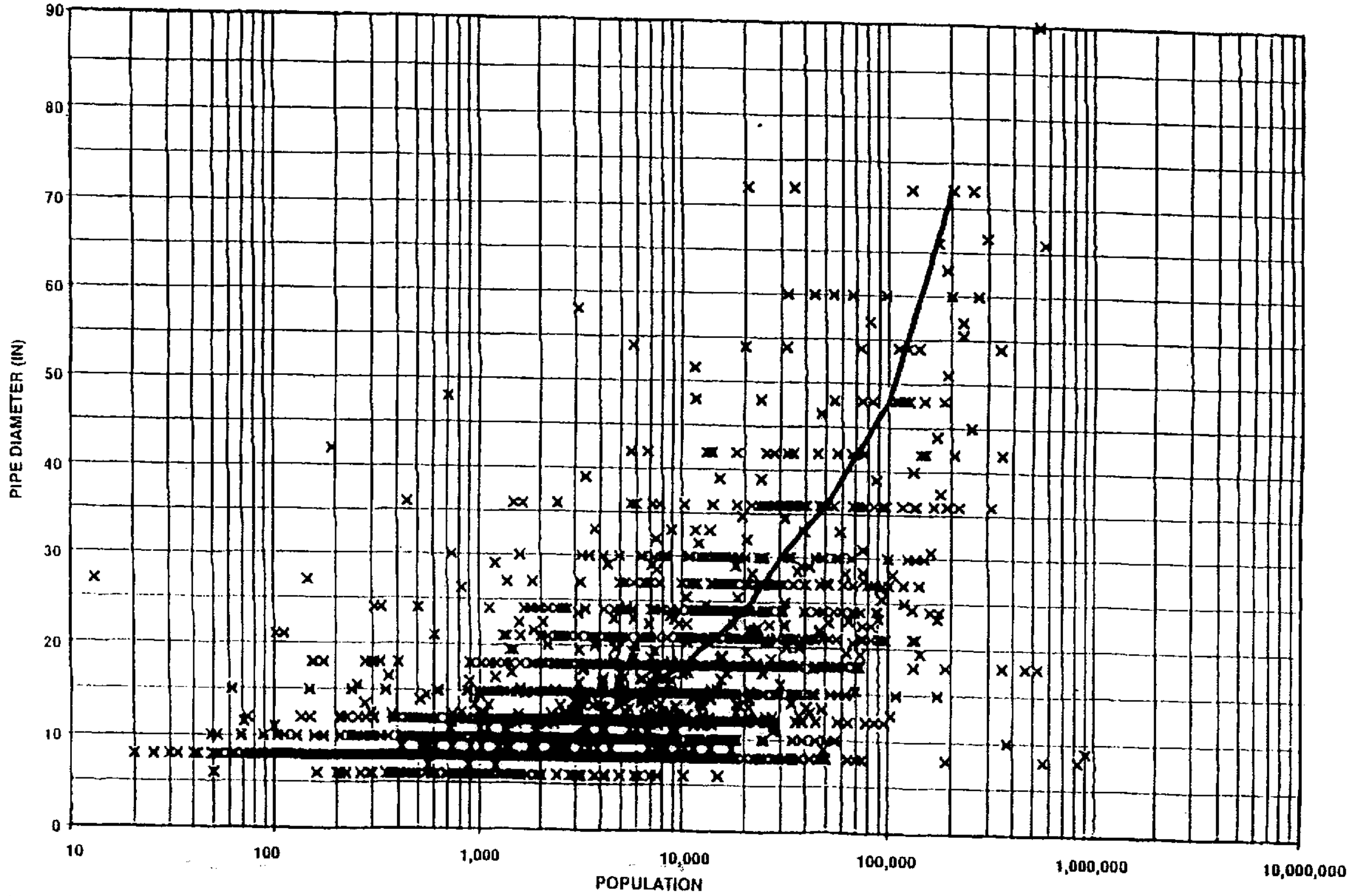
Adding the interceptor and collector sewer lengths from these graphs results in a total sewer length of approximately 5 to 10 feet per person depending on population. Recent data collection efforts have indicated that actual sewer lengths appear to be in the range of 15 to 23 feet per person. This variable is primarily used to calculate the available system storage capacity and the cost of sewer rehabilitation. As discussed below, the calculation for system storage given the above assumptions reasonably predicts system storage for the case study systems reviewed. Therefore, the above relationships (shown in Figures 4-7 and 4-8) are used in the model.

The other main factor in calculating available system storage is the pipe diameter. Since average interceptor pipe diameters generally increase with increasing population, a method for determining the average pipe diameter for each sewer system had to be developed. Figure 4-9 shows the general relationship between interceptor sewer diameter and the present population receiving collection, using data from the 1984 and 1986 Needs Surveys.

Using the present population receiving treatment from the 1996 database, total available system storage could be calculated with the above relationships. However, additional information is required to determine the volume occupied by the dry weather flow and the percent of available volume to store wet weather I/I. For the development of the initial cost estimate, it has been assumed that average dry weather flow uses approximately half of the total system volume. Also, it is assumed that only half of the remaining interceptor volume is available to accommodate additional wet weather flow before overflows occur. The contribution of collector sewers to system storage is assumed to be very small and is not currently considered. These assumptions are based on experience with the design and rehabilitation of sanitary sewers.

4.3.3.5 Rainfall Region

The final variable in the cost estimating model is the rainfall region in which the community is located. Rainfall data from five communities were used to define rainfall for all of the systems in the database. The five communities are Charlotte, North Carolina; Fort Worth, Texas; Wayne County, Michigan;



Source: Harcum, 1995

Figure 4-9. Interceptor Sewer Diameter vs. Present Pollution Receiving Collection

Portland, Oregon; and San Jose, California (as shown in Figure 4-10). Based on the location and rainfall characteristics of these communities, the country was divided into five regions for the purposes of initial model development. It is recognized that these regions will be large and that significant rainfall variation may occur within a region.

4.3.4 Model Input Conclusions

Based on the above assumptions and data developed from the Clean Water Needs Survey database, a complete set of data representing the sanitary sewer system communities in the country was developed. Table 4-1 gives an example page from the model database, which includes similar information for a total of 15,484 sanitary sewer systems. Additional information for each system listed in the table is also available. Figure 4-11 shows an output report that can be used to view all information available for a single sewer system or treatment plant. These reports and tables were used to analyze the data and to ensure that the required data were available for each system and that systems were not being double counted.

4.4 CAPITAL COST MODEL ADJUSTMENTS AND CALIBRATION

As discussed above, the SSO capital cost estimating model uses a series of national, regional, and sewer system wide assumptions to define the input data and parameters for the hydrologic model and cost functions. To assess the model results, cost data were initially collected from communities with available data from a site-specific SSO remediation project/study. Capital costs projected in facility plans for these actual collection system projects, referred to as calibration communities, were used to calibrate several key model parameters and evaluate the accuracy of the model.

The model was run for the case study systems using default parameters (as described above). These initial model results were compared to the projected costs from facilities plans. After reviewing these results, the Expert Panel agreed that the model required modification to address two principal concerns:

The model tended to over-estimate costs for smaller municipalities (particularly those with sewered populations < 75,000), based on comparisons of model-estimated and actual costs for calibration communities.

- Estimates of annual overflow frequencies by the STORM model under existing conditions show unrealistically high overflow frequencies for smaller municipalities (particularly those with sewered populations < 75,000).

Based on a series of recommendations from the Expert Panel, additional model runs using the following parameter adjustments were performed:

- The I/I coefficient distribution was changed so that all communities with average per capita non-industrial flow greater than 150 gpd received an I/I coefficient of 0.05. This would cause more facilities to have higher I/I coefficients.
- The I/I coefficient distribution was changed as above only for communities with populations greater than 100,000. This was suggested because the model tended to underestimate costs for larger facilities and it was thought that these facilities may have a greater proportion of I/I entry points than smaller communities.

The I/I coefficient was adjusted by an I/I factor, which was derived from a regression relationship between the ratio of the adjusted I/I coefficient to the original I/I coefficient.

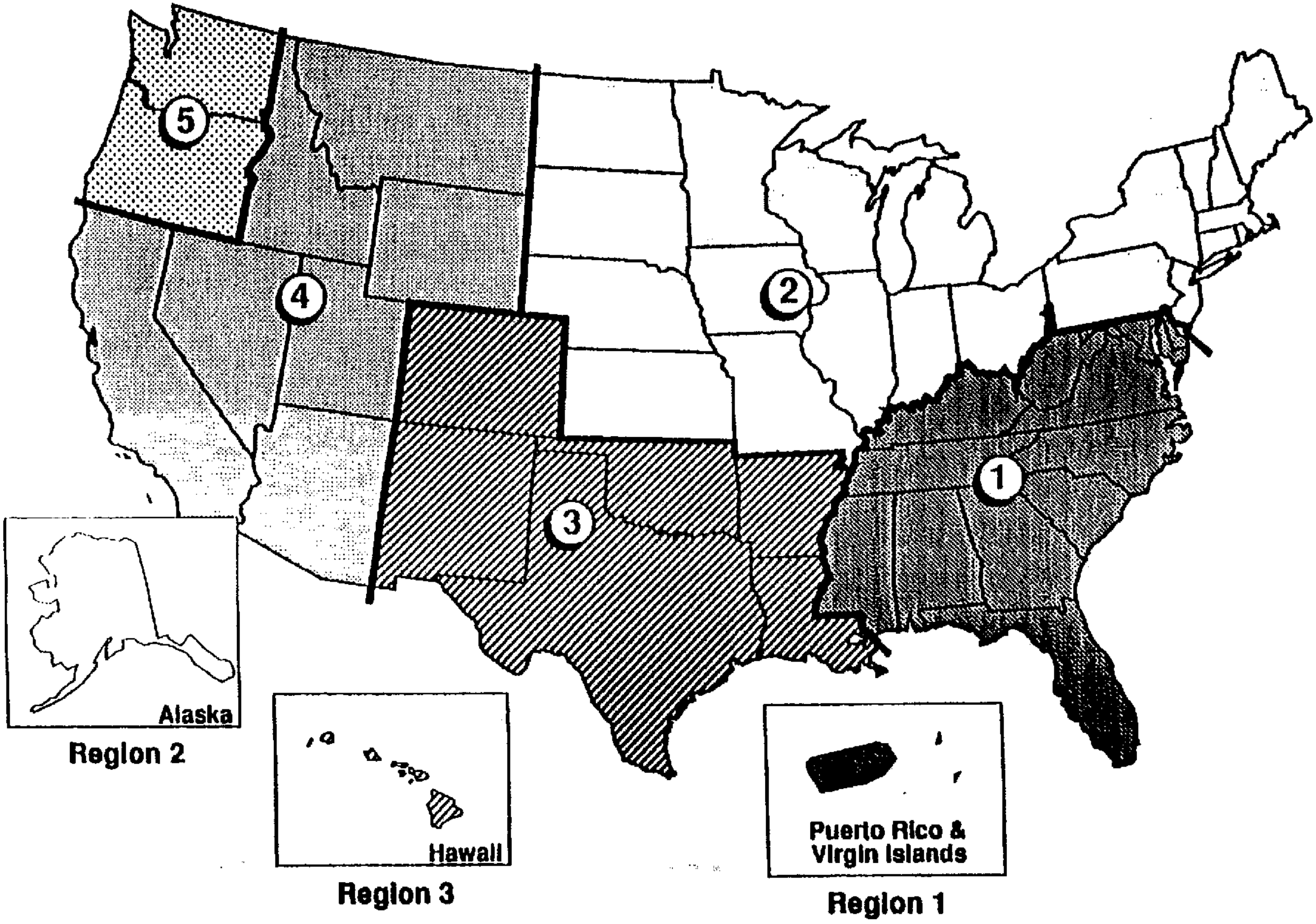


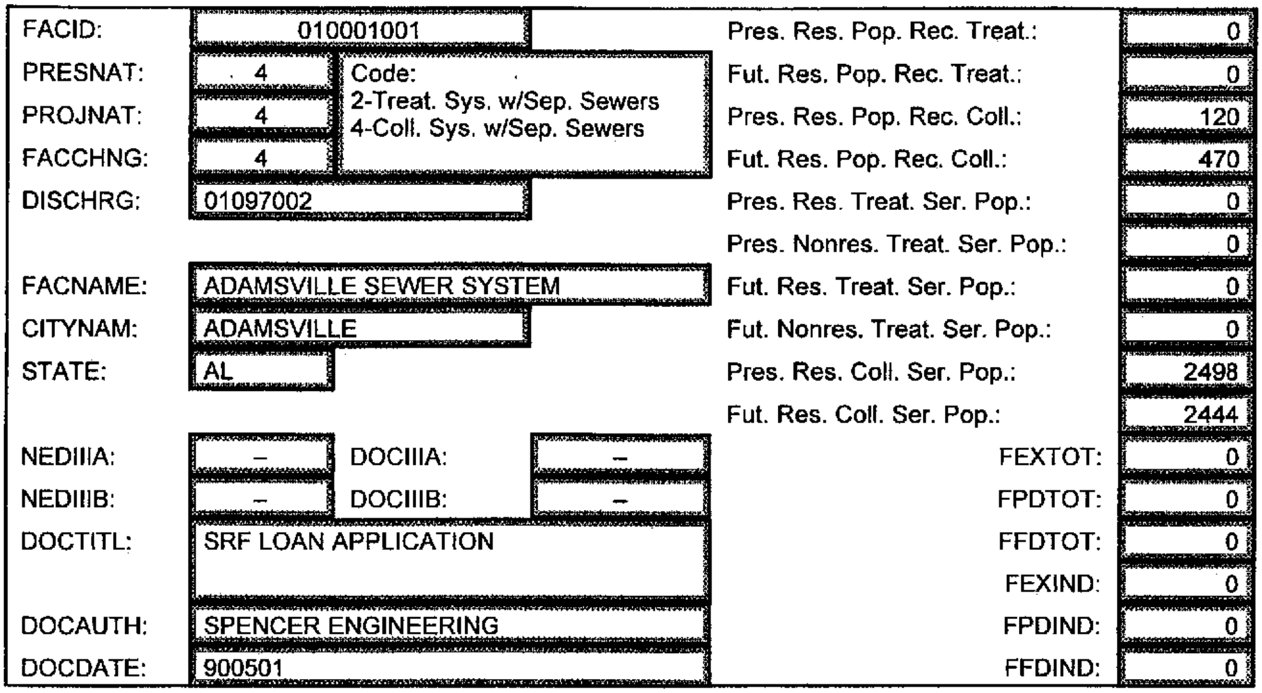
Figure 4-10. Rainfall Regions for Cost Estimating Model

Table 4-1. Sample Database Spreadsheet Output

FACID	FACNAME	CITYNAM	STATE	DISCHRG	PRESNAT	PPRRT	FEXTOT
010002001	AKRON WWTP	AKRON	AL	--	2	200	0.01
010003001	ALABASTER WWTP	ALABASTER	AL	--	2	8918	1.52
010004001	ALEX CITY SUGAR CR. WWTP	ALEXANDER CITY	AL	--	2	5043	6.11
010004002	ALEX CITY COLEY CR. WWTP	ALEXANDER CITY	AL	--	2	3951	0.29
010004003	ALEX CITY DOBBS AREA WWTP	ALEXANDER CITY	AL	--	2	2079	0.32
010004004	ALEX CITY CHRISTIAN CR SP	ALEXANDER CITY	AL	--	2	3640	0.42
010005001	ALTOONA LAGOON	ALTOONA	AL	--	2	855	0.15
010006004	ANDALUSIA RIVERSIDE STP	ANDALUSIA	AL	--	2	10415	1.61
010007001	ANNISTON CHOCCOLOCCO WWTP	OXFORD	AL	--	2	31873	8.93
010007002	ANNISTON FT. MCCLELLAN SP	ANNISTON	AL	--	2	5600	1.50
010009001	RILEY MAZE CK WWTP	ARAB	AL	--	2	1351	0.86
010009002	ARAB GILLIAM CR. WWTP	ARAB	AL	--	2	1351	0.45
010010001	ARDMORE STP	ARDMORE	AL	--	2	981	0.39
010011001	ASHFORD WWTP	ASHFORD	AL	--	2	1321	0.11
010012001	ATHENS WWTP	ATHENS	AL	--	2	13132	6.29
010013001	ATTALLA LAGOON	ATTALLA	AL	--	2	7600	0.80
010014001	AUBURN SOUTHSIDE STP	AUBURN	AL	--	2	24965	3.98
010014002	AUBURN NORTHSIDE STP	AUBURN	AL	--	2	4471	1.33
010015001	AUTAUGAVILLE LAGOON	AUTAUGAVILLE	AL	--	2	300	0.01
010016001	BAY MINETTE WWTP	BAY MINETTE	AL	--	2	5720	1.91
010016002	BAY MINETTE LAGOON	BAY MINETTE	AL	--	2	519	0.20
010017001	BAYOU LA BATRE STP	BAYOU LA BATRE	AL	--	2	2911	0.35
010021001	BOAZ SLAB CR. WWTP	BOAZ	AL	--	2	5097	2.09
010023001	BREWTON EAST LAGOON	BREWTON	AL	--	2	5716	1.23
010027001	CALERA WWTP	CALERA	AL	--	2	1871	0.48
010028001	CAMP HILL LAGOON	CAMP HILL	AL	--	2	838	0.16
010029001	CARBON HILL WWTP	CARBON HILL	AL	--	2	1993	0.32
010031001	CARROLLTON LAGOON	CARROLLTON	AL	--	2	1199	0.38
010032001	CEDAR BLUFF WWTP	CEDAR BLUFF	AL	--	2	750	0.19
010034001	CENTREVILLE WPCP	CENTREVILLE	AL	--	2	3512	0.37
010035001	CHATOM LAGOON	CHATOM	AL	--	2	756	0.20
010036001	CHICKASAW LAGOON	CHICKASAW	AL	--	2	9361	0.70
010037001	CHILDERSBURG BAILEY BR LG	CHILDERSBURG	AL	--	2	4160	0.52

Key:
FACID = Authority/Facility Number
FACNAME = Facility Name
PRESNAT = Present Facility Type
PPRRT = Present Resident Population Receiving Treatment
CITYNAM = City Name
DISCHRG = Facility Discharged To
FEXTOT = Total Existing Flow (MGD)

Source: EPA 1992 Needs Survey Database



FACID:	010001001			Pres. Res. Pop. Rec. Treat.:	0
PRESNAT:	4	Code: 2-Treat. Sys. w/Sep. Sewers 4-Coll. Sys. w/Sep. Sewers		Fut. Res. Pop. Rec. Treat.:	0
PROJNAT:	4			Pres. Res. Pop. Rec. Coll.:	120
FACCHNG:	4			Fut. Res. Pop. Rec. Coll.:	470
DISCHRG:	01097002			Pres. Res. Treat. Ser. Pop.:	0
				Pres. Nonres. Treat. Ser. Pop.:	0
FACNAME:	ADAMSVILLE SEWER SYSTEM			Fut. Res. Treat. Ser. Pop.:	0
CITYNAM:	ADAMSVILLE			Fut. Nonres. Treat. Ser. Pop.:	0
STATE:	AL			Pres. Res. Coll. Ser. Pop.:	2498
				Fut. Res. Coll. Ser. Pop.:	2444
NEDIIIA:	–	DOCIIIA:	–	FEXTOT:	0
NEDIIIB:	–	DOCIIIB:	–	FPDTOT:	0
DOCTITL:	SRF LOAN APPLICATION			FFDTOT:	0
				FEXIND:	0
DOCAUTH:	SPENCER ENGINEERING			FPDIND:	0
DOCDATE:	900501			FFDIND:	0

Note: See Appendix F for a description of each field. Source: EPA 1992 Needs Survey Database

Figure 4-11. Sample Summary Sheet for Sanitary Sewer System and Treatment Plant Data

- In conjunction with the development of an I/I factor, the SSO cost model was recalibrated based on actual data from an additional 67 communities.
- A cost estimate was developed for a small percentage of municipalities which combined the original SSO control strategies as well as primary and high rate treatment of wet weather flows that exceed design capacities.
- All community collector sewer pipes were increased to a length of 20 feet per person regardless of the Clean Water Needs Survey data. A recent survey (ASCE, November 1998: average 21 feet per capita) indicates that the length of pipe used in the model (7 to 15 feet per person) is a low value.
- The relationship between sewered area and population was revisited and the area/population regression was recalculated for small municipalities to discern if a significantly different relationship existed for small municipalities compared to the overall regression. Since the resulting regression curve was nearly identical to the original curve, changes to the area/population relationship were not warranted.

Comparing the results of these model runs with the actual costs derived during facility planning level programs showed that the best results were obtained from the model run using the I/I coefficient adjustment factor (I/I factor). This approach and the calibration results are presented in the next section.

4.4.1 The I/I Factor Approach

Experience with the model has shown that it is most sensitive to the input I/I coefficient. The I/I coefficient is applied over an area to determine the volume of wet weather inflow. It is in effect a runoff coefficient, used to determine the fraction of rainfall that enters the collection system. As such, the I/I coefficient does not account for the fact that smaller municipalities are somewhat likely to be less densely developed than larger municipalities, and therefore to have more opportunity for runoff to infiltrate into the ground or flow into natural channels, rather than enter the collection system. As a result, the original I/I coefficients caused the model to estimate unrealistically high I/I into the smaller municipality collection systems, leading to excessive annual overflow frequencies. This was particularly true for smaller municipalities. Therefore, this provided a sound rationale for modifying the I/I coefficients to improve the overall model calibration and result in more realistic estimated overflow frequencies. Several different means of adjusting the I/I coefficients were investigated, and the final method evolved from investigating the results of each approach.

The best results were obtained from an approach where each calibration community's I/I coefficient was adjusted (within the allowable range of 0.005 to 0.05) such that model-estimated costs matched actual costs as closely as possible. For example, one calibration community had an original I/I coefficient of 0.04. This resulted in an model-estimated cost of $12.2 million to meet its 0.2 overflow/year target, whereas the actual cost was $5.2 million. It was found that decreasing the I/I coefficient to 0.025 resulted in a model-estimated cost equal to the actual cost of $5.2 million.

For this community, the ratio of the adjusted I/I coefficient to the original I/I coefficient was 0.025/0.04 = 0.63. This ratio was termed the I/I factor. A separate I/I factor was calculated for each calibration community, based on its original I/I coefficient and the adjusted I/I coefficient which made the model-estimated cost match its actual cost as closely as possible. Each calibration community's revised I/I coefficient and corresponding I/I factor, are shown in Table 4-2.

The calibration community I/I factors were plotted against their associated populations to determine a trend. Once a relationship was determined—a regression curve allowing the I/I factor to be estimated as a function of population—it would be applied to the complete database to adjust all I/I coefficients. Since there was no strong overall relationship based on all calibration communities, separate regressions were made for small and large communities.

The small-community regression indicated an I/I factor of approximately 0.4 for the smallest communities, increasing to approximately 0.9 for communities nearest a population of 75,000. Small municipality I/I coefficients would thereby be decreased, reducing I/I and therefore lowering cost estimates. The corresponding regression for large communities showed a nearly flat line indicating an I/I factor approximately equal to 1.0 throughout the large community population range (i.e., no revision to the original coefficients). The results of this regression analysis lead to a similar conclusion as was reached by the Expert Panel: the smaller municipality costs needed revision due to model over-estimation, while the larger municipalities were calibrated quite well as a whole. Figure 4-12 shows the I/I coefficient distribution for all the modeled systems, both before and after applying the I/I factor.

4.4.1.1 Evaluating the I/I Factor Approach

In order to evaluate the effect of the I/I factor regressions on the model calibration, the regression equations were applied to the calibration communities themselves. In this fashion, the calibration community I/I factors were calculated as would be done for the complete database, as a function of population. Table 4-2 presents the regression-based calibration community I/I coefficients.

When the actual versus estimated costs for small and large calibration communities were plotted, the line of best fit for the small communities has a slope of 1.02, while the slope for the large communities remained the same as the original calibration, at 1.14.

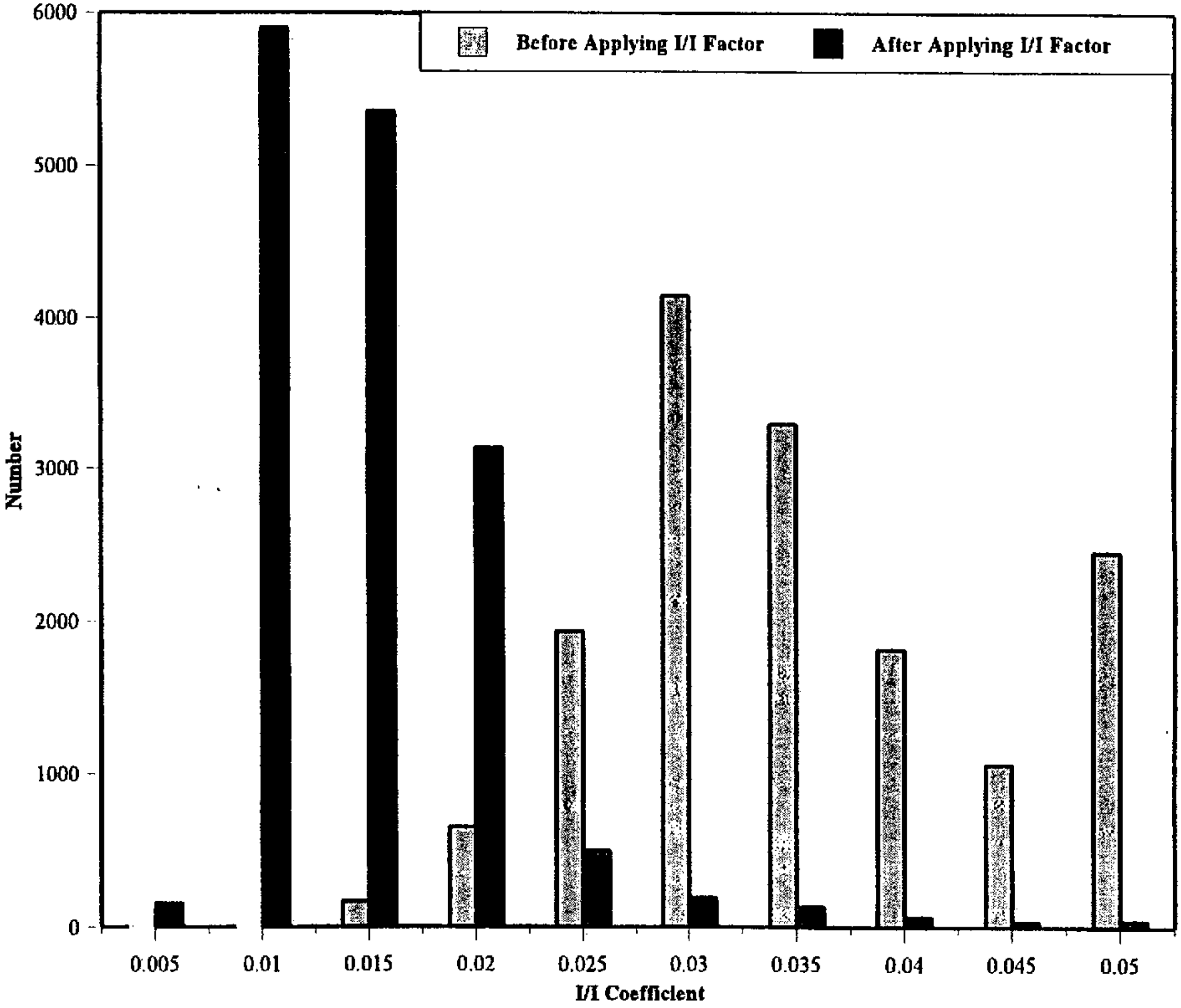


Figure 4-12. Distribution of Model I/I Coefficients

Table 4-2. I/I Factor Calculations for Calibration Communities

Community	Original I/I Coefficient	Modified I/I Coefficient	I/I Factor	Final I/I Coeff. (after regression)
Cincinnati, OH	0.050	0.050	1.00	0.025
Wayne County, MI*	0.040	0.050	1.25	0.040
Charlotte, NC*	0.045	0.030	0.70	0.045
Greenville, SC	0.040	0.050	1.25	0.040
Houston, TX*	0.045	0.050	1.20	0.045
Jewett City, CT	0.040	0.020	0.50	0.015
New London, CT	0.050	0.015	0.30	0.035
Elmhurst, IL	0.050	0.030	0.60	0.035
Belvidere, IL	0.030	0.010	0.33	0.015
Addison, IL	0.025	0.005	0.20	0.015
Saint Charles, IL	0.040	0.025	0.63	0.020
Mission Town, KS	0.035	0.030	0.86	0.025
Turkey Creek, KS	0.035	0.025	0.71	0.025
Indian Creek, KS	0.035	0.035	1.00	0.030
Honolulu, HI	0.050	0.030	0.60	0.050

* I/I Coefficients are the average of several facilities weighted by population.

As further verification, new existing conditions overflow frequencies based on the I/I factor approach were estimated by STORM. In comparison to the overflow frequency distribution based on the original I/I coefficients, the new distribution is more realistic. 19% of municipalities are estimated to have greater than 30 overflows/year, far fewer than the previous 75%. Meanwhile the majority of communities are estimated to have between 10 and 20 overflows/year.

Table 4-3 presents the calibration results. For the calibration communities, the predicted costs are sometimes above and sometimes below the actual costs for individual cities. This results in a predicted total cost for all the calibration communities that is within seven percent of the sum of the actual total cost for the communities. Annualized per capita costs for each of the calibration communities are also shown in Table 4-3.

4.4.2 Population Adjustment Factor

The total population served by all the municipal separate sanitary sewer collection systems in the cost model database is 130,957,360. As explained in Section 4.3.2, this final data set was developed from the 1996 Clean Water Needs Survey database after eliminating the facilities with incomplete information in the database. Since the EPA Needs Survey results indicate that there are approximately 148,000,000 people served by municipal separate sanitary sewer collection systems, the total costs generated by the model were factored up by a straight ratio of the actual population to the model database population (148,000,000/130,957,360) to account for the facilities and population lost when the facilities with incomplete information were eliminated from the data set.

Table 4-3. SSO Wet Weather Capacity Cost Estimating Model Calibration Results

Community	Sanitary Sewer Service Population	Overflow Target (OF/yr)	I/I Coeff.[1]	Model Predicted Capital Costs[2]		Actual Facility Plan Capital Costs[3]		Percent Difference
				Total Cost ($ million)[4]	Annual Per Capita Cost[5]	Total Cost ($ million)[4]	Annual Per Capita Cost[5]	
Cincinnati, OH	22,724	0.0	0.025	$13.6	$56.54	$42.65	$177.16	-68%
Wayne County, MI	167,939	0.0	0.040	$150.6	$84.65	$221.56	$124.53	-32%
Charlotte, NC	338,854	1.0	0.045	$181.9	$50.66	$111.89	$31.17	63%
Greenville, SC	125,884	1.0	0.040	$50.3	$37.75	$70.9	$53.16	-29%
Houston, TX	1,378,300	0.5	0.045	$1,035.5	$70.91	$1,329.26	$91.04	-22%
Jewett City, CT	3,500	1.0	0.015	$2.0	$52.35	$2.22	$59.75	-12%
New London, CT	40,000	0.5	0.035	$26.9	$63.52	$8.86	$20.92	204%
Elmhurst, IL	42,029	0.3	0.035	$27.6	$62.07	$23.71	$53.24	17%
Belvidere, IL	15,193	0.2	0.015	$4.1	$25.44	$2.66	$16.52	54%
Addison, IL	17,138	0.2	0.015	$4.5	$25.07	$1.11	$6.10	311%
Saint Charles, IL	16,935	0.2	0.020	$4.8	$26.61	$5.21	$29.02	-8%
Mission Town, KS[6]	45,309	0.2	0.025	$19.6	$40.84	$24.26	$50.54	-19%
Turkey Creek, KS[6]	50,404	0.2	0.025	$13.3	$24.88	$15.95	$29.88	-17%
Indian Creek, KS[6]	72,000	0.2	0.030	$29.6	$38.75	$34.56	$45.31	-14%
Honolulu, HI	687,475	0.0	0.050	$568.1	$78.01	$387.73	$53.24	47%
TOTAL	3,023,684	NA	NA	$2,132.3	$66.57	$2282.63	$71.25	-7%

[1] For Wayne County, Charlotte, and Houston, the I/I Coefficient is the average of several facilities, weighted by population.

[2] Capital costs for addressing SSOs resulting from wet weather capacity problems.

[3] Planning level estimates for capital costs were developed through conversations with the communities and review of reports.

[4] Total cost represents the full cost associated with SSO abatement for the system.

[5] Represents the annual per capita cost ($ per year) assuming a 20-year life amortization period and 7% interest rate.

[6] Kansas communities use SSO treatment as part of their abatement practices. An equivalent abatement level has been estimated to account for the treatment.

4.5 DEVELOPMENT OF SSO HIGH RATE TREATMENT COST ESTIMATE

The high rate treatment process has potential application within the collection system at permitted sanitary sewer overflow locations to provide greater treatment than with standard stormwater clarifiers.

The existing SSO cost model provides an estimate of the capital costs associated with constructing additional wet weather storage capacity, increased wet weather treatment plant capacity, and sewer system rehabilitation (I/I reduction), to reduce or eliminate SSOs from separate sanitary sewer systems. As part of the SSO cost analysis, EPA developed a cost estimate for a small percentage of municipalities where optimization had indicated the highest costs, which combined the original control strategies as well as high rate treatment of wet weather flows that exceed system design capacities.

This analysis included: modification of the existing cost model; the development of a high rate treatment cost curve; and a cost estimate for a combination scenario of abatement plus high rate treatment to eliminate SSOs to an overflow control frequency of 1.0 overflow every year.

For each population range in Table 4-4, wet weather treatment facility costs were estimated for the most costly three percent of the municipalities on a per capita abatement cost basis (based on the projections of the SSO cost model for 5.0 overflows per year). It was assumed that each municipality would first implement SSO abatement measures to meet a uniform pre-treatment control frequency of 5.0 overflows per year. The high rate treatment costs reflect abatement measures completed prior to sizing treatment facilities, so as to meet the more stringent 1.0 overflow per year final control scenario.

The abatement measures to meet the 5.0 overflows per year control frequency scenario include I/I reduction, additional storage capacity, and/or additional treatment capacity, and were estimated using the existing cost optimization model.

Table 4-4. Municipality Population Ranges

Sewered Population
>100,000
75,000 - 100,000
50,000 - 74,999
25,000 - 49,999
10,000 - 24,999
5,000 - 9,999
2,500 - 4,999
1,000 - 2,499
<1,000

4.5.1 Evaluating the I/I Factor Approach

The STORM model was used to estimate design SSO flowrates for each eligible municipality. STORM was modified to estimate the total overflow volume, overflow duration, and average hourly flowrate of each overflow predicted to occur during the historical rainfall data period. The overflows were ranked by average hourly flowrate from highest to lowest, and the overflow used to determine the design flowrate was selected based on a target of 1.0 overflow per year. For example, if the historical rainfall data period is 40 years, the overflow target is 1.0 overflow/year, the 41st ranked overflow would be selected (40 years x 1.0 overflow/year = 40 overflows allowed in 40 years, thus providing treatment capacity adequate for the 41st ranked overflow during an overflow event).

In this example, treatment capacity would be exceeded only 40 times over 40 years. The design flowrate equals the average SSO flowrate during the selected overflow scenario.

Using the average instead of the peak hourly SSO flowrate compensates for the fact that the STORM model does not account for factors that attenuate flows in real systems. These factors include time of concentration (the time required for runoff to reach the system inflow point), time of travel (the time required for flow in the system to reach the overflow point), and that during the peak hour of large storms, it is likely that only a fraction of available I/I volume is actually able to enter the system due to hydraulic constraints. Using the average flowrated of the selected overflow as the design flowrate is a means of accounting for flow attenuation, and thereby providing a more reasonable cost estimate of SSO treatment facilities.

