City of Ann Arbor, Michigan
Storm Water Master Plan

Prepared for

Ann Arbor
Water Utilities Department

BLACK & VEATCH LLP

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Executive Summary

The City of Ann Arbor staff has taken a positive and important step in the development of one of the City's important utilities--the stormwater conveyance system. The system contains hundreds of miles of channels, culverts, underground pipes, and appurtenances. Although the capacity and capabilities of the system varies, for most of the City most of the time, the stormwater conveyance system collects and conveys flows with minimal problems. However, the level of service provided by the system varies across the City, and when larger, less frequent storms occur, flooding conditions develop and the duration, extent, and damages caused by the flooding vary depending on the location. The results of the analyses for the 10-year design storm confirm that severe and repetitive flooding occurs in the Allen Creek Watershed while the Miller Watershed appears to have many fewer problems. The Allen Creek and Miller watersheds represent the extremes of conditions that exist. The remaining six watersheds--Fleming, Honey, Huron, Mallets, Swift Run, and Traver Creek--have bits and pieces of the conditions that exist in the Allen Creek and Miller watersheds. The main purpose of this report is to identify potential improvements throughout the City's watersheds to assure that the present flooding conditions in the Allen Creek watershed do not similarly develop in other locations throughout the City. The analyses of the eight watersheds present the following information:

1. Identify the location and severity of flooding.

2. Develop planning level improvements and costs for possible inclusion in the City's capital improvements program.

3. Present other options to be considered to proactively address and limit/eliminate future flooding conditions.

4. Identify cost-effective and practical alternatives to be considered for system components and watershed-wide improvements where complying with present design standards are cost-prohibitive and impractical.

5. Provide a starting point for the City to further enhance and develop specific ordinances to limit runoff, limit the development of land in the flood plain, and enhance water quality.

6. Identify enhancements and modifications to present design standards, regulations, and ordinances to provide a consistent, comprehensive, and complete basis for future analyses and development of improvements.

7. Provide a basis for the City to continue to be proactive in its efforts to limit/eliminate future flooding.

A summary of the recommendations and costs for each of the eight watersheds is presented in Table ES-1. These improvements provide the City with a basis for studying the type and extent of flooding and associated costs to correct present and future flooding. Six of the watersheds--Fleming, Honey, Huron, Miller, Swift Run, and Traver Creek--presently experience very little flooding for that portion of the conveyance system analyzed. Thus, most of the improvements for these watersheds are a future action item, and the City has the time to analyze the watersheds in more detail and to properly develop a number of alternatives to minimize the potential for future flooding. In addition to the improvements in Table ES-1, the following recommendations are also presented for consideration by the City to aid in the continued development of the stormwater system beyond this plan.

1. Evaluate enhancing and developing more stringent flood plain restrictions and zoning regulations. It is recognized that regulating zoning and flood plain development can have an adverse impact on developers and on the City's tax-base. However, without these restrictions, more infrastructure improvements, and therefore costs, may be required in the future to the conveyance system. An economic evaluation of the revenue losses associated with the restrictions compared to the potential costs of upgrading the conveyance system should be completed. The restrictions exemplify a truly proactive non-structural approach and represent a potential change in philosophy of the City officials.

2. Identify alternative funding sources to supplement the City's funds. A logical funding source are the developers. Where onsite detention for each development is impractical, funds may be placed in an escrow account. These funds can be used by the City, when and as necessary, to design and construct improvements in the watershed. Coordinated system-wide improvements can be more useful than multiple small and site-specific improvements.

3. The analyses for the Fleming, Honey, Huron, Mallets, Miller, Swift Run, and Traver Creek watersheds be carried forward to preliminary design and design level analyses. Many potential improvement configurations exist, and the costs of additional analyses now will be more than offset by savings in the design and construction of the most cost-effective solution. In addition, once these improvements are constructed, the City will recognize the benefits of limiting the flood frequency and damages that presently occur in the Allen Creek watershed as well as the intangible benefits of positive public relations for being proactive. In other words, these more detailed analyses will provide Ann Arbor with a plan of attack as the City grows and develops.

4. It is recognized that the recommended improvements for the Allen Creek Watershed are expensive, and may well be outside the funding capabilities of the City and residents. In the event that the City should decide not to pursue the improvements, it is strongly recommended that the following be completed for the Allen Creek watershed:

   - Analyze the system for a less severe storm event.
   - Develop and implement improvements for a less severe storm event.
   - Implement flood plain management techniques such as floodproofing and purchasing of flood-prone properties.

5. The Water Utilities Department has developed a good maintenance program. It is recommended that this program be continued, and modified as necessary, to provide the necessary maintenance services. Although the analyses conducted for this report did not attempt to evaluate the structural condition of the conveyance system, or the capacities of inlets and smaller conduits (less than 36-inch diameter), it is a recognized fact that many system inadequacies are caused by system components that are not operating as designed. Generally, regularly scheduled maintenance can provide the solution to flooding caused by inoperable components such as inlets.

6. The City's design standards should continue to be upgraded to provide a technical basis for system analyses and design as discussed in Chapter II. In particular, design standards to be addressed should include open channel design; design storm hyetograph; use of other design tools; more stringent flood plain regulations; and additional improvement alternatives.

7. To properly plan and develop the conveyance system and timing of improvements, the City should consider additional technical staff. Present staff do not appear to have the necessary time to develop to the future needs of the system. Staff should be added to support both engineering and GIS needs.

Table ES-1

Summary of Improvement Costs by Watershed

Watershed	Improvement Costs
Allen Creek	$41,000,000
Fleming	3,498,000
Honey	1,934,000
Huron	4,149,000
Mallets	38,573,000
Miller	5,164,000
Swift Run	$2,685,000
Traver Creek	$625,000
Total	$97,628,000

Zoning, enhancement and enlargement of flood plain restrictions, and development of watershed-wide detention facilities can be the most cost-effective and successful means to proper development of the six watersheds. Although the improvements presented in this report do not reflect these type of improvements, it is crucial that the City move forward and study these options now, before the watersheds develop conditions and problems similar to the Allen Creek watershed.

I. Introduction

A. Purpose

The Infrastructure of Ann Arbor is of concern to its residents as well as to the public officials. The more visible and commonly used elements of the City's infrastructure include the street and highway system, the water distribution system, and the wastewater collection and conveyance system. A vital, yet often forgotten element, is the stormwater conveyance system that winds its way through the City and provides the essential service of collecting stormwater runoff and ultimately conveying it to the Huron River. Although the system was designed to operate efficiently and effectively, its components are becoming inadequate and inoperative, to the point of creating local and region-wide nuisances and hazards.

The reasons behind the inadequacies of the present stormwater conveyance system are multifaceted, and include the following:

- Age of the system components.
- Increased flows beyond the system's design capacity.
- Increased runoff resulting from development.
- Sedimentation occurring from construction-related runoff.
- Channel bank erosion.
- Structural failures.
- New, more stringent legislation resulting in previous designs being inadequate, although properly designed at the time.
- Development in areas where flooding was not a concern in the past, but where upstream development has increased flows.
- Private stormwater facilities, including detention basins, which are not adequately maintained.

Many of these aspects are interrelated; therefore, correction of one may result in the elimination of two or more causes.

The deterioration of the stormwater conveyance system infrastructure has not occurred overnight, nor is it unique to Ann Arbor. The stormwater conveyance system is not a "regularly" used system when compared to other components of the City's infrastructure. Therefore, it has not received the same degree of attention as has the other components. Attention is typically given to the stormwater system when the system fails to operate properly, causing property damage, or potentially even loss of life.

As the City has grown and developed, the expectations for the stormwater system performance have expanded. Although at one time flooding was viewed as an uncontrollable and/or unimportant problem, it can now be controlled and its effects alleviated. As Ann Arbor competes with other cities to attract commerce and industry, prevention and control of flooding becomes increasingly important. The challenge facing the City is to develop, implement, and maintain an adequate stormwater system capable of operating well into the 21st century. Such a system must not only reduce or eliminate stormwater-related damage, inconvenience, and threat to life, but it must also enhance other aspects of the urban system by offering recreational opportunities, complementing the transportation network, and helping to realize development and redevelopment plans.

The Stormwater Master Plan is one of the initial steps towards upgrading the stormwater systems throughout the City. This Master Plan identifies and examines the types and extent of the stormwater flooding problems within Ann Arbor, proposes practical planning level improvements, and provides a sound, technically-based framework for further development of the stormwater conveyance system. Various levels and degrees of flooding exist within Ann Arbor. For example, the Allen Creek Watershed, containing the most developed and older parts of town, has the most severe flooding throughout the City and the least amount of land to devote to improvements. This is contrasted with the Miller Watershed which is not fully developed and has a very adequate system of open channels and room for development of various future improvement options (including site and regional detention facilities). The extent and type of improvements must be tempered with the associated costs; and, the costs to meet present day standards may well be outside the range of City funding capabilities. This Master Plan will provide a basis for the City to continue to evaluate each watershed to provide optional levels of flooding protection and, as necessary, propose and implement technically feasible lower cost solutions, while proactively addressing the potential future system needs as development occurs.

Different kinds of problems are encountered in different parts of Ann Arbor. Damage and disruption caused by inadequate, undersized inlets and structures in the uppermost reaches of the watersheds differs from, and must be managed differently from, the damage and disruption caused by floodwaters concentrated in undersized channels and culverts further downstream. The nature of the corrective measures may vary accordingly. The extent of flooding problems is also important to the City as different approaches and solutions are considered. The extent of the flooding can indicate the location, or both the location and intensity of the problems. The extent of the flooding problem is a factor when developing funding sources and mechanisms, and when assigning the responsibilities and allocating resources to those dealing with the problems.

B. Scope of Master Plan Work

The Stormwater Master Plan presents a preliminary assessment of many aspects of stormwater management practices and the improvements required of the existing systems for the eight major watersheds in Ann Arbor--Allen Creek, Fleming, Honey, Huron, Mallets, Miller, Swift Run, and Traver Creek. The scope of the master planning investigations is broad in physical coverage and non-comprehensive in its assessment of the overall program. The detail provided in the Master Plan is at a planning level, appropriate for this stage in the stormwater system's development, and in keeping with the available resources and time.

The general appraisal of the eight watersheds is based on an overview of specific problems encountered throughout the City. Each problem warrants further attention: whether to analyze the problem in further detail, prepare plans for capital improvements, schedule special maintenance, or postpone action until more pressing needs are met. This study provides general assessments of the costs of improvements and a general strategy for dealing with the various problems. This will allow Ann Arbor the opportunity to properly develop more specific plans for stormwater system projects and maintenance activities in the watersheds in a logical and effective manner.

This Master Plan describes the general location, type, and approximate cost of maintaining, upgrading, or reconstructing current facilities. The recommended improvements and costs information in this Plan are preliminary; final design should not be developed solely on the basis of the recommendations or analyses of this Plan.

II. Existing Stormwater System Data

A. Data and Information Sources

Much data is available to help the Ann Arbor Water Utilities Department manage the City's stormwater conveyance systems. However, as the system develops, additional types of information will become available, and managing the information will become increasingly important. The Water Utilities Department must not only decide how data will be collected, processed, organized, and distributed, it must also decide what information is necessary to properly plan, regulate, design, build, and maintain the physical system.

Ann Arbor's Information Services Division's foresight in the development of a city-wide Geographic Information System (GIS) has proven very beneficial to the completion of this Master Plan and the inclusion of a data management component. Through the use of GIS, this Master Plan has been developed to initiate the data management strategy for the stormwater conveyance system. To the extent possible, data has been entered and stored in the GIS, including historic flooding locations, questionnaire responses, and hydrologic and hydraulic modeling data.

Table II-1 presents a summary of data collected and a brief description of the contents of each piece of information throughout the development of the Master Plan.

Table II-1

Summary of Data Collected

NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
UTILITY MAPS					
1	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	SEWER INDEX MAPS (2 SETS): G6-G10, H5-H11, I4-I10, J5-J10, K5-K11, L5-L10, M6-M10 AND N7-N10	RECEIVED 1991	CITY OF ANN ARBOR - ENGINEERING DIVISION	MAPS INCLUDE STREETS, WATERBODIES, WATERWAYS, DRAINAGE BOUNDARIES, GROUND ELEVATIONS AND SANITARY AND STORM SEWERS WITH SIZE AND GRADE.
2	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	WATER INDEX MAPS (1 SMALL SET): ANN ARBOR TOWNSHIP; A) SECTIONS 9-11 (SW & SE) B) SECTIONS 14-23 (NE, NW, SW & SE) C) SECTION 24 (SW) D) SECTION 25 (NW & SW) E) SECTIONS 26-36 (NE, NW, SW & SE) PITTSFIELD TOWNSHIP; A) SECTIONS 2-6 (NE, NW, SW & SE) B) SECTION 7 (NE) C) SECTION 8 (NE, NW & SE) D) SECTIONS 9-11 (NE, NW, SW & SE) E) SECTION 15 (NE & NW) F) SECTION 16 (NW & SW) G) SECTION 17 (NE, NW, SW & SE) SCIO TOWNSHIP; A) SECTION 13 (SW & SE) B) SECTION 23 (SW & SE) C) SECTIONS 24-25 (NE, NW SW & SE) D) SECTION 36 (NE & SE)	UPDATED 1993	CITY OF ANN ARBOR - ENGINEERING DIVISION	MAPS INCLUDE STREETS, LOT NOS. , WATER BODIES, AND WATERMAINS WITH SIZES, HYDRANTS, ETC.
DATA ON RECENT IMPROVEMENT PROJECTS					
3	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	STORMWATER SUPPLY SYSTEM CAPITAL IMPROVEMENTS PROJECTS PLAN FY 93/94 THROUGH FY 03/04	REVISED NOV. 12, 1993	CITY OF ANN ARBOR - CITY ADMINISTRATION	LISTING OF CAPITAL IMPROVEMENT PROJECTS PROJECTED FOR THE NEXT 10 YEARS.
DEVELOPMENT PLANS					
4	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	A) NORTHEAST AREA PLAN FOR THE CITY OF ANN ARBOR	APR. 25, 1989	CITY OF ANN ARBOR - PLANNING DEPARTMENT	SUB-ELEMENTS OF THE CITY MASTER PLAN CONCERNING LAND USE, CIRCULATION AND PUBLIC FACILITIES FOR DIFFERENT AREAS OF THE CITY.
		B) CITY OF ANN ARBOR - SOUTH AREA PLAN	DEC., 1990		
		C) CITY OF ANN ARBOR - CENTRAL AREA PLAN	DEC., 1992		

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NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
NPDES PART 1 APPLICATION INFORMATION					
5	BLACK & VEATCH	CITY OF ANN ARBOR, MI - BASE MAP (FIGURE 2-1)	DEC., 1991	BLACK & VEATCH	-
6	BLACK & VEATCH	CITY OF ANN ARBOR, MI - LAND USES (FIGURE 2-3)	DEC., 1991	BLACK & VEATCH	-
7	BLACK & VEATCH	CHAPTER 1 - LEGAL AUTHORITY	MAY, 1992	BLACK & VEATCH	-
NPDES PART 2 APPLICATION INFORMATION					
8	BLACK & VEATCH	CHAPTER 1 - ADEQUATE LEGAL AUTHORITY, CHAPTER 4 - MANAGEMENT PROGRAM	MAY, 1993	BLACK & VEATCH	-
AERIAL PHOTOS					
9	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	AERIAL PHOTOS OF THE ANN ARBOR AREA: T.2S., R.6E.: A) SECTIONS 7-11 (SW & SE) B) SECTIONS 14-23 (NW, NE, SW & SE) C) SECTION 24 (SW) D) SECTION 25 (NW, SW & SE) E) SECTIONS 26-36 (NW, NE, SW & SE) T.3S., R.6E.: A) SECTIONS 2-5 (NW, NE, SW & SE) B) SECTION 6 (NW, NE & SE) C) SECTIONS 8-11 (NW, NE, SW & SE) D) SECTION 14 (NW & NE) E) SECTIONS 15-17 (NW, NE, SW & SE) T.2S., R.5E.: A) SECTION 24 (NW, NE, SW & SE) B) SECTION 25 (NW, NE & SE) C) SECTION 36 (NE & SE)	1990	CITY OF ANN ARBOR - PLANNING DEPARTMENT	AERIAL PHOTOS OF THE ANN ARBOR AREA SHOWING STREETS, WATERBODIES, ETC.
MAINTENANCE REPORTS					
10	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	BIG DRAIN ROUTING LIST	-	CITY OF ANN ARBOR - WATER UTILITIES DEPARTMENT, FIELD SERVICES DIVISION	LIST OF BIG DRAINS WITHIN THE CITY OF ANN ARBOR, INCLUDING ROUTING DIRECTIONS FROM ONE DRAIN TO THE NEXT IN A SYSTEMATIC FASHION.
11	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	STORMWATER SYSTEM MAINTENANCE SCHEDULE MAP	-	CITY OF ANN ARBOR - WATER UTILITIES DEPARTMENT, FIELD SERVICES DIVISION	A MAP OF THE ANN ARBOR AREA SHOWING FOURTEEN SEPARATE MAINTENANCE DISTRICTS WHICH ARE ON THE CITY'S FIVE YEAR MAINTENANCE CYCLE.

