Final Report

Lawrence Wastewater Master Plan

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Project No. 49768

BLACK & VEATCH
Corporation

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Executive Summary

1. Purpose

The purpose of this report is to present the results of a comprehensive wastewater master planning evaluation of the City of Lawrence wastewater system. The recommended improvements plan presented herein will serve as a master plan basis for the design, construction, and financing of facilities to meet anticipated regulatory requirements, residential and commercial growth, and system reliability needs for the design year of 2025. Implementation of the recommended improvements will provide an adequate and dependable wastewater system for the City of Lawrence through the year 2025.

2. Study Area and Scope

The Study Area for this investigation and report is shown in Figure I-1. The boundaries of the Study Area were delineated by the City of Lawrence Planning Department. The boundaries are as follows:

- Existing City Limits: City Limits of the City of Lawrence as of year 2000.
- Study Area Limits: The anticipated extent of the year 2025 Urban Growth Area (UGA) as established by the City for the *2025 Transportation Plan*.

The study period for this master plan investigation is from year 2000 through the year 2025. Detailed evaluations of the wastewater system were conducted for the design years 2000, 2010, and 2025.

The Principle elements of the study include the following:

- Review regulatory discharge limits for the Wakarusa River. Determine service area and wastewater flows for a possible wastewater treatment plant located at the Wakarusa River.
- Conduct wastewater treatment plant (WWTP) and collection system analysis to determine feasibility of expanding the Kansas River WWTP or implementing a new Wakarusa River WWTP.
- Review flow metering and rainfall monitoring data provided by the City to determine system flow characteristics.
- Create a trunk sewer inventory for modeling based on existing GIS data provided by the City.

- Develop and calibrate a HydroWorks computer model of the Lawrence sewer system using the trunk sewer inventory.
- Analyze the sewer system for current conditions.
- Define and evaluate alternatives to serve future growth as projected by the Lawrence-Douglas County Planning Office. Create hydraulic models for design years 2010 and 2025.
- Define and evaluate collection system alternatives to serve ultimate build-out conditions for the City of Lawrence.
- Recommend improvements for the collection system facilities and update the wastewater collection system improvements plan.

3. Population and Wastewater Flows

Estimated year 2000 and projected wastewater service population used for this report are summarized in Table ES-1. Population projections were developed by the Lawrence-Douglas County Metropolitan Planning Office.

Table ES-1
Wastewater Service Population

Year	Population	Population Growth	
		Persons	% (Annual)
2000	79,817 (1)		
2010	99,600 (2)	19,733	2.2
2025	149,278 (3)	49,678	2.7
2050	244,906 (4)	95,628	2.0

(1) U.S. Census Bureau population for City of Lawrence, Kansas
(2) Based on spatial analysis of population by TAZ provided by Lawrence-Douglas County Metropolitan Planning Office within assumed year 2010 retail water service limits and excluding population within wholesale water districts
(3) Projection by Lawrence-Douglas County Metropolitan Planning Office for UGA
(4) Projection developed for this report based on 2% per year growth rate from 2025 through 2050

The relative range of population growth by wastewater subbasin area is shown on Figures I-3 and I-4. Figure I-3 shows the difference in population from year 2000 to year 2010 and Figure I-4 shows the difference in population from year 2010 to 2025. As shown on these figures, the largest amount of population growth is projected in west Lawrence and south of the Wakarusa River.

The current annual average capacity of the Kansas River Wastewater Treatment Plant is 12.5 million gallons per day (mgd). The year 2025 annual average wastewater flow projected for two wastewater treatment plant (WWTP) scenarios is summarized as follows:

Scenario 1 - All Flow to Existing Kansas River WWTP

- Kansas River WWTP – 18.8 mgd

Scenario 2 - Flow to Wakarusa River and Kansas River WWTP's

- Wakarusa River WWTP – 6.9 mgd
- Kansas River WWTP – 11.9 mgd

4. Wastewater Collection and Treatment Alternatives

An evaluation was conducted to compare wastewater collection and treatment alternatives, based on wastewater treatment plant location, and recommend the best collection and treatment configuration for final basis of the Wastewater Master Plan. Three wastewater treatment plant (WWTP) locations were considered to determine the recommended wastewater system configuration. The evaluation was based on design year 2025 population and land use projections and includes all projected wastewater flows for the study area. Treatment systems were based on anticipated future regulatory requirements obtained from the Kansas Department of Health and Environment (KDHE).

Alternative 1, shown in Figure II-1, consists of routing all wastewater flow for the study area to the existing Kansas River WWTP. The existing WWTP would need to be upgraded and expanded to a capacity of 18.8 mgd. Alternative 2, shown in Figure II-2, is based on dividing the study area and conveying part of the flow to the existing Kansas River WWTP and the remaining flow to a proposed Wakarusa River WWTP (Site A). The plant capacities for the Kansas River and Wakarusa River WWTP's would be 11.9 mgd and 6.9 mgd, respectively. Alternative 3, shown in Figure II-3, is similar to Alternative 2, however, a different site (Site B) was used for the proposed Wakarusa River WWTP. The selection of two Wakarusa WWTP sites was made to allow consideration of differing project costs due to site location, however, a Wakarusa WWTP could be located in many different locations along the Wakarusa River.