To prevent unrealistically large facilities from being sized based on high hourly SSO flow rates, a maximum design flowrate of 450 gallons per capita per day for each facility was assumed. The 450 gpcd limit was calculated by assuming an average per capita flow of 100 gpcd, multiplied by a future growth factor of 1.5 and an average peaking factor of 3.0. This is a realistic maximum flowrate that could be conveyed by a facility's collection system.

Disinfection (chlorination/declorination) facility construction costs were estimated directly from the design flowrate using the following cost equation (from *Narragansett Bay Commission CSO Mitigation Study, CSO Area C*, CDM, 1989), and updated to 1998 dollars.

$$\mathrm{Cost}_{\mathrm{dis}} = 0.219\ Q_{\mathrm{des}}^{\ 0.496} \qquad \text{(Equation 1)}$$

where: $\mathrm{Cost}_{\mathrm{dis}}$ = Disinfection facility construction cost, \$ million

Q_{des} = Design flowrate, MGD

4.5.2 Development of High Rate Treatment Cost Curve

High rate clarification, or ballasted flocculation, is a physical-chemical clarification process involving the fixing of flocs, or suspended solids, onto ballast sand with the acid of a polymer. A combination of a metal-salt coagulant, micro-sand (or sludge recycle), and enhanced clarifier features (such as lamella settlers) can increase settling velocities by a factor of 10. With this process, screened sewage is combined with a coagulant (typically ferric chloride or alum) in a flash mix tank, where the micro-sand and polymer are added. The micro-sand provides a large number of particles (contact area), enhancing the flocculation rate, and acts as ballast to accelerate the settling of the floc.

The suspended solids in the wastewater, which have been destabilized by the addition of coagulant, bind to the micro-sand particles via polymer bridges. These large particle agglomerates grow into high-density flocs in maturation tanks. There the conditioned wastewater experiences a gentle mixing energy and increased retention time, allowing the agglomerates to trap random flocs and settle faster in the sedimentation tank.

The resulting sludge, which contains the micro-sand mixture, collects at the bottom of the sedimentation basin for pumping to hydrocyclones, where the sludge is centrifuge-separated from the micro-sand. The residual solids are sent through a sludge processing system and the recovered micro-sand is recycled to the injection tank.

A high rate treatment cost function was developed based on data obtained from three manufacturers: Actiflo ® (Kruger, Inc.), Densadeg ® (Infilco Degremont, Inc.), and Microsep ® Advanced Clarification System (Microsep International Corp.). This cost function represents an approximate construction cost curve for a typical high rate treatment facility including costs for earthwork, concrete, aboveground facilities, sitework, process mechanical systems, screening, mechanical, electrical, instrumentation, piping, and site restoration (land acquisition costs are not included).

4.6 DEVELOPMENT OF OPERATION AND MAINTENANCE (O&M) COST ESTIMATE

In addition to the capital costs associated with constructing storage, increased treatment capacity, or by reducing I/I, communities seeking to reduce SSOs will need to increase, and make more efficient, their collection system maintenance activities. This suite of activities is referred to as Management, Operations, and Maintenance (MOM). As discussed in Sections 2 and 3, sewer system MOM activities are very important for reducing SSOs and preventing system blockages and failure. Therefore, the national costs associated with the level of additional O&M required to reduce SSOs has been projected. Because of the inherent difficulties in modeling MOM activities, the costs associated with the increased level of MOM were developed using an empirical methodology, which is discussed in the following sections.

4.6.1 O&M Activities and Frequencies

Sections 2 and 3 described some of the tasks typically associated with sewer system manaagement, operation and maintenance. Proper implementation of these MOM tasks can reduce the frequency and severity of SSOs. Unfortunately, many communities, as can be seen from the national survey results, do not perform these MOM tasks as frequently as they should. The national cost of increased MOM, however, can be difficult to estimate given uncertainties about existing levels of MOM and related expenditures throughout the country.

Defining acceptable levels of MOM activities for sanitary sewer systems depends upon the characteristics of the individual collection system such as age of the infrastructure, number of pump stations, topography and growth patterns. Site-specific considerations, such as flat slopes or poor soils, may require some communities to have a mangement plan that involves cleaning and/or inspecting their sanitary sewer system more regularly than communities with different conditions to obtain a similar level of service. There is, however, a growing awareness that sewer system MOM activities are investments in the sanitary sewer system. Data indicate communities have consistently increased levels of MOM activities–especially the "management" elements--over the last two decades (as noted in Section 3).

4.6.2 MOM Needs Estimates for SSO Abatement

Because of the importance of the MOM element in addressing SSOs, two different approaches were taken to provide a national Needs estimate. The first method applies unit costs for specific maintenance activities to the estimated length of sanitary sewer, nationwide; and the second applies annual MOM cost data (excluding rehabilitation which is a capital cost often included with sewer O&M) from a recent survey conducted by the American Society of Civil Engineers (ASCE) (*Optimization of Collection System Maintenance Frequencies and System Performance*. November 1998) to the estimated length sanitary sewer, nationwide. These approaches, while derived from different data sources, had very similar results: approximately $1.5 billion dollars per year in unmet Needs is required to provide an acceptable level of MOM for SSO control.

The initial estimate of total national MOM costs for SSO abatement was developed based on average costs for specific basic O&M tasks and typical frequencies for performing these tasks. Table 4-5 presents the frequencies and unit costs used for the following basic O&M tasks:

- Jet cleaning to remove deposited materials from susceptible areas of a sanitary sewer system.
- Television inspection of the sewer system to identify areas of I/I and structural defects.
- Root removal to reduce the incidence of blockages.
- Joint testing and repair to reduce the level of infiltration entering the sewer system.
- Manhole inspection and repair to reduce I/I.

Table 4-5. O&M Cost Assumptions for SSO Abatement[1]

O&M Task	Unit	Unit Cost ($)	%/Year*
Jet Cleaning	linear foot	$0.50	8.0%
Television Inspection	linear foot	$1.00	4.0%
Root Removal	linear foot	$1.00	2.0%
Joint Testing/Repair	linear foot	$15.00	2.0%
Manhole Inspection/Repair	per manhole	$90.00	2.0%

* %/Year = % of system cleaned/inspected/repaired each year.

[1] Unit costs and frequencies (%/yr) are based on consultations with sewer maintenance directors, the Expert Panel, and the following studies: CSUS (1997 draft), Arbour and Kerri (1997), Faria and Larson (1996), Knott and Singleterry (1995), Stainaker and Rigsby (1997), and Larson and VonAspern (1995).

These cost and frequency data were gathered from a review of case studies and personal conversations with sewer system maintenance directors including members of the Expert Panel. Using these frequencies, a sewer system would be completely cleaned approximately every 12 years and television inspection of the entire system would theoretically take approximately 50 years. These frequencies are less than that noted in recent ASCE survey data, but are representative of the overall frequencies that could be anticipated by the mix of utilities, nationwide. In actual applications, these tasks would likely be concentrated in specific problem areas. Therefore, some areas of a system may receive maintenance more often than the specified frequency, while other areas receive maintenance less often than the specified frequency.

Secondly, a more detailed analysis of MOM costs was undertaken. The additional analysis was conducted using new data available based on a survey of utilities in the ASCE November 1998 report. This analysis also differentiated between Needs that were met by current collection system MOM activities and the resultant expenditures by utilities, and MOM Needs that are projected to be necessary to support SSO control but are currently unmet. A complete discussion of these MOM cost projections is provided as Appendix H. A synopsis of the methodology used and the need projections follows.

The population receiving collection, as presented in the CWNS database, was used as the basis for projecting the national length of collection system infrastructure. From data on collection systems collected for the Water Environment Research Foundation report, *Benchmarking Wastewater Operations, Treatment, and Biosolids Management* (1997), an average of 11.5 feet of sanitary collection system per capita for large cities and 26.1 feet per capita of sanitary collection system for small cities was used to estimate the national length of collection system based upon the population in cities grouped according to their size. An estimated 3.07 billion feet of sanitary sewer or 580,700 miles of sanitary collection system infrastructure was projected, which corresponds to earlier EPA estimates of national sanitary sewer system length.

Table 4-6. National Annual Cost Estimates for Collection System O&M to Support SSO Abatement (December 1998 dollars)

Collection System MOM	Annual Cost Estimate (Billions)
Current MOM	$1.6
O&M Prior to SSO Control	$1.0
MOM with SSO Abatement	$3.1
MOM - Total Needs	$2.1
MOM - Unmet Needs	$1.5

The current national annual collection system MOM cost was estimated by multiplying the number of collection system miles by the O&M cost per mile. The ASCE November 1998 report provided an average MOM cost of $2,796 per mile per year, adjusted to December 1998 dollars, that was used to estimate current MOM expenditures. Rehabilitation, construction of relief sewers or equalization/storage facilities, have been specifically excluded from MOM Needs as these are considered capital costs for this analysis. The ASCE average MOM cost per mile from their survey of municipal utilities clearly separated the capital cost expenditures for rehabilitation and relief sewers from the routine MOM costs. Other literature on collection systems did not always separate the capital expenses from O&M costs and was not used for this analysis. The current national annual MOM expenditure is estimated to be $1.6 billion.

As discussed in Section 3, collection system O&M has changed in the last two decades. The average cost of conducting MOM, even after adjustment to December 1998 dollars, reflects the increase in certain O&M activities. Based upon the MOM cost data in the ASCE draft report, between 1985 and 1993, MOM expenditures, after adjustment for inflation, rose at an average annual rate of 5%. Much, but not necessarily all, of the increase between historical and current maintenance activity and the corresponding MOM cost may be due to the utilities' increasing SSO awareness and their response to state SSO abatement efforts, especially in the "management" of O&M. An historical MOM cost of $1,986 per mile, adjusted to December 1998 dollars, was obtained from the ASCE November 1998 draft report. After multiplying the length of sewer nationwide by the adjusted cost per mile, the historical national MOM expenditure is estimated to be $1.0 billion dollars.

The MOM activities and corresponding costs are expected to increase to support SSO abatement in the future. The projected increase to support SSO control is estimated to result in an average annual MOM cost of $5,432 per mile. This cost per mile is below the average cost per mile ($7,975) documented in the WERF *Benchmarking* report and some municipalities are already spending the projected cost per mile for their MOM.

Since utilities have been performing collection system O&M prior to programs that control SSOs, not all of the projected expenditure is O&M Needs for SSO abatement. The historical national annual O&M cost can be thought of as collection system O&M without activities targeted at SSO abatement. By subtracting the historical national annual O&M cost ($1 billion) from the national annual MOM costs ($3.1 billion) when SSO abatement programs are fully implemented, the result is an estimate of the total annual MOM needs for SSO abatement of $2.1 billion.

The current O&M practices have changed in response to the increasing SSO awareness on the part of the utilities, and to comply with state NPDES programs to control SSOs in the absence of an explicit federal policy. The difference between the total annual MOM needs for SSO abatement and current practice is the unmet annual MOM needs for SSO abatement. The national annual unmet O&M needs for SSO abatement is estimated to be $1.5 billion or the projected national annual O&M expenditure when SSO abatement is implemented ($3.1 billion) minus the estimated current cost of collection system O&M ($1.6 billion).

SECTION FIVE

ESTIMATED INVESTMENTS REQUIRED FOR CONTROLLING SSOs FROM MUNICIPAL SANITARY SEWERS

5.1 INTRODUCTION

This section presents estimates of the national investments needed to improve the performance of municipal sanitary sewer collection systems to achieve compliance with existing CWA requirements. Section 4 describes the methodology used to develop these estimates.

Two classes of investments are identified in this report:

1) Investments needed to address SSOs caused by wet weather conditions; and
2) Investments needed to reduce SSOs caused by other conditions.

SSOs caused by wet weather conditions are typically addressed through a combination of capital improvements that increase design capacity and remove bottlenecks, flow reduction measures, and operation and non-structural remediation-specific activities that restore the effective capacity to near the design capacity. For the purpose of this report, these costs were assumed to be one-time costs and are annualized over 20 years, assuming the Office of Management and Budget's recommended annual percentage rate of 7 percent for the cost of capital for regulatory analysis. Typically, municipalities are able to pay less than 7 percent interest. For example, AMSA's 1996 Financial Survey reported a State Revolving Fund (SRF) median interest rate of 3.75 percent for sixty-nine large metropolitan agencies. The Survey also reported that about 14 percent of capital comes from SRF Loans and state and federal grants, and 85 percent of the funding comes from local funds, such as revenue bonds and general obligation bonds (AMSA, 1996). Municipal bond rates from Moody's Investment Services average approximately six percent.

EPA believes that SSOs caused by other factors, such as blockages or structural, mechanical or electrical failures, can be reduced through improved collection system management, operation and maintenance ("MOM") programs. These programs restore the structural integrity of the system and reduce the potential for blockages. In this report, these costs were viewed as recurring annual costs.

Section 4.0 presents the assumptions made to develop estimates of MOM costs.

Section 5.2 presents estimates of total and annualized capital investments needed to reduce the number of overflows caused by wet weather conditions to different frequency scenarios. Section 5.2 presents estimates of the cost reductions associated with also incorporating into a comprehensive SSO control strategy some infrequent, controlled discharges of high-rate treated peak wet weather flows that exceed system design capacities. Section 5.3 presents estimates of annual management, operation and maintenance costs. Section 5.4 presents total annualized costs for various performance levels and discusses how total annual costs can be described on a per capita, per household, and regional basis. Section 5.5 presents key findings.

5.2 INVESTMENTS TO REDUCE SANITARY SEWER OVERFLOWS (SSOs) CAUSED BY WET WEATHER CONDITIONS

Two sets of estimates of the costs of controlling SSOs caused by wet weather were developed:

1) The first set of estimates are based on reducing SSOs caused by wet weather with comprehensive programs that may include expanded collection system storage capacity, expanded treatment plant capacity, and reduced peak flows from I/I reduction, but do not provide for peak excess flow treatment facilities (PEFTFs).

2) The second set of estimates are based on expanding the scope of comprehensive control efforts to include, in addition to the measures identified above, infrequent, controlled discharge of treated peak wet weather flows that exceed design capacities. For the purposes of these estimates, it was assumed that the treatment provided for these discharges was an advanced physical/chemical process, such as high-rate clarification, followed by disinfection (PEFTFs). These estimates were applied only for the 3% subset of systems which had the highest conventional remediation costs of the 15,484 separate sanitary systems analyzed. Both sets of capital cost estimates are based on targeted discharge frequency scenarios.

5.2.1 Investments Without Discharges from PEFTFs

Cost estimates presented in this section are based on comprehensive programs that only include expanded collection system capacity, expanded treatment plant capacity, and reduced peak flows. Estimates are made for reducing wet weather SSOs to different frequency scenarios. Figure 5-1 presents estimates of thecosts optimization to reduce annual overflow frequencies in all sanitary sewer collection systems nationwide to 5, 1, 0.5, or 0.2 times per year.

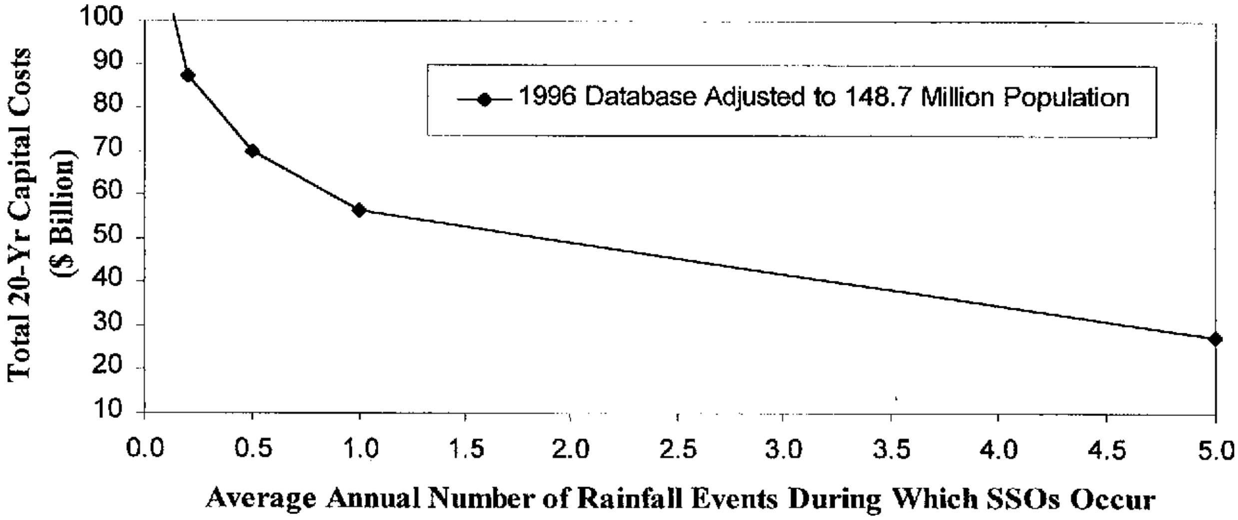


Figure 5.1 Total 20-Yr Costs to Address Wet Weather Overflow Capacity

Figure 5-1 shows the relationship between wet-weather overflows expected to occur at a given frequency and the estimated cost needed over a twenty year period to ensure that all municipal sanitary sewer systems in the United States have wet weather overflows at no greater than the specified frequency. The overflow frequencies depend on the return storm frequency, used as the control objective in local SSO remediation programs, and were assumed to be approximately equivalent to an SSO overflow frequency. For example, the 0.5 overflow frequency represents a scenario where wet weather overflows are expected within systems once every two (2) years (the inverse of 0.5); the 0.2 annual overflow frequency would be equivalent to a five year return storm. these overflow numbers represent average annual overflow storm events, not the number of overflow points, as multiple overflows would occur when the rainfall scenario at which a system failure--wet weather overflows--occurred.)

Figure 5-1 shows that an estimated $27.6 billion in capital investments over twenty years is needed to reduce wet weather SSOs in all collection systems in the United States from existing levels to no more than five overflow events per system per average year. This translates to an average annual per capita cost of $17.51 and average annual household cost of $46.76.[15] Control to one system overflow per system per year would require a total capital investment of $56.3 billion or an additional investment of $28.7 billion to eliminate four overflow events per year or about $7 billion per overflow event per year (see Table 5-1). At the one overflow event per year control level, annual per capita costs are $35.75 and annual household costs are $95.45. Estimated one-time costs–without increased annual investment--to approach eliminating discharges from all but wet weather events that occur on average once every five years are $87.3 billion over a twenty-year period.

Table 5-1. Incremental 20-Yr Capital Cost for Reducing SSOs

Control Objective (Number of System-Level Overflows Per Year)	Total 20-Yr Capital Cost	Incremental Capital Cost per Overflow Reduced Per Year
5	$27.6 Billion	–
1	$56.3 Billion	$7.2 Billion
0.5	$70.0 Billion	$27.4 Billion
0.2	$87.3 Billion	$57.6 Billion

Note: Incremental capital costs based on a baseline of five system-level overflows per year.

5.2.2 Comprehensive Control Efforts With Discharges from PEFTFs

This section provides estimates of the investment needed if the control strategies outlined in the previous set of estimates (e.g., expanding collection system capacity, expanding treatment plant capacity, and reducing peak flows) are expanded for a small percentage of municipalities to include infrequent, controlled discharges of wet weather flows from PEFTFs. Chapter 4 describes the methodology for estimating costs for the construction of treatment systems to treat and infrequently discharge SSOs. When developing these estimates, it was assumed that three percent of municipalities with the highest per capita costs and with collection systems serving 5,000 or more would incorporate controlled treated discharges into their comprehensive control strategies.

Table 5-2 provides the results of the analysis The costs of control strategies that included a combination of rehabilitation (e.g., I/I reduction, increased capacity) and infrequent discharges of treated effluent was compared to the cost of a rehabilitation only control strategy. The model estimated that the costs of the modified control strategies, which includes discharges of treated effluent five times per year, is, for the municipalities that would undertake this approach, about half the cost of a control strategy without treated discharges.

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[15] Household costs are based on an average U.S. household size of 2.67 (U.S. DOC, 1995).

Since the analysis focused on the three percent of collection systems with the highest annual per capita costs, the average annual per capita and household cost of the targeted three percent of municipalities ($43.28 and $115.57, respectively), was 1.4 times higher than the average costs of all systems nationwide ($35.75 annual per capita and $95.45 annual household) for the one overflow event per year objective. Even when modified control strategies with primary treated discharges are considered, the average per capita and household cost for the targeted three percent of systems is 40 percent higher than the average costs for all systems.

Table 5-2. Cost Comparison (20-Yr) for Abatement and Treatment Versus Abatement Only to Achieve One SSO/Year

				One SSO/Year				
Population Range	**Number* of Systems**	**Total Population**	**Rehabilitation to Reach Five SSOs/Year ($ millions)**	**Treatment Facilities Costs ($ millions)**	**Total Costs ($ millions)**	**$ per Capita per year**	**Rehab. Only ($ millions)**	**$ per Capita per Year**
> 100,000	5	680,966	174	54	228	31 58	576	79,82
75,000–100,000	2	178,143	73	16	89	47 23	193	102.13
50,000–74,999	5	332,663	99	31	131	37.08	120	93 57
25,000–49,999	15	581,987	189	63	253	40.97	575	93 29
10,000–24,999	39	442,776	147	66	214	45 67	381	81.31
5,000–9,999	43	245,266	103	45	148	57 16	210	81.12
TOTAL	109	2,461,801	785	276	1062	43 28	2,397	101 03

* Costs are for the Highest 3 Percent of Systems in Each Population Range, Ranked by Per Capita Abatement Cost

2,397
1,062
1,335

5.2.3 Ground Truthing the Wet Weather SSO Cost Model Results

The uncertainty of the estimated costs of controlling SSOs caused by wet weather, (i.e., ~~the precise~~ range of national costs) was not characterized within statistically defined parameters (i.e., confidence limits) because of the highly uncertain nature of some of the input variables (e.g., sewered area and population relationships, rainfall intensity patterns, underlying cost functions, and community strategies for SSO abatement). Alternatively, this section compares the costs estimated by the model with information from other sources.

Cost estimates were compared to actual site-specific costs provided by the 15 calibration communities. The overall difference between modeled costs and actual costs across the 15 communities was less than ten percent (see Chapter 4).

The 1996 Clean Water Needs Survey and its accompanying Report provides estimates of capital expenditures for water quality improvement projects (e.g., sewers, treatment plants, CSOs). Table 5-3 shows reported needs for categories related to sanitary sewer collection systems.

In many cases, documented needs in Categories IIIA and IIIB of the Clean Water Needs [Survey] Report are related to preventing SSOs and addressing related treatment plant compliance problems. In addition, a portion of the $29.4 billion needed for secondary treatment (Category I of the Clean Water Needs Survey) may be to increase capacity for peak flows caused by infiltration and inflow in the collection system.

Table 5-3. Sanitary Sewer Collection Needs Reported in 1996 Clean Water Needs Survey

Selected Needs Categories	20-Yr Costs ($ billions)
IIIA – Infiltration/Inflow Correction	3.6
IIIB – Sewer Replacement/Rehabilitation	7.5
IVA – New Collector Sewers	12.0
IVB – New Interceptor Sewers	12.0
Total	35.1

In general, EPA believes that the needs estimates in the Clean Water Needs Survey categories that are related to SSOs underestimate the total costs associated with preventing SSOs for the following reasons:

- Many municipalities have not fully investigated their SSOs or measures necessary to correct them,
- Some municipalities have not submitted documented needs for SSO correction measures such as I/I measures or sewer rehabilitation/replacement because these types of projects have traditionally been given low priority for SRLF funding, and
- Some of the costs of addressing SSOs do not require capital (e.g., operations and maintenance) and are not eligible for funding under the SRLF program.

5.3 COSTS OF IMPROVING MANAGEMENT, OPERATION, AND MAINTENANCE, OF SEWER SYSTEMS

The basic methodology for estimating national annual MOM costs consisted of assigning unit costs to various tasks (e.g., jet cleaning) and applying these to the universe of collection systems. Table 5-4 presents the estimates of national MOM costs using the procedure described in Chapter 4. The total estimated MOM cost for sanitary sewer collection systems nationwide was estimated to be $1.5 billion per year. This was equivalent to an annual per capita cost of $10.18 and an annual household cost of $27.18.

Because tasks performed under MOM programs are periodic (e.g., a given pipe in a system is cleaned only at a specified frequency), and a given section of pipe cannot be continuously maintained, some SSOs due to blockages or pipe and equipment failures are expected to occur after improved MOM programs are in place. This is consistent with the premise that increased MOM activities would reduce SSOs from blockages and pipe and equipment failures up to a given point, but would not be effective in eliminating all SSOs. Available information does not allow estimation of the frequency of these remaining unavoidable SSOs (or the percentage reduction of SSOs) after the increased levels of MOM program implementation.

5.4 TOTAL COSTS TO CORRECT SSOS

Table 5-5 presents total annual per capita and per household expenditures estimated to address sanitary sewer overflows. The average total per capita expenditures shown in Table 5-5 range from $27.85 per year for 20 years for controlling five overflows per year to a high of $66.09 for controlling to 0.2 overflow per year. On a household basis, average costs range from a low of $74.35 to a high of $160.79.

Table 5-4. Annual MOM Cost Estimate for SSO Abatement

Task	Unit	Unit Cost ($)	%Year*	Subtotal**
Jet Cleaning	linear foot	$0.50	8	$38,735,299
Television Inspection	linear foot	$1.00	4	$29,051,474
Root Removal	linear foot	$1.00	2	$9,683,825
Joint Testing/Repair	linear foot	$15.00	2	$145,257,372
Manhole Inspection/Repair	per manhole	$90.00	2	$3,486,177
			Total	$1,513,766,000

* % Year = % of system cleaned/inspected/repaired each year
** Total Sewer Length Assumed = 3,717,500,000 ft.
Total Number of Manholes = 14,870,000 (approximately 1 manhole per 250 ft of sewer)

The average annual fee for large systems, as reported in AMSA's 1996 Financial Survey (AMSA, 1996), is $208. This rate can also be generally representative of other systems in the United States.

In comparison, the 1996 Clean Water Needs Survey Report to Congress (U.S. EPA, 1997) estimates a $49.5 billion cost to address combined sewer overflows (CSOs). An estimated 42.7 million people in the United States are served by combined sewers. This would be an annual total cost of $4.7 billion and an average annual per capita cost of $110 and a household cost of $294.78.

Table 5-5. Total Annual and Average Annual Per Capita SSO Abatement Costs

Wet Weather SSO Performance Target (Wet Weather SSOs per year)		Annualized Wet Weather SSO Costs	Annual Costs for other SSOs	Total Annual Costs
0.2	Total	$8.3 billion	$1.5 billion	$9.8 billion
	Avg. Per Capita	$55.91	$10.18	$66.09
	Avg. Household	$133.61	$27.18	$160.79
0.5	Total	$6.7 billion	$1.5 billion	$8.2 billion
	Avg. Per Capita	$44.84	$10.18	$55.02
	Avg. Household	$119.73	$27.18	$146.91
1.0	Total	$5.4 billion	$1.5 billion	$6.9 billion
	Avg. Per Capita	$36.04	$10.18	$46.22
	Avg. Household	$96.24	$27.18	$123.42
5.0	Total	$2.6 billion	$1.5 billion	$4.1 billion
	Avg. Per Capita	$17.67	$10.18	$27.85
	Avg. Household	$47.17	$27.18	$74.35

5.4.1 Distribution of Annualized Per Capita Costs

Chapter 2 discusses how the performance of sanitary sewer collection systems varies significantly among systems. Some municipalities would face per capita and household costs that are significantly higher than the average per capita cost (and per household cost) presented in the previous section, while others would experience per capita costs that are significantly lower than the average. Figure 5-2 compares the annual per capita cost to the three systems which the model predicts to have the highest per capita cost to the average annual per capita cost of the universe of systems.

Table 5-6 provides the distribution of annualized average annual per capita and household *total* costs (for addressing wet weather and other SSOs). Table 5-5 shows that 65 percent of the population served by separate sanitary sewer systems would incur an annual per capita cost less than $25 for the five SSO per year performance level. Across all performance levels, most of the service population would incur a cost of less than $50. On a household basis, however, most of the households (except for the 5 SSOs per year performance level) would incur an annual cost of greater than $75.

Table 5-6. Distribution of Per Capita and Household Costs

Annual Per Capita Cost	Percent of Population Incurring Total Cost			
	0.2 SSO/year	0.5 SSO/year	1 SSO/year	5 SSOs/year
All Systems				
Less than $25	15.9%	19.4%	24.5%	64.8%
$25 to $50	30.8%	41.7%	52.5%	31.4%
$50 to $75	32.3%	28.7%	18.5%	2.9%
$75 to $100	15.4%	7.5%	2.9%	0.6%
Greater than $100	5.7%	2.7%	1.6%	0.2%
Annual Household Cost	**0.2 SSO/year**	**0.5 SSO/year**	**1 SSO/year**	**5 SSOs/year**
Less than $25	0%	0%	0%	0%
$25 - $50	9.5%	14.5%	17.9%	43.5%
$50 - $75	8.8%	8.8%	11.2%	29.6%
$75 - $100	9.5%	14.3%	21.8%	17.3%
Greater than $100	72.2%	62.5%	49.1%	9.6%

5.4.2 Regional Average Per Capita Wet Weather Costs

Table 5-7 presents the regional distribution of average annual per capita and per household capital costs for the five rainfall regions evaluated. The average annual per capita and per household costs are higher in the regions of the United States with the highest intensity storms–intensity being a factor that can not be consistently correlated with storm frequency. The highest per capita and per household costs occur in the South Central and Southeast Regions for all four performance levels.

In the South Central and Southeast Regions, shallower building laterals (because of shallower frostlines and the lack of basements) may also contribute to high per capita and household costs.

Table 5-7. Distribution of Annual Per Capita and Per Household Costs by Rainfall Region for Four Control Levels Modeled

Region	Average Annual Per Capita Cost/Household Cost ($)			
	0.2 SSO/year	**0.5 SSO/year**	**1 SSO/year**	**5 SSOs/year**
Southeast	119/316	105/279	94/250	63/169
Northeast/Midwest	130/346	117/314	102/270	61/164
South Central	146/391	126/336	110/291	68/181
West	75/201	72/193	64/172	32/84
Pacific Northwest	63/169	51/136	56/151	48/125

5.5 KEY FINDINGS

This section presents the key findings pertaining to cost as a function of performance levels on a national scale.

5.5.1 Costs of Controlling SSOs caused by wet weather

- **Performance Level** – Figure 5-1 and Table 5-1 illustrate that, on a national basis, the costs to control overflows during peak flows rise rapidly to achieve overflow frequencies of less than once a year. For example, national costs increase by 25 percent when trying to increase the performance level from 5 overflow events per 10-year period (0.5 overflow events per year) to 2 overflow events per 10-year period (a reduction of three overflow events in ten years). Beyond this point, costs to achieve higher performance levels rise even faster.

- **Variance in Per Capita Costs** – Some individual collection systems may currently be meeting or be close to reasonable performance objectives and would face little or no additional costs to address SSOs. However, the current performance of other systems is much poorer, and some of these systems would face annual per capita cost increases greater than $100, and annual per household costs of around $300. The annual per capita and per household cost of controlling wet weather SSOs is expected to vary significantly from system to system. However, the cost estimating model was designed to estimate national costs and the results should not be used to reach any conclusions about individual systems.

5.5.2 Treated Wet Weather Peak Flows

Allowing Treated Wet Weather Discharges – Some systems are expected to face annual per capita (and per household) costs that are significantly higher than the national average (see Figure 5-2). This points to the need to consider either different performance objectives or different control strategies for different systems.

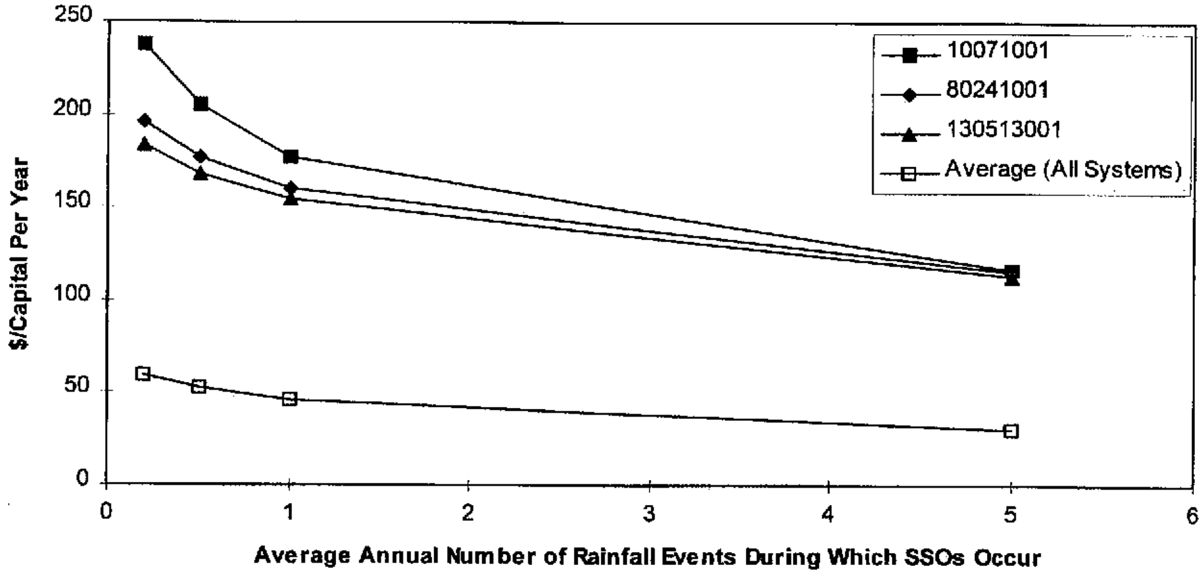

Figure 5-2. Comparison of Three Systems with Highest Per Capita Costs to Overall Per Capita Costs

5.5.3 Increased Management, Operation and Maintenance

- **Costs** – Table 5-4 indicates that the average annual costs of improving MOM of sanitary sewer collection systems appears to be relatively smaller than the average annual costs for addressing SSOs caused by wet weather.

- **Level of Improvement** – Improved MOM of sanitary sewer collection systems would decrease the occurrence of SSOs caused by blockages, pipe collapses and other problems. Even after MOM practices and procedures improve, however, some SSOs will remain. The incremental costs of reducing SSOs that remain is expected to be significantly greater than the incremental costs of initially reducing SSOs. A national SSO program can be effective in preventing recurrent overflows in basements or areas of the sewer system with a pattern or history of overflows. The program can require searches for overflow prone areas of the sewer system and associated remedial actions. By contrast, a national SSO program will not be able to effectively or efficiently address single overflow events at isolated or changing locations in the sewer system.

At this time, the national relationship between reduced SSOs and the cost of improved MOM of sanitary sewer collection systems cannot be quantified. Several current studies promise to increase the understanding of this relationship.

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Appendices

APPENDIX A

CASE STUDY SUMMARIES

APPENDIX A

CASE STUDY SUMMARIES

A.1 INTRODUCTION

A number of case studies were investigated to determine model input parameters for the cost estimating methodology. Many of the case studies did not provide sufficient information to draw conclusions. However, some of the case studies investigated provided more information, and these case studies provided the basis for some of the model input data and the decisions made regarding the parameters to model. This appendix outlines the specific information gathered from those case studies. Each case study is summarized with the following information, where applicable:

- Separate sanitary sewer population and physical description of the community characteristics.
- Percent of the system that is served by separate and combined sewers.
- Total sanitary system area.
- Total length of sewers and ranges of pipe sizes.
- Rough estimate of the age of the system.
- Frequency, volume, and location of SSOs, if available, and data related to infiltration/inflow to the system.
- Alternative system improvements recommended and their costs.
- Expected level of improvements after the recommended solution is implemented.