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Summary of Data Collected

NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
FEMA FLOODPLAIN STUDIES & MAPS					
12	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	PITTSFIELD TOWNSHIP FLOOD INSURANCE STUDY (FEMA), 1982	FEB. 2, 1982	FEDERAL EMERGENCY MANAGEMENT AGENCY	FLOOD BOUNDARY & FLOODWAY MAPS AND FLOOD INSURANCE RATE MAPS INCLUDING THE PITTFIELD-ANN ARBOR DRAIN AND SWIFT RUN DRAIN.
13	CITY OF ANN ARBOR WATER UTILITIES DEPT.	FLOOD PLAIN MANAGEMENT RESOLUTION OF THE CITY OF ANN ARBOR, MI.	NOV. 19, 1991	CITY OF ANN ARBOR - CITY ADMINISTRATION	CITY RESOLUTION PROVIDING REGULATIONS FOR THE MANAGEMENT OF FLOOD PLAINS IN ACCORDANCE WITH FEMA.
14	FEDERAL EMERGENCY MANAGEMENT AGENCY	LETTER FROM FEMA, REGION V TO MAYOR OF THE CITY OF ANN ARBOR	DEC. 10, 1991	FEDERAL EMERGENCY MANAGEMENT AGENCY	A LETTER INDICATING THAT THE CITY'S FLOOD PLAIN RESOLUTION MEETS THE REQUIREMENTS OF SECTION 44 CFR 60.3 AND THEREFORE MAKES THE CITY ELIGIBLE FOR THE NATIONAL FLOOD INSURANCE PROGRAM.
15	CITY OF ANN ARBOR UTILITIES DEPT. FIELD SERVICES DIVISION	FLOOD INSURANCE STUDY, CITY OF ANN ARBOR, MI. WASHTENAW COUNTY	JAN.2, 1992	FEDERAL EMERGENCY MANAGEMENT AGENCY	STUDY OF STORM WATER FLOODING CAUSED BY: HURON RIVER, ALLEN CREEK OVERLAND FLOW, MALLETT'S CREEK, TRAVER CREEK, EBERWHITE DRAIN OVERLAND FLOW, MURRAY-WASHINGTON DRAIN OVERLAND FLOW, WEST PARK-MILLER DRAIN NORTH, AND BRANCH OVERLAND FLOW.
COMPLAINT FILES AND REPORTS					
16	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, WATER UTILITY DEPARTMENT FIELD SERVICES MONTHLY CALLOUTS	1986-1993	CITY OF ANN ARBOR - WATER UTILITIES DEPT, FIELD SERVICES DIVISION	LISTING OF SEWER (STORM & SANITARY) RELATED MAINTENANCE CALL-OUTS RESULTING FROM RESIDENT COMPLAINTS.
ALLEN CREEK STUDIES					
17	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	REPORT - ALLEN'S CREEK DRAIN WASHTENAW COUNTY DRAIN COMMISSION AND CITY OF ANN ARBOR	SEP., 1972	McNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT DISCUSSING ALLEN'S CREEK DRAINAGE SYSTEM, NEED FOR RELIEF, BASIS OF DESIGN, RELIEF SEWERS, COST ESTIMATES AND RECOMMENDATIONS.
18	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	ALLEN'S CREEK DRAIN - ANALYSIS & PRELIMINARY ALTERNATIVES FOR RELIEF	FEB., 1974	McNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	INTERIM REPORT FOR THE WASHTENAW COUNTY DRAIN COMMISSION INCLUDING A REVIEW OF THE ALLEN'S CREEK DRAINAGE SYSTEM, THE FLOOD PROBLEM, BASIS OF DESIGN, AND FLOOD DAMAGE RELIEF ALTERNATIVES.
19	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	ALLEN'S CREEK DRAINAGE DISTRICT - A PRELIMINARY REPORT ON WATER QUALITY CONDITIONS AND ALTERNATIVES FOR REDUCING WET-WEATHER NON-POINT SOURCE WATER POLLUTION LOADINGS	MAR., 1978	E.W. SAY & ASSOCIATES, INC., ENCOTEC, & HYDROCOMP, INC.	A PRELIMINARY REPORT ON WATER QUALITY CONDITIONS AND ALTERNATIVES FOR REDUCING WET-WEATHER NON-POINT SOURCE WATER POLLUTION LOADINGS. (INCLUDES ALLEN CREEK DRAIN DRAINAGE DISTRICT MAP).
20	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	REPORT ON LIBERTY STREET RETENTION BASIN ON THE MURRAY/WASHINGTON DRAIN	SEP. 15, 1978	McNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	BRIEF REPORT ON THE FEASIBILITY OF DEVELOPING A RETENTION BASIN TO ALLEVIATE FLOODING IN THE ALLEN CREEK BASIN.

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Summary of Data Collected

NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
ALLEN CREEK STUDIES (CONT.)					
21	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI. STORMWATER MANAGEMENT PLAN FOR ALLEN'S CREEK DRAINAGE SYSTEM	NOV., 1982	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT ON THE STATUS OF ALLEN'S CREEK DRAINAGE SYSTEM INCLUDING EXISTING CONDITIONS, RECOMMENDED IMPROVEMENTS, & COSTS
22	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI. STORMWATER MANAGEMENT PLAN FOR ALLEN'S CREEK DRAINAGE SYSTEM	FEB., 1983	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT ON THE STATUS OF ALLEN'S CREEK DRAINAGE SYSTEM INCLUDING EXISTING CONDITIONS, RECOMMENDED IMPROVEMENTS, & COSTS.
23	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	LIBERTY KNOLLS, HYDROLOGIC ANALYSIS	FEB., 1983	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	STUDY ON A NATURAL RETENTION AREA AT LIBERTY ROAD EAST OF DARTMOOR. THE ANALYSIS ESTIMATED THE 100 YEAR STORM WATER SURFACE ELEVATION.
24	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	AS-BUILT DRAWINGS FOR ALLEN'S CREEK DRAIN	-	CITY OF ANN ARBOR - WATER UTILITIES DEPT, FIELD SERVICES DIVISION	AS-BUILT DRAWINGS FOR ALLEN'S CREEK DRAIN FROM STADIUM BLVD. TO THE HURON RIVER (INCLUDING DWGS. 426-R THRU 433-R, 3749-R THRU 3751-R, AND 3980-R THRU 3986-R).
PITTSFIELD-ANN ARBOR DRAIN STUDIES					
25	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	PITTSFIELD-ANN ARBOR DRAIN - PRELIMINARY PROGRESS REPORT	JULY, 1974	McNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	MAP NO. 6 - PITTSFIELD-ANN ARBOR DRAIN - PROJECT LOCATION MAP, SUMMARY OF COMMENT QUESTIONS, AND SUPPLEMENTAL REPORT ON P.A.A.D. - ENCLOSED BRANCH - PROJECT LOCATION MAP.
26	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	PITTSFIELD-ANN ARBOR DRAIN PROJECT PROPOSAL	MAY, 1975	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	PROPOSAL ON ALLEVIATING STORM WATER FLOODING ALONG THE PITTSFIELD-ANN ARBOR DRAIN WITH ANALYSIS, RECOMMENDATIONS, & COSTS.
TRAVER CREEK STUDIES					
27	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	TRAVER CREEK DRAINAGE AREA STUDY, CITY OF ANN ARBOR, MI.	APR., 1969	MIDWESTERN CONSULTING, INC.	STUDY ON THE TRAVER CREEK DRAINAGE AREA WHICH GATHERED DATA & PROVIDED A PRELIMINARY ENGINEERING DESIGN FOR FUTURE STORMWATER FLOWS. INCLUDES CALCULATIONS, DESIGNS, & COSTS.
28	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	REVISED FINAL DESIGN RECOMMENDATIONS FOR TRAVER CREEK, CITY OF ANN ARBOR, MI.	JAN., 1974	MIDWESTERN CONSULTING, INC.	REPORT ON THE FINAL DESIGN RECOMMENDATIONS FOR DRAINAGE IMPROVEMENTS TO TRAVER CREEK. INCLUDES CALCULATIONS, DESIGNS, & COSTS.
29	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	WASHTENAW COUNTY DRAIN COMMISSION, TRAVER CREEK DRAIN, 8-T AREA APPORTIONMENTS WITHIN THE DRAINAGE DISTRICT	APR. 3, 1978 REVISED MAY 9, 1978	MIDWESTERN CONSULTING, INC.	CALCULATIONS FOR TRAVER CREEK DRAINAGE AREA & EQUIVALENT RUNOFF AREA.

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NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
TRAVER CREEK STUDIES (CONT.)					
30	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	DESIGN CALCULATIONS, TRAVER CREEK DETENTION BASIN, PONTIAC TRAIL & US-23, CITY OF ANN ARBOR, MI.	DEC., 1979	MIDWESTERN CONSULTING, INC.	DESIGN CALCUATIONS FOR TRAVER CREEK DETENTION BASIN.
31	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	WASHTENAW COUNTY DRAIN COMMISSION, TRAVER CREEK FLOOD PLAIN DELINEATION	FEB., 1993	MIDWESTERN CONSULTING, INC.	FLOOD PLAIN DELINEATION MAPS FOR TRAVER CREEK.
CITY DESIGN STANDARDS FOR STORM SEWERS					
32	CITY OF ANN ARBOR ENGINEERING DIVISION	STORM SEWER DESIGN STANDARDS	NOV., 1992	CITY OF ANN ARBOR - ENGINEERING DIVISION	CRITERIA FOR STORM SEWER DESIGN INCLUDING CAPACITY REQUIREMENTS, PIPE SIZE, MATERIALS, ETC.
CITY ORDINANCES/CODES					
33	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI CITY ORDINANCE: NO. 2:73. STORMWATER SERVICE CHARGE	NOV. 23, 1983	CITY OF ANN ARBOR - WATER UTILITIES DEPARTMENT	CITY ORDINANCE ON STORMWATER SERVICE CHARGE STRUCTURE. INCLUDES ANNUAL BUDGET, MONTHLY CUSTOMER CHARGES, ESTIMATED REVENUES, ETC.
34	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI., MEMO FROM UTILITIES DIRECTOR TO CITY ADMINISTRATOR	JAN. 11, 1984	CITY OF ANN ARBOR - WATER UTILITIES DIRECTOR	MEMO ON DEVELOPMENT OF STORMWATER UTILITY.
35	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI. MEMO FROM UTILITIES DIRECTOR TO CITY ADMINISTRATOR	FEB. 22, 1984	CITY OF ANN ARBOR - WATER UTILITIES DIRECTOR	MEMO ON DEVELOPMENT OF STORMWATER UTILITY REGARDING RATE STRUCTURE.
36	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	SEWERS & SEWAGE DISPOSAL, CHAPTER 28 OF THE ANN ARBOR CITY CODE	JUL., 1990	CITY OF ANN ARBOR - CITY ADMINISTRATION	CITY ORDINANCE WHICH CONTROLS THE USE OF THE STORM & SANITARY SEWER SYSTEMS.
37	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	WETLANDS & WATERCOURSES PRESERVATION ORDINANCE, CHAPTER 60 OF THE ANN ARBOR CITY CODE	JUN., 1992	CITY OF ANN ARBOR - CITY ADMINISTRATION	CITY ORDINANCE ON THE PRESERVATION OF WETLANDS & WATERCOURSES IN THE CITY OF ANN ARBOR, MI.
38	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	DIVISION VII PSD STANDARD SPECIFICATION - SOIL EROSION & SEDIMENTATION CONTROL	NOV., 1992	CITY OF ANN ARBOR - CITY ADMINISTRATION	CHAPTER 63 OF CITY CODE ON SOIL EROSION & SEDIMENTATION CONTROL. INCLUDES PERMIT REQUIREMENTS & ACCEPTABLE METHODS.
39	BLACK & VEATCH	FEDERAL REGISTER, 44 CFR-60.2	NOV., 1992	U.S. GOVERNMENT	MINIMUM COMPLIANCE WITH FLOOD PLAIN MANAGEMENT CRITERIA.
SOILS REPORTS					
40	U.S. DEPARTMENT OF AGRICULTURE - SOIL CONSERVATION SERVICE	SOIL SURVEY OF WASHTENAW COUNTY, MICHIGAN	1991	U.S. DEPT. OF AGRICULTURE, SOIL CONSERVATION SERVICE	SOIL SURVEY OF WASHTENAW COUNTY WHICH INCLUDES THE GREATER ANN ARBOR AREA.

Table II-1

Summary of Data Collected

NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
CORPS OF ENGINEERS STUDIES					
41	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	SPECIAL FLOOD HAZARD INFORMATION REPORT - HURON RIVER	1972	CORPS OF ENGINEERS, U.S. ARMY, DETROIT DISTRICT	FLOOD HAZARD INFORMATION REPORT FOR THE ANN ARBOR/YPSILANTI AREAS ALONG THE HURON RIVER INCLUDING PAST FLOODS, HISTORIC FLOOD PEAKS, AND FACTORS AFFECTING FLOODING AND ITS IMPACT.
WASHTENAW COUNTY STUDIES					
42	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	NONPOINT POLLUTION IN THE ANN ARBOR-YPSILANTI URBAN AREA: A PRELIMINARY CONTROL STRATEGY FOR THE HURON RIVER WATERSHED	OCT., 1991	WASHTENAW COUNTY DRAIN COMMISSIONER	REPORT ON THE NONPOINT SOURCE POLLUTION FROM THE HURON RIVER WATERSHED & SUBWATERSHEDS.
43	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	WASHTENAW COUNTY, MI., REVIEW OF WATER QUALITY REPORTS CONCERNING THE HURON RIVER IN THE ANN ARBOR - YPSILANTI URBAN AREA	OCT.31, 1991	DOUGLAS WILLIAM JACQUES	REPORT ON THE MAJOR WATER QUALITY STUDIES THAT HAVE BEEN CONDUCTED ON THE HURON RIVER & ITS TRIBUTARIES IN THE LAST 10 YEARS.
USGS MAPS AND STUDIES					
44	U.S. GEOLOGICAL SURVEY	A) ANN ARBOR EAST QUADRANGLE MAP	1965	U.S. GEOLOGICAL SURVEY	QUADRANGLE MAPS OF THE GREATER ANN ARBOR AREA SHOWING STREETS, WATER BODIES, TOPOGRAPHICAL INFORMATION, ETC.
		B) ANN ARBOR WEST QUADRANGLE MAP	1965		
		C) YPSILANTI WEST QUADRANGLE MAP	1967		
		D) SALINE QUADRANGLE MAP	1967		
OTHER PAST STUDIES					
45	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI. INTERIM REPORT ON BASEMENT FLOODING IN THE SEQUOIA PARKWAY & HOLLYWOOD PARK AREAS	AUG. 9, 1968	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT ON BASEMENT FLOODING,DUE TO EXCESS FLOW IN SANITARY SEWERS, WITH ANALYSIS, RECOMMENDATIONS, & COSTS.
46	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI, INDUSTRIAL PRETREATMENT PROGRAM	JULY, 1982	FIELD SERVICES DIVISION & MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT ON THE CITY'S WASTEWATER PRETREATMENT PROGRAM ADDRESSING EPA & MDNR REQUIREMENTS.
47	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI. STORMWATER MANAGEMENT PLAN FOR SELECTED DRAINS ON THE EAST SIDE	JAN., 1983	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT ON THE STATUS OF THE FOLLOWING TRIBUTARIES & THEIR STORM SEWER SYSTEMS: AWIXA DRAIN, VINEWOOD DRAIN, DEVONSHIRE DRAIN, ANN ARBOR WOODS DRAIN, KENSINGTON FARM DRAIN, SWIFT RUN DRAIN TRIBUTARIES, AND NORTH CAMPUS DRAIN. THE STATUS REPORT INCLUDES SITE CONDITIONS, RECOMMENDED IMPROVEMENTS, & COSTS.