Anticipated future regulatory requirements for the Kansas River and the Wakarusa River were received from KDHE. The requirements were based on the National Nutrient Strategy developed by the Environmental Protection Agency (EPA). The strategy presents recommended water quality on an Ecoregion basis, which for Region IX, includes the Kansas and Wakarusa Rivers. In order to meet the new EPA nutrient strategy, biological nutrient removal facilities will be required for wastewater treatment at both the Kansas and Wakarusa Rivers. In addition, the wastewater treatment requirements will be the same for discharges to either the Kansas River or the Wakarusa River. KDHE has indicated facilities for both the Kansas and Wakarusa Rivers must meet the following biological nutrient removal requirements:

Biological Nutrient Removal Requirements
Total Phosphorous < 1.5 mg/L
Total Nitrogen < 10.0 mg/L
Ammonia Nitrogen < 1.0 mg/L

An additional requirement for a Wakarusa River discharge is that an anti-degradation review process must be completed before a National Effluent Discharge Elimination (NPDES) permit is issued for the Wakarusa River. KDHE has indicated that this review process will most likely not prevent an NPDES permit from being issued to the City of Lawrence for the Wakarusa River. Therefore, it appears that wastewater treatment plant discharges to the Wakarusa River are viable from a regulatory standpoint.

Alternative 3 has the lowest capital cost and the lowest present worth as shown in the cost-effectiveness analysis, Appendix E. A distinct difference is shown for the present worth of the capital costs. The ranking of alternatives by present worth of capital costs is shown below.

Ranking by Present Worth of Capital Costs

Ranking	Alternative Description	Present Worth	Difference from Alt. 3
1	Alt. 3 – Wakarusa WWTP (Site B)	$48,400,000	
2	Alt. 2 – Wakarusa WWTP (Site A)	$52,000,000	7.4%
3	Alt. 1 – Kansas River WWTP	$56,600,000	16.9%

From a cost standpoint, master planning alternatives may be considered similar if the difference in present worth is less than 10 percent. Based on capital costs only, Alternative 1 is not equivalent to the Wakarusa Alternatives 2 and 3. Alternative 3 has the lowest capital cost, however, Alternative 2 should be given consideration since the capital cost difference is less than 10 percent.

Alternative 3 has the lowest total present worth considering both project and operation and maintenance costs. The ranking of alternatives by present worth cost of both capital and operation and maintenance costs is shown below:

Ranking by Present Worth of Capital and O&M Costs

Ranking	Alternative Description	Present Worth	Difference from Alt. 3
1	Alt. 3 – Wakarusa WWTP (Site B)	$74,300,000	
2	Alt. 2 – Wakarusa WWTP (Site A)	$78,200,000	5.3%
3	Alt. 1 – Kansas River WWTP	$82,000,000	10.4%

The difference in total present worth cost between Alternatives 1 and 3 is larger than 10 percent, so Alternative 1 would still not be considered similar to Alternative 3. The difference in present worth between Alternatives 2 and 3, at 5.3 percent, is close enough that both plant locations should be given consideration, however, Alternative 3 is the best option from a cost standpoint.

Alternative 3 – Wakarusa WWTP (Site B) is the most cost-effective option for the City of Lawrence and, at present, does not appear to have any fatal flaws with respect to additional issues presented in Table II-5.

Consideration should also be given to the long-term expansion of the City wastewater system. After the year 2025, further expansion of the Kansas River WWTP beyond that shown for Alternative 1 would be extremely difficult. Additional space for expansion within the existing plant layout would not be available, therefore, any future expansion after 2025 would likely require a separate treatment plant located adjacent to the existing plant. The collection system would also need to be expanded with parallel pipelines in congested areas to route flow from west and south Lawrence to the existing plant.

In a similar fashion, consideration should also be given to the impact of implementing a Wakarusa River WWTP after 2025 if Alternative 1 – Kansas River WWTP is selected now. If a Wakarusa River WWTP is implemented after 2025, a significant amount of collection system infrastructure would be constructed for Alternative 1 that would not be needed after the year 2025. Alternative 1 collection system improvements that would be unused after 2025 include the 31st Street Relief Sewer, Wakarusa Pumping Station 5C and Force Main 5C, and most of the force main for Wakarusa South Pumping Station WRS-1. The capital cost for these collection system facilities which would not be used after 2025 is $19,200,000.

Based on capital and present worth costs, review of additional issues, and long-term wastewater expansion issues beyond 2025, the recommended plan is Alternative 3 – Wakarusa River WWTP (Site B). It is recommended that collection system improvements proceed on the basis of routing flow for part of the collection system to a future Wakarusa River WWTP. The Four Seasons Holding Basins should be used as a wet-weather handling facility for all Wakarusa River WWTP service area flow originating north of the Wakarusa River. It is also recommended that studies be conducted of the additional issues including environmental, cultural resource, and flood plain impact assessments to determine the best and most favorable location for a Wakarusa River WWTP site.

