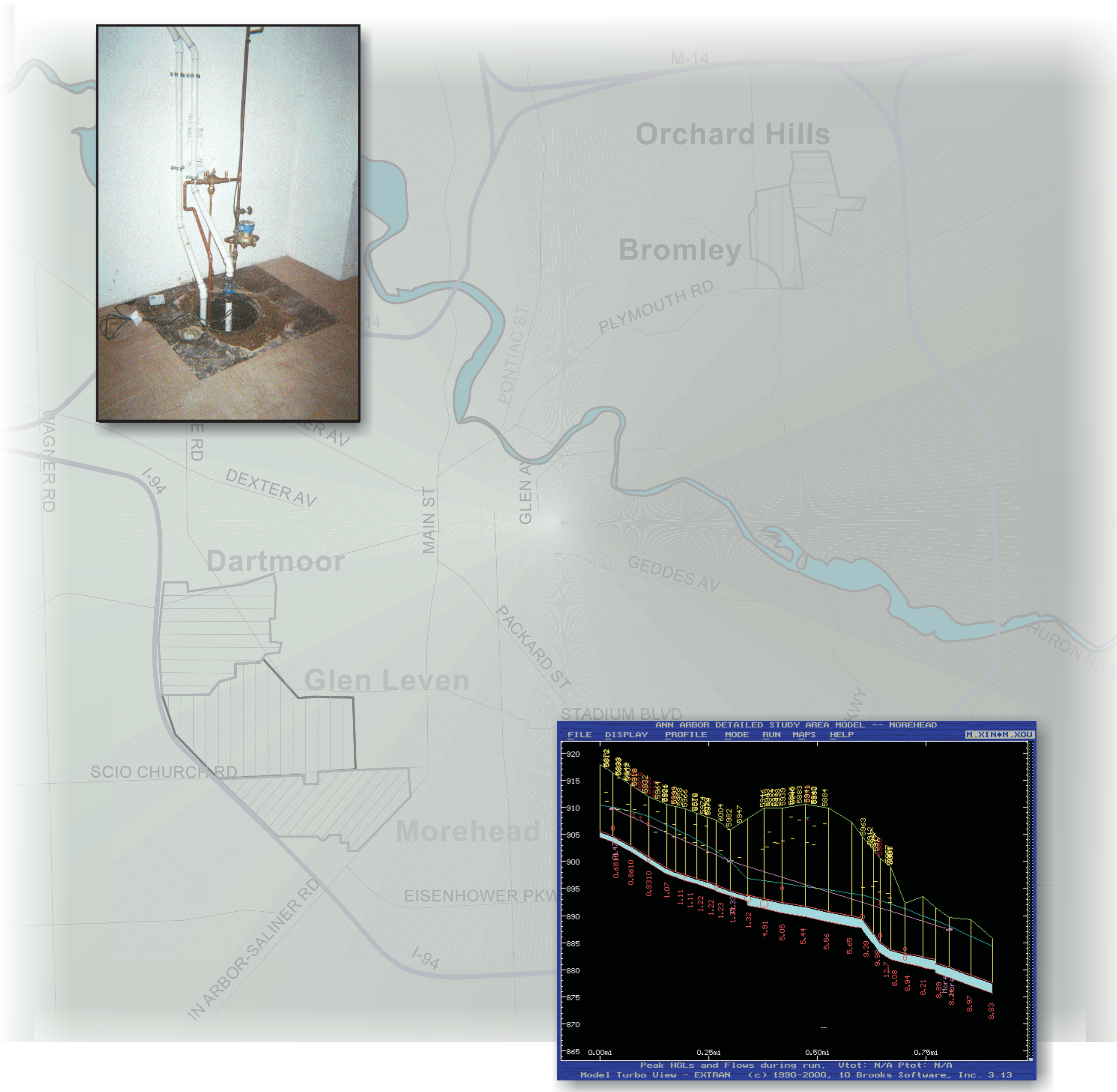
City of Ann Arbor

Sanitary Sewer Overflow Prevention Advisory Task Force



Report

Sanitary Sewer Overflow Prevention Study

CDM Camp Dresser & McKee

June 2001

City of Ann Arbor
Sanitary Sewer Overflow Prevention Advisory Task Force

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ES.1 Recommendation

The Sanitary Sewer Overflow Prevention Advisory Task Force recommends the Mayor and City Council take action to remove rain and ground water inflow sources into the city's sanitary sewer system by implementing a comprehensive city-wide footing drain disconnection (FDD) program within the City of Ann Arbor.

ES.2 Background

Within the City of Ann Arbor, there are groups of homes that have experienced repeated basement flooding problems. These locations are shown in Figure ES-1. Many of these have been the result of

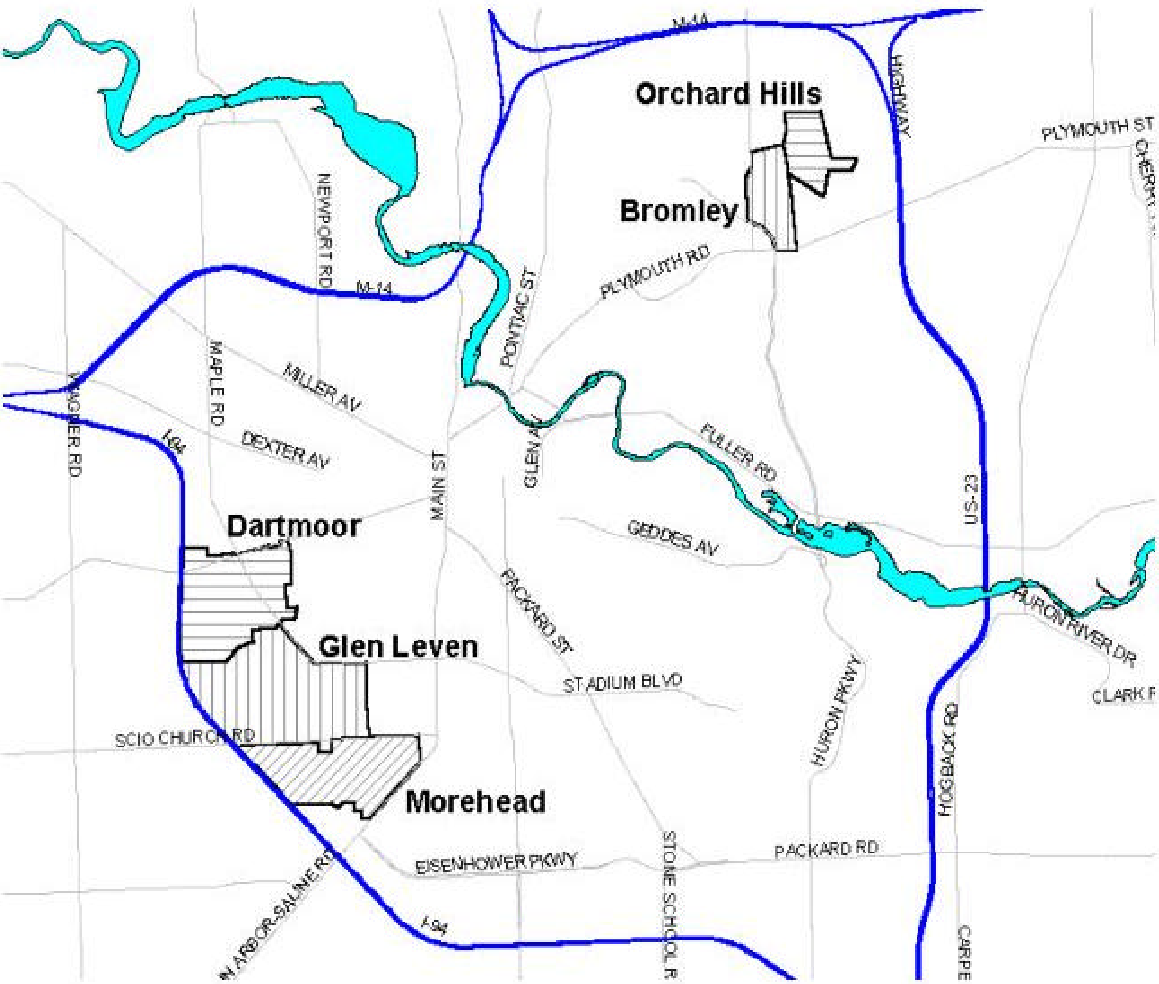

Figure ES-1 Project Study Areas

backup of wastewater from the sanitary sewers through basement floor drains. This has often resulted in a few inches to more than a foot of wastewater entering the basements of some homes. This wastewater presents a potential health risk and can cause damage to the structure and to belongings stored in the basement.

The sanitary sewer system normally moves all of the wastewater to the Ann Arbor Wastewater Treatment Plant (WWTP). However, when it rains, some of this rain enters the sanitary sewer system and has occasionally exceeded the capacity of this system to move flows to the WWTP. The City of Ann Arbor has taken a variety of approaches to correct these problems with varied success.

Because homeowners that experienced multiple flooding lacked confidence in the City of Ann Arbor due to an inadequate response to their flooding problems and past corrective actions have not resolving some of the flooding problems, it was decided that a special Task Force would be developed. The Task Force was comprised of homeowners, city staff and experts in related disciplines. To focus the Task Force efforts, five neighborhoods with high rates of basement flooding were selected for an analysis. The neighborhoods selected include about 5% of the area of the City of Ann Arbor and account for about 50% of the basement flooding problems that have been reported to the Water Utilities Department.

The Task Force developed the following mission statement:

> *To define the scope of sanitary sewer overflow or sewage backup problems due to wet weather conditions in the City of Ann Arbor, and identify through a comprehensive process, possible effective solutions to minimize or eliminate the impact of future sewage backup events.*

Public engagement was essential to the project. It provided the public with information on the status of the work and also provided the project team with feedback on the nature of the problem and the acceptability of the proposed solutions. During the project, the public was involved in the process through a series of workshops. Newsletters, local cable TV interviews, newspaper articles and a project web site were all used to reach out to homeowners.

ES.3 Selected Solution - Footing Drain Disconnection

Alternative solutions were reviewed using a variety of selection criteria including quality of life, cost, and construction impacts. The evaluation showed that in most cases, storage and footing drain removal were closely ranked as the preferred alternatives. The Task Force then solicited public concerns. Public feedback emphasized protection of natural features and elimination of long-term impacts on the environment from sanitary sewer overflows as the important community criteria.

<u>A comprehensive city-wide footing drain disconnection (FDD) program has been determined to be the best solution for the residents of Ann Arbor</u>. Removing rain and groundwater from the sanitary sewer system with an FDD program has the following advantages:

- Solution places first priority on protecting homeowners who have been previously impacted by sanitary backups during severe storm events.
- Eliminates the costs for treatment of this rainwater flow that is required only when it is connected to the sanitary sewer system.
- Saves dollars in wastewater treatment expansion to treat this flow and regulatory penalties for sanitary sewer discharges to the environment.
- Solution does not move the problem downstream to previously unaffected neighborhoods or require extensive construction on downstream trunk sewers.
- Solution provides the greatest level of protection for future large rainstorms.

- Solution compatible with regulatory trend toward disconnection of footing drains from sanitary sewer systems.

Residents also emphasized that the City should take a broader view regarding efficient use of our resources in conjunction with infrastructure issues. Though not a part of the FDD program, the City would also encourage the following through outreach efforts:

- Lower sanitary flows through water conservation practices such as encouraging use of low flow toilets, faucets and showerheads.
- Utilize rain barrels, rain gardens, and/or infiltrator storage systems on sump discharge leads to reduce rain/groundwater flows returned to the storm water system (coordinate with FDD construction efforts when possible).
- Engage the cooperation and support of community, school and environmental groups to fix this problem at its source while preserving and protecting: the health and safety of community members, the natural features of Ann Arbor and the Huron River watershed.

ES.4 Costs

Footing drain disconnection (FDD) is the lowest cost alternative for preventing sanitary sewer backups into homes when consideration is given to construction costs, treatment costs, treatment plant expansion, dollars spent in claims, legal costs, and sanitary sewer overflow penalties. Costs to complete such a program will generally range between $80-130 million depending on the actual number of homes requiring FDD and level of participation of homeowners during FDD incentive programs.

It is estimated that the approximate cost per home is $5,000-6,000 to disconnect the footing drain and provide a curb-side collection system to bring the rain/groundwater from the sump to the storm water system. The basic costs to complete a FDD in a home will be funded from the Sewage Collection System user fees. Additional features or restorations beyond what is required for basic system operation will be done at homeowner's expense.

ES.5 Implementation

The size of this project is such that a deliberate and well-planned approach is needed to prevent excessive expenditure of utility funds, over-commitment of the available contract work force and creating nuisance/hazards by not adequately controlling sump pump discharges. Completion of the program is dependent on commitment of resources, but is realistically expected to last 20-30 years. The FDD program implementation will be accomplished on a block-by block basis in conjunction with construction of the sump discharge collection system generally with the following priority:

- **Priority 1-A -** Homes within the five study areas that have historically flooded or those with the potential for flooding would have their footing drains disconnected and check valves installed. These homes and the collection system would be monitored to confirm the storm flows removed by FDD from the sanitary system. This would begin in summer 2001 and last approximately one year.
- **Priority 1-B -** Homes outside the five study areas that have historically flooded or those adjacent to homes historically flooded with the potential for flooding would have their footing drains disconnected and check valves installed. This would begin late summer 2001 and last several years.
- **Priority 2-A** - Homes that have not historically flooded or those not having the potential for flooding in the five study areas would have their footing drains disconnected because they are contributing flow resulting in basement backups and allowing unmetered rain/groundwater flow into the sanitary sewer that requires treatment at the wastewater treatment plant. Schedule to be determined.
- **Priority 2-B** - Homes that have not historically flooded or those not having the potential for flooding outside of the five study areas would have their footing drains disconnected because

they are contributing flow resulting in basement backups and allowing unmetered rain/groundwater flow into the sanitary sewer that requires treatment at the wastewater treatment plant. Schedule to be determined.

The costs of the different priority steps are provided in Table ES-1. This shows the number of homes that are envisioned in each phase of the work effort.

ES.6 Solutions in Other Communities

The problem of handling the excess storm flows that enter sanitary sewer systems has commonly been handled by providing additional flow capacity to discharge these flows downstream. Others have attempted to remove some of the flows entering the collection system by rehabilitating the manholes and pipe joints, with limited success.

More recently, some communities have tried to remove sources of wet weather flow that are originating from private homes. The most significant source of excessive storm flow is often the connection of foundation footing drains that are frequently connected directly to the sanitary sewer system in homes constructed before 1980. Examples of successful footing drain disconnection programs can be found in West Lafayette, Indiana, Auburn Hills, Michigan, and Canton Township, Michigan.

Table ES-1 Program Costs

Area	Homes	Cost
Priority 1-A		
Orchard Hills	50	336,000
Bromley	70	470,400
Dartmoor	31	208,320
Glen Leven	123	826,560
Morehead	55	369,600
Total	329	$2,210,880
Priority 1-B		
Confirmed	132	996,800
High Potential	93	681,800
Contingency	90	671,400
Total	315	$2,350,000
Priority 2-A		
Orchard Hills	325	1,956,500
Bromley	179	1,077,580
Dartmoor	280	1,685,600
Glen Leven	852	5,129,040
Morehead	685	4,123,700
Total	2321	$13,972,420
Priority 2-B		
City-wide	17,000	$60 million to $110 million
Grand Total	**20,000**	**$80 million to $130 million**

ES.7 Critical Factors for Successful Implementation

The Task Force recognizes the unique nature and challenges inherent in these recommendations. The Task Force offers the following recommendations as to what will support an effective implementation:

- Structure an effective construction management program to oversee all work done on private property.
- Set clear standards and provide support and oversight to ensure that all work done is highly professional, effective and done in a timely manner.
- Provide a strong and comprehensive public engagement program that effectively communicates why this work is needed, what the benefits are for homeowners and for the City, what is included in the work and answers any additional questions of homeowners.
- Collaborate with environmental groups and other stakeholders to engage citizens in supporting this program.
- Demonstrate City is committed to a rapid implementation of these recommendations.

A. Introduction

Contents

A.1 Problem Definition

The City of Ann Arbor has in excess of 200 homes located throughout the City that have repeatedly experienced basement flooding from sewer backups. While some of these are a result of individual problems in the home sewer connections, others are caused by backup of flow from sanitary sewers that do not have enough capacity under wet weather conditions. These basement flooding instances have resulted in significant damage and loss of property by home owners. The potential health and safety concerns arising from basement backups is without a doubt the most important reason to prevent future sewer backups.

The information provided in this section of the report presents the project philosophy that was used to approach the problems and identify solutions. This section also documents the formation of the sanitary sewer overflow (SSO) Task Force used to organize the project activities.

A.2 Project Approach

The City has records of basement flooding since the 1960s. In response to these problems, the City has performed corrective actions to address these problems as the collection system has developed and the customer base has expanded. A major element of this work has been a periodic review of the trunk sewer system. The most recent planning document, dated 1995, was used to identify major conveyance system shortfalls and projects needed to effectively deal with these issues. The City of Ann Arbor has been performing a number of improvement projects to address these deficiencies since that study was completed.

While this planning process has been effective in dealing with conveyance issues in the trunk sewer system, this current SSO prevention project is focused on the issues of flooding within 5 study areas identified in the scope of services for this project. These areas include the Orchard Hills and Bromley areas in the Northeast side of Ann Arbor, and the Dartmoor, Glen Leven, and Morehead areas in Southwest Ann Arbor.

These five areas were identified as having the highest concentrations of flooding incidents based on historical records. This is shown in Figure A-1. Although these study areas represent only 5 percent of the City area, the reported flooding incidents defined that have taken place in these study areas represent approximately 50 percent of the incidents recorded by the City of Ann Arbor.

When this project was developed, it was recognized that corrective actions had been previously taken to resolve problems that were identified. Previous attempts to correct flooding problems were insufficient and in some cases led to new, unanticipated problems. For this project, an approach was developed so that the root causes of the basement flooding problems could be determined in the 5 study areas. The solutions developed would resolve the problems in these areas and not move the basement flooding to other areas of the City.

It was also recognized that while the basement flooding problem had very direct and dramatic impacts on some home owners, there were no or limited impacts on others. To gain input from both of these groups, it was decided that involvement of affected and non-affected homeowners in the formulation and review of control alternatives was key to their acceptability. In many cases, there was poor information about the causes and potential solutions available to the home owners. The involvement of these people was believed to be key to a successful long term program.

In addition, there were issues that home owners had concerning the service provided to them by the City of Ann Arbor. Of particular concern was the

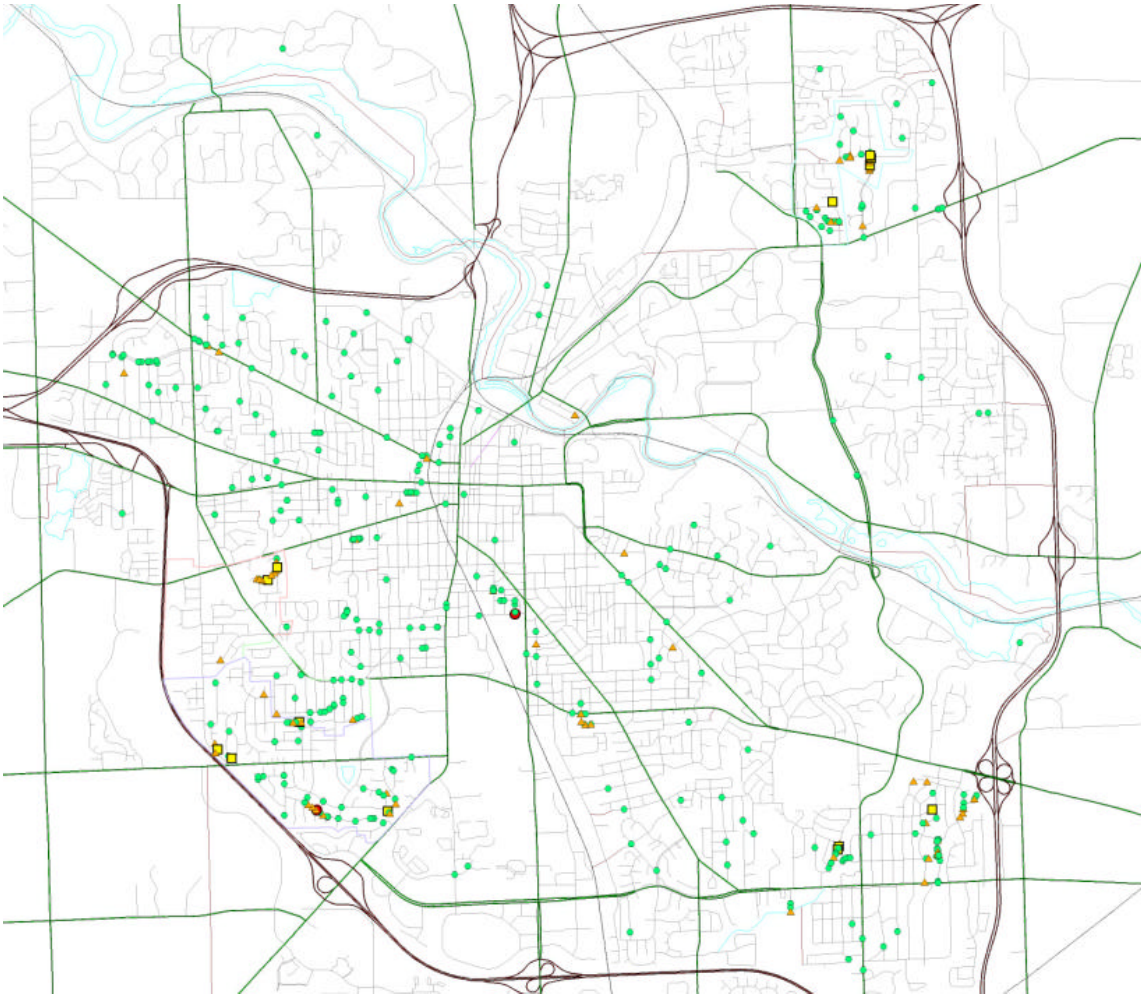

Figure A-1 Historical Sewer Overflows

response of the City during the basement flooding events. It was believed that there was a need to enhance the response program at all levels of the City of Ann Arbor to better meet the urgent needs of citizens who experienced basement flooding problems.

A.3 Task Force

The Mayor and City Council approved the formation of the SSO Prevention Advisory Task Force in July of 1999 to address basement flooding experienced in the five study areas. This group was composed of:

- City of Ann Arbor staff members from the Departments of Public Services, Water Utilities, and Administration.
- Homeowners representatives from the 5 study areas.
- Outside professionals in a variety of fields including the University of Michigan Engineering Department, the Washtenaw County Drain Commissioner, the Huron River Watershed Council, and a plumbing professional.

This group developed project objectives, selected a contractor for this project, and has been involved in the project activities from the outset. The full activities of this group are documented in later sections of this report.

B SSO Advisory Task Force

Contents

B.1 Mission

To define the scope of sanitary sewer overflow or sewage backup problems due to wet weather conditions in the City of Ann Arbor, and identify through a comprehensive process, possible effective solutions to minimize or eliminate the impact of future sewage backup events.

To fulfill this mission, the Task Force developed the following objectives at the onset of the project:

B.2 Specific Objectives

1. Identify critical sewage backup issues and establish parameters for a specific process to resolve the problem.

2. Design and implement a comprehensive sewage "backup" prevention engineering study that should include design specifications and an overall description that can be integrated into an efficient city-wide sanitary sewer system management plan.

3. Solicit input from individuals, communities, agencies and institutions, on possible approaches and solutions for sewage "backup" problems.

4. Establish an open public process and dialog related to sewage "backup" issues thereby enhancing the probability for resident acceptance and compliance in any mitigation steps.

5. Make preservation of health, property and the environment a key feature of the process and any mitigation plan.

6. Explore potential funding sources (federal, state, county, city, and others) to implement any recommended sanitary sewer overflow prevention action plan.

7. Recommend to Mayor and City Council to approve a specific action plan for eliminating or reducing the impact of future sewage backup events, as part of an overall effective sanitary sewer management system.

B.3 Action Steps

1. Define mission, scope, organization, objectives, action steps and timeframe of the Sanitary Sewer Overflow Prevention Advisory Task Force.

2. Present proposed plan by the Sanitary Sewer Overflow Prevention Task Force to the Mayor and City Council for approval and authorization to proceed.

3. Establish immediate and strong communication links with the public, especially with the affected neighborhoods, through public forums, surveys, direct interviews, etc. Task Force meetings should be open to public at all times with adequate notification.

4. Develop an effective and responsive customer service program to deal with consequences of sewage “backups”.

5. Acquire and review historical data of past sewage “backup” events including homes/areas affected and recorded meteorological data.

6. Audit previous sanitary sewerage master plans, individual engineering studies, sewage “backup” event studies, etc. to establish an accurate assessment of the current infrastructure, and evaluate cost/benefit of past actions.

7. Design and implement a Sewage "Backup" Prevention Engineering Study that would utilize a professional engineering consulting firm with demonstrated expertise in sewage overflow remediation. Independent professional oversight should be considered to ensure the integrity of the study.

8. Establish benchmarks for data review and acquisition, engineering study, public input, etc. to ensure a comprehensive approach and an achievable fulfillment of the task force's mandate.

9. Perform a "peer review" of other communities and their specific approaches to dealing with chronic sanitary sewage overflow events.

10. Obtain "expert" advise or perspectives from other communities, agencies and institutions including local government leaders, engineers, and residents that have dealt with sewage overflows, and in addition, from federal/state regulatory authorities and academic professionals.

11. Review and consider sustainable solutions for sewage "backup' and overflow mitigation.

12. Consider funding options for sewage overflow mitigation (public or private or both; bonds, assessments, etc.)

13. Integrate proceedings, findings and plans of Sanitary Sewer Overflow Advisory Task Force with that of any "Stormwater Management" Task Force to ensure a synthesized and cohesive understanding/plan of the City of Ann Arbor's water management system.

14. Review U.S. Federal Government and EPA regulations, as well as those of the State of Michigan, governing SSO and CSO standards and assess implications for sewage "backup" mitigation and infrastructure master planning.

15. Consider incentive programs to maximize compliance by affected residents and effect a greater degree of mitigation.

16. Present draft recommendations to public for review and input.

17. Consider public input, research any new suggestions or concerns (if necessary), and make alterations to the proposed recommendations (if appropriate) before submitting to City Council.

18. Present recommendations to City Council (and Planning Commission) that would delineate specific actions for long-term resolution of sewage overflow problems throughout the city based on the accumulated and reviewed data, engineering study, EPA regulations, etc., and taking into consideration funding options.

C. System Background

Contents

C.1 Sanitary System Description

C.1.1 Purpose/Description

The sanitary sewer system accepts wastewater flows from individual homes and businesses and conveys these flows to the wastewater treatment plant where they receive treatment before discharge to the Huron River. This system is composed of sections of sewer pipe that are located below ground, typically under the street surface. Individual connections from homes and businesses may be made directly into this pipe or to the access points located along the sanitary sewer that are called manholes. These manholes are located every 400' or so and allow access to the sewer for inspection and maintenance.

The sanitary sewers shown in Figure C-1 are normally designed to convey flows from the homes by gravity to the Wastewater Treatment Plant. This reduces the operating costs of the system and also reduces the chances of backup caused by loss of power for pumping stations. However, there are some areas of the City that are serviced by pumping stations.

The flows that are discharged into the sanitary system will vary throughout the day. Typically the flows are lowest in the early morning hours and then rise in the morning as people begin their day, level out during the day, and then peak again after work as people arrive home at the end of the day. Flows from business and industry are often similar, but will have more variability than residential customers.

When sanitary sewers are designed, the variability of the flows throughout the day is accounted for so that the level of the flow in the sewer pipes will always stay below the top, or crown, of the pipe. In fact, the design of these sewers also accounts for additional flows that may be introduced either by future connections or from other sources. These

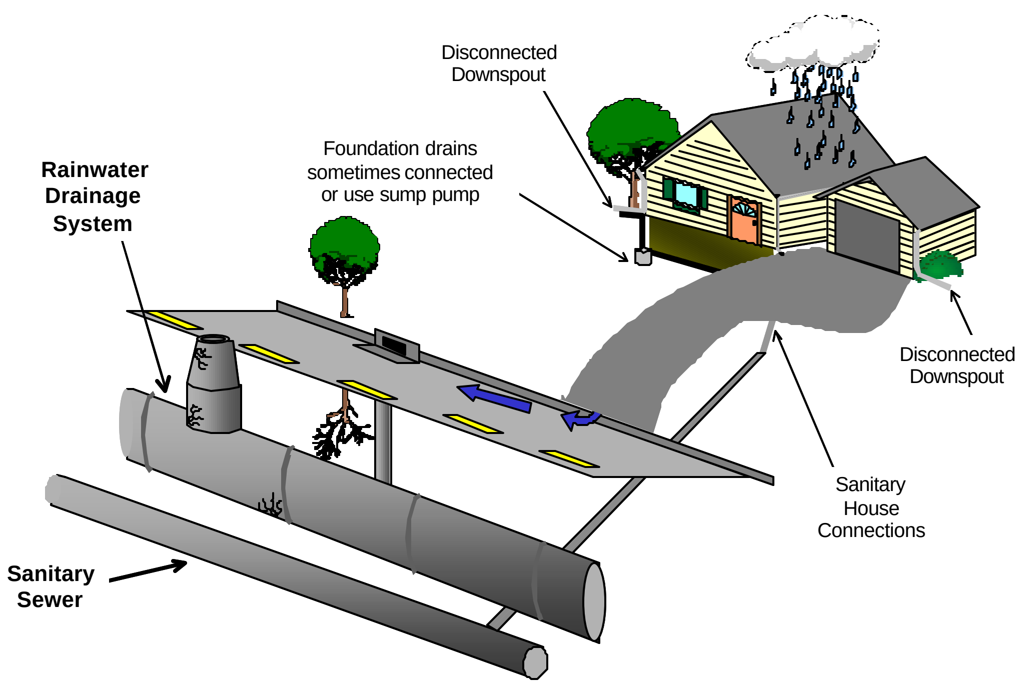

Figure C-1 Collection System Schematic

sewers are designed so that the velocity of the flow keeps solid matter in suspension until it reaches the wastewater treatment plant. It is important that these pipes are not made too large or the velocities will be too low and solids may settle out, potentially causing backups or odors.

C.1.2 Storm Water Drainage System

There is a second collection system that is also normally located below the street surface and collects the surface runoff when it rains. This collection system is also shown in Figure C-1. Typically, these flows come from rooftops, driveways, streets, and parking lots. Homes and businesses are normally constructed so that these flows are directed to the street. Flows will then run along the sides of the streets where the gutters convey these flows into catchbasins. These catchbasins are directly attached to the stormwater system.

The stormwater collection system pipes are generally much larger than the sanitary sewer system pipes since it is designed to handle the peak flows generated during rain storms. During other times, the flows in these sewers are normally very low and free of any solids that might settle out. The stormwater collection system does not bring flows to a treatment plant, but discharges directly to a stream or river since treatment of these flows is not required.

C.1.3 Storm Water in the Sanitary Sewer System

When it rains, a portion of the flow that does not get into the storm collection system finds its way into the sanitary sewer system through Inflow and Infiltration (I/I). Typically, I/I is groundwater that leaks into the sanitary sewer system throughout defects such as cracks in pipes or joints between pipes. This I/I can also enter the system through the manhole structures or even through the manhole covers themselves if the streets flood. Finally, this I/I can also enter the system from the private residential and business connections, and pipes that are on private property. This includes foundation footing drains as shown in Figure C-1.

The amount of the I/I that is accounted for during the design of the sanitary sewer system varies based on the type of pipe and when the pipe was constructed. A fact of life is that the pipes and connections deteriorate over time and flows from these I/I sources will increase as the collection system ages. To account for this, the City of Ann Arbor routinely inspects and repairs these pipe defects to keep the flows from these sources to acceptable levels.

C.1.4 Wastewater Treatment Plant

All flows that enter the sanitary sewer system are conveyed to the WWTP where they receive treatment prior to discharge. Throughout the day, the flow rate at the WWTP will vary based on the discharges from individual users of the system. These are known as the diurnal flow variation. Unfortunately, most of the treatment processes at the WWTP work most effectively with minimal variation of these flow rates. For this reason, there is a storage facility at the WWTP that reduces this variability in flows throughout the day to maximize the efficiency of the treatment processes.

C.1.5 Sanitary Sewer Overflows

When there is a storm, flows received at the WWTP can increase dramatically. Even when the WWTP is operating at its maximum capacity the storage facility can fill to the point where partially treated flows are discharged to the Huron River. At the present time, this is a permitted discharge from the WWTP. Under future regulations and discharge permits, this may be a sanitary system overflow (SSO) with different requirements for discharge.

In addition, there are portions of the sanitary sewer system that may not have sufficient capacity to direct these flows downstream to the WWTP. As a result, these flows may discharge onto the ground or to a surface stream or river without receiving treatment.

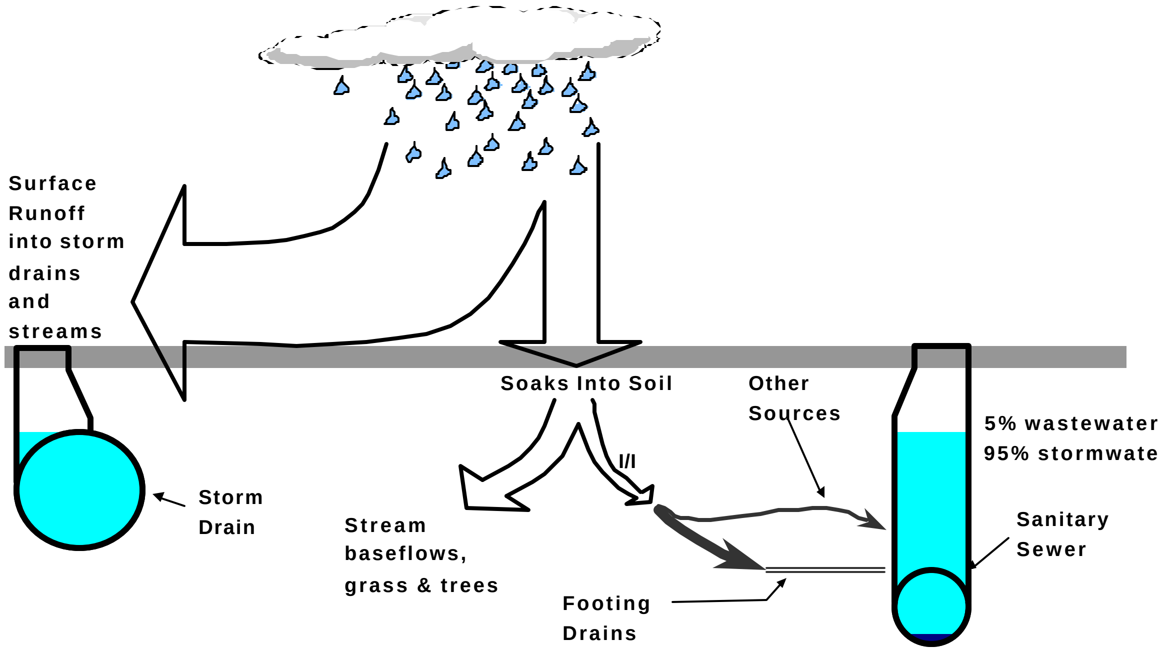

Figure C-2 Rainfall Flow Pathways

C.2 Sources of Flow

There are multiple pathways for wet weather flows to enter both the storm drainage and sanitary sewer system. Figure C-2 shows what happens with it rains. For very large events such as those that cause basement backup problems to take place, the majority of the rainfall runs off the hard surfaces or saturated ground and either enters a stream directly or flows down a street and enters a catchbasin. The storm drainage system will then convey this flow, up to its capacity, to the receiving water. If there is water that ponds on the street or over a manhole cover for the sanitary sewer system, a portion of this flow may flow into this system. The fact that water does pond in the street helps to prevent excessive erosion and disruption to river ecosystems by buffering peak river flow results from large rain storms.

The remainder of the rainfall soaks into the soils. In many cases, the water that runs from roofs of homes and other buildings soaks into the ground around their foundations. In turn, flows entering the groundwater may be introduced into the collection system from cracks and joints in the sewer pipes. Alternatively, the water soaking in around homes may enter the foundation footing drains. If a sump pump is installed, this flow may be pumped out on the ground where it can run off to a surface stream. In the absence of sump pumps, these foundation drains may be directly connected to the sanitary sewer system as is the case for Ann Arbor homes build before the 1980s.

C.3 Environmental Considerations

Once the capacity of the sanitary sewer system is exceeded, the levels in the sewer will rise above the top of the pipe and flows can flow back into the basements of homes and other structures. Homes that have basements that are only slightly above the elevation of the top of these sewers have a higher potential for flooding than homes that have basements at higher levels above the sewer pipe.

Water that enters basements of homes may do so with considerable force and the levels can be substantial, from a few inches to several feet in extreme cases. While the water entering basements may be composed primarily of rain water, it often contains significant amounts of sewage. This mixture of rainwater and sewage, once it has come into contact with basement floors, walls and other items in the basement, should be disinfected to reduce the health hazard to the residents. In many cases, materials stored in the basement need to be discarded because the contamination is impossible to remove or because the water has ruined it.

In the case where flow exits the sewer system to the open environment, the area around the discharge may have health risks associated with contact. These discharges should be properly identified using signage to avoid contact with the public and disinfected if practical.

C.4 Public Health Considerations

Sanitary Sewer Overflows

Involvement of local health departments in sanitary sewer overflows is specifically addressed in a new state law that became effective July 10, 2000.

Michigan State Act 286, Public Acts of 2000, Sec.3112a requires that:

(1) ". . . the municipality responsible for the discharge shall immediately, but not more than 24 hours after the discharge begins, notify the department [MDEQ]; local health departments ... a daily newspaper, ...that a discharge is occurring."

"(3) Each time a discharge occurs under subsection (1), the permittee shall test the affected waters for *E. coli* to assess the risk to the public health as a result of the discharge and shall provide the results to the affected local county health departments and to the department. The testing shall be done at locations specified by each affected local county health department but shall not exceed 10 tests for each separate discharge event. The requirement for this testing may be waived by the affected local county health department if the affected local county health department determines that such testing is not needed to assess the risk to the public health as a result of the discharge event."

Basement flooding with sanitary sewage from the public sewer system is an indication an undersized sanitary sewer system. The MDEQ must be notified of these basement flooding events.

These requirements are more specific than the requirements that are in National Pollutant Discharge Elimination System (NPDES) permits that require notification to the MDEQ on certain discharges. MDEQ had an understanding with the State Health Department that the health department would be notified by MDEQ when discharges occurred. The State Health Department then notified the local health department. In southeast Michigan the environmental health directors requested the sewage treatment plants that bypassed sewage or had sanitary sewer overflows, notify the local health department at the same time MDEQ was notified.

The State Health Department has authority and responsibility to "...monitor and evaluate conditions which represent potential and actual environmental health hazards, reporting its findings to appropriate state departments and local jurisdictions,..." Act 368, P.A. of 1978 as amended, 333.12103. There are other sections of Act 368 (Public Health Code) that gives authority to state and local health departments regarding investigating potential health hazards.

D. Problem Background

Contents

D.1 Basement Backup Locations

Information has been gathered on the locations where basement backup conditions have been reported. Figure D-1 shows these locations. In cases where multiple basement backups have taken place at the same home, these are noted in the figure.

The review of the historical flooding locations has shown that the flooding problems have been clustered in some cases. To make the analysis of the causes of these flooding problems manageable, the neighborhoods with the most significant clusters of problems were selected for this project. These project areas are described below.

D.2 History of Flooding in Study Areas

A general description of the five study areas is provided below along with observations on critical

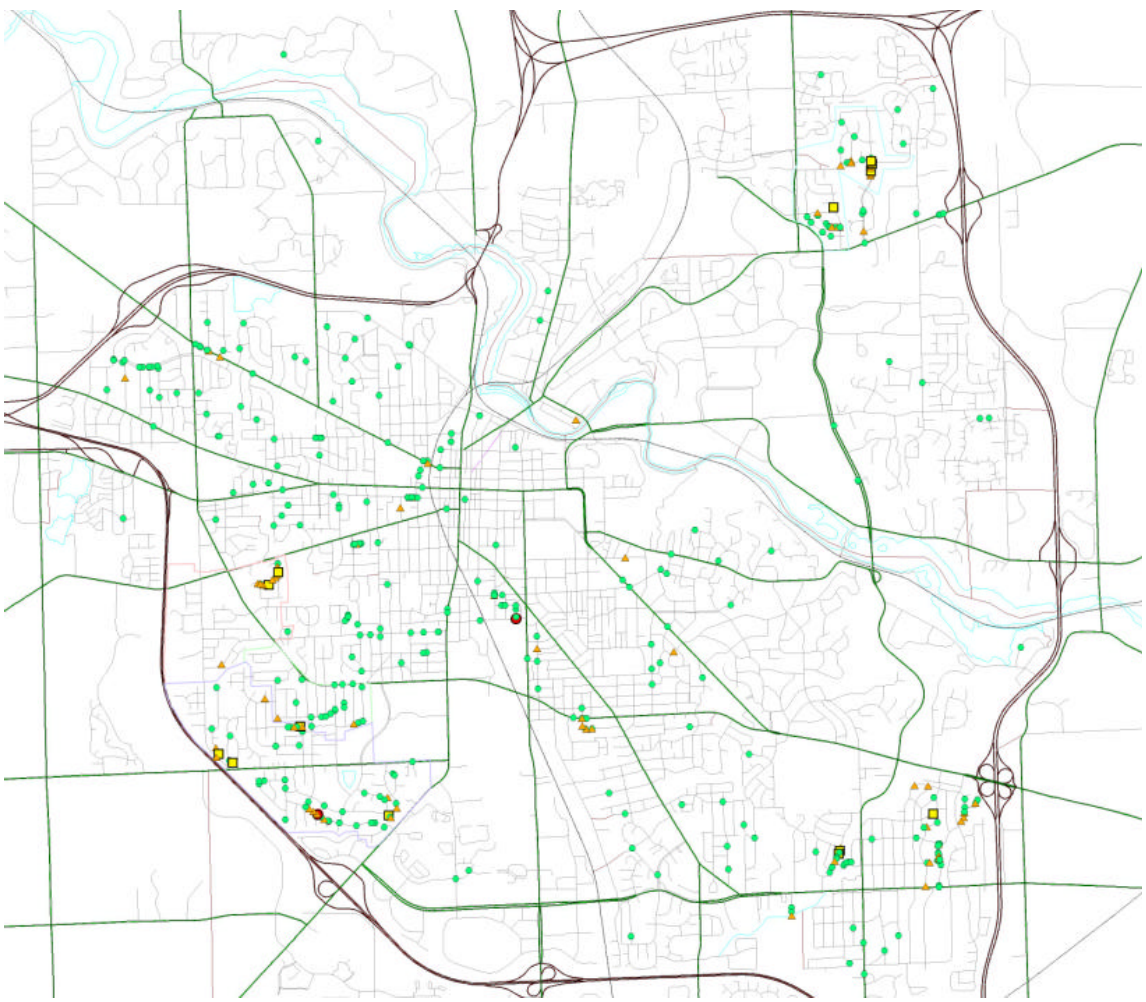

Figure D-1 Historical Flooding Locations

issues. Maps outlining boundaries of the study areas and the locations within each of these sewersheds where monitoring equipment was installed are provided in Figures D-2 and D-3. These monitoring efforts areas are described in more detail in the following sections.

D.2.1 Orchard Hills

The Orchard Hills study area is roughly bounded by Plymouth Road to the south, Rumsey to the north, Bunker Hill Road to the west, and Georgetown Boulevard to the east. There is a single discharge point from this study area on Georgetown as the sanitary sewer flows south to Plymouth Road. Sanitary Sewer backups and basement flooding have mainly been reported along Bluett and Georgetown. Flooding problems have been present in this area since the 1960s. A retention basin was constructed in 1979 at the corner of Bluett and Georgetown to reduce the problems that homeowners have experienced. Basement flooding has continued since the construction of this facility.

D.2.2 Bromley

The Bromley study area is roughly bounded by Plymouth Road to the south, Bluett Road to the north, Nixon to the west, and Prairie to the east. There is a single discharge point from this study area as the sewer flows south to Plymouth Road. Sanitary sewer backups and basement flooding have mainly been reported along Briarcliff Street and Burlington, two streets that are lower in elevation than other streets in the study area.

D.2.3 Dartmoor

The Dartmoor study area is roughly bounded by Liberty to the north, south to Pauline, east to Ivywood, and west to I-94. There are areas west of I-94 that contribute flow to the study area. A portion of this contributing area is outside of the City of Ann Arbor.

There is a single discharge point from this study area on Dartmoor Road. Sanitary sewer backups and basement flooding have not traditionally been a problem in this area, but basement flooding problems were reported along Dartmoor Road in the August 1998 storm and in June of 2000. The reported problems are along the main sewer that discharges from the study area. New development has taken place on the west side of this study area in the past few years.