Table II-1

Summary of Data Collected

NO.	AGENCY CONTACTED FOR DOCUMENT	TITLE OF DOCUMENT	DATE	PREPARER OF DOCUMENT	TYPE OF INFORMATION RECEIVED
OTHER PAST STUDIES (CONT.)					
48	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	BACTERIOLOGICAL EVALUATION OF HURON RIVER WATER IN VICINITY OF GALLUP PARK & BARTON POND	FEB., 1986	JOHN J. GANNON SCHOOL OF PUBLIC HEALTH UNIVERSITY OF MICHIGAN	EVALUATION OF THE BACTERIOLOGICAL WATER QUALITY OF THE HURON RIVER AT GEDDES & BARTON PONDS, THE BACTERIOLOGICAL CONTRIBUTIONS TO THE HURON RIVER FROM MAJOR STORMWATER DRAINS AND THE DEVELOPMENT OF A MODEL FOR PREDICTING BACTERIOLOGICAL LEVELS AND THE APPROPRIATENESS OF A NEW BACTERIOLOGICAL INDICATOR.
49	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	CITY OF ANN ARBOR, MI., GREEN ROAD STORM SEWER STUDY (PRELIMINARY)	APR., 1986	MCNAMEE, PORTER & SEELEY CONSULTING ENGINEERS	REPORT ON STORM WATER FLOODING ON GREEN ROAD NORTH OF PLYMOUTH ROAD. INCLUDING ANALYSIS, RECOMMENDATIONS, & COSTS.
50	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	THE COST OF BIOLOGICAL FIELD MONITORING	MAR. 16, 1990 REVISED FEB. 19, 1991	STATE OF OHIO ENVIRONMENTAL PROTECTION AGENCY	REPORT ON BIOLOGICAL FIELD MONITORING INCLUDING DATA COLLECTION, DEVELOPMENT OF ASSOCIATED COSTS AND IMPORTANCE OF MONITORING.
51	DAVE DRULLINGER MDNR	WATERSHED RESTORATION SOURCEBOOK (INCOMPLETE)	APR., 1992	ANACOSTIA RESTORATION TEAM, DEPT. ON ENVIRON. PROGRAMS, METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS	REPORT DISCUSSING IMPERVIOUS SURFACES AND THEIR IMPACT ON WATERSHEDS.
52	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	ALTERNATE MONITORING METHODS TO ASSESS THE IMPACTS OF STORMWATER & THE EFFECTIVENESS OF MANAGEMENT PRACTICES	July 1992	STATE OF OHIO ENVIRONMENTAL PROTECTION AGENCY	THE REPORT DISCUSSES ALTERNATIVE MONITORING METHODS FOR DETERMINING STORMWATER IMPACTS. THE REPORT FOCUSES ON INVESTIGATION OF POLLUTANTS IN WATER BODIES THROUGH SEDIMENT & ORGANISM ANALYSIS.
53	CITY OF ANN ARBOR WATER UTILITIES DEPT. FIELD SERVICES DIVISION	ALTERNATE MONITORING METHODS TO ASSESS THE IMPACTS OF STORMWATER & THE EFFECTIVENESS OF MANAGEMENT PRACTICES; PART 2 - BIOLOGICAL MONITORING	May 1993	STATE OF OHIO ENVIRONMENTAL PROTECTION AGENCY	THE REPORT FOCUSES ON THE INVESTIGATION OF POLLUTANTS IN WATER BODIES THROUGH BIOLOGICAL ANALYSIS.
MONITORING DATA FROM THE STORMWATER NPDES STUDY					
54	BLACK & VEATCH	CITY OF ANN ARBOR NPDES PERMIT PROGRAM MUNICIPAL SEPARATE STORM SEWER SYSTEM PART 2 APPLICATION INFORMATION - CHAPTER 3	MAY, 1993	BLACK & VEATCH	CHAPTER 3 SUMMARIZES THE MONITORING PROGRAM, DATA COLLECTED, MODELING COMPLETED, MODELING RESULTS, AND FUTURE NEEDS

B. Stormwater Ordinances and Design Criteria Assessment

The City of Ann Arbor regulates its stormwater system through the following documents:

- Chapter 28 of the City Code - Sewer and Sewage Disposal
- Chapter 33 of the City Code - Stormwater System
- Chapter 60 of the City Code - Wetland and Watercourses Preservation Ordinance
- Chapter 63 of the City Code - Soil Erosion and Sedimentation Control
- Standard Specifications of the Public Services Department - Storm Sewer Design
- Chapter 3 of the Drain Code
- Chapter 4 of the Drain Code
- City Council Resolution dated November 18, 1991 - Floodplain Management Resolution

These documents provide the general authority to allow the City to control the quality and conveyance of stormwater and the technical criteria to design and operate a stormwater conveyance system.

Chapters 28, 33, and 63 were reviewed as part of the City's application to the Environmental Protection Agency's (EPA's) Stormwater National Pollutant Discharge Elimination System (Stormwater NPDES) program. The review indicated that in general, the City has adequate legal authority to control the municipal separate storm sewer system. Chapter 28, through sections 2:42, 2:43, 2:44, 2:45, and 2:50, controls objectionable discharges into the storm sewer system; allows the Water Utility Director to require discharge permits of industrial users; provides for inspection, surveillance and monitoring activities; and allows for enforcement of the storm sewer regulations. Chapter 33 has recently been modified and expanded to provide a more comprehensive document.

Chapter 33 establishes a stormwater utility and provides the Water Utilities Director with the authority to promulgate regulations for the operation, management, and maintenance of the storm sewer system - including the authority to assign, bill, and collect service and flat-rate charges for use of the stormwater system. It also allows for control of discharges into the storm sewer system and regulating permit conditions.

Chapter 63 provides for controls for soil erosion and sedimentation during and after construction and requires permits for land distributing activities related to construction. Chapter 63 also specifies violations and penalties for discharging sediment into the storm sewer system and addresses runoff calculations and stormwater retention facilities.

Chapter 60 addresses wetland and watercourse management. It provides for the protection, management, enjoyment, identification, controlled use of wetlands and watercourses, and required permits for activities in wetlands and watercourses. Specific regulations, review standards and replacement and restoration standards are also included.

The standard specifications of the Public Services Department provides the storm sewer design criteria. This document specifies the necessary engineering data to design a storm sewer system. Information provided includes capacity requirements, sewer pipe size, grade, material, depth and location requirements, sewer manholes, inlets, extraneous connection information, siltation/soil erosion control, stormwater retention/detention, and construction document requirements.

Chapter 3, Sections 11.051 through 11.1054 of the Drain Code, provides for the establishment of a county drainage district and the type of construction and design of the drains. Chapter 4, Sections 11.1073 and 11.1074 of the Drain Code, provides for plans, specifications, rights-of-way, and approval of a proposed drain.

The City Council's November 18, 1991 Floodplain Management Resolution, as approved by the Federal Emergency Management Agency (FEMA), Region V, provides for continued participation in the National Flood Insurance Program. The resolution provides flood plain regulations to reduce hazards to persons, property damage, and public expenditures and how to qualify for flood insurance and Federal funds or loans.

In general, the City's stormwater related codes identified above are in order. Each city has its own method for analysis, design, and enforcement of stormwater related policies. There is no one correct method or policy - the policies that are in line with the City's philosophy for stormwater management are best and most appropriate for the City officials and the residents. Policies/regulations which the city may want to consider reviewing include the following:

- Open Channel Design

  The standard specification for conveyance system design does not contain specific criteria regarding open channels, including lining material preferences, side slopes, alignment, and channel easement requirements (mainly for maintenance access).

- Design Storm

  The 10-year design storm intensity equation is the only one provided in the standards. This implies that all stormwater system components will be sized for the 10-year event. The City may wish to consider other, more conservative design events, such as the 25, 50, or the 100-year storm for larger, stormwater system components, or those facilities that pass near, or beneath high priority structures, such as major arterials, and State and Federal highways. The City may also wish to include the more frequent events, such as the 2- and 5-year design storms, for use in developing improvements in existing developed areas where present design standards do not allow for practical and cost-effective improvements.

  To conform to the requirements of FEMA, and other federal agencies, the City may want to include a basis for the 24-hour design storm; particularly since Flood Insurance Studies are typically completed using the SCS 24-hour design storm distribution. Additionally, if stormwater planning and design tools such as XP-SWMM, HEC-1, and other hydrologic computer models are used, a standardized rainfall distribution will be required to assure consistency in the hydrologic modeling.

- Other Design Tools

  Presently the Rational Equation is the hydrologic design method stipulated in the Design Standards. It is a widely used and appropriate method for estimating flows for the design of the stormwater conveyance system. With the development of this Master Plan, the City may want to consider expanding the hydrology section to include the use of XP-SWMM as a basis for the analysis and design of conveyance system components above a stipulated drainage area.

- More Stringent Flood Plain Regulations

  Although not generally favored by developers and land owners, development of stringent flood plain regulations, above those adopted by FEMA, can prove beneficial in the future. The City may wish to consider limitations on location of structures based on a specified minimum vertical elevation above the 100-year floodwater surface elevation, or generate 100-year floodwater surface elevations based on future land use scenarios, instead of the present land use scenarios used by

FEMA. This will primarily be beneficial in the newly developing areas and not to the established areas in Ann Arbor.

- Include Property Acquisition as a Standard Improvement Alternative

  Although purchase of properties is detrimental to the City's tax base, property acquisition can be a very cost-effective method for reducing the extent of flood damages. And with the redevelopment of the property to a park or open space (designed to allow for flooding), recreational and aesthetic benefits can far outweigh the loss of tax revenue and eliminate a flooding condition.

C. Historic Flooding Locations

A list of historic flooding locations was developed as a basis for identifying where the Master Plan should focus for improvement development and to provide a basis for mailing of the stormwater questionnaire. The following two sources of information were used to identify these flooding locations:

- A meeting was held at Field Services Division office (December 1993) to discuss flooding problems throughout the City. City staff, including Don Lucas, Fred Hatfield, and Bill Alber identified stormwater areas where frequent flooding problems exist within the City.
- A record of complaint reports was obtained from City staff. Resident complaints from 1989 to 1993 were reviewed.

The data collected from the two referenced sources above provided the basis for the historic flooding locations identified on Figure II-1.

D. Conveyance System Labeling Scheme

At the inception of the Stormwater Master Plan, Ann Arbor did not have a labeling scheme for the stormwater conveyance system network. The labeling scheme for the stormwater conveyance system has been developed to adhere to the system presently used for the sanitary sewer system. The scheme consists of a unique 10-digit alpha-numeric label for each conduit and node. The labeling scheme is as described on Figure II-2.

Table II-2
Labeling Scheme for Conveyance System

Digit	Description
1-2	Township number
3-4	Section number
5	1/4 Section number
6-8	Structure number
9	Type of structure
10	Identifier for manholes and "dummy nodes"

The first eight digits of the label are identical to the labeling scheme used for the sanitary sewer system--the first five digits identify the location of the structure (township, section, and quarter-section) and the next three digits provide a structure number. To comply with the needs of the stormwater model, fields 9 and 10 have been added.

E. Watershed Data

Ann Arbor is comprised of eight watersheds: Allen Creek, Fleming, Honey, Huron, Mallets, Miller, Swift Run, and Traver Creek. The stormwater conveyance systems modeled in each watershed are generally contiguous segments of 36-inch and larger underground system facilities and the larger open channels. Although, the watershed boundaries extend beyond the Ann Arbor City limits, the conveyance systems modeled are limited to that portion of the system residing within the Ann Arbor City limits. The sewer index maps, combined with field investigations provided the basis for development of the conveyance system model. Figure II-3 shows the eight watersheds and the existing stormwater conveyance system modeled. Table II-3 presents a summary for the eight watersheds.

Table II-3
Watershed Drainage Area and Conveyance System Statistics

Watershed	Area (Acres)	Number of Subareas for Modeling	Number of System Elements$^{(1)}$	Length of System (feet)
Allen Creek	3,398	46	274	62,190
Fleming	322	9	39	6,260
Honey	474	17	44	10,880
Huron	1,577	27	102	17,460
Mallets	6,906	69	315	96,450
Miller	1,552	16	70	22,670
Swift Run	1,617	14	38	14,025
Traver Creek	4,566	18	54	23,240

(1)The "System" information presented includes conduits and open channels but does not include manholes.

Additional data collected for the watersheds to aid in development of the stormwater model included land use and soils characteristics. The land use is presented on Figure II-4 and was provided by Ann Arbor Information Services Division as an Arc/Info GIS coverage. The soils data presented on Figure II-5 was obtained from the Michigan Department of Natural Resources and Soil Conservation Service in digital format and was converted to Arc/Info GIS coverages.

III. Field Monitoring Program

A. Introduction

A field monitoring program was established to measure and record rainfall data and stormwater conveyance system flow data. The decision to proceed with the field monitoring program was based on the fact that the City had the necessary rain gauge and flow monitoring equipment remaining from the Stormwater NPDES permit application development project.

Three rain gauges and five flow monitors were utilized for the field monitoring program. The five flow monitors were cycled between ten locations while the three rainfall gauges remained at the same locations for the duration of the monitoring program. Table III-1 presents a summary of the locations of the flow monitors. The rain gauges were located at easily accessible and "secure" sites. The rain gauge locations included the Water Utilities Department, Field Services Division; the Water Treatment Plant; and the Fire Station on Jackson Road. The flow monitoring locations were selected by project staff and City personnel.

The ten sites for the flow monitoring program were identified based on field visits by project and City staff. The purpose of the field visits was to determine if the location was easily accessible, had a manhole lid which permitted installation of the flow monitor, had a sufficient reach of straight pipe entering and leaving the manhole to minimize flow turbulence, and if the conduit had a diameter less than the maximum measurable level of the flow monitor's depth sensor.

Table III-1

Summary of Flow Monitor Locations

Location ID	Sewer Index Map	Modeling Structure ID	Watershed	Description
MS-1	J7	09294011R0	Allen Creek - Eber-White Drain	Manhole on 1st Street, north of William Street
MS-2	J7	09292014R0	Allen Creek - Murray-Washington Drain	Manhole on Murray Avenue, south of Washington Street
MS-3	I7	09292007R0	Allen Creek - West Park-Miller Drain	Manhole on Chapin Street, south of Miller Avenue
MS-4	J6	09343005R0	Allen Creek - Industrial Park Drain	Manhole on Dartmoor Road at Ivywood Drive
MS-5	I8	09213000C7	Traver Creek	Culvert at Broadway Road Bridge
MS-6	M9	12034003R0	Mallets	Manhole on Towner Boulevard, east of Cranbrook Road
MS-7	L8	12041001R0	Mallets	Manhole on Harpst Street at Page Avenue
MS-8	N8	12093004R0	Mallets	Manhole east of Research Park Drive, north of Ellsworth Road
MS-9	J9	09224000C1	Miller	Culvert at Glazier Way, east of Huron Parkway
MS-10	M9	12023001R0	Swift Run	Manhole north of Packard Road, west of Whitewood Street

B. Results of Flow Monitoring Program

Most of the flow monitoring was completed in the spring, summer, and fall of 1994. For that period of time, data on the storm events collected identified that the storms were low intensity, low volume storms. Incorporation of these events into the computer model did not produce adequate calibration results. Because of the lack of higher intensity and duration storms, the flow monitoring data was not used in the development and calibration of the stormwater model.

IV. Stormwater Questionnaire

A. Introduction

A stormwater questionnaire was prepared and distributed to approximately five percent of the City's residents. The questionnaire was developed to request information from residents on the location, extent, and severity of known flooding conditions throughout the City. The intent of the questionnaire responses was to identify and classify historic flooding locations (in addition to those identified by City staff) for purposes of verifying and assessing the validity of the stormwater model, and to provide a means for resident input. Both are equally important to the overall success of the Master Plan. Citizens are generally more receptive and supportive of the results and recommendations of a master plan when they have input to the project.

B. Questionnaire Development

The stormwater questionnaire was developed in response to needs generated by the project team and City staff to identify what stormwater flooding issues are important to residents, City staff, and overall goals of the project. A cover letter was included with the questionnaire to inform the residents of the ongoing Stormwater Master Plan project, explain the purpose of the questionnaire, convey the importance of their participation, and urge them to respond. The questionnaire was developed to be concise and minimize the time required to fill out and return the questionnaire--this included providing postage and a return address on the back side of the questionnaire. Once the resident responded to the questionnaire, he/she simply folded it so that the return address and postage was showing, and placed it in the mail. With the incorporation of the City's Geographic Information System (GIS), the questionnaire was developed to provide responses that could be coded into a database and queried by the GIS. Although this methodology did not allow for residents to expand on their response, it did provide a straightforward means for interpreting and displaying the responses consistently with the GIS. Additional comments were requested, but were not necessarily used in the GIS analyses. An example of the stormwater questionnaire and accompanying transmittal letter are presented on Figures IV-1 and IV-2.