A.2 JEWETT CITY, CT SSO STUDY

Jewett City is a small community with a sewered population in 1994 of 3350. The sewer system is comprised of 45,000 linear feet of pipe, a significant portion of which was installed between 1900 and 1910 as a combined system. Since the mid 1960s, the system has been separated with the construction of new collection pipes. In response to a persistent overflow problem in the sewer system, an evaluation and improvement project was undertaken. The details of this project are described in a "Final Report to Water Pollution Control Authority, Borough of Jewett City, Connecticut on Evaluation and Improvements to Wastewater Collection and Treatment Facilities," which was completed in September 1994.

Overflows in the system occur at two points in the system during wet weather. One of these points is just upstream of the WWTP headworks and the other is located just upstream of a major pump station. During a temporary (4 week) flow monitoring program in 1994, 3 overflows were recorded at the WWTP headworks. It was determined that this point overflows during rainfall events of 0.2-inches or more. This would result in about 48 overflows per year at that location. It is also estimated that the pump station facility would overflow approximately 7 times per year.

An extensive SSES program and modeling of the sewer system identified specific inflow sources to target for removal. The recommended plan to eliminate SSOs includes:

- Limited sewer replacement
- Sewer grouting
- Internal spot repairs to sewers
- Manhole rehabilitation
- Construction of new drains
- Roof drain disconnection
- Construction of a holding tank for overflows at the WWTP.

The total project cost is estimated to be $2 million. Approximately 50 percent of this cost is associated with infrastructure improvements to the collection system which may not result in significant I/I reduction.

A.3 LOUISVILLE/JEFFERSON COUNTY, KY SSO STUDY SUMMARY

The total residential population of Louisville and Jefferson Counties is approximately 1.3 million with a total service area of approximately 600 square miles The study area is served by 55 wastewater treatment plants, with four of these treating the majority of the wastewater: the Moris Forman WWTP

(105.0 mgd), the West County WWTP (15 mgd), the Hite Creek WWTP (4.4 mgd), and the Jeffersontown WWTP (4.0 mgd). No other WWTP in the system has a design capacity exceeding 0.6 mgd. The total design capacity of the 55 WWTPs is 133 mgd and average daily flows are approximately 120 mgd (the Moris Forman WWTP alone treats approximately 115 mgd). The sewer system consists of both separate and combined systems. The combined areas are concentrated in the Moris Forman WWTP service area and are located in the highly urbanized areas of the system. The exact breakdown of population and area for combined and separate portions of the sewer system are not provided in the documentation available ("EPA Demonstration Grant Project Addressing the Causes and Effects of Separate Sanitary Sewer Overflows," August 1995).

Within the separate sanitary sewer system, there are approximately 8.1 million feet of pipeline and over 23,000 manholes, with sewers in the area ranging from 6-inches to 120-inches in diameter. In addition, the system has approximately 192 pump stations, many of which have designed overflows for protection of homes during power outages. The majority of the sewer pipe installed in the separate sanitary sewer system is 20-40 years old with all of it less than 60 years old.

Records show that during the period of 1989 to 1994 there have been 165 reported SSOs in the separate sanitary sewer system in 80 different locations for an annual average of 35 overflows. Approximately 70 percent of the documented SSOs are caused by rainfall induced I/I. The dry weather overflows that do occur are generally caused by power failures at pumping stations, sewer force main breaks, equipment malfunctions, clogged pipes, and human error. There are no estimates developed for the volume of overflows resulting from dry weather or wet weather causes.

Studies of overflow problems in the sewer areas are ongoing. However, some corrective actions have been instituted to reduce the number and frequency of SSOs. The total long-term capital budget plan for these corrective actions is $14.6 million. Work performed will include the removal of private I/I source connections, such as sump pumps, foundation drains, and other inappropriate connections. In addition specific I/I reduction projects have been undertaken through sewer rehabilitation and joint grouting. Finally, increased preventive maintenance has been instituted to reduce the problems from property service connection stop-ups, sewer clogs, root intrusion, and repair of pressure lines. Additional future SSO abatement projects are being investigated.

A.4 WASHINGTON SUBURBAN SANITARY COMMISSION, MD SSO STUDY SUMMARY

The Washington Suburban Sanitary Commission (WSSC) is a state charted agency providing water and wastewater service to Prince George's and Montgomery Counties, Maryland. The sewer system is completely separate and has a service population of approximately 1.4 million with 355,000 connections. The total service area for the sanitary system is over 1,000 square miles and consists of 5 treatment plants with a total treatment capacity of 180 mgd. The total length of sewer in the study area is estimated to be approximately 4,600 miles ranging from 6-inches to 102-inches in diameter. The system also contains 37 pumping stations. It is estimated that approximately 25 percent to 35 percent of this wastewater flow to the treatment plants is attributable to I/I entering the system.

The majority of the sewer system is from 10 to 40 years old. The breakdown of pipe ages in the system is: less than 5 years-8 percent, 10 years-17 percent, 20 years-20 percent, 30 years-25 percent, 40 years-14 percent, 50 years-8 percent, 60 years-4 percent, 70 years-3 percent and 80+ years-1 percent. From 1991 to 1994, facility overflows at the pumping stations and treatment plants occurred from 11 to 50 times per year prompting a detailed sanitary sewer overflow study ("Separate Sanitary Sewer Overflows: Report to the U.S. Environmental Protection Agency." April 1995). Approximately 47 percent of these overflows were during wet weather conditions and 53 percent occurred in dry weather. Approximately 16 percent of the total facility overflow events occurred at older, mechanically obsolete pumping stations that have since been decommissioned. An additional 57 percent of the overflows occurred at facilities that are currently undergoing upgrades or expansions.

During this time period, however, sewer system overflows were significantly more common than those at pumping stations and the treatment plants. From 1990 to 1994 the number of basement backups ranged from 484 to 659 per year, with a total of 2960 for the 5-year period. Of these, only 5 percent occurred during wet weather, and the remaining 95 percent occurred during dry weather. Manhole overflows occurred 1077 times with only 1.3 percent due to wet weather and the balance occurring in dry weather. Generally , the dry weather overflows are attributable to root intrusion (14 percent), grease blockages (3 percent), poor pipe alignment (33 percent), structural defects (4 percent), or lateral service problems (8 percent). 38 percent of the time no significant problem, beyond the removal of a temporary blockage, was found upon detailed system inspection.

As a result of the SSO studies, system upgrades have recently been implemented. These costs are outlined below:

■ Capital Projects	
- Upgrades at pumping stations and WWTPs	$38 Million
- Collection system improvements	$22 Million
■ Annual Expenditures	
- Sewer reconstruction	$6 Million
- Maintenance program	$10 Million

The general conclusions of the SSO study are that since a large majority of the overflows in the system occur during dry weather, regular system maintenance should be increased. Therefore, a combination of aggressive maintenance and timely facility planning are seen as the most effective solution to the overflow problems.

A.5 DANVERS/BEVERLY, MA SSO STUDY SUMMARY

The South Essex Sewerage District (SESD) provides service for the communities of Danvers and Beverly, MA with a total 1974 sewered population of approximately 60,000 and a projected 2020 population of 103,000. The collection system, which is completely separate, consisted of approximately 170 miles of sewers, including gravity interceptors, numerous river crossings, and two major pump stations. The estimated pipe length in 1995 is 200 miles. The total interceptor system was built in the late 1920s. Due to rapid post-World War II growth in the service area, the interceptor system became overloaded by about 1960. This overloading led to overflow problems which were addressed through an interceptor relief project described in "South Essex Sewerage District - Facility Plan, Phase III Construction Program, Danvers-Beverly Relief Interceptor," February 1976.

SSOs occurred at three locations during peak wet weather events. Records for two of these overflows indicates that from 1971 to 1974 from zero to 17 overflows occurred at each location annually. These were typically rainfall dependent and increased in frequency during years of especially heavy rainfall. The elimination of SSOs was achieved by the construction of the SESD Danvers/Beverly Relief Interceptor from 1975 to 1995. In addition, I/I reduction is ongoing and designed to eliminate overflows from one of the problem locations in the sewer system. The costs for the sewer construction and I/I reduction are listed below:

Relief Interceptor Construction	$7.6 million
Pump Station Modifications	$3.2 million
Beverly Harbor Force Main	$4.5 million
Beverly Sewer Tunnel	$6.8 million
Water Street Interceptor	$2.7 million
Sec II Force Main-Land	$1.0 million
Sec II Force Main-Subaqueous	$6.3 million
Beverly I/I Reduction	$3.1 million
Total:	$35.2 million

A.6 LYNN, MA SSO STUDY SUMMARY

The City of Lynn's WW collection system serves about 80,000 people with a total service area of approximately 6000 acres. The collection system consists of approximately 141 miles of sewer pipe of which approximately 47 percent of the system is combined with four CSO locations. The sewer system has been developed over a long period of time with various materials of construction. The first sewers were constructed in 1866 (2 miles). Approximately 30 miles of large sewers were constructed from 1880-1900, and the remaining 109 miles of sewers were installed from 1900-1995. These pipes were constructed of varying materials with the following proportions: brick sewers (8.5 percent), V.C. (tile) sewers (85 percent), reinforced concrete sewers (5.5 percent), and PVC and other (1 percent).

A detailed SSO investigation and study has not been performed on this sewer system. However, a CSO Facilities Plan on this system has been prepared ("Combined Sewer Overflow Facilities Plan." Prepared for Lynn County Water and Sewer Commission. 1988 and 1989). It is estimated that the four Lynn CSO's discharge about 400-600 MG of mixed wastewater and stormwater each year. In general, during wet weather flows, the combined sewers surcharge due to capacity limitations. This surcharging causes street flooding and basement flooding and house service backups in many low-lying locations of the sewer system. These flooding and backup locations are considered to be SSO's which are caused by rainfall-induced I/I. Many sump pumps have been installed to prevent or reduce the frequency of basements flooding SSO's. The Lynn Water and Sewer Commission (LWSC) has performed some sewer rehabilitation projects, sewer separation projects and various sewer maintenance projects which have resulted in reductions in the number of SSO's and the frequencies of remaining SSO's, including:

5 SSO's eliminated:	3 were due to badly cracked pipe and flow blockage, 2 were due to damaged manhole structures and leakage during high levels of RDI/I flows.
10 SSO's reduced:	7 due to leaky pipe joints and manhole structures during high levels of RDI/I flows, 3 due to roots in pipe joints, large debris in some sewer sections, leaky pipe joints and cracks and leaky manhole structures.

These projects are currently on-going. The costs for the sewer rehabilitation, for which data is available (Contract 1), break down as follows:

REHABILITATION METHOD	TOTAL QUANTITY	TOTAL COST
Trenchless Construction		
Sewers - Cured-in-Place Pipe Lining	11,201 LF	$2,069,519.00
Sewers - Chemical Sealing or Grouting	14,024 LF	$ 173,773.00
Sewer Manholes - Chemical Sealing or Grouting	10 MH	$ 12,000.00
Sewer Manholes - Cured-in-Place Lining	24 MH	$ 72,000.00
Sewer Manholes - Monolithic Surfacing System	18 MH	$ 63,000.00
Subtotal:		$2,390,292.00
Conventional Excavation Construction		
Sewers - Removal and Replacement	620 LF	$106,000.00
Sewers - Spot Repairs	287 LF	$ 94,500.00
Subtotal.		$200,500.00
Grand Total:		$2,590,792.00

A.7 WAYNE COUNTY, MI SSO STUDY SUMMARY

The population served by the Wayne County sewer system totals 310,000 in thirteen communities, including Allen Park, Belleville, Brownstone Township, Dearborn Heights, Ecorse, Lincoln Park, River Rouge, Riverview, Romulus, Southgate, Taylor, Van Buren Township, and Wyandotte. Sixteen percent (8130 acres) of the total 49,918 acres (6.2 people/acre) service area is served by combined sewers. The remainder is served by separate sanitary sewers. The only WWTP serving the system is the Wyandotte WWTP. The WWTP is located adjacent to the Drainage District #5 CSO Retention Treatment Basin, intended to serve only CSO flows from the adjacent cities of Wyandotte and Southgate. Regulated flows from this facility discharge to the Wyandotte WWTP. Currently, flows conveyed to the WWTP that are in excess of the WWTP 100 mgd capacity are routed to this facility, in violation of State regulations.

The County maintained interceptor sewer is about 45 miles in length ranging from 32 inches to 72 inches in diameter. The community sewers were evaluated by the community engineers as part of an I/I and SSES evaluations, and measure approximately 300-400 miles. The majority of the interceptor system was constructed in 1964. Approximately 15 percent of the community collection systems were built prior to 1940, 35 percent built prior to 1964, and the remainder was constructed mostly in the 1960's and 1970's. Almost the entire interceptor system was constructed of reinforced concrete pipe (RCP), although a few sections were built of brick. The community sewers used RCP for diameters greater than or equal to thirty inches. A great deal of the smaller community sewers used vitrified clay pipe (VCP), and is still being used in new construction. Approximately 10 percent of the community sewers (i.e., newer sewers) use plastic pipe. Currently the communities are rehabilitating their sewers through in-situ-forming or joint grouting.

The existing system experiences SSOs on the order of 25 to 35 times per year. These are entirely due to excessive rainfall induced I/I. These SSOs occur either at pumping stations or when flows are discharged to an adjacent CSO retention treatment facility. Currently a 1-inch storm (4-6 hours in duration) or 1 to 1.5-inch over 24 hours will cause an overflow at some pump stations.

The abatement plan for Wayne County includes expansion of the WWTP (from 100 to 146 MGD), some relief facilities (4 miles), local community rehabilitation programs, construction of a tunnel facility (≈30 MG storage), construction of an off-line basin, and an emergency discharge outfall. The design criteria for the upgraded system is to capture the 3-inch 24-hour design storm (about a 15-year event). This will fill the tunnel storage once every 5 years, but the combined effluent from the tunnel and the WWTP will meet the WWTP discharge limits. The costs are as follows:

WWTP expansion	$36.1 mil
Relief Sewer	$ 9.9 mil
Wayne Co. Rehab	$ 0.3 mil
Local Rehab	$58.6 mil
Tunnel	$95.5 mil
Tunnel PS	$ 7.2 mil
Offline Basin	$ 3.1 mil
Emergency Outfall	$19.5 mil
Total	$230.2 mil

None of these costs are in anticipation of future growth, since there is a net projected decrease in the future service population Once this system is in place, it is expected that the annual SSO volume will decrease from 495 MG down to 5 MG. The expected frequency will be on the order of once every five years (i.e., an average episode of 25 MG). It should be noted that this performance is due in large part to the conveyance of these flows to the WWTP where flows in excess of 146 MGD will be mixed with WWTP effluent and will still meet the discharge concentration requirements.

A.8 ST. PAUL, MN SSO STUDY SUMMARY

The Metropolitan Waste Control Commission (MWCC) provides wastewater conveyance and treatment services to 2 million people in 105 communities in the Minneapolis/St. Paul area. This system consists of 11 treatment plants, which combined receive a total dry weather flow of approximately 260 mgd and have peak ratios ranging from 1.29 to 2.50. The entire system consists of separate sewer and storm water collection pipes. The sewer system consists of 510 miles of interceptor sewers, 61 lift stations, and 175 meter stations.

I/I studies conducted for the system ("Systemwide Infiltration/Inflow Evaluation Phase II Report - Volumes 1 and 2," 1992) have shown that, although there are not currently major overflow problems, the approximately 360,000 feet of interceptors would have insufficient capacity to handle wet weather flows for the 2010 development conditions. In addition, 29 lift stations would not meet the requirements under these conditions. No estimates are provided for the volume of overflows anticipated under no action conditions. The recommended plan for the sewer system consists of implementing programs to encourage communities to reduce I/I. The following incentive and disincentive programs are recommended: providing technical assistance and public information, setting I/I reduction goals, charging I/I dependent surcharges, developing peak sensitive rates, and instituting separate I/I charges. Specific recommendations for each community to remove I/I were not included in the program.

A.9 CHARLOTTE, NC SSO STUDY SUMMARY

Three linked WWTP's in the Charlotte, NC area serve a population of approximately 450,000. Irwin Creek WWTP has a tributary area of 37 square miles and has a treatment capacity of 15 MGD. Sugar Creek WWTP has a tributary area of 42 square miles and a treatment capacity of 14.67 MGD. An upgrade to the Sugar Creek plant is currently under construction and will increase plant capacity to 20 MGD. Furthermore, a 20 MG flow equalization facility is scheduled for construction completion in 1997.

McAlpine Creek WWTP has a tributary area of 161 square miles and also treats flows bypassed from the two other WWTP's. An expansion and upgrade of the plant is currently under construction, and will increase the plant capacity from 40 to 48 MGD. Construction of a new 44 MG flow equalization facility was completed in the winter of 1994 and is now in operation.

There are no combined sewers in the collection system, and the total sewered area is approximately 240 square miles. There are approximately 1700 miles of sewer in this system, with approximately 150 miles of trunk sewer over 12-inches in diameter. The collection system construction materials and age are distributed as follows:

Pre-1960	13 percent	VCP with "yarn" and cement joints.
1960-1971	16 percent	VCP with tar joints
1972-1984	41 percent	VCP with bell and spigot joints with rubber gaskets (small diameter), RCP (large diameter)
Past 1984	30 percent	PVC (small), pipe trench and backfill control improved and precast manhole construction required (previously brick). Added a subdivision sewer construction inspector.

Approximately 15-20 SSOs occur yearly due to rainfall induced I/I. These SSOs typically occur at sewer manholes, and are more prevalent in the winter and early spring because of high groundwater table elevations. The recommended sewer facility plan for this system ("Sanitary Sewer Facility Plan for the McAlpine Creek, Sugar Creek, and Irwin Creek WWTP Service Areas", May 1995) includes a combination of relief sewers, flow equalization storage, and sewer rehabilitation as a means of eliminating wet-weather overflows The recommended improvements are aimed at providing sufficient sewer system capacity to handle increased flows from future growth and to eliminate trunk sewer overflow from wet-weather flows caused by rainfall induced I/I. Recommended improvements are designed to convey flows for a 2-year storm event in combination with predicted dry-weather flows for the year 2025 with no overflows. The projected costs for the rehabilitation are:

APPROACH	**QUANTITY**	**COST**
PHASE 1 - complete by year 2000 - corrects major existing wet-weather problems		
Relief Sewer (18-48 in)	52,300 LF	$9.71 million
Irwin Creek Flow Equalization Storage and Pump Upgrades	15 MG Storage	$5.05 million

PHASE II - complete by year 2005 - constructs facilities needed to handle 2-year event

Relief Sewer (18 - 78 in)	139,700 LF	$32.11 million

PHASE III - complete by year 2015 - construct facilities to eliminate overflows 2-year storm

Relief Sewer (18 - 30 in)	47,200 LF	$7.11 million
Flow Equalization Storage U/S of McAlpine Creek WWTP	2.2 MG in system	$3.95 million

PHASE IV - complete by year 2025 - construct additional facilities to handle 2025 flows.

Relief Sewer (18 - 36 in)	20,300 LF	$4.51 million
	Grand Total:	$62.44 million

Throughout the implementation of this plan, ongoing SSES and system rehabilitation at a cost of $3-4 million annually (i.e., 34 miles of sewer evaluated annually) will be performed. The goal of this SSES is to reduce the number of overflows due to the 10-year return period storm event (along with facilities constructed above) by the year 2025. The long-term goal of facility improvements and rehabilitation is to control the 10-year return period storm with no overflows during wet-weather. Furthermore, the system will have capacity to handle increased growth in this portion of Charlotte, NC, through the year 2025.

A.10 CINCINNATI, OHIO SSO STUDY SUMMARY

The residential population in the Cincinnati area in 1990 was 48,000, while the employment population totaled 25,000. The area is served by two WWTP's. The Sycamore WWTP (constructed in 1957) with a current sustained treatment capacity of 6 MGD receives an average daily flow of 5 MGD. The plant has the capacity to treat up to 10 MGD of flow for short periods. The Polk Run WWTP (constructed in 1989) has a current sustained treatment capacity of 6 MGD, and currently receives an average daily flow of 2.2 MGD. This facility is capable of treating up to 12 MGD for short periods.

There are no combined sewers in the study area. However, only 54 percent of the total area is served by sanitary sewers, with the remainder served by either septic systems or a small neighborhood package plant (14,000 gpd), or is undeveloped. The total area of the drainage basin is 36 square miles, 75 percent of which is currently developed. The sewered area is approximately 19.4 square miles and has a total sewer length of approximately 123 miles. Pipe sizes in the system range from 8- to 42- inches in diameter. The majority of the existing sewer system was constructed starting in the mid-1950's. Few areas have reported basement flooding and surcharging lines. Some problems with overloaded sewers, however, exists and is due to the lack of system upgrades following population expansion. High rainfall induced I/I loads observed at the Sycamore WWTP are believed to be the result of poor construction in the system tributary to this plant.

No estimate of the frequency or volume of SSOs I available. However, SSOs appear to be quite frequent ("Sycamore/Polk Run Facility Needs Report", April, 1991. One part of nine studies of various subareas as part of the Stormwater/Wastewater Integrated Management Plan (SWIM) being developed for the City of Cincinnati and Hamilton County). A flow monitoring program was undertaken and it was found that the percent of rainfall entering the system varied from 1.2 to 15 percent.

Alternatives for system improvements to accommodate and reduce SSOs have been developed. The following program is projected to eliminate overflows within 25 years:

Sanitary Sewer Rehabilitation and Main Replacement	$10 million
15-20 MG of flow equalization storage at Sycamore WWTP	$20 million
3.5 MG of flow equalization storage at Polk Run WWTP	$5.3 million
Ongoing SSES to locate sources of RDI/I =$300,000/year	$3.2 million(PW)
Total:	$38.5 million

A.11 GREENVILLE, SC SSO STUDY SUMMARY

The sewer system in Greenville serves a total population of 150,000 and discharges to the Mauldin Road WWTP The plant's permitted weekly average flow and maximum sustained treatment rate (1 week) is currently 29 mgd (while meeting all NPDES requirements). The plant's peak treatment rate is 40 mgd for 1-2 days. There are no combined sewers in the system and cross-connections are not generally a noticeable problem. The total sewered area is approximately 40.5 square miles (total area of 50 square miles).

The total system includes seven sewer subdistricts that own and operate small diameter collection systems (8 inches). The total length of the Authority's trunk sewers is 74 miles. The subdistricts own and operate approximately 569 miles of sanitary sewer. Approximately 60 percent of the Authority's trunk sewer was constructed in 1954, while 40 percent was constructed in 1929 (these are parallel lines). Trunk sewers constructed in 1929 were constructed of VCP, while those constructed in 1954 were made of RCP. The subdistrict owned collection system is constructed of mainly VCP with some PVC while ages of the subdistrict owned collection system are distributed as follows: 19 years old - 2 percent, 27 years old - 16 percent, 34 years old - 9 percent, 37 years old - 35.5 percent, and 64 years old - 2 percent.

Ten to fifteen SSO's due to wet weather occur annually, with a total annual SSO volume of approximately 100 MG. Overflows are more prevalent in the winter and spring because of higher ground water elevations. A detailed study of the system developed a series of recommendations for reducing these overflows ("Mauldin Road Line System Wet Weather Engineering Study", January 21, 1993). The final design will reduce the number of overflow events to zero every 2 years - that is, the 2-year design storm event will not produce any SSOs. The recommended approach, which only considers capacity for rainfall induced I/I flows, includes abandoning the 1929 vintage sewer main and replacing it with a new line ($41 million). This increased system capacity requires additional pumping capacity at the plant and the expansion of existing flow equalization storage ($12 million). Furthermore, the Authority was able to secure a permit allowing the discharge of excess flow equalization storage directly to the river with the WWTP effluent when the river stage was sufficiently high to provide appropriate dilution. After completion of these projects the Authority has been directed to do further flow analysis to determine if more new mains need to be constructed ($18 million, if needed). It was also recommended that the subdistricts perform remediation on their collection systems with a target of removing 10 to 15 percent of their rainfall induced I/I ($20 million).

A.12 FORT WORTH, TX SSO STUDY SUMMARY

A recent SSO study was performed for a portion of the Fort Worth sewer system known to suffer from overflows due to blockages and high levels of I/I ("Sanitary Sewer Main 161 and 221 Drainage Areas Inflow/Infiltration Evaluation Study", February, 1995, DRAFT REPORT). The estimated population of the study area is 2,757 and has an area of 1070 acres. It is served by separate sewers constructed primarily of vitrified clay and concrete with some PVC and ductile iron.. Flows are directed to the Village Creek WWTP, which receives an average daily flow of approximately 115 MGD with a sustained treatment capacity of 144 MGD (wet weather treatment capacity of 29 MGD). The plant has no equalization storage available for wet-weather storage.

The purpose of the study was to find the least-cost alternative to minimize the frequency of SSOs in a portion of the system particularly susceptible to this problem. Examination of city records found that 83 maintenance requests were made for this region from 1987-1983 due to structural failures, vandalism, or overflows. The area contains 66,000 LF of sewer ranging from 6- to 12-inches in diameter. Meanwhile, the entire Village Creek WWTP collection system contains approximately 2100 miles of sewer. The portion of the collection system investigated overflows on the order of ten times per year as a result of rainfall induced I/I. These overflows occur primarily at manholes and basements.
The recommended solution to remove overflows in this region of the system was to replace over 10,000 LF of sewer due to structural defects and perform rehabilitation in the public right of way lines at a total cost of $630,800 (approximately $100,000 of which is for rehab).

A.13 GALVESTON, TX SSO STUDY SUMMARY

The permanent population in Galveston is approximately 50,000 residents. Tourist population can increase island population up to 250,000 during summer weekends and major events. The City of Galveston does not operate any combined sewers. The approximate service area is 9,200 acres (14.37 square miles), with a sewered area of approximately 6,950 acres (10.15 square miles). The total length of the collection system is approximately 176 miles. The majority of the system in the study area is 50+ years old, and pipe material is mostly vitrified clay or concrete (reinforced and unreinforced).

The city suffers from sewer overflow problems that prompted a flow monitoring program and city overflow investigations. During the flow monitoring phase of the project several cross connections were documented and city personnel reported numerous additional connections. Physical inspection of the system is currently underway, which will help to verify the number and locations of cross connections. The city overflow reports indicate that all the reported overflows for the last year were caused by blockages. Also, continuing efforts to document overflows have not shown any during rain events.

A.14 HOUSTON, TX SSO STUDY SUMMARY

The total service population for the Houston Sewer System is 1.7 million with approximately 100 significant industrial users. The sewer area is completely separate and served by 44 separate WWTPs with a total average daily wastewater flow of 250 mgd. The system has a permitted average daily flow of 550 mgd and a peak wet weather capacity of 1525 mgd (full secondary treatment). In general, wet weather flows range from 6 to 20 times the volume of dry weather flows during large rainfall events. However, less than 0.5 percent of annual flow to the WWTPs is associated with I/I.

The total drainage area of the system is 598 square miles, and the total length of sewers in the system is 5,600 miles ranging from 6-inches to 144-inches in diameter. The system contains 320 pumping stations and approximately 80,000 manholes. The sewer system consists mainly of 6 to 8-inch pipes (approximately 70 percent) with unreinforced concrete being the dominant pipe material. Expansive soils are widely present and surface faults provide difficulties in sewer design and contribute to excessive infiltration. The primary system problems are associated deteriorating pipes and defective house laterals. The distribution of system defects is:

36 percent	house laterals
27 percent	main lines
19 percent	manholes
15 percent	lateral sewers
3 percent	illegal connections.

There are no reported dry weather overflows in the city system. However, prior to the implementation of a sewer system rehabilitation and upgrade program, wet weather SSOs occurred at over 224 constructed overflow locations and throughout the system. Overflows occurred approximately 20 to 30 times per year. This precipitated the investigation of overflow problems and development of an abatement plan ("Preliminary Study for the Elimination of Overflows in the Sims Bayou Service Area," 1991; "Analysis of SSO Effects on Surface Water Quality - Volumes I, II, and III," 1994; and associated program updates).

A comprehensive sewer upgrade, rehabilitation, and improvement program is ongoing in the City of Houston at a total cost of $1.2 billion. This program is scheduled for completion in December 1997. The program consists of the following system changes.

- constructing storm water clarifiers

- constructing and rehabilitating lift stations
- construction relief sewers
- sewer rehabilitation
- extensive flow monitoring
- expanded WWTP capacity.

Once the system upgrades are in place, all dry weather SSOs will be eliminated, all SSOs will be eliminated for storms up to the 2-year storm, wet weather facilities will be in place to store dilute sewage for discharge to the WWTPs. Wet weather facilities will be used up to 15 to 20 times per year and will discharge treated effluent up to 4 times per year.

APPENDIX B

ESTIMATE OF THE REPLACEMENT VALUE OF SEWAGE COLLECTION SYSTEMS IN THE UNITED STATES

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ESTIMATE OF THE REPLACEMENT VALUE OF SEWAGE COLLECTION SYSTEMS IN THE UNITED STATES

In this appendix, the replacement value of sewage collection systems is estimated. This estimate is a gross estimate of the national replacement value using the best professional judgement of the design engineering firm of Metcalf and Eddy and readily available literature.

B.1 METHODOLOGY

The general approach was to estimate the replacement cost of each component of a sewage collection system by determining a low and a high estimate of unit values (e.g., dollar per foot replaced) for sewage collection system components and escalating these values to derive a national estimate.

Sewage Collection Systems

A sewage collection system was first defined to consist of the following components:

1. Sewage collection pipes
2. Pumping stations
3. Building connections

The unit costs for each of these components were then estimated as follows.

Sewage Collection Pipes

Sewered Population

The 1992 USEPA Needs Survey report estimates that the sewered population in the United States consists of 181 million individuals. However, there are residential and commercial properties that have sewage collection systems available but have not been reconnected Typically, these buildings were built before the system was available. Some homeowners may have adequate on-site disposal systems and elect not to connect to the sewer. Some communities do not require immediate connection, or only require connection with property transfer. Accordingly, the number of potential users who have sewers available but are not currently connected is estimated at about ten percent of the 181 million connected population. Therefore, in order to calculate total length of sewers in the entire U.S., a population of 200 million was used.[1]

Sewer Length Per Capita

The sewer length per capita multiplied by the sewered population is the total length of sewers in the United States. Data reported in the 1985 EPA Needs Survey tended to differ considerably from case studies. Table B-1 presents the estimates from two sources on sewer length per capita.

According to Table B-1, the EPA Needs data shows a trend of declining length per capita with increasing population to a low value of 2 feet per capita. Other sources indicated that the length per capita reported in the EPA Needs Data may be too low.[2] Based on the use of available data and the case studies, a value of 18 ft/capita was used.[3]

Cost Per Foot of Replacement

The cost per foot for replacing sewers was estimated to be $200 and $500 representing high and low estimates, respectively.[4]

Pumping Stations

Pumping stations are used in sanitary collection systems to overcome unfavorable gradients. Topography and the size of the service area play an important role on the extent of pumping systems in a sewage collection system. A rough estimate of the replacement value of pumping stations is 10 percent of the value of sewer pipelines in any community.[5]

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[1] Best Professional Judgement, Metcalf and Eddy May 23, 1996 Memorandum to U.S. EPA.

[2] The Water Encyclopedia, Second Edition 1990. Lewis Publishers.

[3] Best Professional Judgement, Metcalf and Eddy. May 23, 1996 Memorandum to U.S. EPA.

[4] Ibid.

[5] Ibid

Table B-1

ESTIMATES OF SEWER LENGTH PER CAPITA BASED ON 1985 EPA NEEDS SURVEY AND OTHER SOURCES

	Population (thousands)	Length (miles)	Feet/Capita
EPA 1985 NEEDS SURVEY DATABASE	0.5	0.8	8
	1	1.1	6
	10	5.7	3
	50	19	2
	100	38	2
INDIVIDUAL CASE STUDIES			
Central Contra Costa Sanitary District	398	1,500	20
East Bay MUD	572	1,800	17
Fairfield, Ohio	40.2	150	20
Fredericksburg, VA	22.5	75.8	18
WSSC	1,500	4,600	16
Cincinnati, OH	580	2,200	20
3 Cities in Kansas	111.5	285	13.5
	130	600	24
	285	1,500	28
Elmhurst, IL	44	145.8	17.5
OTHER SOURCE			
The Water Encyclopedia	178,000	706,992	21.7

Sources Metcalf and Eddy May 23, 1996 Memorandum to U S. EPA and The Water Encyclopedia, Second Edition 1990

Building Laterals

A sewage collection system also consists of pipes that connect residences and commercial establishments to a service area's public sewer system. While the value of these connections are generally not considered in estimating the value of wastewater collection and treatment systems in general, they can collectively comprise a significant portion of a system's total value. The cost of replacing building laterals was estimated to be $160 and $240 billion for the low and high-end, respectively.[6]

B.2 RESULTS

Using the assumptions and methods described above, the total replacement cost for sewers was estimated. For pipes, the replacement costs represent the sewered population multiplied by the length of sewer per capita and $200 and $500 for the low and high estimates, respectively. The replacement costs for pumping stations were calculated by taking 10 percent of the low and the high values for pipes. Finally, replacement costs for building laterals were estimated to be $160 and $240 billion for the low and high-end, respectively.

Table B-2 presents the total estimated value, which ranges from a low estimate of $950 billion to a high of $2,200 billion. In the low-end estimate, 75.8 percent or $720 billion of the total value is represented by sewage collection pipes. In the high-end estimate, 81.8 percent or $1,800 billion of the total value is represented by sewage collection pipes.