5. Collection System Findings and Recommendations

This section summarizes collection system findings and recommendations for the Wastewater Master Plan.

5.1 Summary

A sanitary sewer flow and rainfall monitoring program was conducted by the Lawrence Utility Department for portions of the existing Lawrence wastewater collection system. The flow and rainfall data provided by the City was used in this master planning effort to determine system flow rates, to evaluate the rates of infiltration and inflow (I/I), and to calibrate a computer model of the Lawrence wastewater system. Six open channel flow meters and four rain gauges were installed in the study area and monitored during April and May 2000.

The City provided Black & Veatch with GIS databases that contained information on trunk sewer lines and manholes within the City limits. The trunk sanitary sewer computer model consists of approximately 87.9 miles (464,000 feet) of sewer pipe ranging in size from 8 inches to 48 inches in diameter. The trunk sewer inventory data was imported into Black & Veatch's Sanitary Sewer Management System (SSMS) to create a computerized hydraulic model.

The existing model inventory and planned collection system and wastewater treatment improvements comprise the future model inventory. Hydraulic capacity analyses were performed to identify sewers, pump stations, and force mains with insufficient capacity for future growth peak flows. Projected future growth peak flows assume the successful completion of a 20 percent I/I removal program. The analyses were then used to develop an Implementation Plan to address improvements and the phasing of the improvements.

5.2 Findings

Flow and rainfall monitoring showed that the levels of I/I in the collection system during storms had decreased since the 1995 Wastewater Master Plan flow and rainfall monitoring program. Sewer rehabilitation efforts by the City have reduced the number of defects through the rehabilitation program. The 1995 Wastewater Master Plan called for 30 percent removal. After review and evaluation of the successful decrease in I/I, it was estimated that the goal should be revised to 20 percent I/I removal to reflect the improvements made with I/I removal.

The results of the hydraulic modeling indicate that the Alabama pump station (PS-8) is currently overloaded. This was confirmed in conversations with City Staff. Since space to expand this pump station is limited, the preferred alternative is to redirect flow from the pump station to another subbasin by a gravity sewer line.

Based on future growth patterns, the existing treatment plant capacity, and the hydraulic modeling undertaken for current and future planning years, three alternatives were evaluated for future collection system configurations. In one alternative, all wastewater is conveyed to the existing treatment plant. In the other two alternatives, most additional future flow is to be conveyed to the proposed Wakarusa River WWTP.

5.3 Recommendations

It is recommended that the Alabama Pump Station be abandoned and a gravity sewer line be installed to redirect this flow to another subbasin.

The City's current Infiltration and Inflow (I/I) removal program should be continued. Future improvements and alternatives assume that 20% of the I/I will be removed from the existing system.

It is recommend that most additional future flow be conveyed for treatment at a new Wakarusa River WWTP located south of the Wakarusa River. Flow from the Yankee Tank Creek Basin will be conveyed from the Four Seasons Pumping Station to the new WWTP via a new force main.

Recommended collection system improvement projects are shown in Table IV-4 and on Figure IV-1.

6. Wastewater Treatment Plant Findings and Recommendations

This section summarizes wastewater treatment plant findings and recommendations for the Wastewater Master Plan.

6.1 Kansas River WWTP Improvements

Several improvements will be required for the Kansas River WWTP to meet regulatory requirements and maintain system reliability. Capacity expansion is not required for liquid treatment because City growth requirements will be accommodated with the implementation of a new Wakarusa River WWTP in the year 2011. Capacity expansion is required for solids treatment because the existing anaerobic digester capacity will be exceeded. Anaerobic digester improvements will consist of converting the existing anaerobic digester storage tank to a secondary digester with gas mixers and a floating cover, expanding the gas control building, and upgrading the digester SCADA system to current City standards.

The existing dissolved air flotation (DAF) thickener is designed to normally operate on a continuous 24-hour basis without polymer addition to thicken waste activated sludge (WAS). The DAF was sized for an annual average flow capacity of 12.5 mgd to the treatment plant. With polymer addition, the DAF is sized to process maximum month WAS quantities at 12.5 mgd design within an 8 hour period per day. Without polymer addition, it is anticipated that the DAF thickener will reach its design capacity by the year 2009. However, with polymer addition, the

DAF should be capable of thickening WAS during the interim period of 2009 to 2011, prior to start-up of the new Wakarusa River WWTP in 2011. Once the Wakarusa River WWTP starts operation, the existing DAF will have capacity to thicken WAS on a 24-hour basis, without polymer addition, during the design period of 2012 to 2025.