FIGURE IV-1
STORMWATER QUESTIONNAIRE

1. Date ________________

2. What is your name and street address? (Attach Pre-Printed Label or Print)

____

(Name - Optional)

____

(Street No. & Name - Ave., Rd., etc.)

____

(City, State & Zip)

____

(Subdivision Name), if known

3. Has any of the following occurred in your area? Circle one number for each item.

	Major Problem	Minor Problem	Not a Problem	Don't Know
Basement Flooding	1	2	3	4
Street Flooding	1	2	3	4
Backyard Flooding	1	2	3	4
Trash and Debris in Ditches	1	2	3	4
Erosion	1	2	3	4

4. Has rainfall or stormwater entered your home or business in the past? Circle as many sources as applicable.

   1. No Water has entered
   2. Floor drains
   3. Bathtub, toilet or sink
   4. Windows or window wells
   5. Leaks in floor or walls
   6. Other ________________
      ____

5. Has flooding occurred around your home or property? Circle as many as applicable.

   1. No flooding has occurred
   2. Flooded yard, little or no damage
   3. Damage to lawn, trees or shrubs
   4. Damage to fences or buildings
   5. Erosion of ditches
   6. Other
      ____
      ____

6. Has flooding occurred in a street near your home? Circle one.

   1. No
   2. Yes - If so, where? Intersection of ________ & ________

7. How many times has flooding occurred at your location during the past five years? Circle one number.

   1. Has not occurred
   2. One time
   3. Two times
   4. Three times
   5. Four times
   6. Five or more times

   Briefly discuss (i.e., describe situation)____
   ____
   ____

8. Do you live next to a creek or drainage ditch?

   1. Yes
   2. No

9. Additional comments or concerns.

____

____

____

FIGURE IV-2
TRANSMITTAL LETTER FOR STORMWATER QUESTIONNAIRE

June 9, 1994

Re: Stormwater Master Plan Drainage Studies

Dear Homeowner:

We need your help to develop a long-term management plan for stormwater facilities in your area. The present and future environmental quality of life of our neighborhoods is important to the City. As part of an overall program to ensure continuous improvements to this quality of life and economic viability, flooding situations need to be addressed and a comprehensive plan for stormwater management developed.

The Utilities Department has recently contracted with a consulting firm, Black & Veatch, to provide preliminary facilities planning and engineering analysis as well as to assist us with any necessary field investigations toward this effort. By sharing your experience with any flooding in your area, you can make certain all these situations are addressed and that an appropriate and more complete master plan is developed for our community.

How can you assist us? Please take a few minutes to complete the enclosed questionnaire and mail it in the pre-addressed, stamped envelope provided.

Thank you for your cooperation and assistance. If you have any questions, please call Pete Perala, City of Ann Arbor, (313) 994-1760.

Yours truly,

Frank R. Porta, Utilities Director

clr/4738/R

cc: Black & Veatch

Questionnaires were mailed out in July 1994 and responses received through October 1994. Residents were selected to receive the questionnaire based on the following criteria:

- Residents living along major stormwater conveyance systems (both enclosed and open channels).
- Review of Field Services Division's stormwater complaints file. Resident complaints from 1989 to 1993 were incorporated into the mailing list. Nearly 60 percent of these complaints were from residents who live along the major stormwater conveyance systems identified above.

Nearly 13,000 residents/occupants and 7,000 property owners were identified through these two criteria. To limit excessive project costs while maintaining a statistically relevant sample distribution, the stormwater questionnaire was mailed to approximately 5,400 residents/occupants and owners. Generation of mailing labels was automated through involvement of the City's Administrative Services, Information Services Division. City block address ranges for the residents selected for receiving the questionnaire were developed and provided to Information Services Division staff. In addition to generating the mailing labels, Information Services Division staff also provided a unique number for each label to automate the matching of the questionnaire to an address in the GIS. The unique number and the associated responses to the returned questionnaires were keyed in to the database. This unique number eliminated data entry errors for the addresses and address matching.

C. Summary of Responses

Tables IV-1 through IV-6 present summaries of responses to the questionnaire. Figure IV-3 presents the locations of the responses that identify major, minor, and no flooding problems as compared to the system inadequacies identified through the computer modeling (see Chapter VII). A good correlation exists between the identified system inadequacies and the questionnaire responses along the reaches of conveyance system that was modeled. Responses that are a measurable distance away from the conveyance system are most likely on smaller system components that drain to the analyzed system. These flooding problems may be alleviated with the improvements to the identified inadequacies since the amount and extent of system surcharging will be significantly reduced. Additionally, the identified inadequacies are based on future land use, so system inadequacies may be identified where flooding does not presently exist. This approach

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Table IV-1
Stormwater Questionnaire Summary

Watershed	Number of Questionnaires Mailed	Number of Responses Returned
Allen Creek	1,682	517
Fleming	283	101
Honey	80	33
Huron	139	58
Mallets	1,768	475
Miller	315	94
Swift Run	442	96
Traver Creek	371	75

Table IV-2
Summary of Question 3
"Has any of the following occurred in your area:
Basement Flooding/Street Flooding/Backyard Flooding/
Trash and Debris in Ditches/Erosion?"

Watershed	Major Problems	Minor Problems	No Problems	Don't Know
Allen Creek	136	301	1,523	284
Fleming	15	50	319	63
Honey	10	31	87	14
Huron	12	39	199	18
Mallets	114	274	1,441	285
Miller	28	45	311	29
Swift Run	30	60	281	57
Traver Creek	7	41	267	35

Note: Each questionnaire response had the potential for providing five responses to major problem, minor problem, no problem, don't know--one each for (1) basement flooding; (2) street flooding; (3) backyard flooding; (4) trash and debris in ditches; and (5) erosion.

Table IV-3
Summary of Question 4
"Has rainfall or stormwater entered your home or business in the past?"

Watershed	No	Floor Drains	Bathtub Toilet or Sink	Windows/ Window Wells	Floors or Walls	Other
Allen Creek	318	51	6	32	95	36
Fleming	63	9	1	10	20	3
Honey	20	7	1	4	8	2
Huron	32	8	1	6	14	2
Mallets	261	58	7	35	109	29
Miller	60	4	0	8	12	10
Swift Run	60	8	0	7	24	7
Traver Creek	52	0	0	8	10	3

Table IV-4
Summary of Question 5
"Has flooding occurred around your home or property?"

Watershed	No	Yard Flooding	Damage to lawn/trees	Damage to fences/ buildings	Erosion of Ditches	Other
Allen Creek	350	75	15	11	13	29
Fleming	78	17	2	1	1	1
Honey	23	9	1	1	0	2
Huron	41	7	4	1	1	4
Mallets	318	88	15	9	8	21
Miller	60	20	3	3	5	3
Swift Run	60	21	3	1	4	8
Traver Creek	58	8	1	0	2	2

Table IV-5
Summary of Question 6
"Has flooding occurred in a street near your home?"

Watershed	No	Yes
Allen Creek	414	103
Fleming	95	6
Honey	27	6
Huron	45	13
Mallets	415	60
Miller	82	12
Swift Run	65	31
Traver Creek	66	9

Table IV-6
Summary of Question 7
"How many times has flooding occurred at your location during the past 5 years?"

Watershed	Never	Once	Two Times	Three Times	Four Times	Five or More
Allen Creek	307	25	24	20	14	68
Fleming	69	6	1	4	1	8
Honey	18	3	1	1	1	6
Huron	36	3	4	5	1	6
Mallets	308	17	26	19	11	46
Miller	57	3	1	1	2	16
Swift Run	57	7	3	3	2	14
Traver Creek	51	3	3	2	0	2

V. Preliminary Needs Assessment

A. Introduction

The identification of present and future needs for the full development of the Stormwater Master Plan is important to assess what needs to be considered now, while recognizing that some are a future action item. The Ann Arbor Water Utilities Department is making a conscious effort to be proactive in the development of the Stormwater Master Plan, to develop an action plan for the resolution of existing flooding problems, and to identify potential future flooding problems and appropriate solutions. The Water Utilities Department recognizes that the Master Plan will not be a static document; it will be the basis for the future development of the stormwater system, including the identification and alleviation of flooding problems and the development and enforcement of stormwater regulations. With this goal in mind, several items have been addressed in the Master Plan that either impact the deliverables or provide a solid foundation on which the City will continue to develop the Master Plan.

B. GIS Requirements

The Water Utilities Department, as well as other City departments, has an excellent opportunity to properly integrate GIS through the City's Administrative Services, Information Services Division staff. The Information Services staff is responsible for city-wide GIS services, including development and upkeep of basemap coverages. The Information Services staff has been involved throughout the development of this Stormwater Master Plan, and has had input in the creation of GIS data sets. Information Services staff has been working with and supporting the Water Utilities Department staff for obtaining GIS hardware, software, and training. At this time, the Water Utilities Department has purchased and obtained an IBM UNIX workstation, Arc/Info GIS software, necessary training, and have hired GIS staff. In addition to the field data needs discussed below, additional training may be required in the future as the Water Utilities Department continues to implement GIS.

C. Additional Field Data

Field investigations were performed to verify specific components of the stormwater system; however, a majority of the physical data for the conveyance system (size, type, invert elevations) were obtained from the sewer index sheets and as-built drawings. Because of the lack of consistency and accuracy between the data sources, the additional field data necessary to continue to develop the GIS data and the computer model input files requires a comprehensive field survey of the conveyance system. Due to limitations of planning-level data collection, it is important that the conveyance system physical data be verified and updated as necessary. The new data will not only aid in the computer modeling, but should fit in with the Water Utilities Department development of a comprehensive system inventory and operation and maintenance programs. One critical component of the conveyance system physical data that was not readily available was information on the smaller local detention basins.

D. General Corrective Measures

The proper development of a stormwater conveyance system from the master planning level to design, construction, operation, and maintenance includes identification and qualification of corrective measures to be implemented. Historically, corrective measures have focused principally on structural improvements such as channel lining and enclosing open channels. Although effective, these solutions are not necessarily consistent with the present views of City officials and residents, and they do not positively impact water quality and present and future peak flow reduction. Figure V-1 presents the corrective measures discussed below.

1. Introduction

The application of corrective measures will be only as good as the methods used to identify the problems, their locations, and the most appropriate combination of measures to provide practical solutions. The corrective measures available for a comprehensive Stormwater Master Plan can be divided into two basic categories--storm drainage system improvements and flood plain improvements. The main difference between them is the location of the improvements. Storm drainage system improvements are aimed at lowering flood water elevations or eliminating the flooding altogether. Flood plain improvement measures, on the other hand, are directed at limiting the damage caused by flooding. The flooding, however, will still occur and the flood water elevations will usually remain the same.

Storm drainage system improvements can be divided into two components: (1) maintenance and (2) system component construction. A portion of maintenance, which requires special attention, is system initialization. System initialization is the work required to restore the components of the storm drainage system to their initial, or appropriate, hydraulic capacities. Although considered as part of maintenance, the level

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FIGURE V-1
General Corrective Measures

- **Stormwater System Improvements**
  - System Initialization(2)
  - Maintenance
    - Regular
      - Regular and Periodic Site Visits and Evaluations
      - Silt Removal
      - Channel and Culvert Cleaning
      - Channel Grubbing and Mowing
      - Storm Sewer System Cleaning
    - Remedial
      - Channel Bank Improvements
      - Silt Removal
      - Channel and Culvert Cleaning
      - Minor Structural Rehabilitation
      - Storm Sewer System Cleaning
      - Detention and Retention Cleaning(1)
  - System Component Construction
    - Channel Lining
    - Pilot Channel Improvements
    - Detention / Reten. Storage
    - Culvert / Bridge Modifications
    - Culvert / Bridge Replacement
    - Channel Reshaping and Realignment
    - Storm Sewer System Modifications
    - Storm Sewer System Replacement
- **Floodplain Improvements**
  - Planning Process Efforts
    - Flood Planning Preparedness
    - Zoning
    - Land Acquisition
    - Floodplain Management Enforcement
    - Stormwater Runoff Regulations
  - Physical Improvements
    - Erosion and Sediment Controls
    - Flood Proofing (Wet and Dry)
    - Minor Flood Walls / Berms
    - Elevating Structures
    - Building Relocation / Removal

(1) Responsibility of property owner

(2) System Initialization Components are consistent with, but more expensive than the Remedial Maintenance components and have therefore not been repeated in the text. See the discussion for Remedial Maintenance for the component descriptions.

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of effort involved in system initialization falls between remedial maintenance and system components construction. It is a one-time task and is carried out before the implementation of a regular maintenance plan. System initialization is similar to remedial maintenance in that the intent is to upgrade existing facilities to their original capacity. The difference, however, is in the timing. System initialization is a one-time effort whereas remedial maintenance may be required after each major storm. The descriptions of corrective measures in the remedial measures section are applicable to system initialization.

The solution to storm drainage problems in a watershed typically consists of a combination of drainage system improvements and flood plain management improvements. Both categories are of equal importance, and usually neither is adequate by itself when considering not only alleviation of flooding, but also project life expectancy, cost-benefit, future maintenance and upkeep, initial cost, effects on water quality, and compliance with local, state, and federal laws. The water quality issue is becoming increasingly important. Recent regulations (the National Pollutant Discharge Elimination System, or the NPDES regulations, which were signed October 31, 1990) will require communities such as Ann Arbor to monitor stormwater quality and to evaluate measures such as erosion repair, infiltration swales, or detention/retention basins to improve the water quality.

The general corrective measures available and applicable to the City of Ann Arbor's watersheds are discussed below. Figure V-1 presents a schematic of the divisions of available corrective measures.

2. Storm Drainage System Improvements

A key element in improving an existing storm drainage system is to provide practical improvements; however, a more vital element is to assure that the improvements are provided at the necessary level and at the appropriate time. For example, although a section of channel may be inadequate, timely cleaning or reshaping the channel may be a more appropriate solution than lining it with concrete later. The intent of such a measure is to provide an early improvement to the storm drainage system without the expense or effect associated with capital improvements. Such upgrading measures are practical and cost-effective, and are categorized as system initialization.

a. Maintenance. Maintenance is defined as the upkeep necessary for efficient operation of the system. The theory is that it is better to maintain a facility now than to rebuild it later. In general, maintenance can be categorized as regular maintenance and remedial maintenance.

Regular maintenance differs from remedial maintenance in the scope, level of effort, and timing. If the regular maintenance program cannot keep pace with deterioration, the program should be adjusted or supplemented before remedial maintenance or structural improvements become necessary. Regular maintenance is repetitive, whether it be several times each year as for channel mowing, or once every five years as in the case of channel and culvert cleaning. Remedial maintenance, however, is the effort necessary to return a system component to proper condition after it has been damaged.

The criterion for differentiating between remedial maintenance and the need for replacing a component is whether the component will function properly when returned to its intended use after remedial maintenance.

(1) Regular maintenance. Regular maintenance of storm drainage facilities is defined as the necessary repetitive attention to all components of the system to assure that it continues to operate as designed. Improving regular maintenance of existing facilities could potentially alleviate flooding without the need for costly construction of additional system components. For future facilities, proper planning, design, and construction, supplemented with a well-planned regular maintenance program, is vital. Examples of regular maintenance tasks are listed below. Regular maintenance is repetitive; however, requirements can vary from year to year depending on the frequency and intensity of storms and the general conditions in the watershed. This is further discussed for each type of regular maintenance:

- Regular and periodic site visits and evaluations.
- Silt removal.
- Channel and culvert cleaning.
- Channel grubbing and mowing.
- Storm sewer system cleaning.

(a) Regular and periodic site visits and evaluation. The site evaluation is usually done early in the spring and after major rainfall events. The purpose is to inspect the condition of major channels and structures and to identify maintenance requirements, both regular and remedial, as well as the need for constructing or replacement of system components. Site investigations should also be made after major rainfall events to check on damage and to identify possible preventive measures against future damage.

(b) Silt removal. Silt removal is part of regular maintenance to keep the channels and culverts clean from solids deposits. Siltation is the result of the erosion from upstream construction sites; channel erosion caused by high flow velocities and inadequate channel protection; and runoff from impervious areas, particularly in highly urbanized districts. The amount and frequency of silt removal will vary depending on the location and the frequency and intensity of rainfall events.

(c) Channel and culvert cleaning. Channel and culvert cleaning consists of removing large debris such as tree limbs, abandoned shopping carts, household items, and tires, to name a few. Locations and amounts of debris are typically identified during site investigations. Cleaning is typically performed once each year, usually in the spring.