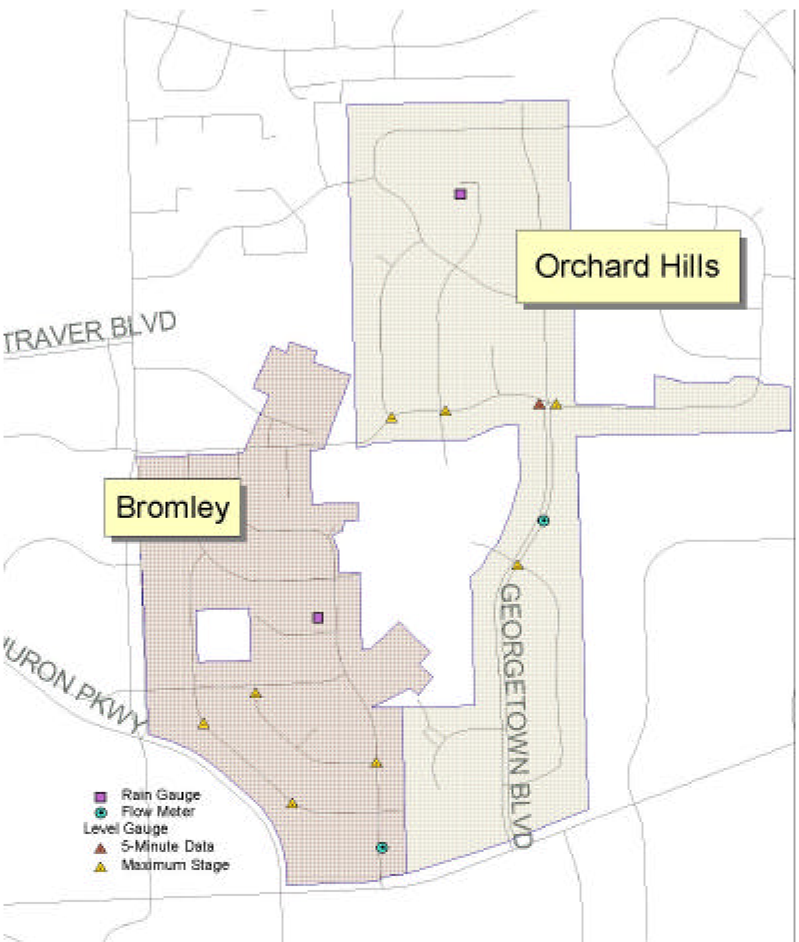

Figure D-2 Orchard Hills and Bromley Field Gages

Flows from both Scio Township and a section of Ann Arbor west of I-94 and north of Liberty Road discharge through a pumping station on Liberty Road, west of I-94. These flows discharge upstream from the Dartmoor Road sewer.

The study area discharges under Liberty Road and combines with the flows Liberty Washington area north of the Dartmoor study area. To account for the interaction of these two areas, the Liberty Washington area discharge was also monitored to understand its impacts on the Dartmoor study area. The trunk sewer accepting the discharge from both the Dartmoor study area and the Liberty Washington area consists of two parallel lines that flow through Virginia Park to Virginia Avenue and Bemidji Drive.

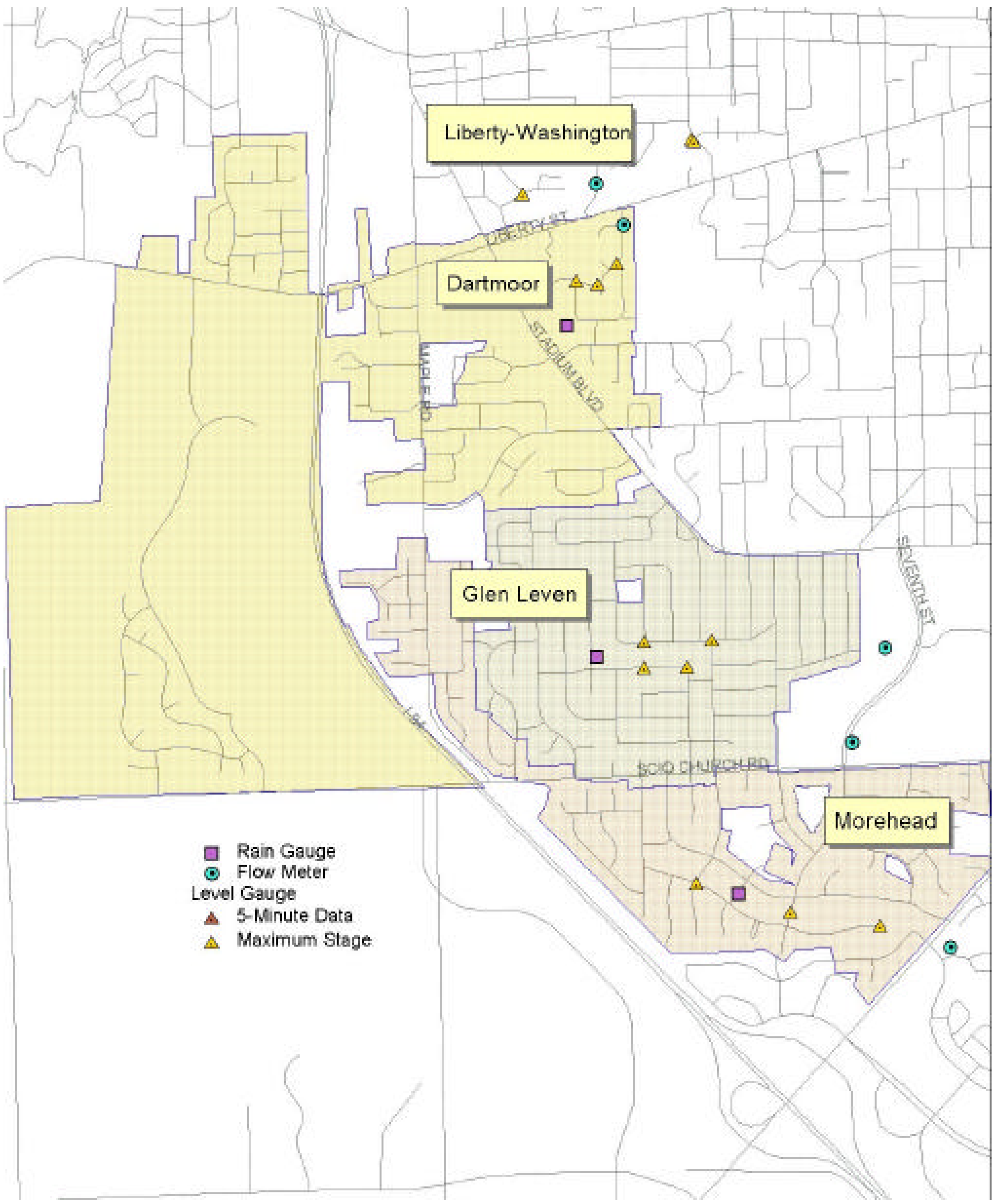

Figure D-3 Dartmoor, Glen Leven, Morehead, and Liberty-Washington Field Gages

D.2.4 Glen Leven

This study area extends roughly from Stadium to the north, Scio Church to the south, I-94 to the west, and Woodland to the east. There are two discharge points from this study area. Sanitary sewer backups and basement flooding have been reported along Avondale Avenue and Weldon Boulevard. There are also other areas within this study area that have experienced problems during the 1998 storm.

D.2.5 Morehead

The Morehead study area is roughly bounded by Scio Church on the north, south to Northbrook, west to I-94, and east to Ann Arbor-Saline. There is a single discharge point from this study area. Sanitary Sewer backups and basement flooding have mainly been reported along Morehead Drive and Morehead Court near the south side of this district. These reported problems are generally in a low-lying area adjacent to a tributary to Malletts Creek. Several of these houses are next to ponds that are along the watercourse.

While this study area consists mainly of mature neighborhoods, there is more recent development to the west.

D.3 Previous Mitigation Attempts Specific to the Study Areas

A number of changes to the collection system have been made through the years to address the observed basement backup problems. The most recent investigations and changes to the collection system are identified in the following subsections.

D.3.1 Smoke Testing Georgetown Area - 1998

This study detailed the results of smoke testing performed in the Bromley and Orchard Hills study areas. The work was performed to document potential sources of rainwater inflow and infiltration that may have been the cause of basement flooding in August, 1998. It also included a list, by address, of the number of downspouts potentially connected to the sanitary collection system. This report contained an inspection log of manholes in the two study areas. The inspection included cover type, chimney type and condition, wall type and condition, observed infiltration, and potential infiltration. Individual field inspection forms for each manhole are available.

D.3.2 Sanitary Trunk Sewer Study - July 1995

This study compiled and analyzed information on the sanitary trunk sewer system so that capacity issues in that system could be identified. Assessments of the immediate and future needs of the trunk sewer system were made. The study contains estimates of population and area, both existing and future, for 22 tributary service areas that are served by the Ann Arbor WWTP.

This report contained a number of dry weather flow (DWF) measurements made throughout the system to support the evaluation and modeling efforts. The DWF values collected appear to be instantaneous readings. These were used to validate static model estimates of flow in each section of the trunk sewer system. The report contains a set of maps that presented the results of the model development, calibration, and capacity assessment work. This report includes a comprehensive list of recommended system improvements that have a 1995 construction cost of $7 to $8 million.

The report did not show any trunk sewer problems in the Northeast study areas, but did show a marginal discharge pipe from the Dartmoor area. The trunk sewers serving the Glen Leven and Morehead areas did not show significant capacity problems.

D.3.3 Lansdowne Investigations - 1987

Three related reports prepared by Soil and Materials Engineers, Inc., McNamee Porter & Seeley, and Harza, document contributing factors to flooding in the Morehead area. These reports provide boring logs that document area geology, groundwater elevation data, and a recommendation for three relief sewer projects. These reports include information on the impacts of the August 22, 1987 storm event, a summary table listing the impacted residences, and a discussion of flow-monitoring performed in the area.

D.3.4 Northeast Ann Arbor - Ann Arbor Internal Memoranda - 1982

This document provides a detailed review of the Bromley and Orchard Hills study areas and documents the flooding that took place during a June 28, 1982 storm event. There is information regarding roof drain downspouts connected to the sanitary system and reference is made to a basement elevation survey conducted in 1970 for some homes in the study areas. There is also a reference, including some technical information, concerning the retention basin constructed in the Orchard Hills area in 1970. While there is mention of a flow meter installed in the Bromley area, data from that meter was not included in the document.

D.3.5 Sanitary Trunk Sewer Study - Report on Traver Creek Sanitary Trunk Sewer System - February 1980

This study determined present and potential system problems of the Traver Creek service area. At the time, this area's northern portions were undeveloped. The project recommended a new gravity relief sewer to accommodate an estimate of more than doubling the tributary population in this area. The Traver Creek area is not part of the project study areas, nor is it expected to impact flows discharging from any of the project study areas.

D.3.6 Report on Sanitary Trunk Sewer System - Phase I - Audit of Existing Systems - June 1979

This study audited the existing sanitary trunk sewer system and provided the basis for subsequent studies. The report included design, construction, and cost information as well as identified service agreements for ten years prior to the study. This audit includes a review of the 1969 report and a few other documents used for design of system facilities. This review, where possible, provided a check of each improvement constructed to determine if it complied with the study recommendations.

D.3.7 Sanitary Sewerage Study for the North and West Sides of the City for Ann Arbor, Michigan - March 1969

This study of the sanitary trunk sewer system focused on Fleming Creek, Traver Creek, Honey Creek, the West Side sub-mains and a proposed North Side interceptor. The study addressed capacity concerns and made recommendations to address these issues. The document contains a section titled "Present and Future Flows". This section includes estimates of tributary area, flows and unit rates for components such as per capita sanitary flow and a 2-gpm estimate of footing drain contribution during rainfall. While these estimates may be somewhat dated, they provide background on the design criteria used for the trunk sewer system and approaches to managing wet weather flow in the sanitary sewer system.

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E. Study Design

Contents

E.1 Field Monitoring

E.1.1 Introduction

The field-monitoring program was prepared specifically to support the development and calibration of models in each of the five problem areas included in this project. To do this, activities were performed to verify the location, configuration, and characteristics of the collection system sewers and manholes. To identify the specific response of the collection system to rainfall in each study area and level data was collected. At the same time, rainfall was monitored in each of the areas, as well as information recorded on the peak depth observed in the parts of the collection system where flooding had previously been observed.

Another aspect of the field program was to perform collection system inspections in and around the five problem areas. This included manhole inspections, downspout inspections, dye testing, and smoke testing. During the manhole inspection work, a number of individual residential connections were identified that were subsequently monitored during rain events. This was done to make estimates of the flows from residential footing drains. Flows from areas and pumping stations impacting the Dartmoor study area were also monitored to better understand these effects.

E.1.2 Monitoring Program Configuration

The field-monitoring program included installation of devices to establish the dry weather flow generation rates and wet weather response rates of the sanitary collection systems serving the study areas, as shown in Figures E-1 and E-2. This effort included collecting data from existing pumping stations and at the WWTP. In addition, flow, level and rainfall monitors were installed as part of the project. The data was used to understand in detail the flows discharging from each of the study areas and to calibrate both a trunk sewer model and individual study area models.

Data collected from existing flow monitoring devices included hourly and equalized daily flows at the Ann Arbor WWTP, rainfall from three existing rain gages at the Ann Arbor Airport (hourly data), and from the Midwest Regional Climate Center located on the North Campus of the University of Michigan (15-minute data). This data was used to calibrate the trunk sewer model as described later in this report. Data on pump run times was also collected from the Liberty Road and Lakewood pumping stations. This

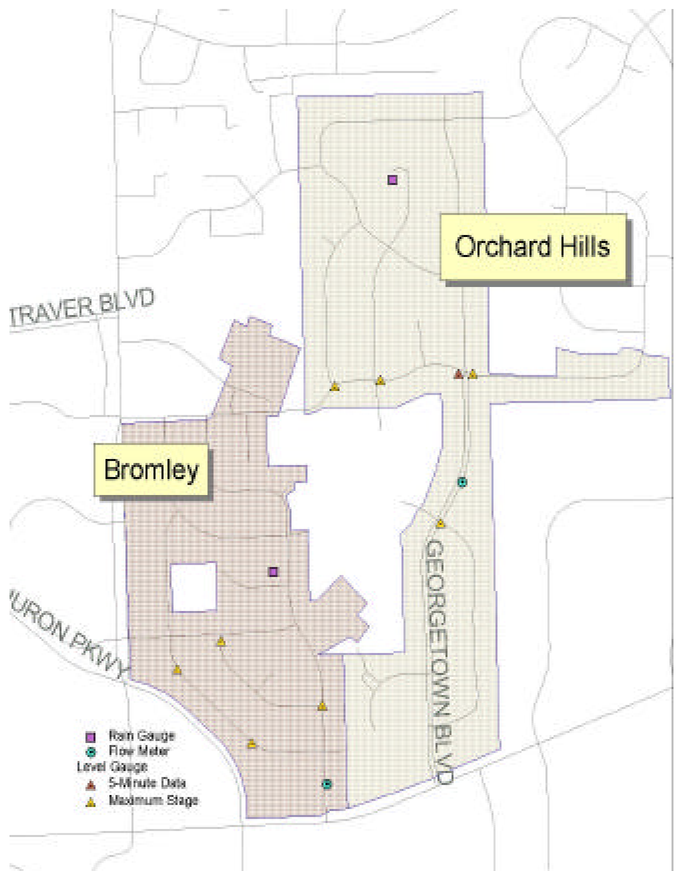

Figure E-1: Orchard Hills and Bromley Field Gages

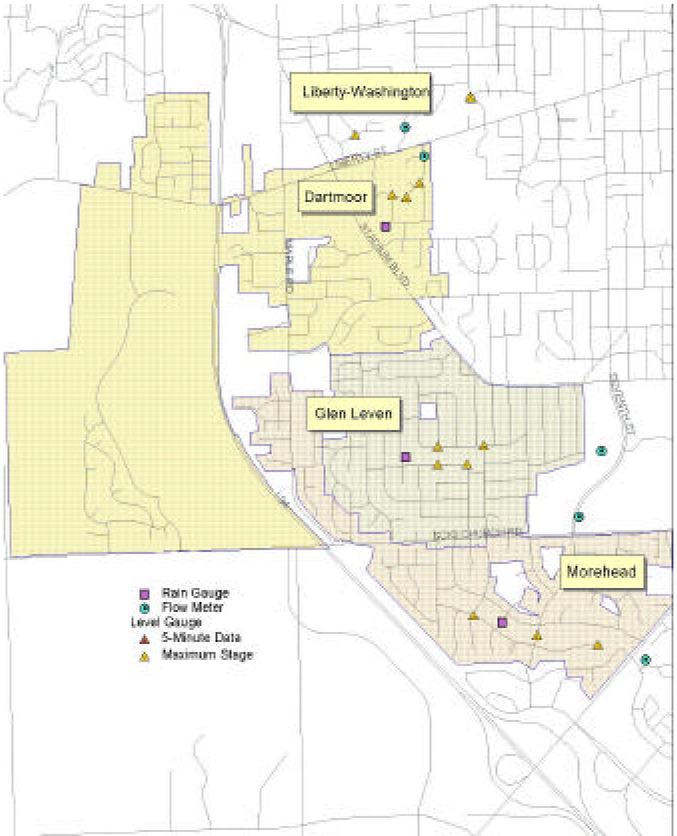

Figure E-2 Dartmoor, Glen Leven, Morehead, and Liberty-Washington Field Gages

E.1.3 Flow and Rain Monitoring

E.1.3.1 Monitoring Locations

Figures E-1 and E-2 present the general locations of the monitoring devices installed to collect data. Table E-1 lists the street location for each installation, the manhole ID identified on sewer index map, and the diameter of the pipe at the installation location.

All level and rain data was collected from the end of

data was used for calibration of the detailed study area models.

Flow meters were installed to monitor total flows at the discharge of each study area. Rain gages were installed near the center of each study area to reduce errors in estimating rainfall response. Peak level recorders were installed in parts of the collection system where basement flooding was known to take place, to better understand the maximum flow level that took place during large storms. Level recorders were also installed downstream of problem areas if backwater was a potential problem and at existing storage facilities to monitor their use and effectiveness.

Table E-1. Flow Meter Installations

Study Area	Manhole	Diameter	Location
Orchard Hills	47	10"	Georgetown Boulevard north of Yorktown Drive
Bromley	2	10"	Prairie Street north of Plymouth Road
Dartmoor	2	15"	Corner of Dartmoor Road and Peppermill Way
Glen Leven	11	15"	East of corner of Glen Leven and Woodland in field.
Glen Leven	102	18"	On east side of South Seventh Street north of Scio Church Road
Morehead	49	18"	East of Ann Arbor-Saline Road and South of Malletts Creek
Liberty Washington	49	12"	Westwood Apartments drive, next to bridge

May until the end of November 2000. Flow data, continuous level, and peak level data was collected from the end of May until the end of September in the five study areas. The Dartmoor study area flow meter remained installed until the end of November to supplement the Liberty Washington meter, which collected data between the middle of September and the end of November 2000. Five rain gages were used to collect data from the end of May until the end of November 2000, except for the Orchard Hills rain gage, which was installed in the beginning of May. No rain data was collected between April 21st and May 10th due a metering problem.

A total of seven flow monitors were installed at study area discharge locations. The discharge flow meter locations were evaluated for acceptable flow conditions and access constraints.

These meters collected level and velocity data at 5-minute intervals. This data was used to calculate flows at these same intervals. During installation, each of these meters were calibrated to the levels and velocities observed in the sewers. During the monitoring period, the meters were visited twice a month for maintenance and to validate the meter calibrations. This visit gathered information on the condition of the meter and to calibrate and validate the devices. This data was used to ensure that the meters were operating properly between visits and make sure that the appropriate flow values were available for the modeling efforts.

In addition to the continuous flow monitors, a continuous stage recorder was installed at the Orchard Hills underground retention basin at the corner of Georgetown Boulevard and Bluett to monitor its operation during storms. This meter was used to collect level data at 5-minute intervals so changes in storage could be calculated. During installation, this level meter was calibrated to the levels observed in the sewer. This meter was visited twice a month to provide maintenance and validate the level calibrations. The third type of monitor installed were peak level recorders.

Table E-2 lists the locations and manhole identifiers for each level recorder installed. A total of 21 peak level recorders were installed to collect information about maximum levels taking place in the collection system. Each of the locations were reviewed for suitability for the installation of these devices. These were rela-

Table E-2. Peak Level Recorder Installation

District	Manhole	Location
Glen Leven	62	Corner of Avondale Avenue and Granada Avenue
	50	Corner of Avondale Avenue and Mershon Drive
	1	Weldon Boulevard East of Waverly Road
	59	Corner of Weldon Boulevard and Winsted Boulevard
Morehead	15	East end of Morehead Court
	33	South Seventh north of Morehead Drive
	47	Corner of Morehead Drive and Mershon Drive
Orchard Hills	3	Corner of Bluett Drive and Bunker Hill Road
	7	Bluett Drive East Antietam Drive
	12	Corner of Bluett Drive and Georgetown Boulevard
	23	Corner of Georgetown Boulevard and Yorktown Drive (South end)
Bromley	4	Corner of Prairie Street and Burlington Street
	19	Burlington Street south of Aurora Street
	4	Briarcliff Street west of Prairie Street
	7	Briarcliff Street south of Aurora Street
Dartmoor	10	Corner of Dartmoor Road and Ivywood Drive (East)
	17	Corner of Dartmoor Road and Dover Court
	27	Corner of Dartmoor Road and Ivywood Drive (West)
Liberty	55	Intersection of Carolina and Thaler
Washington	NA	Virginia Park at Virginia Ave. and Bemidji Road: 12" pipe
	NA	Virginia Park at Virginia Ave. and Bemidji Road: 15" pipe

Table E-3. Rain Gage Installations

District	Location
Orchard Hills	2699 Antietam Court
Bromley	2335 Prairie Street at Corner of Sheffield Court
Dartmoor	1925 Ivywood Drive near corner of Dartmoor
Glen Leven	1609 Glastonbury at Corner of Weldon
Morehead	1496 Morehead Drive
Liberty Washington	Used the Dartmoor gage

tively simple devices that recorded the maximum water level that occurred since the previous visit. These devices did not record time so they were visited after each major storm to determine peak sewage levels that took place.

All peak level recorders installed in the five study areas were located along streets where flooding had previously been reported. One exception was an Orchard Hills peak stage recorder installed on Georgetown Boulevard south of the flow meter. This recorder was placed at this location to monitor for potential backwater affects caused by the trunk sewer system. Peak level recorders installed for the Liberty Washington area were located to monitor the levels downstream of the Dartmoor study area discharge to the trunk sewer system and upstream of the Liberty Washington flow meter.

Table E-4 Rainfall Volumes

Number of storms that exceeded

Area	1”	2”	3”
Orchard Hills	12	2	0
Bromley	12	3	1
Dartmoor	11	2	1
Glen Leven	11	3	1
Morehead	11	2	1

To determine rainfall/flow relationships, five rain gages were installed, one near the center of each study area. Locating these rain gages using this criteria helped to reduce errors in estimating average rainfall that took place in each study area. Rain data from Dartmoor study area gage was used for the Liberty Washington area. Table E-3 documents the location of each rain gage installation. These rain gages were tipping bucket type devices that collect data on the quantity of rainfall over 5-minute intervals. This data was collected on a 2-week cycle during the life of the project. Maintenance of the gages included checking for debris in the gage funnel and material on the tipping bucket.

E.1.3.2 Rainfall Statistics

Rainfall data were collected between the end of May 2000 and the end of November 2000 for all five of the study areas. Table E-4 lists the number of storms monitored in each study area over the data collection period that exceeded 1", 2" and 3". The most significant storm that was monitored took place over June 24-25, 2000. This significant storm produced from 2.93" in the northeast Ann Arbor, Orchard Hills study area to 3.96" is the southwest Ann Arbor, Glen Leven study area.

A number of other sources of rainfall information were also used for this project. This included rain data from the following sources:

(1) The Ann Arbor Airport provided hourly data from 11/1998 through 5/2000

(2) The Midwestern Regional Climate Center of the University of Michigan (North Campus) included 15 minute data from 1/1995 through 12/1998

(3) The Midwestern Regional Climate Center in Ypsilanti, MI included 15 minute data from 1/1995 through 12/1998

The rainfall data collected were a valuable component used for the evaluation of the wet weather

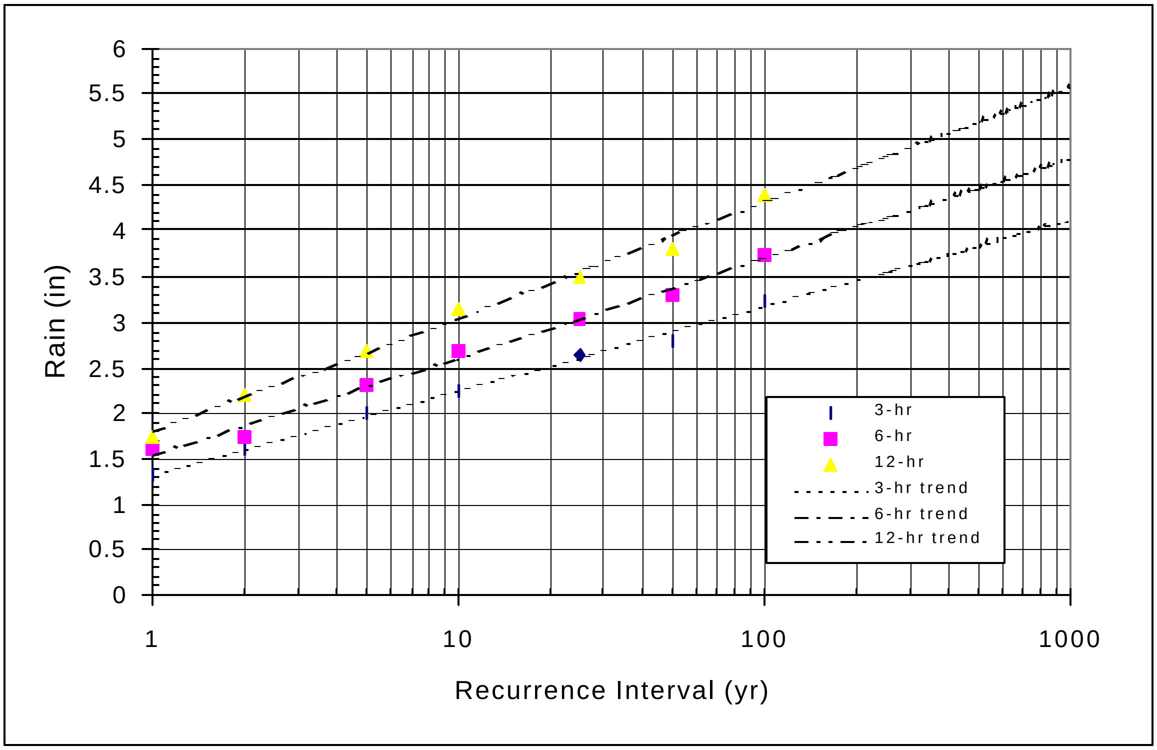

Figure E-3 - Statistical Rainfall Recurrence Intervals

response in each study area. To better understand how the historical rainfall events compare to statistical averages assembled for the Ann Arbor Area, Figure E-3 was prepared.

The information used to generate this figure is taken from the National Weather Service (NWS) Technical Paper 40 (TP-40). The individual points included on this figure are taken from recurrence plots for different storm duration time periods. Note that for this project, the large events that have caused the greatest impacts on the collection system and been the major cause of problems in the five study areas are the events with rainfall duration that are between 4 and 6 hours. The June 24-25, 2000 storm produced between 3" and 4" of rainfall across the City of Ann Arbor over a 4-6 hour period. For the Ann Arbor area, this would represent a recurrence interval of between 25 and 200 years depending on rainfall amount.

The significant rainfall event that took place in August 1998 produced up to 4.5" of rainfall in certain parts of the city. However, this rainfall amount took place over a period of 8-12 hours. This would relate to a recurrence interval of slightly over 100 years for the City of Ann Arbor. Both of these storms represent extremely large and infrequent events.

These recurrence statistics are intended for a single location. The largest storm amount for the August 1998 storm took place in the northeast study areas and the largest storm volume for the June 2000 storm took place in the Southwest study areas. Specific magnitude and duration storm events from historical rainfall data are used to determine the "return period". As an example, a "return period" of 100 years means that, on the average, an event of this magnitude and storm duration, or greater, is not expected to occur more often than once in 100 years.

Because statistical analyses are employed to make an assessment of probability, the longer the period of record the better. Because detailed records of precipitation exist for not much more than 100 years, the longer "return period" storm events have much

Table E-5. Daily Average Flows (cfs)

Study Area	No. Days Analyzed	Ave. Flow	Max Flow	Min Flow
Orchard Hills	35	0.15	0.22	0.06
Bromley	38	0.14	0.20	0.08
Dartmoor	27	0.93	1.36	0.43
Glen Leven North	32	0.08	0.14	0.03
Glen Leven South	34	0.22	0.36	0.07
Morehead	34	0.30	0.51	0.12
Liberty-Washington	8	0.43	1.03	0.06

greater uncertainty than a 1-year storm would, for example. It is also important to understand that this relationship is intended for a specific location. In other words, each of the study areas could expect large storms at different times other that at the recurrence period.

E.1.3.3 Flow Statistics

The analysis of flow data was performed using data collected from the seven flow meters. These meters collected data between May and November 2000. A summary of the average daily, maximum, and minimum flows observed during dry weather flows in cubic feet per second (cfs) observed at each meter are shown in Table E-5.

The June 24-25, 2000 rain event caused sewer surcharging and high flows in each of the five study areas. Since the flow meters were installed during this period, valuable information was able to be collected. Table E-6 summarizes the amount of rainfall, the maximum flows recorded, and the calculated peaking factor for each of the study areas during this large storm.

The peaking factor is calculated as the maximum flow recorded divided by the average daily dry weather flow. This factor becomes a measure of how responsive each study area is to wet weather. In general, the wet weather response ranged from 9 to 31 times the average dry weather flow between the different study areas.

The lowest peaking factor identified was for the Dartmoor study area. This information might suggest that this area is the least responsive to wet weather or it may indicate that this study area collection system has less capacity to handle wet weather flows. The lower capacity could be due to the trunk sewer limiting discharge from the area and is not necessarily a result of undersized pipes inside Dartmoor. In contrast, the Glen Leven North study area generated up to 31 times more flow than its average dry weather flow. This suggests that Glen

Table E-6. Rainfall, Meter Level, Flow, and Peaking Factor for Study areas

Study Area	Total Rain (in.)	Meter Level Max. (in.)	Max. Flow (cfs)	Peaking Factor Q_{max}/Q_{avg}	Peak Surcharge Meter (in.)	Peak Surcharge PLR** (in.)
Orchard Hills	2.9	104	2.3	15	94	88
Bromley	3.2	76	3.15	23	66	77 .0
	9.7	5.2	24	-----	-----	
Dartmoor	4.0	177	8.02	9	162	150
Glen Leven N.	4.0	84	4.2	31*	69	87
Glen Leven S.	4.0	9.7	5.2	24	-----	-----
Morehead	3.5	104	8.5	28	-----	81

* Used 0.14 as the average dry weather flow due to a meter calibration change after the June 25 event.
** PLR = Peak Level Recorder

Table E-7 Number of Surcharge Events Recorded by Meter and PLR.

Study Area	Pipe Diameter (in.)	Total Surcharges Meter (#)	Total Surcharges PLR** (#)	Peak Surcharge Meter (in.)	Peak Surcharge PLR* (in.)
Orchard Hills	10	11	8	94	87.5
Bromley	10	9	7	66	77.3
Dartmoor	15	8	3	162	149.5
Glen Leven N.	15	3	5	69	87
Glen Leven S.	18	0	-----	-----	-----
Morehead	18	2	3	-----	81
Liberty - Washington	12	0	-----	-----	-----

* PLR = Peak Level Recorder
** based on 8 readings after the 8 largest storms

Leven is the most responsive to wet weather. It also shows that the discharge sewer serving this area has more capacity to handle these large peak flows compared to the other areas monitored.

E.1.3.4 Stage Statistics

Stage analysis included the review of data from the peak level recorders installed in all study areas and review of the continuous level meter installed in the Orchard Hills retention basis. The total number of surcharge events recorded by the flow meters and peak level recorders (PLR) is shown in Table E-7. In general, a surcharged pipe indicates that the capacity of the sewer system has been exceeded and flows have the potential to cause basement backups in homes adjacent to the sewer system.

The number of surcharge events recorded ranges from zero at the Glen Leven South study area to as many as 11 in the Orchard Hills study area. Based on the data collected in 2000, the sewer system in many of the study areas was shown to regularly reach its capacity during storms that exceed 1" of total rainfall. However, basement flooding in the five study areas, was only reported during the largest rainfall event on June 24-25, 2000, when 3 to 4 inches of rainfall was recorded in the study areas.

Table E-7 presents the maximum amount of sewer surcharging, defined as the height of water above the crown (top) of the pipe, recorded by the flow meters and PLRs during this event. The PLR in Dartmoor Road indicates that the levels rose to near the top of the manhole.

A summary of the PLR data collected between May and November 2000 is given in Table E-8. A total of eight surcharge events were recorded using the devices. The biggest storm on June 24, 2000 registered surcharging of the collection system at all peak level recorders that were installed. The Liberty Washington PLRs were installed in September 2000 and did not record any surcharge conditions for the two months that they were installed. The Orchard Hills recorder registered a surcharge condition after every significant rainfall event. The Bromley recorder registered a surcharge after all but one significant rainfall event.

Level data was also analyzed in the Orchard Hills retention basin at Georgetown and Bluett. This basin is a 58" x 94" arch shaped overflow pipe that extends about 400' along Bluett and Georgetown Boulevard. A level recorder was installed inside the overflow storage basin to monitor its operation. There are six overflow points from the sanitary sewer to the basin along the basin's reach. Note that these overflow points are located about 41" above the inverts of the sanitary sewer.

Only the June 24-25, 2000 rainfall event caused overflows into the basin. Figure E-4 shows the level recorded by a level sensor in the retention basin and the level data collected at the flow meter located in the sanitary sewer downstream from the basin. The

Table E-8 Summary of PLR Data Collected between May 2000 and Nov. 2000

			Maximum Surcharge (Inches)							
District	MH	Diameter (in)	4/20/00 Event	5/9/00 Event	6/5/00 Event	6/25/00 Event	7/10/00 Event	8/5/00 Event	8/23/00 Event	9/10&11 Event
Glen Leven	62	8				4.8	8.0			
	50	12	10.0	9.0		54.5	19.0	3.0		
	1	8				55.0				
	59	8				87.0				
Morehead	15	8				81.0	19.0			
	33	8				67.0	17.5			
	47	8				63.0			1.0	
Orchard Hills	3	8	6.5			74.5		31.0		12.5
	7	8	16.5			64.4	8.0	16.8	3.0	26.8
	12	10	33.5	5.9	3.3	87.5	22.0	34.5		48.5
	23	10	33.0	8.1	6.5	49.0	6.8	11.5	1.0	25.0
Bromley	4	10	10.8			77.3		5.5		28.8
	19	8				43.8				
	4	8	5.8	6.4		77.3	5.0	0.5	1.5	20.5
	7	8				61.4				
Dartmoor	10	15				149.5				
	17	15				145.0		4.5		
	27	12				141.0	133.0*			
Legacy Park	15"	15								
	12"	15								
	49	12								

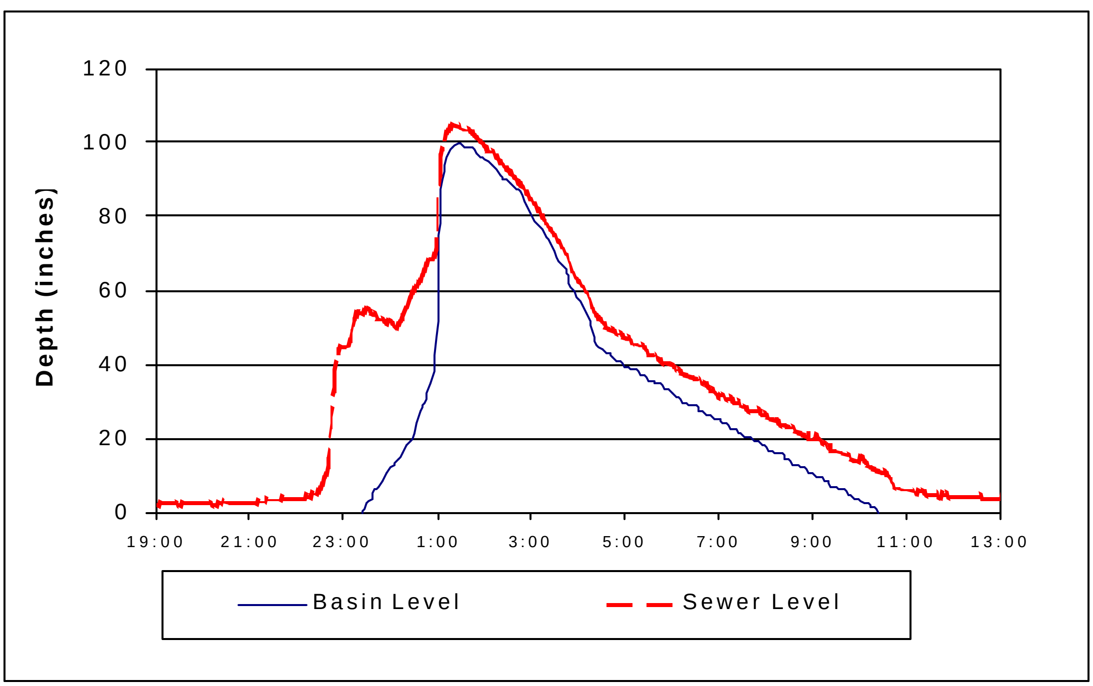

Figure E-4 Orchard Hills Retention Basin Levels

operation of the basin is seen as it starts to fill just before midnight and is surcharged between 1:00 and 4:30 AM. During surcharged conditions, the levels rise and fall quickly as storage in the collection system is limited.

E.1.3.5 Footing Drain Monitoring

One potentially significant source of inflow into the sanitary sewer system during storms is from house foundation footing drains that are directly connected to the sanitary sewers. Previous studies conducted in Ann Arbor have reported that the footing drain connection from a single home could contribute as much as 10 gpm during a storm. Since most of the houses in the study areas have directly connected footing drains, footing drains can introduce a significant proportion of the observed

Table E-9. Footing Drain Study Locations

Region	Manhole ID	Approximate Address
Orchard Hills	2	3000 Bluett
Orchard Hills	4	3022 Bluett
Orchard Hills	7	3130 Bluett
Orchard Hills	29	2488 Antietam
Orchard Hills	60	2537 Georgetown
Bromley	49 (E&W)	2814 Renfrew
Bromley	55	2500 Prairie
Bromley	5 (E)	2235 Prairie
Bromley	5 (W)	2235 Prairie
Glen Leven	94	1707 Tudor
Glen Leven	95	1706 Tudor
Glen Leven	22	1315 Glen Leven
Glen Leven	101 (E)	1530 Dicken Drive
Glen Leven	101 (W)	1530 Dicken Drive
Morehead Street	75	2189 Seventh
Morehead	35	2095 Chaucer

To estimate the amount of footing drain flow in each of the study areas, 20 locations were identified throughout the 5 study areas (about 4 per area) where house connections enter the sanitary sewer in manholes above the manhole benching. This configuration allowed the installation of temporary house lead extensions of about 1' into each manhole. Of the 20 locations identified, 16 installations were made as shown in Table E-9.

To estimate flows produced from individual homes, these house leads were visited during rainfall events to measure the flows being generated. Flows were measured using bucket and stopwatch methods. During each storm being monitored, flows were measured a number of times as field crews visited multiple manholes during the monitoring events. The storms of 8/17/00 and 9/11/00 were monitored by field crews. Two to three tests were performed at each location during each event.

As noted earlier, footing drain flows were monitored during selected storms. This information was collected on August 17, 2000 and on September 11, 2000. The August 17, 2000 storm was short and of low volume and produced a limited wet weather flow response. During this period, footing drain flows ranged from 0.1 to 0.5 gpm.

The September 11, 2000 storm produced between 1.57" to 1.8" of rain over a 5-hour period. During this storm, footing drain flows were collected during a period of steady rainfall. Figure E-5 shows the footing drain flows measured during this storm. The measured flows ranged from 0 to 3 gpm, with an average of 1.4 gpm for all locations measured. The average footing drain flows for the tests performed

Table E-10 Average Footing Drain Flows

Study Area	Flow (gpm)
Orchard Hills	1.1
Bromley	1.9
Dartmoor	No Test Locations
Glen Leven	1.8
Morehead	1.4

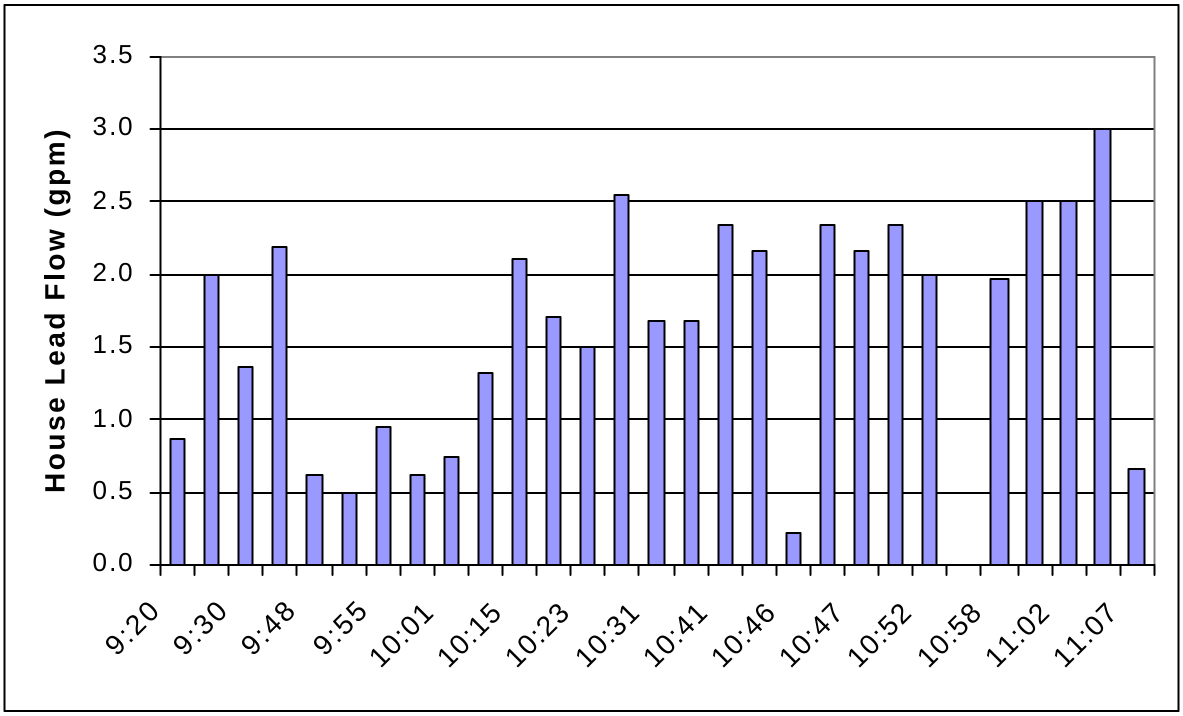

Figure E-5 Footing Drain Flow Measurements

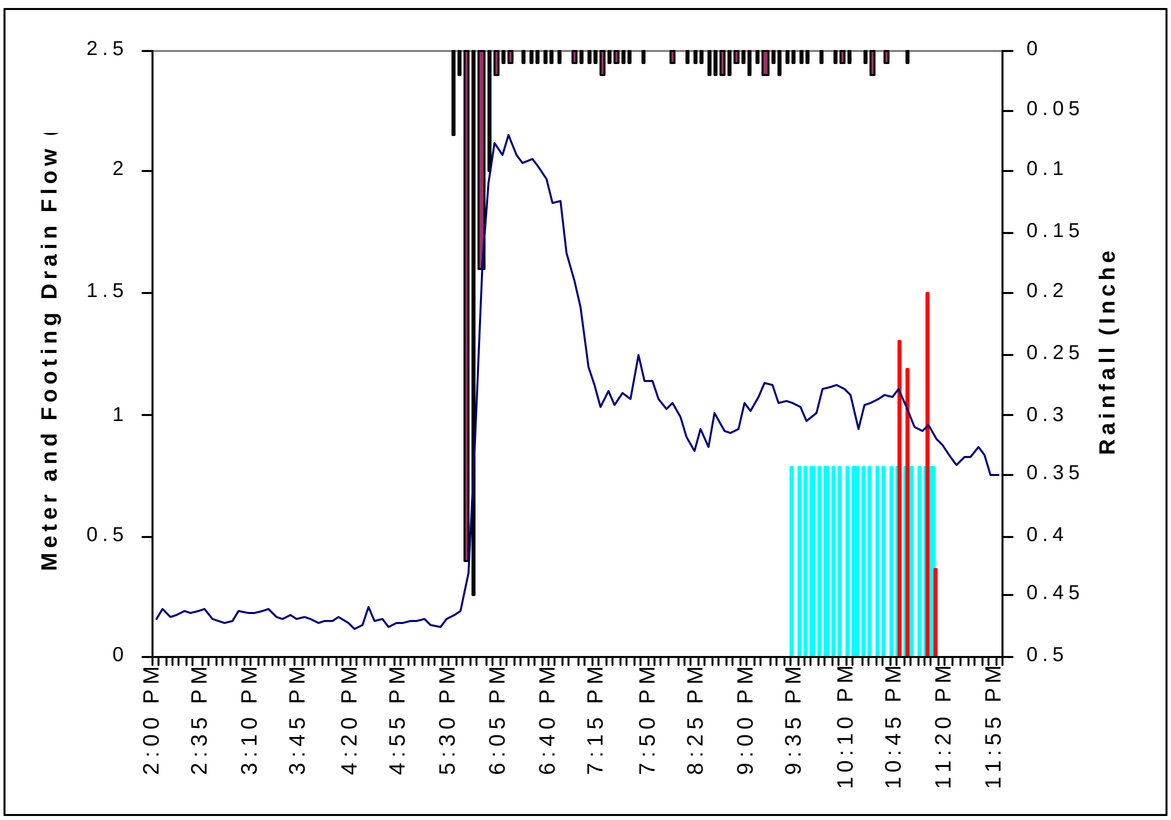

Figure E-6 Rainfall, Metered Flow, and Footing Drain Flows for Bromley Study Area

in each study area are summarized in Table E-10.

The rainfall, metered flow, and calculated footing drain flows were then compared for each study area. An example of this is shown in Figure E-6 for the Bromley study area. The rainfall data is graphed on the top of this figure. The peak of the storm took place at about 5:45 PM and then produced lower, but consistent, rainfall over the next five hours. The flow meter data is plotted as the continuous line with its ordinate of flow in cfs shown on the left axis. This figure shows a response that is similar in shape to the rainfall, peaking at about 6:00 PM and leveling off for a few hours before dropping back to a dry weather flow pattern.