It is anticipated that future regulations will require the addition of biological nutrient removal (BNR) facilities for total nitrogen removal and phosphorous removal. KDHE indicated the liquid treatment facilities will need to be upgraded to meet a total nitrogen limit of 10 mg/L, an ammonia limit of 1 mg/L, and a phosphorous limit of 1.5 mg/L. The timetable for these regulatory improvements has not been dictated by KDHE at this time; therefore, a speculative timeframe for BNR improvements at the Kansas River WWTP is approximately the year 2015. BNR improvements would consist of external BNR basins for Aeration Basin No.s 1 and 2, BNR modifications internal to Aeration Basin No.s 3 and 4, and a fermentor/gravity thickener for primary sludge to produce volatile fatty acids for the BNR process.

New facility improvements required for the Kansas River WWTP are as follows:

- Anaerobic Digester Improvements
- Roof for Dewatered Biosolids Storage Basin
- Vehicle and Equipment Storage Building
- Biological Nutrient Removal Facilities

6.2 Wakarusa River WWTP Improvements

It is recommended to implement a new Wakarusa River WWTP to meet the growth requirements for the City of Lawrence and effectively comply with future regulatory requirements. As described in the WWTP evaluation section of this Master Plan, it is the best and most cost-effective solution to implement a Wakarusa River WWTP rather than conveying and treating all wastewater flow at the Kansas River WWTP. The Wakarusa River WWTP would be designed to accommodate all flow from west Lawrence that is pumped from the Four Seasons Pumping Station and all flow conveyed from south of the Wakarusa River.

Based on population projections, it is projected that a 6.9 mgd (annual average) WWTP will be required to meet 2025 growth projections for the service area. The WWTP should be designed with BNR facilities and contain space in the hydraulic profile for filtration facilities, if required in the future. The Four Seasons Pumping Station will pump flow directly to the WWTP for the west Lawrence service area. It is anticipated the design capacity of the existing Kansas River WWTP will be reached in the year 2011, therefore, the new Wakarusa River WWTP should be constructed and in service by the year 2011. A septage receiving facility should be provided at the WWTP to serve residential and commercial customers located south of the Wakarusa River.

It is recommended that studies be conducted of plant site issues including environmental, cultural resource, and flood impact assessments to determine the best and most favorable location for a Wakarusa River WWTP site. These studies should commence immediately so that adequate time is allowed to study, identify, and purchase the land for the Wakarusa River WWTP site. Sufficient land should be procured to allow for future WWTP expansions and provide an adequate buffer zone to residential and commercial development.

6.3 Project Costs and Implementation Plan

All costs presented within this report are Opinions of Probable Project Cost and have been developed from previous Black & Veatch projects of similar size and scope. All collection system related improvements including pipelines, storage facilities and pumping stations include a 20 percent allowance for contingencies and 20 percent allowance for engineering, legal and administrative (ELA) costs. All wastewater treatment plant related improvements include a 25 percent allowance for contingencies and 20 percent allowance for engineering, legal and administrative costs.

The overall wastewater system capital costs, in 2003 dollars, for the 2025 planning period are summarized in Table ES-2. Wastewater treatment plant improvements indicated below include a new 6.9 mgd Wakarusa River WWTP, with biological nutrient removal and biological nutrient removal improvements for the existing 12.5 mgd Kansas River WWTP.

Table ES-2
Capital Cost Summary of Implementation Plan

	Capital Cost ($)
Gravity Sewers	$18,059,000
Pump Stations and Force Mains	$11,607,000
Sewer Extensions (City Developed) [1]	$7,079,000
I/I Reduction Program	$650,000
Wastewater Treatment Plant Improvements	$70,570,000
CMOM	$200,000
General Improvements	$1,500,000
Total	$109,665,000

[1]City developed sewer extensions only include extension projects E-WRS-3-01, E-WRS-4-01, E-WRS-5-01, E-WRS-5-05, E-WRS-6-01, E-NL3PS1, and E-FM-NL3.

A detailed wastewater system implementation plan containing capital costs by planning year is shown in Table IV-4.

SECTION I – GENERAL

1.0 Introduction

1.1 Purpose

The purpose of this report is to provide the City of Lawrence with a comprehensive master planning evaluation of the City's wastewater system. The recommended plan presented herein addresses the design, construction, and financing of facilities to meet anticipated regulatory requirements, residential and commercial growth, and system reliability needs for the City of Lawrence. Implementation of the recommended improvements will provide an adequate and dependable wastewater system for existing and future customers.

1.2 Study Area and Scope

The Study Area for this investigation and report is shown on Figure I-1. The boundaries of the Study Area were delineated by the City of Lawrence Planning Department. The boundaries are as follows:

- Existing City Limits: City Limits of the City of Lawrence as of year 2000.
- Study Area Limits: The anticipated extent of the year 2025 Urban Growth Area (UGA) as established by the City for the *2025 Transportation Plan*.

The study period for this investigation is from year 2000 through the year 2025. Detailed evaluations of the wastewater system were conducted for year 2000, 2010, and 2025. Alternative collection system configurations were evaluated to serve future growth.