Table B-2
ESTIMATE OF TOTAL VALUE OF SEWAGE COLLECTION SYSTEMS IN THE UNITED STATES

Component	**Low Estimate ($ Billion)**	**High Estimate ($ Billion)**
Sewers	720	1,800
Building laterals	160	240
Pump Stations (10% of Sewers)	72	180
Totals	**950**	**2,300**

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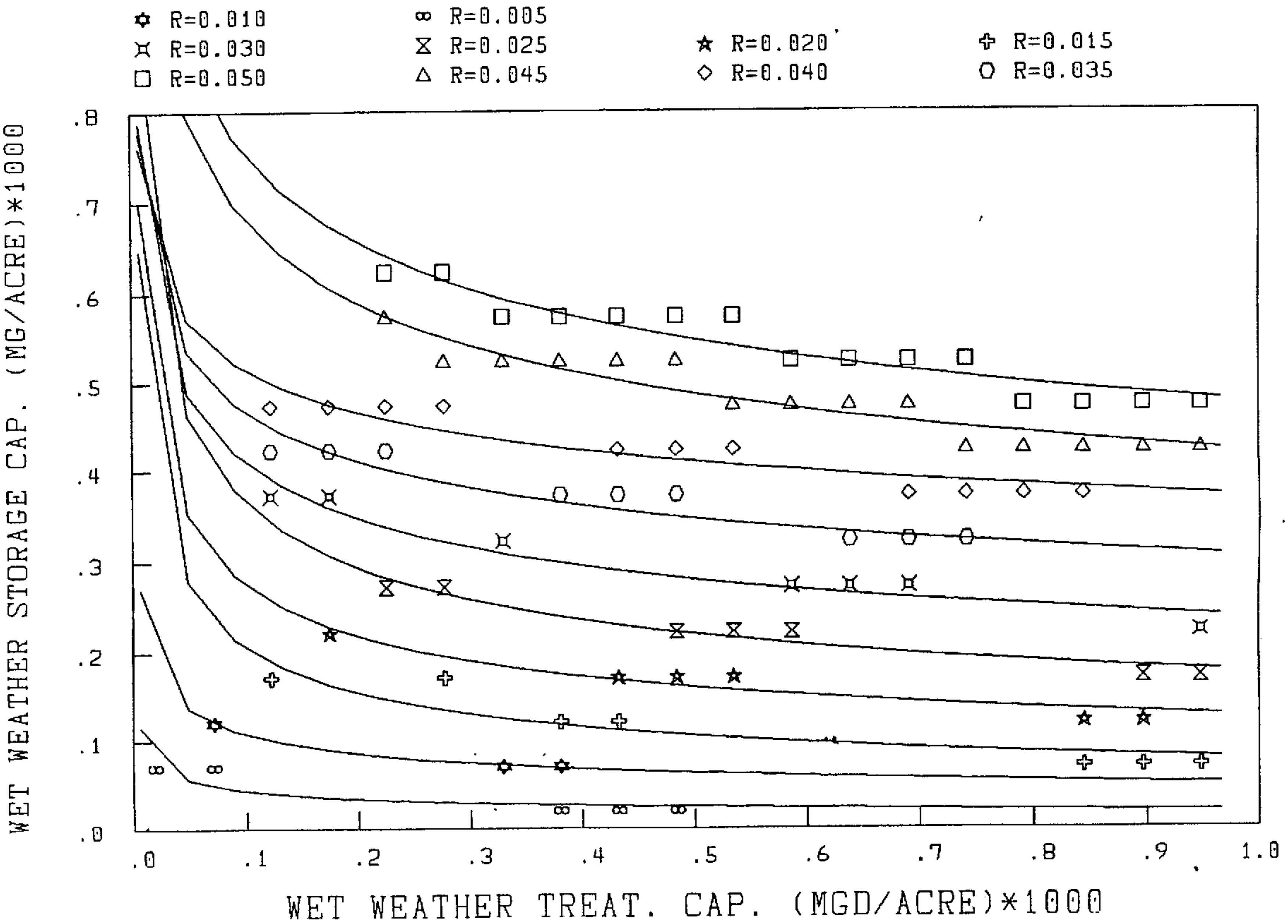
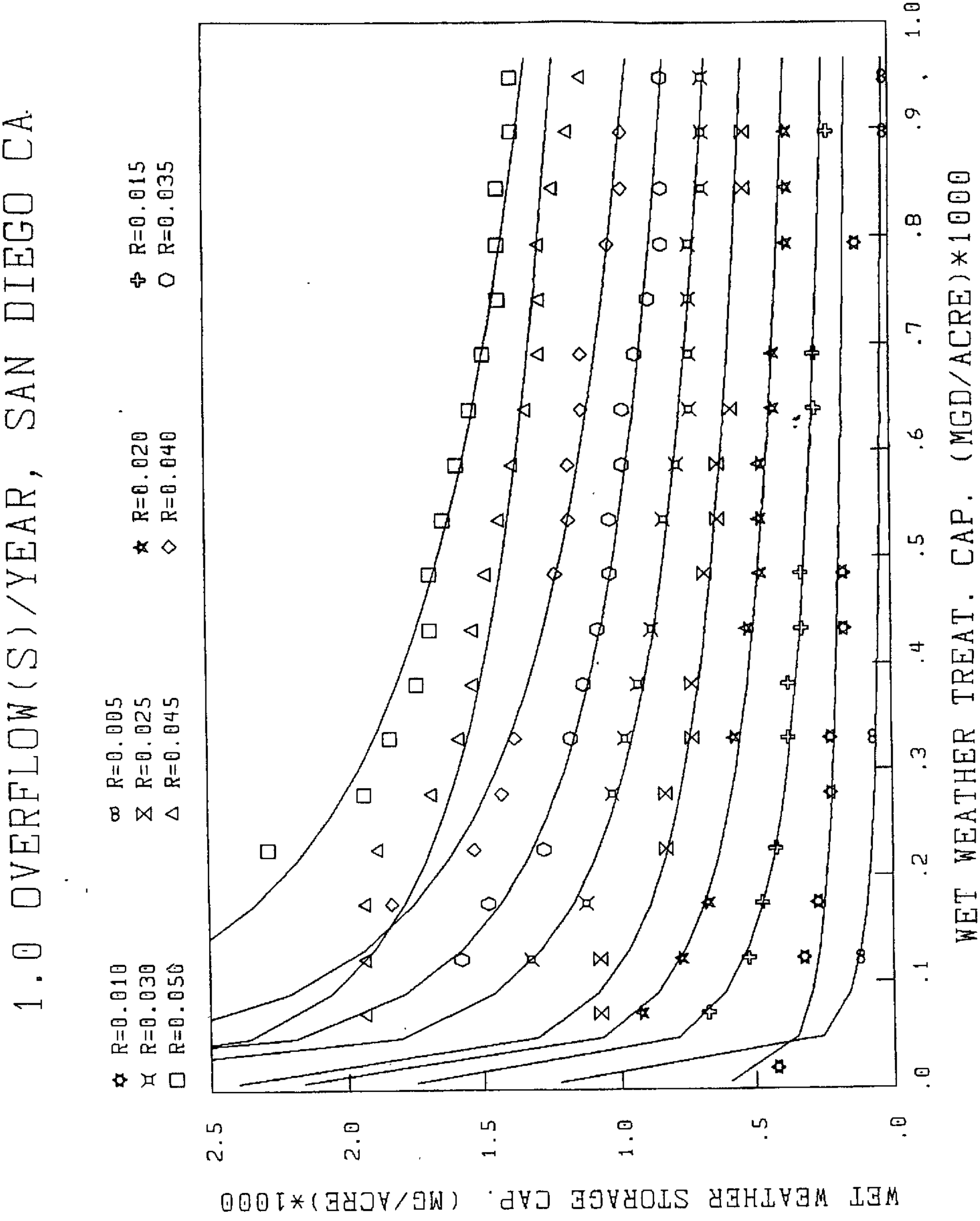
[6] Ibid

APPENDIX C

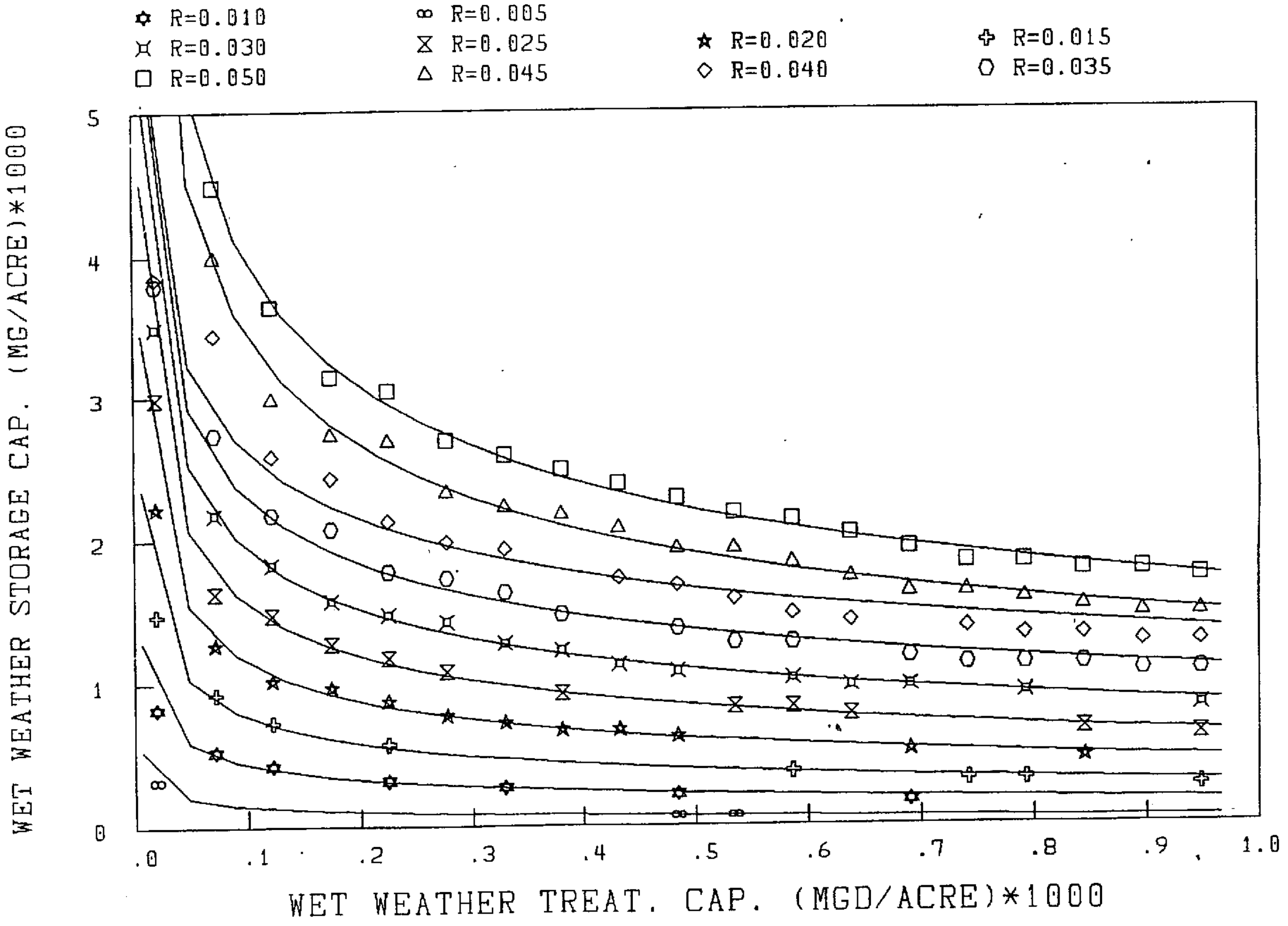
PLOTS OF R-VALUE, TREATMENT, AND STORAGE RELATIONSHIPS TO ACHIEVE N OVERFLOWS PER YEAR

5.0 OVERFLOW(S)/YEAR, SAN DIEGO CA

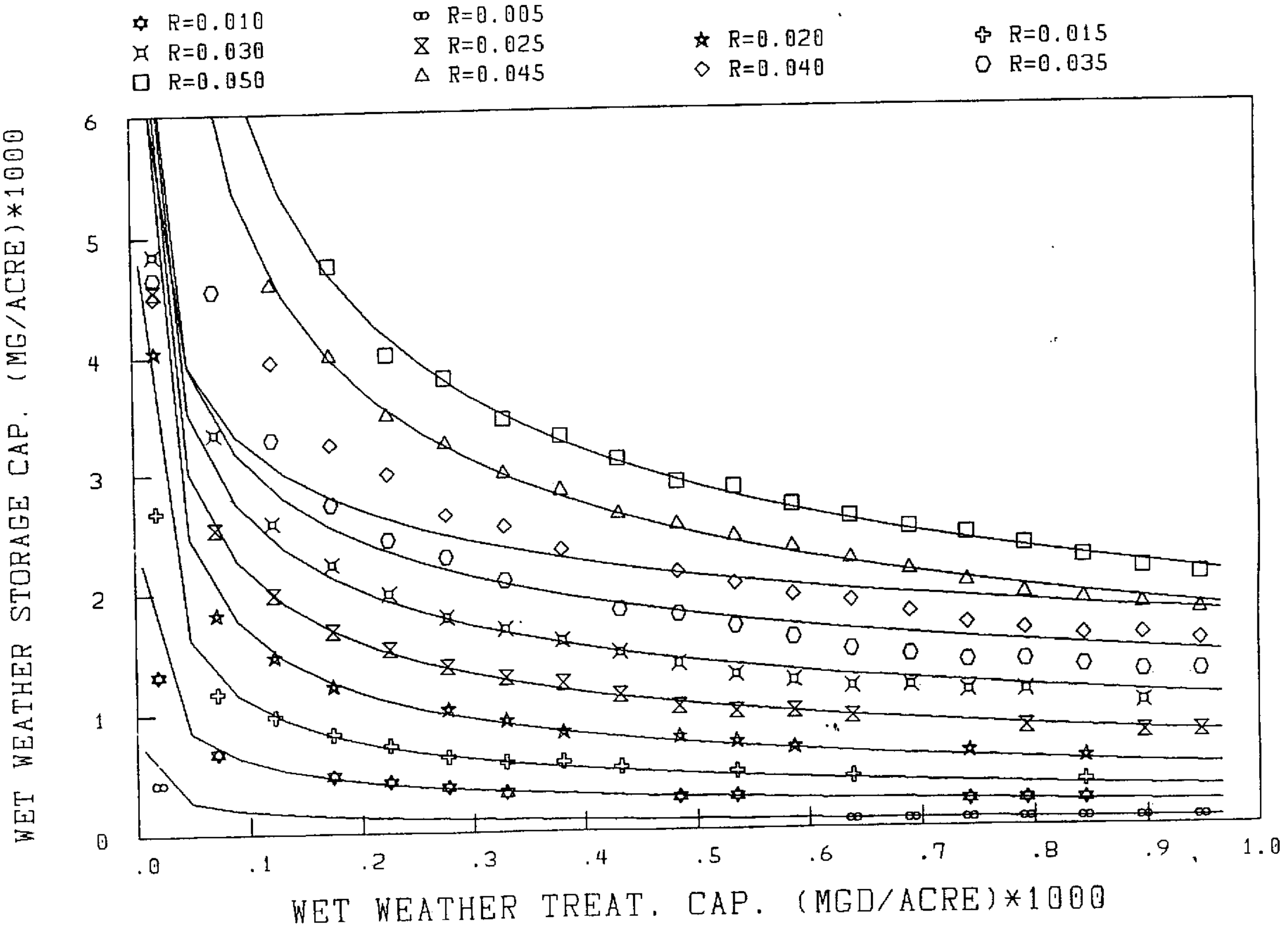



1.0 OVERFLOW(S)/YEAR, SAN DIEGO CA
✡ R=0.010
ϖ R=0.005
✶ R=0.020
✢ R=0.015
⌑ R=0.030
⊠ R=0.025
◇ R=0.040
○ R=0.035
□ R=0.050
△ R=0.045
WET WEATHER STORAGE CAP. (MG/ACRE)*1000
.0
.5
1.0
1.5
2.0
2.5
WET WEATHER TREAT. CAP. (MGD/ACRE)*1000
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

0.5 OVERFLOW(S)/YEAR, SAN DIEGO CA



0.2 OVERFLOW(S)/YEAR, SAN DIEGO CA



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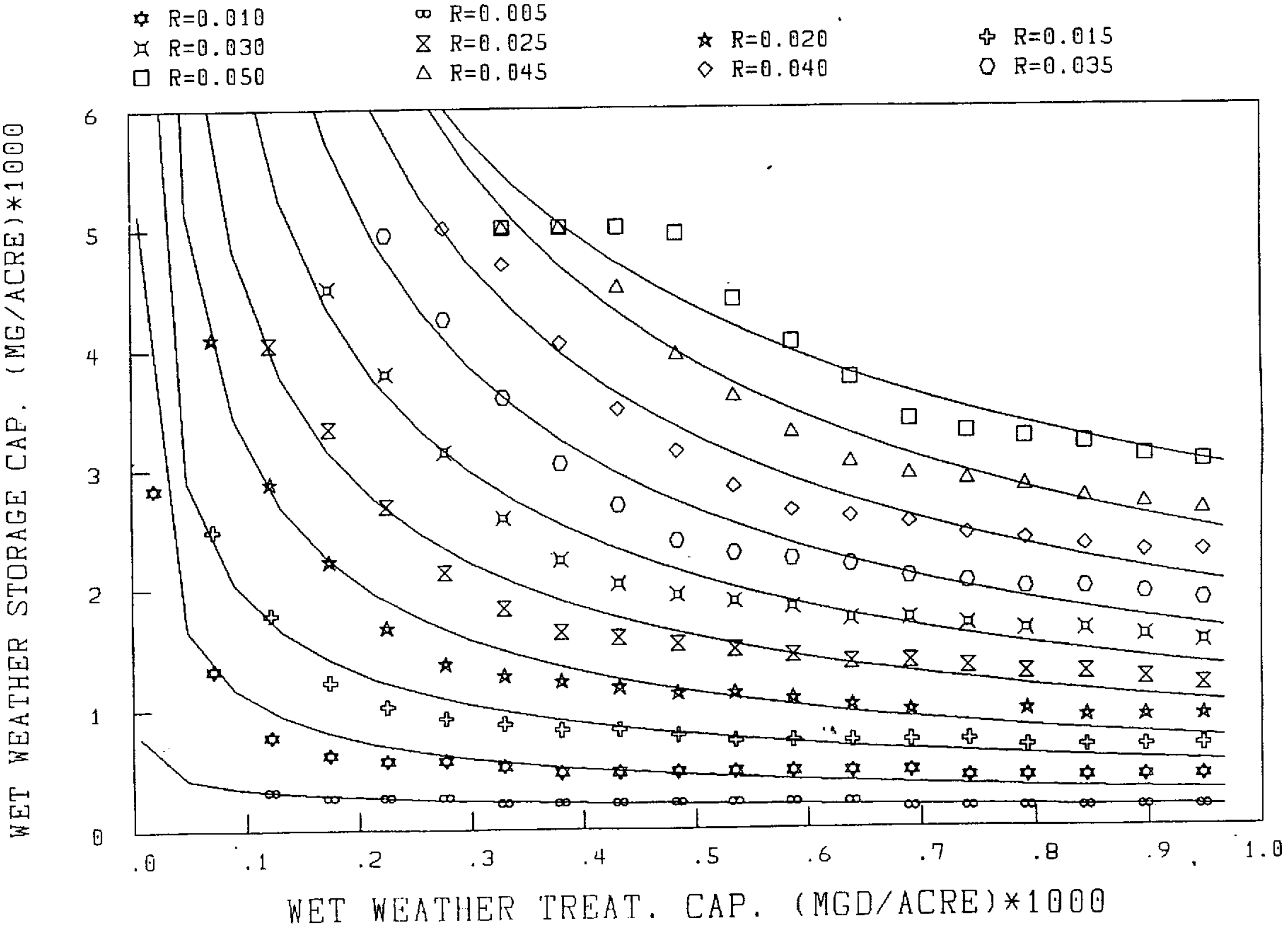
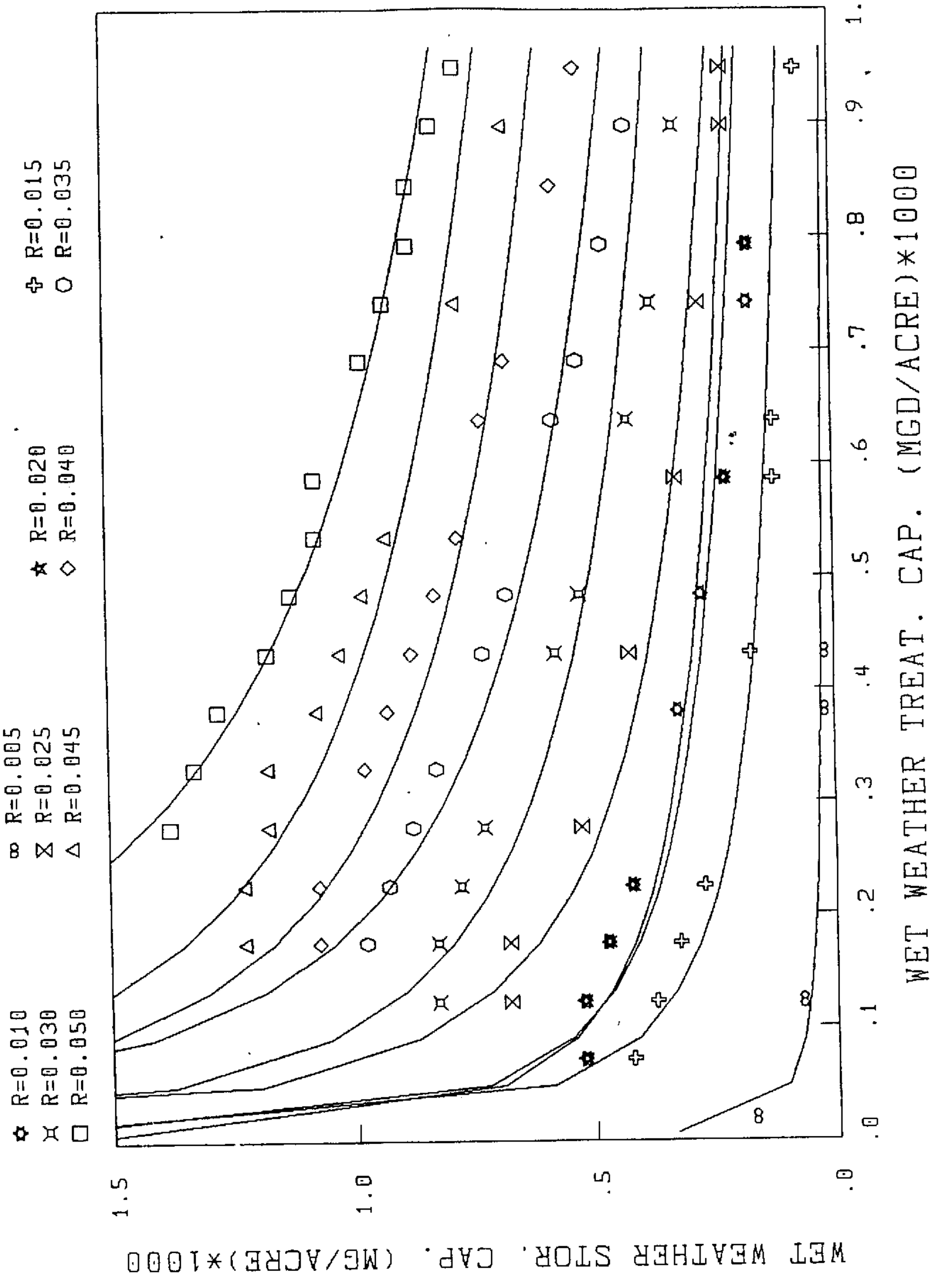
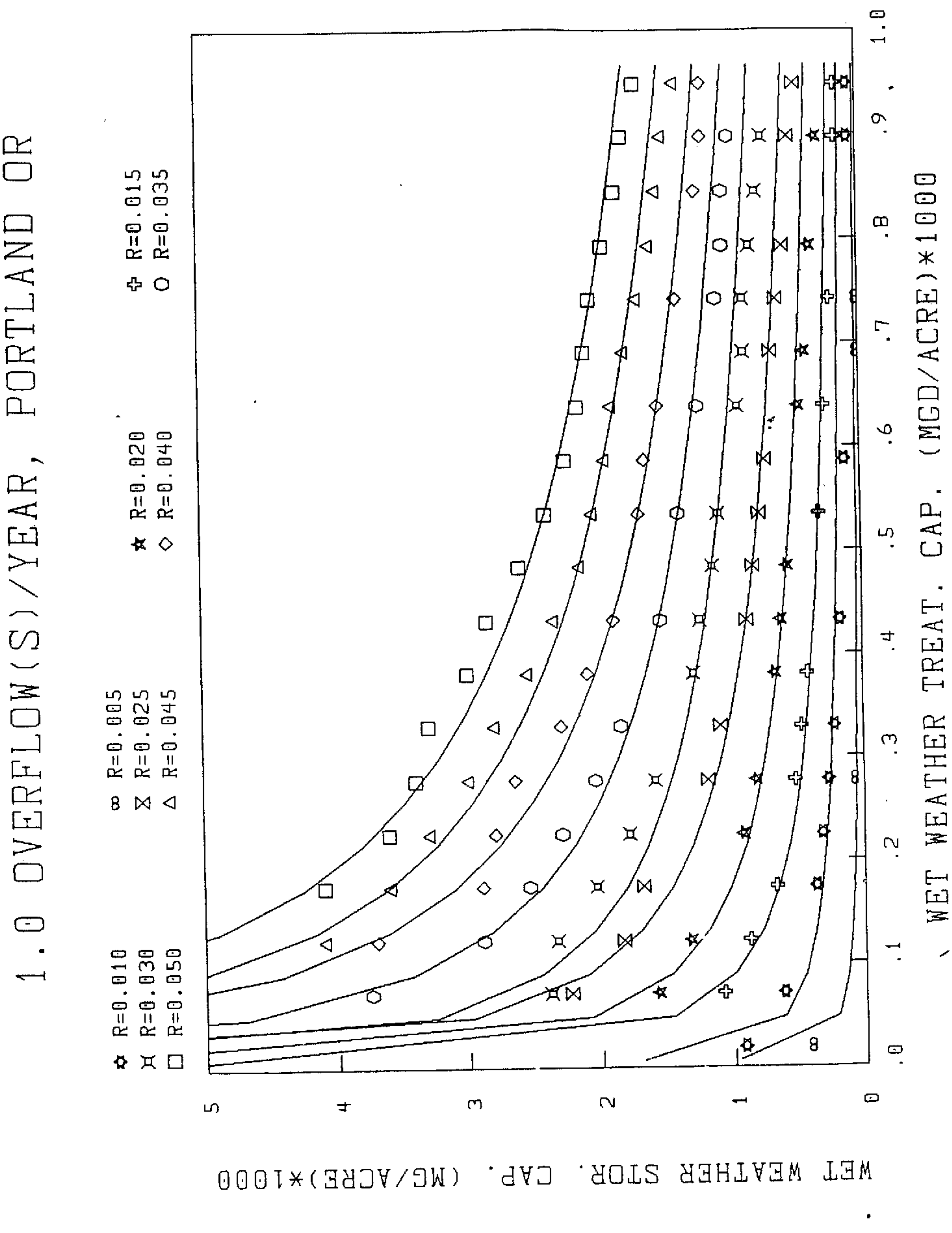
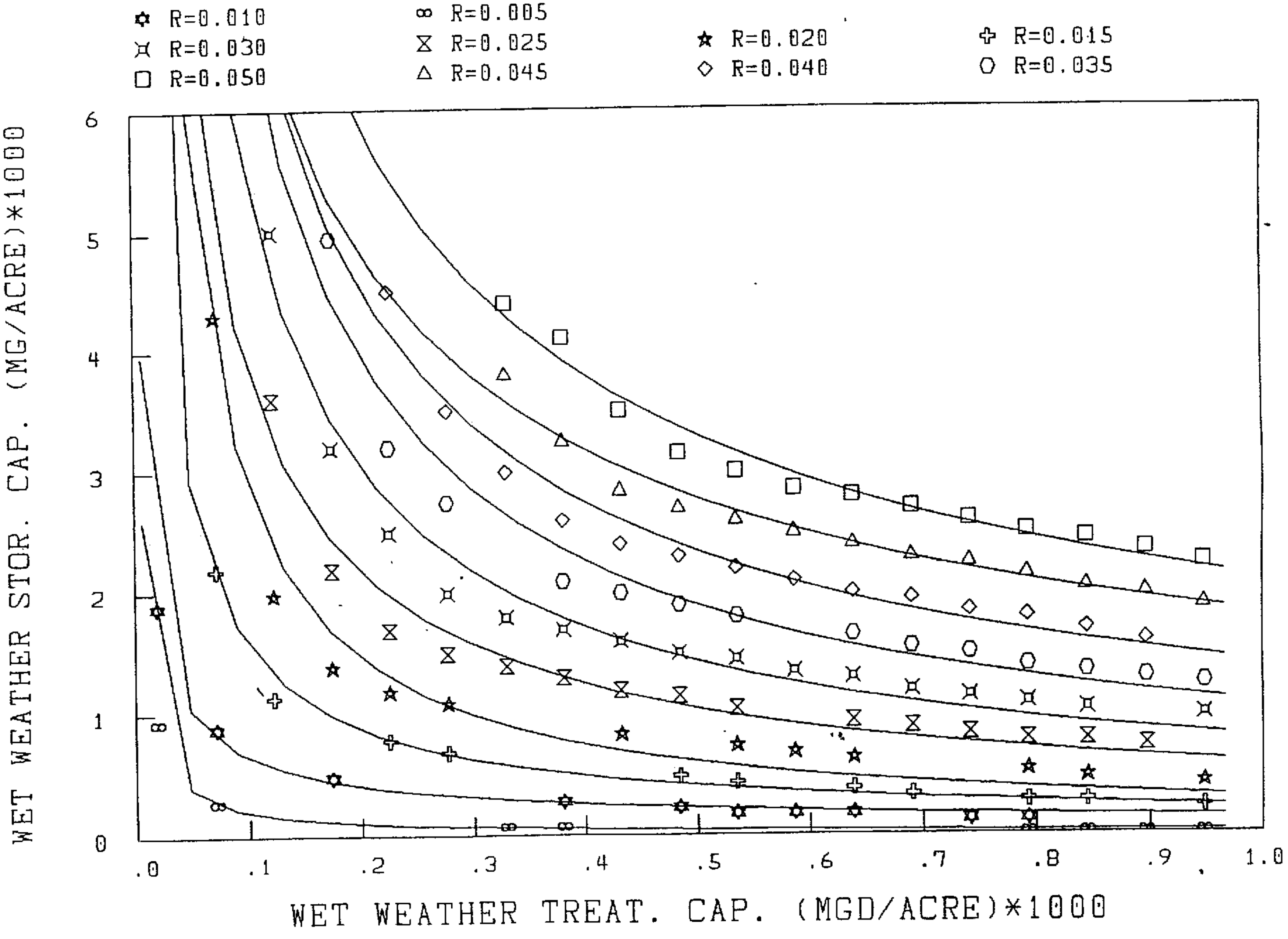


5.0 OVERFLOW(S)/YEAR, PORTLAND OR

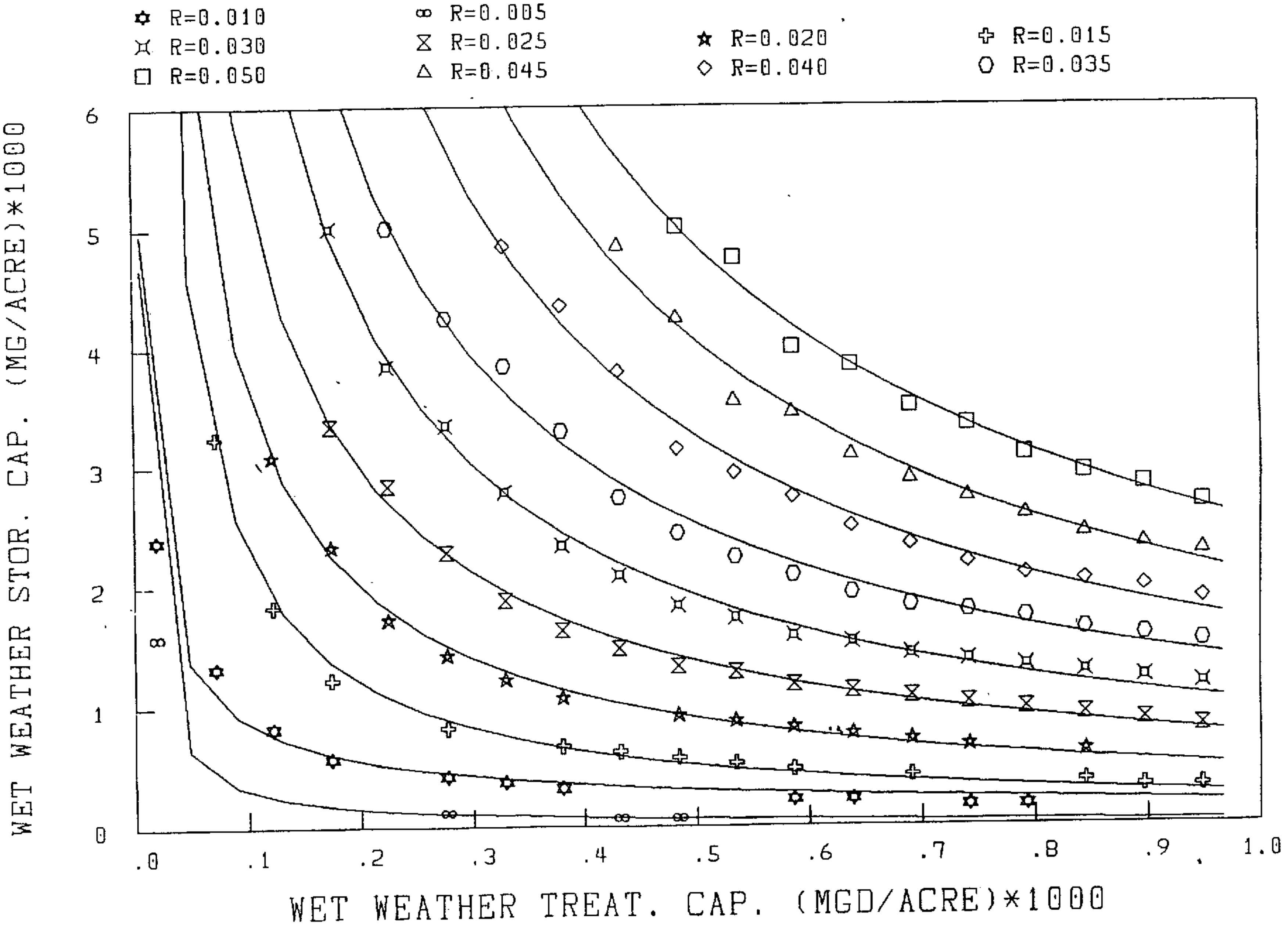


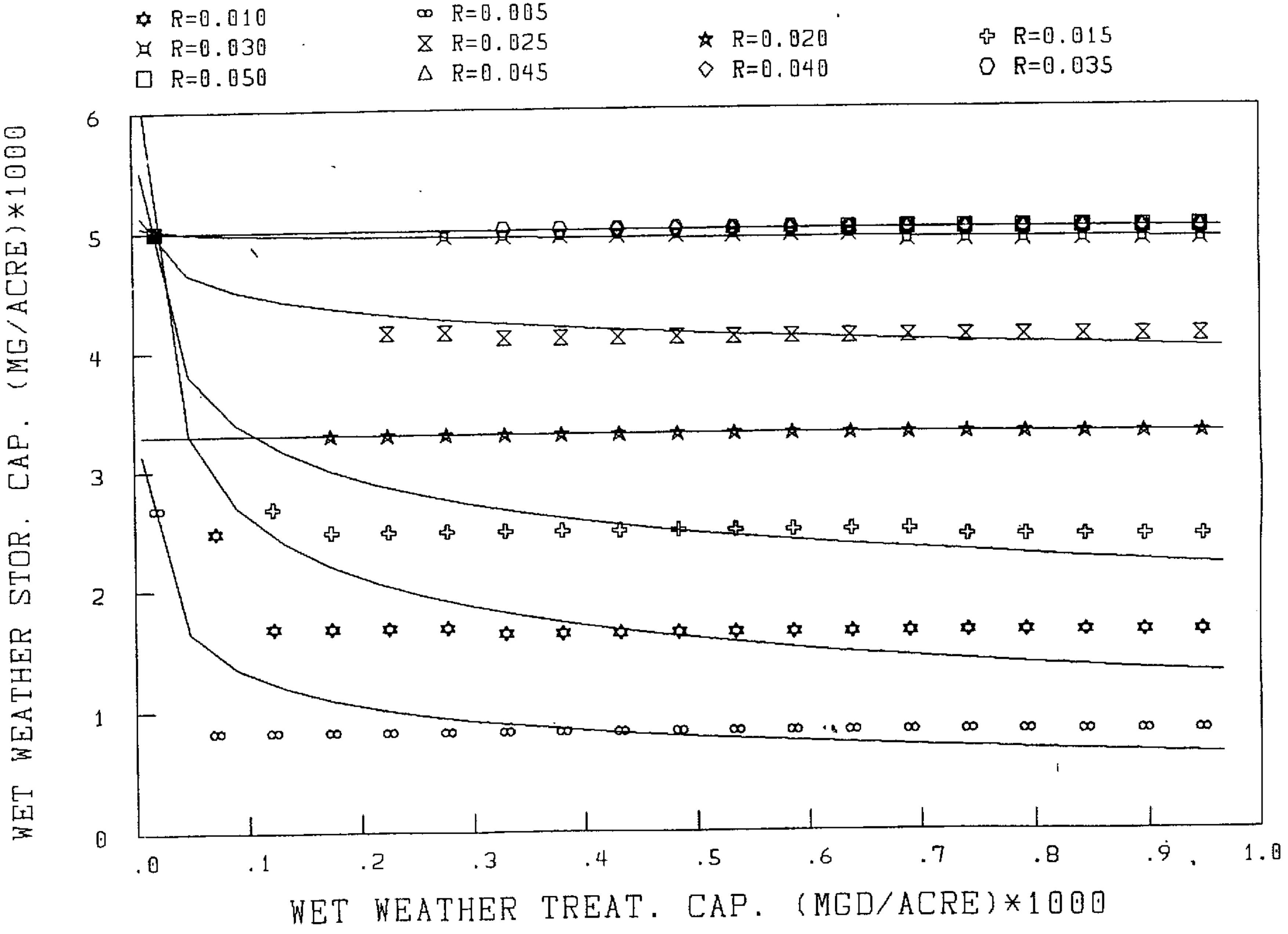

1.0 OVERFLOW(S)/YEAR, PORTLAND OR
✡ R=0.010
¤ R=0.030
□ R=0.050
ʚ R=0.005
⊠ R=0.025
△ R=0.045
✯ R=0.020
◇ R=0.040
✚ R=0.015
○ R=0.035
WET WEATHER TREAT. CAP. (MGD/ACRE)*1000
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
WET WEATHER STOR. CAP. (MG/ACRE)*1000
0
1
2
3
4
5