An estimate of the total flow generated by all footing drains in each area was made using the assumption that the average footing drain flow of all areas, 1.4 gpm, is multiplied by the number of homes with footing drains in each study area. This estimate is graphed over the time the data was collected in all areas, and shown as the vertical blue bars in Figure E-6. The total footing drain flow estimates based on the individual measurements taken directly within the Bromley area are also shown as the variable height bars.

Figure E-6 suggests that as much as 90% of the wet weather flow in the Bromley area was caused by flows generated from footing drains. Similar results were found for three of the other study areas, with the Dartmoor study area being an exception. In this area, there appear to be other sources of RDI/I that are contributing to the flows recorded at the flow meter or the flow contribution from footing drain flows are higher than the average measured in the other areas.

E.1.4 Collection System Inspection Programs

E.1.4.1 Manhole Inspections

As part of the project scope, inspection of each accessible manhole in the study areas was performed. This work was performed to assess the current condition of the manholes and better understand the sewer connections between the manholes. The inspection work was documented on forms completed by field crews and through digital photographs to document manhole condition, sewer connections, and specific defects. Over 800 manholes were inspected as part of this effort. The overall condition of the manholes and the sewer connections was found to be excellent. The inspection did identify 24 minor maintenance issues, which the Water Utilities Department addressed shortly after identification.

In addition to providing information regarding infrastructure condition, the inspection notes and photos provided useful information when assembling the collection system computer models. These photos allowed rapid verification of the collection system connectivity and other attributes such as approximate invert elevation.

Field notes and digital photographs were provided to the Water Utilities Department separately. The field notes and photos are accessible using the project GIS. The available GIS coverage includes the manhole identifier used to locate manholes as part of this project and this identifier is also cross-referenced to the City's identifier system where possible. The identifier used is also listed on the field forms and is contained in the filename of the digital images. The digital images referred to on each field sheet were, with a few exceptions, taken in the following order:

1. The downstream pipe was photographed looking down the pipe from the manhole.

2. Each upstream pipe was photographed (clockwise, looking down manhole, from the downstream pipe).

3. Each house lead was photographed (clockwise, looking down manhole, from the downstream pipe).

4. Specific defects, blockages, or sources of I/I

were photographed in the images.

5. The last image is taken in plan view looking down into the manhole with the top of the image oriented to the downstream pipe.

E.1.4.2 Downspout Investigations

To further evaluate potential I/I sources within the study areas, downspout investigations were performed. These inspections were used to determine the number of homes that have directed roof downspouts away from the foundation. The statistical information from this effort is included in Table E-11.

Table E-11. Downspout Inspection Summary

Element	Dartmoor, Glen Leven, & Moorhead	Bromley & Orchard Hills*	Total (#)	Total (%)
Single-family homes	1,876	511	2,387	100%
Homes inspected	1,876	511	2,387	100%
Downspouts located within 5-feet of home	815	372	1187	50%
Downspouts discharging into ground	161	41	202	8%
Exterior Drains	2	6	8	0.3%

* Previous work and estimated numbers in the project study area

All of the homes within the study areas were inspected. Approximately half of the homes were found to have extended downspouts the recommended five feet away from their foundations. During the inspections it was noted that the remaining 50% of the homes that had not extended the downspouts five feet from the homes often had limited space to further extend downspouts.

Also, there were a number of homes that had downspout discharges that entered the ground. In many cases, the discharge points for these downspouts were determined at the time of the initial inspections. In the remaining cases, the homeowners were contacted to gain permission to do a more detailed inspection to determine if these connections discharged to the sanitary sewer or to another location on the property.

E.1.4.3 Dye Testing

After permission was granted to perform detailed inspections of the remaining downspouts that discharged into the ground, most of these discharge locations were determined. In cases where this could not be determined by inspection, flooded water tests were performed. Of the total of 48 homes that were visually inspected, 11 homes required flooded water testing to identify downspout discharge location. In two cases, dye tests were required to confirm the discharge location. The downspout inspection performed is documented in Table E-12.

Table E-12. Home Inspections Relative to Discharge Locations

Discharge Location	Number of Inspected Homes
Discharge location not to sanitary sewer	45
Confirmed connection to sanitary sewer	2
Discharge location unidentified	1

E.1.4.4 Smoke Testing

Smoke testing was planned to diagnose potential connections between sources of I/I and the sanitary sewer system. Because the results of previous smoke testing in two of the study areas showed limited value, it was decided not to pursue further testing under this study.

E.1.4.5 Scio Ridge Inspections

Portions of the flows that discharge through the Dartmoor study area originate in Scio Township. Much of this flow passes through a sewer along Scio Ridge. In many cases, this sewer is located in low lying areas that have the potential for I/I from surface sources. To provide a complete accounting for this potential, this system was reviewed as part of this project. An initial review of the Liberty Road pumping station pump run times showed that there was the potential for I/I from this area lasting several days after a storm. Therefore, an inspection of each of the manholes along the Scio Ridge sewer was performed to investigate for potential I/I. Representatives from Scio Township, the City of Ann Arbor, and CDM participated in the inspection.

A total of 15 manholes along the sewer were identified and inspected for cracks and poor seals that could potentially allow water to enter the sanitary system. The location of each manhole was also checked for its potential to become submerged by ponding or flooding. This was especially important as part of the Scio Ridge sewer line runs under a wetland area. The inspection found that in general the manholes appear to be in good condition with no signs of cracks or leaking around seals. However, in areas prone to flooding, it was found that there is potential for inflow through manhole cover holes and frames.

Two of the 15 manholes were not located and are probably buried. The City of Ann Arbor had recently located these two manholes by televising the sewer line. Based on the investigation, the City of Ann Arbor has asked Scio Township to replace the manhole as tree roots have broken into it. However, based on its location, it is unlikely that significant I/I would enter at this location. The second manhole that was not found probably buried under a berm. Based on its probable location, it is unlikely to be a significant source of I/I.

The first 11 manholes upstream from the Liberty Road PS were either not in areas prone to flooding or had rim elevations high enough to prevent any inflow through holes in the cover. The next three upstream manholes, however, were located in a low area prone to flooding several days after rain events. Two of the manhole rims were at ground level and one was 6-12 inches below grade. Figure E-7 is a picture of the below grade manhole and its location in a low area.

Snowmelt was observed entering through the cover holes of the manhole below grade. Furthermore, a

Figure E-7 Low Manhole location along Scio Ridge

newer lateral line recently installed in this area also had manhole rim elevations at or close to grade. Although no significant inflow was observed at the time of the inspection, flooding high enough to cause manholes in this area to become submerged has been observed in the past.

Based on these observations, it was concluded that there is a high potential for significant I/I to enter the Scio Ridge sewer. Furthermore, the prolonged wet weather response observed in the Liberty Road pump station data is most likely due to I/I caused by the submergence of manholes in the Scio Ridge area. As a first step to towards better monitoring and regulating wet weather flows entering the Ann Arbor system, it is recommended that a flow meter be installed at the Scio Ridge sewer discharge, just upstream of the Liberty Road pump station. It is further recommended that Scio Township work to prevent I/I in this area.

E.1.6 Pumping Station Data Collection

Data on the operation of the Liberty Road and Lakewood pumping stations were collected by the WWTP. This information documented the operation of the two pumps present in each pumping station. The data collected showed that the tributary areas for both of these pumping stations had significant response to wet weather.

E.2 Homeowner Survey

E.2.1 Introduction

The City of Ann Arbor has background information on basement flooding developed from customer complaints and from prior homeowner surveys. There has also been a considerable amount of public feedback on the need to better understand the cause of the problems and develop solutions that will relieve the basement flooding problems experienced by the homeowners.

To develop a better understanding of the nature and extent of the basement flooding problem, this section documents the development of a homeowner survey that was used to determine if basement flooding has taken place, determines the frequency of the problem, and also seeks information to help understand the root cause of the flooding incidents. Another part of the survey work was to estimate the elevation of the basement floors of homes in the affected areas to assist with the computer modeling efforts.

E.2.2 Project Homeowner Survey

E.2.2.1 Survey Formulation and Implementation

The extent of basement flooding in the study areas was determined through door-to-door surveying. The first step in determining where to perform this survey was to identify flooded areas using the existing City of Ann Arbor database of reported flooding incidents. The areas with historical flooding were refined throughout the survey process and as more information was gathered.

Initially a questionnaire was developed through pilot sampling of the survey population. Using the questionnaire, crews conducted a field-survey in the areas of known basement flooding. The field survey included those households in the five study areas for which a significant cluster of problems had been identified, particularly during the 1998 event. The objective of the survey was to better define the extent of the problem and characterize the impact of the flooding on the households.

All questionnaires were kept confidential and this confidentiality was communicated to the participants. The field survey focused on only those problem areas that required greater detail to characterize the type and extent of the problem. All of the questions were worded to get more meaningful responses.

Initially, the questionnaires were distributed at the first project Workshop. The Workshop 1 attendees were asked to discuss the project and provide additional copies of the survey questionnaire to their neighbors. Shortly after the survey work began, the project team decided to add an additional question to help the modeling efforts. This additional question helped the project team determine the basement floor elevation. The homeowners were asked to measure the vertical distance from the front door sill to the basement floor. A diagram was provided to give clear instructions.

The initial survey results of workshop attendees and their neighbors were compiled. The compiled results were reviewed to identify households that would require field surveying. After these areas for field surveying were determined, the project team began an intense door-to-door survey effort. Using this method, all houses in the historically flooded areas were visited.

The field survey continued along each identified problem sewer segment until three to five homes were confirmed to not have been impacted by basement flooding. In some cases, other system features dictated where surveying would stop such as the upstream most point of a sewer. Where residents were unavailable to discuss the survey with the field crews, a letter and survey was left behind. Overall, an 80 percent response rate was achieved. The homeowners were typically very cooperative with the survey efforts.

Prior to the field-survey, notices were mailed informing these residents of the dates and times to expect surveyors. All survey participants received a phone number to call in the event that they preferred to schedule an appointment for the survey, or if they had questions or additional information to provide the City of Ann Arbor. Numerous scheduled meetings were arranged to address questions pertaining to the survey or to inspect the residents' property. Also, each participant received a thank you postcard.

E.2.2.2 Survey Results

The primary results of the homeowner survey were communication with the residents and an accurate definition of the extent of the flooding problems within each of the study areas was determined. Although establishing communication with the residents was not the original goal, the door-to-door survey provided an excellent opportunity to listen to the homeowners describe their basement flooding experience and inform the project team about how it impacted them. Furthermore, this communication helped answer numerous residents' questions regarding the project.

Approximately 500 homes received surveys and over 400 responses were received. This represents a greater response than anticipated and provided greater confidence in understanding the defined extent of the basement flooding problems. Appendix A provides a detailed summary of survey results. An overview of the results of the homeowner surveys is as follows:

- 412 surveys were submitted or collected by field personnel.
- 98% of respondents are homeowners.
- More than 86% of respondents lived at the residence during the August 1998 major storm event.
- 96% of respondents have downspouts discharging to lawn.
- 83% of residences have a full basement.
- 15% of residences currently have a sump pump.
- 49% of respondents have experienced damp basements (without flooding or standing water).
- 49% of respondents have experienced flooding or standing water.
- 55% of respondents have attempted some form of corrective action to prevent flooding.

E.2.2.3 Basement Elevation Survey

Basement elevations were determined for homes within areas that had historically experienced basement flooding within the project study areas. These basement elevations were needed to identify which homes had the potential for basement flooding using a model simulation calibrated to field-measured peak sewage levels. Furthermore, by viewing basement elevations that had been known to flood or not flood, additional information was provided with which to calibrate study area models. The vertical measurements collected for this work included:

- Manhole rim to sewer invert. This was determined in the field using measurements in each manhole.
- Manhole rim to front door sill. This was measured using in the field with survey equipment.
- Front door sill to basement. This was determined in most cases based on the response from the homeowner questionnaire. In some cases this was estimated based on house type.

During the modeling phase of the project, these basement elevations were compared to the model predicted peak water elevations in the sewers.

E.2.3 June 24-25, 2000 Incident Survey

During the course of the project, one major flooding event took place. Immediately following the June 24-25, 2000 storm, the project team and Task Force members went to the neighborhoods to better understand the nature of the flooding. In addition to this firsthand information, the Water Utilities Department received telephone reports, the project team members received homeowner calls, and project web site survey forms were provided that showed the extent of the flooding. The Water Utilities Department compiled all this information. In addition, this information was compiled and used during model calibration to help with assessing model accuracy.

E.2.4 Summary

The extent of the area impacted by basement flooding within each of the study areas was better defined through the door-to-door survey. This activity was critical to the success of the subsequent tasks performed as part of this project. Available information was used to define where basement elevation surveying would be focused. The basement elevations coupled with reported flooding during the June 24-25, 2000 storm event were used to enhance the model calibration. Furthermore, the basement elevations were used to assess which homes could be subject to basement flooding under a large storm condition.

E.3 Peer Community Review

E.3.1 Introduction

The project scope provides for a review of communities similar to Ann Arbor to determine what they have done to reduce sanitary sewer overflows and in particular to correct conditions that cause chronic basement flooding problems. The effort documented in this section has been to focus on communities with collection systems and conditions that are similar to those in the City of Ann Arbor. The communities selected were used to provide a frame of reference for developing corrective alternatives in Ann Arbor. The methods used, costs, institutional hurdles, and success of these various community approaches have been factored into recommendations developed for Ann Arbor.

Many communities have used traditional engineering based approaches that include providing additional relief sewer capacity and constructing equalization storage to reduce basement flooding problems to address wet weather problems. For this effort, the peer communities selected represent a wide range of alternative methods used to reduce wet weather related capacity problems.

E.3.2 Community Reviews

The following peer reviews were performed through contacts with those involved in the projects. In some cases the information is from consulting engineers involved in the work, but in most cases the success of the programs were based on comments from the utility staff who saw the results of the various programs. Since the success or failure of the different methods chosen to correct the problems directly impacted the utility staffers, they were often those with the best information on this important element of the review.

A brief description of each of the communities contacted is provided below. More detailed descriptions are included in the tables that follow.

1. West Lafayette, Indiana - A basement flooding problem was corrected through footing drain disconnections made at individual private homes using a reimbursement incentive program that involved local contractors. The overall program was found to be successful in controlling the basement flooding.

2. Auburn Hills, Michigan - To address contract capacity limitations and basement flooding issues, the City of Auburn Hills has undertaken a disconnection program of all homes in a single neighborhood in that community. The disconnection program is about one half complete and is expected to be complete in another year. Work on private property is coordinated by a City of Auburn Hills staff person.

3. Columbus, Ohio - A significant flooding basement problem led to recommendation of relief sewers in this project. This was recommended since it was believed that sufficient wet weather flows could not be removed from the system through remedial I/I programs.

4. Riverview, Michigan - The City of Riverview undertook a complete reconstruction and rehabilitation of their collection system because of its deteriorated condition. Prior to this final solution, a pilot footing drain removal program was found to be unacceptable because of social issues.

5. Canton Township, Michigan - To address chronic basement flooding and SSO issues, Canton Township has installed over 2,500 sump pumps throughout their community using Township utility staff. Since the installation of these sump pumps, the Township no longer has significant basement flooding or SSO issues.

6. Cedar Rapids, Iowa - Repeated basement flooding problems led to a recommendation for disconnecting foundation footing drains. Because of concerns about performing work on private property, the community did not undertake this program but instead is working on relief sewer projects to correct the problem. It is expected that basement flooding problems will remain an issue until these projects are completed.

7. Lynn, Massachusetts - The collection system was found to have excessive wet weather flows that resulted in basement flooding problems. A consent decree provided the impetus to inspect at least 80% of the homes in the area to determine if there were I/I sources connected to the sanitary sewer system. Much of the excessive wet weather flows were found to be the result of an inadequate storm drainage system, but connections of sump pumps in private homes was also an important issue. Significant steps were taken to ensure that sump pumps discharging to the sanitary system were removed.

E.3.3 Local Regulation Use

Examples of other communities that have used local regulations to address removal of I/I flows generated on private property include:

- City of Cincinnati, Ohio - Provided reimbursement funding for up to $3,000 for individual homeowners to disconnect footing drains with costs over that amount the responsibility of the homeowner.
- Montgomery County, Ohio - Used an authorized contractor approach to provide funding up to $3,000 per home for footing drain disconnection. Program included a public information component.

- Lower Paxton Township, Pennsylvania - To provide compliance with a consent order, the program reimbursed homeowners up to 50% of the cost for removing sump pump discharges entering the sanitary sewer system.
- City of Bellaire, Texas - Developed an ordinance to inspect and disconnect footing drains. The work could be performed by the homeowners, but in some cases the City paid the contractor directly and then allowed the homeowner to pay this back over a period of five years.
- City of Denver, Colorado - Used authority of entry to inspect individual homes. The City required that the disconnections of these connections to be made but provided reimbursement for the work that was performed. This program was undertaken after a voluntary disconnection program was not successful.
- Johnson County Unified Wastewater Districts, Kansas - Developed an ordinance that provided for entry to inspect homes and included sections on penalties if disconnections were not made. The program allowed the district to determine if the source was major enough to remove and partial compensation was provided in those cases.

E.3.4 Summary

The review of peer communities shows that traditional approaches such as use of relief sewers to provide additional capacity are still being widely employed. From those communities that have chosen to remove the flows generated from connected residential footing drains, it has been shown that care must be taken to account for the impacts of the work on individual homeowners. Since these methods rely on the cooperation of the homeowners to make the program successful, a public information program is a must. The use of regulatory requirements such as the pending SSO regulations may also assist in allowing the application of new methods such as footing drain removal on a non-uniform basis. Also, the cost of making the improvements on private property must be considered before implementing on a large scale program.

The peer review resulted in these important findings:

- Traditional engineering solutions are continuing to be employed in many communities because of the perceived difficulty in gaining homeowner support for removal of I/I sources from private property.
- Footing drain removal has been employed successfully and it has resulted in the elimination of basement flooding problems. Good public information is required for this to work properly.

To accomplish footing drain removal, a proper regulatory framework is needed, including local regulations or regulatory requirements.

E.4 System Modeling Approach

E.4.1 Introduction

The trunk sewer model is a computer-based model of the city-wide sanitary sewer system that was developed to understand system-wide impacts for various wet weather events and design storms. The trunk sewer model enabled the project team to evaluate a number of proposed alternatives and their impacts on flow and stage throughout the system. This approach ensured that the alternatives considered in the flooded areas did not merely result in moving the problem elsewhere.

E.4.2 Previous Trunk Sewer Model

Previous reviews of the collection system capacity have been based on a static peak dry weather and wet weather flow analysis. The previous trunk sewer model developed in 1995 used a steady-state hydraulic model, Hydra, to review the peak dry and wet weather flows projected for 1995 and future conditions. The peak dry and wet weather flows were generated based on population and equivalent population. In addition to these population-based flow rates, contracts, pump station capacities, and in some cases, pipe capacities were used to set a peak dry or wet weather flow rate for certain reaches.

The unit rates that were employed for this previous work are documented in Table E-13 . The population estimates for 1995 and future conditions provided in this table include both residential and equivalent nonresidential population estimates. These population estimates exclude tributary populations in Ann Arbor Township, Pittsfield Township, and Scio Township. For these areas, the purchase capacity agreements were used to determine their flow contributions.

Table E-13 Unit Flow Rates

Condition	Population	MGD	GPCD
Dry - 1995	193,300	56	290
Wet - 1995	193,300	88	455
Dry - Future	265,500	76	286
Wet - Future	265,500	109	411

The flow rate estimates were previously developed for four conditions:

1) Existing (1995) dry weather flows

2) Existing (1995) wet weather flows

3) Future ultimate service population dry weather flows

4) Future ultimate service population wet weather flows.

The time period to reach future ultimate service population values was expected to be approximately 15-years.

Under this approach, peak flow rates were calculated for each reach of the trunk sewer system and comparisons were made between these flow values and the gravity flow capacity of each section of the sewer system. If the calculated peak flow rate was less than 91% of the full pipe capacity, the sewer section was classified as adequate. If the rate was greater than 107% of the pipe capacity, the sewer section was judged to be unsatisfactory. A peak flow rate in the range of 91 to 107% was classified as marginal. These results were plotted on a map using a color-coded scheme shown in Table E-14.

Table E-14 Color-coded Scheme for Map Plot

Peak Flow/ Pipe Capacity	Rating	Map
< 91%	Satisfactory	Green
91% to 107%	Marginal	Yellow
> 107%	Unsatisfactory	Red

E.4.3 Trunk Sewer Model Upgrades and Detail Study Area Models

As part of this project, a dynamic hydraulic model was developed using the US EPA SWMM model. This model can handle dynamic flow routing and backwater effects that occur in sewer systems. This model can perform calculations of RDI/I for different rainfall conditions, such as historical storms, design conditions, and dynamically route the flows through the conveyance system that composes the trunk sewer system.

The available collection system data used to prepare the 1995 Trunk Sewer Model was used to prepare the upgraded trunk sewer model for this project. The model incorporated the elements used in the 1995 model through the use of the model database to generate initial connectivity and attributes of the trunk sewers. These attributes included pipe diameter and length, upstream and downstream inverts and ground elevations. In addition, key diversions and cross connections locations that exist in the trunk sewer system needed to be field checked to better understand how they operate.

This effort improved the confidence how these hydraulic connections work in the trunk system. These investigations included the two diversions from the High Level Interceptor to the Northside Interceptor to determine how to best represent these diversions in the model. These diversions are physically based in the model. This means that the diversion in flows will be based on hydraulic calculations and not estimated flow splits as they are in the 1995 trunk sewer model.

Changes to the collection system that have taken place since 1995 were also incorporated as needed to reflect current conditions. One major change included was the removal of the Arbor View pump station, which was replaced with a gravity sewer.

The model also includes the in-system lift pumps that are in the collection system. These lift pumps are represented in the model using a head-discharge curve used to approximate their operation. The model does not include the pumps at the Wastewater Treatment Plant; rather, the collection system is included only up to the headworks of the WWTP.

A sewer attribute database was used together with the manhole inspection field work to create detailed system models for each of the five study areas. Approximately 10 to 20 percent of the information needed for these detailed models was found to be missing from the sewer attribute database.

E.4.4 Model Comparisons

Model comparisons to design flow capacities are provided in Figure E-8. Although the trunk model

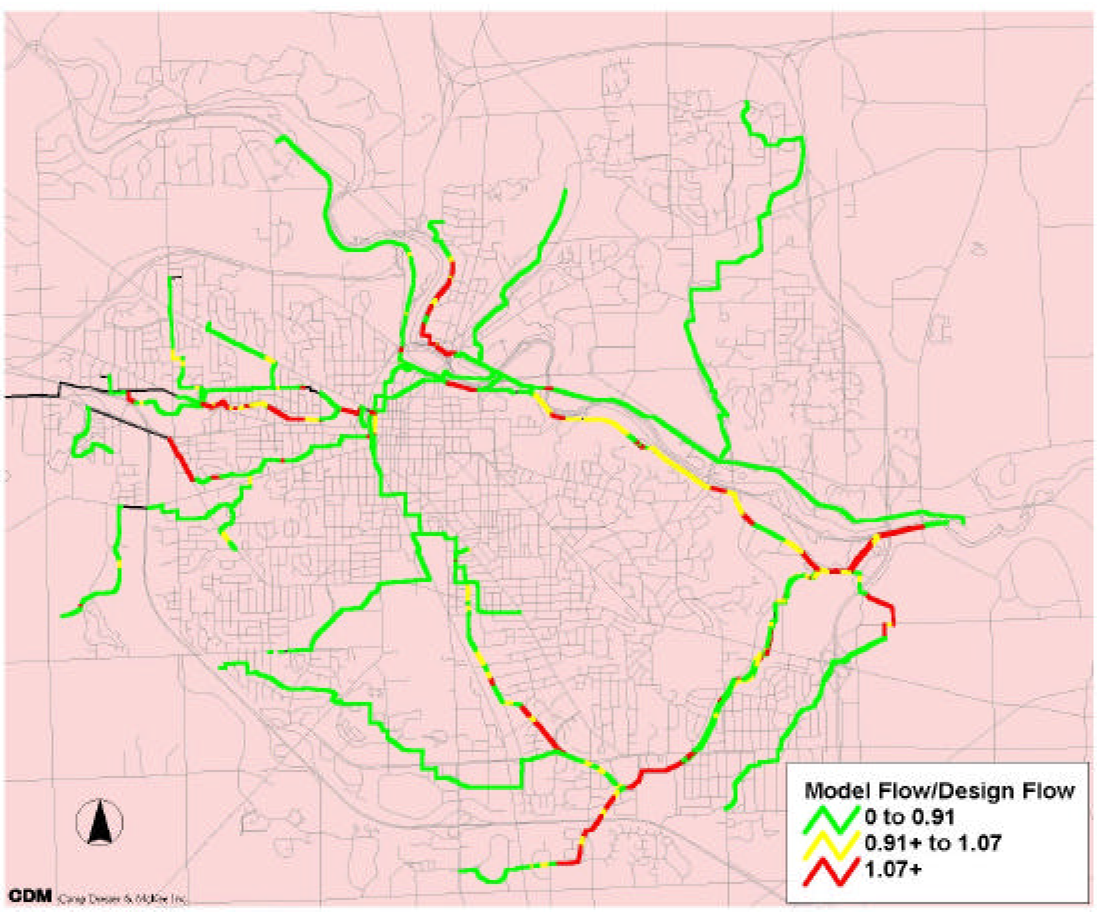

Figure E-8 Trunk Sewer Model Flow Comparison

was developed to handle dynamic simulations, the model was first configured to use steady state conditions so that a comparison could be made to the 1995 model results. This version of the model used the same future wet weather flows used in the 1995 Trunk Sewer Model. This allows a comparison to the thematic map produced by the 1995 model, as described earlier.

In general, a comparison of the results showed good correlation between the two models. Differences noted in some places were reviewed to understand the reasons. For instance, differences were noted in the results in the vicinity of the Arbor View pumping station. This difference is explained by the fact that changes to the system occurred in this location by installation of a gravity sewer used to replace a pump station.

Another significant upgrade was that the 1995 model included flows from Ann Arbor Township that resulted in significant surcharging in the Traver Creek submain. Since these customer flows are no longer being planned for, they were removed from the upgraded model. As a result, the Traver Creek submain no longer shows surcharging under future wet conditions.

Once the model was considered to properly represent the collection system under steady state conditions, the model was calibrated using flow data collected at the WWTP before and during actual storm events.

E.5 Pilot I/I Program

A pilot footing drain disconnection and I/I program was undertaken on this project to better understand the technical and implementation hurdles that may be present. Two types of pilot work were performed. The first investigated the separation of footing drain connections (FDD) in the basements of homes. The second addressed stairwell drain inflow sources (I/I) and methods that could be employed to reduce rainwater flows into them.

The key elements of the footing drain pilot program included the installation of check valves for backflow prevention , disconnection and rerouting of footing drain flows to a new sump, and installation of sump pumps to discharge these flows out of the homes. Details and specifications of the equipment used were developed to guide this installation work.

Preliminary work included inspections of 24 selected homes to determine the plumbing methods that have been employed by the homebuilders. Of this, 11 homes received the pilot installations. A summary of the different installations performed in each of the 11 homes is given in Table E-15.

At each home, check valves were installed on all basement level floor drains, sink/laundry, shower, or water closet to prevent sewer backups from entering the basement. A total of 11 floor drains with integral ball check valves were installed as shown in Figure E-9. A total of 11 vertical ball check valves were installed on basement sinks/laundry as shown in Figure E-10. Two flap gate check valves were installed in series to protect one water closet and

Table E-15. Summary of Pilot Home Installations

House Number	Floor Drain	Sink or Laundry	Shower Drain	Water Closet
1	1	2	1	1
2	1	1	0	0
3	1	1	0	0
4	1	1	0	0
5	1	0	0	0
6	1	1	0	0
7	1	1	0	0
8	1	1	0	0
9	1	1	0	0
10	1	1	0	0
11	1	1	0	0

Figure E-9. Floor Drain

one shower, as indicated in Figure E-11.

As part of installing check valves for basement facilities, it was important to also disconnect the footing drain connection to the sanitary house lead at all locations. Doing so prevents damage to the basement floor that could result from a buildup of water pressure underneath it. At all pilot locations, the footing drain was physically disconnected from the sewer line. A sump was installed at the disconnection point for pumping footing drain flows to a location in the yard that would keep the discharged water away from the house and not create a nuisance or safety hazard. A sump pump with a standard 120V electrical service was installed along with a water-powered backup pump. This backup sump pump can operate in the event of a power outage. A picture showing a typical installation is shown in Figure E-12.

Figure E-10. Vertical Check Valve

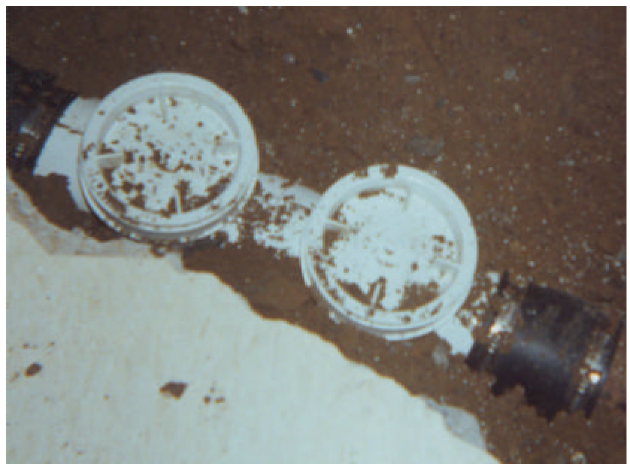

Figure E-11. Flap Check Valves

A local residential plumbing contractor was use to perform the installation work in October and November 2000. Feedback from both the plumbing contractor and homeowners was solicited to better understand the problems with this installation process. Feedback from the contractor was obtained through a personal interview and discussion of the work performed. Feedback from the homeowners was obtained using a standard questionnaire along with inspections of the completed work. The feedback collected included the elements of communication, construction impacts, training needs, financial considerations, and other miscellaneous items. Based on the feedback, the following recommendations were made for future installations:

- To improve communication and construction coordination, a single construction manager

Figure E-12. Sump Installation

should be used to coordinate the different types of work needed.

- It is important to use a residential plumbing company to provide a high level of service. An industrial contractor may not provide the level of service necessary.
- A method to reduce dust from the construction activities would be very beneficial. This may be accomplished using negative pressure venting of the basement to keep dust out of the main part of the house.
- A maintenance information sheet should be provided to homeowners.
- A tool should be provided to allow the homeowners to maintain the floor drain check valve.
- A fact sheet concerning the installation process should be distributed, including the benefits it has to the home and the community.
- The contracted price of approximately $3,500 per home is believed to be a reasonable cost and may have a significantly higher value to the homes with a potential for basement flooding.
- An alternative to the water powered backup sump pump, which requires an annual backflow prevention inspection, should be available. This alternative backup sump pump could be battery powered.
- It may be very difficult to have a successful program if the homeowners must pay for the installation themselves.

A second part of the pilot program was the rerouting of rainfall from a stairwell drain. During the inspection work performed as part of this study, a stairwell drain was identified that allowed a significant amount of flow to enter the collection system. To address this specific issue, three modifications were made. First, a large area upstream from the stairwell drain was found to drain to it. A portion of this area was located on Ann Arbor Public School property. To address this, the property was re-graded to direct this overland flow away from the stairwell drain.

Second, the stairwell itself was modified. This included blocking a connection made through the side of the stairwell to allow drainage from the home's backyard and the top of the stairwell was also raised to ensure that this overland flow does not enter the stairwell in the future. Finally, the drainage from the backyard was directed to a new catchbasin location next to the homeowner's property. This reduced the problem of ponding in the backyard of the home.

E.6 Summary

The field data collected as part of this project and trunk sewer modeling activities provided valuable information that supported other project activities. The flow, level, and rainfall information was used for subsequent analysis, including model calibration and validation. The collection system inspections allowed an assessment of the condition of the system components that were factored into the model development. The manhole inspection work was also very valuable for gathering additional information on the collection system attributes and connectivity that could not be determined any other way.

The pilot installation programs provided valuable information on the implementation hurdles that may be faced if these elements are included in a larger scale program. Many of the issues faced will be potential social impacts that must be fully understood before implementation.

The field data collection work resulted in several important findings:

- Good field data on flows, levels, and rainfall was collected in the City of Ann Arbor sewer system.
- The review of manholes in the field revealed that the condition of the manholes and the sewers adjacent to the manholes were in very good condition.
- The manhole review did identify some locations where minor cleaning was required. The Water Utilities Department corrected these maintenance issues once identified.
- The field inspections identified a few locations where the sewer maps differed from the actual connections.
- Attribute information contained in the Water Utilities Database was current for about 80% to 85% of the sanitary sewer system. The remaining data for changes or improvements needed to be collected in the field and from other sources.
- Inspections of house downspouts showed that a large number of these were directed away from the homes.
- In general, it was determined that directing the remaining house downspouts away from the home would be difficult because of constraints.
- Very few connections from the surface to the sanitary sewer system were identified. These inflow sources are not believed to be a significant problem.
- Dye and flood testing is believed to provide a good indication on the connection of any inflow sources. Because of traps in most footing drain systems, smoke testing is believed to provide limited information.
- The pilot footing drain removal program was successful in demonstrating that this work can be accomplished in a timely fashion.
- The keys to success in footing drain removal are providing complete information on the process to the homeowners and addressing their concerns in an expeditious manner.
- Discharges from footing drain disconnection sump pumps should be directed into the storm sewer in most cases as surface discharges often cause nuisance problems.

F. Public Process

Contents

F.1 Introduction

An important element of this project was the public engagement process. This process was designed to provide and receive information from customers on the status of the project, the activities that were underway, the results of the evaluation work, and the recommendations. The program provided numerous opportunities and mediums for customers to provide information to the project team. This information was very valuable in developing and refining final recommendations.

The major components of the public engagement process were:

- Home Owner Public Workshops
- Neighborhood Meetings
- Newsletters and Website
- Televised presentations to City Council
- Local TV coverage
- Home owner access to the project manager (City staff) and the project consulting engineer.

F.2 Public Workshops

Four public workshops were held during the course of the study. These workshops were held at two separate locations (Northeast and Southwest) on different nights during the week to ensure that there was adequate opportunity for the public to be informed. These workshops always included a presentation on the status of the project. Feedback was sought as this work developed to ensure that the concerns, priorities and suggestions of the citizens were understood and included within the project work tasks and ultimately, the recommendations.

Results: Representatives from over 140 homes attended the workshops. 85% of surveyed home owners agreed that the sessions helped them understand the dynamics of basement flooding and helped them to understand the possible remedies for the problem.

Copies of presentations made at those workshops are provided in Appendix I.

F.3 Neighborhood Meetings

A series of three neighborhood-specific meetings (Orchard Hills/Bromley, Dartmoor, Glen Leven/Morehead) were held January 9, 10, and 11, 2001 during the development of corrective alternatives. These meetings were used to focus on the area specific alternatives developed and to gain input into the acceptability of each option. Draft costs were provided at these meetings and the specific impacts on customers were identified.

The meetings were particularly helpful with identifying which aspects of the alternatives would be acceptable and which raised concerns for the respective neighborhoods.

Copies of presentations made at those workshops are provided in Appendix J. Responses to questionnaires received after these meetings are provided in Appendix L.

F.4 Newsletters and Website

Another method used for outreach and information sharing was through project newsletters. Four newsletters were published during the project to keep the citizenry informed on project status and to provide feedback on homeowner workshops sessions. These documents were mailed to all residents in the study areas to ensure that the public was able to have information on the work being performed.

Additionally, a project web site was developed that provided information on the work underway on the project. This web site was updated monthly and was used to provide copies of meeting minutes, newsletters, FAQ, and related links. Information on upcoming events was also provided.

Copies of newsletters provided during the project are provided in Appendix H.

F.5 Council Presentations

Two separate presentations were held on September 11, 2000 and January 29, 2001 to City Council at scheduled work sessions to inform them of the status of the project. These presentations provided information on the causes of the basement flooding , the range of alternatives under review, homeowner concerns, and the early recommendations and expected costs of the programs. These working sessions were televised throughout the area on CTN.

Copies of presentations made to City Council are provided in Appendix K.

F.6 Local Television Coverage and Press Coverage

The Task Force arranged project coverage from the local cable access station. The chairs of the Task Force joined the consulting engineer for an interview covering the scope of the Task Force's work and the timeline for the project. This taped broadcast aired several times. Additionally, the Task Force was available for interviews with local press reporters who covered the homeowner workshops, neighborhood meetings and Council presentations. This medium supported broader city coverage for the work of the project.

F.7 Homeowner Access to Project Managers

Throughout the course of the study, home owners had direct contact with the City staff project manager and consulting engineer via toll free business phone numbers and a 24-hour emergency number. Numerous homeowners made use of this contact to have specific questions answered and to help keep the Task Force informed of emerging home owner issues. The emergency number was very helpful during a major storm event that flooded some basements mid way through the study.

F.8 City Service Survey

To better understand the needs of the homeowners and the service provided by the City of Ann Arbor, the Water Utilities Department prepared a survey. This was conducted with homeowners that had a history of basement flooding. The results of this survey are found in Appendix O.

F.9 Summary

The public engagement process provided information to the affected home owners and also solicited feedback to help the final recommendation reflect the issues, opportunities and concerns experienced by customers.

In the later stages of the decision making process, the Task Force drafted initial recommendations and reviewed them at neighbor hood meetings (January 2001). From those sessions customers clarified the following priorities, concerns, and suggestions:

- Effectiveness and speed of the solution was paramount to people whose homes had been flooded
- Rapid action by the City was desirable, and not just for the 5 study areas.
- Ensure that the solution for flooded basements does not have a negative impact on

natural features, either through construction or via significantly increased flows to the storm water system.

- Compliance by unaffected home owners willing to have work done on their property will be a challenge.
- Use of this program to help educate people about flow restrictors and alternative storm water collection methods (rain barrels and rain gardens) would be beneficial for the community.
- Attentiveness to potential household risks (radon) from any basement construction.

For a detailed summary of customer feedback throughout the process see the Appendices H, I, J, K, and L.

This process built confidence in the methods used to evaluate and prepare alternatives, and in the Task Force itself. It also helped to focus the program on the elements that were most highly sought by the home owners who were most affected by past basement flooding incidents.

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G. Study Area Evaluations

Contents

G.1 System-wide Analysis

G.1.1 WWTP Flow Analysis

Hourly and daily flow monitoring data was obtained from the City of Ann Arbor for the WWTP. This information was analyzed to understand the rainfall response relationship for the service area. This characterization was required for use with the trunk sewer model. The events used in this evaluation are summarized in Table G-1. Due to incomplete rainfall data sets, the flow information was evaluated for April, May, and July 1997, March - April 1998, April - September 1999 and April - June 2000. The months of August 1998 and May - July 2000 were also included in the evaluation. During this period, a total of 29 storm events were reviewed.

The wet weather volume for each event was determined by subtracting the dry weather flow rate estimated prior to each event. This volume represents the rainfall dependent inflow/infiltration (RDI/I) volume that entered the sanitary sewer system for the given event. These RDI/I volumes were plotted against rainfall to develop a correlation between the RDI/I response for the various size rainfall events. The RDI/I volume was presented as inches by dividing the volume by the tributary sewer area.

Results of this analysis are shown in Figure G-1. Each individual event was classified as taking place either during dormant season (spring) or growing (summer) season conditions. A regression line was developed for each set of data. The slope of the lines correspond to the RDI/I response coefficient, R, which is defined in the following equation:

R = RDI/I Volume/(Rain - Initial Abstraction)

G.1.2 WWTP Results

The total response "R" value for dormant and growth seasons, respectively, are 2.0% and 3.8% for the entire collection system. These response rates indicate that the City of Ann Arbor's collection system has about average wet weather response compared to other sanitary collection systems located in the Midwest. Highly responsive systems can have "R" factors on the order of 15% or higher. These rates were calculated using the entire service area included in the 1995 Trunk Sewer Report and may be increased if there are significant unserviced areas within the boundaries of the City of Ann Arbor.

G.1.3 System-wide Model Calibration

Calibration of the trunk sewer model to wet weather events first required the development of the RDI/I response component of the model. The comparison to the previous model involved only the hydraulic component of the model, which uses the SWMM EXTRAN module. The hydrology component uses the SWMM RUNOFF module. This component was developed using the subareas as previously delineated for the 1995 Trunk Sewer Model. A total of 182 subareas were defined, with a total area of 21,819 acres.

The model was calibrated using two large recent storms, the August 6, 1998, event of approximately 4.5 inches and the June 24, 2000, event of between 3 inches and 4 inches . The calibration was preformed using hourly flow data available from the WWTP for these two events. Level data for the influent interceptors at the plant were not available for either event. The hourly data that was collected represents the equalized flow recorded at the WWTP. To determine the actual flow rates discharging from the interceptors at the plant, an estimate needed to be made. Figure G-2 shows the flow pathways that were used to make the estimate of flows exiting the collection system.

Table G-1 Rainfall Events and RDI/I Volumes

Date	Rainfall (in.)	RDI/I Volume (c.f.)	RDI/I Volume (in.)
Growing Season			
7/5/97	1.00	2,475,539	0.0342
7/13/97	0.60	2,193,427	0.0303
7/19/97	0.40	930,972	0.0129
7/23/97	0.30	486,645	0.0067
7/30/97	1.90	1,890,156	0.0261
8/8/98	4.83	3,312,840	0.0458
6/18/99	2.25	1,358,771	0.0188
8/3/99	2.99	6,125,149	0.0847
8/21/99	0.63	2,873,708	0.0397
9/11/99	1.17	4,539,471	0.0628
10/2/99	1.90	1,820,594	0.0252
6/23/00	3.71	7,514,620	0.1039
Dormant Season			
4/10/97	1.10	2,531,962	0.0350
4/23/97	0.30	2,330,957	0.0322
4/30/97	0.20	402,011	0.0056
5/11/97	1.30	4,147,058	0.0574
3/13/98	1.70	4,785,338	0.0662
3/17/98	0.20	2,441,915	0.0338
3/28/98	1.70	8,245,327	0.1140
4/4/98	1.00	3,704,335	0.0512
4/13/98	1.00	2,641,281	0.0365
4/21/98	0.30	1,898,972	0.0263
5/1/98	1.70	3,466,461	0.0479
4/27/99	1.60	3,731,950	0.0516
5/19/99	1.31	668,708	0.0092
5/24/99	1.11	57,394	0.0008
4/18/00	2.54	4,512,776	0.0624
5/6/00	0.90	2,993,835	0.0414
5/15/00	2.43	7,581,357	0.1049

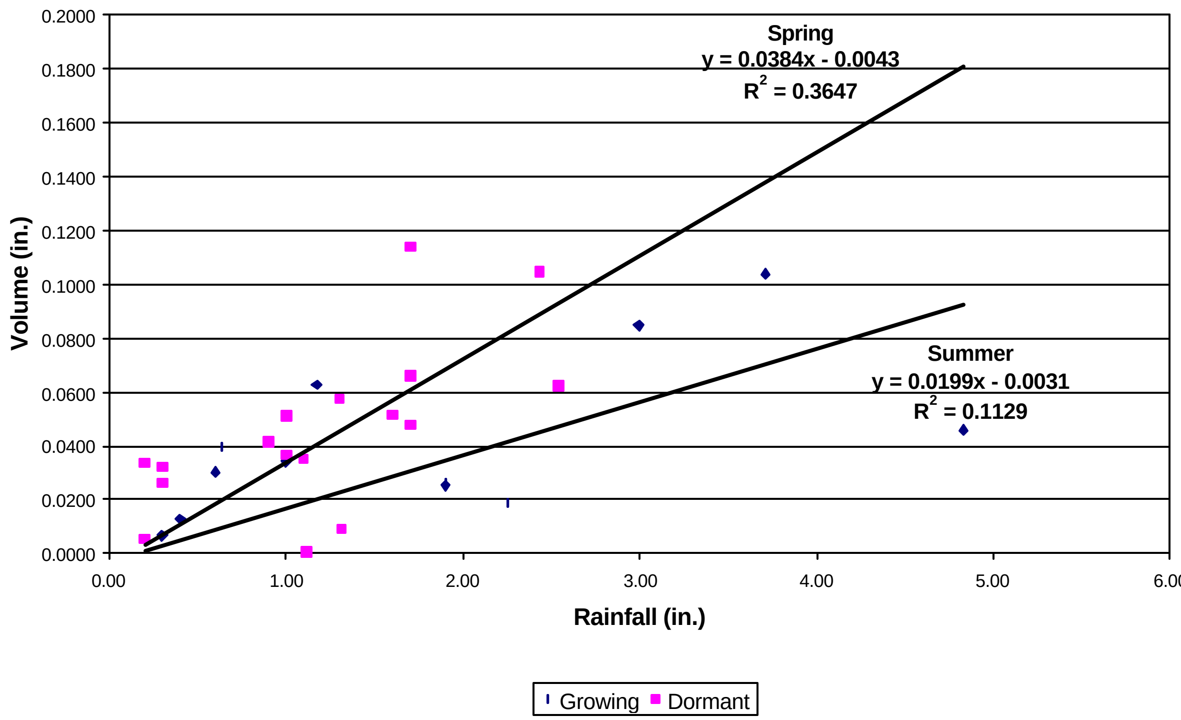


Figure G-1 Wet Weather Response Curves

For each event, the wastewater flows were used to make estimates of the RDI/I component. This process was described in Section E. For the trunk sewer work, a single RDI/I factor was used in all the areas, except the study areas, since the distribution of the response was not known. It is expected that these response rates will vary spatially across the collection system, but there is no data available to allow calculation of these values other than in the areas evaluated under this study. It was considered sufficient for purposes of the trunk sewer model, to use a uniform value for the non-metered areas.

Rainfall data for the August event were obtained from a rain gage located at Eisenhower Parkway and State Street. This single source of data was used, as data was not available from the National Weather Service for this event. The distribution of this data is shown in Figure G-3.