The principal elements of this study include the following:

- Review regulatory discharge limits for Wakarusa River. Determine service area and flows for a possible future wastewater treatment plant located at the Wakarusa River.
- Conduct wastewater treatment plant (WWTP) and collection system analysis to determine feasibility of expanding the Kansas River WWTP or implementing a new Wakarusa River WWTP.
- Analyze flow and rainfall data for the flow meters at six locations and determine average daily dry weather flow, average annual flow, infiltration and inflow rates, and total peak flow.
- Prepare flow projections for each subbasin based on future land use, population projections, and flow and rainfall evaluation.
- Create trunk sewer inventory for updating the 1995 Master Plan computer model.

- Develop and calibrate a Hydroworks computer model based on updated inventory and previous flow monitoring data.
- Analyze the existing system for the selected design condition using the updated model.
- Define and evaluate alternative collection system configurations for future growth and ultimate build-out of each subbasin including routing flow from the Alabama and Wakarusa Pumping Stations.
- Recommend size and capabilities for Wakarusa Pumping Station 5C and force main including schedule and phasing considerations.
- Update relief sewer improvement projects and some extensions, cost estimates for all recommended improvements, update on current status of I/I control program, and update of trunk sewer map.

Figure I-1 Study Area

1.3 Abbreviations

The Abbreviations used in this report are as follows:

BAT	Best Available Technology
$CaCO_3$	Calcium carbonate
CIP	Capital Improvements Program
CPE	Comprehensive Performance Evaluation
DOC	Dissolved organic carbon
EPA	United States Environmental Protection Agency
ft	Feet
gals/sq ft	Gallons per square foot
GIS	Geographical Information System
gpcd	gallons per capita per day
gpm	gallons per minute
HGL	Hydraulic Grade Line
Hp	Horsepower
I/C/I	Industrial/Commercial/Institutional
I/I	Inflow and Infiltration
in	Inch
KDHE	Kansas Department of Health and Environment
L	Liter
Lawrence Planning Office	Lawrence-Douglas County Metropolitan Planning Office
MGal	Million gallons
mg/L	Milligrams per liter
mgd	Million gallons per day
pCi/L	Picocuries per liter
rpm	Revolutions per minute
SCADA	Supervisory Control and Data Acquisition
TAZ	Traffic Analysis Zone
UGA	(Year 2025) Urban Growth Area
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

2.0 Population, Employment, and Land Use

2.1 General

Development of a comprehensive water system master plan begins with an evaluation of the area's historical population trends and projected growth patterns. To accurately predict future water demands, it is necessary to determine the magnitude, direction, and characteristics of future population growth.

The study years for this project include 2000 (existing), 2010, and 2025. In addition, ultimate build-out was considered in the extension watersheds.

2.2 Population

2.2.1 Historical Population

Historical population data for the City of Lawrence (City) was obtained from the U.S. Census Bureau and is summarized in Table I-1.

Table I-1
City of Lawrence Population

Year	Population (1)	Population Growth	
		Incremental Population Increase	Avg. per Year (%)
1960	32,858		
1970	45,698	12,840	3.9
1980	52,738	7,040	1.5
1990	65,608	12,870	2.4
2000	80,098	14,490	2.2

(1) U.S. Census Bureau population for the City of Lawrence, Kansas.

2.2.2 Wastewater Service Population

The City's wastewater service population is limited to the transportation 2025 plan growth boundary developed by the City. Areas outside the 2025 boundary limits are served by individual treatment systems.

Lawrence-Douglas County Metropolitan Planning Office (Lawrence Planning Office) provided the overall population projections and the housing unit counts and population per household data by traffic analysis zone (TAZ) for years 2000, 2010, and 2025 used in this report. Spatial distribution of population by subbasin and section for years 2000, 2010, and 2025 was based on this data. The estimated wastewater service population for existing and future years is presented in Table I-2 and shown graphically on Figure I-2.

Table I-2 Wastewater Service Population			
Year	Population	Population Growth	
		Incremental Population Increase	(Annual) (%)
2000	79,817		
2010	99,600[(1)]	19,783	2.2%
2025	149,278[(2)]	49,678	2.7%
2050	244,906[(3)]	95,628	2.0%

(1) Based on spatial analysis of population by TAZ provided by Lawrence-Douglas County Metropolitan Planning Office within assumed year 2010 wastewater service limits.
(2) Projection by Lawrence-Douglas County Metropolitan Planning Office for UGA.
(3) Projection developed for this report based on 2% per year growth rate.

2.2.3 Population Distribution by Wastewater Subbasin

The study area was divided into 39 wastewater subbasins. This is 15 subbasins more than the 1995 City of Lawrence Wastewater Master Plan. The increase is due to new subbasins added for the new growth areas located south of the Wakarusa River and the west side of the City. For year 2000, populations by subbasin were calculated for the additional and existing subbasin boundaries. TAZ information provided by the City was used to determine the population for each subbasin. This was similarly done for planning years 2010 and 2025.

Table I-3 presents a summary of projected population for each wastewater subbasin for years 2000, 2010, and 2025. These population values were used as the basis for determining future wastewater flow projections.