0.5 OVERFLOW(S)/YEAR, PORTLAND OR



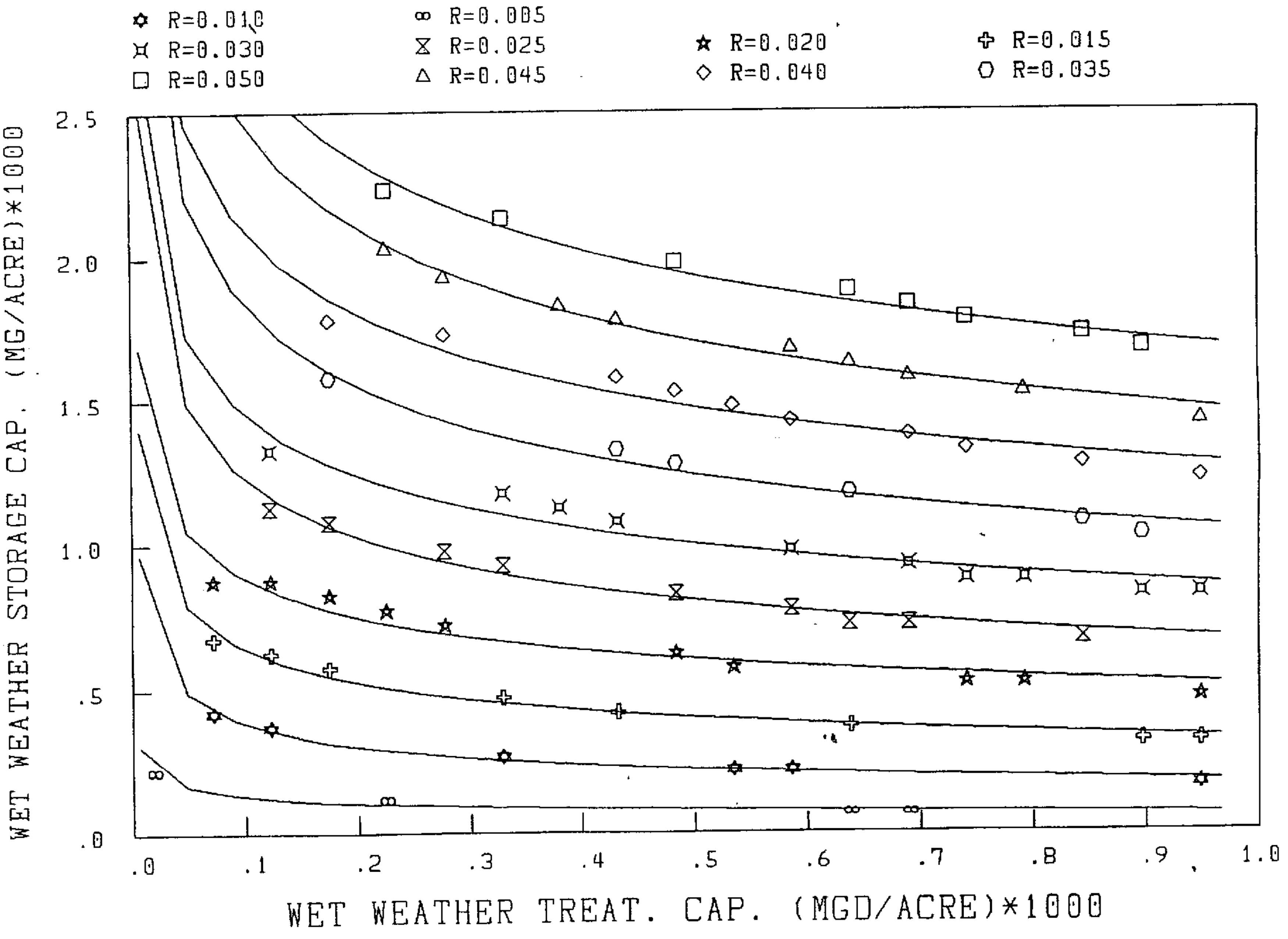
0.2 OVERFLOW(S)/YEAR, PORTLAND OR



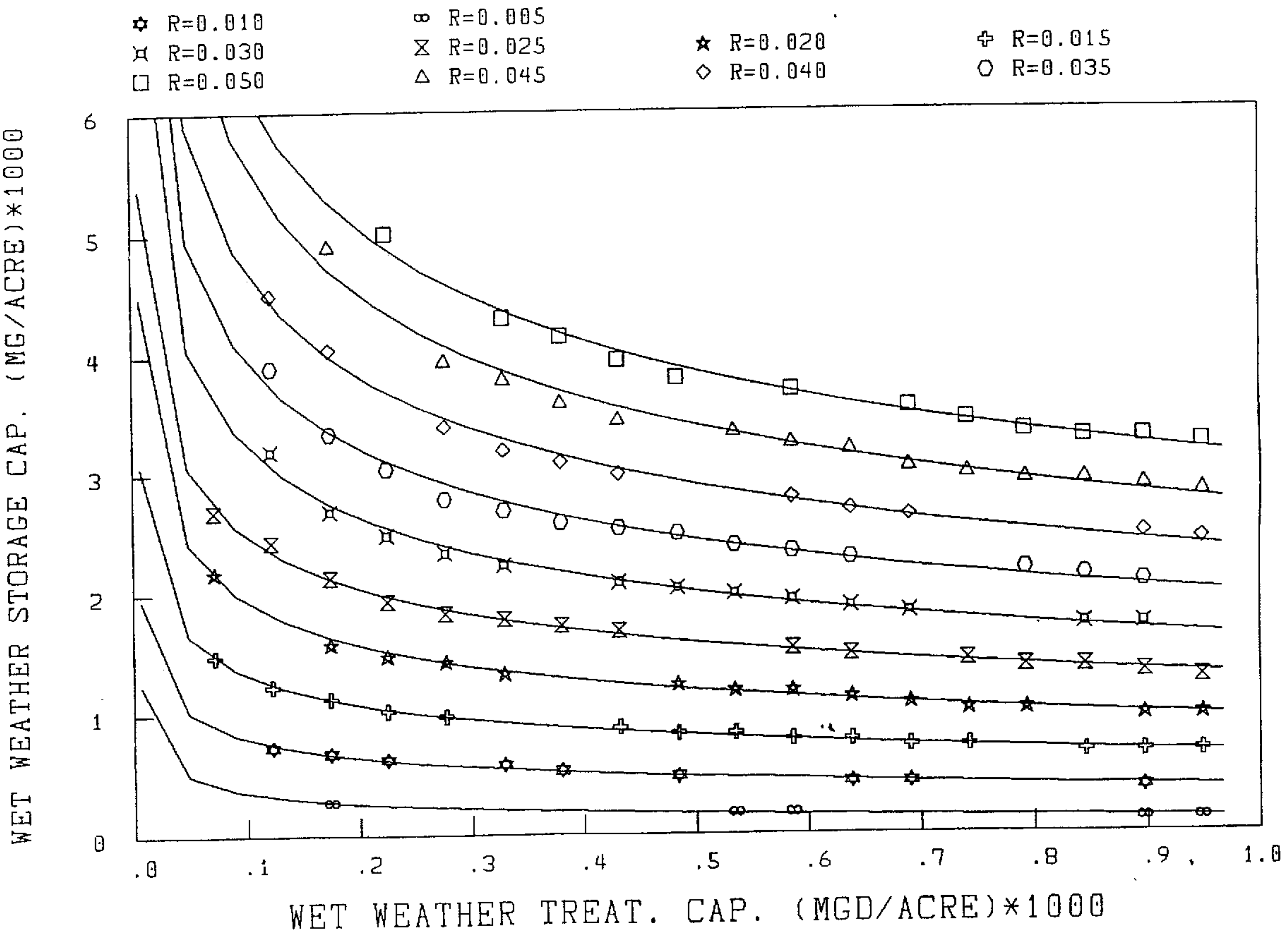


0.0 OVERFLOW(S)/YEAR, PORTLAND OR

5.0 OVERFLOW(S)/YEAR, CHARLOTTE NC



1.0 OVERFLOW(S)/YEAR, CHARLOTTE NC



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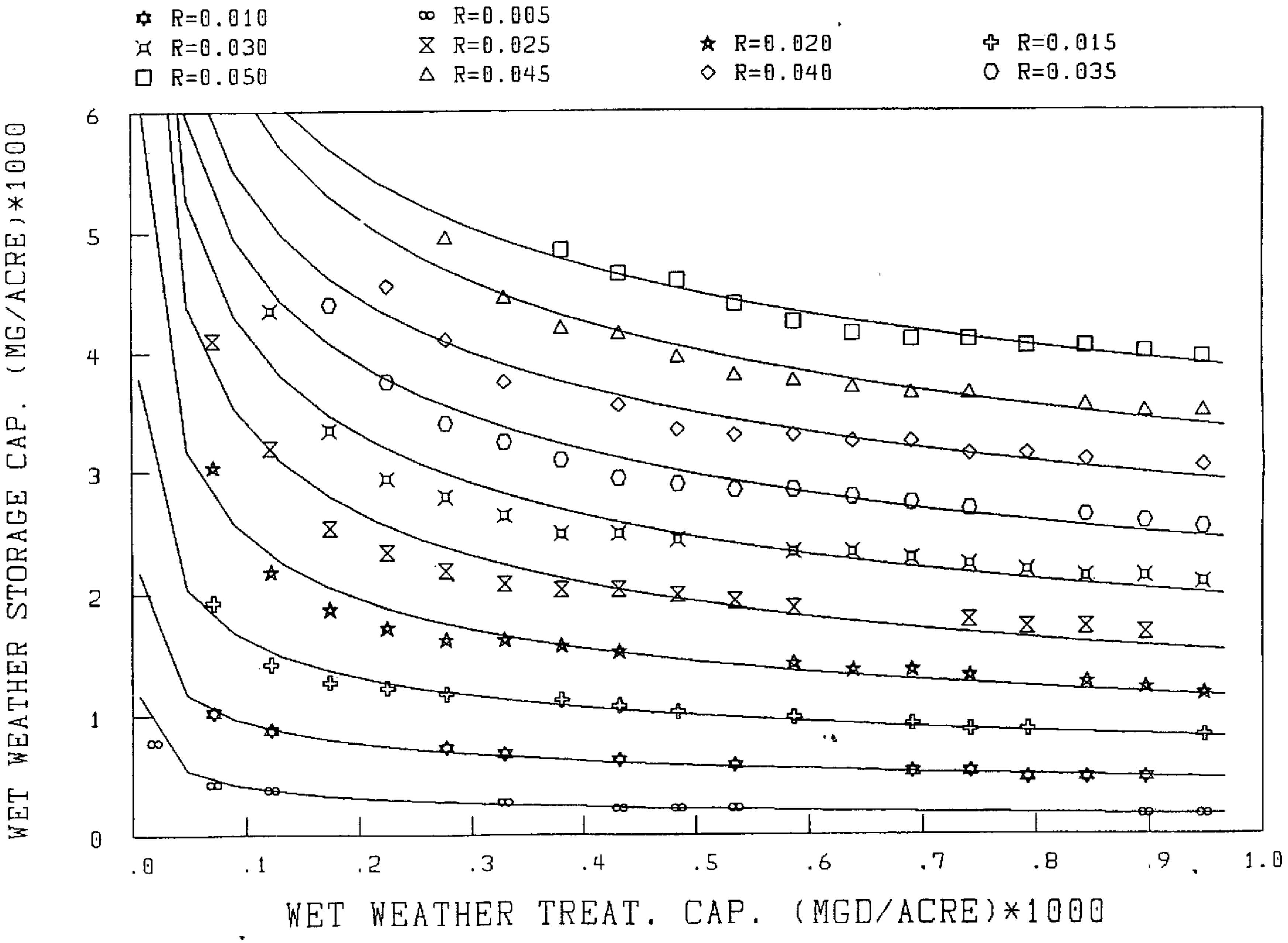

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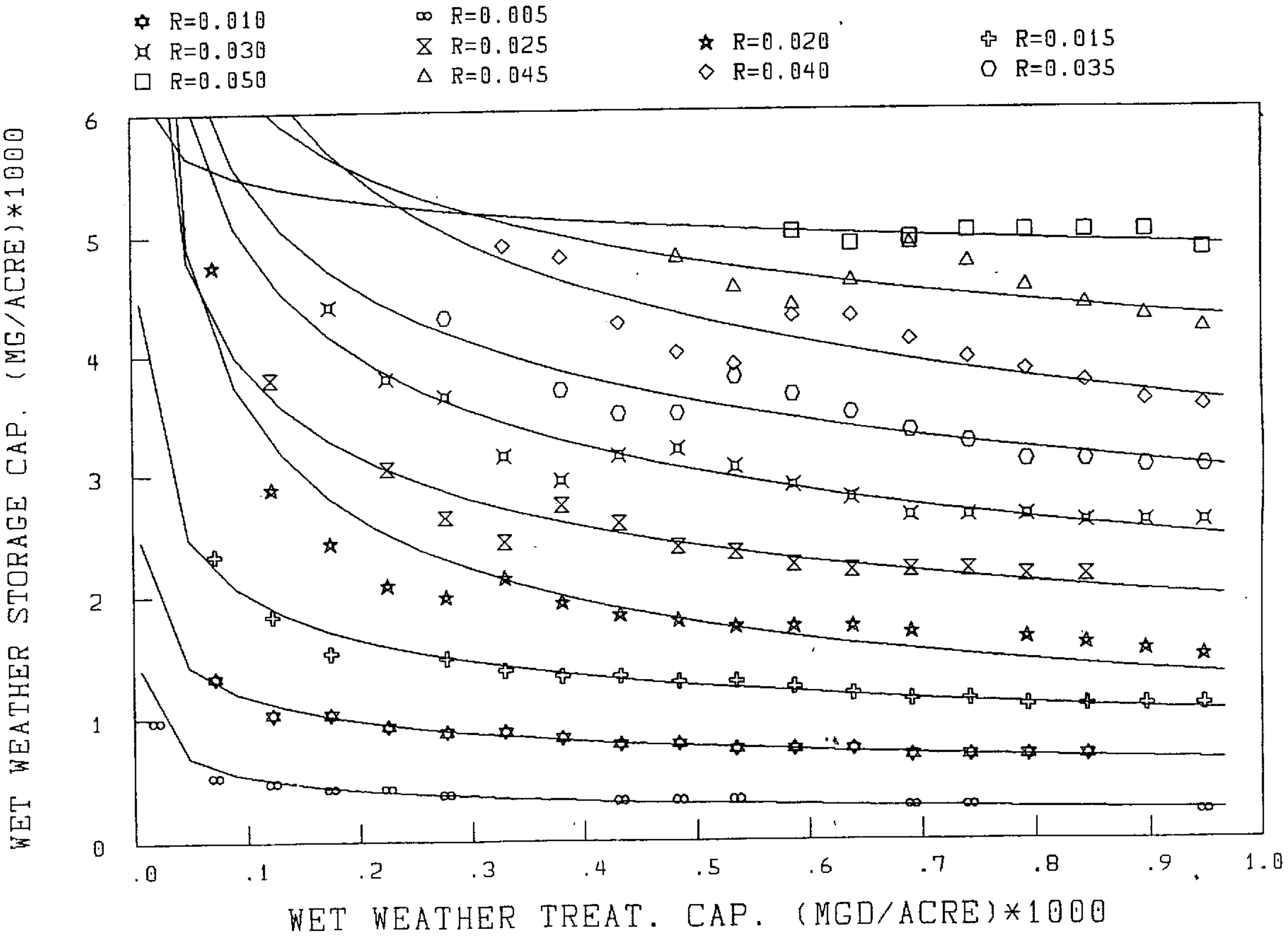

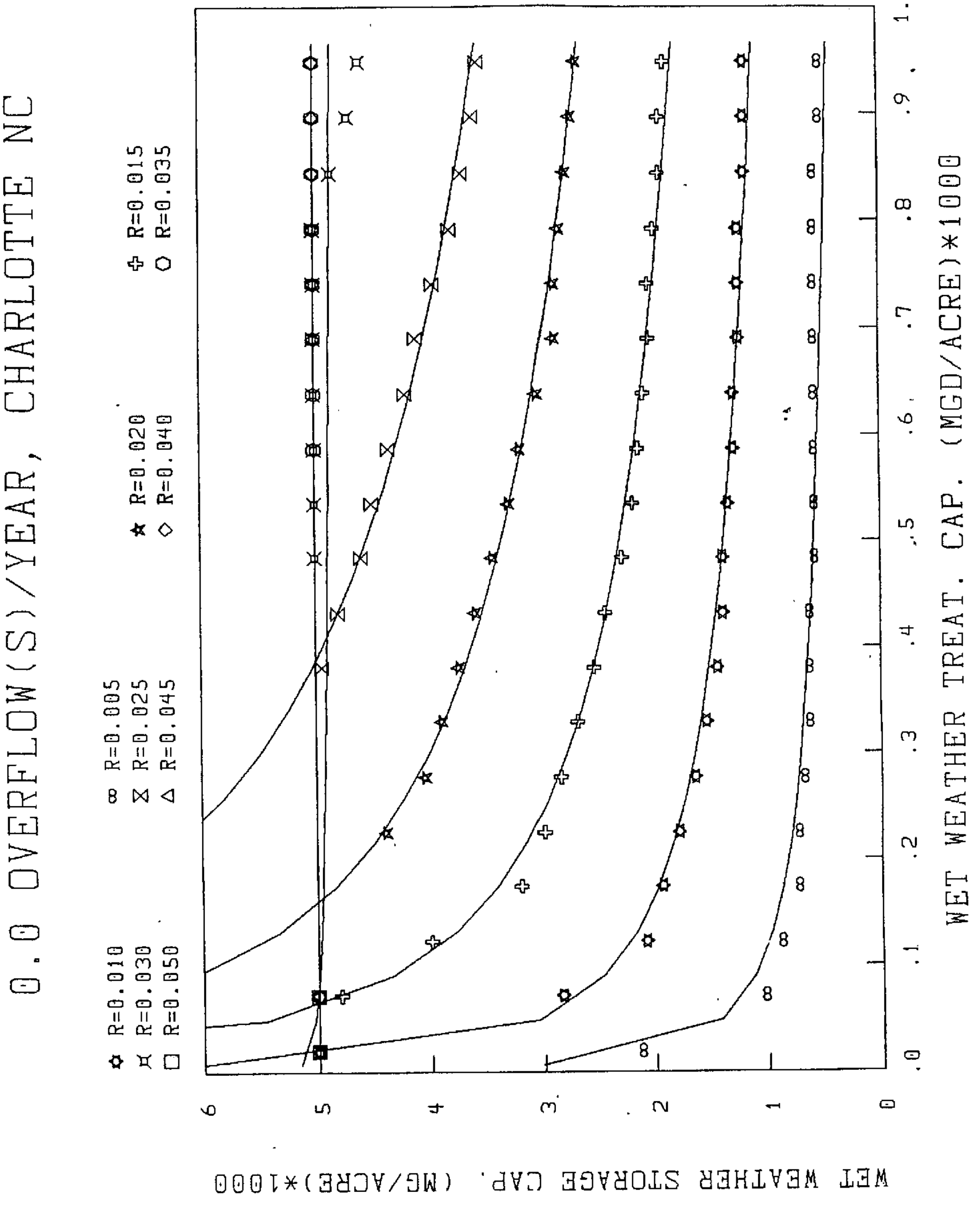
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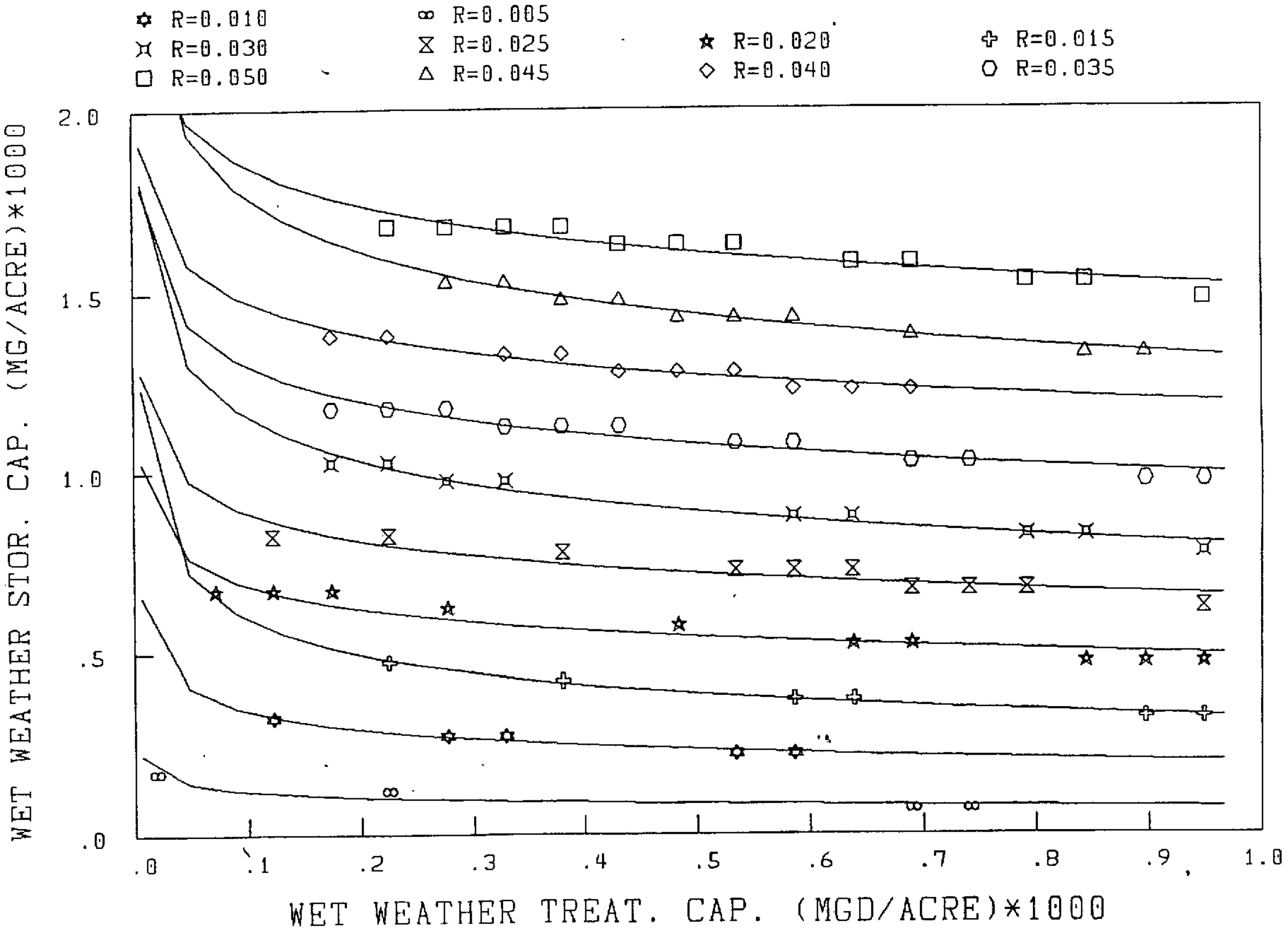
R=0.050
R=0.005
R=0.025
R=0.045
R=0.020
R=0.040
R=0.015
R=0.035
WET WEATHER STORAGE CAP. (MG/ACRE)*1000
0
1
2
3
4
5
6
WET WEATHER TREAT. CAP. (MGD/ACRE)*1000
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

5.0 OVERFLOW(S)/YEAR, FORT WORTH TX



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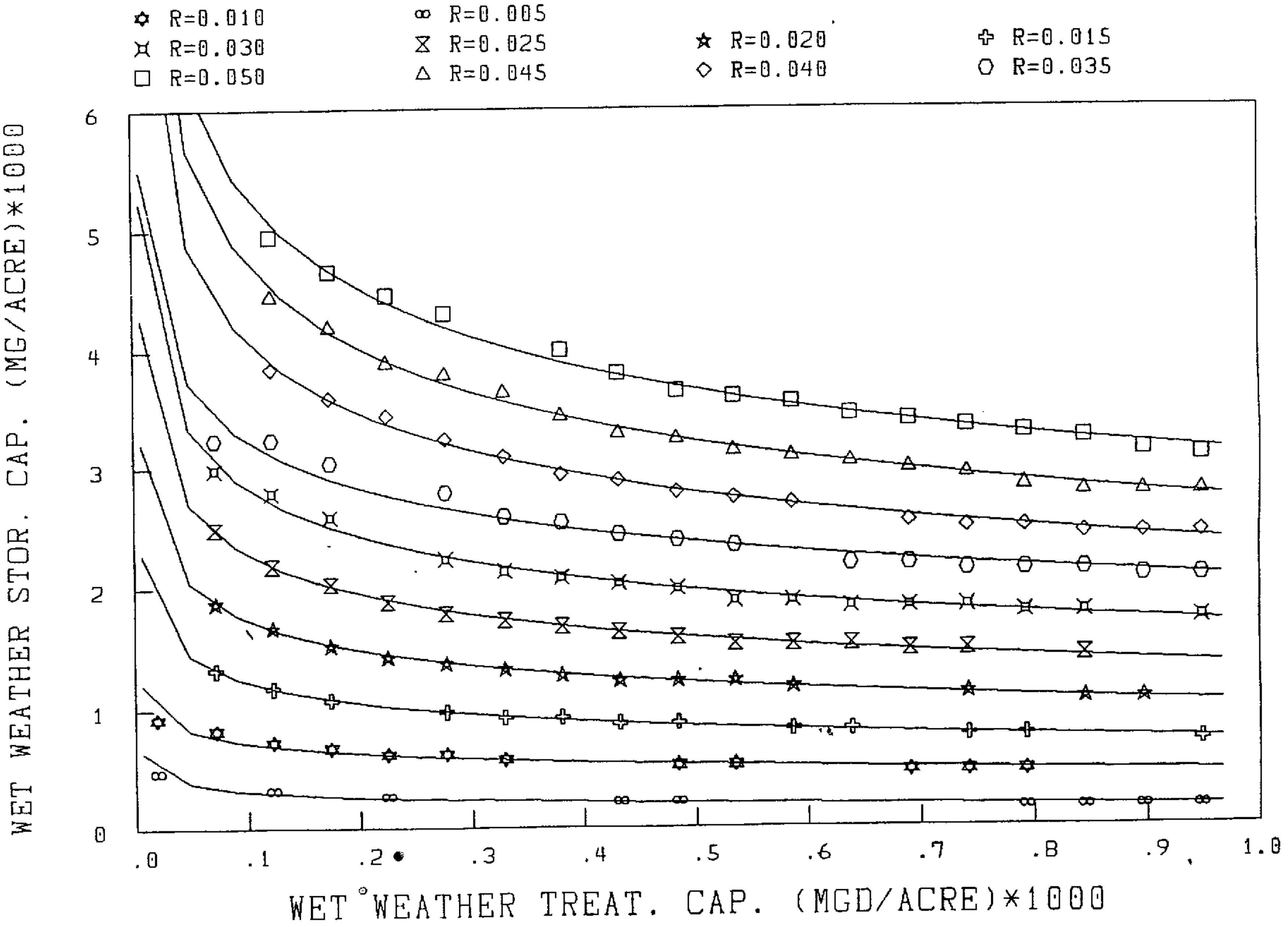