Rainfall data for the June event were obtained from the project meters. The rainfall amount ranged from 3.0" to 4.1". Data collected from the Orchard Hills gage and the Dartmoor gage were not used because of observed inconsistencies with these two gages. The distribution of the rainfall data collected at the gages used for the calibration work are shown in Figure G-4.

The model was used to simulate both events, and the flows estimated by the trunk sewer model to discharge to the WWTP, were compared to the interceptor flows recorded at the WWTP. The results of these comparisons are provided in Figures G-5 and G-6 for the two calibration events. It should be noted that the trunk model does not include diurnal variation of the wastewater flows, as shown on these figures. Also, Figure G-5 suggests that the model over-predicted the peak flow rate for the August 1998 event. However, the actual flow rate represents an averaged hourly rate and information from the WWTP notes peak instantaneous flows that were estimated to reach 78 MGD.

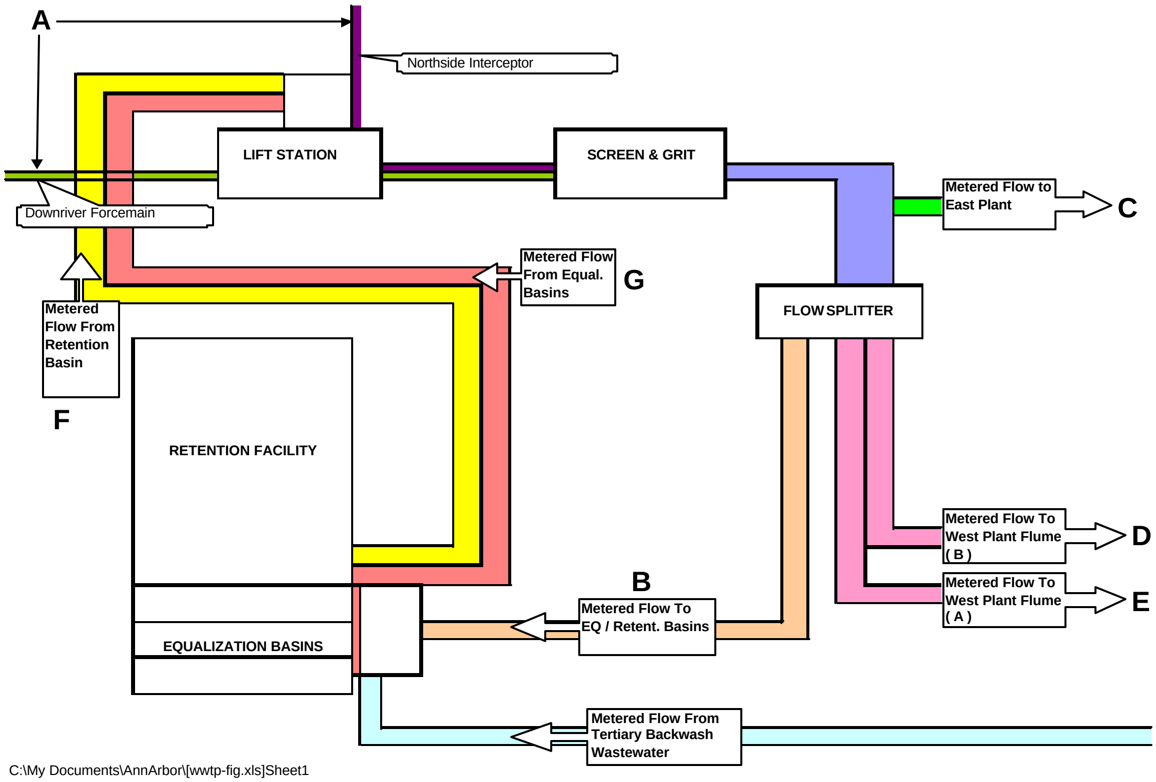


Figure G-2 Ann Arbor Wastewater Treatment Influent Flow Scheme

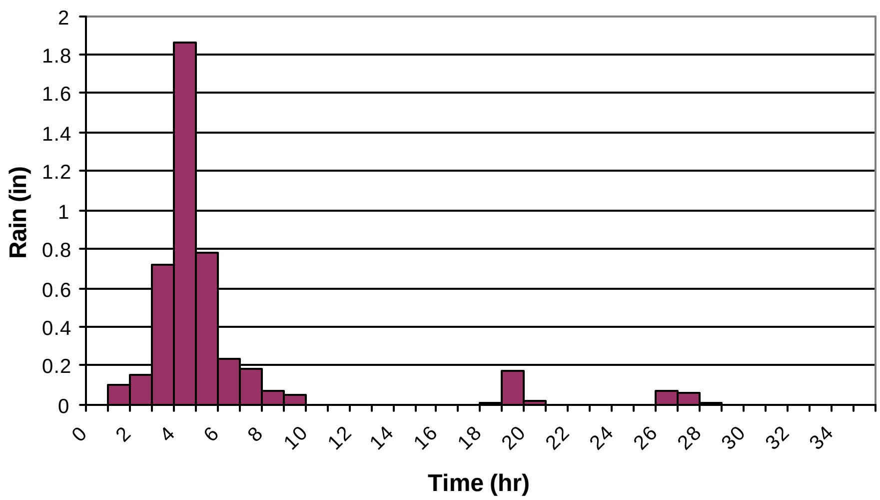
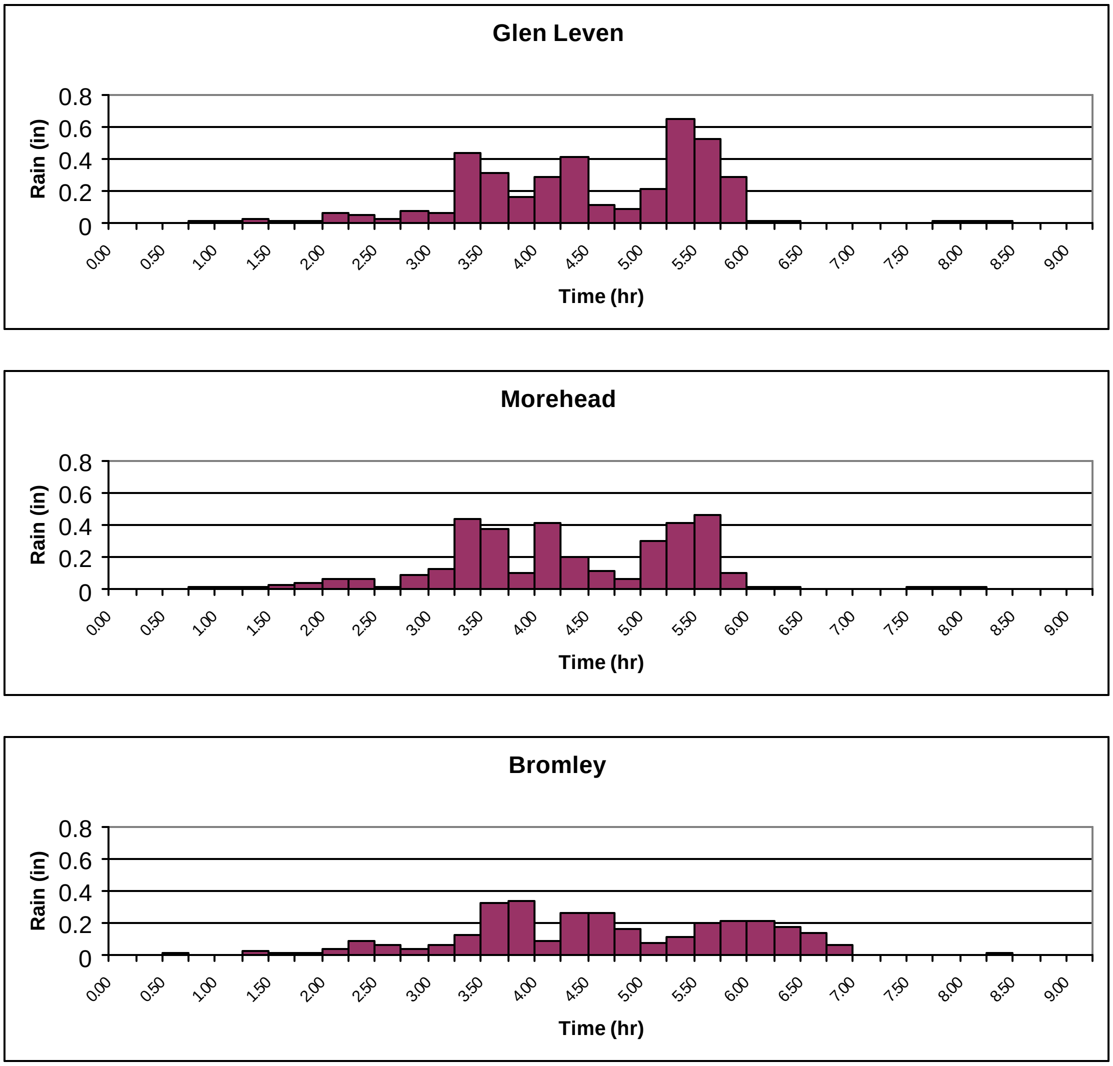


Figure G-3 August 6, 1998 Rainfall Event



O:\PROJ\28478\E_Model\RDII\WWTP\RAIN2000\[June00.xls]Rain Graphs (2)

Figure G-4 June 24, 2000 Rainfall Event

The flows shown in Figures G-5 and G-6 range from a low of 18 MGD to a high of 72 MGD. These values are compared to the previous model unit values in Table G-2 using 1995 populations. For the dry weather flow conditions, the 1995 Trunk Sewer Model applies a unit flow rate that is about three times the amount of flow that have been previously recorded. These higher flows are in part a reflection of the larger contract flows applied in the 1995 Trunk Sewer Model that generally are much larger than the actual dry weather rates that would be generated from these communities. The comparison for peak wet weather conditions at the WWTP are in reasonable agreement with the current model predicting 372 gpcd compared to 455 gallons per capita per day (gpcd).

G.1.4 System-wide Problem Identification

The calibrated trunk sewer model was used to identify potential problems within the collection system under current conditions. To do this, the trunk sewer model was used to simulate a large design storm condition. Design Condition 1 was used, as described in Section E of this report. The results were reviewed to determine capacity con-

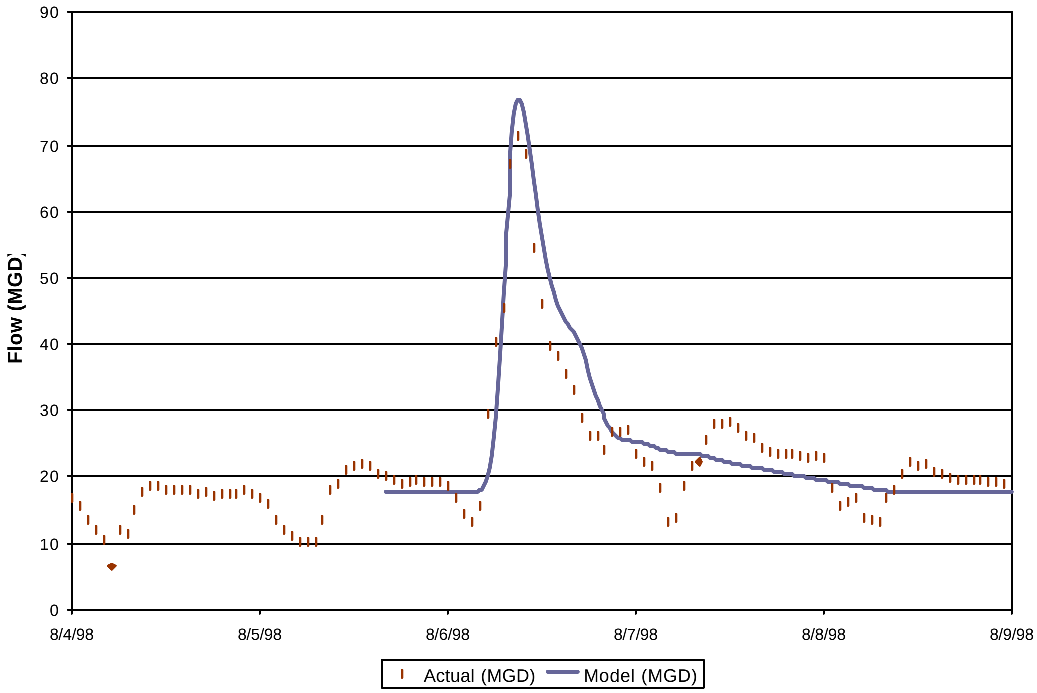


Figure G-5 Trunk Model Calibration for August 6, 1998 Event

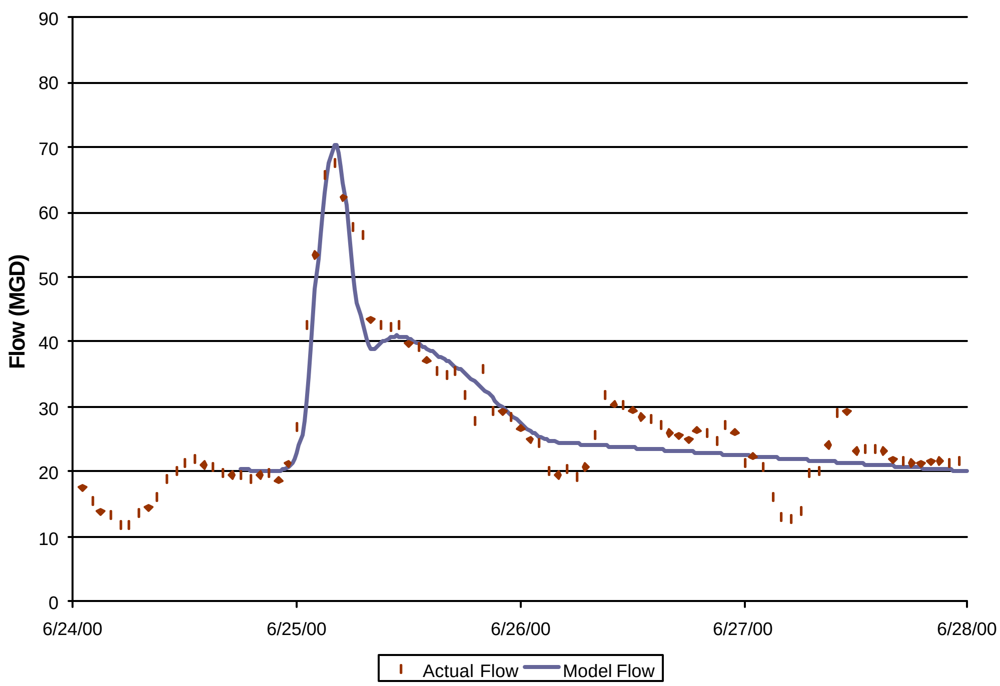


Figure G-6 Trunk Model Calibration for June 24, 2000 Event

Table G-2 Flow Rate Comparison of Trunk Sewer Models

Model	Condition	Population	MGD	GPCD
1995 Model	Dry	193,300	56	290
Current Model	Dry	193,300	18	93
1995 Model	Wet	193,300	88	455
Current Model	Wet	193,300	72	372

straints within this trunk sewer system. These results are presented in a thematic map shown in Figure G-7.

The following observations can be made based on this simulation:

- The model confirms that the lower section of the Swift Run trunk has capacity problems as already identified under previous trunk sewer modeling efforts.
- There are capacity issues noted along the Huron River Trunk. It is questionable that problems really do exist along this section of the sewer system, since this area is expected to have less responsive flows based on the age of the houses and lower density of housing in this area.
- The South Interceptor appears to have capacity

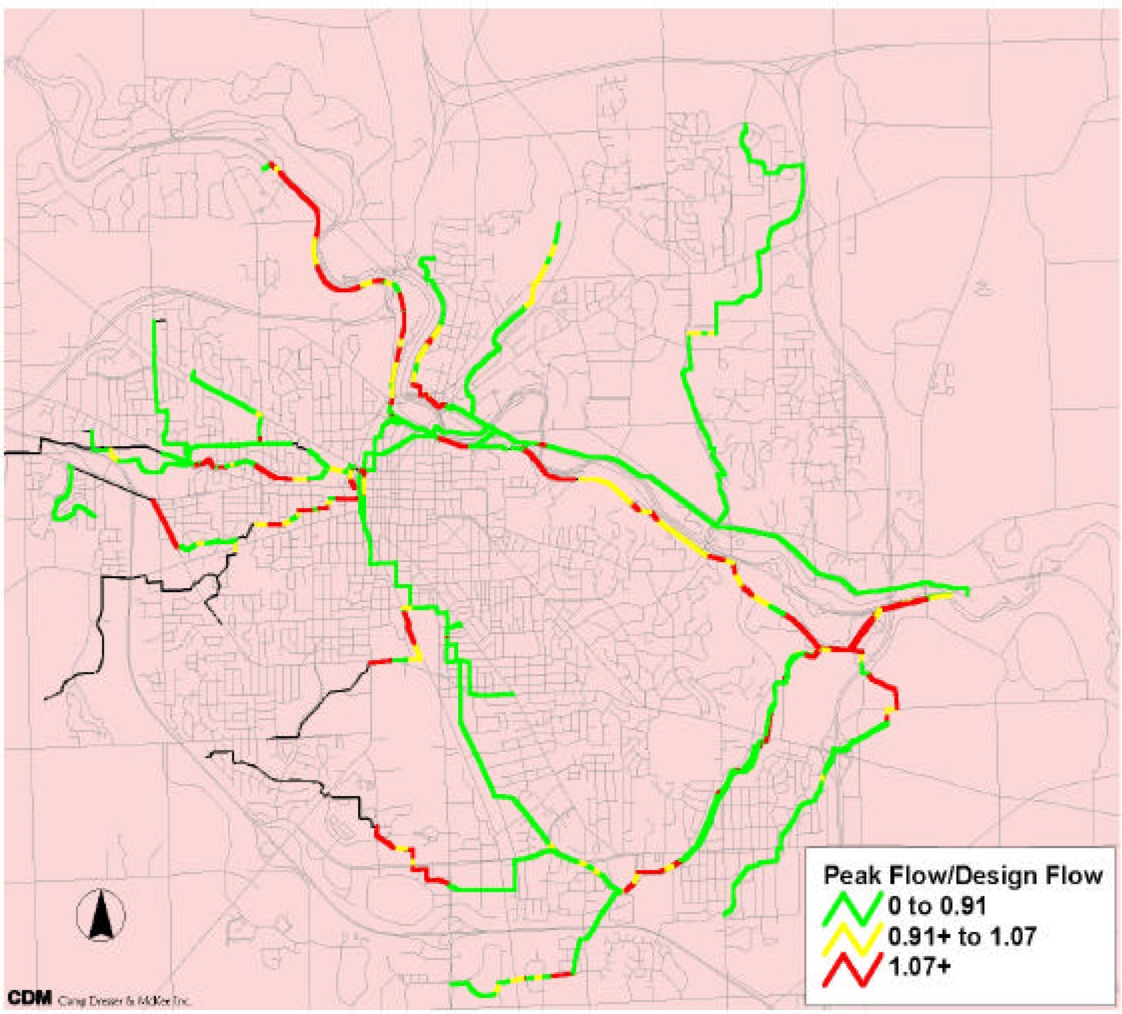


Figure G-7 Trunk Sewer System Problem Assessment

problems while the North Interceptor has sufficient capacity. From a review of the results for these two interceptors, it is believed that a diversion between the two interceptors could be used to balance the flows under wet weather so that no surcharging would take place.

- There are a number of capacity issues on the west side trunk sewers that are likely more significant than noted.
- Collection of flow data to support calibration of the remaining subbasins would be recommended to make more informed decisions about the adequacy of the elements in the trunk sewer system.

G.1.5 System-wide Analysis Summary

Past projects used flow projections based on design flow estimates developed in the late 1960s. This approach has been consistently and widely used in evaluations of the sewer system since that time. While this approach has merit during the design of the collection systems, it has limitations for evaluation of the problem areas in these same systems.

The development of a dynamic model for this project allows an alternative approach to the design rate based method. The trunk sewer model developed for this project is able to predict the RDI/I hydrograph response to design objectives and dynamically route these flows through the system. With the model calibrated for base wastewater flow and for wet weather flow, the model can be used to evaluate the hydraulic capacity of the sewer system for existing and various alternative conditions.

The trunk sewer model analysis has resulted in several important findings:

- The wet weather response observed at the WWTP is moderate.
- More complete flow information is needed to better understand the wet weather response from all the districts that are tributary to the trunk sewer system.
- The trunk sewer system appears to have adequate capacity for the design condition simulated to identify problem areas.

G.2 Study Area Analysis

G.2.1 Introduction

Previous sections have described the field activities and data analysis used to understand the condition and behavior of the sewer system. To make estimates of the response of these systems within the study areas to large storms, models needed to be developed. This section documents the preparation of these models for the individual study areas.

The Orchard Hills, Bromley, Dartmoor, Glen Leven, and Morehead areas have all experienced flooding problems as a result of surcharged pipes in the sanitary sewer system. However, the flooding problem in each area is unique. Therefore, a variety of alternatives need to be examined in order to find the appropriate solution for each area.

Three design conditions were defined for development and evaluation of various alternatives to alleviate flooding problems. Four alternatives were examined including relief sewers, increasing capacity by upsizing pipes, collection system storage, and footing drain disconnection. All four corrective methods were modeled separately for each study area and design condition.

G.2.2 Study Area Approach

G.2.2.1 Introduction

Following development of the trunk sewer system hydraulic model, models were developed for each of the five study areas. Study area model preparation began by assembling information available from existing Ann Arbor attribute databases, drawings, the 1995 trunk sewer model attribute database, and project field efforts. To make sure that each sewer and manhole was properly located within the study area these elements were digitized into a GIS format consistent with that used by the City of Ann Arbor. Sewer and manhole locations were converted using the digital copies of sewer index maps.

As these sewers and manholes were digitized, an ID was assigned that corresponded to an ID in the City's sewer attribute database. This ID provided the link between the tabular attributes and the spatial location of each sewer and manhole. Having this link was important so that the GIS could be used to produce maps and to facilitate fieldwork, model construction, and alternative analysis.

During model preparation, the attribute database was used to define the "connectivity" of the sewer system using an upstream manhole and downstream manhole designation for each sewer segment. In a number of cases, this information was incorrect. To resolve these types of issues, the spatial information provided by the GIS was combined with field investigations. In addition, a significant portion of the sewers were not included in the City's attribute database. This missing information was later obtained from maps, field investigations, or estimation so that a complete modeling database was available.

In addition to sewers and manholes, sub-basins were delineated and converted to a GIS format. Sub-basins define the area tributary to specific sections of the sewer system. Each sub-basin was assigned an inflow manhole. Each of these study area sub-basins contains information about the dry weather and wet weather flows that are generated. Tributary areas for each of these sub-basins were determined using GIS tools.

Each sub-basin was also related to the 1995 trunk sewer sub-basin delineation that included more coarsely defined sub-basins appropriate for the trunk sewer modeling. This relationship facilitated the use of 1995 modeling estimates of dry weather for estimating dry weather flow for the more detailed study area sub-basins. The dry weather flow originating from the original trunk delineation was distributed to the new study area sub-basins proportional to area.

Because of the complexity and number of model elements required to represent each study areas, separate sub-models were prepared. The exceptions are Orchard Hills and Bromley. Because Orchard Hills and Bromley share a common outlet into the trunk sewer system, these two areas were modeled together to better understand the interaction between these two areas.

G.2.2.2 Flow Evaluation Methodology

The information collected from the flow monitoring efforts was used to estimate the RDI/I response of each study area. To estimate the RDI/I response for the different types of conditions, the measured flows observed in the flow meter hydrographs were classified into groundwater infiltration, base wastewater flow, and RDI/I components, as shown in Figure G-8.

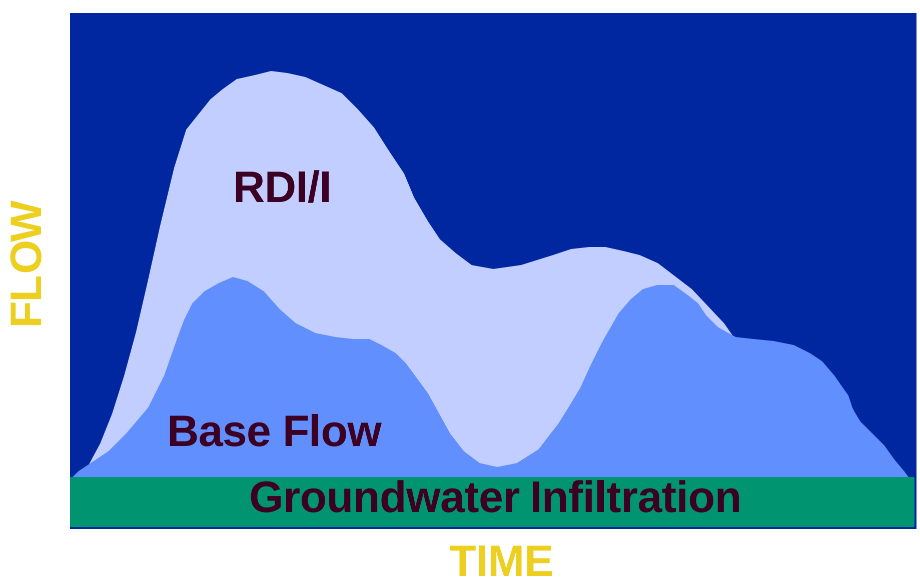


Figure G-8 Wet Weather Flow Components

These different components were determined based on review of the data collected. The base wastewater flow and groundwater infiltration terms were determined for the period of time just before each storm. The RDI/I values were determined by subtraction from the base flow and groundwater infiltration terms.

Once the RDI/I component of the flow was isolated, a unit hydrograph approach was used to further break RDI/I flow term into components based on the average time from the peak rainfall to the average time to peak of three triangular unit hydrographs. These three triangular unit hydrographs are used to simulate the different stages of I/I, that when summed, represent the total RDI/I hydrograph. This unit hydrograph approach provides a better definition of the flow components and therefore provides a more accurate basis for developing system response.

The analysis of RDI/I response also classifies each storm as taking place during either a dormant or growing season. This seasonal impact is particularly important in Michigan. During the growing season, which typically extends from mid-May to mid-September in the Ann Arbor area, groundwater levels and soil moisture levels are reduced through transpiration. This correspondingly reduces the RDI/I response from storms into the sanitary sewer system.

G.2.3 Design Conditions

Three design conditions were developed. The first two design conditions were used in the design of remedial alternatives. The third design condition was used to evaluate the response of the various alternatives under a more severe rainfall event.

Each design condition was based on several parameters. These parameters included the area of each region, the amount, time, and intensity of rainfall, an initial abstraction value (V_o), and a corresponding RDI/I factor (R). The rainfall amount was the same for all five regions. However, the remaining parameters varied by study area. The rainfall dependent inflow and infiltration volume (or wet weather volume) is calculated by subtracting the initial abstraction value from the amount of rainfall and then multiplying that value by the area and RDI/I factor.

Design Condition 1 was also used to identify potential problems, as described in Section E. It was based on the June 24, 2000 event. Design Condition 1 consisted of using the highest recorded rainfall amount from the five gages used in the study. That rainfall amount was 4.15”. It also consisted of using the results of the wet weather response analysis for the site to define the initial storage, V_o, and a corresponding RDI/I factor, R.

Design Condition 2 consisted of a two-step process. First, two design events of 4.5” were generated using distributions obtained from the August 1998 and June 2000 events. The second step consisted of running the model using both events to determine which event had the most significant impact on the system. In all cases, the June event was determined to stress the system slightly more than the August event. For this condition, the RDI/I factor and the initial storage value remained the same as set for Design Condition 1.

Design Condition 3 consisted of increasing the wet weather response to reflect spring or dormant conditions. The worst-case storm distribution of Design Condition 2 was used, but with the total volume reduced to 4.0”. For this condition, the RDI/I factor and initial abstraction value did not remain the same as in the case of the previous design conditions.

The model parameters for the three design conditions for the Orchard Hills, Bromley, Dartmoor, Glen Leven North, Glen Leven South, and Morehead subareas are summarized in Table G-3 to Table G-8, respectively. The last line of each table gives the amount of RDI/I volume that enters the sanitary system.

Table G-3. Design Condition Parameters for the Orchard Hills Region

Orchard Hills	Design Condition 1	Design Condition 2	Design Condition 3
Area (acres)	107.9	107.9	107.9
Precipitation (in.)	4.00	4.5	4.00
R (%)	10.90	10.90	17.95
V_o (in.)	0.67	0.67	0.50
RDI/I Volume (MG)	1.1	1.2	1.8

Table G-4. Design Condition Parameters for the Bromley Region

Bromley	Design Condition 1	Design Condition 2	Design Condition 3
Area (acres)	74.1	74.1	74.1
Precipitation (in.)	4.00	4.5	4.00
R* (%)	9.89	9.89	13.22
V_o (in.)	0.85	0.85	0.50
RDI/I Volume (MG)	0.9	1.0	1.3

**Area-weighted average R value*

TableG-5. Design Condition Parameters for the Dartmoor Region

Dartmoor	Design Condition 1	Design Condition 2	Design Condition 3
Area (acres)	719	719	719
Precipitation (in.)	4.00	4.5	4.00
R* (%)	3.00	3.00	5.11
V_o (in.)	0.80	0.80	0.5
RDI/I Volume (MG)	1.9	2.2	3.5

** Weighted average R for the upstream and downstream areas with respect to the Liberty Rd. P.S. (weighting for comparative purposes only, model included unique parameters).*

Table G-6. Design Condition Parameters for the Glen Leven North Region

Glen Leven North	Design Condition 1	Design Condition 2	Design Condition 3
Area (acres)	134	134	134
Precipitation (in.)	4.00	4.5	4.00
R (%)	5.20	5.20	9.94
V_o (in.)	0.83	0.83	0.50
RDI/I Volume (MG)	0.6	0.7	1.3

Table G-7. Design Condition Parameters for the Glen Leven South Region

Glen Leven South	Design Condition 1	Design Condition 2	Design Condition 3
Area (acres)	281	281	281
Precipitation (in.)	4.00	4.5	4.00
R (%)	3.42	3.42	7.36
V_o (in.)	0.82	0.82	0.50
RDI/I Volume (MG)	0.8	1.0	2.0

Table G-8. Design Condition Parameters for the Morehead Region

Morehead	Design Condition 1	Design Condition 2	Design Condition 3
Area (acres)	268.9	268.9	268.9
Precipitation (in.)	4.00	4.5	4.00
R* (%)	18.48	18.48	22.18
V_o (in.)	0.50	0.50	0.50
RDI/I Volume (MG)	4.7	5.4	5.7

** Weighted average R for the primary Morehead tributary area and the newer construction portion of the Saxon/Tudor area (weighting for comparative purposes only, model included unique parameters).*

G.2.4 Corrective Methods Reviewed

G.2.4.1 Relief Sewers

The relief sewer option consists of placing a parallel pipe next to a pipe that is already in the ground and is under capacity. This will enable the flow that is currently in one pipe to be divided between two pipes. The relief sewer option has the following advantages. First, construction is performed in existing right-of-way (ROW) and easements. Second, contractors are familiar with this construction method.

The relief sewer option has disadvantages as well. Construction causes disruption in the streets; also, larger peak flows would impact the trunk sewer system. This could mean additional relief pipe or other construction would have to be completed further downstream in the sewer system.

G.2.4.2 Increasing Capacity

The increasing capacity method consists of bursting an existing pipe or replacing by open cut with a larger diameter pipe, and then using the new pipe in place of the old one. The new pipe can be up to two diameter sizes larger than the existing pipe, if pipe bursting. There are advantages to using the increasing capacity method. Pipe bursting construction has less of an impact on traffic than relief pipe construction. Pipe bursting can also be completed in a relatively short amount of time. Even the open trench option may be beneficial, if there is limited space to place a relief sewer.

There are also disadvantages to using the increasing capacity method. Access pits would be required to connect homes to the new pipe. A specialized contractor would be needed for all pipe bursting work. Also, larger peak flows should impact the trunk sewer cost. This could mean increased construction and costs downstream in the sewer system.

G.2.4.3 Collection System Storage

The collection system storage option consists of placing storage basins in the system to temporarily store sewage during heavy rainfall events. This would enable peak flows to be reduced downstream of the basins by storing it until the rainfall intensity has been reduced. The collection system storage option has several advantages. Most importantly, additional peak flows are not moved downstream into the trunk sewer system. This option does not require additional downstream construction, which helps to offset its cost. Storage may require increased pipe capacity upstream of potential storage facilities.

The collection system storage option does have disadvantages as well. The storage basins must be properly maintained; therefore, access to storage basins is required. There are also additional costs associated with maintenance. There is the potential for odors in the storage basin.

G.2.4.4 Footing Drain Disconnection

It is known that inflow and infiltration from footing drains that are connected to the sanitary sewer system add rainfall and ground water to sanitary sewers. The footing drain disconnection option prevents this clean water from reaching the sanitary sewer system. A sump pump would be installed in each home that has the footing drain disconnected. The sump pump would direct all storm water and ground water into the storm sewer system. Reducing the volume of water that enters the sanitary sewer system reduces the peak flows during a storm and therefore reduces surcharging.

The footing drain removal option has several advantages. There will be limited construction in the street; pipe construction would take place between the sidewalk and the street. Also, flows to the trunk sewer system are reduced, as are the costs for unnecessary treatment of rainwater.

The footing drain disconnection option also has several disadvantages. Construction on private property can be difficult, since it requires construction in basements and lawns. Homeowners are responsible for maintaining the sump pumps that would be installed along with the footing drain disconnect. Also, the sump pumps must be connected to the storm sewer system.

G.3 Study Area Models

G.3.1 Orchard Hills Study Area

The Orchard Hills study area is located in northeast Ann Arbor, roughly bounded on the south by Plymouth Road, on the east by Sugarbush Park, on the north by Rumsey Drive, and on the west by Georgetown and Bunkerhill as shown in Figure G-9.

Basement flooding was observed in the Orchard Hills study area during the August 1998 and June 2000 major storm events. Prior to that, flooding in this area has been recorded since the 1960s. Because of the frequency of basement flooding problems, the City of Ann Arbor had previously installed a storage facility at the corner of Georgetown and Bluett.

To better understand the distribution of the basement flooding problems, Figure G-10 was developed to present the percent of homes in a number of parcel groups that reported flooding during the August 1998 and June 2000 major storm events. The parcels are grouped in a way to logically represent flooded areas without compromising residents' privacy by classifying individual parcels.

The study area model developed for Orchard Hills included every manhole and sewer main. These were included, in as much detail as possible, to better understand the dynamics of the local collection system. The retention basin was included directly in the model, as were the overflow connections into this facility. In addition, the basement elevations of homes adjacent to the sewer in areas that had flooded were included in the model.

G.3.1.1 Flow Analysis

A total of 16 storms were analyzed for the Orchard Hills study area. For each event, the total RDI/I

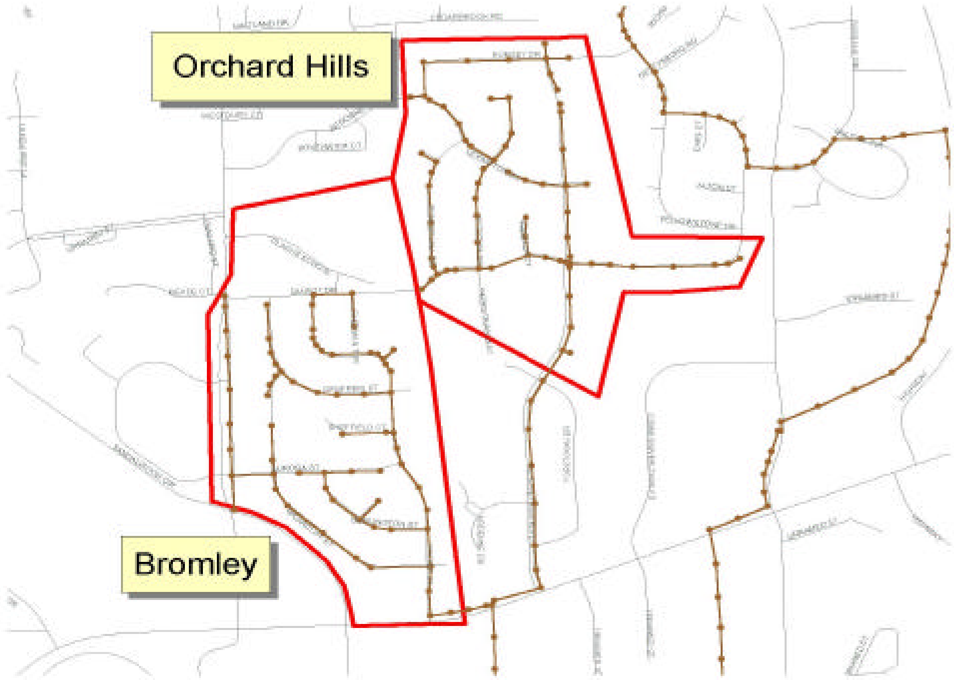


Figure G-9 Schematic of the Orchard Hills and Bromley Study Areas

volume was calculated and the volume divided by the tributary area. The resulting value was plotted against the corresponding rainfall volume in inches. In addition, each event was classified as occurring during spring (dormant) conditions or during summer (growing) conditions. Lines were then drawn to define the envelope of responses to be expected.

Results of this analysis are presented in Figure G-11. Note that the variations in response are due to differences in season, antecedent conditions (number of days since previous rainfall), and storm characteristics that include such elements as rainfall intensity and duration.

In addition to defining growing and dormant season events, the June 24-25, 2000 storm was classified as a major storm event in Figure G-11. This major storm yielded a response midway between the growing and dormant season envelope lines in this study area.

Note that there is also an initial abstraction term shown in the figure. The initial abstraction represents the amount of rainfall that must take place before any response is observed in the collection system. In general, all of the five study areas responded similarly, requiring 0.5" of rainfall before responding in dormant conditions and about 1" of rainfall before responding during growing conditions.

The results of this analysis provide insight into the amount of rainfall that finds its way into the sanitary sewer system, after accounting for initial abstraction. For the Orchard Hills study area this ranges from 2.8% during the growing season to 13.8% for dormant times. This amount of wet weather response is an indication of a fairly wet sanitary system and can typically be attributed to footing drains being connected to the sanitary collection system.

G.3.1.2 Calibration

Table G-9 gives the rainfall response factor ("R") and initial abstraction terms (V_o) values for all three events for the Orchard Hills region. With these parameters defined for the calibration events, the shape parameters were adjusted so the model predicted flows and levels that adequately matched the field-recorded flows and levels. Note that for these events, the initial abstraction term was reduced to account for rainfall that had taken place prior to the storms being simulated.

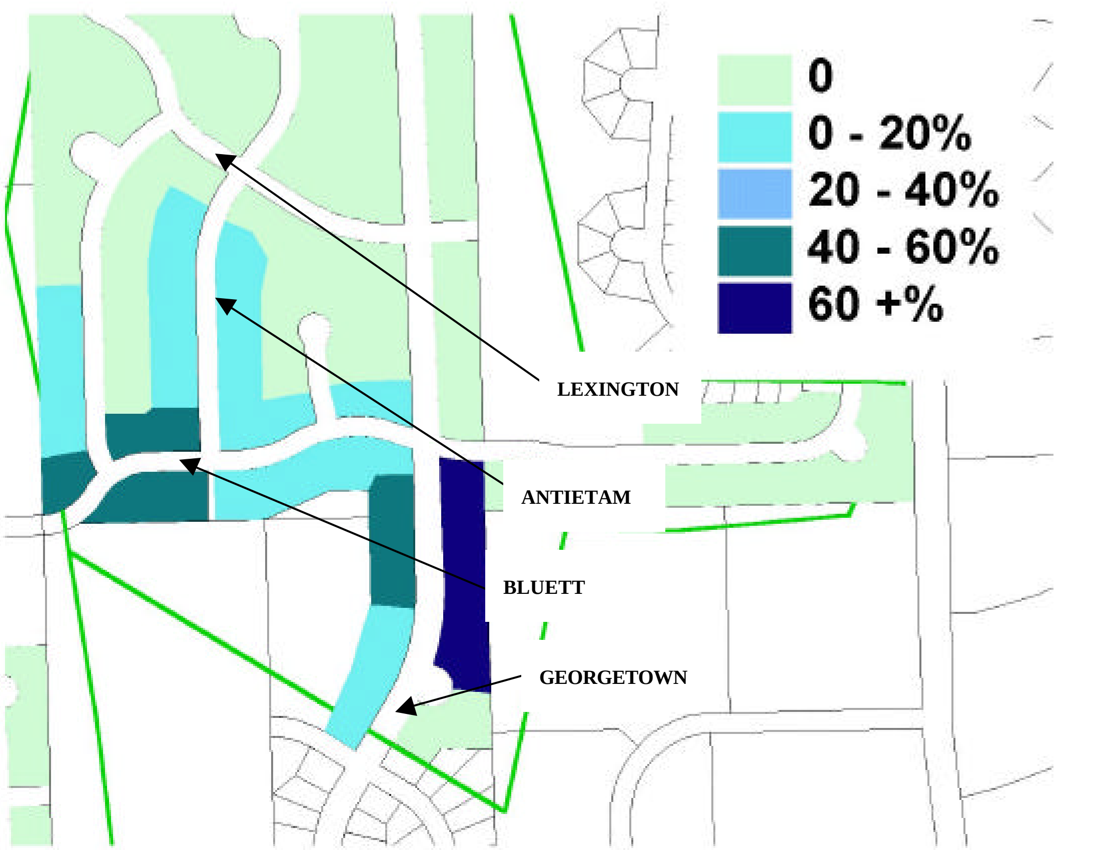


Figure G-10 Reported Flooding in Orchard Hills

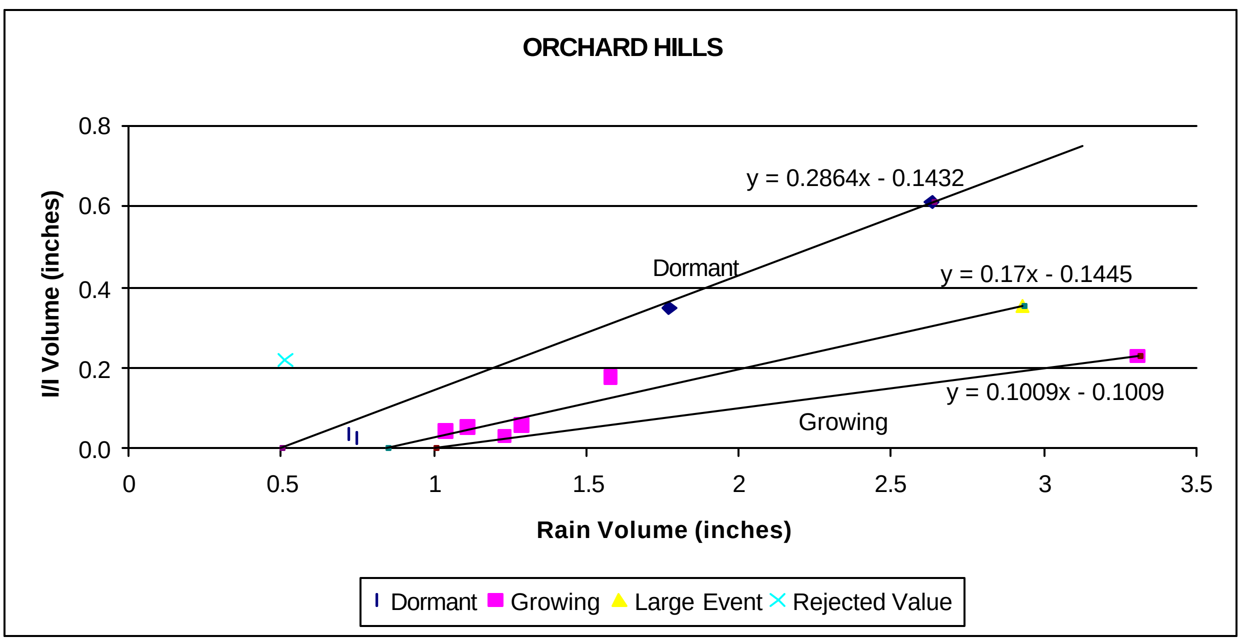


Figure G-11 RDI/I Response for Orchard Hills Study Area

Table G-9 RDI/I Parameters for calibration events for Orchard Hills

Region	Parameter	May Event	June Event	July Event
Orchard Hills	R (%)	13.8	10.0	2.8
Orchard Hills	V_o (inches)	0.2	0.30	0.15

G.3.1.3 Problems

Figure G-12 contains the thematic map of surcharging for the Orchard Hills study area. The marginal sewers identified in Orchard Hills includes portions of sewers under Georgetown, Bluett, Trenton, and Bunkerhill. Sewers with significant surcharging include portions of sewers under Rumsey, Lexington, Antietam, Bunkerhill, Bluett, and Georgetown.

Figure G-13 shows the thematic maps of the peak flow to design flow for the Orchard Hills study area. No sewers were identified as being marginal within the Orchard Hills study area. Sewers in which the flow to design flow ratio is viewed as having significant problems include portions of sewers under Rumsey, Lexington, Antietam, Bluett, and Georgetown. It is believed that excessive RDI/I is the cause of the surcharging and flow exceedances in this study area.

G.3.1.4 Alternatives

The costs of all four alternatives were compiled separately for Orchard Hills and Bromley. However, Orchard Hills and Bromley share a common connection to the trunk system.