Figure I-2 Historical and Future Population

Table I-3
Population Projections by Wastewater Subbasin

Subbasin	Base Year 2000		Design Year 2010		Design Year 2025	
	Total UGA	WW Service	Total UGA	WW Service	Total UGA	WW Service
Baldwin Creek Basin						
BC-1	250	250	3,376	3,376	7,369	7,369
BC-2	46	46	952	952	2,049	2,049
BC-3	146	146	958	958	2,041	2,041
BC-4	5	0	125	0	264	264
Subtotal	447	442	5,411	5,286	11,723	11,723
Central Basin						
C-1	4,265	4,265	4,714	4,714	5,034	5,034
C-2	4,846	4,846	4,974	4,974	5,216	5,216
C-3	1,266	1,266	1,266	1,266	1,266	1,266
Subtotal	10,377	10,377	10,954	10,954	11,516	11,516
East Lawrence Basin						
EL-1	3,712	3,712	3,812	3,812	3,929	3,929
EL-2	229	229	1,200	1,200	2,900	2,900
Subtotal	3,941	3,941	5,012	5,012	6,829	6,829
Kansas River Basin						
KR-1	396	396	1,082	1,082	1,939	1,939
KR-2	6,659	6,659	8,351	8,351	12,091	12,091
KR-3	2,849	2,849	2,877	2,877	2,905	2,905
KR-4	5,386	5,386	5,386	5,386	5,386	5,386
KR-5	12,311	12,311	12,348	12,348	12,805	12,805
KR-6	4,308	4,308	4,808	4,808	5,308	5,308
Subtotal	31,909	31,909	34,852	34,852	40,434	40,434
North Lawrence Basin						
NL-1	1,156	1,156	2,952	2,952	3,836	3,836
NL-2	17	17	90	90	161	161
NL-3	31	31	401	401	802	802
Subtotal	1,204	1,204	3,443	3,443	4,799	4,799
Wakarusa River Basin						
WR-1	289	289	738	738	1,395	1,395
WR-2	8,212	8,212	8,433	8,433	11,359	11,359
WR-3	4,369	4,369	4,623	4,623	5,036	5,036
WR-4	7,978	7,978	8,179	8,179	8,646	8,646
WR-5	2,027	2,027	2,027	2,027	2,027	2,027
WR-6	7,111	7,111	7,111	7,111	8,105	8,105
Subtotal	29,986	29,986	31,111	31,111	36,568	36,568
Wakarusa River South Basin						
WRS-1	111	0	200	0	400	400
WRS-2	225	0	1,009	0	2,094	2,094
WRS-3	111	0	678	0	1,472	1,472
WRS-4	308	0	1,566	0	3,392	3,392
WRS-5	282	0	1,347	0	3,399	3,399
WRS-6	281	0	1,545	1,545	3,428	3,428
WRS-7	91	0	724	0	1,434	1,434
WRS-8	141	0	1,800	0	3,894	3,894

Table I-3 Population Projections by Wastewater Subbasin						
Subbasin	Base Year 2000		Design Year 2010		Design Year 2025	
	Total UGA	WW Service	Total UGA	WW Service	Total UGA	WW Service
WRS-9	17	0	264	0	564	564
Subtotal	1,567	0	9,133	1,545	20,077	20,077
Yankee Tank Creek Basin						
YTC-1	1,403	1,403	1,403	1,403	1,403	1,403
YTC-2	348	348	2,279	2,279	4,859	4,859
YTC-3	179	179	2,257	2,257	4,985	4,985
YTC-4	224	28	1,546	1,458	3,408	3,408
YTC-5	524	0	890	0	1,836	1,836
YTC-6	190	0	567	0	912	912
Subtotal	2,868	1,958	8,942	7,397	17,403	17,403
Total	**82,299**	**79,817**	**108,858**	**99,600**	**149,349**	**149,349**

The relative range of population growth by wastewater subbasin area is shown on Figures I-3 and I-4. Figure I-3 shows the difference in population from year 2000 to year 2010 and Figure I-4 shows the difference in population from year 2010 to 2025. As shown on these figures, the largest amount of population growth is projected to occur in west Lawrence and south of the Wakarusa River.

2.3 Employment

Employment data is used to estimate Industrial/Commercial/Institutional (ICI) wastewater flows. The Lawrence Planning Office provided employment data by TAZ within the UGA. This information was used to determine employment by wastewater subbasin for years 2000, 2010, and 2025 and is presented in Table I-4.

The relative range of employment growth by wastewater subbasin area is shown on Figure I-5 and I-6. Figure I-5 shows the difference in employment from year 2000 to year 2010. Figure I-6 shows the difference in employment for year 2010 to year 2025. The largest amount of employment growth is projected to occur in north Lawrence, the East Hills Business Park area, and along the 31st Street and Iowa Street corridors.