(d) Channel grubbing and mowing. Channel grubbing and mowing consists of removing unwanted vegetation within the limits of the channel section and maintaining the wanted vegetation to improve the capacity of the channel. Typically, grubbing at the regular maintenance level is done with light equipment only. Primary locations for grubbing are channel sections where the overgrowth of trees and brush has progressed beyond the scope of mowing. Channel grubbing should be performed once each year at locations where needed.

Although channel mowing is one of the more obvious maintenance procedures, it is sometimes forgotten or considered an unnecessary task. Often, steep slopes or the overgrowth of trees and brush make mowing channel banks difficult or impossible; however, mowing is crucial to maintaining the channel capacity. The required frequency of mowing depends primarily on the amount of rainfall. Typically, it should be scheduled three times a year.

(e) Storm sewer system cleaning. Storm sewer system cleaning consists of cleaning debris and silt from inlets, manholes, and the underground conveyance system so that the system can operate as intended. Locations and amounts of debris and silt are typically identified during site investigations. Cleaning is typically performed once each year, usually in the spring.

(2) Remedial maintenance. Remedial maintenance involves upgrading the storm drainage system to a degree beyond regular maintenance, but to a lesser extent than system component construction. Where a regular maintenance program has been implemented, remedial maintenance should be necessary only after major storm events. Typical remedial maintenance tasks to correct system deficiencies are as follows:

- Channel bank improvements.
- Silt removal.
- Channel and culvert cleaning.
- Minor structural rehabilitation.
- Storm sewer system cleaning.

(a) Channel bank improvements. Channel bank improvements consists of reconfiguring the channel to stabilize its cross-section, make it easier to maintain, reduce the erosion potential, and increase the channel capacity. Typical improvements include minor reshaping to increase channel capacity or to improve maintainability of its cross-section, and providing erosion control such as riprap, gabion baskets, concrete, or a fabric liner to reduce the erosion potential. At the remedial maintenance level, channel bank improvements are most likely to be needed near existing structures (both upstream and downstream) and at locations where the original cross-section has become inadequate, such as at bends in the channel, or where the existing channel bank material is not suitable or is generally saturated and difficult to maintain. A secondary benefit of channel bank improvements is the potential for reducing siltation downstream since upstream erosion is being reduced.

(b) Silt removal. Silt removal at the remedial maintenance level consists of the same type of work as regular maintenance. The difference is in the timing. Silt removal at the remedial maintenance level should be necessary only after major storm events, and therefore, the frequency and level of effort will vary.

(c) Channel and culvert cleaning. Channel and culvert cleaning at the remedial maintenance level consists of the same type of work as regular maintenance. The difference is in the timing. Channel and culvert cleaning at remedial maintenance level should be required only after major storm events, and therefore, the frequency and level of effort will vary.

(d) Minor structural rehabilitation. Minor structural rehabilitation consists of improvements to the structural components of the system. These improvements are often necessary after major storm events where either the volume or velocity of the stormwater flows, or debris carried by the stormwater, has degraded and damaged the system's integrity to the point of creating potentially dangerous conditions.

(e) Storm sewer system cleaning. Storm sewer system at the remedial maintenance level consists of the same type of work as described for the regular maintenance. The difference is in the timing. Cleaning at remedial maintenance level should be required only after major storm events; therefore, the frequency and level of effort will vary.

b. System Component Construction. System component construction involves improvements to the conveyance system to reduce or alleviate present flooding, to eliminate the potential for future flooding, and to replace deteriorating or structurally deficient components. System component construction is the most obvious and most labor- and cost-intensive corrective measure and is not always the most practical or cost-effective. Detailed assessments should be performed to assure that construction is necessary, and that maintenance, either regular or remedial, is not more appropriate. If it is determined that system component construction is the most practical and cost-effective corrective measure to be used, care must be taken to thoroughly analyze the conditions to minimize costs. The more practical system component construction measures to alleviate flooding, for both present and future conditions, are listed below:

- Channel lining.
- Pilot-channel improvements.
- Detention/retention storage.
- Culvert and bridge modifications.
- Culvert and bridge replacement.
- Channel reshaping and realignment.
- Storm sewer system modifications.
- Storm sewer system replacement.

(1) Channel lining. As a form of bank stabilization and erosion protection, channel lining is also used to increase the capacity of a channel section by decreasing its roughness. When used to increase flows, care must be used to assure that the greater flows do not have an adverse impact on the downstream system. A second potential drawback to channel lining is the detrimental effect on the natural setting. Although natural-looking linings are available, some scenic value may still be lost. Therefore, lining improvements must be carefully selected. Examples of channel lining materials include concrete, riprap, and gabion baskets. Regardless of the material used, lining can be provided for the entire channel cross-section or just part-way up the bank, and for considerable distances or only at critical locations such as bends and constrictions.

(2) Pilot-channel improvements. Pilot-channel improvements, in addition to protecting against erosion, also improve the low-flow capabilities of the channels and eliminate meandering of the pilot section. Pilot channel improvements differ from channel lining by the extent of lining provided. Pilot-channel lining is limited to the immediate area of the flow-line and is generally provided along extended lengths of channel. A drawback to pilot-channel lining is its vulnerability to undercutting by flow at the interface between the lining and the natural channel. This condition can be caused by siltation in the pilot channel forcing the low flows to coincide with the interface, and can be prevented by maintaining the pilot channel free from silt. Typical materials for lining the pilot channel include concrete, riprap, and gabions.

(3) Detention/retention storage. Detention storage ranges from on-site detention of excess stormwater to the use of large basins, either at remote locations or directly upstream from the flood-prone areas. Detention storage makes it possible to store the water temporarily and to release it at a rate that will not cause flooding downstream. Detention storage also makes it possible to comply with local ordinances that restrict the peak flow rates from developing areas. Two types of detention storage can be considered --below-ground and above-ground. An alternative form of above-ground basis is the retention basin in which a portion of the water is restrained for aesthetic and recreation amenities. Drawbacks of detention facilities include large construction costs for the below-ground facilities; land acquisition costs for regional type facilities; increased maintenance requirements if site-specific basins are used since there will be a large number of basins; and, liability concerns, especially in the case of the above-ground multiple use facilities. Potential benefits include reduced flows downstream; improved water quality since the basins can function as settling basins; and, multiple uses, as the ponds and the surrounding sites can be used as parks and recreation areas during dry weather. Detention storage is ideal for undeveloped and developing areas; it is difficult to implement in highly urbanized areas.

(4) Culvert and bridge modifications. Culvert and bridge modifications are made to supplement the capacity of existing structures. Generally, the structures are upgraded by lining the barrels to decrease their roughness, adding wingwalls to increase efficiency, installing new barrels or enlarging the opening to increase capacity, or by improving the structural integrity.

(5) Culvert and bridge replacement. If the construction measures described above are not applicable or are not sufficient to correct system deficiencies, culvert and bridge replacement may be necessary. It is generally the most obvious and common solution; however, its drawbacks include high costs and loss of value of the existing structure. In certain instances, such as in highly developed areas, or where structurally unsafe components are involved, replacement may be the only viable and cost-effective solution.

(6) Channel reshaping and realignment. Channel reshaping and realignment is a means of increasing channel capacity, improving its maintainability, and decreasing erosion potential. This reshaping is similar to the remedial maintenance; however, it is more extensive and also includes realignment of the channel. The channel realignment is particularly important in developing areas where it can increase channel capacity while making more area available for development.

(7) Storm sewer system modifications. Storm sewer system modifications are made to supplement the capacity of existing capture and conveyance system. Generally, the system components are upgraded by adding more inlets; lining the underground conveyance system to decrease its roughness; installing new, parallel conduits to supplement the capacity of the existing conduits; or by improving the structural integrity of the system components.

(8) Storm sewer system replacement. If the construction measures described above are not applicable or are not sufficient to correct system deficiencies, storm sewer system replacement may be necessary. It is generally the most obvious and common solution; however, its drawbacks include high costs and loss of value of the existing system. In certain instances, such as in highly developed areas, or where structurally unsafe components are involved, replacement may be the only viable and cost-effective solution.

3. Flood Plain Improvements

Flood plain improvements differ from system improvements in that the flood plain improvements do not affect the conveyance system components, nor do they reduce the floodwater elevations. The primary benefits from flood plain improvements include reduction of the effects of damage caused by flooding and decreasing the potential for the floodwaters to cause damage in the future. Costs incurred for flood plain improvements can equal or exceed those of structural improvements. Depending on the present land use and availability and value of the land, flood plain improvements can be extremely cost-effective.

Flood plain improvements can be categorized as planning process efforts or physical improvements. The improvements listed below are the more general types of flood plain improvements. The concept behind the flood plain improvements is to provide feasible and cost-effective relief to property owners, and to assure that the hazards of major damage and loss of life are minimized or eliminated.

a. Planning Process Efforts. There are certain measures that a municipality can employ to prevent flooding problems before they develop. These measures should be viewed as "preventive medicine" in the control of flood plain problems, as opposed to "corrective measures" after flooding has occurred. These measures, identified as Planning Process Efforts, all need to be initiated prior to development, and generally require action by the legislature of the municipality. Planning Process Efforts for improvements to the flood plain generally represent the least expensive remediation to flooding problems, but require diligent efforts and extreme foresight on the part of planners, lawmakers, and other City officials. A definite distinction can be made between Planning Process Efforts and Physical Improvements to the flood plain: Physical Improvements can be readily seen as modifications to the flood plain, whereas Planning Process Efforts will be less apparent to the average citizen. Because of the absence of any tangible evidence in the community, promoting and recommending Planning Process Efforts to the public is probably the most difficult barrier to overcome in their effective use. The public must be informed of how these types of improvements would have prevented loss of life and expenditure of public money if Planning Process Efforts had been employed prior to past flooding events; as well as of the cost of current "structural" improvements to remedy the effects of past flooding. If this is successfully accomplished, public acceptance and backing of Planning Process Efforts will increase substantially, ultimately saving considerable tax monies. Recommended Planning Process Efforts are described in detail below:

- Flood preparedness planning.
- Zoning changes.
- Land acquisition.
- Flood plain management enforcement.
- Stormwater runoff regulations.

(1) Flood preparedness planning. The most serious consequence of stormwater flooding problems is loss of life. Therefore, prevention of this outcome is the most important consideration of Planning Process Efforts.

There are several steps that the City can take in Flood Preparedness Planning. The first of these is to implement an early warning system that detects flooding at threatening levels in flood-prone areas. Such a system can consist of electronic sirens that audibly notify the public of impending danger, mechanical alarms that notify City or local authorities to proceed with evacuation or warning plans, or any similar means of alerting the public.

The next step in Flood Preparedness Planning is to make the public aware of the early warning systems and to provide proper training for dealing with an impending flooding problem. Public meetings and mailings should be utilized to spread general information of Flood Preparedness Planning efforts. These methods of informing the public can then be reinforced by establishing local or neighborhood liaisons or associations that can act as leaders and organizers in the event of actual flooding. In this way the public can learn the basic requirements for meeting an emergency, with advanced training and preparedness provided to volunteers or selected key personnel. All phases of Flood Preparedness Planning work in harmony with one another. For this type of planning to be effective, it is essential to inform the public of any systems or plans that are to be implemented during an emergency.

(2) Zoning changes. Zoning changes are a means of restricting or prohibiting development in flood-prone areas. Depending on the value, availability, location, and ownership of land, zoning changes can be difficult and time-consuming.

(3) Land acquisition. As an alternative to zoning restrictions, the City or other government entity can purchase the flood-prone land. Although this can be expensive, using the land for amenities such as parks, playgrounds, or athletic fields can make this option viable. These amenities, combined with detention storage if necessary and applicable, can serve as ideal multi-purpose facilities.

(4) Flood plain management enforcement. Most communities participate in the Federal Emergency Management Agency's (FEMA) Flood Insurance Program (FIP). Under the FIP, communities are required to administer and enforce proper flood plain management in order to receive federal flood insurance in the event of a flood. Although FEMA provides the flood insurance coverage for those communities who participate in the program, the overall enforcement of the program's requirements falls into the realm of the communities' responsibility. Under the City's Floodplain Management Resolution adopted on November 19, 1991, the City provides for continued participation in the National Flood Insurance program. The resolution provides flood plain regulations to reduce hazards to persons, property damage and public expenditures and qualify for flood insurance and Federal funds or loans. This is truly a planning process effort in that no actual improvement in the flood plain will be immediately visible until severe flooding occurs in the future. With proper implementation, flood plain management enforcement by the City will accomplish the following:

- Ensure that all new development in the flood plain fringe areas are planned and constructed in such a manner that future flooding potential for these areas is essentially removed.

- Ensure that the City will continue to comply with FEMA regulations, thus removing the potential for future violations and possible termination of flood insurance benefits to the City.

- Ensure that any new legislation and other flood plain improvements are carried out properly and implemented as they were intended.

(5) Stormwater runoff regulations. Probably the most effective way to correct flooding by stormwater is prevention. Although Planning Process Efforts such as flood plain management and flood preparedness planning can significantly reduce flooding problems and damage, nothing reduces the potential for flooding, with respect to effort and cost, more efficiently than proper stormwater runoff regulations. Implementation of such regulations allows communities to attack the flooding problems before they occur. Expense for the regulations would typically be shouldered by developers and owners of new developments in the form of onsite or regional detention facilities. Although the ultimate outcome of stringent stormwater runoff regulations is physical improvements such as detention or retention facilities, their implementation involves a Planning Process Effort by the City.

The City currently has adequate stormwater runoff regulations in place as described in Chapter 63, Section 5:673 - Stormwater Retention Facilities, of the City code. This section provides regulations for the control of stormwater runoff and design requirements for retention basin facilities.

b. Physical Improvements. Similar to the Planning Process Efforts for flood plain improvements, physical improvements to the flood plain system are another, vitally important, less expensive remedy to flooding problems. The Physical Improvements are described in detail below.

- Erosion and sediment control.
- Floodproofing (wet and dry).
- Minor flood walls and berms.
- Elevating buildings.
- Relocating/removing buildings.

(1) Erosion and sediment control. Erosion and sediment control involves methods to reduce the degradation of channels and to limit the amount of suspended matter carried in the stormwater. A key element is the installation and maintenance of sufficient control facilities to retain sediment within the boundaries of a particular site, especially during construction activities. Factors that affect erosion and sedimentation processes include soils, surface cover (vegetation) topography, climate, channel cross-sections, channel lining, and water velocity. Effective methods for erosion and sediment control include providing adequate vegetative cover; controlling velocities in the channel;

buffer strips between the channel and the source of the stormwater runoff; providing sediment traps or barriers (especially at construction sites); retention facilities; and stream bank stabilization.

(2) Floodproofing. Floodproofing is a method of reducing and preventing flood damage. Two types of floodproofing techniques are available - wet and dry. Wet floodproofing techniques consist of altering existing buildings to minimize damage when floodwaters rise and enter the building. Elements of wet floodproofing include uses for below-ground and ground-level space that will not be adversely affected by floodwaters. This technique is geared mainly towards commercial buildings and would be of less use for residential buildings.

Dry floodproofing techniques involve making the building walls watertight and sealing the openings so floodwaters cannot enter. This method of protecting existing structures can be incorporated into the design of new buildings. Elements of dry floodproofing include installation of watertight seals at doors and windows and at other above-ground locations below the flood level; applying sealing compounds to foundations and subsurface walls; sealing off or eliminating below-ground openings; and installing check valves on the sewer drains to prevent backups.

(3) Minor flood walls and berms. Flood walls are constructed of concrete, and berms are built of earth to provide a physical barrier against the floodwaters. Depending on the degree of flooding and the height of the floodwaters, this option may not be practical.

(4) Elevating buildings. Elevation is a floodproofing technique whereby a building is physically raised to allow floodwaters to pass beneath it. This is ideal for structures such as storage buildings and sheds but may be less practical for homes and larger buildings.

(5) Relocating/removing buildings. In the event that the measures discussed above do not provide sufficient protection from floodwaters, relocation of the building may be an option. Whether it be on the same property to higher ground that is not affected by the floodwaters, or to an entirely new site, building relocation can eliminate the flooding potential. This measure is generally limited to smaller structures and can be quite expensive.

VI. Stormwater Model

A. Introduction

The primary purpose of reviewing computer models for master planning is to help assure that the appropriate models are selected for analyzing both water quantity and quality. The models selected will serve as a basis for providing the following information: estimating flow quantity and quality at various locations throughout the City; identifying inadequate conveyance system components, including open channels, culverts, bridges, and underground systems; identifying potential point and non-point pollution sources; locating existing and potential future flooding areas; developing flood plain limits consistent with the requirements of the Federal Emergency Management Agency (FEMA); estimating detention volumes necessary to limit peak flows; identifying locations for detention basins; quantifying and evaluating the potential effects of proposed improvements; and helping to develop planning level costs to improve the conveyance system.