Relief Sewers

The relief option was examined first. In this option, a series of parallel pipes would be constructed to accommodate high flows. The model was used to determine where relief pipes would need to be added, as well as the size of those pipes. In Orchard Hills, relief sewers would be placed along Lexington to Antietam, south to Bluett, east to Georgetown, then south along Georgetown, and

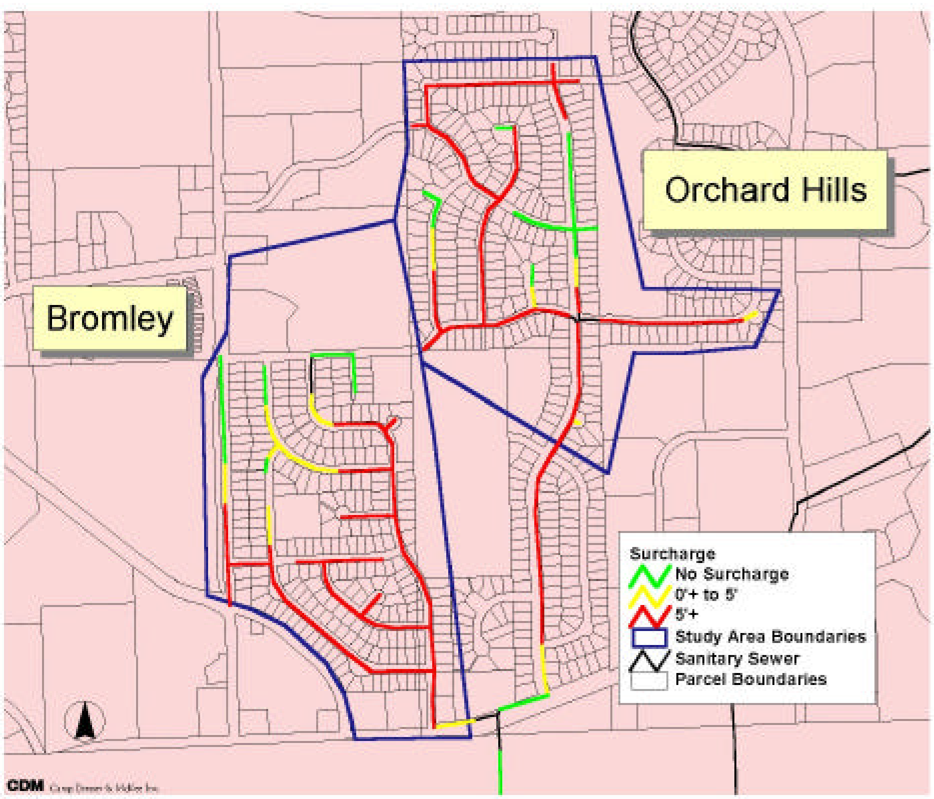


Figure G-12 Thematic Map of Surcharging for Orchard Hills and Bromley

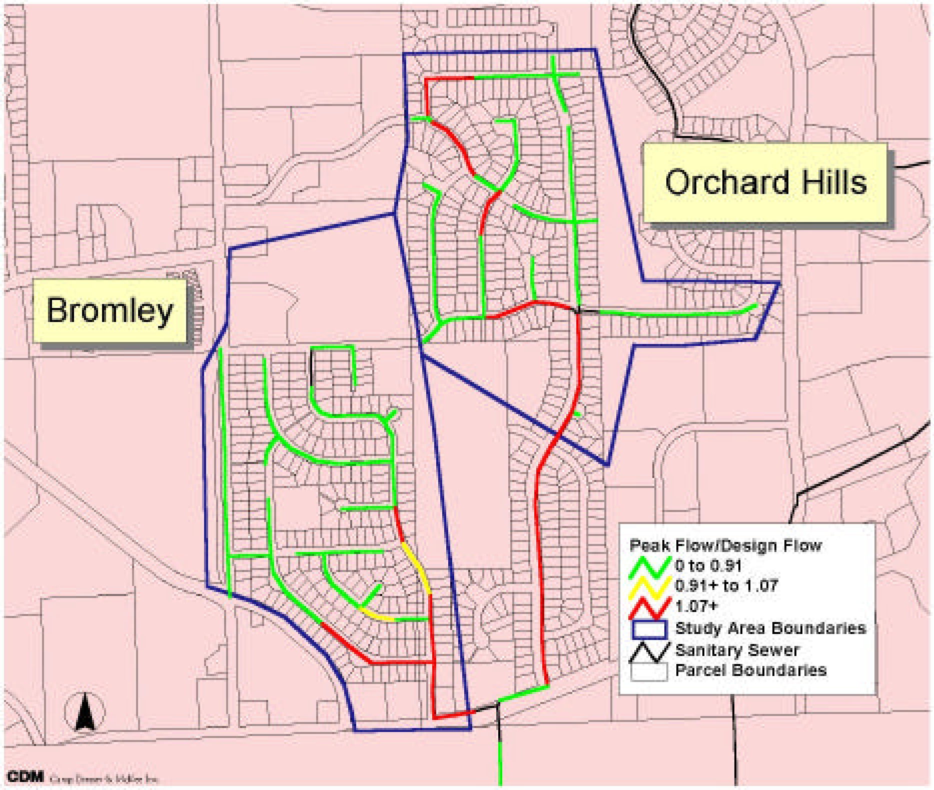


Figure G-13 Flow / Design Flow Thematic Map for Orchard Hills and Bromley

along Plymouth south towards Huron Parkway. This is shown in Figure G-14.

The costs associated with the relief option include the cost of 5,193 feet of relief pipe, the maintenance costs for pipe cleaning, and restoration costs for streets. This option, as do all options, also provide for footing drain disconnection and protection for 50 homes in areas that have historically had basement backup problems. Engineering/construction fees are also included.

The construction costs for the relief option are $2.86 million for this area. Lifecycle costs for the relief sewer alternative include an additional $43,000 for Orchard Hills. This includes the present worth cost of sewer cleaning, based on a life cycle of 30 years and an annual discount rate of 8%.

To prevent adverse impacts on residents downstream of Orchard Hills, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Orchard Hills area construction and the wastewater treatment plant. This capacity increase would cost an additional $0.42 million for trunk sewer construction, and incur additional lifecycle costs of $10,000.

Increasing Capacity

In Orchard Hills, relief sewers and/or pipe bursting would be placed along Lexington to Antietam, south to Bluett, east to Georgetown, then south along Georgetown, and along Plymouth south to Huron Parkway. This is shown in Figure G-15. This alternative cannot entirely consist of pipe bursting. Pipe bursting may only be used if the new pipe diameter is no greater than two standard sizes larger than the existing diameter.

The costs associated with the increased capacity option include the cost of 2,474 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, 2,719 feet of relief pipe, pipe cleaning, and restoration costs for streets. This option, as do all options, also provide for footing drain disconnection and protection for homes in areas that have historically had basement backup problems. Engineering/construction fees are also included.

The construction costs for the increased capacity method is $2.79 million for Orchard Hills. Lifecycle costs for the increasing capacity alternative include an additional $23,000 for Orchard Hills. This is the cost of sewer cleaning and inspection, based on a life

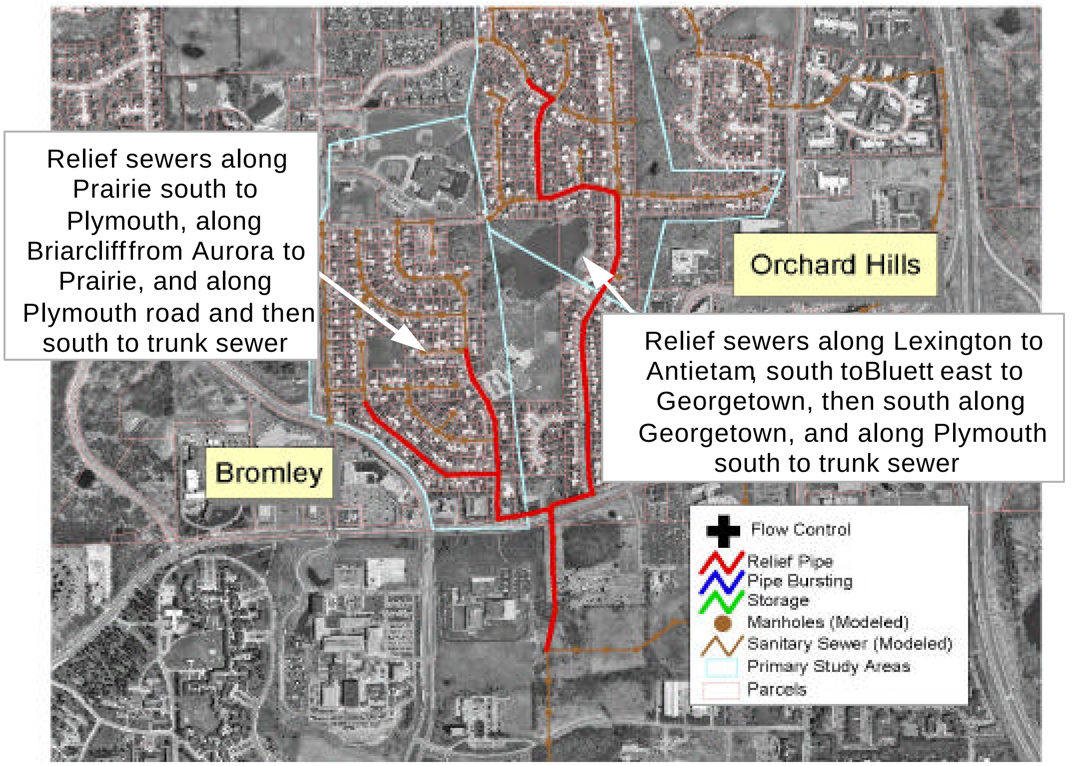


Figure G-14. Relief Sewer Option for Bromley and Orchard Hills.

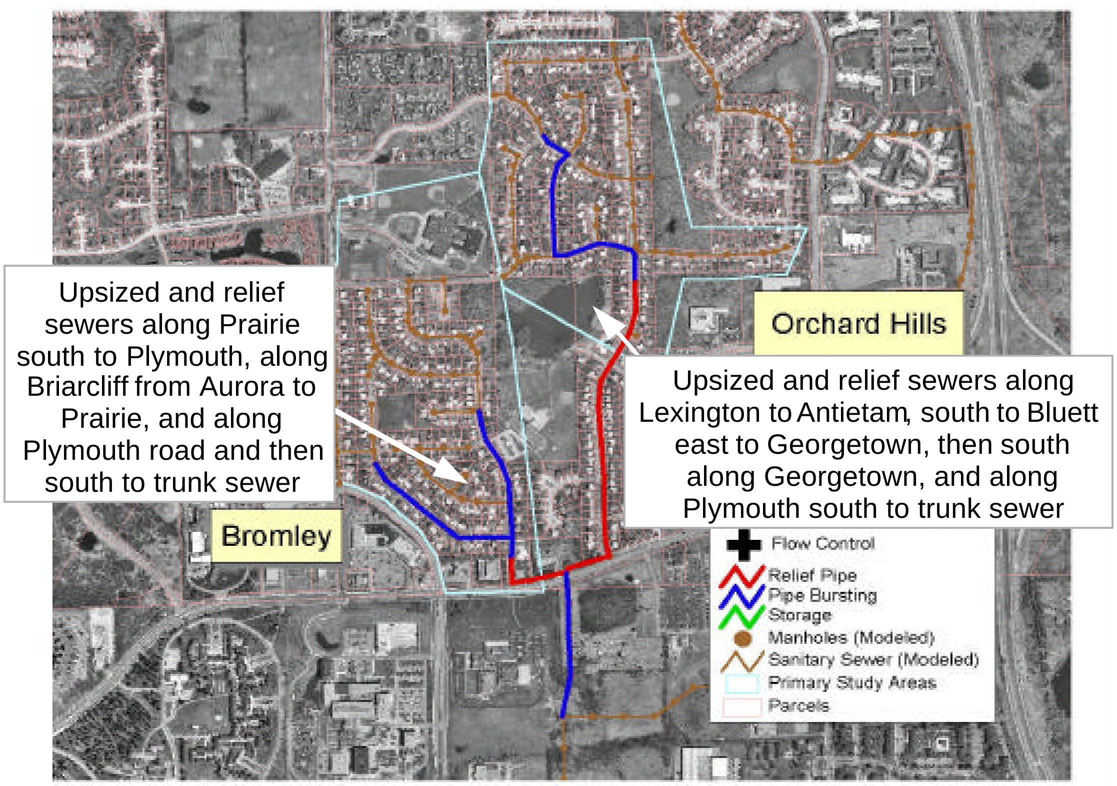


Figure G-15. Increased Capacity Option for Bromley and Orchard Hills.

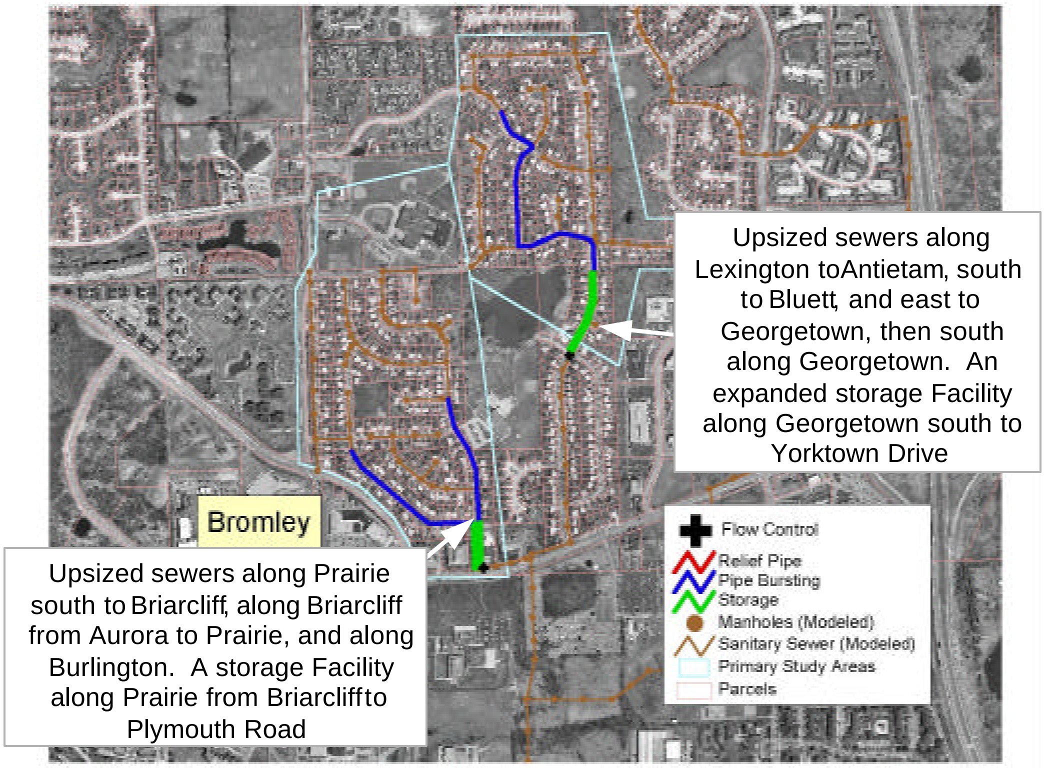


Figure G-16. Collection System Storage Option for Bromley and Orchard Hills.

cycle of 30 years and an annual discount rate of 8%.

To prevent adverse impacts on residents downstream of Orchard Hills, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Orchard Hills area construction and the wastewater treatment plant. This capacity increase would cost an additional $0.42 million for trunk sewer construction, and incur additional lifecycle costs of $10,000.

Collection System Storage

The collection system storage option includes increasing the size of the existing storage basin in the Orchard Hills region. This increase in capacity would be accomplished by adding two parallel 5' diameter pipes that would be placed along Georgetown south to Yorktown Drive.

No pipes downstream of the storage facilities would need to be enlarged as a result. However, pipes upstream of the storage facilities will have to be increased in size to accommodate large flows to the storage basins. The upsized sewers will be placed along Lexington to Antietam, south to Bluett, and east to Georgetown, then south along Georgetown. This is illustrated in Figure G-16.

The costs associated with this option include the cost of 2,474 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, 1,398 feet of five-foot diameter storage pipe, control connections, discharge connections, access manholes, and restoration costs for tearing up the streets. This option, as do all options, also provide footing drain disconnection and protection for 50 for homes in areas that have historically had basement backup problems. Engineering/construction fees are also included.

The construction cost for the upsizing/storage option are $2.24 million for Orchard Hills. Lifecycle O&M costs for the collection storage system alternative amounts to $3,000 for this area. This is the cost of basin maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

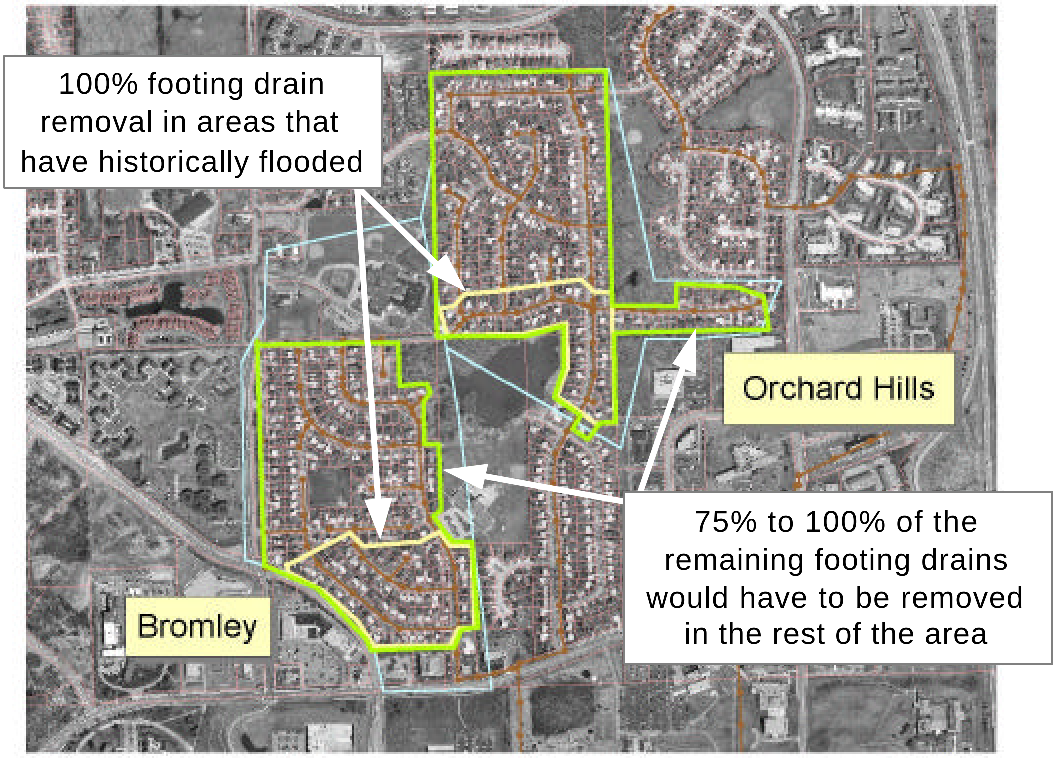


Figure G-17. Footing Drain Disconnection Option for Bromley and Orchard Hills.

Footing Drain Removal

The fourth option involves the disconnection of footing drains in the region. Based on field measurements, it is estimated in the Orchard Hills region that footing drains account for between 70% and 90% of the wet weather flow that enters the sanitary sewers. To reduce flows to the point where the sanitary sewers would not surcharge, between 310 and 375 homes would need to be disconnected, this includes 50 homes that are in the vicinity of the area that has previously flooded and require flood protection. The areas where the initial footing drain disconnection would be performed is shown in Figure C-17. This includes 100% of the homes in the historically flooded areas and 75% to 100% of the remaining homes.

The cost of this disconnection work is estimated to be between \$1.93 million and \$2.32 million. Because of the reduced flow discharged to the wastewater treatment plant, the lifecycle costs are estimated to be between \$1.67 million to \$2.06 million for this alternative.

G.3.2 Bromley Study Area

The Bromley study area is located in northeast Ann Arbor, bounded on the south by Plymouth Road, on the east by Prairie, on the north by Bluett, and on the west by Huron Parkway and Nixon Road. This area is shown in Figure G-9.

Basement flooding was observed in the Bromley study area during the August 1998 and June 2000 major storm events. Previous to that, flooding has been recorded in the area since the 1960s. Figure G-18 shows the percent of homes in each defined parcel group that reported flooding in the August 1998 and June 2000 major storm events in Bromley. The parcels are grouped in a way to logically represent flooded areas without compromising residents' privacy by classifying individual parcels.

The study area model developed for Bromley included every manhole and sewer main in the study area. These were included in as much detail as possible to better understand the dynamics of the local collection system. The model also included the section of the collection system discharging down to Plymouth Road and connecting to the trunk sewer system south of Plymouth Road and Huron Parkway. In addition, the basement elevations of homes adjacent to the sewer in areas that had flooded were included in the model for this area.

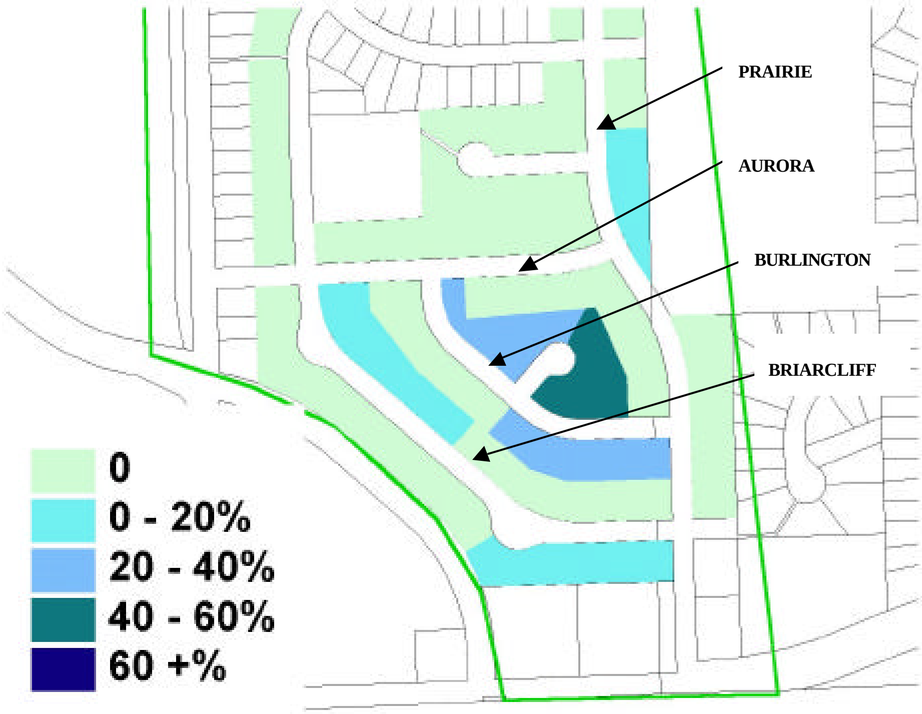


Figure G-18. Reported Flooding in Bromley Study Area

G.3.2.1 Analysis

A total of 16 storms were evaluated for the Bromley study area. For each event, the total RDI/I volume in calculated in inches and the volume is divided by the tributary area, was plotted against the corresponding rainfall volume in inches. In addition, each event was classified as occurring during spring (dormant) conditions or during summer (growing) conditions. Lines were then drawn to define the envelope of responses to be expected.

Results of this analysis are presented in Figure G-19 Note that the variations in response are due to differences in season, antecedent conditions (number of days since previous rainfall), and storm characteristics that include such elements as rainfall

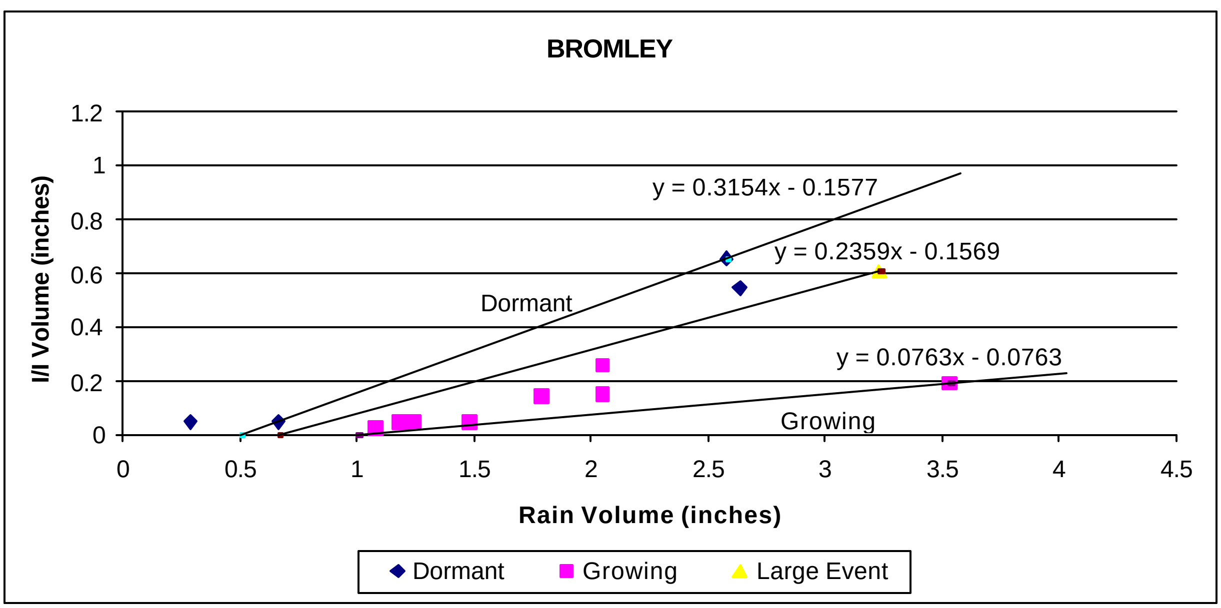


Figure G-19. RDI/I Response for Bromley Study Area

Table G-10. RDI/I Parameters for calibration events for Bromley

Region	Parameter	May Event	June Event	July Event
Bromley	R (%)	19.7	11.7	5.0
Bromley	V_o (inches)	0.2	0.2	0.3

intensity and duration.

The results of this analysis provide insight into the amount of rainfall that finds its way into the sanitary sewer system, after accounting for initial abstraction. For the Bromley study area this ranges from 5.0% during the growing season to 20.9% for dormant times. This amount of wet weather response is an indication of a fairly wet sanitary system and can typically be attributed to footing drains being connected to the sanitary collection system.

G.3.2.2 Calibration

Table G-10 gives the rainfall response factor ("R") and initial abstraction terms ("V_o") values for all three events for the Bromley study area. With these parameters defined for the calibration events, the shape parameters were adjusted so the model predicted flows and levels that adequately matched the field-recorded flows and levels. Note that for these events, the initial abstraction term was reduced to account for rainfall that had taken place prior to the storms being simulated.

Results of the calibration efforts suggested that values of "R" in Bromley varied spatially to some extent. Seven subareas in the northern portion of Bromley were assigned a lower response factor based on newer construction and higher elevations that would result in lower RDI/I. In addition, one subarea was assigned a higher response factor because of a documented inflow source. The higher R-value for this subarea was not used for design conditions however, as this inflow source has been corrected.

G.3.2.3 Problems

Figure G-12 contains the thematic map of surcharging for the Bromley study area. The marginal sewers identified in Bromley include portions of sewers under Plymouth, Prairie, Renfrew, Briarcliff, and Nixon. Sewers experiencing significant surcharging include portions of sewers under Prairie, Renfrew, Burlington, Burlington Court, Briarcliff, Aurora, Sheffield, and Nixon.

Figure G-13 shows the thematic maps of the peak flow to design flow for the Bromley study area. Sewers that are considered marginal include portions of sewers under Prairie and Burlington. Sewers with significant flow issues include portions of sewers under Prairie, Briarcliff, and Plymouth. It is believed that excessive RDI/I is the cause of the surcharging and flow exceedances.

G.3.2.4 Alternatives

The costs of all four alternatives are compiled below for Bromley.

Relief Sewers

The relief option was examined first. In this option, a series of parallel pipes would be constructed to accommodate high flows. The model was used to determine where relief pipes would need to be added, as well as the size of those pipes.

In Bromley, relief sewers would be placed along Prairie south to Plymouth, along Briarcliff from Aurora to Prairie, and along Plymouth Road and then south towards Huron Parkway. This is shown in Figure G-14.

The costs associated with the relief option include the cost of 3,436 feet of relief pipe, the maintenance costs for pipe cleaning, and restoration costs for streets. This option, as do all options, also provide for footing drain disconnection and protection for 70 homes in Bromley that are in the vicinity of historical flooding areas. Engineering/construction fees are also included, but not CM costs for FDD/protection.

The construction costs for the relief option is $2.06 million for Bromley. Lifecycle O&M costs for the relief sewer alternative include an additional $35,000 for Bromley. This is the present worth cost of sewer cleaning, based on a life cycle of 30 years and an annual discount rate of 8%.

The trunk sewer system would also have to be upsized in order for this method to be used. An additional $0.42 million in construction costs, or $0.43 million in lifecycle costs.

Increasing Capacity

In Bromley, relief sewers and/or pipe bursting would be placed along Prairie south to Plymouth, along Briarcliff from Aurora to Prairie, and along Plymouth Road and then south to Huron Parkway. This is shown in Figure G-15. This alternative cannot entirely consist of pipe bursting. Pipe bursting may only be used if the new pipe diameter is no greater than two standard sizes larger than the existing diameter.

The costs associated with the increased capacity option include the cost of 2,690 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, 746 feet of relief pipe, pipe cleaning, and restoration costs for streets. This option, as do all options, also provide for footing drain disconnection and protection for 70 homes in Bromley in areas that have previously had basement flooding problems. Engineering/construction fees are also included.

The construction costs for the increased capacity method are $1.99 million for Bromley. Lifecycle costs for the increasing capacity alternative are essentially the same as construction costs

The trunk sewer system would also have to be upsized for this method to be used. An additional $0.42 million in construction costs, or $0.43 million in lifecycle costs, would be required for Bromley.

Collection System Storage

The collection system storage option includes a storage basin in Bromley. The proposed basin in Bromley consists of two parallel 5’ diameter pipes that will run along Prairie Street between Briarcliff and Plymouth Road. No pipes downstream of the storage facility would have to be enlarged as a result. The storage basins attenuate peak flow, thus eliminating the need to enlarge pipes downstream. However, pipes upstream of the storage facilities will have to be burst in order to accommodate large flows to the storage basin.

The model simulation was performed and produced the following results. The volume of storage required in Bromley was 16,642-ft^3. In Bromley, upsized sewers will be placed along Prairie south to Briarcliff, along Briarcliff from Aurora to Prairie, and along Burlington. This is illustrated in Figure G-16.

The costs associated with this option include the cost of 2,476 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, 848 feet of five-foot diameter storage pipe, control connections, discharge connections, access manholes, and restoration costs for tearing up the streets. This option, as do all options, also provide footing drain disconnection and protection for 70 homes in Bromley that are in areas that have historically had basement flooding problems. Engineering/construction fees are also included.

The construction cost for the upsizing/storage option was $1.95 million for Bromley. Lifecycle O&M costs for the collection storage system alternative include an additional $2,000 for Bromley. This is the cost of basin maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

Footing Drain Disconnection

The fourth option involves the disconnection of footing drains in the region. Based on field measurements, it is estimated in the Bromley region that footing drains account for between 70% and 90% of the wet weather flow that enters the sanitary sewers. To reduce flows to the point where the sanitary sewers would not surcharge, between 194 and 249 homes would need to be disconnected, this includes 70 homes that are in the vicinity of areas that have previously flooded and require flood protection. The areas where the initial footing drain disconnection would be performed is shown in Figure G-17. This includes 100% of the homes in the historically flooded areas and 75% to 100% of the remaining homes.

The cost of this disconnection work is estimated to be between $1.23 million to $1.57 million. Because of the reduced flow discharged to the wastewater treatment plant, the lifecycle costs are estimated to be between $1.01 million to $1.35 million for this alternative.

G.3.3 Dartmoor Study Area

The Dartmoor study area is located on the west side of Ann Arbor and is roughly bounded on the south by Pauline Road, on the east by Eberwhite Woods, on the north by Liberty Road, and on the west by I-94 as shown in Figure G-20. In addition to this portion of the study area, flows from a small area of Ann Arbor to the west of I-94 and north of Liberty and a section of Scio Township flow in from the west. These flows enter the study area just downstream of the Liberty Road pumping station. The Dartmoor study area discharges under Liberty Road into the Liberty-Washington trunk sewer.

Basement flooding had not been observed in the Dartmoor study area until the August 1998 major storm event. The flooding since that time has been concentrated along Dartmoor Road. Figure G-21 shows the percent of homes in each defined parcel group that reported flooding in the June 2000 major storm event. The parcels are grouped in a way that logically represents flooded areas without compro-

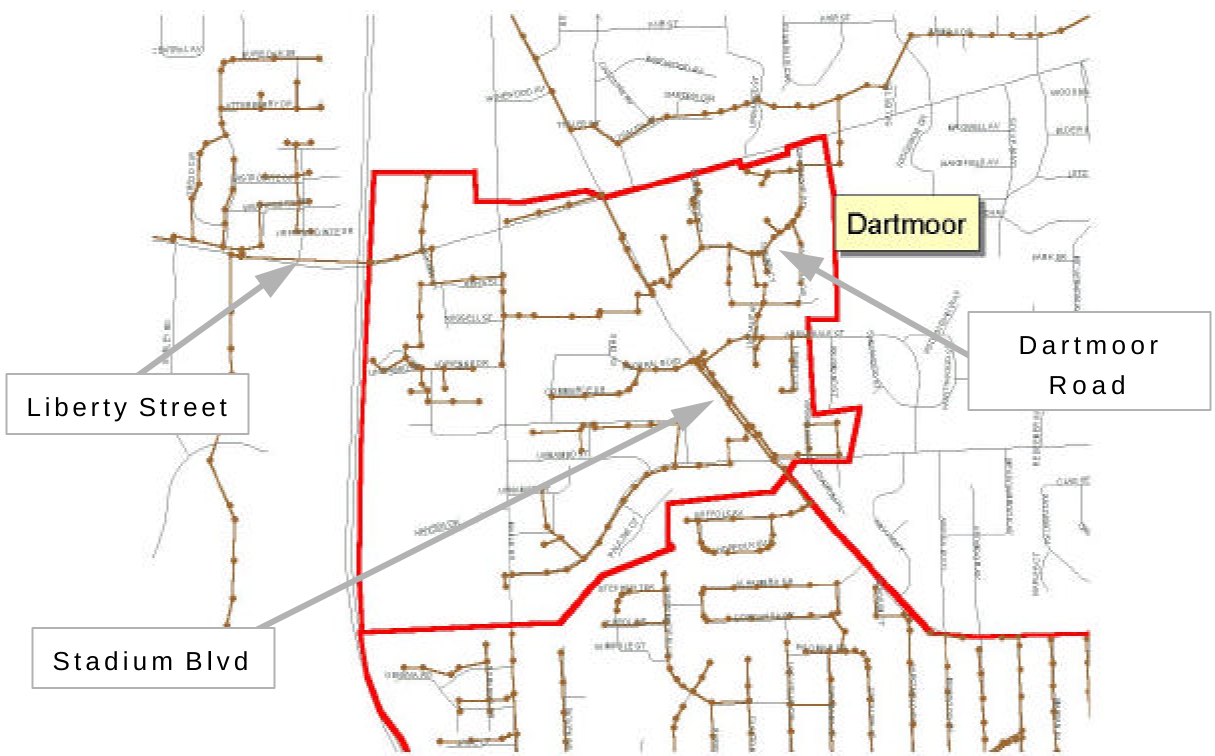


Figure G-20. Dartmoor Study Area Schematic

Figure G-21. Reported Flooding in Dartmoor Study Area

mising residents' privacy by classifying individual parcels.

The study area model developed for Dartmoor includes every manhole and sewer main in the study area. These were included in as much detail as possible to better understand the dynamics of the local collection system. The model also included the section of the collection system discharging downstream from Liberty Road and into the Liberty-Washington trunk sewer. The model also includes the pumping station located on Liberty Road west of the I-94 freeway. In addition, the basement elevations of homes adjacent to the sewer along Dartmoor Road were included in the model for this area.

G.3.3.1 Flow Analysis

A total of 16 storms were analyzed for the Dartmoor study area. For each event, the total RDI/I volume in inches, total volume is divided by the tributary area, was plotted against the corresponding rainfall volume in inches. In addition, each event was classified as occurring during spring (dormant) conditions or during summer (growing) conditions. Lines were then drawn to define the envelope of responses to be expected.

Results of this analysis are presented in Figure G-22. Note that the variations in response are due to differences in season, antecedent conditions (number of days since previous rainfall), and storm characteristics that include such elements as rainfall intensity and duration.

The results of this analysis provide insight into the amount of rainfall that finds its way into the sanitary sewer system, after accounting for initial abstraction. For the Dartmoor study area this ranges from 2.2% during the growing season to 4.8% for dormant times.

The area tributary to Dartmoor Road flow meter

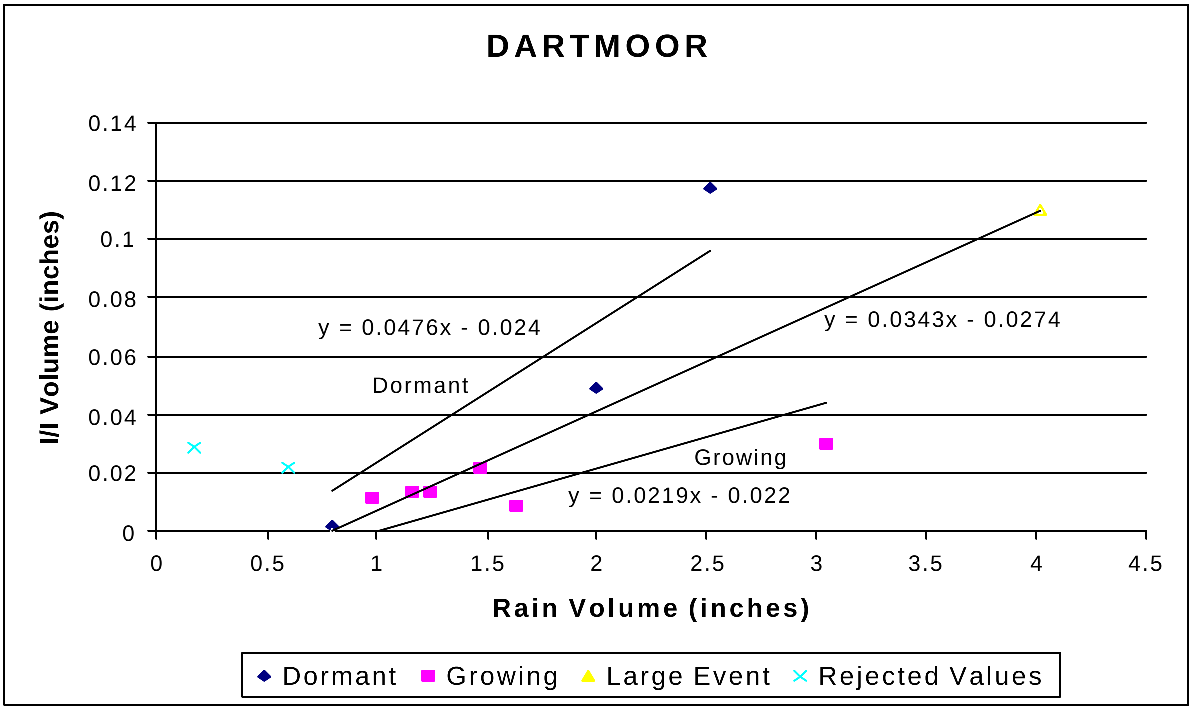


Figure G-22. RDI/I Response for Dartmoor Study Area

represents a range of land uses. The older residential areas, primarily those south of Liberty Street and east of Stadium Boulevard, probably contribute a larger portion of the wet weather response than do the commercial and multifamily housing areas that are west of Stadium. In addition, there are newer residential areas upstream from the Liberty Street pumping station that probably do not contribute at the rate of older residential areas. A significant portion of the flow for this study area is generated within Scio Township.

Performing the necessary level of flow monitoring to account for the variation within the study area was beyond the scope of the project. However, an attempt was made to estimate the variability in response between the areas upstream and downstream of the Liberty Street pumping station. During a September 10-11, 2000 storm, the available pump runtime data was used to show that approximately 70% of the wet weather response was generated in the area downstream from the pumping station. There is, however, some uncertainty in the

Table G-11. RDI/I Parameters for calibration/validation events for Dartmoor

Region	Parameter	May Event	June Event	July Event
Downstream of Pump Station	R (%)	5.4	4.1	1.1
Downstream of Pump Station	V_o (inches)	0.2	0.3	.4
Upstream of Pump Station	R (%)	1.7	1.5	0.4
Upstream of Pump Station	V_o (inches)	0.2	0.3	0.4

assessment of this flow apportionment because of the limited dataset.

G.3.3.2 Calibration

Table G-11 gives the rainfall response factor ("R") and initial abstraction terms ("V_o") values for all three events for the Dartmoor study area. With these parameters defined for the calibration events, the shape parameters were adjusted so the model predicted flows and levels that adequately matched the field recorded flows and levels. Note that for these events, the initial abstraction term was reduced to account for rainfall that had taken place prior to the storms being simulated.

The RDI/I parameters determined from the flow analysis were modified to account for the flow split between the areas upstream and downstream of Liberty Road pumping station. Table G-11 provides the "R" and "V_o" values for all three events for the areas upstream and downstream of the Liberty Road pumping station. With these parameters defined for the calibration events, the shapes of the response curves were adjusted until the model predicted flows and levels adequately matched the field-recorded flows and levels.

In addition to varying shape parameters, it was determined that the Manning's roughness parameter needed to be increased for the sewer between Dartmoor Road and Liberty Road to improve calibration results.

G.3.3.3 Problems

Figure G-23 contains the surcharging thematic map for Dartmoor area. In the Dartmoor study areas, sewers that have marginal surcharging include sewers in Ivywood, Stadium, and Liberty. Sewers with significant surcharging include Dartmoor Road, Ivywood, Peppermill Way, Hampton Court, Dover Court, Stadium, and Pauline.

Figure G-24 contains the ratio of peak flow to design flow for the Dartmoor area sewers in which the

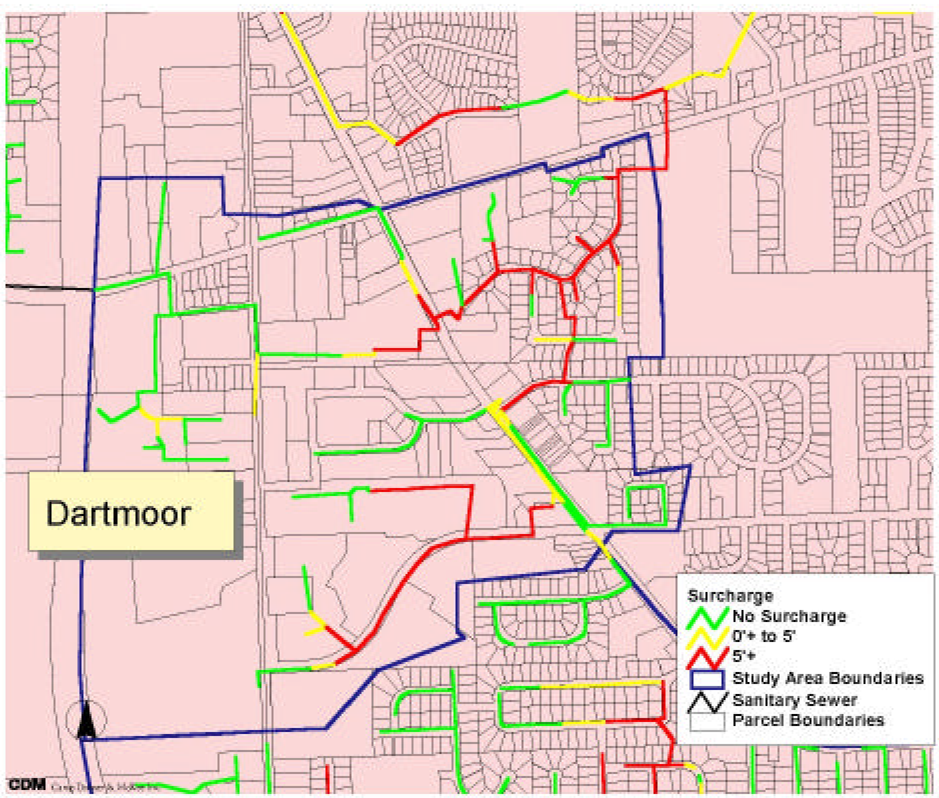


Figure G-23. Thematic Map of Surcharging for Dartmoor

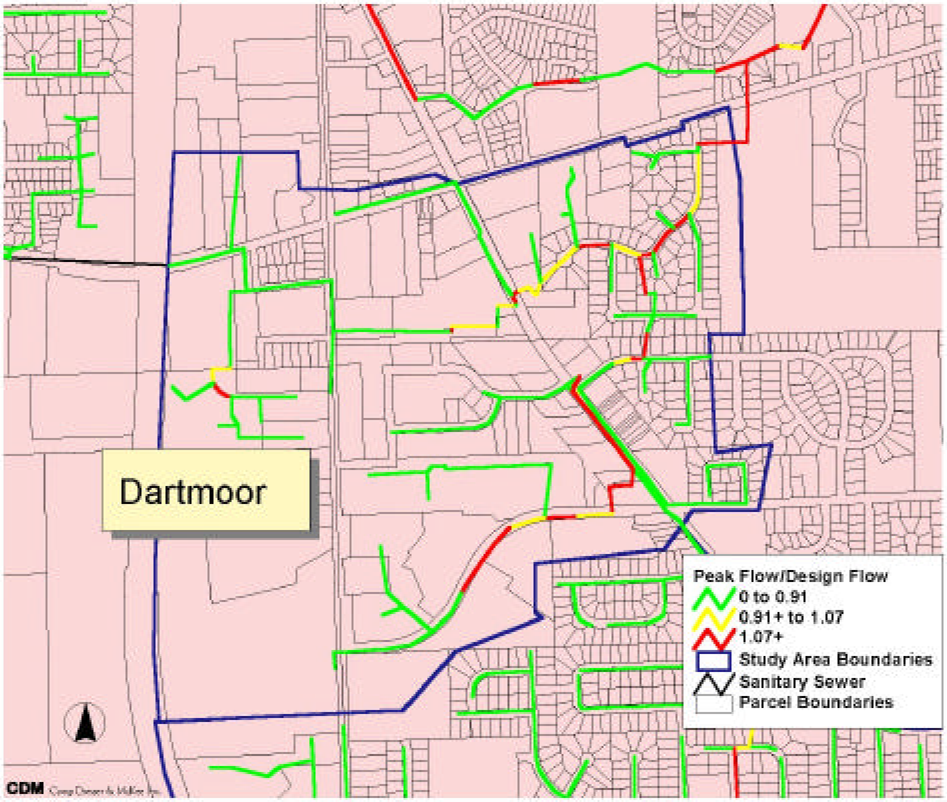


Figure G-24. Flow / Design Flow Thematic Map for Dartmoor

flow-to-design flow ratio is marginal includes sewers under Dartmoor Road, Arbordale, and Pauline. Sewers with significant flow-to-design flow ratio problems include portions of sewers under Dartmoor, Paulene, Stadium, Arbordale, and Evelyn Court. It is believed that excessive RDI/I is the cause of the surcharging and flow exceedances in the Dartmoor study area.