Figure I-3 2010 Population Increase from 2000 to 2010

Figure I-4 2025 Population Increase from 2010 to 2025

Table I-4
Employment Projections by Wastewater Subbasin

Subbasin	Base Year 2000		Design Year 2010		Design Year 2025	
	Total UGA	WW Service	Total UGA	WW Service	Total UGA	WW Service
Baldwin Creek Basin						
BC-1	206	206	724	724	1,424	1,424
BC-2	45	45	202	202	442	442
BC-3	4	0	155	155	308	308
BC-4	0	0	17	11	21	21
Subtotal	254	250	1,097	1,092	2,196	2,196
Central Basin						
C-1	3,776	3,776	4,087	4,087	4,247	4,247
C-2	2,596	2,596	2,612	2,612	2,673	2,673
C-3	610	610	610	610	610	610
Subtotal	6,981	6,981	7,308	7,308	7,530	7,530
East Lawrence Basin						
EL-1	1,809	1,809	1,809	1,809	2,204	2,204
EL-2	45	45	232	232	487	487
Subtotal	1,855	1,855	2,041	2,041	2,692	2,692
Kansas River Basin						
KR-1	1,831	1,831	2,606	2,606	3,574	3,574
KR-2	1,743	1,743	1,743	1,743	1,790	1,790
KR-3	2,612	2,612	2,671	2,671	2,740	2,740
KR-4	4,395	4,395	4,395	4,395	4,395	4,395
KR-5	9,242	9,242	9,312	9,312	9,703	9,703
KR-6	1,669	1,669	2,946	2,946	4,710	4,710
Subtotal	21,493	21,493	23,673	23,673	26,911	26,911
North Lawrence Basin						
NL-1	48	48	1,560	1,560	2,405	2,405
NL-2	1	1	27	27	41	41
NL-3	0	0	670	670	1,358	1,358
Subtotal	49	49	2,258	2,258	3,805	3,805
Wakarusa River Basin						
WR-1	17	17	48	48	95	95
WR-2	3,085	3,085	3,085	3,085	3,227	3,227
WR-3	1,190	1,190	1,273	1,273	1,404	1,404
WR-4	2,243	2,243	2,514	2,514	2,911	2,911
WR-5	104	104	104	104	104	104
WR-6	5,100	5,100	5,401	5,401	6,590	6,590
Subtotal	11,739	11,739	12,424	12,424	14,330	14,330

Table I-4
Employment Projections by Wastewater Subbasin

Subbasin	Base Year 2000		Design Year 2010		Design Year 2025	
	Total UGA	WW Service	Total UGA	WW Service	Total UGA	WW Service
Wakarusa River South Basin						
WRS-1	19	0	38	0	66	66
WRS-2	74	0	102	0	161	161
WRS-3	308	0	308	0	308	308
WRS-4	21	0	77	0	156	156
WRS-5	45	0	45	0	45	45
WRS-6	37	0	37	37	37	37
WRS-7	23	0	23	0	23	23
WRS-8	7	0	8	0	10	10
WRS-9	0	0	1	0	1	1
Subtotal	534	0	637	37	806	806
Yankee Tank Creek Basin						
YTC-1	139	139	314	314	681	681
YTC-2	615	615	881	881	1,428	1,428
YTC-3	120	120	170	170	278	278
YTC-4	12	0	224	224	420	420
YTC-5	19	0	58	58	117	117
YTC-6	24	0	24	0	27	27
Subtotal	930	972	1,672	1,647	2,951	2,951
Total	**43,834**	**43,245**	**51,110**	**50,480**	**61,221**	**61,221**

The population is projected to increase by 69,251 or 86 percent from 2000 to 2025. This represents an average annual growth rate of 3.4 percent. Over the same period, employment is projected to increase by 17,976 or 42 percent. This represents an average annual growth rate of 1.7 percent.

For purposes of modeling, population and employment numbers are combined into a single number, population- equivalent. The population equivalent and developed acres for each subbasin is found in Appendix A, Population Equivalent and Developed Acres.

Figure I-5 Employment Increase from 2000 to 2010

Figure I-6 Employment Increase from 2010 to 2025

2.4 Land Use

The City land use plan for year 2025 was provided by the Lawrence Planning Office and is shown in Figure I-7, for information.

Figure I-7 Land Use Plan

3.0 Wastewater Flows and Rainfall Analysis

3.1 Introduction

A sanitary sewer flow and rainfall monitoring program was conducted by the City of Lawrence Department of Utilities for portions of the existing Lawrence wastewater collection system. The flow and rainfall data provided by the City was used in this master planning effort to determine system flow rates, to evaluate the rates of infiltration and inflow (I/I), and to calibrate a computer model of the Lawrence wastewater system. Six open channel flow meters and four rain gauges were installed in the study area and monitored during April and May 2000. The flow meter and rain gauge locations are shown in Figure I-8.

3.1.1 Rainfall Monitoring

Rainfall monitoring was performed to develop a correlation between wet weather system flows and rainfall. Data from four rainfall gauges were used in evaluating the relationship of rainfall and system flows. Rainfall gauges were installed in clear open spaces and were serviced at least weekly to ensure proper operation. The gauges are continuously recording, tipping-bucket type, with electronic recorders, which record each 0.01 inch increment of rainfall. The continuous data record was processed to define each rainfall event and to determine the amount of rainfall over 15-minute intervals.