B. Model Evaluation

Several models were identified to be evaluated for applicability: the Penn State Urban Runoff Model (PSRM); the U.S. Army Corps of Engineers' HEC-1 and HEC-2; the Soil Conservation Service's (SCS) TR-20 and TR-55; the US Environmental Protection Agency's (EPA) Stormwater Management Model (SWMM); XP-Software's XP-SWMM; and the P8 Urban Catchment Model. The two key factors in the selection of a computer model included the ability to model both open channel/culvert systems and underground systems, and the ability to model the hydraulics to account for backwater effects. A secondary factor was the model's ability to perform water quality modeling. Based on these factors, the list of applicable models was reduced to HEC-1 and HEC-2, SWMM, XP-SWMM, and P8. A brief description of each of these models is presented below and in Table VI-1.

1. HEC-1 and HEC-2

In the HEC-1 and HEC-2 combination, HEC-1 performs the hydrologic modeling to be used as input to HEC-2 for the hydraulic modeling. HEC-1 and HEC-2 were developed and are supported by the US Army Corps of Engineers; are public domain software; are accepted by the Federal Emergency Management

Table VI-1 Computer Model Comparisons								
Model	Criteria							
	Technical Support Provided	Public Domain(1)	Accepted by FEMA(2)	User Friendly(3)	Hydraulic Modeling(4)	Water Quality Modeling	Hydraulic and Quality Modeling(5)	Flexible(6)
HEC-1/HEC-2	X	X	X	X				
EPA SWMM	X	X	X		X	X		X
XP-SWMM	X			X	X	X	X	X
P8		X		X		X		

Notes:

(1) Public domain software can usually be purchased at a minimal cost, (e.g. $100), and can be placed on multiple machines at no additional charge.

(2) Accepted by FEMA for preparing flood insurance studies.

(3) User-friendliness is based on ability to set up, enter, access, display, and review the input and output files.

(4) Hydraulic modeling for both open channel/culvert and underground conveyance systems, and taking into account backwater effects.

(5) Ability to model water quantity and quality from the same routine (same data file).

(6) Flexibility is based on adaptability of the model to a variety of conditions of setup, analyses, and display of results.

Agency (FEMA) for flood insurance studies; and, can be used to model open channel/culvert systems and account for backwater effects. However, they cannot be used for direct modeling of underground conveyance systems or for modeling water quality.

2. EPA's Stormwater Management Model (SWMM)

The SWMM model has been developed and supported by the US EPA; is public domain software; the hydrologic analyses are accepted by the Federal Emergency Management Agency (FEMA) for flood insurance studies; is very flexible; provides the capability to model open channel/culvert systems and underground conveyance systems; takes into account backwater effects; and, models water quality. However, the backwater effects and water quality are modeled using separate "blocks" (routines) requiring separate data files, and the SWMM model can be very difficult and frustrating to set up and use.

3. XP-SWMM

XP-SWMM was developed by XP-Software and is an enhancement of EPA's SWMM model. XP-SWMM is supported by XP-Software; is very flexible; provides the capability to model open channel/culvert systems and underground conveyance systems; accounts for backwater effects and models water quality in the same "block" (routine); has a graphical interface; and, is user-friendly. However, XP-SWMM is newer to the modeling arena, is not public domain software, and has not been accepted by FEMA for flood insurance studies.

4. P8 Urban Catchment Model

P8 is a water quality model, with its routines based on the algorithms from EPA's SWMM model. Although it performs the basic hydrologic analyses of rainfall and runoff, for practical purposes it performs no hydraulic analyses. The strengths of the P8 model for water quality modeling are that the quality data is based on the Nation-wide Urban Runoff Program and it models structural Best Management Practices (BMPs) such as wet and dry detention basins, infiltration basins, and infiltration swales. P8 would therefore be selected as a model for completing water quality modeling only.

C. Model Selection

Based on the evaluation of the four models listed in Table VI-1, XP-SWMM was selected as the model for completing the Stormwater Master Plan. The controlling factors in the selection of XP-SWMM over the other models, particularly EPA SWMM, were overall user-friendliness, graphics capabilities, and the ability to import and export data from the model. A critical component of the selection of XP-SWMM was that if the model was not user-friendly, it would be used only by a few City personnel once the Master Plan project was complete.

D. Hydrologic Data Requirements

1. Introduction

The hydrologic modeling for Ann Arbor was completed using the runoff block of XP-Software's Storm Water Management Model, XP-SWMM, (an enhanced version of EPA's SWMM model).

2. Data Requirements

Each of the eight watersheds in Ann Arbor has been divided into subareas. The hydrologic data requirements for the subareas are listed below:

- *Size*. The size of each subarea, in acres, was determined based on topography (from GIS) and the layout of the conveyance system being modeled.

- *Width*. The width of each subarea, in feet, was determined based on the general shape of the subarea. The model idealizes each subarea as a rectangle; therefore, estimating the subarea's width enables the model to calculate the subarea's length. The length is used by the model as the length of overland flow for the calculation of surface runoff, and thus, the time of concentration. The XP-SWMM and EPA-SWMM manuals present a discussion on estimating the width of the subareas. Generally, the length of the overland flow should not exceed 300 to 500 feet.

- *Percent imperviousness*. The percent imperviousness was estimated for each subarea based on land use. Future land use information was provided by Information Services Division personnel in digital (GIS) format. Table VI-2 presents the default value and the range of values for percent imperviousness by land use.

Table VI-2 Imperviousness by Land Use		
Land Use/Zoning	Default Imperviousness (percent)	Range of Imperviousness (percent)
1. Commercial/Industrial		
commercial	85	80-95
office	85	70-95
research and industrial	85	75-95
2. Residential		
single-family attached	35	25-45
single-family detached	35	25-45
multi-family	60	40-70
3. Open Areas		
parks, cemeteries	15	5-25
4. All Surfaces		
impervious: asphalt, concrete, roofs	100	100
Pervious: turfed	0	0
wet detention basins	100	100

- *Average drainage area ground slope.* The ground slope was calculated by averaging the ground slopes at a number of separate and representative locations in each subarea from the contours generated in GIS.

- *Impervious area overland flow roughness coefficient (Manning's "n").* In the absence of field data, the default impervious area roughness coefficient value presented in Table VI-3 were used.

- *Pervious area overland flow roughness coefficient (Manning's "n").* In the absence of field data, the pervious area roughness coefficient value presented in Table VI-3 were used.

- *Impervious area depression storage.* In the absence of field data, the impervious area depression storage value presented in Table VI-3 were used.

(Note: Depression storage is defined as low points, or "hollows," where stormwater is trapped and forms localized puddles.)

- *Pervious area depression storage.* In the absence of field data, the pervious area depression storage value presented in Table VI-3 were used.

3. Design Storms

Based on Ann Arbor design standards, the 10-year design storm has been used as a basis for conveyance system analyses. Since the standards do not specify a particular distribution, the Soil Conservation Service's 24-hour distribution was selected as input to XP-SWMM.

Table VI-3
Hydrologic Parameters

Variable	Default Value	Range
1. Manning's Overland Flow Roughness Coefficients		
pervious areas	0.3	0.2-0.5
impervious areas	0.02	0.015-0.04
2. Depression Storage		
pervious areas	0.2	0.1-0.40
impervious areas	0.06	0.01-0.15

4. Land Use

To assure that the identified improvements would continue to be adequate as Ann Arbor continues to grow and develop, the future land use conditions were used as the basis for modeling. Additionally, the future land use condition provide for determination of future peak flows, total runoff volumes, runoff water quality, and to identify structures that may become inadequate in the future as the land uses change. Therefore, improvements have been sized based on future land use conditions.

5. Assumptions

The following assumptions have been made to simplify the hydrologic modeling and to provide the accuracy necessary for planning level analyses:

- In general, small detention ponds throughout the City have no storage capacity.
- Manning's roughness coefficients for pervious and impervious areas are constant and of areal extent.
- Pervious and impervious depression values are constant and of areal extent.

E. Hydraulic Data Requirements

1. Introduction

The hydraulic modeling was performed using the EXTRAN block of XP-SWMM. The EXTRAN block will perform the hydraulic analyses, including accounting for backwater effects in calculating water surface profiles. The purpose of the hydraulic modeling is to analyze the major culverts, bridges, channels, and enclosed stormwater conveyance system components for present and future conditions; locate system deficiencies and inadequacies; and recommend practical and cost-effective improvements to alleviate flooding. The goal of the hydraulic modeling is to provide a base model of the major conveyance system that can be extended upstream as necessary.

For modeling purposes, the conveyance system has been divided into two separate systems: the local drainage system consisting of inlets and small underground conduits, generally less than 36 inches in diameter (or equivalent), and the major conveyance system consisting of the enclosed system conduits 36 inches in diameter (or equivalent) and larger, large open channels, culverts, and bridges. The actual division between the two systems will vary throughout the City, but the 36-inch diameter (or equivalent) was used as a basis.

2. Data Requirements

Data used in the hydraulic modeling was collected for the major conveyance system. Data on the enclosed system, culverts, and bridges was obtained from information provided on the City's sewer index sheets. This data has been incorporated into the City's GIS; therefore, a copy of the data will be presented to the City in an Arc/Info format.

The following hydraulic data was required for modeling:

Open channel conveyance system:

- Channel length.

- Upstream flowline elevation.
- Downstream flowline elevation.
- Channel type.
- Manning's "n" value for channel.
- Manning's "n" value for overbank.
- Channel cross-section.
- Limits of main channel width.

Enclosed system, culverts, and bridges:
- Structure dimensions.
- Structure type.
- Manning's "n" value.
- Upstream flowline elevation.
- Downstream flowline elevation.

Manholes:
- Rim elevation.
- Invert elevation.

3. Assumptions

The following assumptions have been made to simplify the hydraulic modeling:

- If the local stormwater conveyance system is not analyzed, it is assumed to be adequate to convey the flows to the major system.
- The drainage system outside the Ann Arbor City limits has not been analyzed. For modeling purposes, it is assumed to be adequate to convey flows to the system within the City as well as out of the city without backwater effects.
- Information contained on the sewer index sheets is accurate for planning level system analyses.

F. Model Verification

1. Introduction

Model verification and calibration was used to aid in "fine-tuning" the computer model to better reflect the operation of the conveyance system.

2. Verification

The purpose of the model verification was to achieve a level of accuracy in the computations consistent with the level of detail required for planning. Peak runoff for each watershed was verified by comparing the XP-SWMM generated subarea flows with an independent runoff calculation using the Rational Equation. For planning level analyses, ±30% difference in runoff peak flows is acceptable. The results of the peak runoff verification is presented in Tables VI-4 through VI-11.

Table VI-4
Allen Creek Watershed Peak Runoff Verification

Subwatershed	10 Year Storm Event Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	Flow Comparison (%)
1	122	114	8	6
2	621	506	116	19
3	245	200	45	18
4	131	118	12	9
5	80	82	-2	-3
6	153	144	8	5
7	81	63	18	22
8	22	23	-1	-4
9	74	73	2	2
10	229	220	9	4
11	66	74	-8	-12
12	169	142	27	16
13	113	112	1	1
14	514	431	82	16
15	263	209	54	21
16	134	135	-1	-1
17	58	54	4	8
18	280	237	43	15
19	97	92	5	5
20	148	159	-11	-7
21	146	131	15	10
22	155	179	-24	-16
23	248	210	38	15
24	80	92	-12	-15
25	633	494	139	22
26	143	177	-35	-24
27	104	93	11	11
28	469	396	73	16
29	240	225	15	6
30	163	127	37	23
31	45	39	6	13
32	285	248	37	13
33	189	210	-21	-11
34	108	104	5	4
35	198	175	23	11
36	257	238	18	7
37	223	232	-9	-4
38	144	114	30	21
39	328	259	68	21
40	77	95	-18	-24
41	71	89	-17	-24
42	34	38	-4	-11
43	192	237	-45	-24
44	77	89	-11	-15
45	101	95	5	5
46	147	110	37	25
		Absolute Min.	1	1
		Absolute Max.	139	25
		Absolute Avg.	26	13

Table VI-5
Fleming Watershed Peak Runoff Verification

Subwatershed	10 yr Storm Event			
	Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	Flow Comparison (%)
1	239	205	35	14
2	59	55	4	7
3	41	38	3	7
4	34	32	3	7
5	71	70	1	1
6	419	360	59	14
7	31	33	-2	-7
8	8	10	-2	-23
9	56	61	-5	-9
		Absolute Min.	1	1
		Absolute Max.	59	23
		Absolute Avg.	13	10

Table VI-6
Honey Watershed Peak Runoff Verification

	10 Year Storm Event			
	Rational Method 10-yr Flow, Q	XPSWMM 10-yr Flow, Q	Flow Comparison	
Subwatershed	(cfs)	(cfs)	(cfs)	(%)
1	39	36	4	9
2	29	34	-5	-16
3	167	126	41	25
5	85	64	21	24
6	82	63	19	23
7	133	109	24	18
8	75	56	19	25
9	53	54	-1	-1
10	71	66	5	6
11	152	114	38	25
12	44	48	-4	-9
13	10	12	-2	-22
14	22	21	1	3
15	56	47	8	15
16	48	42	6	13
17	57	57	-0	-0
		Absolute Min.	0	0
		Absolute Max.	41	25
		Absolute Avg.	12	15

(Note: Area 4 has been eliminated from the model)

Table VI-7
Flow Calculations for Huron Watershed

	10 Year Storm Event			
Subwatershed	Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	(%)
1	221	194	27	12
2	246	201	45	18
3	47	44	3	7
4	588	608	-20	-3
5	66	55	11	17
6	64	52	12	19
7	96	102	-6	-7
8	79	63	16	20
9	10	8	2	18
10	116	89	27	23
11	47	39	8	17
12	69	60	10	14
13	16	11	6	35
14	314	319	-5	-2
15	35	33	2	6
16	95	88	8	8
17	39	31	9	22
18	96	81	14	15
19	150	143	8	5
20	127	132	-5	-4
21	188	150	38	20
22	95	97	-1	-2
23	38	30	8	22
24	377	286	91	24
25	93	75	19	20
26	213	159	53	25
27	27	20	7	27
		Absolute Min.	1	2
		Absolute Max.	91	35
		Absolute Avg.	17	15

Table VI-8
Flow Calculations for Mallets Watershed

	10 Year Storm Event			
	Rational Method 10-yr Flow, Q	XPSWMM 10-yr Flow, Q	Flow Comparison	
Subwatershed	(cfs)	(cfs)	(cfs)	(%)
1	82	83	-1	-2
2	61	56	5	8
3	173	132	41	24
4	11	12	-2	-15
5	16	17	-1	-3
6	131	110	21	16
7	96	97	-1	-1
8	86	83	3	3
9	231	238	-7	-3
10	155	153	2	1
11	95	85	9	10
12	71	64	7	10
13	180	198	-18	-10
14	58	46	13	22
15	45	44	1	2
16	450	349	101	22
17	24	26	-2	-7
18	25	29	-4	-15
19	13	15	-2	-12
20	431	427	4	1
21	41	49	-8	-20
22	253	279	-26	-10
23	99	74	25	25
24	324	335	-10	-3
25	559	592	-33	-6
26	40	38	2	4
27	61	47	14	23
28	318	280	38	12
29	146	163	-17	-12
30	60	56	4	6
31	51	50	1	2
32	288	245	43	15
33	262	260	2	1
34	307	233	74	24
35	86	67	19	22
36	141	110	31	22
37	221	259	-38	-17
38	244	193	51	21
39	260	207	53	20

Table VI-8 (cont)
Flow Calculations for Mallets Watershed

Subwatershed	10 Year Storm Event Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	(%)
40	188	169	19	10
41	245	241	3	1
42	29	32	-3	-11
43	55	59	-4	-7
44	116	112	4	3
45	99	99	0	0
46	385	293	92	24
47	73	79	-6	-8
48	365	349	16	4
49	58	65	-7	-12
50	510	517	-7	-1
51	97	101	-4	-4
52	1107	933	175	16
53	185	140	44	24
54	203	165	38	19
55	137	145	-7	-5
56	1789	2051	-261	-15
57	277	252	25	9
58	357	294	63	18
59	192	158	34	18
60	240	192	48	20
61	76	88	-12	-16
62	202	169	33	16
63	91	73	18	20
64	37	29	8	21
65	75	61	14	19
66	95	81	14	15
67	715	798	-82	-12
68	310	321	-10	-3
69	2344	1822	523	22
		Absolute Min.	0	0
		Absolute Max.	523	24
		Absolute Avg.	33	12