G.3.3.4 Alternatives

In addition to the select alternative discussed in this section, other model simulations were considered, but discarded due to ineffectiveness. These included evaluation of Liberty Road pump station by reducing flows during wet weather to single-pump, and zero-pump, operation. Often during wet weather events, both pumps at this pump station operate simultaneously. Although this did have some effect, it was not sufficient to warrant further consideration.

Relief Sewers

The relief option was examined first. In this option, a series of sewer pipes would be constructed parallel to the existing sewer to accommodate high flows. The model was used to determine where relief pipes would need to be added, as well as the size of those pipes.

In Dartmoor, relief sewers would be placed along Dartmoor Road, through Eberwhite Woods, across Liberty Street, through the Commons area and Virginia Park, to Bemidji Drive. This is shown in Figure G-25. The costs associated with the relief option include the construction of 3,160 feet of relief pipe. This option, as do all options for Dartmoor, provides footing drain disconnection and flooding protection for 31 homes in Dartmoor that are potentially that are in the vicinity of the area which has previously flooded.

The construction costs for the relief option are $1.79 million. Lifecycle costs for the relief sewer alternative include an additional $27,000. This is the cost of

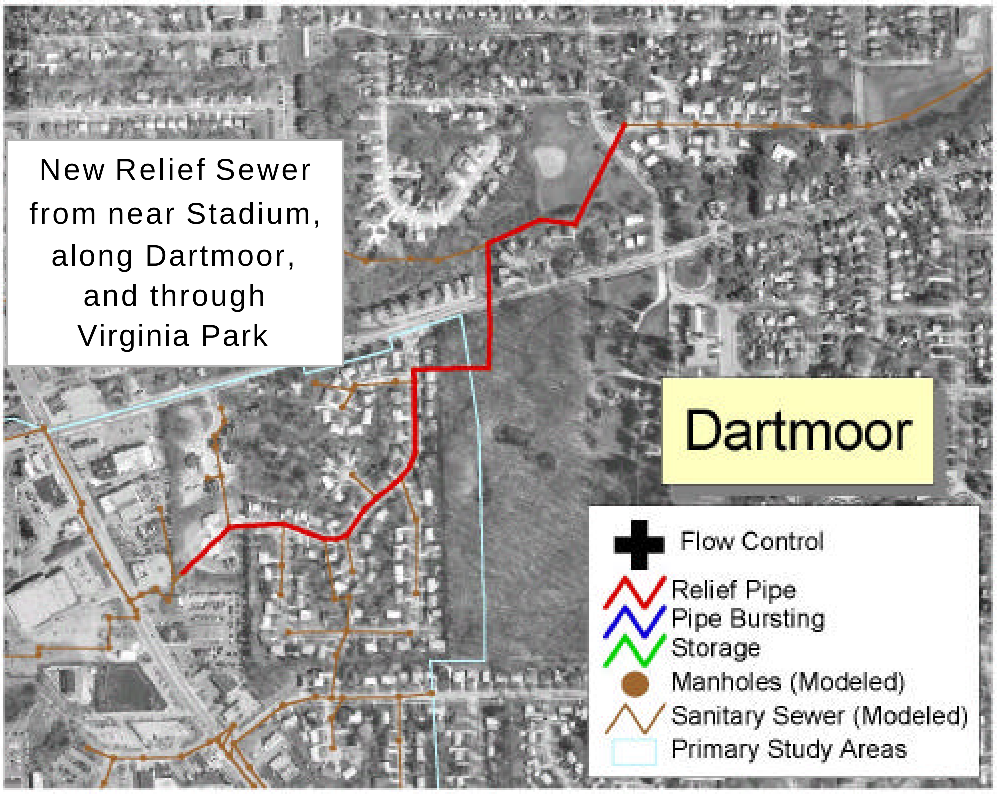


Figure G-25. Relief Sewer Option for Dartmoor.

sewer cleaning and inspection, based on a life cycle of 30 years and an annual discount rate of 8%.

To prevent adverse impacts on residents downstream of Dartmoor, the trunk sewer system would require increased capacity along the existing trunk sewer between the proposed Dartmoor area construction and the wastewater treatment plant. This capacity increase would cost an additional $3.95 million for construction, and incur additional lifecycle O&M costs of $90,000.

Increasing Capacity

In Dartmoor, pipe bursting was considered as an option to increase capacity where possible, rather than relief. This option affects the same reach of sewer as the relief option. However, pipe bursting is performed from the west end of Dartmoor Road through Eberwhite Woods. From Eberwhite Woods to Bemidji Drive, requires relief sewer construction because pipe bursting cannot be performed due to construction method limitations. This is shown in Figure G-26.

The costs associated with the increased capacity option include the construction of 1,198 feet of relief pipe and pipe bursting of 1,962 feet of sewer. This option, as do all options for Dartmoor, provides footing drain disconnection and flooding protection for 31 homes in Dartmoor that are potentially at risk of basement flooding.

The construction costs for the increased capacity option are $1.81 million. Lifecycle costs for the increased capacity alternative include an additional $10,000. This is the cost of sewer cleaning and inspection, based on a life cycle of 30 years and an annual discount rate of 8%.

To prevent adverse impacts on residents downstream of Dartmoor, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Dartmoor area construction

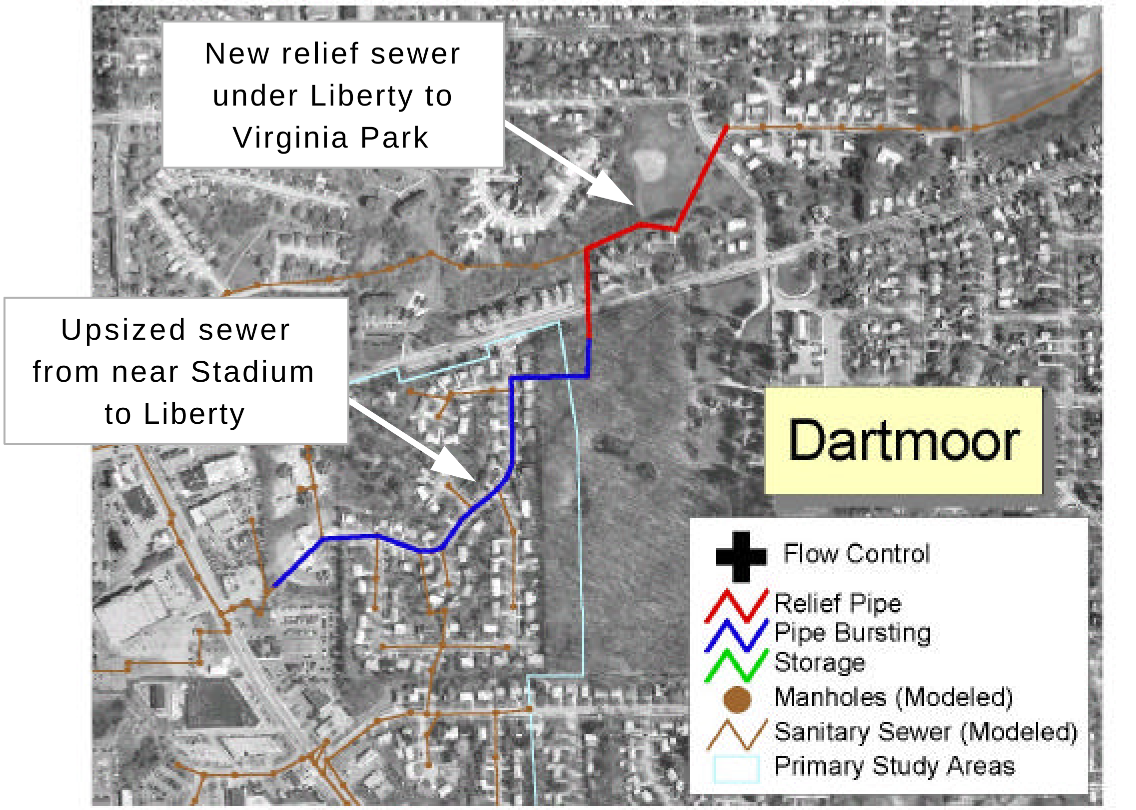


Figure G-26. Increased Capacity Option for Dartmoor.

and the wastewater treatment plant. This capacity increase would cost an additional $3.95 million for construction, and incur additional lifecycle O&M costs of $90,000.

Collection System Storage

The collection system storage option includes a 45,000-ft^3 storage basin in Dartmoor. The proposed basin consists of six parallel 5' diameter pipes that could possibly run under the Commons area, North of Liberty Street or under Virginia Park. An advantage of this option is that capacity of the downstream trunk system does not need to be increased. The storage facility includes a control that limits flow out of the facility to an acceptable rate. Due to capacity limitation in the Dartmoor area, increased pipe capacity upstream of the storage area is required. This is illustrated in Figure G-27.

The costs associated with the storage option include the construction of 387 feet of relief pipe, pipe bursting of 1,962 feet of sewer, and 2,292 feet of 60" in-line storage pipe. This option, as do all options for Dartmoor, provides footing drain disconnection and flooding protection for 31 homes in Dartmoor that are in the vicinity of the area which has previously flooded.

The construction costs for the storage option are $2.66 million. Lifecycle costs for the storage alternative include an additional $5000. This is the cost of sewer storage facility maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

Footing Drain Disconnection

The fourth option involves the disconnection of footing drains in the region. Based on field measurements, it is estimated in the Dartmoor region, footing drains account for between 80% and 100% of the wet weather flow that enters the sanitary sewers. To reduce flows to the point where the

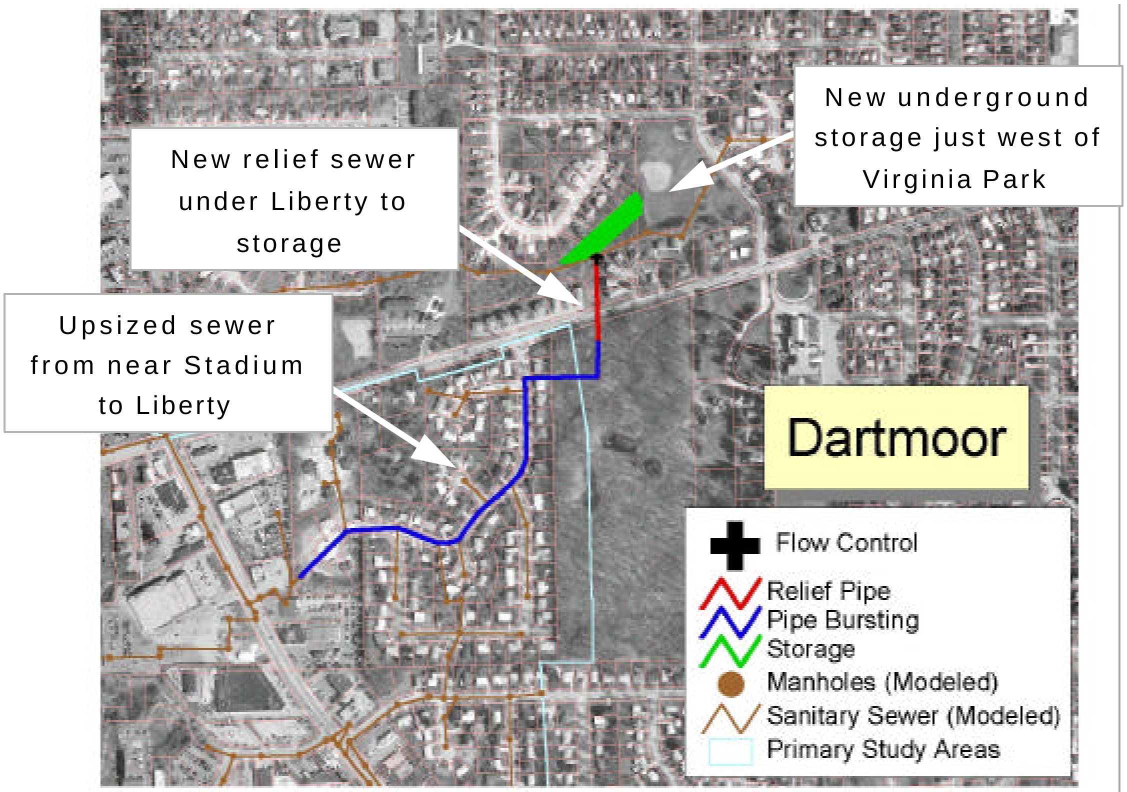


Figure G-27. Collection System Storage Option for Dartmoor.

sanitary sewers would not surcharge, between 243 and 311 homes would need to be disconnected, this includes 31 homes that are in the portion of the area that has previously flooded. The areas where the initial footing drain disconnection would be performed is shown in Figure G-28. This includes 100% of the homes in the historically flooded areas and 80% to 100% of the remaining homes.

The cost of this disconnection work is estimated to be in the range of $1.5 to $1.92 million. Because of the reduced flow discharged to the wastewater treatment plant, the lifecycle costs are estimated to be in the range of $1.09 to $1.51 million for this alternative.

Of the five study areas considered, the footing drain disconnect option in Dartmoor has the most uncertainty. Dartmoor is the most diverse of the study areas, including significant flows from more newly constructed areas, commercial buildings, apartments, and the more typical older construction with footing drains. Because of this uncertainty, should this solution be selected, more investigation into flows within the study area is recommended. This would include a flow meter located in the trunk sewer along Scio Ridge, evaluation of Liberty Road pumping station pump run-time data, and a flow meter along Stadium Boulevard.

G.3.4 Glen Leven Study Area

Glen Leven study area is located in southwest Ann Arbor, north of Scio Church Road and west of Seventh Street as shown in Figure G-29. This area actually consists of two separate sewershed areas for purposes of the analysis. A north portion of the area discharges via a sewer along Glen Leven Road and a southern portion of the study area discharges through a sewer along South Seventh Street. These two regions are referred to as Glen Leven North and Glen Leven South. There are no interconnections between these two regions.

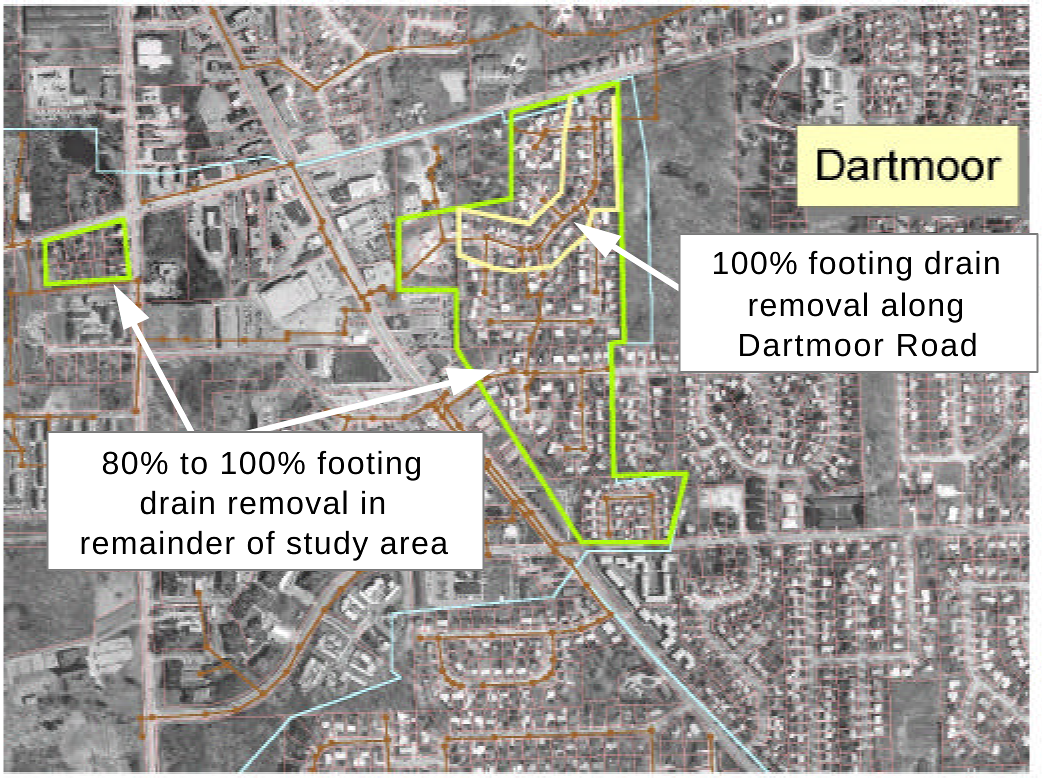


Figure G-28. Footing Drain Disconnection for Dartmoor.

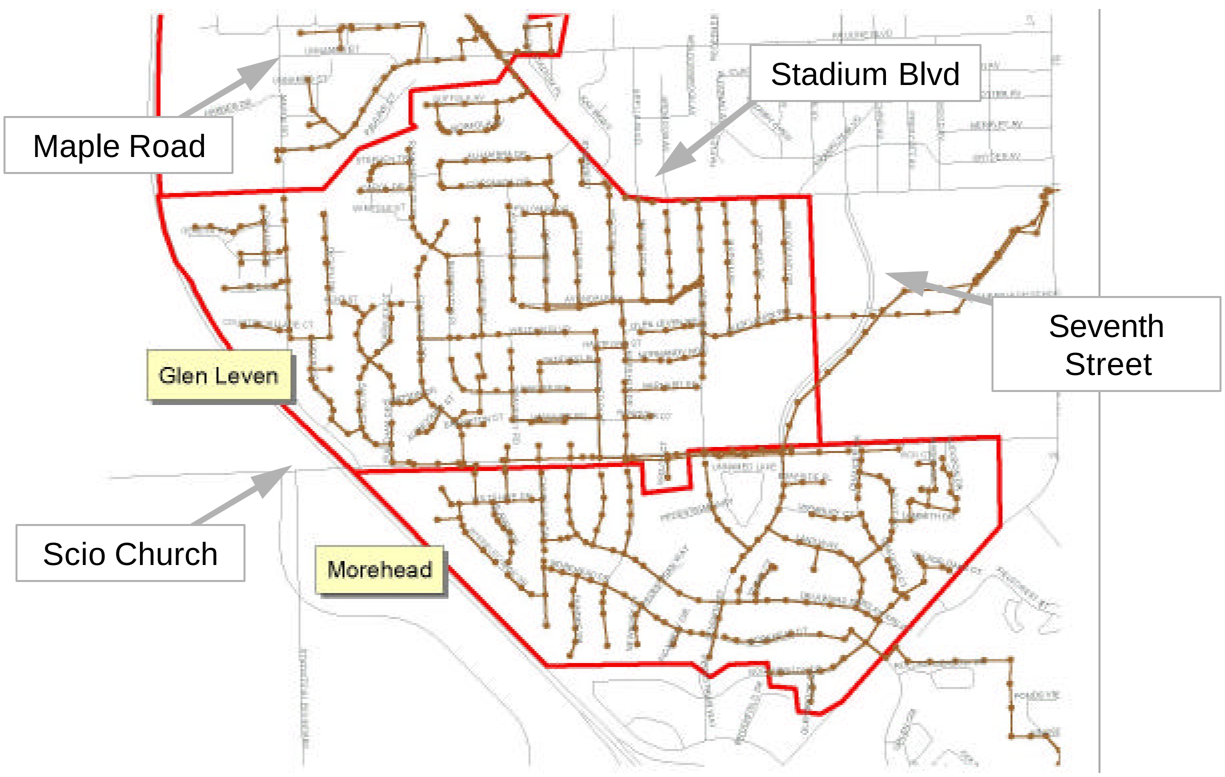


Figure G-29. Schematic of Glen Leven Study Area

Basement flooding has been observed in the Glen Leven study area since the 1970s. These flooding occurrences have generally been concentrated along Glen Leven, Weldon and Avondale. Figure G-30 shows the percentage of homes in each defined parcel group that reported flooding in the August 1998 event and the June 2000 event. Past construction has provided relief of some of the issues, but not all.

The study area model developed for Glen Leven includes every manhole and sewer main in the study area. These were included in as much detail as possible to better understand the dynamics of the local collection system. The model also included the section of the collection system discharging down to Main Street and Stadium Boulevard and connecting to the trunk sewer system at that point. In addition, the basement elevations of homes adjacent to the sewer in areas that have flooded were included in the model for this area.

G.3.4.1 Flow Analysis

A total of 19 storms were analyzed for this study area. For each event, the total RDI/I volume in inches, total volume is divided by the tributary area, was plotted against the corresponding rainfall volume in inches. In addition, each event was classified as occurring during spring (dormant) conditions or during summer (growing) conditions. Lines were then drawn to define the envelope of responses to be expected.

Results of this analysis are presented in Figure G-31 and G-32 for Glen Leven North and Glen Leven South, respectively. Note that the variations in response are due to differences in season, antecedent conditions (number of days since previous rainfall), and storm characteristics that include such elements as rainfall intensity and duration.

The results of this analysis provide insight into the amount of rainfall that finds its way into the sanitary sewer system, after accounting for initial abstraction. For the Glen Leven North area this ranges from 5.0% during the growing season to 22% for dormant times. For the Glen Leven South area this ranges from 4.0% during the growing season to 27% for dormant times. This amount of wet weather response is an indication of a fairly wet sanitary system and can typically be largely attributable to

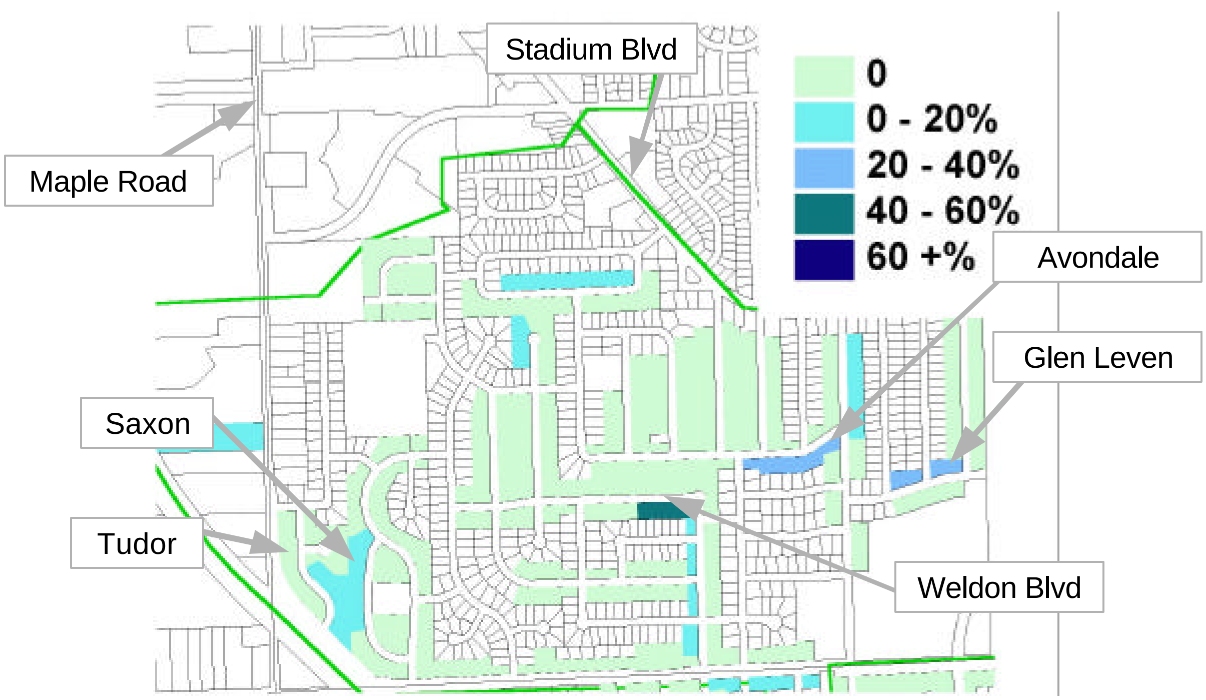


Figure G-30. Reported Flooding in Glen Leven Study Area

footing drains being connected to the sanitary collection system.

G.3.4.2 Calibration

Table G-12 gives the rainfall response factor ("R") and initial abstraction terms (V_o) values for all three events for the Glen Leven study area. With these parameters defined for the calibration events, the shape parameters were adjusted so the model predicted flows and levels that adequately matched the field recorded flows and levels. Note that for these events, the initial abstraction term was reduced to account for rainfall that had taken place

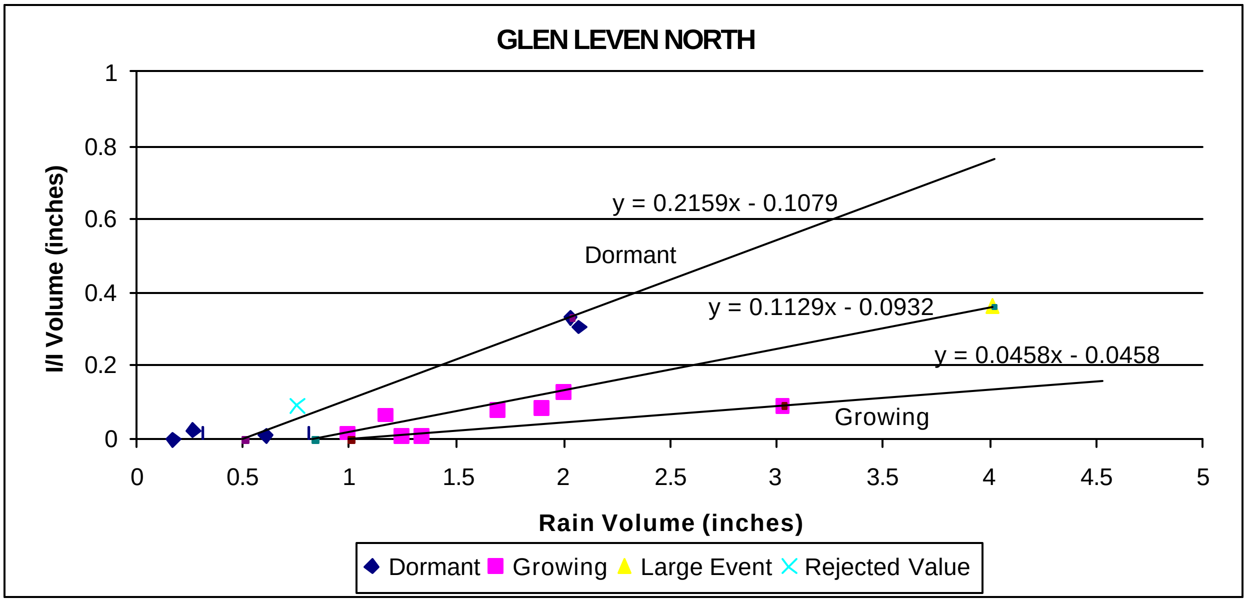


Figure G-31. RDI/I Response for Glen Leven North Study Area

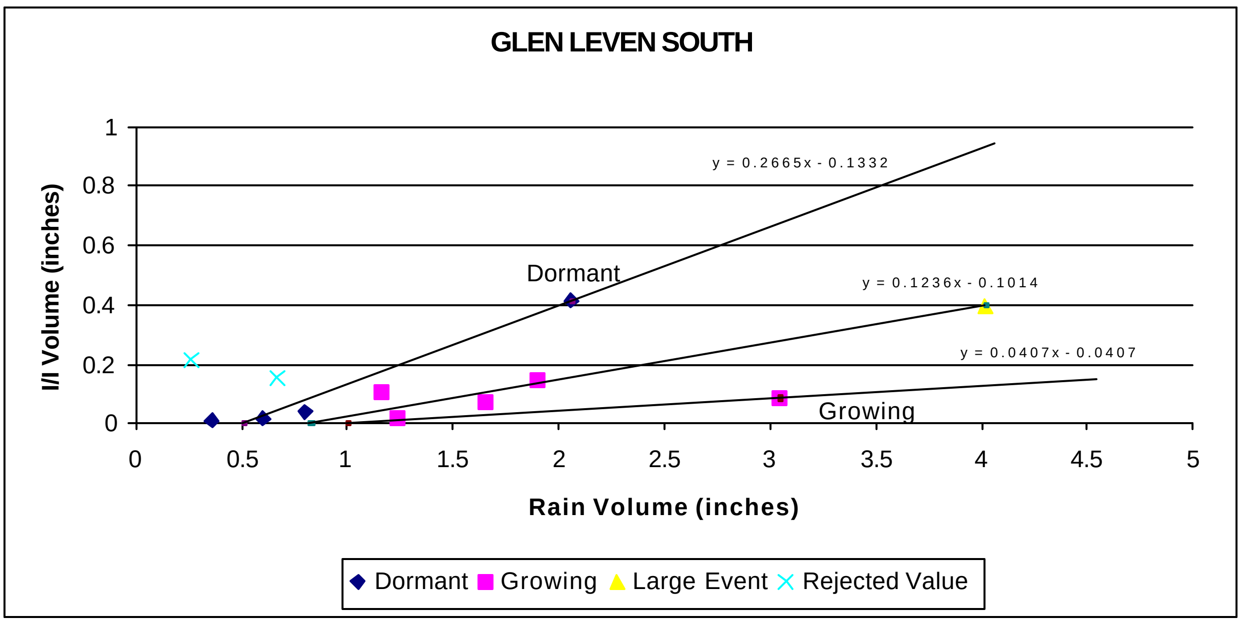


Figure G-32. RDI/I Response for Glen Leven South Study Area

Table G-12. RDI/I Parameters for calibration events for Glen Leven

Region	Parameter	May Event	June Event	July Event
Glen Leven North	R (%)	10.1	4.5	4.0
Glen Leven North	V_o (inches)	0.20	0.30	0.30
Glen Leven South	R (%)	5.5	3.0	3.0
Glen Leven South	V_o (inches)	0.20	0.35	0.40

prior to the storms being simulated.

G.3.4.3 Problems

Figure G-33 provides the thematic map of the surcharging present for Glen Leven study area. Sewers with marginal surcharging conditions include portions of sewers under Scio Church, Welch Court, Woodland, Kirtland, Marian, Greenview, Glen Leven, Avondale, Ardmoor, Maywood, Mershon, Westfield, Las Vegas, Coronada, Alhambra, Runnymeade, Glastonbury, Weldon, Winsted, Sanford, Dunmore, Hanover, Waltham, and Saxon. Sewers with significant surcharging include portions of sewers under Glen Leven, Kirtland, Marian, Greenview, Avondale, Westfield, Catalina, Granada, Las Vegas, Palomar, Coronada, Hartford, Weldon, Winsted, Sanford, Dunmore, Scio Church, Saxon, Tudor, Eton Court, Dicken, and Maple.

Figure G-34 contains the ratio of flow to design flow for the Glen Leven area. Sewers with marginal flow-to-design flow ratios include portions of sewers under Scio Church, Glen Leven, Winsted, Glastonbury, Waltham, Tudor, Maple, and Palomar. Sewers with significant flow-to-design flow ratio issues include portions of sewers under Glen Leven, Greenview, Avondale, Granada, Winsted, Weldon, Scio Church, Tudor, and Dicken. It is believed that excessive RDI/I is the cause of the surcharging and flow exceedances in the Glen Leven study area.

G.3.4.4 Alternatives

Relief Sewers

The relief sewer alternative consisted of determining where a series of parallel pipes would need to be constructed to accommodate high flows within the system. Figure G-35 shows the location of the relief sewers that would be required to eliminate flooding within the Glen Leven area.

The costs associated with the relief option include the cost of 11,523 feet of relief pipe, the maintenance costs for pipe cleaning, and restoration costs for streets. This option, as do all options, also provide for footing drain disconnection and protection for 123 homes in areas that have historically had basement backup problems. Engineering/construction fees are also included.

The construction costs for the relief option are $4.62 million for this area. Lifecycle costs for the relief sewer alternative include an additional $100,000 for Glen Leven. This includes the present worth cost of sewer cleaning, based on a life cycle of 30 years and an annual discount rate of 8%.

To prevent adverse impacts on residents downstream of Glen Leven, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Glen Leven area construction and the wastewater treatment plant. This capacity increase would cost an additional $3.03 million for

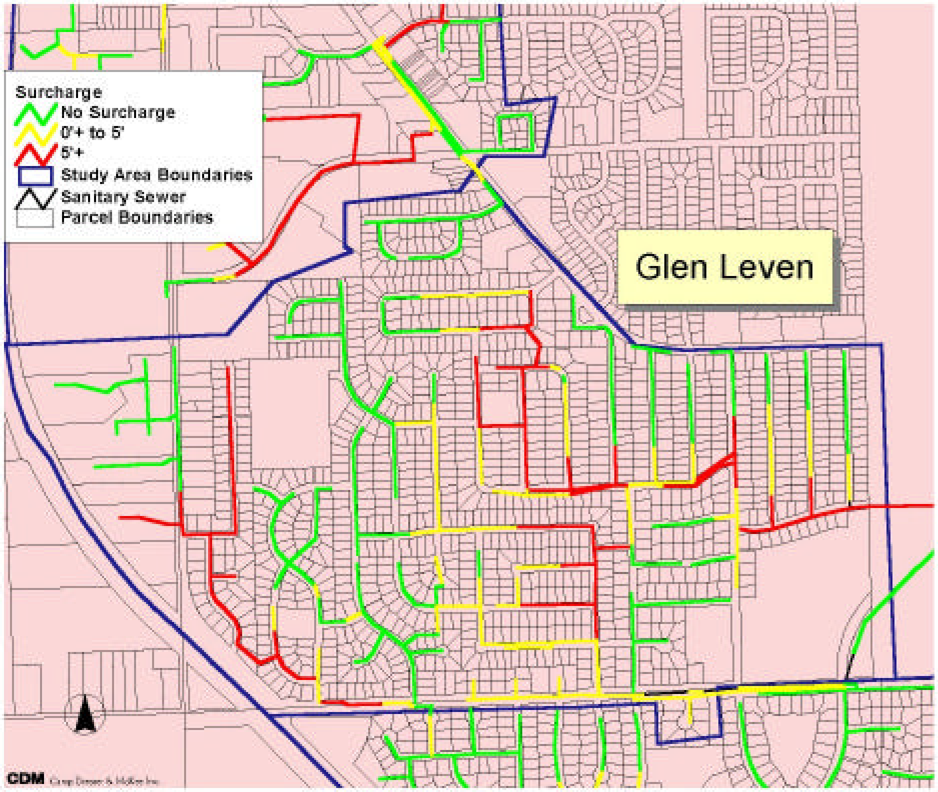


Figure G-33. Surcharging Thematic Map for Glen Leven

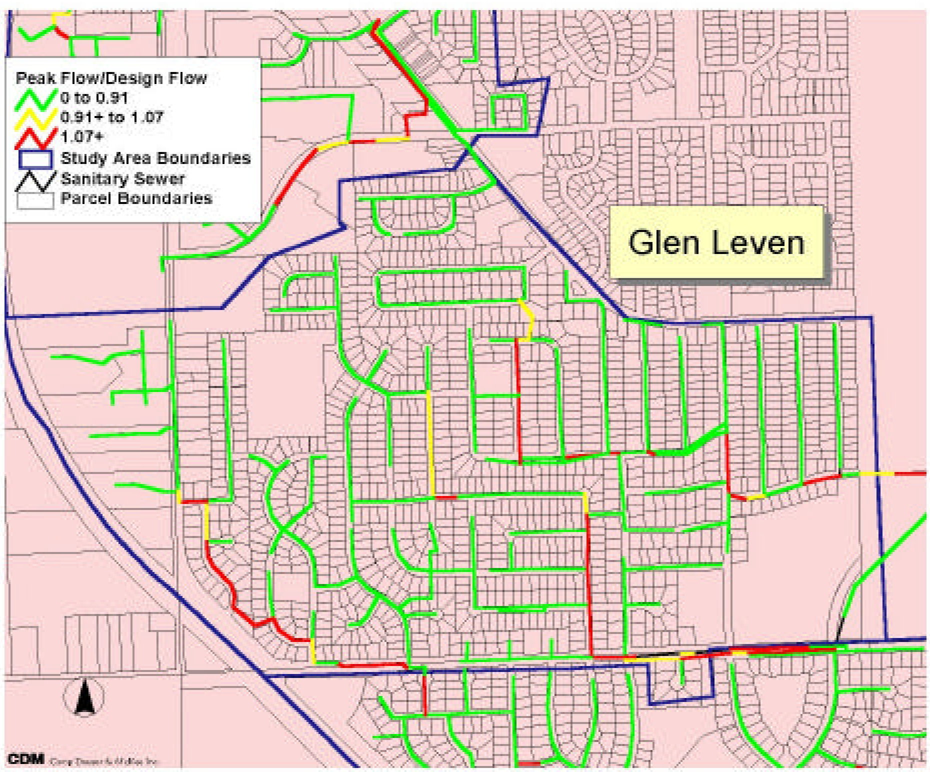


Figure G-34. Flow / Design Flow Thematic Map for Glen Leven

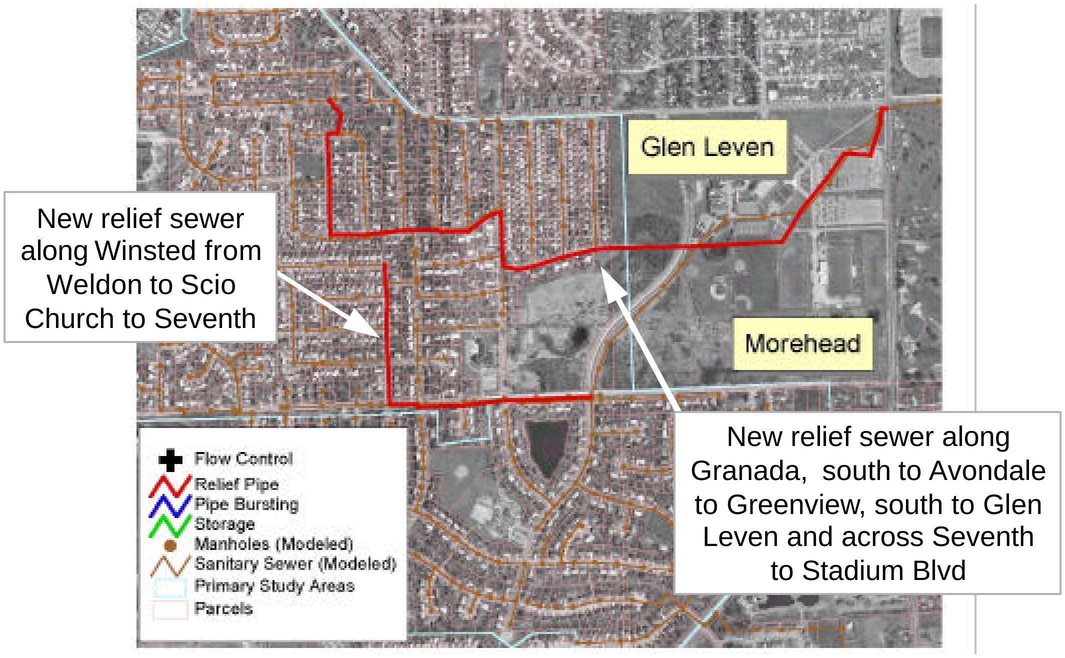


Figure G-35. Location of relief sewers required to eliminate flooding

construction, and incur additional lifecycle costs of $60,000.

Increasing Capacity

The upsizing alternative consists of determining where pipe bursting could be performed to increase the carrying capacity of the existing sewers. The amount that a pipe can be upsized by pipe bursting is limited, but in the Glen Leven area, this approach was determined to be sufficient. Figure G-36 shows the location of pipe bursting. In general, the location is the same as where a relief sewer would be required.

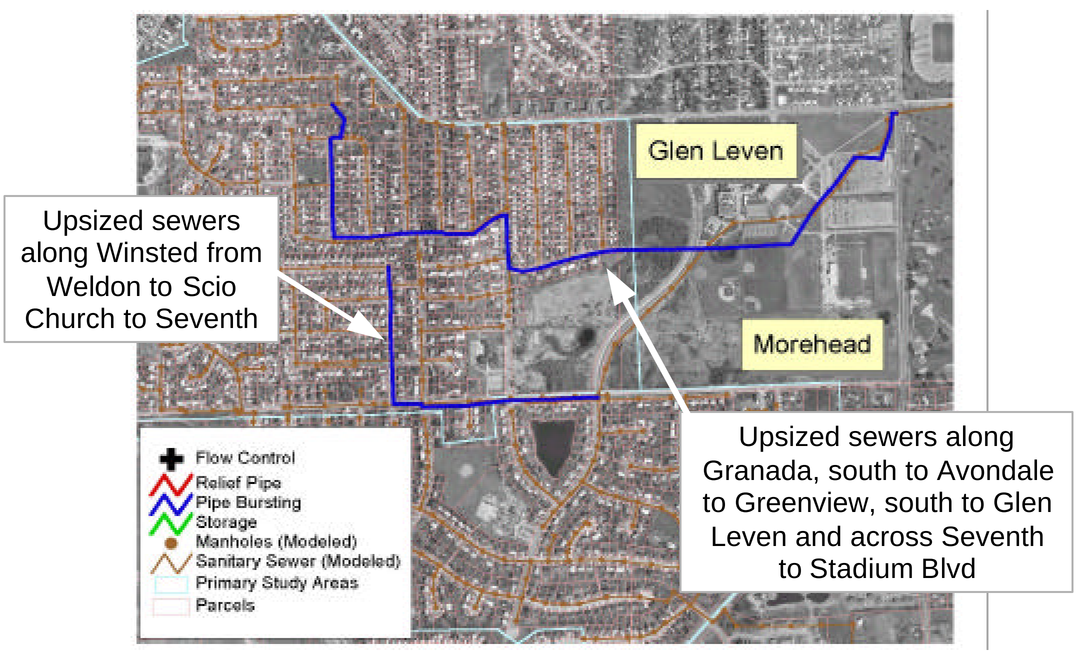


Figure G-36. Location of upsizing sewers required to eliminate flooding

The costs associated with the increased capacity option include the cost of 10,879 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, and restoration costs for streets. This option, as do all options, also provide for footing drain disconnection and protection for homes in areas that have historically had basement backup problems. Engineering/construction fees are also included.

The construction costs for the increased capacity method is $4.58 million for Glen Leven. There are no lifecycle costs for this alternative.

To prevent adverse impacts on residents downstream of Glen Leven, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Glen Leven area construction and the wastewater treatment plant. This capacity increase would cost an additional $3.03 million for construction, and incur additional lifecycle costs of $60,000.

Collection System Storage

This alternative consisted of including a storage facility to eliminate flooding problems. For both Glen Leven North and Glen Leven South, locating the storage in the vicinity of the flooding problem areas was not feasible due to lack of space. Instead, in both cases the storage facilities were located downstream to limit peak flow rates and thus avoid causing downstream impacts. This alternative, in both cases, consisted of upsizing of the sewers in addition to the use of a storage facility.

Two options were reviewed for this alternative. One option was to locate a storage facility for both Glen Leven North and Glen Leven South. Figure G-37 shows the location of the upsized sewers and storage facilities that would be required to eliminate flooding within the Glen Leven area and prevent adverse impacts downstream for this option.

The costs associated with this option include the cost of 7,720 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, 927 feet of five-foot diameter storage pipe, 277 feet of four-foot diameter storage control connections, discharge connections, access manholes, and restoration costs for tearing up the streets. This option, as do all options, provide footing drain disconnection and protection for 123 for homes in areas that have historically had basement backup problems. Engi-

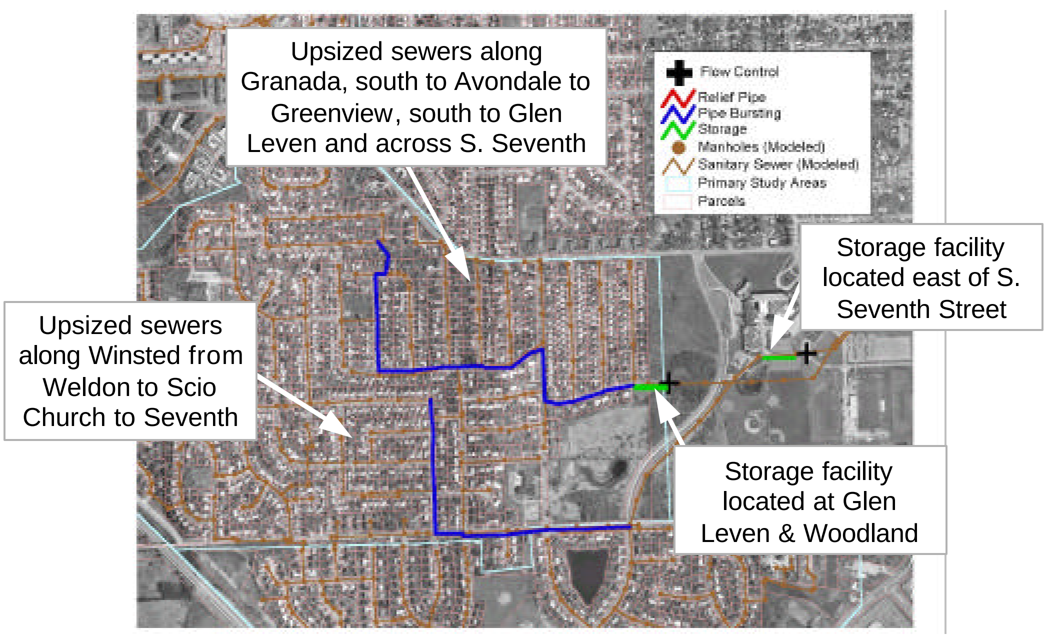


Figure G-37. Location of upsized sewers and storage facilities for option

neering/construction fees are also included.