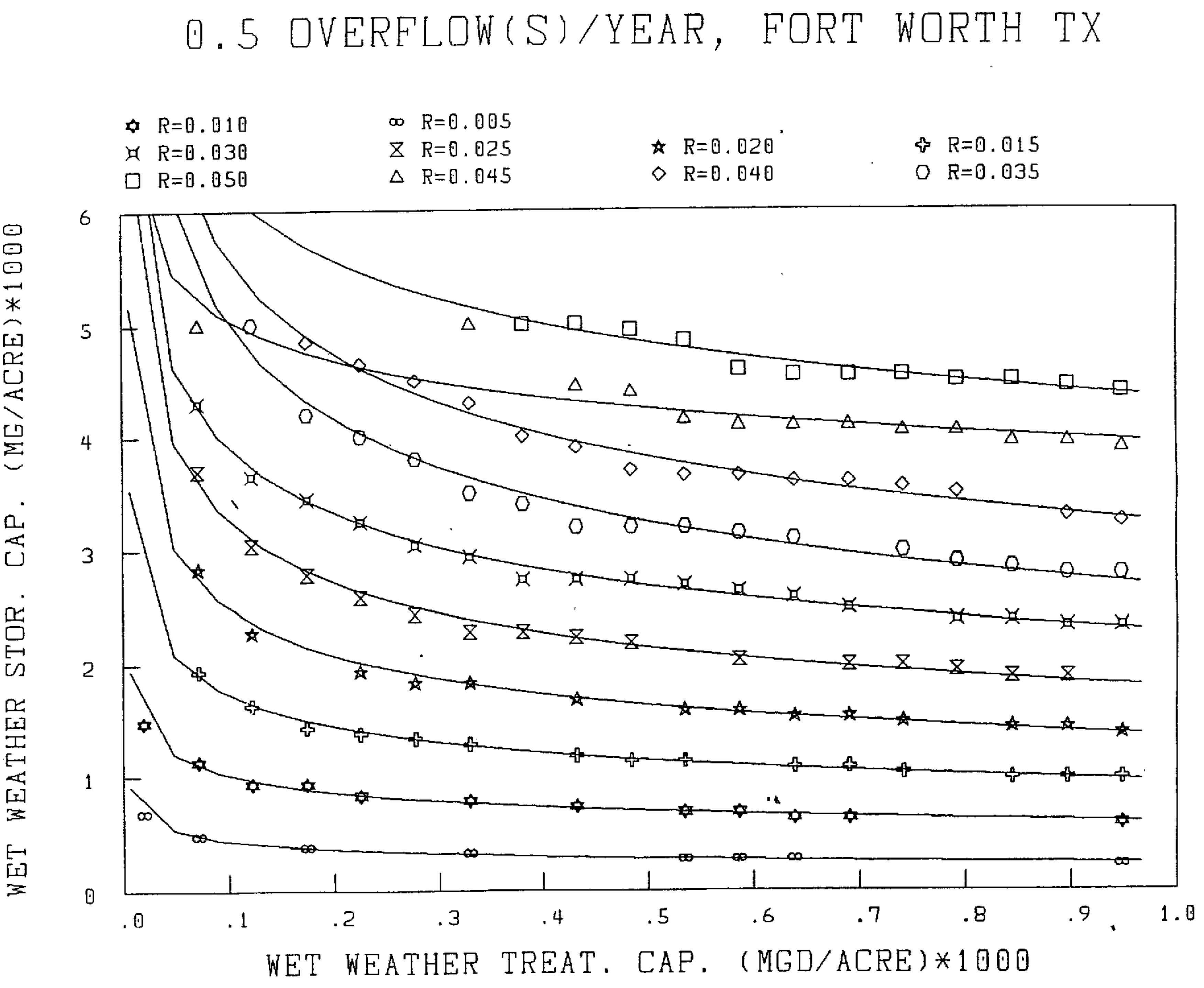
0.5 OVERFLOW(S)/YEAR, FORT WORTH TX
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R=0.050
R=0.005
R=0.025
R=0.045
R=0.020
R=0.040
R=0.015
R=0.035
WET WEATHER STOR. CAP. (MG/ACRE)*1000
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2
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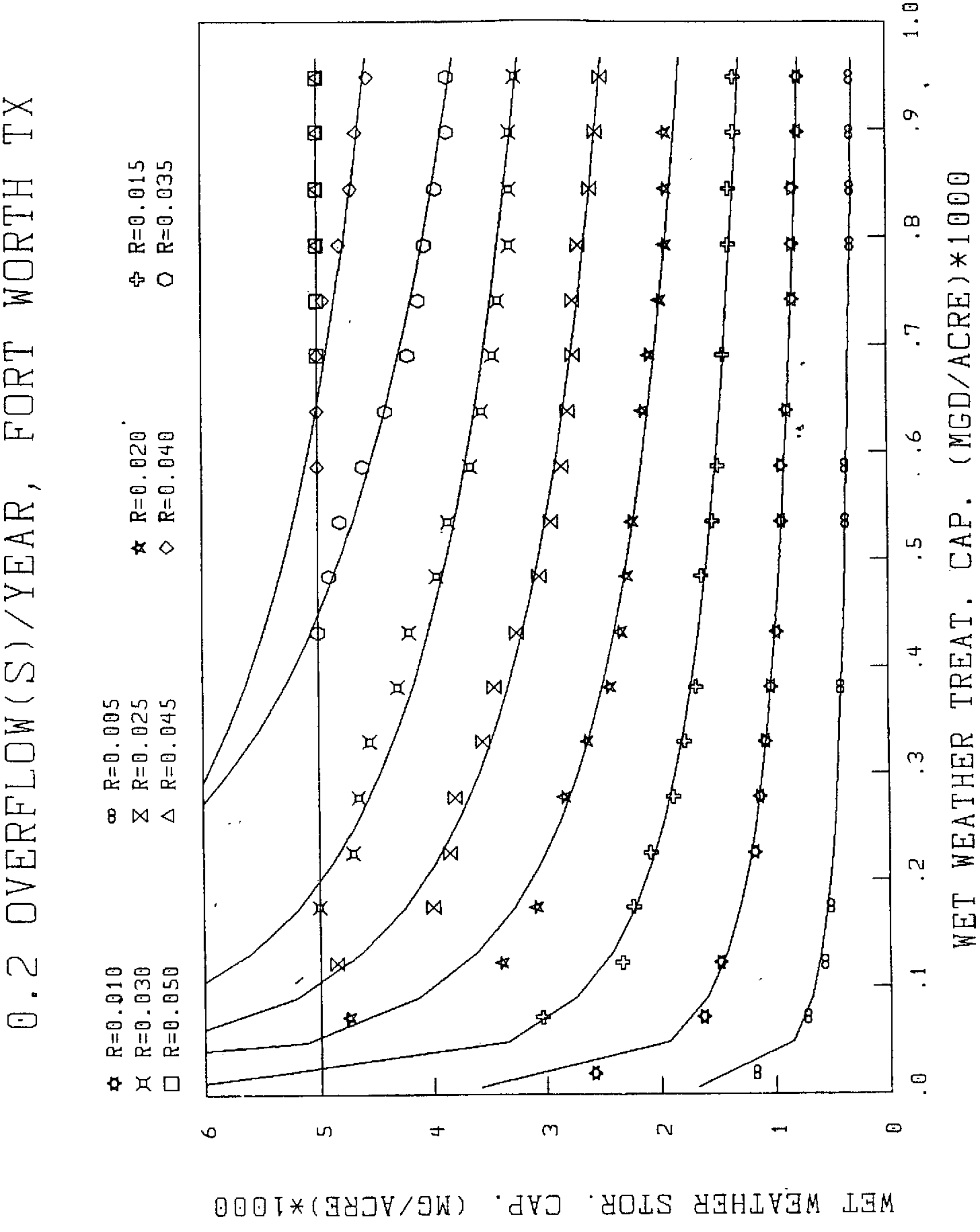
1.0
WET WEATHER TREAT. CAP. (MGD/ACRE)*1000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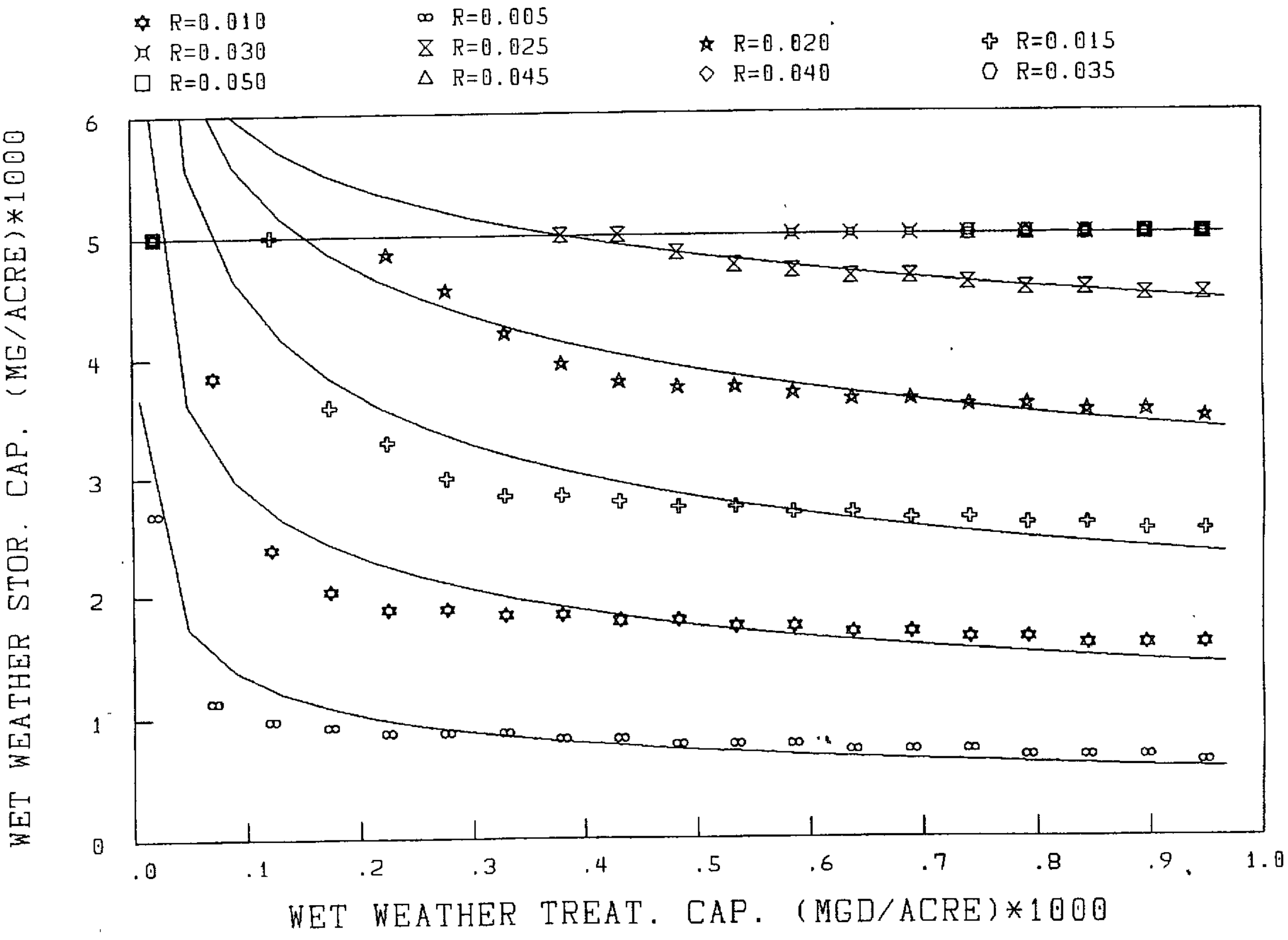
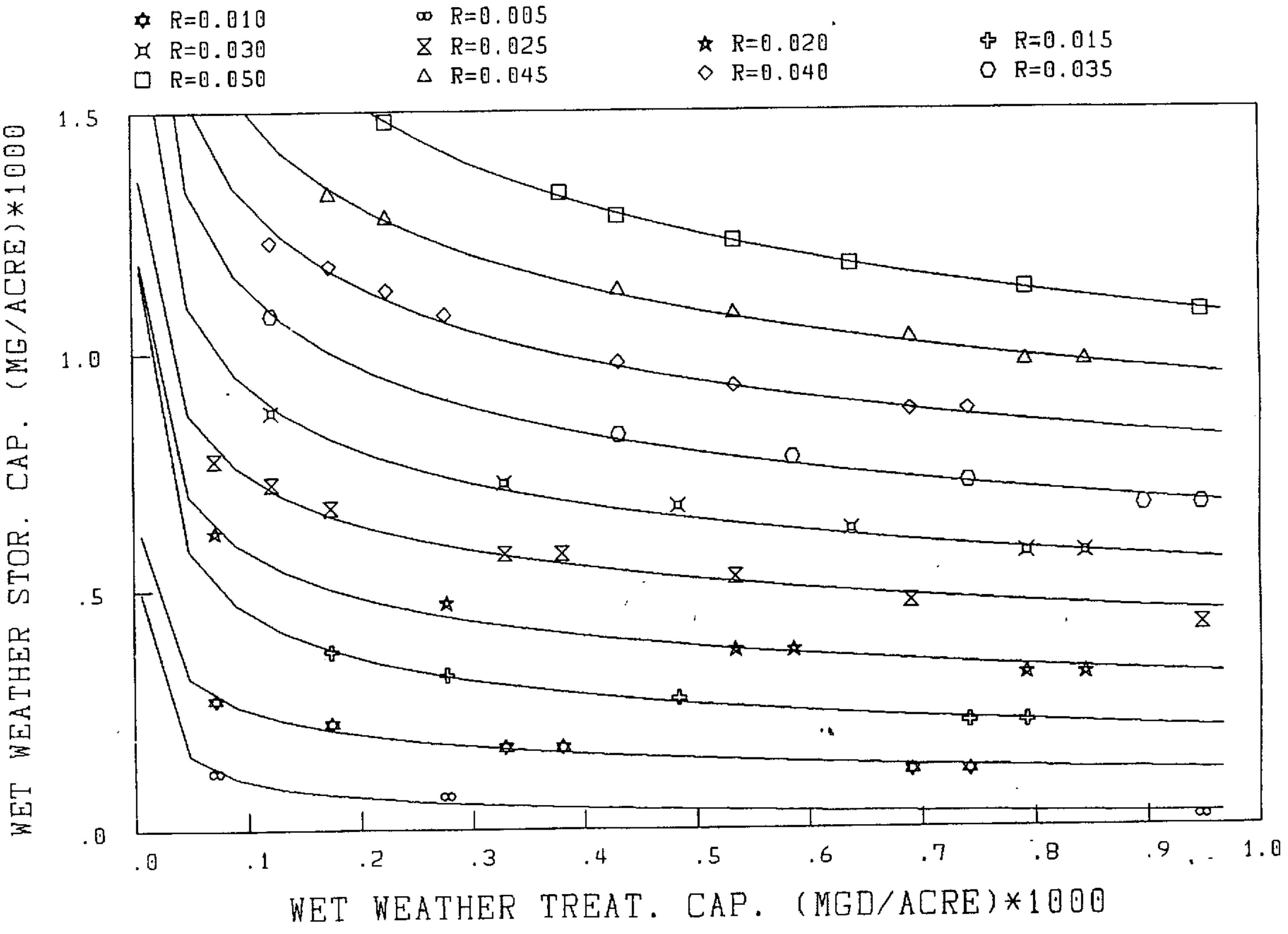
R=0.030
R=0.050
R=0.005
R=0.025
R=0.045
R=0.020
R=0.040
R=0.015
R=0.035
WET WEATHER TREAT. CAP. (MGD/ACRE)*1000
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
WET WEATHER STOR. CAP. (MG/ACRE)*1000
0
1
2
3
4
5
6

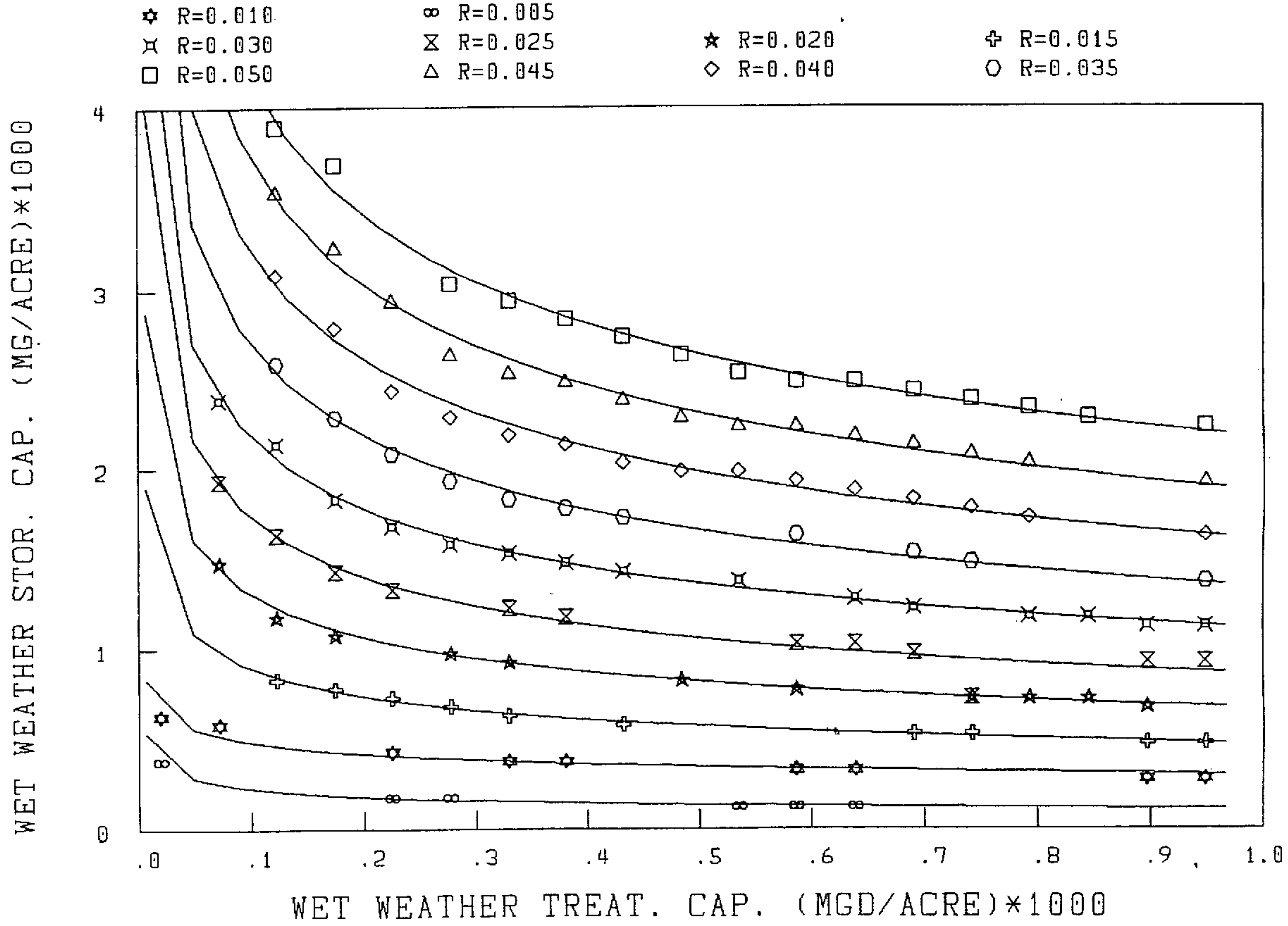
0.0 OVERFLOW(S)/YEAR, FORT WORTH TX



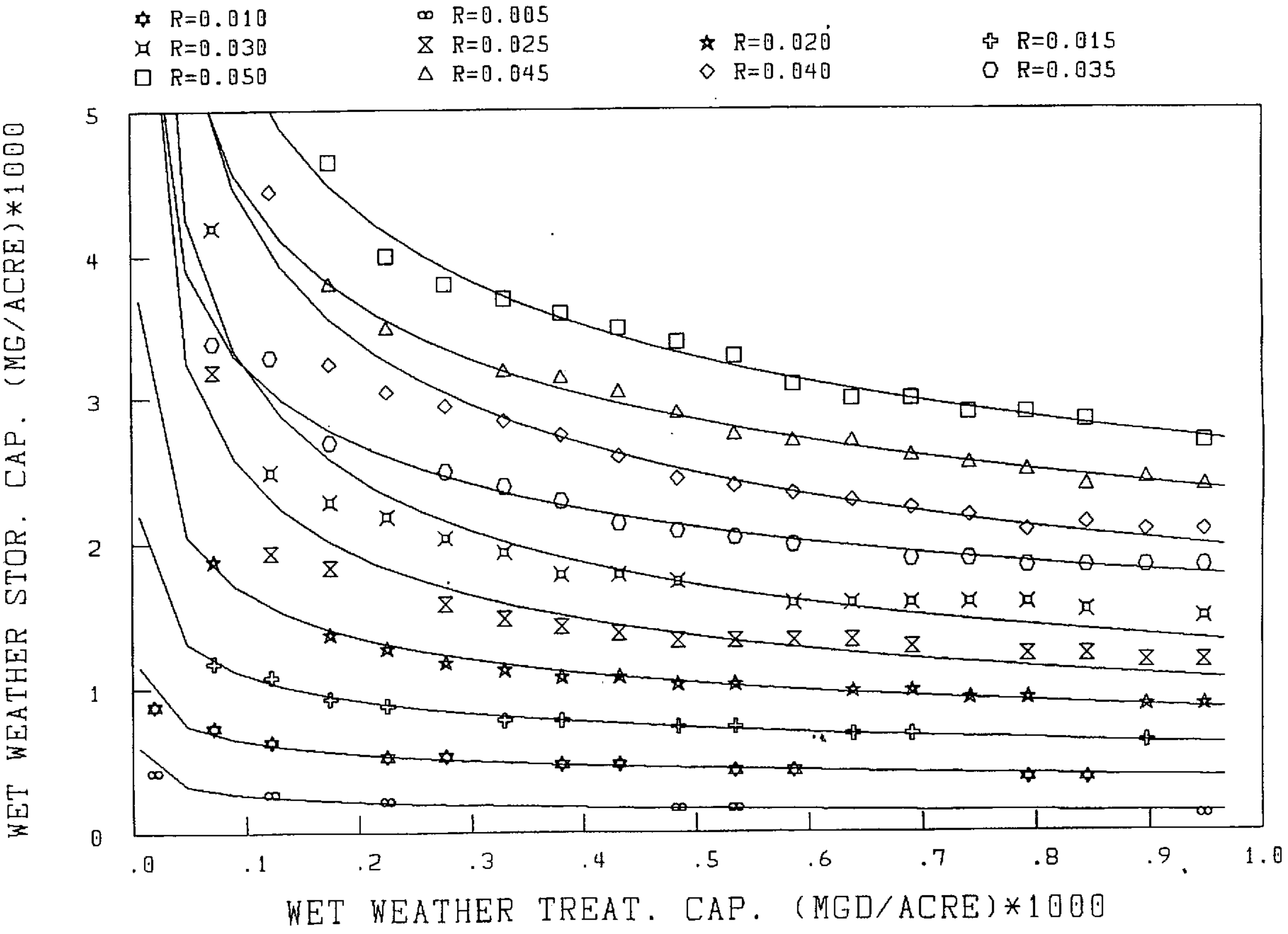
5.0 OVERFLOW(S)/YEAR, WAYNE COUNTY MI



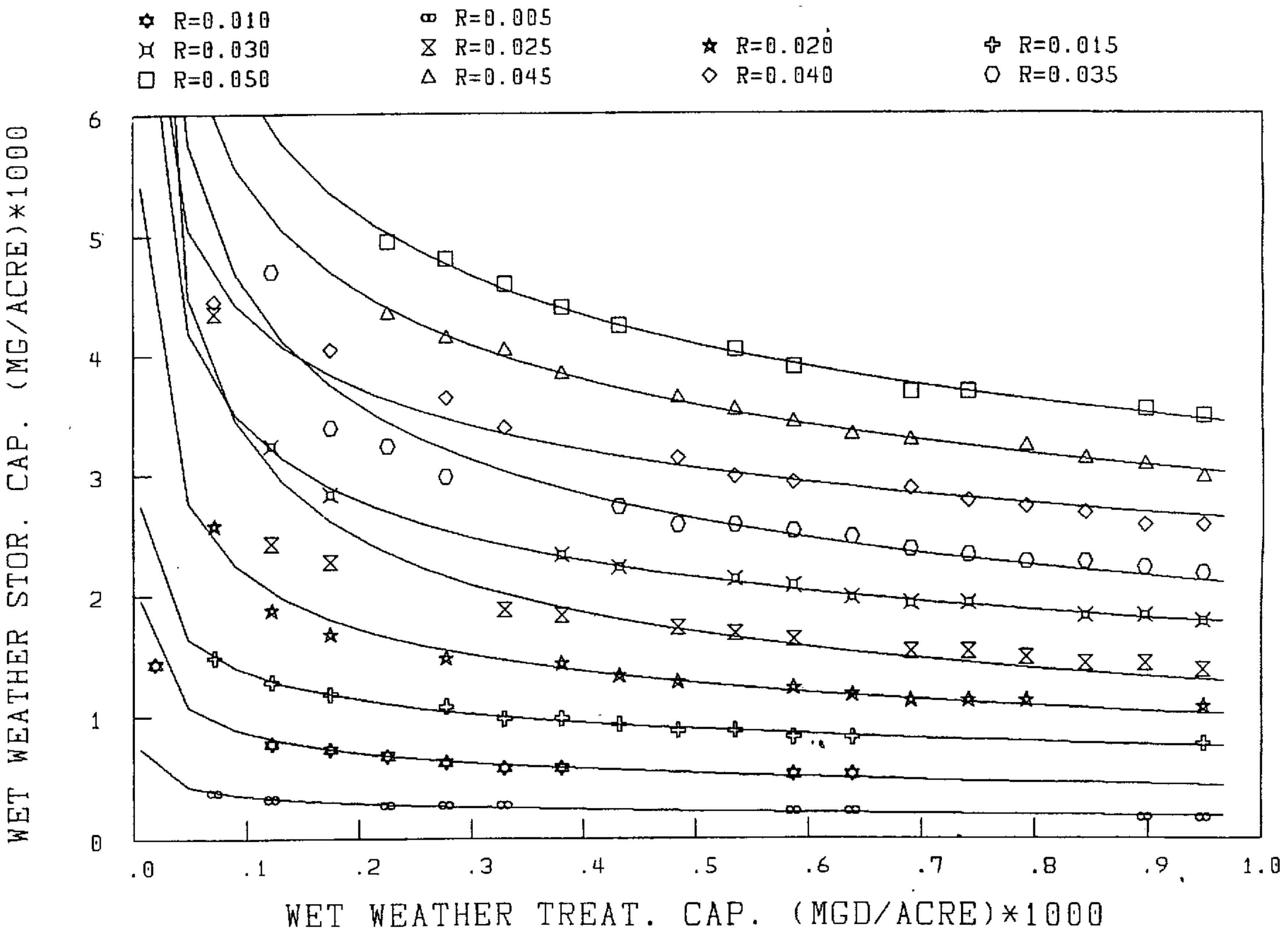
1.0 OVERFLOW(S)/YEAR, WAYNE COUNTY MI



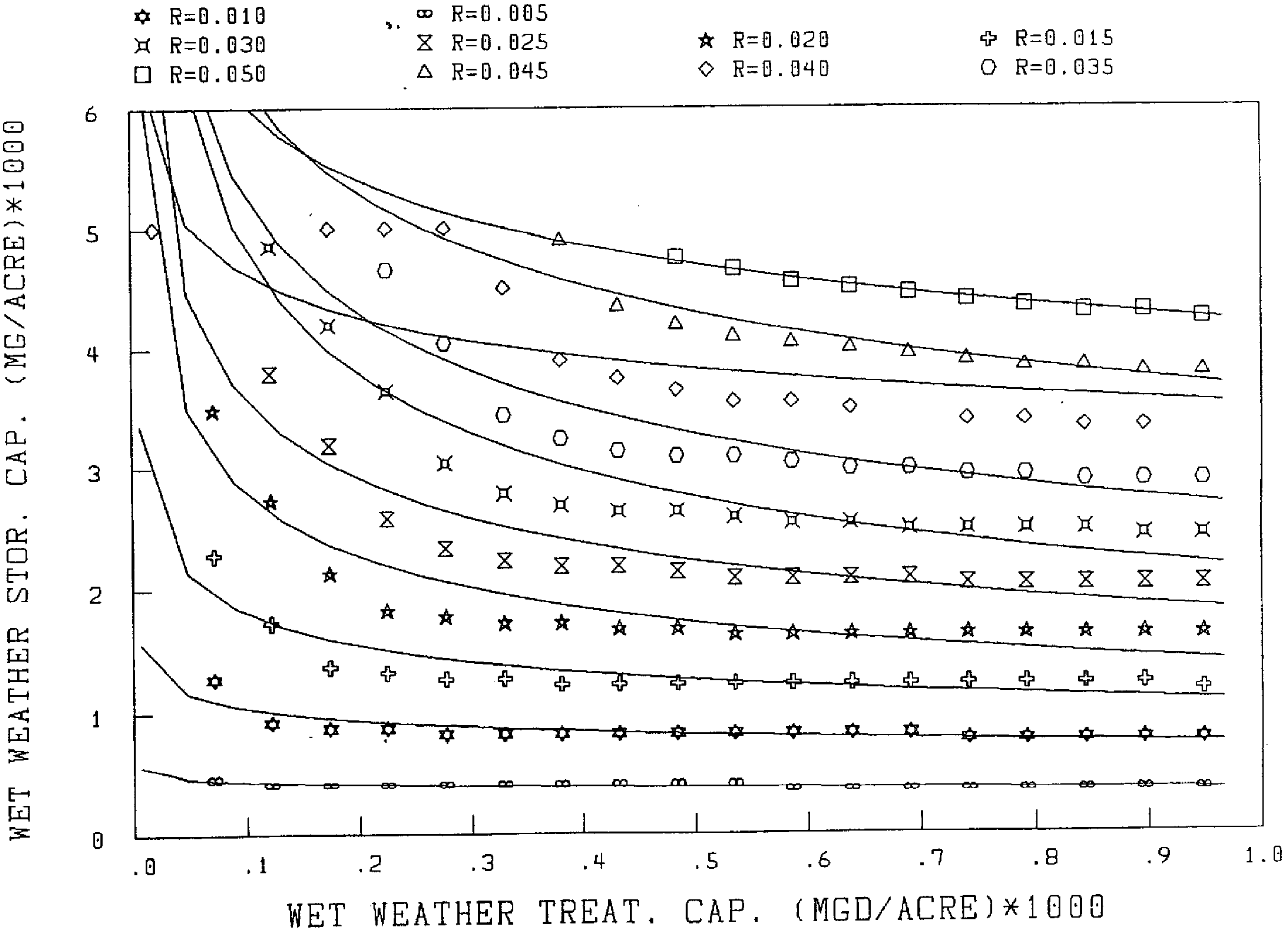
0.5 OVERFLOW(S)/YEAR, WAYNE COUNTY MI



0.2 OVERFLOW(S)/YEAR, WAYNE COUNTY MI



0.0 OVERFLOW(S)/YEAR, WAYNE COUNTY MI



APPENDIX D

DESCRIPTION OF THE OPTIMIZATION ROUTINE USED BY THE COST MODEL

APPENDIX D

DESCRIPTION OF THE OPTIMIZATION ROUTINE USED BY THE COST MODEL

Numerous optimization routines are available to solve problems like that posed by the cost model. Gradient-based optimization techniques (e.g., dynamic programming, non-linear programming) require estimates of the first-order derivatives of the mathematical functions. However, these methods are limited to local search only and do not guarantee global optima. Alternatively, non-gradient based methods may be applied to this problem and do not require similar first-order derivatives of the mathematical functions. A non-gradient based solution approach was, therefore, chosen for determining the least-cost solution for each sewer system to meet the overflow frequencies specified. The optimization routine implemented uses a random search for optimal solutions method where one set of potential results sets boundaries for the generation of the next random search (Goldberg, 1989; Holland,1975).

The optimization routine operates by first reading in information describing an individual system, which consists of regional location, sewered area, estimated R-value, length of sewer, wet-weather treatment capacity, and wet-weather storage capacity. The optimization routine then checks whether the existing system performs adequately for a given number of annual overflow events (i.e., if the system already meets the requirements for 0.2, 0.5, 1, or 5 overflow events per year and therefore does not need upgrading). If the system is acceptable, the optimization routine writes this information to an output file (i.e., final cost = $0). If the system requires some form of improvement, however, the optimization routine is initiated.

The optimization routine consists of the following steps: (1) generate an initial set of potential solutions, (2) pair the solutions randomly to determine the lower cost solution, (3) generate new potential solutions using the qualities of the lower cost solutions from step (2), and (4) generate additional random solutions to ensure convergence to a correct optimum value. This process is run three times for each system—once for each overflow reduction objective (0.2, 0.5, 1, or 5 overflow events per year).

To begin the simulation, 50 possible solutions are generated randomly based upon the system's existing configuration. Each solution consists of an R-value, wet weather treatment capacity (mgd/acre), and wet-weather storage capacity (mg/acre). The R-value's are constrained to be greater than or equal to one-half of the existing systems' R-value. Meanwhile, the wet-weather treatment capacities are constrained to be greater than or equal to the system's existing capacities. These restrictions ensure that impossible solutions are not developed. To generate the initial set of potential solutions, random combinations of treatment and R-values, within restrictions outlined above, are produced. Then, the wet-weather storage capacity is calculated using the STORM results for that given region, R-value, and wet-weather treatment capacity. Therefore, each random value represents a unique alternative improvement to the existing system such that the target maximum allowable overflow frequency objective is met.

The next step of the optimization process is to calculate the cost for each combination using the cost functions described above. Since each value developed represents a potential solution to the overflows occurring in the existing system). The potential solutions are randomly paired and the solution with the lower of the two costs is kept. This process is carried out twice for the entire set of potential solutions through random pairing so that the final number of potential solutions equals the initial number.

Once the set of potential solutions has been changed through the above process, various pairs of solutions are randomly selected. The solutions not selected in this pairing are maintained in their existing conditions. The selected pairs of solutions, however, are used to generate additional potential solutions where characteristics of the pairs are used as boundaries for the characteristics of the new potential solutions. For example, if a selected pair of potential solutions have R-values of 3.5 and 5, respectively, the new potential solutions generated would have R-values ranging from 3.5 to 5 and slightly outside this range. These new potential solutions then replace the initial pair in the new pool of potential solutions.

In addition to this systematic generation of potential solutions, the optimization routine generates other random solutions at each step. These additional random solutions are generated at a constant low rate, less than one percent of the total number of generated solutions. These randomly generated solutions are produced to ensure that the initial set of 50 randomly generated solutions was not biased toward a particular non-optimum solution because of potential inherent non-randomness. These periodic, randomly generated cases will likely represent solutions very different from those contained in the bulk of the generated solutions. This is because, as the process continues, the potential solutions are converging to some low-cost combination while the periodic, randomly generated solutions are not restricted.

The entire process of generating, comparing, and pairing potential solutions continues until some stopping criteria is met, such as a maximum number of iterations or minimum difference between the costs in different iterations. A final important function, whereby the least-cost solution from each generated set replaces the highest-cost solution during each cycle of the process, is also performed. This process reduced potential system perturbations and greatly accelerates system convergence to an optimal solution.

APPENDIX E

U.S. EPA NEEDS SURVEY DATABASE DATA MANIPULATION

APPENDIX E

U.S. EPA NEEDS SURVEY DATABASE DATA MANIPULATION

The U.S. EPA Needs Survey Database contains information on separate and combined sewer systems nationwide. However, these data are not easily reviewed and summarized because of the large number of individual data records, the amount of overlapping information, and the lack of some important data records for some sewer and treatment plant systems. Therefore, pertinent information had to be selected and downloaded from the database to a local computer system, manipulated to eliminate "double counting" of data records, and updated to include data not contained in the system. Figure E-1 is a flowchart outlining the steps in data manipulation from downloading the data to developing final inputs for the cost estimating methodology.

E.1 ACCESSING THE DATABASE

The EPA's 1996 Needs Survey database, developed in response to the Water Quality Act of 1987, contains detailed cost and technical information on publicly owned wastewater treatment and collection facilities nationwide (U.S. EPA, 1997).

This database provides a comprehensive set of data related to all the separate sanitary sewer systems in the country. Many of the parameters from this database provide useful information for the development of a national cost estimate for the elimination or reduction of SSOs. Therefore, this database was used as the primary source of input data for the SSO cost model.

Initially, all database entries related to separate sanitary sewers were gathered through a search of present facility type [PRESNAT] and projected facility type [PROJNAT]. The database categorizes present and projected facility type by the following codes:

1: Treatment system with combined sewers
2: Treatment system with separate sewers
3: Regional treatment plant
4: Collection system with separate sewers
5: Collection system with combined sewers
6: Facility classified as "other"

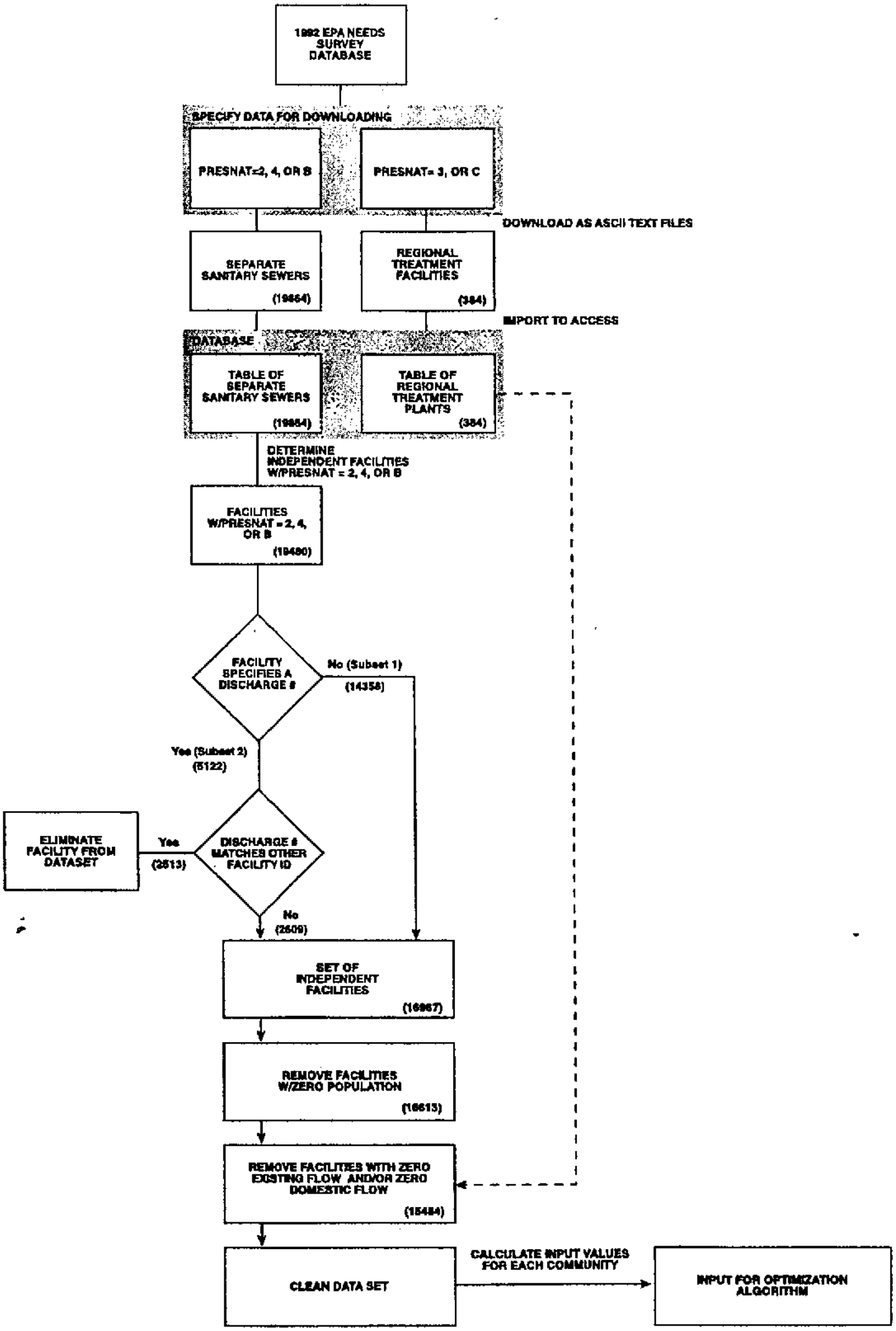
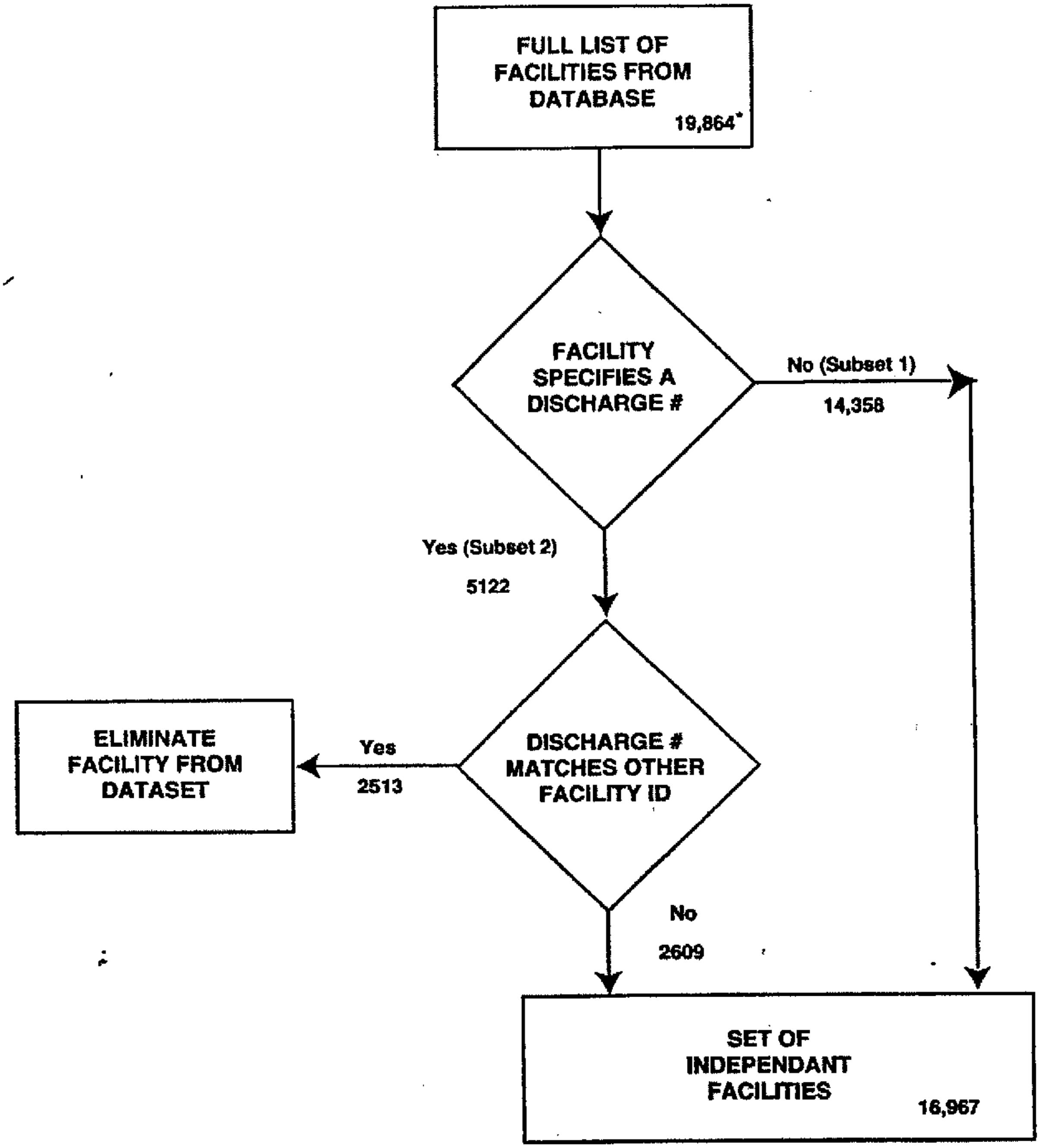


Figure E-1. Data Collection Flowchart



*Note: 19,480 facilities with presnat = 2, 4, or B

Figure E-2. Flowchart for Determining Independent Facilities the facility was kept as a member of Subset 2 because the population would not previously have been counted. After all the matches were eliminated, Subset 1 and the remainder of Subset 2 were joined and the separate sewer population was calculated as the sum of each facility's PPRRT or, if PPRRT equaled zero, its PPRRC. This provided a total set of treatment plants and collection systems that can be used, in conjunction with the cost estimating methodology, to develop a national SSO cost estimate.