Table VI-9
Miller Watershed Peak Runoff Verification

Subwatershed	10 Yearr Storm Event Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	Flow Comparison (%)
1	107	105	2	2
2	96	90	6	6
3	50	53	-2	-5
4	264	264	-1	-0
5	64	71	-7	-10
6	135	157	-22	-16
7	508	579	-71	-14
8	197	222	-25	-13
9	88	85	3	4
10	543	429	114	21
11	44	38	6	14
12	93	92	1	1
13	340	263	77	23
14	599	448	151	25
15	128	97	31	24
16	382	289	93	24
		Absolute Min.	1	0
		Absolute Max.	151	25
		Absolute Avg.	38	13

Table VI-10
Swift Run Watershed Peak Runoff Verification

Subwatershed	10 yr Storm Event Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	Flow Comparison (%)
1	285	222	63	22
2	179	135	45	25
3	394	390	265	67
4	333	248	85	25
5	107	115	-8	-8
6	157	139	18	12
7	21	26	-5	-22
8	65	68	-3	-5
9	98	95	3	3
10	278	213	64	23
11	52	41	11	21
12	208	157	50	24
13	165	138	27	16
14	308	234	74	24
		Absolute Min.	3	3
		Absolute Max.	265	67
		Absolute Avg.	52	21

Table VI-11
Traver Creek Watershed Peak Runoff Verification

Subwatershed	10 yr Storm Event: Rational Method 10-yr Flow, Q (cfs)	XPSWMM 10-yr Flow, Q (cfs)	Flow Comparison (cfs)	Flow Comparison (%)
1	70	67	2	4
2	166	134	32	19
3	845	680	165	20
4	330	320	10	3
5	146	146	-0	-0
6	473	354	118	25
7	267	248	19	7
8	361	271	90	25
9	91	70	21	23
10	62	63	-1	-1
11	204	157	47	23
12	1017	772	244	24
13	95	88	7	7
14	128	134	-6	-5
15	200	182	17	9
16	100	88	11	11
17	97	96	2	2
18	220	234	-14	-6
		Absolute Min.	0	0
		Absolute Max.	244	25
		Absolute Avg.	45	12

VII. Stormwater System Improvements Evaluation

A. Introduction

The system improvement alternative evaluations consist of the corrective measures discussed in Chapter V. With the overall and comprehensive focus of this Plan, general discussion is presented for each watershed for a variety of the solutions discussed in Chapter V. The stormwater analyses have been completed for each watershed based on a system-wide approach. Thus, improvements have been developed and are presented as improvements to the entire system--and not as a series of individual improvements. In some instances, the opportunity may exist for development and completion of individual improvements; however, the impacts of the improvement must be analyzed for the entire watershed and not only for the specific improvement.

A wide variety of conditions exist throughout Ann Arbor. The Allen Creek Watershed presents one extreme where there is a severely inadequate system and a history of flooding in a fully developed watershed. Very little opportunity exists for improvement alternatives to meet present design standards in the watershed other than construction of replacement and parallel conveyance systems; and the cost of such improvements may very likely make them impractical. The Miller Watershed, on the other hand, has a conveyance system that is mostly adequate and opportunity exists for a variety of improvements, including detention, conveyance system modification and replacement, and both planning process efforts and physical flood plain improvements.

The recommended improvements have been sized for future land use, to assure that the improvements are designed and constructed proactively to meet the future needs as Ann Arbor continues to grow and develop. The improvements are based on planning level analyses; and accordingly, the sizes, types, locations, and costs associated with the improvements are at a planning level, consistent with the intent and goals of this Plan. More detailed analyses will be required to identify the design configurations and construction-level costs for the improvements.

Ann Arbor has taken a significant step to proactively address the needs of the stormwater system. With proper guidance, Ann Arbor can continue the planning of the future stormwater conveyance system and help assure that the system inadequacies that exist in the Allen Creek Watershed do not occur in the other watersheds.

In general, the types of improvements identified and evaluated can be categorized as follows:

(1) Structural improvements to the conveyance system.

(2) Structural improvements to the flooded properties.

(3) Policy/standards development and enforcement.

Category (1) and (3) improvements are ideal for proactively addressing potential future flooding while category (2) improvements are reactionary and are typically developed in response to flooding problems that already exist. Thus, for all watersheds except the Allen Creek Watershed, category (1) and (3) improvements are discussed, while category (1) and (2) improvements are presented for the Allen Creek Watershed. Category (1) improvements are presented and recommended for all eight watersheds to provide a consistent level of improvement throughout the City and a common ground for the development of cost estimates. However, the category (2) and (3) improvements are presented and should be considered on a watershed by watershed basis. Significant cost savings can be realized by category (2) and (3) improvements; however, the development of these type of improvements will require a significant level of involvement and commitment from various public officials since these type of improvements, particularly development and enforcement of new policies, involve not only public official support, but also the support of developers and City residents. Although not quantified, the category (2) and (3) improvements are presented to ensure that the City begins to seriously considers these type of improvements and move forward with them proactively.

B. Identification of Flooding Locations, Recommendations, and Costs

In many watersheds, the potential for flooding is based on future development that may occur, and therefore, the recommended improvements are future action items. The Allen Creek and Mallets watersheds are the two watersheds that have a history of severe and repetitive flooding. The recommendations and cost estimates presented have been developed to provide Ann Arbor with a basis for the extent and magnitude of the necessary improvements to upgrade the system to comply with present City standards for a 10-year storm event. Although a variety of options exist for several of the watersheds, the recommendations and cost estimates are based on providing a technically feasible and practical solution to comply with City standards. What is not, and cannot be accounted for in the recommendations is the sentiment and philosophies of City residents and public officials as to the need and importance of providing and moving forward with the recommended improvements to provide a common level of stormwater protection throughout the community.

Due to limited funds, it may not be possible, or feasible, for Ann Arbor to meet present design standards and fully correct flooding conditions that have developed over many years. However, it may be very appropriate to evaluate the viable options of developing and constructing improvements for a less severe storm, or implementing the flood plain improvements presented in Chapter V.

As a basis for providing consistent cost estimates throughout the City, the recommended improvements have been developed to comply with the present City standards to convey the 10-year design storm.

1. Allen Creek

The Allen Creek Watershed has a history of flooding problems. The watershed contains the older and more developed portions of Ann Arbor. Because of the nature of the watershed and past design and development of the conveyance system, the system is severely undersized and improvements to the system necessary to adequately convey the 10-year storm are extensive. The existing conveyance system is presented on Figure VII-1. Alternatives that exist for conveying/controlling the stormwater flows include the following:

(1) Modify/replace the existing stormwater conveyance system.

(2) Provide detention storage.

(3) A combination of modifying/replacing the system and detention storage.

(4) Land acquisition of flood-prone properties.

(5) Floodproofing properties.

(6) Develop improvements for a lessor storm event.

Alternatives (1) through (3) are viable to comply with City standards to adequately convey the 10-year stormwater flows. However, all three options are costly and although alternatives (2) and (3) are technically feasible, they may not be practical due to the amount and location of land that would be required to adequately detain the flows. Since very little vacant/open land is available in the watershed, presently developed land would be required to be purchased and buildings demolished - which would decrease the City's tax-base as a result of loss of the property taxes associated with the properties.

Alternatives (4) and (5) do not comply with present City standards, and would not eliminate flooding for the 10-year design storm. However, they do provide cost-effective alternatives to reducing the extent of flooding and the flood damages. Similar to alternatives (4) and (5), alternative (6) does not comply with present City standards. Alternative (6) does provide a higher level of protection than presently exists and it can greatly reduce the costs of the improvements.

To comply with present City standards, alternative (1), modify/replace the existing stormwater conveyance system, is recommended. Although this alternative does not provide the potential for enhancements to water quality as alternatives (2) and (3) would, it does provide the most feasible and practical solution available to comply with present City standards. Alternatives (2) and (3) are technically feasible; however, the acquisition of land, and particularly of citizens homes and/or businesses is typically a long and slow process, and nearly always is viewed negatively from a public relations perspective.

The improvements for Allen Creek have been divided into six logical groupings. Summaries for the improvements are presented in Tables VII-1 through VII-6 and on Figure VII-2. The total estimated cost for the Allen Creek improvements is $41,000,000. In light of the extent of flooding and the associated costs, it is highly recommended that the City pursue land acquisition of flood-prone properties, floodproofing of properties, and/or development of improvements for a lessor storm event. Any one, or a combination of these options will benefit the residents and the City and may be a better solution than the "do-nothing" alternative.

2. Fleming

The Fleming stormwater conveyance system consists of a series of underground conduits at two locations, which discharge out of the City limits. The Fleming watershed and existing conveyance system are presented on Figure VII-3. Presently, the Fleming watershed experiences minor flooding, and the system appears to be operating properly. However, modeling the effects of future development identifies system inadequacies as presented on Figure VII-4. To assure that the Fleming conveyance system complies with design standards for future land use conditions, the following alternatives exist for conveying/controlling the stormwater flows:

Table VII-1
Allen Creek Watershed
West Park - Miller Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
42 inch RCP	357	lf	90	50,130
48 inch RCP	456	lf	110	50,160
60 inch RCP	2,063	lf	200	412,600
72 inch RCP	3,374	lf	250	843,500
78 inch RCP	2,223	lf	270	600,210
8 X 7 RCB	1,995	lf	450	897,750
Double 6 X 6 RCB	911	lf	590	537,490
Double 8 X 7 RCB	700	lf	820	574,000
Double 12 X 9 RCB	250	lf	1,370	342,500
Manholes: 6 ft or less diameter	43	ea	2,380	102,340
Manholes: greater than 6 ft diameter	15	ea	5,320	79,800
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	281,700
			Subtotal	4,772,000
			Contingencies (15% of Subtotal)	716,000
			Total Construction Cost (TCC)	5,488,000
			Utility Relocation Costs (7% of TCC)	384,000
			Engineering, Legal & Administration Costs (15% of TCC)	823,000
			Total Project Cost	6,695,000

Table VII-2
Allen Creek Watershed
Murray Washington Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	440	lf	110	48,400
60 inch RCP	2,730	lf	200	546,000
66 inch RCP	370	lf	220	81,400
78 inch RCP	2,530	lf	270	683,100
6 X 5 RCB	370	lf	370	136,900
8 X 6 RCB	720	lf	440	316,800
10 X 8 RCB	680	lf	540	367,200
12 X 9 RCB	4,950	lf	730	3,613,500
Manholes: 6 ft or less diameter	36	ea	2,380	85,680
Manholes: greater than 6 ft diameter	19	ea	5,320	101,080
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	936,200
			Subtotal	6,916,000
			Contingencies (15% of Subtotal)	1,037,000
			Total Construction Cost (TCC)	7,953,000
			Utility Relocation Costs (7% of TCC)	557,000
			Engineering, Legal & Administration Costs (15% of TCC)	1,193,000
			Total Project Cost	9,703,000

Table VII-3
Allen Creek Watershed
Eber-White Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
54 inch RCP	2,227	lf	140	318,780
60 inch RCP	469	lf	200	93,800
Single 6 X 5 RCB	1202	lf	370	444,740
Single 8 X 6 RCB	1,716	lf	440	755,040
Manholes: 6 ft or less diameter	24	ea	2,380	57,120
Manholes: greater than 6 ft diameter	5	ea	5,320	26,600
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	325,500
			Subtotal	2,022,000
			Contingencies (15% of Subtotal)	303,000
			Total Construction Cost (TCC)	2,325,000
			Utility Relocation Costs (7% of TCC)	163,000
			Engineering, Legal & Administration Costs (15% of TCC)	349,000
			Total Project Cost	2,837,000

Table VII-4
Allen Creek Watershed
Stadium Branch Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
54 inch RCP	2,145	lf	140	300,300
66 inch RCP	775	lf	220	170,500
72 inch RCP	1,544	lf	250	386,000
78 inch RCP	2,472	lf	270	667,440
Trapezoidal, Conc.-Lined Channel	245	lf	lump sum	117,200
Manholes: 6 ft or less diameter	19	ea	2,380	45,220
Manholes: greater than 6 ft diameter	19	ea	5,320	101,080
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	181,900
			Subtotal	1,973,000
			Contingencies (15% of Subtotal)	296,000
			Total Construction Cost (TCC)	2,266,000
			Utility Relocation Costs (7% of TCC)	159,000
			Engineering, Legal & Administration Costs (15% of TCC)	340,000
			Total Project Cost	2,765,000

Table VII-5
Allen Creek Watershed
Allen Creek Drain (Upstream) Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	675	lf	110	74,250
66 inch RCP	470	lf	220	103,400
72 inch RCP	400	lf	250	100,000
5 X 3 RCB	1,240	lf	320	396,800
5 X 4 RCB	800	lf	350	280,000
6 X 5 RCB	1,200	lf	370	444,000
Double 6 X 5 RCB	2,040	lf	590	1,203,600
Double 7 X 6 RCB	820	lf	670	549,400
Double 8 X 6 RCB	3,182	lf	780	2,481,960
Double 10 X 6 RCB	350	lf	950	332,500
Manholes: 6 ft or less diameter	61	ea	2,380	145,180
Manholes: greater than 6 ft diameter	1	ea	5,320	5,320
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	716,400
			Subtotal	6,833,000
			Contingencies (15% of Subtotal)	1,025,000
			Total Construction Cost (TCC)	7,858,000
			Utility Relocation Costs (7% of TCC)	550,000
			Engineering, Legal & Administration Costs (15% of TCC)	1,179,000
			Total Project Cost	9,587,000

Table VII-6
Allen Creek Watershed
Allen Creek Drain (Downstream) Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
Double 10 X 6 RCB	167	lf	950	158,650
Double 12 X 9 RCB	1,021	lf	1,370	1,398,770
Triple 12 X 9 RCB	3,354	lf	1,430	4,796,220
Manholes: 6 ft or less diameter	54	ea	2,380	128,520
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	228,700
			Subtotal	6,711,000
			Contingencies (15% of Subtotal)	1,007,000
			Total Construction Cost (TCC)	7,718,000
			Utility Relocation Costs (7% of TCC)	540,000
			Engineering, Legal & Administration Costs (15% of TCC)	1,158,000
			Total Project Cost	9,416,000

Table VII-7 Fleming Watershed Improvements Cost Estimate				
Item Description	Qty	Unit	Unit Cost $	Total Cost $
72 inch RCP	2,500	lf	250	625,000
78 inch RCP	1,580	lf	270	426,600
96 inch RCP	330	lf	360	118,800
Excavation & Embankments	4,676	cy	10	46,760
Manhole: 6 ft or less diameter	15	ea	2,380	35,700
Manhole: greater than 6 ft diameter	8	ea	5,320	42,560
Miscellaneous (paved area removal & replacement, street crossings, seeding, tunneling & jacking, etc....)			lump sum	1,197,300
			Subtotal	2,493,000
			Contingencies (15% of Subtotal)	374,000
			Total Construction Cost (TCC)	2,867,000
			Utility Relocation Costs (7% of TCC)	201,000
			Engineering, Legal & Administration Costs (15% of TCC)	430,000
			Total Project Cost	3,498,000

(1) Upgrade the existing stormwater conveyance system.

(2) Provide detention storage.

(3) A combination of upgrading the system and detention storage.

These alternatives are viable and would provide a conveyance system that meets present City standards to adequately convey the future 10-year stormwater flows. Since the Fleming watershed is not fully developed, particularly in the upper reaches, open land is available for the development of a detention facility capable of reducing flows and augmenting replacing portions of the conveyance system.

Improvements for alternative (1), upgrade the existing conveyance system are presented on Figure VII-4 and in Table VII-7. Alternative (3), a combination of system upgrade and detention storage, should be evaluated in further detail. This is particularly true for the northern watershed since the upper reaches have not yet been fully developed.

Development of a regional detention facility could reduce peak flows and minimize structural improvements, while enhancing water quality, aesthetics and the potential for multi-use facilities. However, the upper reaches contain marshlands and the viability of construction of a detention basin will need to be further investigated.

3. Honey

The Honey stormwater conveyance system consists of a series of underground conduits which discharge out of the City limits. The Honey watershed and conveyance system are presented on Figure VII-5. The Honey stormwater conveyance system appears to be operating properly, but future conditions modeling identifies system inadequacies as presented on Figure VII-6.