The construction costs for the upsizing/storage option are $4.30 million for Glen Leven. Lifecycle costs for the collection storage system alternative amounts to $4,000 for this area. This is the cost of sewer storage facility maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

The second option was to locate a storage facility that would serve both regions. An opportunity for this option exists as the outlet sewer from each region cross one-another downstream from the two regions, near Pioneer High School. Figure G-38 shows the location of the upsized sewers and storage facility that would be required for this option to eliminate flooding within the Glen Leven area and prevent adverse impacts downstream for this option.

The costs associated with this option include the cost of 8,027 feet of pipe bursting, pipe bursting pit construction, connection of homes to the new pipe, 548 feet of five-foot diameter storage pipe, control connections, discharge connections, access man-holes, and restoration costs for tearing up the streets. This option, as do all options, provide footing drain disconnection and protection for 123 for homes in areas that have historically had basement backup problems. Engineering/construction fees are also included.

The construction costs for the upsizing/storage option are $4.01 million for Glen Leven. Lifecycle costs for the collection storage system alternative amounts to $2,000 for this area. This is the cost of sewer storage facility maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

Footing Drain Disconnection

The final option involves the disconnection of footing drains in the region. Based on field measurements, it is estimated in the Glen Leven region that footing drains account for between 70% and 90% of the wet weather flow that enter the sanitary sewers. To reduce flows to the point where the sanitary sewers would not surcharge, between 535 and 657 homes would need to be disconnected, including 123 homes that are in the vicinity of the area that has previously flooded and require flood protection. The areas where the initial footing drain disconnection would be performed is shown in Figure G-39. This in-cludes 100% of the homes in the historically flooded areas and 55% to 70% of the remaining homes.

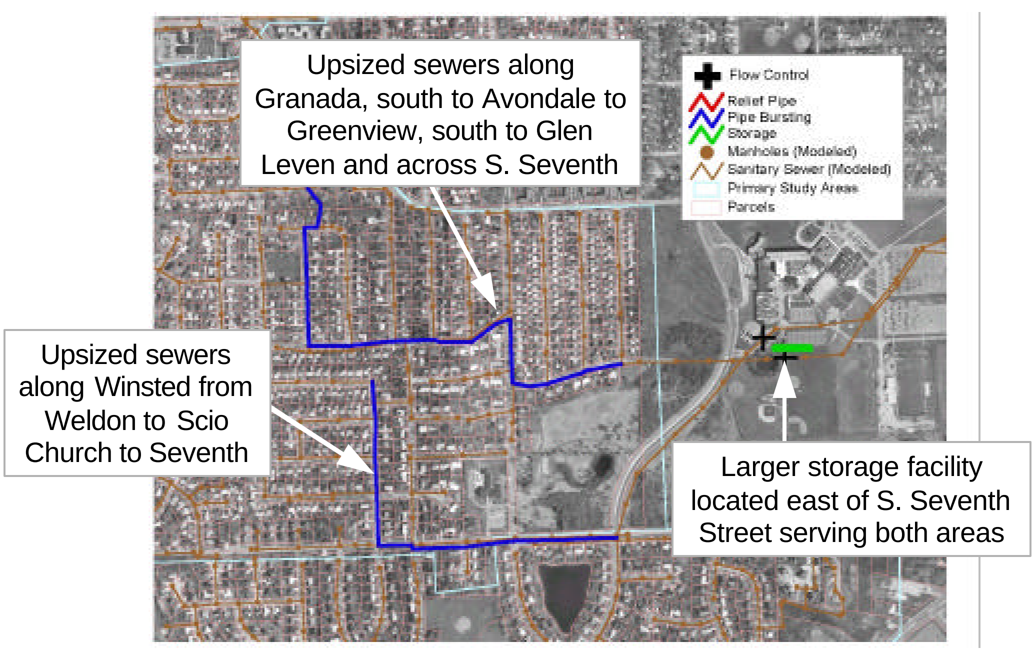


Figure G-38. Location of upsized sewers and storage facility for option 2

The cost of this disconnection work is estimated to be between $3.34 million and $4.08 million. Because of the reduced flow discharged to the wastewater treatment plant, the lifecycle costs are estimated to be between $2.95 million to $3.69 million for this alternative.

G.3.5 Morehead Study Area

The Morehead study area is located in southwest Ann Arbor, bounded on the south by Northbrook Drive (not all of Northbrook is included in study area), on the east by Ann Arbor-Saline Road, on the north by Scio-Church Road, and on the west by I-94 as shown in Figure G-40. In addition, the study area includes a small area to the west of the Glen Leven study areas. This portion is referred to as the Saxon/Tudor area. The Saxon/Tudor flows cross Scio Church Road at Rugby Court.

Most of the flooding in this study area is concentrated along and near Delaware Court, Morehead Drive, and Morehead Court. The Saxon/Tudor area includes concentrated flooding problems along Saxon Street and Tudor Drive. Figure G-41 shows the percentage of homes in each defined parcel group that reported flooding during the June 2000 major storm event. Figure G-30 shows the percentage of homes in each defined parcel group that reported flooding in the June 2000 major storm event in the Saxon/Tudor area. The parcels are grouped in a way that logically represent flooded areas without compromising residents' privacy by classifying individual parcels.

The study area model developed for Morehead includes every manhole and sewer section in the study area. These were included in as much detail as possible to better understand the dynamics of the local collection system. The model also included the section of the collection system discharging east of Ann Arbor Saline Road and connecting to the trunk sewer system to the east. In addition, the basement elevations of homes adjacent to the sewer in areas that had flooded were included in the model for this area.

G.3.5.1 Flow Analysis

A total of 16 storms were analyzed for this study area. For each event, the total RDI/I volume in inches, total volume is divided by the tributary area,

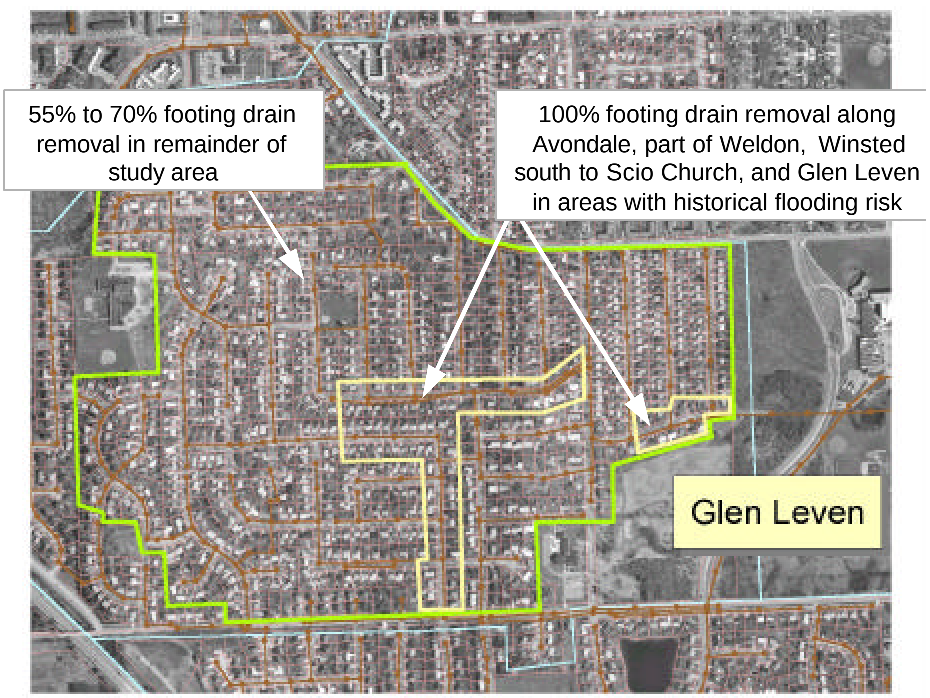


Figure G-39. Location of footing drain disconnections for Glen Leven

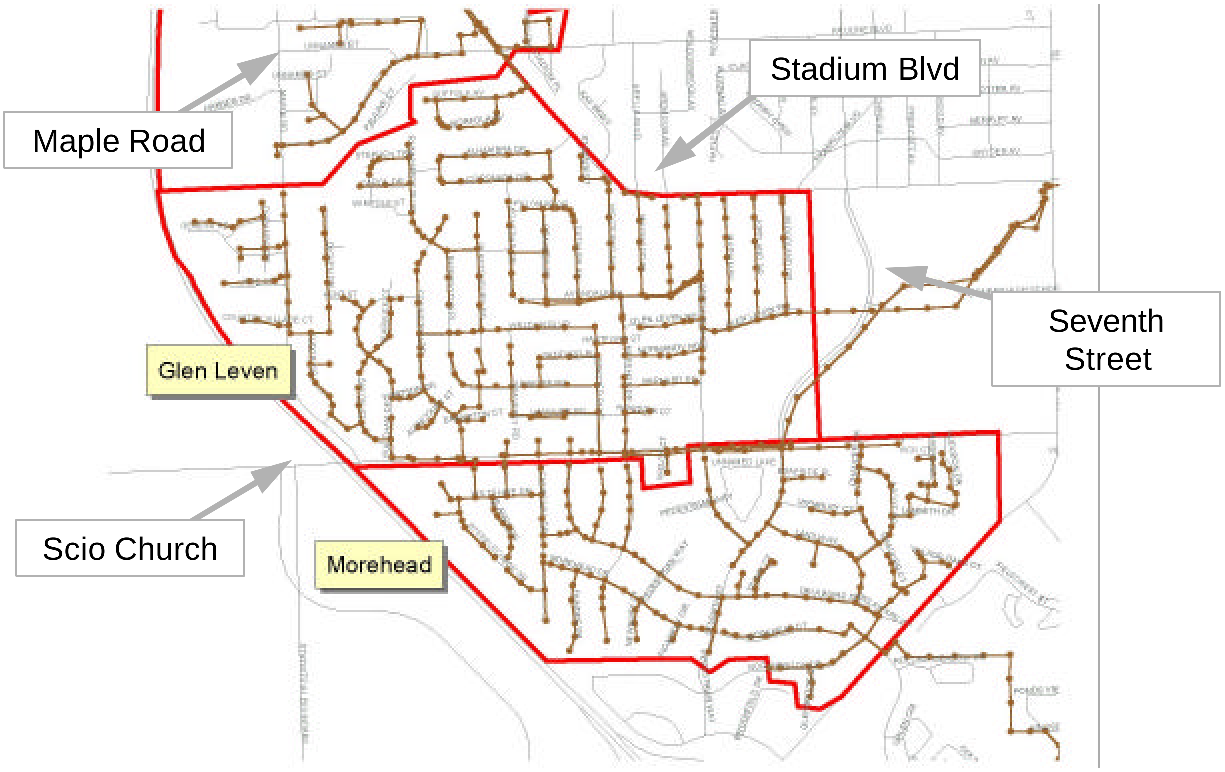


Figure G-40. Schematic of Morehead Study Area

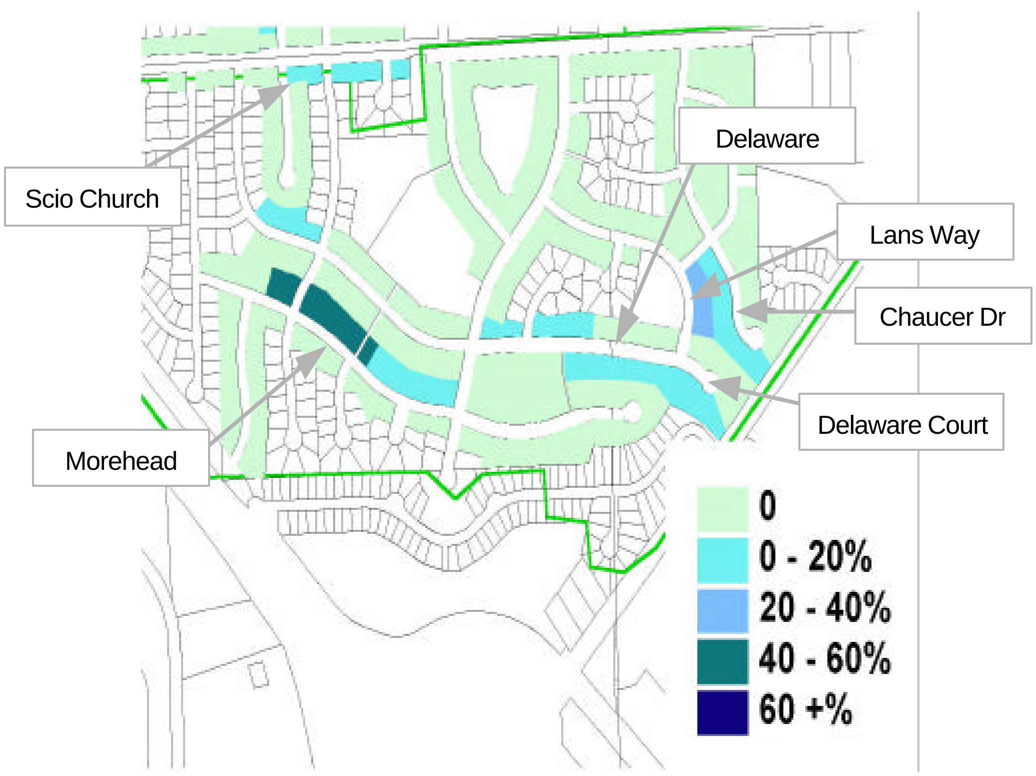


Figure G-41. Reported Flooding in Morehead Study Area was plotted against the corresponding rainfall volume in inches. In addition, each event was classified as occurring during spring (dormant) conditions or during summer (growing) conditions. Lines were then drawn to define the envelope of responses to be expected.

Results of this analysis are presented in Figure G-42 for the Morehead study area. Note that the variations in response are due to differences in season, antecedent conditions (number of days since previous rainfall), and storm characteristics that include such elements as rainfall intensity and duration.

The results of this analysis provide insight into the amount of rainfall that finds its way into the sanitary sewer system, after accounting for initial abstraction. For the Morehead area this ranges from 10% during the growing season to 25% for dormant times. This amount of wet weather response is an indication of a very wet sanitary system and can typically be largely attributable to footing drains being connected to the sanitary collection system.

The area tributary to the meter is nearly homogenous and is mostly residential of similar construction age. In one portion of the system, know as the Saxon/Tudor area, there is an area of new construction upstream that are assumed to consist of homes that do not have footing drains connected to the sanitary sewer system.

Providing flow monitoring to account for the variation within the study area was beyond the scope of the project. Therefore, uniform hydrologic response parameters were used throughout Morehead, with the exception of the Saxon/Tudor area. After reviewing overall system response, the response from this area was reduced to better approximate the actual conditions. The assumption was made to reduce the response for the newer areas just west of Maple Road.

G.3.5.2 Calibration

Table G-13 gives the rainfall response factor ("R") and initial abstraction terms ("V_o") values for all three events for the Morehead study area. With these parameters defined for the calibration events,

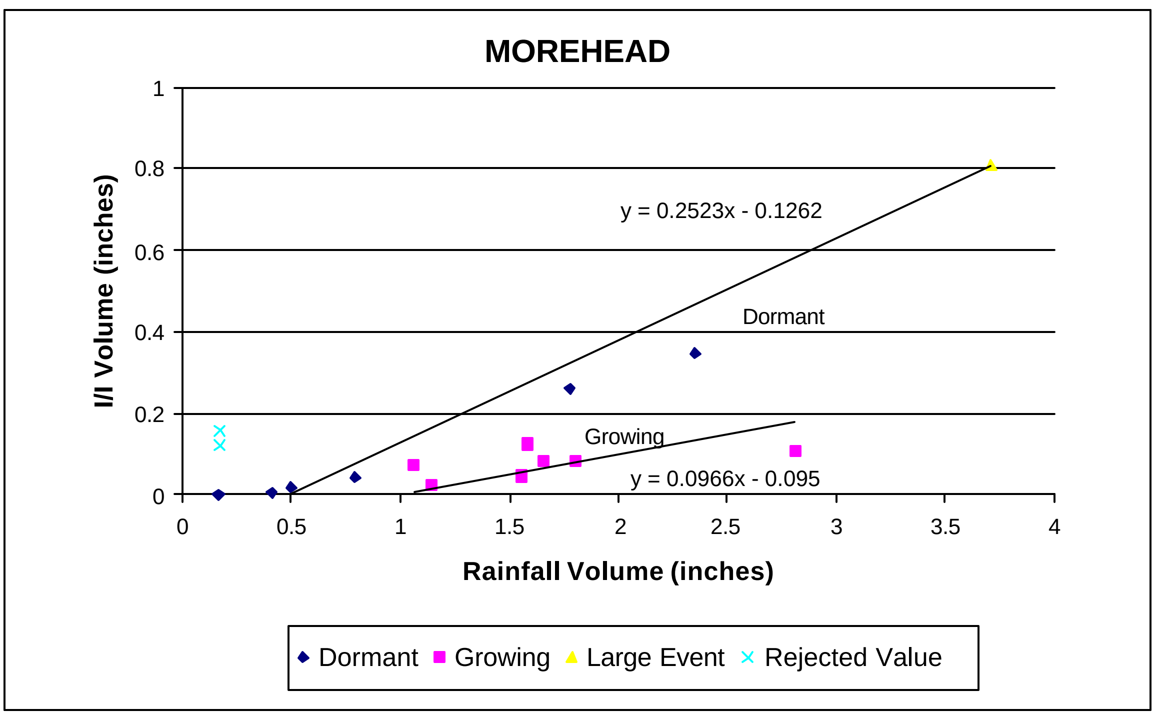


Figure G-42. RDI/I Response for Morehead Study Area

Table G-13. RDI/I Parameters for calibration/validation events for Morehead

Region	Parameter	May Event	June Event	July Event
Primary Morehead	R (%)	11.9	18.4	3.7
Primary Morehead	V_o (inches)	0.2	0.3	0.4
Newer Construction in Saxon/Tudor	R (%)	6.8	10.4	2.1
Newer Construction in Saxon/Tudor	V_o (inches)	0.2	0.3	0.4

the shape parameters were adjusted so the model predicted flows and levels that adequately matched the field recorded flows and levels. Note that for these events, the initial abstraction term was reduced to account for rainfall that had taken place prior to the storms being simulated. The RDI/I parameters determined from the flow analysis were modified to account for the portion of the Saxon/Tudor area just west of Maple Road.

In addition to varying shape parameters, Manning's roughness parameter was increased for a portion of the sewer between Morehead Drive and Delaware Drive along Seventh Street. Two relatively sharp sewer directional changes occur through this stretch, which account for these losses.

G.3.5.3 Problems

Figure G-43 contains the thematic map of surcharging within the Morehead study area. Sewers that have marginal surcharging include portions of sewers under Rugby, Delaware, Winsted, Mershon, Tilsby, Lans Way, Worthington, Chaucer, Ascot, Village Oaks, Northbrook, Dundee, Newbury, and Scio Church. Sewers with significant surcharging include portions of sewers under Churchill, Morehead, Dundee, Mershon, Newbury, Picadilly, Seventh, Northbrook, Delaware, Lans Way, Chaucer, and Ascot.

Figure G-44 shows the thematic map of ratio of flow to design flow for the Morehead study area. Sewers with marginal flow-to-design flow ratios include portions of sewers under Scio Church, Delaware, and Morehead. Sewers with significant flow-to-design flow ratio issues include portions of sewers under Scio Church, Rugby, Amesbury, Delaware, Morehead, Seventh, and Lans Way.

It is believed that excessive RDI/I is the cause of the surcharging and flow exceedances in the Morehead study area.

G.3.5.4 Alternatives

The Morehead study area solution alternatives account for the Saxon/Tudor region of the Glen Leven study area. This Saxon/Tudor area is tributary to the Morehead study area.

Relief Sewers

The relief option was examined first. In this option, a series of sewer pipes would be constructed parallel to the existing sewer to accommodate high flows. The model was used to determine where relief pipes would need to be added, as well as the size of those pipes.

In Morehead, relief sewers would be placed along Tudor and Saxon, along Scio-Church Road to Covington Road, ending at Wiltshire Road. Another stretch of relief sewer would also be added from

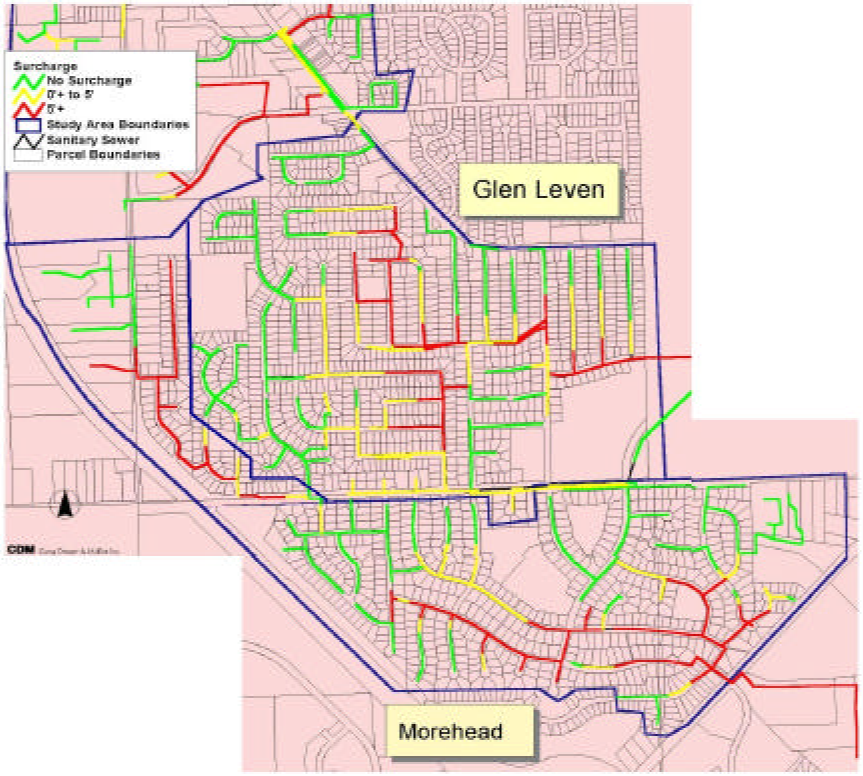


Figure G-43. Thematic Map of Surcharging for Morehead

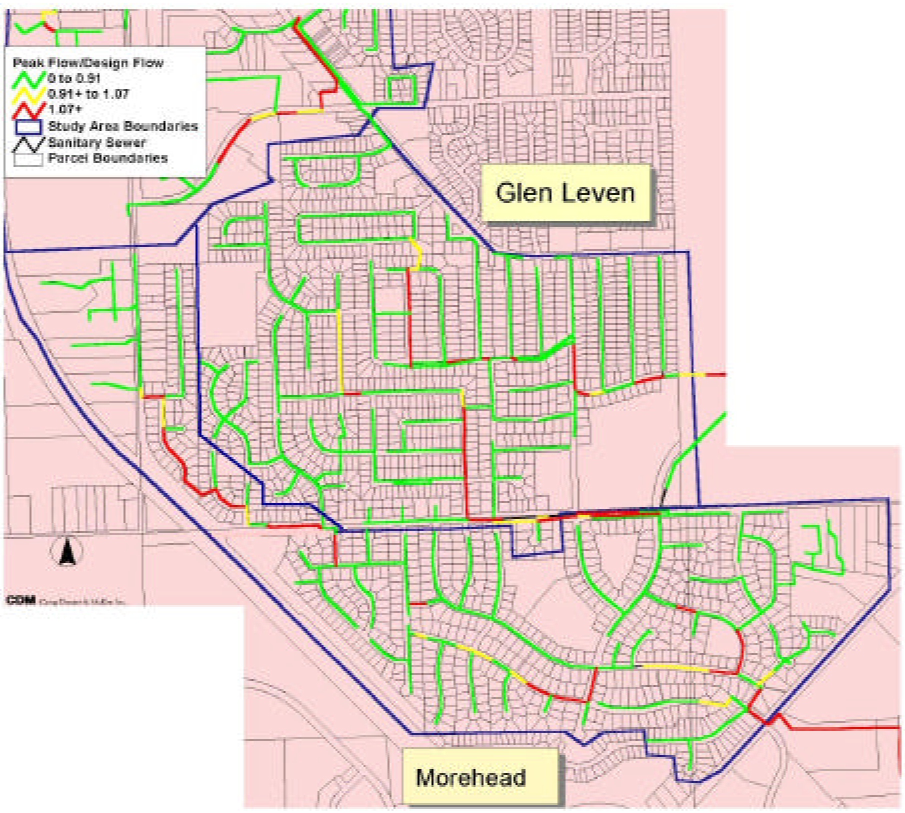


Figure G-44. Flow / Design Flow Thematic Map for Morehead

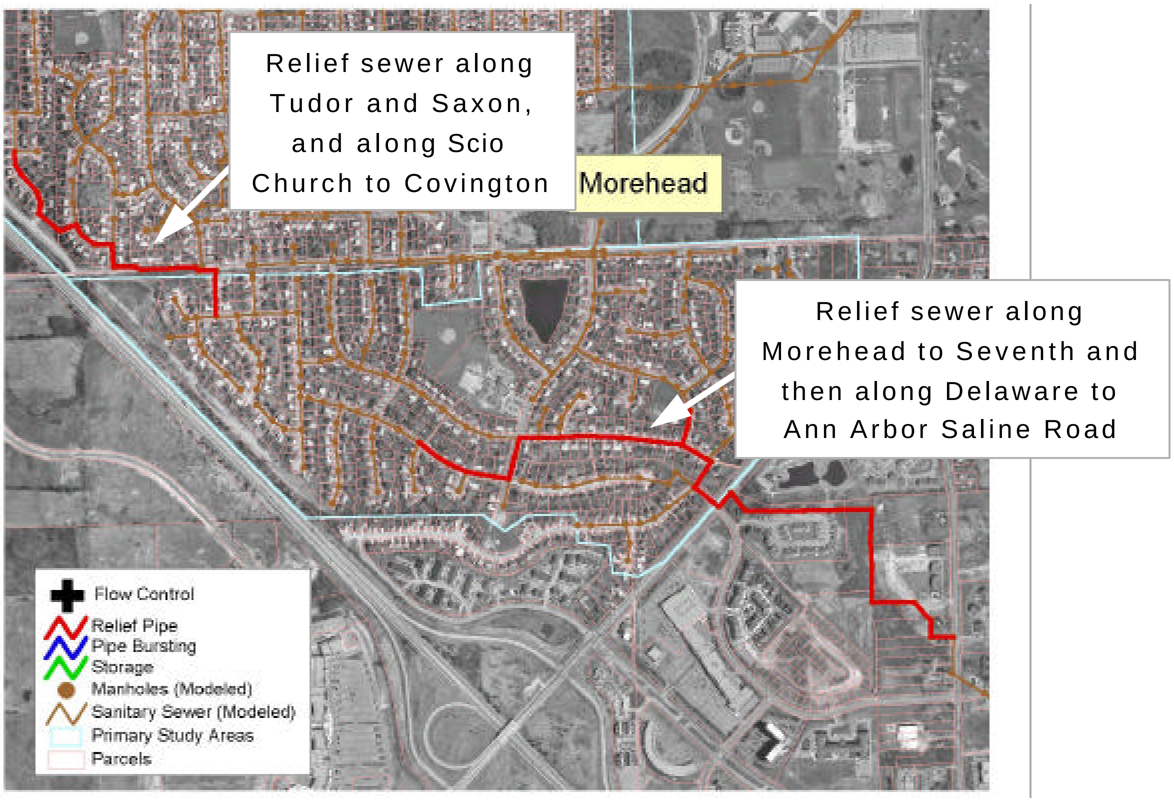


Figure G-45. Relief Sewer Option for Morehead.

Morehead Drive, along Seventh Street to Delaware Road, to Delaware Court, and across Ann Arbor-Saline running North of Rolling Meadow Drive, then south, just west of Kingsbrook Avenue. Also, a short relief sewer would be required along Lans Way. This is shown in Figure G-45.

The costs associated with the relief option include the construction of 9,788 feet of relief pipe. This option, as do all options for Morehead, provides footing drain disconnection and flooding protection for 55 homes in Morehead that are in the vicinity of the area which has previously flooded.

The construction costs for the relief option are $4.23 M. Lifecycle costs for the relief sewer alternative include an additional $80,000. This is the cost of sewer cleaning and inspection, based on a life cycle of 30 years and an annual discount rate of 8%.

To prevent adverse impacts on residents down-stream of Morehead, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Morehead area construction and the wastewater treatment plant. This capacity increase would cost an additional $2.98 M for construction, and incur additional lifecycle costs of $60,000.

Increasing Capacity

In Morehead, pipe bursting was considered as an option to increase capacity, rather than relief, where possible. This option effects the same reach of sewer as the relief option. However, there is a short section along Delaware Road that did require relief sewer under the previous option that does not require pipe bursting. This is due to improved hydraulics associated with the materials used to construct the pipe-bursted sewers. This is shown in Figure G-46.

The costs associated with the increased capacity option include pipe bursting of 9,371 feet of sewer. This option, as do all options for Morehead, provides footing drain disconnection and flooding protection for 55 homes in Morehead that are in the vicinity of the area which has previously flooded.

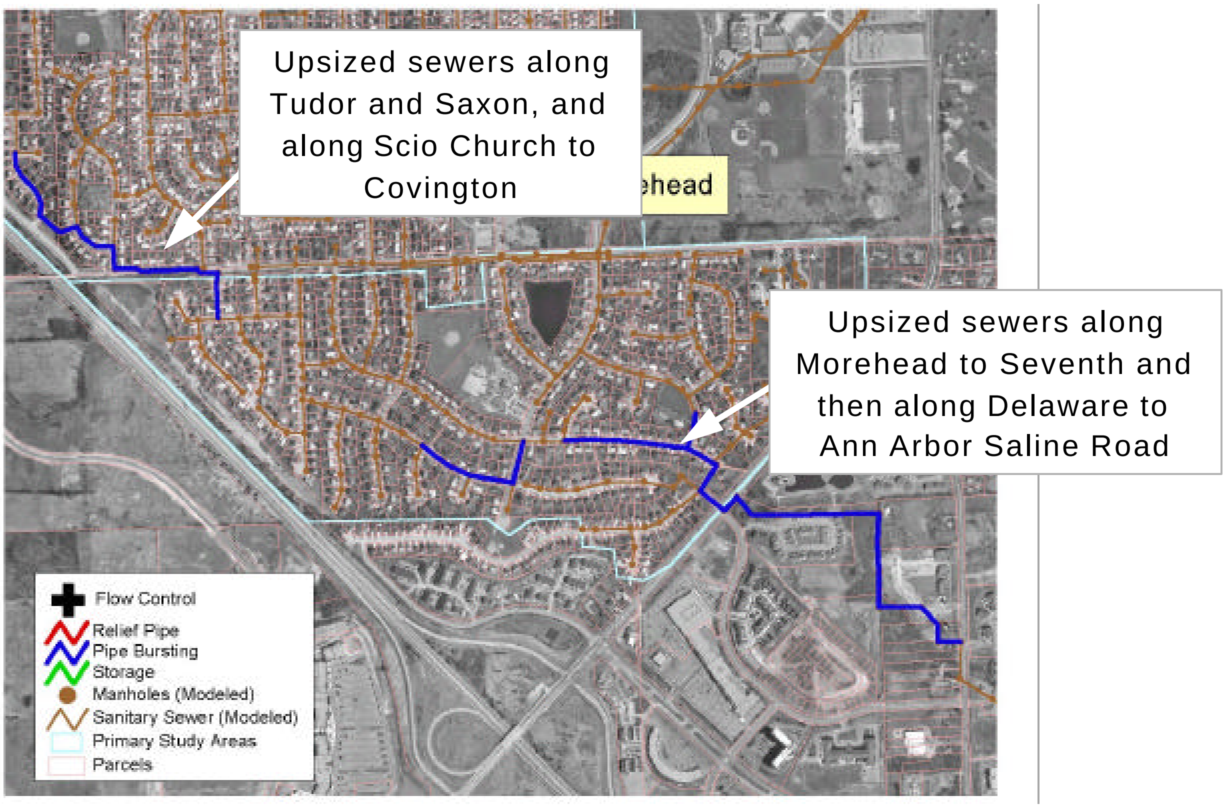


Figure G-46. Increased Capacity Option for Morehead.

The construction costs for the increased capacity option are $4.35 M. There are no lifecycle costs for additional sewer pipe, the increased capacity alternative.

To prevent adverse impacts on residents downstream of Morehead, the trunk sewer requires increased capacity along the existing trunk sewer between the proposed Morehead area construction and the wastewater treatment plant. This capacity increase would cost an additional $2.98 M for construction, and incur possible additional lifecycle costs of $60,000.

Collection System Storage #1

The collection system storage option includes a 4,000 to 17,500 ft^3 storage basin in Morehead. This range in storage facility size reflects what is required based on the Design Conditions 1 and 2, respectively. The proposed basin consists of two to eight parallel 5' diameter pipes that will run in the easement on the west side of Ann Arbor-Saline Road.

An advantage of this option is that capacity of the downstream trunk system does not need to be increased. The storage facility includes a control that limits flow out of the facility to the existing rate. Due to capacity limitation in the Morehead area, increased capacity upstream of the storage area is required. This is illustrated in Figure G-47.

The costs associated with the first storage option include the construction of 317 feet of relief pipe, pipe bursting of 3,784 feet of sewer, and from 204 to 891 feet of 60" in-line storage pipe. In addition to these costs, additional costs are required for the Glen Leven option to accommodate the additional flow from Saxon/Tudor, rerouted from Morehead to Glen Leven. This option, as do all options for Morehead, provides footing drain disconnection and flooding protection for 55 homes in Morehead that are potentially in the vicinity of the area which has previously flooded.

The construction costs for the storage option are $2.91 M to 3.24 M. Lifecycle costs for the storage

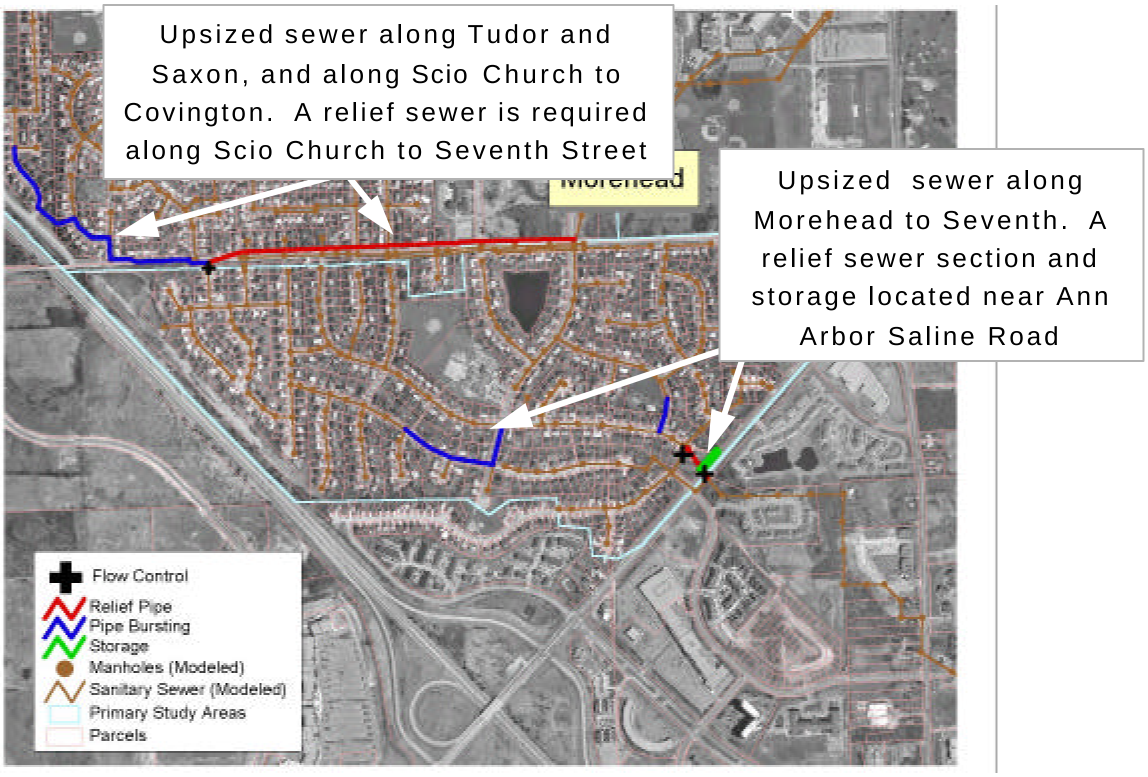


Figure G-47. Collection System Storage Option #1 for Morehead.

alternative include an additional $20,000. This is the cost of sewer storage facility maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

Collection System Storage #2

The collection system storage option #2 includes an 8,000 to 17,500 ft^3 storage basin along Ann Arbor-Saline Road, and an 8,000 ft^3 storage basin at Morehead Road and Seventh Street. This range in the Ann Arbor-Saline Road storage facility size reflects what is required based on the Design Conditions 1 and 2, respectively. The proposed Ann Arbor-Saline Road basin consists of four to eight parallel 5' diameter pipes that will run in the easement on the west side of Ann Arbor-Saline Road. The proposed Morehead Road and Seventh Street basin consists of two parallel 4' diameter pipes that will run along Seventh Street, just south of Morehead Road.

An advantage of this option is that capacity of the downstream trunk system does not need to be increased. The Ann Arbor-Saline Road storage facility includes a control that limits flow out of the facility to the existing rate. The Morehead and Seventh Street storage facility limits flow toward the Delaware Road sewer, and instead forces wet weather flow south along the newly constructed sewer to an existing sewer running along Brookfield Drive, just West of Ann Arbor-Saline Road. Due to capacity limitation in the Morehead area, increased capacity upstream of the storage area is required. This is illustrated in Figure G-48.

The existing collection system appears to have sufficient capacity to convey flows from this newly constructed sewer to the wastewater treatment plant without adversely impacting those connected. The sewer along Brookfield was evaluated and shows sufficient capacity for this additional flow. Also, the trunk sewer model downstream of State Street was evaluated, given near-term system improvements, and the results indicate that the trunk sewer can convey these additional flows. There does remain one stretch of sewer that has not been

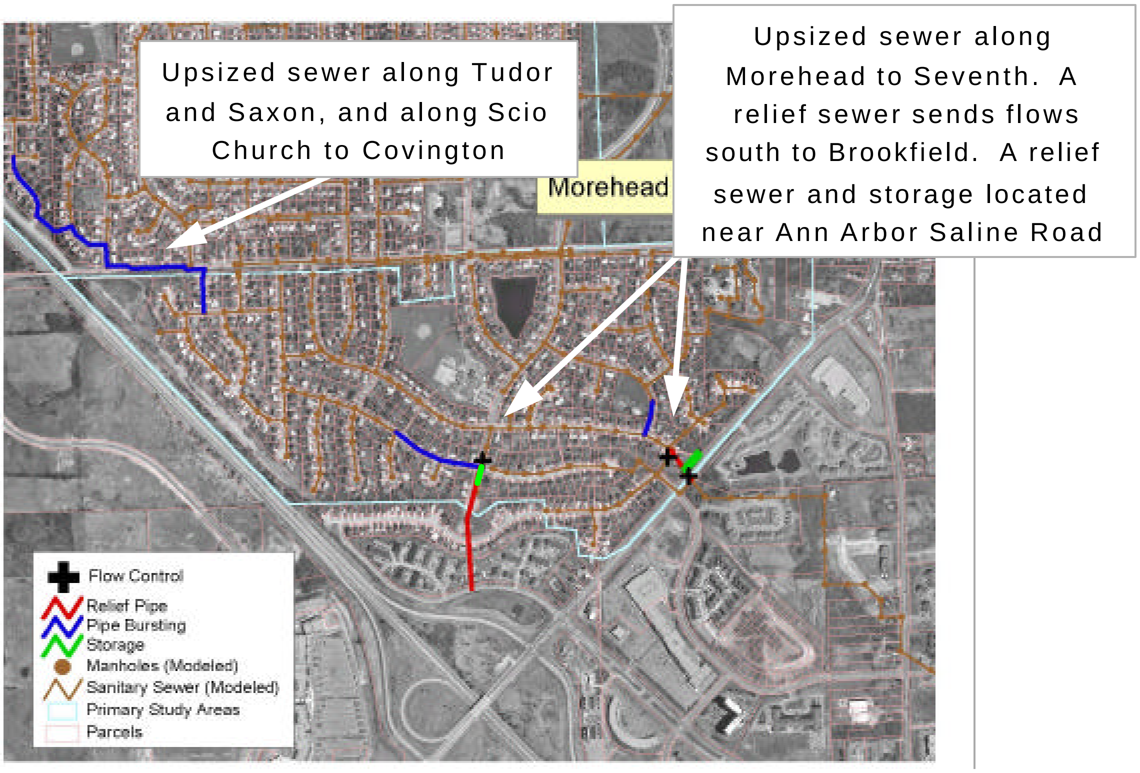


Figure G-48. Collection System Storage Option #2 for Morehead.

evaluated, the sewer between Brookfield Drive and State Street. It is recommended that this portion of the collection system be modeled and evaluated prior to proceeding with this alternative.

The costs associated with the second storage option include the construction of 1,417 feet of relief and new sewer, pipe bursting of 4,369 feet of sewer, 637 feet of 48" in-line storage pipe (Morehead Road and Seventh Street), and from 407 to 891 feet of 60" in-line storage pipe (Ann Arbor-Saline Road). This option, as do all options for Morehead, provides footing drain disconnection and flooding protection for 55 homes in Morehead that are potentially in the vicinity of the area which has previously flooded.

The construction costs for the storage option are $2.70 M to $2.93 M. Lifecycle costs for the storage alternative include an additional $10,000 to $20,000. This is the cost of sewer storage facility maintenance, based on a life cycle of 30 years and an annual discount rate of 8%.

Footing Drain Disconnection

The final option involves the disconnection of footing drains in the region. Based on field measurements, it is estimated in the Morehead region that footing drains account for between 70% and 90% of the wet weather flow that enters the sanitary sewers. To reduce flows to the point where the sanitary sewers would not surcharge, between 451 and 555 homes would need to be disconnected, including 55 homes that are in the vicinity of the area that has previously flooded and require flood protection. This includes disconnecting all of the homes in the Tudor/ Saxon area because of the limited capacity in the sewers in this section of the system. This includes 100% of the homes in the historically flooded areas and 60% to 75% of the remaining homes. This is illustrated in Figure G-49.

The cost of this disconnection work is estimated to be between $2.78 million and $3.42 million. Because of the reduced flow discharged to the wastewater treatment plant, the lifecycle costs are estimated to be between $2.49 million to $3.13 million for this alternative.

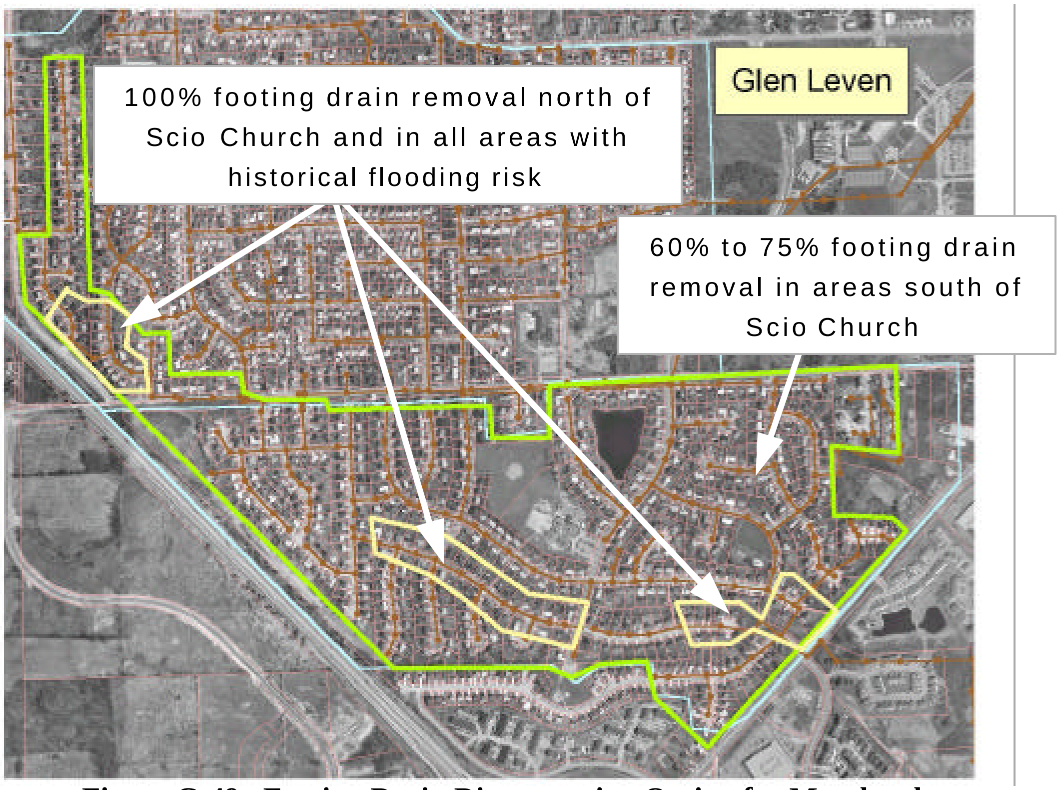


Figure G-49. Footing Drain Disconnection Option for Morehead.

G.4 Summary

Study area models have been developed for the study areas to analyze the system for various actual and design storm conditions. These study area models include all the local sewers in each area and a delineation of each sewershed. Flow data was used to define the wet weather response parameters of the model through a RDI/I analysis. The models were then calibrated and validated using data collected for three storm events during the course of the project.