When the two subsets were combined 16,967 independent facilities remained. Of these facilities 354 did not contain information on population. Since population is one of the key components in determining the input parameters for the cost estimating model, the facilities without population information were eliminated, reducing the number of independent facilities to 16,613.

E.3 CALCULATION OF ADDITIONAL DATA

Once the complete set of independent sewer systems and treatment plants was developed, areas of incomplete data were addressed. One of the those areas was the existing flow for each facility. Some of the independent facilities indicated population data but no flow data. In the cases where the facilities indicated a population, a discharge facility and zero flow, information on the facility being discharged to was reviewed. Since discharge numbers were already checked against the facilities with present facility types of 2, 4, or B in the previously described process to avoid double counting, the discharge numbers for this evaluation were reviewed against facilities with a present facility type of 3 (regional treatment plant). There were 384 facilities with a present facility type of three. Also, 1,129 facilities existed with a present nature of 2, 4 or B, a population greater than zero, and an existing flow equal to zero. It was assumed that those 1,129 facilities discharged to regional treatment plants (present facility type = 3) and that the flow listed for the regional treatment plant would be proportional to the flow at the individual facility in the same proportions as the respective populations.

Since there are fewer regional treatment plants than facilities with zero existing flow, each facility identification number for the regional treatment plant was checked against the discharge facility numbers in the set of facilities with no flow. If a match existed, the flow was calculated assuming that the ratio of facility populations was equal to the ratio of facility flows. This process of calculating flows was performed for all facilities indicating zero flow for both the total flow and the industrial flow. After all the regional treatment plants were compared to the zero flow facilities, the number of independent facilities with all the necessary information for further evaluation was further reduced to 15,484.

E.4 REFERENCES

U.S. Environmental Protection Agency (U.S. EPA). 1992. 1992 Needs Survey User's Manual. Office of Wastewater Management. Municipal Support Division. Washington, DC. February.

U.S. Environmental Protection Agency (U.S. EPA). 1997. 1996 Clean Water Needs Survey Report to Congress and associated 1996 Needs Survey Database. Office of Water, Washington, D.C. EPA 832-R-97-003. September.

APPENDIX F

U.S. EPA NEEDS SURVEY DATA FIELDS USED

APPENDIX F

U.S. EPA NEEDS SURVEY DATA FIELDS USED

FIELD NAME	DESCRIPTION
FACID	Authority/Facility Number
FACNAME	Facility Name
CITYNAM	City Name
STATE	Alphabetic State Code
PRESNAT	Present Facility Type
PROJNAT	Projected Facility Type
FACCHNG	Facility Change
NEDIIIA	Cost estimate required to satisfy the category IIIA needs for 2012 population
NEDIIIB	Cost estimate required to satisfy the category IIIB needs for 2012 population
DOCIIIA	Documentation for Category IIIA Need
DOCIIIB	Documentation for Category IIIB Need
DOCTITL	Documentation Title
DOCAUTH	Documentation Author
DOCDATE	Documentation Date
PPRRT	Present Resident Population Receiving Treatment
PFRRT	Future Resident Population Receiving Treatment
PPRRC	Present Resident Population Receiving Collection
PFRRC	Future Resident Population Receiving Collection
PPRTANT	Present Resident Treatment Service Population
PPNTANT	Present Nonresident Treatment Service Population
PFRTANT	Future Resident Treatment Service Population
PFNTANT	Future Nonresident Treatment Service Population
PPRCANC	Present Resident Collection Service Population
PFRCANC	Future Resident Collection Service Population
FEXTOT	Total Existing Flow (MGD)
FPDTOT	Total Present Design Flow (MGD)
FFDTOT	Total Future Design Flow (MGD)
FEXIND	Existing Industrial Flow (MGD)
FPDIND	Present Design Industrial Flow (MGD)
FFDIND	Future Design Industrial Flow (MGD)
DISCHRG	Facility Discharged To

APPENDIX G

SSO JUNE, 1997 COST/BENEFIT ANALYSIS REPORT COMMENTS AND EPA RESPONSES

APPENDIX G

SSO JUNE, 1997 COST/BENEFIT ANALYSIS REPORT

Comments Raising Technical Issues

Model

1) Section 4.3.1.3 describes the use of an "optimization routine" to find the least costly solution from the combination of storage, sewer rehabilitation, and increased treatment capacity to reduce wet weather overflows. The "trial and error" optimization method used is not appropriate. The methodology outlined in the optimization routine needs to be described in greater detail and presented for peer review. (WEF)

   Response: A more detailed description of the optimization routine is included in the final report. This description was included in a previous draft report (*Sanitary Sewer Overflow Cost/Benefit Analysis, Phase I: Development of a Cost Estimating Methodology and Scoping Analysis of Benefits*, September 30, 1995). The cost/benefit analysis has received peer review from an Expert Panel throughout its development, and has gone through an extensive public comment process.

2) Page 4-28/Figure 4-12: The figure does not match its corresponding curve in Appendix G. (AMSA/NLC)

   Response: Figure 4-3 (previously Figure 4-12) has been revised.

3) Section 4.3.2/Model Adjustments and Calibration: Much of the information is arbitrary. Information accurately representing actual conditions should be developed. (AMSA/NLC)

   Response: The cost model has been revised since the June 1997 draft report. Section 4.3.2 has been modified to discuss the model adjustment and calibration efforts for the revised model.

4) Page 4-30/Table 4-2: For the calibration communities, for the three Kansas facilities the facility plan capital costs are actually completed project costs. These costs did not eliminate all the SSOs, but eliminated uncontrolled SSOs in less than a 10-yr storm while allowing the extensive use of controlled and treated SSOs in substantially less than 10-yr storms. These wastewater treatment facilities activate about four times per year, so it may not be accurate to say the facility plan costs "addressed" SSOs. (AMSA/NLC)

   Response: A footnote has been added to Table 4-2 to provide further explanation.

5) It is not clear if the model takes into account the variability of flow in the sewer system and treatment plant and the hydrograph of the I/I flow to the sewer system. It seems that a number of variables are averaged in the methodology. Since several variables are difficult to account for, a model-free regression analysis might be considered (as was done in the Penn Hills and Plum Borough cases). The best fit line was drawn for the frequency of rain storm events verses the required size of the holding tank to contain the SSO low at a given location in the sewer system. For Penn Hills, the size of the tanks required for a 2-yr 24-hr storm was determined with this method by drawing the 95% confidence bands for the plot and selecting the tank size corresponding to the upper band at the 2-yr event. (EPA Region 3)

For this method, a problem is that, for a given size tank, a different number of bypasses was determined for each year the simulation was done. Should one say that the average or maximum number of bypasses should be used in determining the compliance level expected in such a system? Using the regression analysis for the Penn Hills example, the compliance level would be no discharge in a 2-yr storm (i.e., a discharge once every two years). (EPA Region 3)

Response: This is a national SSO abatement cost estimate. The national capital cost model cannot be used to estimate compliance targets or costs of individual projects. The analysis does not account for the variability of flow in the sewer system and treatment plant. The model-free regression analysis suggested seems too complex for an analysis of 15,000 communities. However, this analysis and various other analytical methods may be useful for evaluating individual cases. A footnote making this point has been added to the report.

SSO Treatment

6) The cost model should include direct treatment of SSOs as well as storage for the network cost components. Other direct treatment technologies should be considered. (WEF)

Response: Direct treatment of SSOs at wet weather facilities is included as an option in the final report.

O&M

7) **Costs:** O&M costs for storage/treatment and bleedback impacts of stored flows on the POTW need to be included. (WEF)

The O&M cost of treating any RDI/I that is not removed but captured and transported for treatment needs to be included (if not already included). (City of Lima)

Response: While a POTW may incur additional O&M costs for treating stored flows, these costs will be offset by reduced stress on the overall collection system from installing storage and reducing stress/damage to potential overflow points. Quantifying increased O&M costs from treating stored flows would also necessitate quantifying the offsetting impact of reduced levels of stress on the collection and treatment system. Because of the offsetting nature of the impacts and the complexities involved in quantifying these impacts, the report does not address this issue. This issue could be investigated during the regulatory impact phase of the analysis.

8) The O&M tasks and frequency of performance, used to develop the cost estimates in Table 4.3, may not adequately describe the level of effort for a system suffering from both dry weather and significant wet weather overflows. In the context of this report, enhanced O&M is for wet weather SSO abatement; however, backups and manhole overflows can be a primarily dry weather phenomena. (WSSC)

Response: It is correct that backups and manhole overflows can occur during either dry or wet weather. The O&M model identifies activities (e.g., sewer cleaning) that will reduce backups and overflows during both dry weather and wet weather conditions.

9) The frequencies for some of the O&M tasks (% of system receiving root removal, joint testing/repair, and manhole inspection/repair) in Table 4-3 seem low. (Ginny Kibler) Once per 100 years seems too little to obtain results. Suggest increase to 2-3 times as often. (John Mancini)

Response: Additional data on current O&M practices have been evaluated and compared with the Table 4-3 frequencies (which were agreed to by the Expert Panel). Based on this evaluation and the above comments, the frequencies for the three tasks mentioned in the comment have been changed from 1% to 2% (twice as often for all the tasks that had a once per 100 years frequency). Based on data from three studies, the frequency for television inspections has also been increased (from 2% to 4%). References to the studies are included in the final report.

10) Disagree with using a hard and fast rule for cleaning an entire system every 12 years, since cleaning should be done more frequently in areas with recurring problems and less frequently where problems seldom, if ever, occur. (AMSA/NLC)

Response: The assumed parameters in the O&M model are not intended to be "hard and fast" rules, but rough projections on national average values. A predictive preventive maintenance approach for a given city may result in higher cleaning frequencies in some parts of the system and lower frequencies in other parts. The goal is to try to estimate a national average value. The frequencies for the O&M tasks in Table 4-3 were agreed upon by the Expert Panel and compared with data from studies (e.g., California State University- Sacramento study).

11) **Costs:** Page 4-32/Table 4-3 - Does the manhole inspection and repair cost of $90 include manholes that are inspected but do not need repair? If not (i.e., only includes manholes that need repair), the unit cost is too low. (City of Lima) The unit costs identified in Table 4-3 appear low for all categories. (City of Columbus)

Response: The unit costs were determined in consultation with the Expert Panel and have been checked against data from five studies. Study data on costs are consistent with the unit cost in Table 4-3 for jet cleaning, and indicate that $1.00/linear foot is more appropriate than $1.50 for the unit cost of television inspections. There are limited data on the unit costs for root removal, joint testing/repair, and manhole inspection/repair, so the costs recommended by the Expert Panel for these tasks have been retained. Manhole unit costs include those manholes that are inspected but do not need repair. Costs may very greatly depending on the amount of rehabilitation that is done. References to the studies are included in the final report.

12) **Costs:** Page 5-6 - "Using one estimate of cost for all flow scenarios is probably only a very rough approach because O&M costs may increase in tandem with increased capital costs (up to a point)..." - consider 5-15% of capital and O&M as additional to O&M costs in Table 4-3. (John Mancini)

Costs: Table 5-2 - It is doubtful that O&M costs will remain constant regardless of rainfall event scenario. O&M costs for the prevention of SSOs to a lower frequency per year would likely be higher than those associated with the prevention of SSOs to a higher frequency per year. Strongly believe that the analysis needs to account for the variations in O&M costs that are likely to be experienced with increased emphasis on controlling SSOs. (AMSA/NLC)

Response: Many O&M procedures are done for dry weather, so only part of the O&M costs would be attributed to abatement of wet weather SSOs and thus only this portion would considered for any variance across overflow event scenarios. Because of the intermittent nature of storm events, O&M costs associated with wet weather facilities were not considered significant since these facilities would only activate a few times per year. In addition these facilities can be designed for low maintenance and minimal operator involvement (e.g., RTBs in Michigan). Therefore, these costs would only vary a small amount across the different scenarios. However, since cumulative costs for all O&M activities would show more variance across all scenarios, future analysis will add a fraction to costs based on the present worth of 20 years of O&M costs.

Baseline

13) Section 5.5 is overly optimistic regarding assumptions for baseline initiatives. It is likely that only a limited number of sewer systems will undergo comprehensive hydraulic evaluations and corrective facility plan development/implementation without a National policy. (WEF)

Response: The Agency's policy on estimating compliance needs always looks at going from current conditions to 100% compliance. Our experience indicates that hydraulic analysis is a very cost effective way of reducing SSOs. At the time of this report, there was no information as to how many systems would undergo comprehensive hydraulic evaluations and corrective facility plan development/implementation. Projected outlays were used as a very general surrogate in pointing out that in the absence of a National Policy, enforcement or other impetus for SSO correction would not be nil. The report does not attempt to estimate enforcement or compliance rates. Baseline initiatives will be evaluated in more detail in the regulatory impact analysis process.

14) Page 5-11: For baseline, how would the consideration of "regulatory actions...taken by the States and EPA in the absence of a National policy" be developed? This might require site-specific water quality benefits. The core for this is weak, so it should be dropped. (John Mancini)

Response: This document has been rewritten to focus primarily on the estimated national costs and benefits of improving sanitary sewer collection systems from their existing conditions to full compliance with existing Clean Water Act requirements. As such, this document supplements EPA's Needs Survey report which estimates municipal water pollution control infrastructure needs. EPA will develop a separate economic analysis document (formerly called a regulatory impact analysis) to evaluate the costs and benefits of potential changes to NPDES regulations for addressing SSOs and sanitary sewer collection systems.

15) Disagree that all sewers replaced at the end of their design life (50 years) will be designed to have NO wet weather overflows. Replacements are often made to address structural problems, not wet weather capacity issues. (WEF)

Page 5-11: Strongly disagree with the "zeroing" out of the cost for sewer replacement. These costs should not be considered zero. Also a brand new system will deteriorate over time to the point of having SSOs. This needs to be included in the discussion, as well as the design of sewer systems (to provide for overflow points). (AMSA/NLC)

Page 5-11: Do not agree with assumption that sewers are automatically replaced at 50 years of age; they are generally replaced due to structural failure or because they are undersized, but not due to age. (City of Lima)

Response: While sewers may not be replaced automatically every 50 years, the costs for upgrades resulting from normal wear and tear and rehabilitation costs attributable to age need to be incorporated in the baseline analysis. This was one way to look at potential baseline scenarios. Baseline issues and the specific costs of various options, as well as issues pertaining to design life, will be addressed in the separate regulatory impact analysis phase.

16) In Section 5.5.1, baselines of 0.5 (2 yr storm) and 0.2 (5 yr storm) rainfall event scenarios were used

to account for compliance levels in absence of a national SSO policy. Figure 5-1 shows that at 0.2 events/yr and fewer, the capital cost curve becomes asymptotic, yielding potentially imprecise estimates and raising concerns about the validity and accuracy of costs. The 0.2 event may be unattainable on a national scale. (WSSC)

Figure 5-1 shows an exponential increase in cost to achieve lower numbers of SSO events per year (from 7 events per year down to zero). However, most communities have many more SSO events per year (some even in the hundreds, based on data cited in the report) so it may be more appropriate and accurate to develop costs that extend the number of events to 500 per year and see what communities will spend to reach the proposed baseline range. It would be more appropriate for a community's baseline to be what it is for them today. (AMSA/NLC)

Response: The model was developed to estimate the cost of reducing system overflow events for each sanitary sewer system to various levels, including one overflow every five years (0.2/yr), one overflow every two years (0.5/yr), one overflow per year, and five overflows per year. A system overflow event is defined as a rainfall event that causes at least one overflow in a system, regardless of the total number of individual locations where SSOs occur. If a single rainfall event causes SSOs for more than one day, this would be counted as one SSO. The estimate does not address dry weather SSOs that can result from pipe blockages and occur at a distinct point in a sanitary sewer system. Given this definition, a system could not have 500 SSO events in a year. It is agreed that, because the slope of the cost curve is so great, the estimates from the capital cost model become increasingly inaccurate as the level of system overflow events drops below one every five years (0.2/yr). The commenter is invited to submit data supporting the assertion that 0.2 system overflow events per year is unattainable on a national scale.

17) Support the consideration of different storm events, but cannot support limiting overflows on a system wide basis to one or even five rainfall events per year. Duration of a rainfall event is more important than frequency, but that does not seem to be considered in the analysis. Establishing SSO abatement on a three month storm design basis would only slightly increase costs yet likely produce substantial benefits. (Municipal Caucus)

Response: This report does not recommend national "design" frequencies. Rather, this report is intended to support policy and regulatory decisions by presenting cost and benefit estimates for the range of alternatives potentially considered. The comment has been noted and will be considered during policy and regulatory decision-making processes.

18) Page 5-13: Using baselines of 0.5 and 0.2 rainfall event scenarios is arbitrary. Suggest that this should be regional and perhaps site specific for the actual policy. Why not use five rainfall events per year unless there are water use impacts? (John Mancini)

Cities need to have the flexibility to look at the level of control from an individual watershed viewpoint and set the goal for the number of (rain) events allowable on the basis of what and which control efforts provide the greatest benefit for the least cost, rather than prescribing a nationwide goal that requires a specific level of effort for everyone. (AMSA/NLC)

Response: This report does not recommend national "design" frequencies. Rather, this report is intended to support policy and regulatory decisions by presenting cost and benefit estimates for the range of alternatives potentially considered. The comment has been noted and will be considered during policy and regulatory decision-making processes.

19) Not enough emphasis is placed on the relationship of water quality to SSO abatement and the reasonable use attainment of the receiving waters. (AMSA/NLC, City of Columbus)

Response: The June, 1997 draft only addressed the costs of SSO abatement. The benefit analysis has been added to this version of the report and addresses the issue raised by the comment.

20) Page 5-14: "Based on the 'best professional judgement' of the expert review panel, $46 million (20 percent)...is currently being spent for SSO abatement by systems serving a population of 75,000 or more..." Did the panel really say this? (John Mancini)

Response: The Expert Panel estimated that municipalities currently conduct about 20% of the O&M that is estimated by the model O&M scenario. This 20% of the projected total cost for the model O&M scenario amounts to $46 million.

21) Page 5-14: Why are there still incremental O&M costs if it is assumed that SSOs will be controlled to at least the 5-year design storm without a national Policy? What are the benefits to the additional O&M? (John Mancini)

Response: Incremental O&M is intended to address SSOs that are not entirely wet weather events, such as repair of lines and ensuring pump station reliability.

22) Page 5-14: The assumptions of a baseline of a 5-year design storm and a compliance level of a 10-year design storm need to be seriously assessed and discussed further. (John Mancini)

Response: Baseline issues will be addressed during the separate regulatory impact analysis phase.

23) Need to recognize that existing infrastructure continues to degrade, so while existing expenditures will lessen I/I from some areas of a sewer system, normal wear and tear will result in increases from other parts of the system. Rather than assuming existing and proposed expenditures by utilities will improve the SSO situation, it would be a more reasonable baseline to assume that existing expenditures will keep SSO frequency about the same. (AMSA/NLC)

Response: It appears that this assumption would imply that all of the future investments on SSOs are simply to maintain the status quo. If this perspective is taken for baseline analysis, it will be addressed during the regulatory impact phase of the analysis.

Affirmative Defense

24) Page 1-2: There are no cost estimates in the report specific to raising the affirmative defense, including alternative scenarios for frequency in which the affirmative defense would be allowed. (WEF, AMSA/NLC)

Response: An affirmative defense could potentially look at criteria such as SSOs caused by extreme weather conditions or those SSOs that occur even though good O&M measures are used. While addressing all the criteria that may be considered under an affirmative defense is beyond the scope of this report, some of the potential criteria are considered. When developing baseline scenarios, an affirmative defense will be addressed by evaluating the costs and estimating corresponding frequencies at which affirmative defense-type of SSOs might be occurring. Linking the model's result to a national policy will occur during the regulatory impact analysis phase of the analysis.

I/I

25) Page 3-3/Figure 3-1: Definitions of "direct inflow" and "rain induced I/I" expressed graphically are outdated. Rain induced I/I may begin as an immediate response to rainfall. The distinction between "direct inflow" and "rain induced inflow" is not explained in the report and is not necessary. The use of "rainfall induced infiltration" is also incorrect as describing the area labeled on the figure as "rain induced I/I" since inflow must last as least as long as the rainfall period plus the time of concentration of the contributing area. The area of the graph labeled "direct inflow" should be deleted and this area included as "rainfall induced I/I." Delete label "peak inflow". (WEF #22)

Figure 3-1: The figure appears to be mislabeled and misdrawn: indication of peak inflow, double labeling of the cross-hatched area as direct inflow and direct inflow plus rainflow-induced infiltration, and the position of the dashed line to the edge of the direct inflow area. (AMSA/NLC)

Response: Figure 3-1 has been revised.

26) Section 4.2.1/Page 4-3: Discussion of I/I coefficient is weak with little substantive data. (Bud Curtis)

Response: The I/I coefficient is discussed further in Section 4.2.3.2.

27) Page 4-8/Figure 4-3: The correlation coefficient for this relationship should be presented. (WEF #32, AMSA/NLC)

Response: The correlation coefficient for the population/area relationship is 0.62 and has been added to the text that explains the figure.

28) Pages 4-8 & 4-9: More justification is needed for the I/I coefficient (1 to 5%), which seems too low. Was a sensitivity analysis conducted on this parameter with the overall results of the calibration on 17 communities? Further explain this. (WEF #33)

Some collection systems have I/I during significant storm events that increase the flow 200% or more. Limiting the I/I coefficient to a high of 5% does not adequately address these systems. (MD DoE)

An I/I coefficient of 6-10% is advocated in the text, while the model uses 1-5%. The text advocated value seems more reasonable, but more justification is needed for the selection of the final value and the inconsistency needs to be cleared up. (AMSA/NLC)

Response: As explained in the report, the I/I coefficients are applied on a system-wide basis and therefore reflect the condition of the collection system as a whole, not just those areas with the most extreme I/I problems. I/I coefficient values were calculated assuming a constant relationship between I/I coefficient and average per capita non-industrial flow for each municipality, and were revised during the latest model calibration with assistance from members of the Expert Panel. A sensitivity analysis on the three principal system parameters (existing I/I coefficient, existing storage capacity, and existing treatment capacity) was conducted.

29) Page 4-10: Should revisit the assumption that systems with greater than two to three times the typical per capita non-industrial flows be excluded from the data set as inaccurate. The higher values may not be as common but they certainly have been documented and confirmed in previous

work. (AMSA/NLC)

Response: The systems with greater than two to three times the typical per capita non-industrial flows were not excluded from the cost model; rather their calculated I/I coefficients were limited to the model maximum of 0.05, instead of allowing the higher values that would have resulted from their flow data. The explanation has been clarified in the report.

30) The analysis sets the value for typical per capita non-industrial flows without the influence of I/I at 70 gpd, but this is not typical for some systems in Maryland. (MD DoE)

Response: The rate of 70 gpd was used only in the development of the model as a reference point; whether this number is high or low has no bearing on the overall estimate.

31) Page 4-26: Pilot level estimates should not be necessary for rehabilitation. In addition, R value reductions of 50% seem too high (see page 3-17). (WEF #43)

I/I reduction of 30% is mentioned as the maximum realistic reduction in the text, but the model assumes 50% I/I reduction. The text value seems more reasonable. The inconsistency needs to be resolved and the value used in the model justified. (AMSA/NLC)

The draft does not adequately address problems associated with privately-owned portions of the sewage collection system (i.e., service laterals) and therefore overestimates removal of storm water/infiltration/inflow sources from the sanitary sewer system. (City of Columbus)

Response: The term "pilot" was incorrectly used and thus misleading, so it has been deleted from the paragraph referenced in the comment. After the Expert Panel review in November 1996, the model was revised to reflect a maximum of 60 percent I/I reduction for the maximum unit cost. This was based on actual results from case studies and reflects the fact that the model addresses wet weather SSOs which occur during the peak flows caused by rainfall dependent I/I entering the system. The text in the final report has been revised to reflect the 60 percent maximum reduction.

32) **Costs** - Page 4-26: $80 per foot seems too high for sewer rehabilitation since costs have decreased in past few years with improved methodologies. (WEF #43, Bud Curtis) Recent cost in the Virginia area have been $40-60 per foot for rehabilitation of 8, 10, and 12" pipes. (Bud Curtis) The sanitary sewer system rehabilitation formula appears to be flawed. Also, the assumption of $80 per foot for an average rehabilitation cost for all sewers seems low. (City of Columbus)

Response: The Expert Panel provided the case studies to support this analysis.

33) Page 4-26: Need to clarify whether the rehabilitation costs of $80/lf accounts for any private I/I removal and engineering fees. (AMSA/NLC)

Response: The $80/lf cost used was for comprehensive rehabilitation, which can include private source reduction to some extent. Engineering fees are not included.

34) Page 4-26: Once sewer rehabilitation has been completed, the system tends to start leaking again until an equilibrium is reached with the topography and ground conditions that exist at the location of the sewer system. Rehabilitation has to be maintained to prevent this leaking, but the equation for rehabilitation cost does not appear to take this into account. (EPA Region 3)

Response: The comprehensive rehabilitation efforts considered by the model include a range of activities (e.g., root removal, spot repairs) that overall have an average anticipated design life of 20 years.

Wet Weather Treatment Capacities

35) Page 4-10: Need to explain the basis for using 80% of annual average flow for dry weather flow. (WEF #34)

The assumption that dry weather flow is approximately 80% of the average annual flow is not valid for many systems. (MD DoE)

Response: The model required an estimate of the amount of available treatment capacity at a treatment facility prior to a wet weather event. The model assumes that, prior to a wet weather event, a treatment plant is operating at 80 percent of its *average annual (recorded) flow* as indicated on the Clean Water Needs Survey database. To determine the available treatment capacity, a peaking factor (variable based on plant capacity) is multiplied by the *design average flow* as indicated in the Needs Survey database. The difference between the two values represents the capacity available to handle the increased flow during wet weather. Although some plants may have a dry weather flow greater or less than 80 percent of the average recorded flow, this value is a reasonable average across all facilities. In addition, changing this parameter would have little effect on the estimated model costs.

36) **Costs** - Page 4-25: Costs for wet weather treatment should be provided in $/gpd of treatment rate, not $/gallon of tank volume. (WEF #41, AMSA/NLC)

Response: Costs for secondary treatment are based on the tankage volume (gallons) required to provide a minimum detention time for a given treatment flow rate (gpd).

37) In the Carolinas, the cost is closer to $3-5 per gallon treated. (AMSA/NLC)

Response: The $1/gallon cost is for adding capacity to an existing facility, and refers only to secondary treatment facilities. The cost is per gallon of aeration basin volume that is required to provide a 6 hour minimum detention time to a given flow rate, not per gallon treated. Calibration of the model showed that cost of treatment has very little effect on the national estimate. Additional storage capacity and I/I reduction tend to be more cost-effective means of abatement.

38) Page 4-25: It is incorrect to assume that the first choice for technology at a wet weather facility would be secondary treatment. (WEF #42)

In assessing SSO control costs, the parameters used assume that wet weather treatment will use secondary treatment technology. Houston is constructing three upstream WWFs that will be operated under NPDES authority and do not have secondary treatment because of insignificant impact to receiving water. Need to further discuss the cost of facilities that are permitted to discharge wet weather flows after primary clarification, odor control, and removal of floatables. (AMSA/NLC)

Response: The first choice for treatment at proposed wet weather facilities will be primary clarification not secondary treatment. The section referred to in the comments pertains to increasing POTW treatment capacity for handling wet weather flows. The comment confuses wet weather treatment capacity from the cost/abatement model, which refers to wastewater treatment plant capacity, with treatment of SSOs themselves at overflow points in the collection system. Wet weather treatment capacity in the cost/abatement model, as discussed in Section 4, refers to the treatment plant to which the collection system discharges, and is assumed to include secondary treatment. A primary treatment cost curve was used temporarily as a calibration attempt, but the final model configuration reverted back to the original secondary treatment cost curve. Treatment of SSOs themselves would involve remote facilities at the overflow point. SSO treatment is considered as an option for some municipalities and is described in the final report.

39) Pg 4-25: It seems odd that the cost for tankage at a secondary plant is less than for storage, on a per gallon basis. (WEF #42)

Response: The equations for estimating costs were developed from documented cost curves based on actual data. In addition, these two costs are not directly comparable. Treatment costs in the model are for aeration tankage with appurtenances, and are in terms of cost per volume. The treatment capacity of this volume was based on a 6-hour detention time. Per the direction of the Expert Panel, cost estimates were made with the model using costs for preliminary and primary treatment. Cost curves for preliminary and primary treatment were based on flow rate rather than volume. The model runs using the alternative cost curves showed that the modification had little impact on the estimated costs.

Storage Capacities

40) Section 4.2.3.4: Only the volume of the sewer below the first SSO point in elevation will be available for storage since any volume above the first SSO point will only add to the total quantity discharged from the SSO. Therefore, it is doubtful that the full length of interceptor sewers in a system is available for storage. (AMSA/NLC)

Response: This is likely true for some actual systems, however the unique configurations of individual systems are not taken into account by the model. The model assumes only one theoretical overflow point per system. This assumption, as well as other assumptions used in the model, were checked during the calibration process and adjusted, as appropriate, to improve the model calibration.

41) In Figures 4-6, 4-7, and 4-8, the information is very widely dispersed. It is hard to imagine how a single line can properly represent the bulk of information presented in the figures. (AMSA/NLC)

Response: It is acknowledged that the information is widely dispersed, but it was necessary to determine the regression relationships nonetheless given that specific system parameters (such as total interceptor sewer length) are not available from the 1996 Needs Survey database. These regression relationships were evaluated during the calibration process and adjusted, as appropriate, to improve the calibration.

42) Page 4-16, first paragraph: Which relationships are referred to in saying "...the above relationships are used...?" (WEF #36)

Response: The relationships referred to on page 4-16 are described in Figures 4-6 and 4-7. A reference has been added in the text to clarify this.

43) **Costs** - Page 4-25: Only $2.12 per gallon for less than 5 million gallons seems too low for most cities. (WEF #40)

Costs - Page 4-25: SSO control costs can vary widely for the same activity. For flow storage costs, one AMSA agency reported an overestimation of costs by the formula used by the model: for a 205 MG holding facility, the in-house estimate was $16 million while the model equation estimated $185 million. For another agency with 115 million gallons of flow equalization storage, the cost model equation gives $104 million, 40% less than the agency's own estimate of $173 million. (AMSA/NLC)

Response: The construction cost function is based on the references cited in the text surrounding the equation. As noted in the comment, site specific cost estimates can vary greatly from those generated by the cost model for individual facilities. However these functions were used to develop national cost estimates, thus variances from facility to facility tend to cancel each other out to a large degree.

44) Most systems that have installed flow equalization find it to be a significant O&M problem. The SSO O&M Work Group thought this type of solution should be a last resort. (Bud Curtis)

Response: It is recognized that there are O&M costs associated with flow equalization storage. However, storage facilities would only be used during wet weather events. Given the intermittent nature of wet weather events, storage facilities may require significant operator attention on only a limited number of days per year. These costs could be considered during the economic analysis phase.

Rainfall Regions

45) Page 4-18: For Portland, did the model only use the separate sewered area? (WEF # 37)

Response: The only specific data used from Portland were rainfall. The text has been clarified in the final report.

46) Page 4-19/Figure 4-9: Rainfall region map is flawed - it links rainfall in Houston (56 in/yr) with rainfall in Midland (14 in/yr). (WEF # 38)

The U.S. should be divided into several more regions to properly apply cost estimates to SSO abatement. (AMSA/NLC)

Response: The draft report recognized that the rainfall regions used in the model development were large and that significant variation could occur within a region. The locations cited in this comment are in Region 3. For this region, 55 years of rainfall data for Fort Worth, TX were analyzed, resulting in an average annual precipitation of 26.6 inches.

SSO Studies

47) Page 3-13: Need more explanation of Sacramento County study - what type of system and pipes were involved? Was 1974 the base year? Needs more explanation. (WEF #28, Bud Curtis)

Response: A more detailed description of the Sacramento County study was not available in the source document. However, the text in the final report has been slightly revised to provide additional clarity.

48) Page 3-16: Have the O&M costs in Figure 3-3 been adjusted for inflation? If not, this could account for much of the increase. If so, state the base year and that costs have been adjusted. (WEF #29)

Response: The O&M costs in Figure 3-3 were not adjusted for inflation. The data simply indicate a marked increase in spending after about 1980 by the communities surveyed, when the average system was 30 years old. Refer to reference cited for more information.

Costs

49) Page 5-13/Table 5-5a: Table contains the cost for a 0.1 rainfall event scenario, derived by simple extrapolation. Did the extrapolation consider the exponential cost increases (shown in Figure 5-1)? (WEF #45)

Up to Table 5-4, the most severe storm criteria is the 5-yr (0.2 failures/yr), but then the discussion jumps to the 10-yr storm. Table 5-5a states that the 0.1 rainfall event (10-yr storm) was derived using a simple extrapolation. More explanation is needed, particularly since Figure 5-1 shows it would be difficult to interpolate between 0.0 and 0.2. (AMSA/NLC)

Response:, The purpose of the interpolation was to present a general convention for evaluating baseline and incremental costs. The exponential nature of the curve does indeed affect any interpolations and will be considered when baseline issues are addressed in the regulatory impact analysis phase.

50) Section 3.4.3 indicates that the present value of benefits was calculated using a lower discount rate than that used for calculating the present value of costs, leaving the perception that benefits are overestimated by the analysis. The rationale for using different discount rates needs to be better explained and justified. (California State Water Resources Control Board)

Response: **INPUT IS NEEDED FROM EPA (NORBERT) AND/OR ERG AS TO WHY 3% AND 7% WERE USED FOR THE DISCOUNT RATES FOR BENEFITS AND COSTS, RESPECTIVELY. THE METHOD NEEDS TO BE JUSTIFIED TO RESPOND TO THE COMMENT.**

51) Page 3-20: The lifetime of most structural sewerage facilities is generally considered to be 40 to 50 years, not 20 years. (City of Columbus)

Response: The cost estimating model estimates costs for sewer rehabilitation, expanding treatment, and increased storage. These are typically retrofit measures to existing sewerage systems. Assuming a 20-year discounting period is a reasonable period for these retrofit measures. In developing the economic analysis for any potential rule, EPA may vary discounting periods and interest rates as part of its analyses.