Because of the limited number of system inadequacies and the extent of present development, the modify/replace the existing stormwater conveyance system alternative improvements are presented on Figure VII-6 and in Table VII-8. Numerous locations exist for "site-specific" detention facilities and should be investigated in more detail.

4. Huron

The Huron watershed consists of five individual areas that are drained by stormwater conveyance systems of 36-inch and larger conduits. The Huron stormwater conveyance systems modeled consist of a series of underground conduits and open channels that discharge into the Huron River. The Huron watershed and conveyance systems are presented on Figure VII-7. Presently, the Huron watershed experiences some flooding, and the system appears to be operating properly. However, modeling the effects of future development identifies system inadequacies as presented on Figure VII-8 and in Table VII-9. To assure that the Huron conveyance system complies with design standards for future land use conditions, the following alternatives exist for conveying/controlling the stormwater flows:

(1) Modify/replace the existing stormwater conveyance system.
(2) Provide detention storage.
(3) A combination of modifying/replacing the system and detention storage.

Because of the nature and extent of the five individual areas and the location of the system inadequacies, alternative (1) modifies/replaces the existing stormwater conveyance system which is recommended and presented on Figure VII-8 and in Table VII-9.

Although numerous locations exist for "site-specific" detention facilities, the fact that five individual areas exist may cause too many operational and maintenance challenges to be cost-effective.

Table VII-8
Honey Watershed Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	25	lf	110	2,750
54 inch RCP	1,770	lf	140	247,800
60 inch RCP	1,470	lf	200	294,000
72 inch RCP	300	lf	250	75,000
78 inch RCP	1,450	lf	270	391,500
Excavation & Embankments	2,154	cy	10	21,540
Manhole: 6 ft or less diameter	10	ea	2,380	23,800
Manhole: greater than 6 ft diameter	3	ea	5,320	15,960
Miscellaneous (paved area removal & replacement, street crossings, seeding, tunneling & jacking, etc....)			lump sum	305,200
			Subtotal	1,378,000
			Contingencies (15% of Subtotal)	207,000
			Total Construction Cost (TCC)	1,585,000
			Utility Relocation Costs (7% of TCC)	111,000
			Engineering, Legal & Administration Costs (15% of TCC)	238,000
			Total Project Cost	1,934,000

Table VII-9
Huron Watershed Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
36 inch RCP	90	lf	70	6,300
42 inch RCP	339	lf	90	30,510
48 inch RCP	1,210	lf	110	133,100
54 inch RCP	3,530	lf	140	494,200
60 inch RCP	1,143	lf	200	228,600
66 inch RCP	1,886	lf	220	414,920
72 inch RCP	610	lf	250	152,500
78 inch RCP	341	lf	270	92,070
84 inch RCP	200	lf	290	58,000
6 X 5 RCB	60	lf	370	22,200
7 X 4 RCB	46	lf	380	17,480
12 X 4 RCB	196	lf	570	111,720
14 X 10 RCB	40	lf	840	33,600
Excavation & Embankments	4,100	cy	10	41,000
Manhole: 6 ft or less diameter	49	ea	2,380	116,620
Manhole: greater than 6 ft diameter	6	ea	5,320	31,920
Miscellaneous (paved area removal & replacement, street crossings, seeding, tunneling & jacking, etc....)			lump sum	971,900
			Subtotal	2,957,000
			Contingencies (15% of Subtotal)	444,000
			Total Construction Cost (TCC)	3,401,000
			Utility Relocation Costs (7% of TCC)	238,000
			Engineering, Legal & Administration Costs (15% of TCC)	510,000
			Total Project Cost	4,149,000

5. Mallets

The Mallets watershed contains the largest drainage area of any watershed within Ann Arbor. The stormwater conveyance system consists of a series of underground conduits within the upper reaches of the conveyance system with a series of open channels, culverts and underground conduits in the main reaches of the system. The Mallets watershed and conveyance system are presented on Figures VII-9 and VII-10. Currently, the Mallets watershed experiences flooding in locations throughout the watershed, including both upper and main reaches of the conveyance system. Modeling the effects of future development within the watershed identifies additional inadequacies within the conveyance system, as presented on Figures VII-11 and VII-12 and in Table VII-10. To assure that the Mallets conveyance system complies with design standards for future site conditions, the following alternatives exist for conveying/controlling the stormwater flows:

(1) Modify/replace the existing stormwater conveyance system
(2) Provide detention storage
(3) A combination of modifying/replacing the system and detention storage
(4) Land acquisition of flood prone areas
(5) Floodproofing properties
(6) Develop improvements for a lesser storm event

Alternatives (1) through (3) can adequately convey the 10-year stormwater flows and therefore can comply with City standards. The required improvements for (1) would be extremely costly. Alternatives (2) and (3) are technically feasible and existing detention ponds currently provide storage at several locations within the watershed. However, the areas within the conveyance system with the most severe flooding problems do not have sufficient land available to adequately detain the flows and therefore may not be practical.

Alternatives (4) and (5) do not comply with present City standards, and would not eliminate the flooding for the 10-year design storm. However, they do provide cost-effective alternatives to reducing the extent of flooding. Alternative (6) also does not comply with present City stands, but it does provide a higher level of protection than presently exists and can greatly reduce the cost of improvements.

To comply with City standards, alternative (3), a combination of modifying/replacing the system and detention storage, is recommended. Areas exist upstream of the main reaches of the conveyance system where detention storage may be possible. This would limit the peak runoff experienced within the main reaches of the conveyance system and may eliminate the need for modifying/replacing portions of the system downstream. However, details, including the location of the detention ponds and required land acquisition costs to site the ponds, are beyond the planning level analysis of this study. In addition, the cost of modifying/replacing portions of the system alone may be impractical. It may be prudent for the City to investigate less costly measures within this watershed such as the land acquisition of flood-prone properties, floodproofing of properties, and/or development of improvements for a lessor storm.

6. Miller

The upper reaches of the Miller stormwater conveyance system consists of a series of underground conduits while the main reaches of the conveyance system is a series of large open channels and culverts. The Miller watershed and conveyance system are presented on Figure VII-13. Presently, the Miller watershed experiences flooding primarily in the upper reaches of the watershed. Modeling the effects of future development identifies system inadequacies as presented on Figure VII-14 and in Table VII-11. To assure that the Miller conveyance system complies with design standards for future land use conditions, the following alternatives exist for conveying/controlling the stormwater flows:

(1) Modify/replace the existing stormwater conveyance system.
(2) Provide detention storage.
(3) A combination of modifying/replacing the system and detention storage.
(4) Zoning and flood plain restrictions and enforcement.

Table VII-10
Mallets Watershed Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	5,376	lf	110	591,360
54 inch RCP	8,025	lf	140	1,123,500
60 inch RCP	1,225	lf	200	245,000
72 inch RCP	3,451	lf	250	862,750
84 inch RCP	40	lf	290	11,600

Table VII-10 (continued)
Mallets Watershed Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
90 inch RCP	153	lf	330	50,490
6 X 5 RCB	1099	lf	370	406,630
7 X 5 RCB	1909	lf	390	744,510
8 X 6 RCB	924	lf	440	406,560
8 X 7 RCB	850	lf	510	433,500
8 X 8 RCB	1,169	lf	480	561,120
9X 6 RCB	3,020	lf	470	1,419,400
9 X 7 RCB	331	lf	440	145,640
10 X 6 RCB	790	lf	490	387,100
16 X 12 RCB	4,944	lf	790	3,905,760
12 X 8 RCB	370	lf	660	244,200
12 X 10 RCB	570	lf	730	416,100
14 X 10 RCB	55	lf	840	46,200
14 X 12 RCB	702	lf	970	680,940
Double 7 X 6 RCB	1,362	lf	670	912,540
Double 7 X 7 RCB	2,602	lf	690	1,795,380
Double 9 X 6 RCB	60	lf	1,370	82,200
Double 10 X 8 RCB	192	lf	1,010	193,920
Double 12 X 10 RCB	1,913	lf	1,370	2,620,810
Double 12 X 12 RCB	1,850	lf	1,520	2,812,000
Triple 10 X 6 RCB	99	lf	870	86,130
Six 7 X 6 RCB	168	lf	2,010	337,680
Excavation & Embankments	4,100	cy	10	41,000
Manhole: 6 ft or less diameter	156	ea	2,380	371,280
Manhole: greater than 6 ft diameter	18	ea	5,320	95,760
Excavation and Embankments	304,227	cy	5	1,521,135

Table VII-10 (continued) Mallets Watershed Improvements Cost Estimate				
Item Description	Qty	Unit	Unit Cost $	Total Cost $
Miscellaneous (paved area removal & replacement, street crossings, seeding, tunneling & jacking, etc....)			lump sum	3,706,640
Subtotal				27,259,000
Contingencies (15% of Subtotal)				4,089,000
Total Construction Cost (TCC)				31,348,000
Utility Relocation Costs (7% of TCC)				2,194,000
Engineering, Legal & Administration Costs (15% of TCC)				5,031,000
Total Project Cost				38,573,000

These alternatives are viable and would provide a conveyance system that meets present City standards to adequately convey the 10-year stormwater flows. A combination of the Miller watershed not being fully developed and the size of the open channels along the mid-portion of the watershed provide an excellent opportunity for the development of detention facilities. The Miller watershed conveyance system is unique in that the middle reaches of the conveyance system consists of very large open channels, while the lower portion of the conveyance system is a small and confined channel. This configuration requires that increasing the upstream conveyance system capacities will not provide for adequate improvements since the downstream channels are confined and will not be able to convey these increased flows. Presently, the open channels in the middle reaches of the watershed provide a significant amount of natural detention/storage. Although structural improvements and detention storage are required, a combination of flood plain enforcement and land use/zoning restrictions may provide the most cost-effective solutions by offsetting the extent of some of the required improvements.

The recommended improvements are presented on Figure VII-14 and in Table VII-11. The culvert improvements have been designed to allow natural detention to continue to occur, but not to the extent that it presently occurs. Some channel widening may also be required to convey and store flows. The enforcement and expansion of flood plains could effectively decrease the extent of improvements by allowing additional natural storage to occur. Therefore, in addition to the improvements presented on Figure VII-14 and in Table VII-11, it is recommended that flood plain limits be confirmed and expanded, where feasible, to limit the amount of structural improvements required.

Table VII-11 Miller Watershed Improvements Cost Estimate				
Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	4,162	lf	110	457,820
54 inch RCP	826	lf	140	115,640
60 inch RCP	3,063	lf	200	612,600
72 inch RCP	862	lf	250	215,500
84 inch RCP	584	lf	290	169,360
90 inch RCP	130	lf	330	42,900
120 inch RCP	200	lf	620	124,000
10 X 7 RCB	343	lf	510	174,930
2 X 6 X 6 RCB	900	lf	590	531,000
2 X 10 X 6 RCB	65	lf	950	61,750
Excavation & Embankments	43,700	cy	10	437,000
Manholes: 6 ft or less diameter	42	ea	2,380	99,960
Manholes: greater than 6 ft diameter	3	ea	5,320	15,960
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	622,600
			Subtotal	3,681,000
			Contingencies (15% of Subtotal)	552,000
			Total Construction Cost (TCC)	4,233,000
			Utility Relocation Costs (7% of TCC)	296,000
			Engineering, Legal & Administration Costs (15% of TCC)	635,000
			Total Project Cost	5,164,000

7. Swift Run

The Swift Run watershed stormwater conveyance system consists of a series of large open channels and culverts and some lengths of underground conveyance system. The Swift Run watershed and conveyance system are presented on Figure VII-15. Presently, the Swift Run watershed experiences minimal flooding in the middle reaches of the watershed. Modeling the effects of future development identifies additional system inadequacies in the lower reaches as presented on Figure VII-16. The location and extent of the system inadequacies lends itself to site-specific detention and not regional detention. Because of this, the improvements and cost estimates are based on replacing the existing stormwater conveyance system.

Table VII-12
Swift Run Watershed Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	381	lf	110	41,910
60 inch RCP	1,697	lf	200	339,400
7 X 7 RCB	1,413	lf	400	565,200
10 X 7 RCB	591	lf	510	301,410
Manholes: 6 ft or less diameter	13	lf	2,380	30,940
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)			lump sum	634,800
			Subtotal	1,914,000
			Contingencies (15% of Subtotal)	287,000
			Total Construction Cost (TCC)	2,201,000
			Utility Relocation Costs (7% of TCC)	154,000
			Engineering, Legal & Administration Costs (15% of TCC)	330,000
			Total Project Cost	2,685,000

8. Traver Creek

The Traver Creek watershed stormwater conveyance system consists of a series of large open channels and culverts. The Traver Creek watershed and conveyance system are presented on Figure VII-17. Presently, the Traver Creek watershed experiences some flooding in the lower reaches. Modeling the effects of future development identifies system inadequacies as presented on Figure VII-18. To assure that the Traver Creek conveyance system complies with design standards for future land use conditions, the following alternatives exist for conveying/controlling the stormwater flows:

(1) Modify/replace the existing stormwater conveyance system.
(2) Provide detention storage.
(3) A combination of modifying/replacing the system and detention storage.
(4) Zoning and flood plain restrictions and enforcement.

These alternatives are viable and would provide a conveyance system that meets present City standards to adequately convey the 10-year stormwater flows. The Traver Creek watershed is not fully developed, thus there is an excellent opportunity for the development of detention facilities. Although structural improvements are required, a combination of flood plain enforcement and land use/zoning restrictions may provide the most cost-effective solutions by offsetting the extent of some of the required improvements. The location of system improvements are sparse and length of the improvements are minimal; these facts lend the improvements to replacing the existing conveyance system components.

Table VII-13
Traver Creek Watershed Improvements Cost Estimate

Item Description	Qty	Unit	Unit Cost $	Total Cost $
48 inch RCP	530	lf	110	58,300
54 inch RCP	1,010	lf	140	141,400
72 inch RCP	320	lf	250	80,000
Manholes: 6 ft or less diameter	7	ea	2,380	16,660
Manholes: greater than 6 ft diameter	2	ea	5,320	10,640
Miscellaneous (paved area removal & replacement, street crossings, seeding, etc....)		lump sum		138,100
			Subtotal	445,000
			Contingencies (15% of Subtotal)	67,000
			Total Construction Cost (TCC)	512,000
			Utility Relocation Costs (7% of TCC)	36,000
			Engineering, Legal & Administration Costs (15% of TCC)	77,000
			Total Project Cost	625,000

C. Capital Improvements List

The finalization of this master plan concludes the study of Ann Arbor stormwater management system's capabilities and needs, and the planning phase of a comprehensive stormwater capital improvements program to address these needs. It is recommended that Ann Arbor proceed, by watershed, with more detailed analyses, and design and construction of stormwater improvement projects. This master plan provides a sound basis for these detailed analyses and ultimately design and construction. It has been completed on a watershed basis, and therefore, the capital improvements list has also been generated on a watershed basis. The capital improvements list below has been developed from a technical engineering perspective - that being "composite projects" that are coordinated and are developed from downstream to upstream on a watershed basis. Other critical factors such as financing and the degree, extent, and timing of development will directly impact how and when these projects are completed. Therefore, this list should be constantly reviewed, updated, and refined to reflect the dynamic changes occurring in Ann Arbor and the additional analyses completed. Each project on the list consists of numerous components that have been grouped by watershed or by logical groupings within a watershed. As Ann Arbor develops and expands on the results of this study, smaller "sub-groupings" will be developed, prioritized, and implemented within each watershed and, ultimately, within the city. Preliminary-design level analyses, by watershed, will better define the extent and groupings.

Allen Creek Watershed and Mallets Watershed are prime examples of the need for further, more detailed analyses to help better define the improvements and prioritization of the improvements due to the watershed sizes and amount of flooding. Both watersheds are large and have a significant amount of flooding. It will take many years to design and construct the improvements, and the phasing of the improvements will need to account for funding availability, severity and frequency of flooding, and development. The preliminary design level analyses will more accurately identify the extent of flooding and the implications of phasing the construction of improvements throughout the watershed.

Table VII-14
Capital Improvements List

Grouping	Project Cost ($)
Allen Creek Watershed - West Park-Miller	6,695,000
Allen Creek Watershed - Murray Washington	9,703,000
Allen Creek Watershed - Eber-White	2,837,000
Allen Creek Watershed - Stadium Branch	2,765,000
Allen Creek Watershed - Main Branch Upstream	9,587,000
Allen Creek Watershed - Main Branch Downstream	9,416,000
Fleming Watershed	3,498,000
Honey Watershed	1,934,000
Huron Watershed	4,149,000
Mallets Watershed	38,573,000
Miller Watershed	5,164,000
Swift Run Watershed	2,685,000
Traver Creek Watershed	625,000

97.3