Based on these calibration efforts, the following findings were developed:

- In general, comparisons between the actual flows and stages recorded in the study areas could be closely replicated using response values generated during the flow analysis.
- In cases where these comparisons deviated, there were sound reasons for adjusting either the distribution of response factors hydraulic losses through specific pipe or connections to account for these differences.
- The calibrated model is expected to provide a good representation of study area response to not only historical storms, but also for larger design storms used to develop alternatives.

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H. Initial Recommendations

Contents

H.1 Selection Criteria

To properly evaluate the alternatives developed under this project, evaluation criteria were developed. These criteria allowed each alternative to be ranked with respect to each criteria and selection of an alternative based on the results. This resulted in a more objective evaluation of each alternative. The following is a discussion of the criteria used. In all cases, the methodology used was to assign a rating that increases with positive impacts (or no impacts) and provided lower ratings for those cases where the impacts (negative) were the largest.

H.1.1 Quality of Life Issues

Several of the selection criteria were associated with quality of life because they either enhanced or detracted from the ability of homeowners affected by these alternative solutions to enjoy the amenities provided by the City of Ann Arbor. The following is a discussion of the specific elements of the quality of life grouping and how they were evaluated for each alternative.

Impact on Open Space/Park/School Areas

In some cases, the alternative may have impacted an open space, park, or school area. These impacts may be temporary in the case of construction of a sewer passing through these areas, or of a permanent impact if a new facility was located in these areas. Alternatives having permanent impacts received the lowest rating.

Impact on Natural Features

Natural features include such things as existing wetlands, forested areas, natural watercourses and wildlife. Alternatives that required construction in these areas received a lower rating. Alternatives that included large facilities that would impact the character of these natural features itself after construction received a lower rating. Temporary construction could also destroy the natural character of the land or watercourse and received a lower rating.

Impact on Receiving Waters

Certain types of alternatives could impact the amount and type of discharge to the receiving waters, potentially affecting humans and wildlife. Alternatives that reduced SSO discharges or the potential for SSO discharges received the highest rating while those alternatives that increased the discharges to the river received a lower rating.

Customer Disruption (Outside Study Areas)

This element measures that amount of construction disruption resulting from an alternative on Ann Arbor residents and businesses outside of the study areas. The highest rated alternatives were those that did not have any work outside of the study areas.

Customer Disruption (Inside Study Areas)

This element measured the amount of construction disruption resulting from an alternative on Ann Arbor residents and businesses inside the study areas. The highest rated alternatives were those that had limited disruption on everyday activities such as driving and walking around the study area neighborhoods, and involved less construction noise and dust.

Odor Issues

This item addressed those alternatives that could generate odors. The highest rated alternatives were those that did not have the potential for generating odors.

Maintenance Access Issues

Maintenance access could be required for some alternatives, such as storage facilities. In these cases, the homeowners may be impacted by increased noise and vehicular traffic. The highest rated alternatives had no additional maintenance access compared to current conditions.

Time for Implementation

Many alternatives would most likely be installed using construction phasing. The highest rated alternatives provided a complete solution in the shortest amount of time.

Certainty of Solution

Each of the alternatives was developed to solve the basement flooding problems for rainfall events similar to those that occurred in August 1998 or June 2000. In some cases, the information used to evaluate the control option was not complete. In these cases, the alternative received a lower rating because of the potential that the control option might not provide a complete solution for all of the homeowners.

H.1.2 Costs Issues

A second category evaluated was on the cost elements of the alternative, including construction costs, maintenance costs, operational costs, and the potential SSO costs that may be required to address the pending SSO regulations. These issues are described below:

Construction Costs

Construction costs included the cost for engineering, design and construction services. The lowest cost alternatives for a study area received the highest rating, while the highest cost alternatives received the lowest ratings.

Maintenance Costs

Alternatives that included components requiring periodic maintenance by the Water Utilities Department received the lowest ratings. Alternatives that minimized these annual cost requirements were the most highly rated.

Operational Costs

Alternatives that reduced the cost of operations at the WWTP by reducing annual flows were the most highly rated. Alternatives that required additional operational cost at the WWTP received a lower rating.

Future SSO Costs

Pending SSO regulations could impact the costs of treating flows generated during wet weather. Alternatives that reduced these requirements to treat these wet weather flows received the highest ratings while alternatives that increased the costs related to an SSO received a lower rating.

H.1.3 Construction Issues

The final set of criteria used to evaluate the alternatives was based on construction issues. This criteria was used to rate the alternatives based on how quickly and easily they could be built.

Construction Constraints

For alternatives that had facilities, utilities, or natural features to contend with that add to the complexity and/or risk of the construction, the alternative received a lower rating. Alternatives that would be constructed in areas with minimal conflicts received the highest ratings.

Contractor Availability

If the alternative used standard construction techniques and equipment and if there are many available contractors, then the alternative was highly rated. If the construction requires special equipment and only a few firms were qualified to perform the work, the alternative received a low rating.

Traffic Control

Traffic control is required for construction activities that take place in the street right of way. Highly rated alternatives had minimal requirements for traffic control and alternatives that had low ratings required high traffic control requirements.

Construction on Private Property

Alternatives that required coordination with private property owners received the lowest rating. Alternatives that did not have construction on private property received the highest rating.

Easement Availability

Alternatives that required the acquisition of easements to complete the construction activities received the lowest rating. Alternatives that included work in existing easements received the highest ratings.

Construction Season Constraints

In some cases, components of the alternatives could only be constructed during fair weather periods. Underground construction is limited during cold weather due to frozen ground and weight limits on roads imposed by frost laws. Alternatives that were constrained by the construction season received the lowest rating. Alternatives that could continue construction throughout the year received the higher ratings.

H.2 Alternative Ranking and Selection

H.2.1 Methodology

The selection criteria described in the previous section were applied to the different alternatives described in Section G of this report for each study area. The rating values assigned to each alternative ranged on a continuum between 0 and 5 for each of the selection criteria. Lower values were less favorable and higher values were more favorable alternatives.

After development of the criteria ratings, different weights were applied to each of the criteria. These weighting values ranged between 1 and 4, with 1 having the least importance and 4 having the highest importance. Once this was completed, the total rating for each alternative was calculated. The highest total composite rating was used to select the preferred alternative. This alternative was given a ranking of 1. The other alternatives within each study area were then ranked according to the decreasing rating values. The calculations for each study area are provided in the Decision Matrix, shown in Table H-1.

As a final step, a calculation was performed to understand how close the other alternatives were to the rating received by the preferred alternative. This allowed the project team to determine if alternative solutions could be selected in each study area based on other factors.

H.2.2 Decision Matrix Development

The decision matrix developed for the evaluation of the alternatives is presented in Table H-1. This matrix embodies all of the ratings, weights, and calculation of the alternative ranking described in the previous section. The headings across the top of the table provides a short description of all of the alternatives and provides the ratings that were assigned by the Task Force for all selection criteria, as well as the weighting factors developed by the Task Force for each selection criteria.

As an example, in Orchard Hills, the highest weighted score for this study area is the “Upsize/Storage” option with a total of 137 points, As a result, this alternative received an Alternative Ranking of 1 (the most favorable alternative). The second ranked alternative is the Footing Drain Disconnection alternative with a total of 136 points.

The table also includes the construction cost for the alternative solutions that were developed for reference in applying cost ratings to selection criteria. This cost is shown for the work inside of the study areas as well as the cost of improving the trunk sewer system if needed. These detailed costs are provided in Appendices F and G.

Table H-1 Alternative Decision Matrix

	Rating: Quality of Life (21)									Rating: Cost (11)				Rating: Construction (10)						Value		Costs (Millions $)			Rank		
	Impact on Open/Park/School Areas	Impact on Natural Features	Impact on Receiving Waters	Customer Disruption (Outside Study Areas)	Customer Disruption (In Study Areas)	Odor Issues	Maintenance Access Needs	Time for Implementation	Certainty of Solution	Construction Costs	Maintenance Costs	Operational Savings	Future SSO Costs	Construction Constraints	Contractor Availability	Traffic Control During Construction	Construction on Private Property	Easement Availability	Construction Season Constraints	Total (Weighted)	Total (Unweighted)	Construction Cost in Study Area	Trunk Sewer Construction Costs[1]	Total Construction Cost	Alternative Ranking	Best Alternative Cost	Percent of Highest Weighted Option
Weight	**3**	**4**	**2**	**2**	**2**	**1**	**1**	**2**	**4**	**4**	**2**	**3**	**2**	**2**	**2**	**1**	**3**	**1**	**1**								
Area Option																											
Orchard Hills																											
Relief	3	3	0	0	2	4	5	4	5	1	1	0	0	4	5	1	5	5	2	109	24	2.9	0.4	3.3	4		80%
Upsize/Relief	3	3	0	0	3	5	5	4	5	1	5	0	0	5	2	2	5	5	2	117	27	2.8	0.4	3.2	3		85%
Upsize/Storage	3	4	3	4	2	2	2	3	4	5	4	1	3	3	4	2	4	3	0	137	29	2.2	0.0	2.2	1	2.2	100%
Footing Drain Removal	5	2	5	5	0	4	2	2	2	4	4	5	5	3	4	4	0	4	4	136	37	2.3	0.0	2.3	2		99%
Bromley																											
Relief	3	3	0	0	2	4	5	4	5	1	1	0	0	4	5	1	5	5	2	109	24	2.1	0.4	2.5	4		78%
Upsize/Relief	3	3	0	0	3	5	5	4	5	2	5	0	0	5	2	2	5	5	2	121	28	2.0	0.4	2.4	3		86%
Upsize/Storage	3	4	3	4	2	2	2	3	4	4	4	1	3	3	4	2	4	3	0	133	28	2.0	0.0	2.0	2		95%
Footing Drain Removal	5	2	5	5	0	4	2	2	2	5	4	5	5	3	4	4	0	4	4	140	38	1.6	0.0	1.6	1	1.6	100%
Dartmoor																											
Relief	1	1	0	0	2	4	5	4	5	0	1	0	0	3	5	1	5	5	2	89	22	1.8	3.1	4.9	4		64%
Upsize/Relief	3	3	0	0	3	5	5	4	5	0	5	0	0	5	2	2	5	5	2	113	26	1.8	3.1	4.9	2		81%
Upsize/Storage	1	0	3	2	4	2	2	3	4	3	4	1	3	1	4	2	4	1	0	101	23	2.8	0.0	2.8	3		72%
Footing Drain Removal	5	2	5	5	0	4	2	2	2	5	4	5	5	3	4	4	0	4	4	140	38	1.9	0.0	1.9	1	1.9	100%
Glen Leven																											
Relief	3	3	0	0	2	4	5	4	5	0	1	0	0	4	5	1	5	5	2	105	23	4.6	2.4	7.0	5		77%
Upsizing	3	3	0	0	3	5	5	4	5	0	5	0	0	5	2	2	5	5	2	113	26	4.6	2.4	7.0	4		83%
Upsize/Storage 1	2	3	3	4	2	2	2	3	4	3	4	1	3	3	4	2	4	2	0	121	26	4.3	0.0	4.3	3		89%
Upsize/Storage 2	3	3	3	4	2	2	2	3	4	5	4	1	3	3	4	2	4	2	0	132	28	4.0	0.0	4.0	2		97%
Footing Drain Removal	5	2	5	5	0	4	2	2	2	4	4	5	5	3	4	4	0	4	4	136	37	4.1	0.0	4.1	1	4.1	100%
Morehead																											
Relief	3	3	0	0	2	4	5	4	5	0	1	0	0	4	5	1	5	5	2	105	23	4.2	1.3	5.5	5		78%
Upsizing	3	3	0	0	3	5	5	4	5	0	5	0	0	5	2	2	5	5	2	113	26	4.4	1.3	5.7	4		84%
Upsize/Storage 1	3	3	3	4	2	2	2	3	4	4	4	1	3	3	4	2	4	3	0	129	28	3.2	0.0	3.2	3		96%
Upsize/Storage 2	4	3	3	4	2	2	2	3	4	5	4	1	3	3	4	2	4	2	0	135	28	2.9	0.0	2.9	1	2.9	100%
Footing Drain Removal	5	2	5	5	0	4	2	2	2	3	4	5	5	3	4	4	0	4	4	132	36	3.4	0.0	3.4	2		98%
																				Minimum		**12.5**	**0.0**	**12.6**		**12.7**	
																				Maximum		**16.8**	**7.6**	**23.4**			

Definitions

Rating: Range from 0 to 5. In this range, 0 = lowest benefit and 5 = highest benefit

Weight: Range from 1 to 4. In this range, 1 = lowest importance and 4 = highest importance

Value: The higher the alternative value, the better the alternative is considered

Ranking: Ranges from 1 to 5. In this range, 1 = best alternative with higher rankings representing less attractive alternatives. These rankings are based on the weighted values

Notes

[1] Trunk sewer costs attributed to these alternatives are a portion of more extensive upgrades needed to handle wet weather flows

Table H-2 Alternative Ranking

Alternative Solutions	Alternative Cost (Millions of $) Study Area	Trunk Sewer	Total Project	Ranking	Percent of Preferred Option
Orchard Hills					
Upsize/Storage	2.2	0.0	2.2	1	100%
Footing Drain Removal	2.3	0.0	2.3	2	99%
Upsize/Relief	2.8	0.4	3.2	3	85%
Relief	2.9	0.4	3.3	4	80%
Bromley					
Footing Drain Removal	1.6	0.0	1.6	1	100%
Upsize/Storage	2.0	0.0	2.0	2	95%
Upsize/Relief	2.0	0.4	2.4	3	86%
Relief	2.1	0.4	2.5	4	78%
Dartmoor					
Footing Drain Removal	1.9	0.0	1.9	1	100%
Upsize/Relief	1.8	3.1	4.9	2	81%
Upsize/Storage	2.8	0.0	2.8	3	72%
Relief	1.8	3.1	4.9	4	64%
Glen Leven					
Footing Drain Removal	4.1	0.0	4.1	1	100%
Upsize/Storage 2	4.0	0.0	4.0	2	97%
Upsize/Storage 1	4.3	0.0	4.3	3	89%
Upsizing	4.6	2.4	7.0	4	83%
Relief	4.6	2.4	7.0	5	77%
Morehead					
Upsize/Storage 2	2.9	0.0	2.9	1	100%
Footing Drain Removal	3.4	0.0	3.4	2	98%
Upsize/Storage 1	3.2	0.0	3.2	3	96%
Upsizing	4.4	1.3	5.7	4	84%
Relief	4.2	1.3	5.5	5	78%

H.2.3 Alternative Ranking

Once the decision matrix was developed, the alternative rankings for all of the alternatives were compiled. The alternative costs and rankings are summarized in Table H-2. In Table H-2, the highlighted alternatives are the most highly ranked ones as well as those having a rating score within 10% of the most highly rated, or preferred, alternative. These highlighted alternatives were viewed as the most viable for implementation.

H.3 <u>Initial</u> Selected Alternatives

The following sections provide a description of the alternatives that were selected initially for each study area. Note that in some areas there was more than one viable alternative that could be implemented, and the final option selected was based on other constraints that might face the City of Ann Arbor.

H.3.1 Orchard Hills

In the Orchard Hills Study area the most highly ranked alternative was the Upsizing and Storage option with a total cost of $2.2 million. This alternative had the lowest construction cost of all of the evaluated alternatives because it made use of the existing retention storage in Georgetown Boulevard. This option also included immediate footing drain disconnection for those homes that had previous basement flooding problems and those homes that had the potential for basement flooding.

The second ranked alternative, footing drain disconnection, had a rating that was 99% of the most highly ranked alternative. This alternative had a construction cost of $2.3 million, which was slightly higher than the preferred alternative. As with the Upsizing and Storage option, this alternative would include immediate footing drain disconnection for those homes that have previously had basement flooding problems and those homes that have the potential for basement flooding. Once this was completed, disconnected footing drain flows would be monitored to establish the final number of footing drain connections requiring removal to provide adequate protection within the study area.

H.3.2 Bromley

In the Bromley Study area the most highly ranked alternative was the use of Footing Drain Disconnection with a total cost of $1.6 million. This alternative also has the lowest construction cost of all of the evaluated alternatives. This option includes immediate footing drain disconnection for those homes that have previously had basement flooding problems and those homes that have the potential for basement flooding.

Once this work is completed, these disconnected footing drain flows would be monitored to establish the final number of footing drain connections that need to be removed to provide adequate protection within the study area. If it were found that sufficient flows could not be removed through the use of a Footing Drain Disconnection program, then the Upsizing and Storage alternative could be used as the final corrective alternative. Alternatively, Footing Drain Disconnection could proceed and used in combination with a smaller Storage/Upsize option.

The second ranked alternative, Upsizing and Storage, had a rating that was 95% of the most highly ranked alternative. This alternative has a construction cost of $2.0 million, which is higher than the highest ranked alternative. As with the Footing Drain Disconnection alternative, this alternative would include immediate footing drain disconnection for those homes that have previously had basement flooding problems and those homes that have the previously had basement flooding problems and those homes that have the potential for basement flooding.

The two lowest ranked alternatives each include increasing sewer capacity. Both of these alternatives had considerably lower ratings and significantly larger construction costs. These alternatives should only be considered if the two most highly rated alternatives couldn't be constructed for either regulatory, construction, or institutional issues.

H.3.3 Dartmoor

In the Dartmoor study area the most highly ranked alternative is the use of footing drain disconnection with a total cost of $1.9 million. This alternative also has the lowest construction cost of all of the evaluated alternatives. This option includes immediate footing drain disconnection for those homes that had previous basement flooding problems and those homes that have the potential for basement flooding.

Once this work is completed, these disconnected footing drain flows would be monitored to establish the final number of footing drain connections that need to be removed to provide adequate protection within the study area. If it were found that sufficient flows could not be removed through the use of a footing drain disconnection program, then another alternative would need to be used as the final corrective alternative or the footing drain disconnection alternative could be combined with one of the other alternatives evaluated to create a hybrid alternative.

The other alternatives for solving the basement flooding problems in this area each had a significantly lower rating compared to Footing Drain Disconnection. The primary reasons were significantly higher costs and impacts on quality of life issues where construction needed to take place.

H.3.4 Glen Leven

In the Glen Leven study area the most highly ranked alternative is the use of Footing Drain Disconnection of between 55% and 70% of the homes with a total cost of $4.1 million. This alternative has a slightly higher construction cost compared to the other alternatives. This option includes immediate footing drain disconnection for those homes that have previously had basement flooding problems and those homes that have the potential for basement flooding.

Once this immediate footing drain disconnection work is completed, these disconnected footing drain flows would be monitored to establish the final number of footing drain connections that need to be removed to provide adequate protection within the study area. This work would be used to determine the number of residential footing drains that would need to be disconnected to provide the desired level of protection for the residents in this study area.

If sufficient flows could not be removed through the use of a footing drain disconnection program, then the second highest ranked alternative, Upsizing and Storage Alternative 2, would be used as the final corrective alternative. This alternative includes a single storage facility possibly located near South Seventh Street and the Pioneer High School property.

The second ranked alternative described above had a rating that was 97% of the preferred alternative. This alternative had a construction cost of $4.0 million, which was slightly lower than the highest ranked alternative. As with the Footing Drain Disconnection program, this alternative included immediate footing drain disconnection for those homes that had previous basement flooding problems, and those homes that had the potential for basement flooding.

The three lowest ranked alternatives each included increasing sewer capacity and one included multiple storage facilities. Each of these alternatives had considerably lower ratings and significantly larger construction costs. These alternatives should only be considered if the two most highly rated alternatives couldn't be constructed for either regulatory, construction, or institutional issues.

H.3.5 Morehead

In the Morehead study area the most highly ranked alternative was the use of Upsizing and Storage with a total cost of $2.9 million. This alternative included increasing capacity in the section of the district flowing through Tudor and Saxon streets. It also included a storage facility and discharge of wet weather flows out of the district in the area of South Seventh Street and Morehead. Finally, a new sewer segment and storage facility would be located near Ann Arbor Saline Road and Mallets Creek. This option included immediate footing drain disconnection for those homes that have previously had basement flooding problems, and those homes that have the potential for basement flooding.

There were two other highly rated alternatives; Footing Drain Disconnection with 98% and Upsizing and Storage (variation of most highly ranked Upsizing and Storage option) with 96% of the highest ranked alternative. Because these top three alternatives were so closely rated, they could all be used to provide a successful outcome. Each of these alternatives included immediate footing drain disconnection for those homes that had previous basement flooding problems, and those homes that had the potential for basement flooding. Because of this, it is recommended that a final decision on the selected alternative await completion of the immediate footing drain disconnection work and a flow removal evaluation.

If it were found that sufficient flows could not be removed through the use of a footing drain disconnection program, then one of the Upsizing and Storage Alternatives could be used as the final corrective solution.

The two lowest ranked alternatives each included increasing sewer capacity. Each of these alternatives had considerably lower ratings and significantly larger construction costs. These alternatives should only be considered if the three most highly rated alternatives could not be constructed for either regulatory, construction, or institutional issues.

I. Additional Decision Influences

Contents

I.1 Stakeholder Input

Once the alternative analyses were completed and the decision matrix prepared, a series of neighborhood meetings with homeowners were held and City Council was briefed on the pending program. These presentations are provided in Appendices J and K. Based on input received from these sessions, an implementation program was developed. Survey forms from these sessions are included in Appendix L. The following are the issues resulting from those sessions.

I.1.1 Customers

Neighborhood meetings were held in Bromley and Orchard Hills, in Dartmoor, and in Glen Leven and Morehead. These meetings were conducted to present the different alternatives that had been evaluated and to provide information on the advantages and disadvantages of each alternative. The costs for the different alternatives were also presented. From those meetings, a number of common themes were received from the attendees:

Quick Action is Needed - For those affected by the flooding problems, it was clear that homeowners wanted to have a quick remediation of the problem in their area so that they would no longer be at risk for flooding.

All Affected Homeowners Want Protection - Homeowners from areas outside of the five study areas made it clear that they also wanted a solution to the flooding problem as soon as possible.

Work on Private Property Causes Concern - For those homeowners that had previously have basement flooding, they generally said that work on their property (basement and lawn) would be acceptable if this would resolve their problem. However, there were some affected homeowners who were very resistant to allowing any work to be performed. There was also a general concern from unaffected homeowners regarding potential work on their property.

How Work is Paid For - In general, the homeowners believed that costs of the program should be paid for by the Water Utilities Department as a system cost. There was recognition that all users of the system should pay for the resolution of the basement flooding issue.

Uniform Solution Desired - There was confusion about how the City would handle situations where a limited number of homes would need to be disconnected to eliminate the flooding. Some homeowners felt singled out and believed that a uniform application of work on private property would be fairer.

Don't Move the Problem Downstream - As in other meetings, it was clear that homeowners wanted to see the problem resolved in a way that did not just move it to another group of homeowners.

Natural Features are Important to Homeowners - There was significant resistance to those alternatives requiring construction in areas that would impact natural features.

Environmentally Sensitive Solutions Supported - In general, homeowners wanted alternatives that dealt with the basement flooding issue in an environmentally sensitive manner.

I.1.2 City Council

A presentation was made to the Ann Arbor City Council on April 9, 2001 to outline the different alternatives, the preliminary costs and implementation issues associated with them. The following were comments that came out of this session.

Which Solutions Have Been Successful Elsewhere - The City Council was interested in how each of the different options had performed in other communities. The issue of how excessive footing drain flows had been handled in other communities was discussed. The Council was particularly interested in communities that had instituted a footing drain disconnection program successfully.

Can the City Work on Private Property - The option of footing drain disconnection was seen as a viable solution only if access to private property could be arranged. The Council was interested in how other communities had handled this issue.

How Would the Work be Paid For - For work on private property, the issue of what was appropriate for individual homeowners and the City to pay was discussed.

What are the Future SSO Requirements - There are pending SSO regulations that have impacts on discharges and on the operation of the WWTP. The Council was interested in how each of the alternatives would impact the ability of the City to comply with these new requirements.

Quick Action is Needed - The Council was aware that there are significant problems of basement flooding and they recognized that the solutions need to be implemented quickly.

This feedback from customers and Council members indicated to the Task Force that the rankings on the decision matrix should be modified to better represent community values and interests. This effort led to a review of the advantages of footing drain disconnection for all 5 study areas.

I.2 Regulatory Framework

The control of sanitary sewer overflows has been under increasing scrutiny in recent years. While discharges of untreated wastewater to the open environment has been illegal for many years; the infrequent and emergency nature of these discharges has limited the regulatory response. Following is a summary of the regulations being adopted.

I.2.1 State and Federal Regulations

On January 5, 2001 EPA signed and issued a draft rule on sanitary sewer overflows (SSOs). The following is an overview discussing the impact of the official draft regulation:

- ***Municipal Satellite Collection System*** - This section of the regulation will require owners of satellite collection systems to obtain a no discharge NPDES permit or issue a permit amendment to the owner of the POTW facility that receives wastewater from the satellite collection system.
- ***Municipal Sanitary Sewer Systems*** - Capacity, Management, Operation and Maintenance (C-MOM) Programs. As a result of this requirement, all NPDES permittees will be required to develop and implement a C-MOM program following the standards prescribed in the regulation. A complete C-MOM program is quite comprehensive.
- ***Municipal Sanitary Sewer Systems*** - Prohibition of Discharges. This portion of the regulation defines the general prohibition of SSO discharges and the use of enforcement discretion for SSOs caused by "severe natural conditions" and affirmative defenses for discharges caused by other factors beyond the "reasonable control" of the utility. The affirmative defense clause is very important to provide appropriate liability protection for SSOs that are beyond the control of the utility.
- ***Municipal Sanitary Sewer Systems*** - Reporting, Public Notification, and Recordkeeping. This rule defines what is considered an SSO and defines--in a certain level of detail--procedures for agency notification, public notification, and recordkeeping. In the current versions of the regulation, US EPA has broadened the definition of SSOs to include discharges that reach waters

of the US, as well as overflows that do not reach waters of the US such as wastewater backups into buildings caused by the utility operation.

- ***Pending State of Michigan Regulations*** - Several bills are being developed in the State legislature that may limit the liability of communities having an approved SSO prevention plan. The new bills would provide funding for the SSO programs. These new legislation will be reviewed once enacted.

I.3 Project Delivery Methods

There are alternative methods that can be used to contract for the construction work that needs to be performed. Each of these methods has implications on the completion schedule of the work and on the ultimate cost for the work to be performed. Following is a description of the different methods that could be employed for the alternatives described above.

I.3.1 Design/Bid/Construct

Under the traditional delivery method, the City would own a separate design contract to prepare a biddable project. Once this is completed, a contractor (or contractors) would be selected to perform the different projects. The City would own all of the contracts and would manage the construction work being undertaken by the contractor. This may include a shop drawing review, request for information, and resident services components. The construction contractor would be selected using low-bid format.

I.3.2 Design with Construction Manager

Under the traditional construction manager approach, a design would be prepared, as with conventional Design/Bid/Construct and a construction contractor (or contractors) would be selected. Under this approach, the City would also enter into a contract for a construction manager to handle the coordination with the construction contractor as well as the homeowners.

I.3.3 Construction Manager at Risk

Under this approach, the City would hold the contract with the designer and also the Construction Manager. Under this approach, however, the Construction Manager would then hold the contracts for the construction contractors. This would provide the flexibility to use a variety of subcontractors for different aspects of the work (plumbing, electrical, trenching) and locations where the work is being performed. The bidding of the work could also be performed throughout the project as the work progresses. The Construction Manager would also control the schedule under which the work is performed. The contract with the Construction Contractor could either be lump sum or on a not to exceed or unit cost basis.

I.3.4 Design/Build

In this approach, the Construction Management team also includes the Designer. Under this approach the City sets general objectives. The Design/Build team is responsible for the preparing the design and implementing the design in the field. As in Construction Manager at risk, the Design/Build contractor holds all construction contracts. These could be bid competitively by the D/B contractor.

This approach has the advantage of not having to have a complete design for all areas before the work starts. It allows the Design/Build contractor to adjust the design to the conditions as the construction process unfolds. This approach allows enough design to be prepared to begin the work and provides the flexibility to make changes in the field. This may be particularly helpful for footing drain disconnection work since each homeowner will have different ideas of what is important to them.

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J. Funding Options

Contents

J.1 Project Funding

Funding for the Footing Drain Disconnection alternative is critical. A discussion of the funding elements is described below.

J.1.1 Funding Sources

The City of Ann Arbor Water Utilities Department operates as an enterprise fund. That is, it uses the fees that it charges for water and sewer services to fund the operation, maintenance, and capital improvements within the systems that it administers. These include water, sewer, and stormwater systems.

To fund capital programs such as this, the Water Utility Department would typically sell bonds to perform the construction activities and then repay those loans out of the fees that they collect for service. Significant capital programs such as this will result in an increase in fees to cover the cost of the construction.

J.1.2 Home Owner Financing

The footing drain disconnection alternatives described earlier are on private property. In many situations where corrective actions like this are undertaken, the responsibility for funding this falls on the homeowner. An example of this is the financial responsibility to provide or maintain the sewer service lead to the collection system. This is wholly the responsibility of the homeowner at the present time.

In cases where this approach is employed, it is done by the homeowner to get access or continue to have access to a service. The home owner therefore funds this part of the work.

J.1.3 Selected Funding Program

For alternatives that are within the public right of way and serve the system at large, the cost of this work is typically born by the entire customer base because it is a system improvement cost. In the case of the footing drain disconnection option, the primary purpose of the work is to remove individual sources of flow, even in homes that are not experiencing the negative impacts of the flooding. Because of this, even though the construction may take place on private property, it is thought to be part of a systemic solution and the cost shared by all of the system users.

It is recommended that the funding of the footing drain disconnection work and routing of these flows to the storm drainage system be funded by the Water Utilities Department and made a part of the fees paid by all the customers within the City of Ann Arbor.

J.1.4 Customer Costs

There are certain components of the work on private property that may in fact need to be paid for by the customer. In some cases, there will be additional work that the homeowner may request to resolve a drainage problem or make the construction in the basement more aesthetically pleasing. If these requests go beyond an established set of guidelines, then these elements should be funded by the homeowner.

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K. City Customer Service Plans

Contents

K.1 City Customer Service Plan

The homeowners with basement backups in June 2000, experienced difficulty in procuring services of cleaning and sanitizing contractors in a timely manner. Many of these same homeowners had basement backups in August 1998 during heavy rainfall. These homeowners also expressed their concerns to the City staff and Council members with the City's existing policy for reimbursement of damage claims. The reimbursement was limited to $3,500. Another issue noted was that the City staff inconsistently reported the details of the backups.

The City implemented changes to policies and procedures to address these and other issues. The City Council approved resolution No. R-401-8-00 to change the City's policy to better assist households experiencing sanitary sewer backups. These changes included removing the $3,500 limit on the reimbursement of damaged property claims, improvement of emergency response policies to better assist impacted properties with cleanup personnel, claims coordinators, and processing of claims.

For details of resolution R-401-8-00, please see Appendix M . The City also surveyed the impacted homeowners to gather information regarding the services they would like the City to offer for dealing with such backups. The information received with this survey is being used to change existing services, policies and information provided to homeowners in the event of basement back-ups.

K.2 Emergency Response Policies

Currently, in cases of a basement backup due to a sanitary sewer maintained by the City, the property owner arranges for clean-up services and files claim against the City. At the homeowner's request, the City staff sanitizes the areas touched by the sanitary sewer backup. In an effort to improve response time, particularly following big events, the City is in the process of contracting with private local companies that provide cleaning and sanitizing services.

These contracts will also include removal of damaged goods from basements or other areas to curbside, currently being done by homeowners, for disposal by the City,. The updated list of these contractors will be included in the homeowner information packet as it becomes available. In addition, the City now sends claims coordinator(s) to assist individual property owners with filling out the claim forms and assessing damages.

K.3 Claims Processing and Forms

Prior to July 2000, the City only provided information about how to file a claim with the City. In July 2000, the City responded to customer requests by developing a claim form to use for filing claims. The City has also contracted with a company to provide claims coordinators to help property owners fill out the claim form and assess damages. Coordinators are available on an as-needed basis in case of a large backup event. Claim forms and claim filing information is included in Appendix N.

K.4 Staff Training and Internal Communication

The flow and level data collected during the study indicates that the sanitary sewer system has a very quick response to the rainfall. This means that the sewer surcharging and return to normal conditions happen very quickly. This adds to the difficulty of assessing the reason for basement flooding. Now whenever the City staff responds to a call for a backup, the staff performs a more detailed investigation to assess the situation and cause of the backup and take action appropriately.

In addition, the staff has received training to gather information as complete as possible from the callers reporting basement flooding and to contact appropriate personnel to address the situation.

K.5 Homeowner Information Packet

Prior to June 2000 backups, homeowners were given information about what to do in case of a basement backup. The information included the responsibilities of the City and the homeowner when a basement backup was due to a surcharged sanitary sewer maintained by the City. It also gave guidance on filing a claim against the City.

The City staff now provides claim forms and claim filing information also in addition to customer information guide when they respond to call. The City is expanding the scope of the information it will provide in future to homeowners when the City staff responds to a basement backup call. The packet will include:

- Customer Information Guide -What to do in case of a basement back up,
- What services a homeowner can expect if the City sewers cause the backup,
- Health risks of exposure to sewage
- Information on how homeowners can sanitize their basement.
- City of Ann Arbor claim form and claim filing information.

Please see Appendix N for details of this packet.

L. Final Recommended Program

Contents

L.1 Recommendation

The Sanitary Sewer Overflow Prevention Advisory Task Force recommends the Mayor and City Council take action to remove rain and ground water inflow sources into the City's sanitary sewer system by implementing a comprehensive city-wide footing drain disconnection (FDD) program within the City of Ann Arbor.

L.1.2 Selected Solution - Footing Drain Disconnection

Alternative solutions were reviewed using a variety of selection criteria including quality of life, cost, and construction impacts. The evaluation showed that in most cases, storage and footing drain removal were closely ranked as the preferred alternatives. The Task Force then solicited public concerns. Public feedback emphasized protection of natural features and elimination of long-term impacts on the environment from sanitary sewer overflows as the important community criteria.

A comprehensive city-wide footing drain disconnection (FDD) program has been determined to be the best solution for the residents of Ann Arbor. Removing rain and groundwater from the sanitary sewer system with an FDD program has the following advantages:

- Solution places first priority on protecting homeowners who have been previously impacted by sanitary backups during severe storm events.
- Addresses the root cause of the problem which is the excessive wet weather flows introduced into the sanitary collection system from foundation footing drains.
- Eliminates the costs for treatment of this rainwater flow that is required only when it is connected to the sanitary sewer system.
- Saves dollars in wastewater treatment expansion to treat this flow and regulatory penalties for sanitary sewer discharges to the environment.
- Solution does not move the problem downstream to previously unaffected neighborhoods or require extensive construction on downstream trunk sewers.
- Solution provides the greatest level of protection for future large rainstorms.
- Solution compatible with regulatory trend toward disconnection of footing drains from sanitary sewer systems.

Residents also emphasized that the City should take a broader view regarding efficient use of our resources in conjunction with infrastructure issues. Though not a part of the FDD program, the City would also encourage the following through outreach efforts:

- Lower sanitary flows through water conservation practices such as encouraging use of low flow toilets, faucets and showerheads.
- Utilize rain barrels, rain gardens, and/or infiltrator storage systems on sump discharge leads to reduce rain/groundwater flows returned to the storm water system (coordinate with FDD construction efforts when possible).
- Engage the cooperation and support of commu-

nity, school and environmental groups to fix this problem at its source while preserving and protecting: the health and safety of community members, the natural features of Ann Arbor and the Huron River watershed.

L.1.3 Costs

Footing drain disconnection (FDD) is the lowest cost alternative for preventing sanitary sewer backups into homes when consideration is given to construction costs, treatment, treatment plant expansion, dollars spent in claims, legal costs, and sanitary sewer overflow penalties. Costs to complete such a program will generally range between $80-130 million depending on the actual number of homes requiring FDD and level of participation of homeowners during FDD incentive programs.

It is estimated that the approximate construction cost per home is $5,000-6,000 to disconnect the footing drain and provide a curbside collection system to bring the rain/groundwater from the sump to the storm drainage system. It is the recommendation of the SSO Advisory Task Force that the basic costs to complete the FDD in each home be funded from the Sewage Collection System user fees. The different elements of the footing drain disconnection program and the elements that are recommended for funding are described below:

- **Sump and Sump Pump** - This installation and the electrical service needed for operation of the sump pump should be funded in all homes.
- **Backup Sump Pump** - This should be funded in all homes. Either a water powered or battery powered option should be made available.
- **Check Valve** - In homes where the basement elevation is lower than the downstream manhole elevation, this should be funded. If this is desired in homes where this is not the case, this should be a homeowner funded option.
- **Basement Restoration** - This basic restoration should be funded in all homes. Special restoration or construction of new walls to hide the installed equipment should be at homeowner expense.
- **Radon Gas Remediation** - This should be funded in homes where post-installation testing is higher than pre-installation testing for radon gas.
- **Sump Pump Discharge and Curb Drainage** - This should be funded for all homes. Restoration of the outside trenching or boring work should be performed using reseeding. Any additional outside restoration should be at owner expense.

L.2 Implementation Challenges

To implement the alternatives described earlier, it is important that the challenges to their success be understood. For a footing drain disconnection solution, there are a number of issues that would need to be addressed. These are as follows:

- **Legal Authority** - Can and will the City of Ann Arbor have the legal framework to accomplish the work required on private property?
- **Funding** - Is there a funding mechanism available for work performed on private property?
- **Certainty of Solution** - Currently, the data for footing drain disconnection flows is limited and additional flow removal data should be collected with backup protection and footing drain disconnections planned with all alternatives.
- **Public Acceptance** - To be implemented on a wide scale, public support needs to be developed. This would require a public information/ involvement program that is tailored to each area where this work is performed.
- **Flexibility** - To provide an acceptable solution, the construction manager and contractor need to have a certain amount of flexibility to respond to

individual homeowner needs and desires. A one size fits all approach will not be acceptable to all homeowners

L.3 Proposed Implementation Steps

Following is a description of the implementation steps needed.

- A first step is to develop a legal framework that would allow access and work on private property. To be effective, the City of Ann Arbor would need to have the power to accomplish the disconnection work on private property.
- A second step would to be able to provide a funding mechanism so that this work on private property can be paid for with public funds. The available funding would control the schedule under which the work would proceed.
- Next is the immediate disconnection of homes that have previously flooded and those homes that have a high potential for having basement flooding in the five study areas. This work would include significant amount of public information to support the program and ensure that it is acceptable to early program participants.
- After these first footing drain disconnection projects are completed, the flows removed through this method would be validated in each study area. This would be done by monitoring both the flows discharging from individual sump pumps and also monitoring the flows measured at the discharge from each study area. Rainfall would also be monitored in each study area.
- Then the disconnection work will proceed to areas outside of the study areas that have had basement flooding or have the potential to have basement flooding. This disconnection work will proceed in logical groups of homes that can be served by sump pump drainage systems.
- Once these are completed, footing drain disconnection will proceed on a city-wide basis to include all homes that discharge footing drain flows to the sanitary collection system.
- In all cases, once the City has constructed a means to dispose of sump pump flows, the homeowners will either have their homes disconnected or face paying for wet weather flows being discharged to the sanitary system by their footing drains.

This stepwise approach provides the City of Ann Arbor the ability to tailor the program to both be the most cost effective and environmentally responsible. It also provides a solution that ultimately solves the basement flooding issues as well as other SSO related issues.

L.4 Implementation Priorities

The size of this project is such that a deliberated and well-planned approach is needed to prevent excessive expenditure of utility funds, over-commitment of the available contract workforce and creating nuisance/hazards by not adequately controlling sump pump discharges. Completion of the program is dependent on commitment of resources but realistically expected to last 20-30 years. The FDD program implementation will be accomplished on a block-by block basis in conjunction with construction of the sump discharge collection system generally with the following priority:

- **Priority 1-A** - Homes within the five study areas that have historically flooded or those with the potential for flooding would have their footing drains disconnected and check valves installed. These homes would be monitored and the collection system monitored to confirm the storm flows removed by FDD from the sanitary system. This would begin in summer 2001 and last approximately one year.
- **Priority 1-B -** Homes outside the five study areas that have historically flooded or those adjacent to homes historically flooded with the potential for flooding would have their footing drains disconnected and check valves installed. This would begin late summer 2001 and last several years.
- **Priority 2-A** - Homes that have not historically flooded or those not having the potential for

flooding within the five study areas would have their footing drains disconnected because they are contributing flow resulting in basement backups and allowing unmetered rain/groundwater flow into the sanitary sewer that requires treatment at the wastewater treatment plant. Schedule to be determined.

- **Priority 2-B** - The remaining homes that have not historically flooded or those not having the potential for flooding outside of the five study areas would have their footing drains disconnected because they are contributing flow resulting in basement backups and allowing unmetered rain/groundwater flow into the sanitary sewer that requires treatment at the wastewater treatment plant. Schedule to be determined.

Table L-1 Program Costs

Priority 1-A

Area	Homes	Cost
Orchard Hills	50	336,000
Bromley	70	470,400
Dartmoor	31	208,320
Glen Leven	123	826,560
Morehead	55	369,600
Total	329	$2,210,880

Priority 1-B

Area	Homes	Cost
Confirmed	132	996,800
High Potential	93	681,800
Contingency	90	671,400
Total	315	$2,350,000

Priority 2-A

Area	Homes	Cost
Orchard Hills	325	1,956,500
Bromley	179	1,077,580
Dartmoor	280	1,685,600
Glen Leven	852	5,129,040
Morehead	685	4,123,700
Total	2321	$13,972,420

Priority 2-B

Area	Homes	Cost
City-wide	17,000	$60 million to $110 million
Grand Total	**20,000**	**$80 million to $130 million**

L.4.1 Program Costs

The costs of the different priority steps are provided in Table L-1. This shows the number of homes that are envisioned in each priority level of the work effort.

The different elements of the program may be funded by the City of Ann Arbor. This discussion can be found in Appendix P. These document the rationale for inclusion of these different components in the program.

The wide range in city-wide costs is due to difficulty in estimating the number of homes with footing drains connected to the sanitary sewer and the level of homeowner participation that the program will receive during the incentive periods as the program becomes active in each neighborhood.

L.4.2 Critical Factors for Successful Implementation

The implementation of the program is provided Appendix Q. This shows the steps that are needed to complete the program successfully.

The Task Force recognizes the unique nature and challenges inherent in these recommendations. The Task Force offers the following recommendations as to what will support an effective implementation:

- Structure an effective construction management program to oversee all work done on private property.

- Set clear standards and provide support and oversight to ensure that all work done is highly professional, effective and done in a timely manner.
- Provide a strong and comprehensive public engagement program that effectively communicates why this work is needed, what the benefits are for homeowners and for the City, what is included in the work, and that answers any additional questions of homeowners.
- Collaborate with environmental groups and other stakeholders to engage citizens in supporting this program.
- Demonstrate City commitment to a rapid implementation of these recommendations.
- Structure the FDD program with the flexibility for homeowners to control the level of City support or assistance they receive

L.4.3 Implementation Schedule

City is currently developing an ordinance, contractor pre-qualifications and contract specifications needed to begin the FDD program. After approval of an ordinance providing authority to proceed, the city can begin with Priority 1-A homes late this summer or early fall.

Additional FDD flow removal data will be collected next spring to validate the program and it is anticipated that 1-B homes could begin as early as summer 2002.

Plans for reimbursement of FDD for homeowners wishing to proceed with the disconnection ahead of the city schedule are being considered. An announcement will be made once information becomes available.

L.5 Recommended Delivery Method

In Priority 1-A, all of the study areas will have immediate disconnection of footing drains for those homes that have historically flooded or have a demonstrated potential for basement flooding. To effectively implement this and subsequent phases of the program requires a significant amount of coordination with the homeowners and flexibility to perform the work so that the homeowners receive a solution that fits their needs.

To best accomplish this, the recommended method to deliver these services offered by the FDD Program would be through use of a contracted Construction Manager in conjunction with a City ombudsperson. This method provides the needed flexibility to control the process, provides the homeowners with sufficient information on the location and time of the work in their area and ensures the highest level of communication to prevent and resolve issues associated with performing this work on private property. This will help make continued progress of the program more supportable and acceptable.

To provide homeowners with the opportunity to select the contractor working inside their home, the City of Ann Arbor will prequalify potential plumbing Contractors. This prequalification process will based on criteria to ensure the work performed is of the highest quality and completed in a timely manner by polite and courteous contractors with a minimum amount of disruption and inconvenience.

Once a homeowner has selected a contractor, they are responsible for scheduling the work with that contractor and notifying the construction manager when the work is completed within the home so that a final inspection can take place.

As an alternative for those homeowners that do not want to manage the work, the homeowner may select the contractor and allow the contract manager to assist by coordinating construction between the homeowner and the contractor. This arrangement will include the scheduling the access to the home for the work needed and for final inspection of the completed footing drain disconnection work.

During the construction process, each prequalified contractor will be periodically reviewed to ensure that they are providing the level of service called for in the standards established by the City of Ann Arbor. If at any time these standards are not met, the City of Ann Arbor may remove them from the list of prequalified firms.

L.6 Summary

The final alternative selected for implementation includes the disconnection of all homes in the City of Ann Arbor that have connected footing drains. This alternative provides a solution that addresses the root cause of the basement backup problems that have been taking place in the City. It also addresses not only the basement flooding issues but also the issue of controlling SSOs that occur from time to time in portions of the collection system.

The final alternative will address the basement flooding potential immediately in all homes that have previously flooding, and in areas that are judged to have the potential to flood. This solution is applied uniformly to all homeowners in the City of Ann Arbor. The program also will provide funding to accomplish this disconnection on private property.

The footing drain disconnection process will be accomplished with the assistance of a construction manager in combination with a city ombudsperson to ensure that each homeowner is handled on an individual basis so a solution that best meets their needs, within the constraints of the program, can be developed. The construction manager and city ombudsperson will assist in coordinating the field efforts and will work with prequalified contractors selected by the homeowner to perform the construction. The construction manager will coordinate sump pump discharge connections to the city stormwater system and manage the installation of a curb drain collection system as required.