52) Section 3.4.3.1: Need better explanation of opportunity cost and decision to use 7%. (AMSA/NLC)

Response: The 7% interest rate is based on OMB guidance (OMB Circular No. A-94, October 29, 1992. "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs"). Opportunity cost is also explained in the circular.

53) Page 5-2/Figure 5-1: Think the capital cost is underestimated because the model does not account for snow melt, high water table, flow limited sewer lines, the peaking flow in the hydrograph of I/I

flow to the sewer system, and possibly the variation of the flow in the sewer system. Also, the rate of decrease in costs is too large in the range near the zero rainfall event. The behavior of the curve may be governed by the increase in the rainfall amounts with reduction in the rainfall frequency. This should only increase in a logarithmic manner. (EPA Region 3)

Response: The model does not account for the factors noted. However, it is important to note that the model was developed to estimate a national abatement cost. The model does account for geographic differences in the rainfall analysis. The model was calibrated against data from actual communities with facility plan capital costs for SSO abatement and adjusted, as appropriate, to reasonably approximate actual costs.

54) Cost estimates for the CSO program were low across-the-board and the SSO abatement costs appear to be following the same scenario. (City of Columbus)

Response: The estimates of capital costs associated with addressing wet weather flows were compared with available information from case studies. This comparison showed good agreement between estimated costs and known actual costs. The estimates of O&M are based on best professional judgement estimates and have been reviewed in light of information received from commenters, as well as information from a national survey conducted by the California State University - Sacramento. To improve the estimates, reviewers are encouraged to submit additional factual information on case studies with actual costs.

Other

55) The analysis does not consider situations where separated sewers are located upstream of combined sewers, which is probably fairly common. (City of Lima)

Response: The analysis included only those systems with the following classification categories in the EPA Needs Survey database: treatment system with separate sewers, collection system with separate sewers, and interim treatment system with separate sewers. Since no category exists for systems with both combined and separate sewers, only such systems classified as one of the above categories has been included in the analysis. It is expected, however, that in most cases such systems would be classified as combined systems, and therefore not included. It is not possible to discern from the database whether a system classified as combined includes separate sewers, nor whether a system classified as separate includes combined sewers.

56) There were so many assumptions, with many of them biased to conservative estimates (see above I/I comments), that the final results could be dramatically different for certain systems if actual data were used instead of suggested default values. Perhaps the analysis should allow for the use of actual values on a case by case basis instead of attempting to force the myriad of different systems into a limited range. (MD DoE)

Response: As part of the modeling process, values assumed for certain model parameters, such as I/I coefficients, were analyzed and assessed for accuracy using actual data for a set of calibration communities. The assumed values for various parameters were adjusted, as appropriate, to develop a better calibrated model. However, this is a national estimate and SSO control costs for some individual communities will differ from more detailed analyses. It is impossible to obtain individual data for 18,000 systems.

57) The case studies should be expanded from the original five communities and should include as many different systems as possible. Some large, older cities in the Northeast (e.g., New York, Philadelphia, Boston, or Baltimore) should be included. There may be significant differences between areas serving populations of 75,000 and those serving 750,000 or many million people. A more comprehensive background of case studies is needed to establish credibility of the cost/benefit analysis. (MD DoE)

The use of limited data from only a few specific cities and sewer districts does not accurately depict the majority of sewer districts in the U.S. Additional information is needed to refine the values used to calculate costs. Several AMSA agencies have offered to provide data on costs. (AMSA/NLC)

Response: The case studies represented the most comprehensive selection of communities (with sufficient data) available to EPA. Commenters are invited to submit relevant data for additional communities.

58) If the cost analysis is to address "key regulatory options for addressing SSOs," it should be representative of a larger number of systems (not just those serving populations greater than 75,000). (WEF)

Response: The final report addresses all separate sanitary sewer systems.

Comments Raising Non-Technical, Non-Editorial Issues, Including Policy Issues

Definitions

1) **SSOs:** The report consistently uses terminology such as "discharges from uncontrolled locations (e.g., manholes and basement backups)..." (pg 3-20) to establish the premise for these actions to be violations of the authorized NPDES permits. However, basement backups drain back into the collection system and are not discharged to "waters" of the United States and should not be NPDES permit violations. (WSSC)

   Response: This report is not intended to define which raw sewage releases or inadequate O&M are violations of the CWA. Rather, this report addresses the costs and benefits of improved design, operation, maintenance, and management of collection systems. A major indicator of improved operation of a collection system will be a reduction of discharges and releases of raw sewage from the collection system, including basement backups. The terms avoidable and unavoidable are introduced to help explain the concept that even well-operated sanitary sewer systems can experience occasional SSOs that are beyond the reasonable control of the operator. In this report, they are not intended to define liability.

2) **Unavoidable SSOs:** The criteria provided to determine unavoidable SSOs are vague and subject to interpretation. While imprecision provides a basis for negotiation of the intent, it also can contribute to inconsistency and inflexibility in enforcement by the regulatory community. It can be reasonably argued that first occurrence dry weather backups are unavoidable. For a first time backup, a utility could be placed in an untenable situation whereby it has violated a permit requirement yet was incapable of preventing it and thus not legally liable for damage under State law. (WSSC)

   Report should have a clearer definition of unavoidable discharges and strongly endorse that enforcement policy take unavoidable circumstances into account. (AMSA/NLC)

   Response: The term "unavoidable" was introduced to help explain the concept that even well-operated sanitary sewer collection systems can experience occasional SSOs that are beyond the reasonable control of the operator. This report does not attempt to recommend language for permits, regulations, or policies for defining the legal framework for defining Clean Water Act liabilities.

   Page 3-20: In the first bullet, remove the word "all" from before "feasible steps to remove I/I." (AMSA/NLC)

   Response: The term "all" was retained because often, well-operated I/I programs will take more than one approach to controlling I/I.

   Avoidable SSOs: How is "appropriate preventative maintenance" determined? Maintenance needs to get at site-specific problems as they develop. (John Mancini)

   Response: It is agreed that maintenance needs to get at site-specific problems as they develop. EPA is not intending to define national standards for preventive maintenance in this report. Rather, this discussion helps to explain the concept that even well-operated sanitary sewer collection systems can experience occasional SSOs that are beyond the reasonable control of the operator.

3) Page 1-3 footnote: Put the definition (and ramifications) of bypasses and overflows in the definition section (currently Section 3.4). (WEF)

Response: The footnote has been deleted since it longer applies; the sentence it pertained to has been revised.

4) Define "upsets" and distinguish between bypasses, upsets, and overflows to clarify whether they are used synonymously or have a different meaning. (WEF)

Salem, OR's NPDES permit uses the word "bypass" to list permitted SSO points upstream of the treatment plant. The word "overflow" is used when our pump stations are listed as overflow points, and are only allowed if caused by an upset. (AMSA/NLC)

Response: Use of the terms "upset" and "bypass" has largely been eliminated from the report.

5) Page 2-3: The terms "municipal collection system" and "satellite collection system" are used and should be defined in the definitions section in Section 3.4. A distinction should be made between satellite collection systems, municipal systems, and independent utilities. (WEF, WEF #31, AMSA/NLC)

Response: Definitions for "municipal sanitary sewer system" and "satellite collection system" have been added to the document in the key concepts/definitions section. The term "independent utility" is not a key term in the report and thus does not require a definition.

6) Use of the terms "collector sewer" and "interceptor" need to be clarified. (AMSA/NLC)

Response: Use of these terms has been reviewed to add clarification, as appropriate.

7) Page 3-19/Section 3.4: The definitions section should be moved to Section 1 since the concepts should be introduced and defined prior to being used. (WEF #31, AMSA/NLC)

Response: The key concepts/definitions section has been moved to Section 1.

8) Page 4-9: Should the definition of "F" in the I/I coefficient equation specify "dry weather flow?" (AMSA/NLC)

Response: No, F is a measure of overall average annual per capita non-industrial flow; the I/I coefficient is a measure of rainfall entering the system as I/I, so it needs to compare differences between average flow (as reported in the Needs Survey) and minimum flows (which would be associated with dry weather/low infiltration periods).

Data

9) Data in Table 2-3 are incorrect for WSSC and should be corrected by referring to the referenced report for WSSC. (WSSC)

Response: The data for WSSC were revised and clarified based on the report "Washington Suburban Sanitary Commission, 1995. Separate Sanitary Sewer Overflows, Report to the U.S. EPA."

10) In Table 2-3, the data should distinguish overflows from backups. (WSSC)

Response: The data sources used for Table 2-3 were consulted to determine if they distinguish overflows from backups. Table 2-3 has been revised according to the available data.

11) Page 3-2: Peak wet weather flow vs average dry weather flow - EPA should have much more data than from 10 case studies with all the I/I studies available. (Bud Curtis)

Response: The intent was to exhibit that a wide range of peak wet weather flow to average dry weather flow exists, which is done adequately by the 10 case studies.

12) Page 5-4: Need to formally document that the "shape of the curve in Figure 5-1 also compares well with several case studies' results..." since this may come into play in the policy area. (John Mancini)

Response: The model was calibrated using actual data from 15 case study communities. This is now noted in the text to document the statement about the curve.

13) Page 5-5: Need to better explain the difference between the estimated costs generated from the model and those estimated in the 1996 EPA Needs Survey. (WEF)

Response: The estimated costs generated by the model and the estimates in the EPA 1996 Needs Survey are not directly comparable. However, the Needs Survey estimates provide some reference to compare the SSO Cost Model's results. At the same time, EPA believes that the 1996 EPA Needs Survey estimates may not fully capture all of the costs that the SSO Cost Model predicts (i.e., I/I control, rehabilitation, increased treatment).

Policy

14) Wet weather treatment facilities should be allowed as an SSO abatement option. (Municipal Caucus)

Response: Wet weather treatment facilities are an abatement option in the final report.

15) Continue to support the provision for avoidable vs unavoidable SSOs as set forth in pages 3-19&20. The SSO Subcommittee agreed that if an SSO was unavoidable it would have to be <u>repeated</u> before proceeding to Box 3 in the SSO Management Flow Chart. The Municipal Caucus' position is that a "repeated" SSO means an avoidable SSO that occurs at one location more than four times per year. Failure to follow this principle in the cost analysis has and will result in an overstatement of the costs without providing significantly greater benefits. (Municipal Caucus)

Response: The SSO Cost model is designed to project costs to correct overflows at discrete rainfall scenarios. The levels of abatement reflect the frequency of wet weather events. The model is not designed to address specific causes, locations, or number of overflows within a system. Unavoidable SSOs, such as collapsed pipes and unforeseeable failures, are not reflected in this cost estimate. On a national scale, it would be impossible to model individual overflow points within a system, the frequency of overflow, and the cause of failure.

16) The "R" factor needs further refinement. Do not believe policy should be tied to a type of defined rainfall event or enforced on a rainfall frequency. There are too many variables (e.g., ground water, season, antecedent rainfall, type of storm). (Bud Curtis)

Response: The "R" factor was adjusted during model calibration before running the model to obtain the results in the final report. There has not been any decision to tie policy to a rainfall event. A complete set of hydrologic variables is a more precise approach, however, for national cost estimating purposes, the model considers the R factor as its primary basis for the percentage of rainfall that enters the sewer.

Other

17) Change title to "The Sanitary Sewer Overflow (SSO) Problem and a Cost/Benefit Analysis to Solve It." (DE River Basin Commission)

Response: Due to changes in the content of the report, the title has been otherwise revised.

18) There should be more emphasis on O&M. (WEF, Bud Curtis) This report does not adequately recognize the importance of proper O&M in preventing SSOs. (WEF, AMSA/NLC)

Response: The importance of proper O&M in preventing SSOs is discussed in several locations within the report (for example, refer to pp. 3-12 to 3-15, 4-29, and 5-5).

The report should take note of the difficulty local governments face in obtaining funding for O&M. (WEF, AMSA/NLC)

Response: Such funding difficulties are certainly a concern for local governments. This analysis attempts to quantify the costs and benefits of SSO abatement efforts (including O&M). Implementation issues such as funding are beyond the scope of this analysis.

Page 5-16: The Increased Operation and Maintenance section needs to advocate improved O&M practices. All stakeholders would agree that O&M is extremely important to preventing SSOs. (WEF #46)

Response: As noted above, the value of good O&M practices is discussed in Sections 3, 4, and 5 of the report.

19) Support the cost approach on an aggregate basis, but stress that the cost estimating methodology not be applied at the local level to individual sewer systems. This point should be emphasized throughout the report. (AMSA/NLC)

Response: This point has been added to the relevant places in the report (e.g., Sections 1, 4, and 5).

20) Concept of health risks and SSOs are introduced (Sections 1.3.3 and 1.3.4), but there is nothing specific on how to implement this in an SSO Policy. Basement flooding should not be treated the same as overflows to a receiving stream from a heath risk or cost prevention standpoint. The analysis should also differentiate between the health risks from wet weather vs dry weather SSOs. The first priority should be preventing dry weather SSOs. (AMSA/NLC)

Response: These concerns are addressed in the benefits portion of the analysis.

21) Page 1-5/Section 1.4: "Because the costs of increased sewer rehabilitation will be borne by all residents but the benefit may accrue to a minority..." - need to document with a reference that this actually occurs with persistent basement flooding of the same housing area. (John Mancini)

Response: Some basements have a higher risk of flooding than others. For documentation, refer to "Old Data and New Tools - Maintaining the Sewers That Need It," by Drew Hardin and Charlie

Messer, in the proceedings from the WEF specialty conference on *Collection Systems Rehabilitation and O&M: Solving Today's Problems and Meeting Tomorrow's Needs*, 1997.

22) Page 2-9: Add a conclusion to Section 2 that emphasizes the need for more attention on collection systems and SSOs.

Response: Section 2 of the report presents data supporting several general statements about sanitary sewer collection systems in the United States. These general statements and the supporting data indicate the need to better address collection systems and SSOs. EPA believes it is better to let the factual information directly show this need, rather than to add a conclusion that expresses an opinion.

23) Page 3-2: Delete paragraph beginning with "Separate sanitary sewer systems..." since it does not clarify any issue and is ambiguous. (WSSC)

Response: The paragraph has been revised to add some specificity and has been retained.

24) Page 3-5: Insert "backup(s) and" before the word "overflow(s)" all three times in the second paragraph of 3.1.3. (WSSC)

Response: The requested changes have been made.

25) Section 3.2.1.1: Sewers of brick construction are not mentioned although they constitute a substantial portion of many systems. (AMSA/NLC, City of Columbus)

Response: Brick has been added as a construction material in section 3.2.1.1.

26) Page 3-10/Section 3.2.2.2: Soil type may not matter. If any type of gravel is used as embedment material, groundwater will travel along and through the embedment material and act as a french drain, having a better chance of seeping into pipe joints and seals. (AMSA/NLC)

Response: Section 3.2.2.2 already states that sands and gravels will generally exhibit high groundwater flow which can lead to increased I/I through joints and cracks.

27) Page 3-10/Section 3.2.3.1: Term should be "diameter-inch-miles" of sewer, not "inch-miles" of sewer. (AMSA/NLC)

Response: "Inch-miles" is commonly understood in the wastewater industry to mean pipe diameter in inches multiplied by pipe length in miles, so the term does not need to be changed. However, an explanatory footnote has been added to avoid confusion.

28) Page 3-12/Section 3.2.4.2: Need to note that infiltration from foundation drains connected to the sewers is especially active and can have substantial impact on SSOs during long duration, low intensity, and multiple storm events. (AMSA/NLC)

Response: A sentence conveying the above point has been added to Section 3.2.4.2.

Section 3.2.4.2 infers that groundwater levels increase when snow melt occurs simultaneous with rainfall. However, if the ground is frozen during the rainfall event, then stream levels are impacted and only groundwater levels under the direct influence of stream levels will be impacted. Modify the section to state that only the sewer systems under I/I effects from increased stream levels are impacted by these conditions. (AMSA/NLC)

Response: A sentence conveying the above point has been added to Section 3.2.4.2.

The effect of groundwater on I/I which leads to SSOs does not appear to be discussed consistently throughout the document. Groundwater infiltration uses treatment capacity and it may be prudent to treat it differently than groundwater which only rises from a major storm event and then immediately recedes. (AMSA/NLC)

Response: Groundwater infiltration not induced by rainfall would be considered a component of dry weather flow, which is accounted for in the model.

29) Page 3-17: In the analysis of survey results, if the annual O&M frequencies of 6-10% of the system per year means every 10-15 years a section would be repeated, this is not consistent with Figure 3-2. (Bud Curtis)

Response: The survey results (annual inspection and maintenance frequencies of 6-10%) refer to the results of the Kansas study presented in Figure 3-3, not Figure 3-2.

30) Page 5-7/Table 5-2: Need to add some discussion on the $44 total annual cost per capita as compared to the per capita cost of $63 in Table 4-2 since the $44 includes O&M but is still 1/3 lower. (John Mancini)

Response: The per capita costs presented in Table 5-2 are for all communities, some percentage of which will have no overflows. The magnitude and distribution of populations and costs of the calibration communities are not identical to those of the whole nation, so per capita costs would not be expected to be equal. Calibration communities by nature have SSO problems severe enough to call for abatement measures, and therefore would be expected to have higher costs than the national average, as is the case.

31) Page 5-9: It is difficult to distinguish the contrasts in Figure 5-4. (WSSC)

Response: In the final report, Figure 5-4 has been changed to a table so that the information can be more clearly presented.

32) Page 5-16: Increased O&M Costs needs to be explained more; list some categories from Table 5-1. (Ginny Kibler)

Response: More discussion will be provided about increased O&M and incremental O&M costs in the separate report generated for the regulatory impact portion of the analysis (RIA).

33) Page 5-16: In the section on Increased O&M/Level of Improvement, add the following text: "A national SSO program can be effective in preventing recurrent overflows in basements or areas of the sewer system with a pattern or history of overflows. The program can require searches for overflow prone areas of the sewer system and associated remedial actions. By contrast a national SSO program will not be able to effectively or efficiently address single overflow events at isolated or changing locations in the sewer system." (John Mancini)

Response: Similar text has been inserted in Section 5 of the final report.

34) Report should offer practical guidance on how to address I/I problems originating from private sources. These problems are extremely difficult due to liability issues, so practical solutions are essential. (AMSA/NLC) More guidance on the issue of public versus private responsibility is needed. (City of Columbus)

Response: Such guidance is beyond the scope of this analysis and is better left to O&M manuals. EPA has provided funding to WEF to support development of a WEF monograph addressing I/I from private property.

35) Additional causes of SSOs should be addressed: 1) Grease, construction materials, and vandalism should be given more attention, and 2) Damages caused to sewerage facilities by storm water runoff, which can expose and wash out pipelines. These are more often spills of larger volume and greatest impact, and abatement of these conditions relate to expensive pipeline relocations, pump station installations, and remedial protection of pipelines. (AMSA/NLC) The issue of vandalism causing SSOs is not addressed. (City of Columbus)

Response: Although these causes are not specifically discussed, they are implicitly addressed in the general category of blockages and other "factors."

36) Acceptance of satellite community sewage flows without proper control of wet weather flows needs to be addresses in detail, especially when existing, long-term agreements are already in place. (AMSA/NLC, City of Columbus)

Response: Data for facilities classified as collection systems discharging to other collection systems (e.g., satellite communities) were examined during pre-processing of the Needs Survey database. The flows from these 2,632 facilities are assumed to be accounted for in the data for the receiving facility (generally classified as a regional system in the Needs Survey database). A detailed discussion of the mechanisms for controlling the wet weather flows from these communities is beyond the scope of this report.

37) There is no discussion relative to the fact that just because an overflow point or cross-connection exists does not mean that it is active and actually discharges to receiving waters. (City of Columbus)

Response: EPA recognizes that some emergency overflows have not discharged for an extended period of time. This report does not address the issue of constructed emergency overflow structures that are located in accordance with good engineering practices.

38) Exposure to raw sewage in a basement is more hazardous to an individual's health than exposure to diluted sewage in the receiving water; the contaminated receiving water can be avoided, while basement contamination cannot. Additional consideration should be given to the issue of basement flooding. (City of Columbus)

Response: This is addressed in the benefits portion of the report.

Page 1-1: At what point do problems with the operation of a wastewater collection system change from being a nuisance to a public health problem? (City of Columbus)

Response: The risks from SSOs are characterized, from a national perspective, in the benefits section of the report, however, distinguishing between "nuisance" and "public health problem" is beyond the scope of this report.

39) Page 1-6: Does the "general public" agree on the "optimal quantity and quality" that makes up a "clean environment?" We do not agree with the assumption, as various members of the group making up the general public do not have the same priorities for how their tax and rate dollars should be spent. (City of Columbus)

Response: The sentence referred to in the comment has been revised to eliminate the assumption that all in the general public agree on the optimal quantity and quality for a clean environment.

APPENDIX H

M, O&M DETAILED COST ESTIMATING METHODOLOGY

PARSONS ENGINEERING SCIENCE, INC.

MEMORANDUM

Revised February 22, 1999

To: Kevin Weiss
Norbert Huang

From: Lauren Fillmore

Subject: National Annual Cost Estimates for Collection System O&M to Support SSO Abatement Work Assignment 3-16 68-C6-0001

This memo summarizes the final results of the revised O&M cost projections completed per the Project Plan to Supplement O&M Cost Development (Parsons ES, July 24, 1998). This memo supersedes the September 24, 1998 and the January 26, 1999 memoranda. Attached to this memo is the step by step approach taken to reach these cost projections. These steps are presented to enable a thorough review of the assumptions and methodology upon which these cost estimates are based as small changes in the assumptions will affect the cost projections. Upon your review, the approach and results of the O&M cost projections will be documented in a report that can be summarized in and appended to the Needs Report or, in the case of the enhanced O&M cost development, presented in the EA.

The cost projections have been developed for the likely upper bound and lower bound cost bracket for each category. Collection system rehabilitation and other capital costs that are occasionally included with collection system O&M have been excluded from this cost estimate. This eliminates duplication of capital costs included in the M&E model projections. These costs are national, annual projections. We used December 1998 dollars as a consistent cost basis in our analysis.

The following table presents the draft cost projections. The relationship between the national annual historical O&M projections, the current O&M projection, the estimate of total O&M needs for SSO abatement, and estimate of unmet O&M needs for SSO abatement is illustrated in Section 4 of the Needs Report.

Table 1 National Annual Cost Estimates for Collection System O&M to Support SSO Abatement (December 1998 dollars)

Collection System O&M Annual Cost	Figures 1 and 2 Location	Lower Bound Estimate (Billions)	Upper Bound Estimate (Billions)
Current O&M	A	$1.6	$1.9
O&M Prior to SSO Control+	B	$1.0	$1.1
O&M with SSO Abatement	C	$2.7	$3.1
O&M - Total Needs	D	$1.6	$2.1
O&M - Unmet Needs	E	$0.8	$1.5
Enhanced O&M Gross Cost for SSO Abatement #		$0.4	$0.6

Note: O&M activities include sewer cleaning, root removal/treatment, cleaning of line stoppages, cleaning of house service stoppages, inspections and service of lift stations plus the elements of an inspection program: flow monitoring, manhole inspection, smoke/dye testing, CCTV and private sector inspections. Rehabilitation, construction of relief sewers or equalization/storage facilities are considered capital costs and specifically excluded.

[+] Data prior to SSO control awareness is an average of spending by utilities on collection system O&M (excluding capital expenditures) between 1980 and 1989. This number has been adjusted to December 1998 dollars.

[#] Cost does not include any benefit (i.e. cost savings for the utilities) which may reduce or negate these cost estimates. Includes preventative maintenance and other expenses such as training and information management systems.

Methodology

Basis for O&M Cost Projections

1. We used the 1996 Clean Water Needs Survey (CWNS) database in Microsoft Access format that was provided by M&E. The 1996 CWNS database contained 20,670 collection system facilities. The 880 CSO communities and the 750 collection systems having no data for population receiving collection were eliminated from further consideration in the O&M cost projections. This resulted in 19,040 facilities as given in Table 2.

2. The data was sorted by population receiving collection into the following size categories: large cities over 75,000 people; small cities between 75,000 and 10,001; communities between 10,000 and 3,501; communities between 3,500 and 1,001; and communities between 1,000 and 1. The breakdown in size between large and small cities at the population cutoff of 75,000 people corresponds with the distinction made in the SSO capital cost model. The size breakdown for communities less than 10,000 people corresponds to the breakdown of small communities in the 1996 CWNS Report to Congress.

3. The population, as presented in the database, of each community size category was totaled and rounded.

4. As described in the Project Plan, we obtained raw survey data on collection systems from the Water Environment Research Foundation (WERF) that was collected for their report: *Benchmarking Wastewater Operations - Collection, Treatment, and Biosolids Management*. We removed all CSO system data leaving data on 47 sanitary collection systems in the database. The data were sorted by population. The smallest community was just under 10,000 people. We divided the communities into two groups (i.e., above or below 75,000 people) to correspond with the capital cost model. We then calculated the average length of sanitary sewer per capita from the data for both small and large cities.

5. The WERF data sorted by community size yielded an average of 11.5 feet of sanitary collection system per capita for large cities and 26.1 feet of sanitary collection system for small cities. These per capita numbers were used in the appropriate community groups to estimate the length of collection system. Small city per capita sewer length rates were used on the very small community groups to approximate the lower density characteristic of these communities. This approach resulted in an estimate of 580,700 miles of sanitary collection system which is approximately 3.07 billion feet of sanitary sewer.

6. As a reference, the ASCE November 1998 final draft report *Optimization of Collection System Maintenance Frequencies and System Performance* identified an average of 18 feet of sewer per capita. For a cross-check, we applied this metric to estimate the miles of sewer in each community based on the corresponding population. Using that metric, we found that the total miles of collection system was projected to be 504,545 miles. EPA estimated the total miles of municipal sewage pipe at 1 million miles per the EPA February 1996 SSO Framework and estimated 3 billion feet of sanitary sewer in the March, 1998 report on SSO abatement. We used the WERF data on sewer length per capita sorted for large and small communities as the basis

for our estimate of miles of sanitary sewer. The results of these steps are summarized in Table 2.

Table 2. Facility, Population and Collection System Length Basis for O&M Cost Projections (Revised Dec 7, 1998)

Categories	Collection System Facilities on the CWNS Database	Population Served	Estimated Miles of Collection System
Total All Municipal Systems	20,670	189,710,899@	722,897
CSO	880	41,710,899#	142,196*
Other systems eliminated due to data anomalies	750		
1-1,000	7,465	3,200,000	21,818
1,001-3,500	5,822	10,600,000	64,242
3,501-10,000	3,082	15,200,000	80,606
10,001-75,000	2,397	56,000,000	276,818
>75,000	274	63,000,000	137,216
Total Sanitary Sewer	19,040	148,000,000	580,700

@ Taken from the 1996 CWNS Report to Congress

\# Difference between population served by sanitary systems and total population receiving collection

* Based on the average of 18 feet of sewer per person in the ASCE 1998 draft report.

Estimate of Current O&M Costs

7. An examination of the O&M frequencies between cities categorized by size in the ASCE November 1998 final draft report *Optimization of Collection System Maintenance Frequencies and System Performance* supported the conclusion from the WERF data that O&M activities and their frequencies differ between small and large cities. The ASCE data are summarized in Table 3.

Table 3. Reported Maintenance Rates in ASCE Draft Report (Table 6.3) Sorted by Community Size as Percent of System per Year

Maintenance Activity	Small Community	Large Community*
Cleaning	37.6%	28.4%
Root Removal	1.3%	3.3%
Flow Monitoring	8.4%	23.3%
Manhole Inspections	14.0%	20.3%
Smoke and Dye Testing	8.7%	7.6%
CCTV	5.4%	7.0%

* ASCE report used slightly different community size categories, Small communities are under 100,000 people; medium are between 100-500,000; and large are >500,000. For our analysis we grouped ASCE's medium and large community data in the large city category.

8. We estimated the upper bounds of the current national annual collection system O&M cost by multiplying the number of collection system miles for each community size category by the O&M cost per mile and summing the products. For all sizes of communities, we used the average O&M cost of per mile from the ASCE November 1998 report for the period 1990- 1996. We evaluated other sources of O&M cost data, including the WERF *Benchmarking* data obtained earlier. However, only the ASCE cost data clearly separated the capital cost expenditures for rehabilitation and relief sewers from the routine O&M costs. The O&M cost from Table 4-16 (revised) of $2,796 per mile per year was inflated from the mid-point of the current period (1993) to December 1998 dollars by using the ENR skilled labor index. This index was used to standardize the cost data between periods since a significant component of the O&M cost would be skilled labor.

9. We also estimated the lower bounds of the current national annual collection system O&M cost by multiplying the number of collection system miles for the large and medium communities by the average O&M cost per mile from the ASCE report converted to 1998 dollars and summing the products. For small communities (all groups with populations under 10,000) we used half the adjusted O&M cost per mile value. Surveys like the ASCE report tend to reflect the data provided by more proactive, and therefore more responsive, utilities. The O&M cost per mile from the survey may be slightly biased and, therefore, higher than the "true" average. As a result of the survey bias, an adjustment was made to the the cost per mile from the survey as applied in the O&M model for small communities.

10. We estimated the current national annual O&M expenditure to be $1.9 billion dollars (upper bounds) and $1.6 billion (lower bounds) in December 1998 dollars.

Estimate of Historical O&M Cost

11. The ASCE Report looked at maintenance activities and costs over time. The current time period was from 1990-1996. O&M activity frequency and cost data were collected from earlier periods. The ASCE maintenance activity results are summarized in Table 4.

Table 4. Changes in Maintenance Activities over 20 Years based upon the ASCE Survey Results (Percent of Collection System per Year)

Maintenance Activity	20 Years Ago	Current (1990-1996)
Flow Monitoring	9%	31%
Manhole Inspection	12%	27%
Smoke/Dye Testing	2%	8%
CCTV	2%	7%

12. We estimated the upper bound historical national annual collection system O&M cost by multiplying the number of collection system miles by the average rate of spending by utilities between 1980-1989 obtained from the revised Table 4-16 in the ASCE November 1998 draft final report. We used a historical O&M cost of $1,362 per mile. The historical cost was inflated from mid-point (1985) to 1998 dollars using the ENR skilled labor index. This yields a historical O&M cost of $1,986 per mile when converted to 1998 dollars. The historical national O&M expenditure is estimated to be $1.1 billion dollars (upper bounds).

13. We estimated the lower bound historical national annual collection system O&M cost by multiplying 1980-1989 annual O&M cost per mile, once adjusted for inflation, by the number of collection system miles for the large and medium cities categories and summing the products. For small communities (all groups with populations under 10,000) we used half the O&M cost per mile value ($993) adjusted to 1998 dollars. The historical national O&M expenditure is estimated to be $1.0 billion dollars (lower bounds).

Estimate of O&M Cost with SSO Abatement

14. Based upon the O&M cost data in the ASCE report between 1985 and 1993, O&M expenditures, after adjustment for inflation, rose at an average annual rate of 5%. Much, but not necessarily all, of the increase between historical and current maintenance activity frequencies and the corresponding O&M cost may be due to the utilities' awareness and response to state SSO abatement efforts. However, a prosperous economy affecting the utilities' reinvestment rate in their infrastructure may also be a factor.

15. We projected that the O&M activities and corresponding costs would continue to increase to support SSO abatement based upon the current rate of increase in O&M expenditures. We used

the current O&M cost from revised Table 4-16 in the ASCE report ($2,796 per mile per year adjusted to $3,289 1998 dollars) as a basis. The projected increase in O&M resulted in an annual unit O&M cost of $5,432 per mile when SSO abatement programs are implemented. For a reasonableness check, this cost per mile is below to the average operations cost per mile ($7,975) documented in the WERF *Benchmarking* report. Seven of the respondents in the ASCE survey are already spending over the projected cost per mile for routine O&M.

16. We estimated the upper bounds of the national annual collection system O&M cost for SSO abatement by multiplying the number of collection system miles by the projected O&M cost per mile when SSO abatement programs are implemented. The annual national O&M expenditure when SSO abatement is implemented is projected to be $3.1 billion (upper bounds).

17. We estimated the lower bounds of the national annual collection system O&M cost for SSO abatement by multiplying the number of collection system miles for the large and medium cities categories by the projected O&M cost of $5,432 per mile when SSO abatement programs are implemented and summing the products. For small communities (all groups with populations under 10,000) we used half of the projected O&M cost per mile or $2,716 1998 dollars. For a check, this number is close to the average O&M cost per mile in the ASCE report. The annual national O&M expenditure when SSO abatement is implemented is projected to be $2.7 billion (lower bounds).

Needs Estimates

18. Since we were tasked to project the O&M needs associated with SSO abatement, we subtracted the historical O&M national annual cost from the national annual O&M costs when SSO abatement programs are fully implemented. This is an estimate of the total annual SSO abatement O&M needs. The total annual SSO abatement O&M needs yielded an upper bound cost estimate of $2.1 billion and a lower bound estimate of $1.6 billion.

19. Clearly, the current O&M costs includes activities and frequencies of activities that have changed in response to the SSO awareness and state NPDES programs in the absence of a federal policy. Therefore, we also projected unmet SSO abatement O&M needs by calculating the difference between the projected annual O&M cost when SSO abatement is fully implemented and the current annual O&M cost which includes some increase in O&M for SSO abatement. The difference is the unmet annual SSO O&M needs. The national annual unmet O&M needs for SSO abatement yielded an upper bound cost estimate of $1.5 billion and a lower bound estimate of $0.8 billion.

Estimate of Enhanced O&M Program (Gross) Cost

20. The proposed SSO abatement regulations will emphasize 'enhanced' O&M programs. One of the key program components in enhanced O&M programs is the GIS/Information management systems that allows collection system maintenance performance to be tracked and system defects to be identified in support of preventative maintenance programs. Several vendors on these products were contacted for cost information even though these systems can and are developed by numerous consulting engineers for municipal utilities. In some cases, utility employees have also designed and implemented their own programs. A general vendor estimate for data collection into a database, reporting and analysis of the data is $1 per linear foot (ADS Environmental, personal conversation 12/29/98 and Byrd/Forbes Associates, personal conversation January 11, 1999) or $5,280 dollars per mile. These are not annual costs but initial setup and evaluation costs.

21. We annualized these enhanced O&M costs over a ten year life using a rate of 7%. We selected a ten year life even though the information management software and computer systems will not last the ten year period without upgrade. The significant cost component is the development of the system data and GIS data layers. These are anticipated to be adequate to support these systems for ten years prior to expenditures to significantly update the GIS interface. The resulting annual cost per mile is $1,039.

22. We multiplied the length of sewer system miles by the annualized cost for the GIS-based information management systems and summed the products. The upper bound estimate for enhanced O&M is $0.6 billion.

23. For a lower bound estimate, we annualized the cost of the GIS information management system over 20 years then multiplied the length of sewer system miles by the annualized cost for the GIS-based information management systems and summed the products. The resulting lower bound estimate for enhanced O&M is $0.4 billion.

24. We have not estimated the potential cost savings that these enhanced information management expenditures may produce for the utilities that use them. Small expenditures for enhanced maintenance may reduce the increased rate of expenditure on maintenance activities in the future. There has been some evidence that utilities using information management systems to anticipate sewer rehabilitation needs experience cost savings. Because enhanced O&M systems are so new, even our case study cities did not have adequate data to demonstrate cost savings even though the Los Angles data showed that the O&M budget remained constant while the level of service has continued to improve due to "condition assessment" program that uses a SCADA system.