Daily rainfall totals and distributions were developed for each gauge site and compared against the known rainfall intensity-duration-frequency relationship for the Lawrence study area to determine the return interval of each storm event. A Thiessen analysis was performed to relate the point rainfall recorded at the rain gauge locations to the average rainfall in the area tributary to each flow metering site.

3.1.2 Flow Metering

Flow metering was performed to obtain system flow rates during dry and wet weather conditions in an attempt to identify the portions of the wastewater system that may contribute significant amounts of I/I and to use the system flow rates to calibrate a computer model of the Lawrence wastewater system. The flow metering program was designed to monitor the flow exiting the Kansas and Wakarusa River Basins. In addition to the six temporary flow meters, data from the Lawrence Wastewater Treatment Plant influent flow meter was collected and used in the program.

Figure I-8 Flow Metering and Rainfall Monitoring Program

3.1.2.1 Flow Components

Definitions of the flow components used within the report are as follows. Wastewater production (WWP) is defined as wastewater exclusive of infiltration and inflow. The daily WWP flow rate can be approximated by using (1) winter month water consumption data or (2) direct measurement during dry weather/low groundwater conditions (average daily dry weather flow, ADDF). WWP flow rate can also be estimated by using a per capita flow rate. This per capita flow rate is usually about 100 gpcd. The WWP flow rate varies throughout the day, with the highest rate normally occurring between 8:00 and 11:00 a.m. The ratio of peak 60-minute flow to total average daily flow is defined as the WWP flow peaking factor.

Infiltration is groundwater that enters the wastewater collection system and private building lines through defective pipes, pipe joints, and manhole structures below the manhole cone. The rate of infiltration depends on the depth of groundwater above the defect, the size of the defect, and the percentage of the collection system that is submerged. Groundwater levels and the associated infiltration vary seasonally and depend on weather. Dry weather infiltration occurs year-round and is measured during dry weather when the previous rainfall no longer has an effect on flows. High groundwater/dry weather infiltration is additional infiltration, which is caused by higher groundwater following rain events.

Inflow is rainfall-related water which enters the collection system from sources such as private sewer laterals, downspouts, foundation drains, yard and area drains, storm water sump pumps, manholes, defective piping, and cross-connections with storm drains. Inflow is directly influenced by the intensity and duration of a storm event, and therefore is not a fixed quantity.

Figure I-9 illustrates the flow components.

3.1.2.2 Equipment

Open channel flow for this project was measured with temporary flow meters at six locations. Each flow meter included sensors that measured depth and velocity. The depth of water was determined by pressure measurement, and the velocity was measured using an electromagnetic field. The sensors were mounted on an expandable aluminum ring installed in the sewer pipe, normally upstream from the manhole invert. The signal from the sensors was transmitted to the monitor through a communications cable.

Figure I-9 Typical Flow Components

The monitors were suspended from brackets mounted in the manhole wall near the top of each manhole and were set to collect and store depth of flow and velocity readings at 15-minute intervals. A 6-volt battery powers the meter. A backup battery permits servicing to the primary battery without data loss. Data from the meters were retrieved using a portable laptop computer.

The most representative days of data were selected for use in determining dry and wet weather flow parameters. Seven days, one for each day of the week, were identified for the analysis of dry weather flows. All of the days with rainfall that produced a measurable increase in wastewater flow were used for the I/I analysis.

Flow meters, their identification numbers, location, and metering periods are summarized in Table I-5. A detailed description of flow metering can be found in Appendix B, Flow Metering Methodology.

Table I-5
Metering Sites

Meter	Basin	Manhole Number	Meter Type(1)	Pipe Size at Meter (in)	Installation Date	Removal Date
FM01	Wakarusa	SW07-098	D/V	48	17-Apr-00	19-Jun-00
FM02	Wakarusa	SW07-091	D/V	24	17-Apr-00	19-Jun-00
FM03	Wakarusa	SE07-155	D/V	18	14-Apr-00	12-Jul-00
FM04	Kansas	SE01-018	D/V	10	14-Apr-00	12-Jul-00
FM05	Kansas	SE01-081A	D/V	12	14-Apr-00	12-Jul-00
FM06	Kansas	NE12-115	D/V	15	14-Apr-00	12-Jul-00
WWTP(2)	WWTP	-	Flow	48	-	-

(1) D/V = depth and velocity meter open channel.
(2) WWTP is the permanent flow meter at the Lawrence wastewater treatment plant.

3.2 Rainfall Data Analysis

3.2.1 Design Flow and Probability

The Design flow for a sewer is defined as the maximum flow that a specified structure can pass without exceeding selected loading criteria. Since a significant portion of the peak flow in sanitary sewers is inflow resulting from rainfall, the design flow that the sewer must convey is related to the probability of occurrence of a design storm event. Design flow for a selected rainfall event is the sum of three components: (1) wastewater production multiplied by the diurnal peaking factor; (2) infiltration; and (3) inflow. As presented later, inflow is a function of the local intensity-duration-frequency relationship for rainfall. This relationship adds a probability consideration to the design flow.

A summary of the probability that a storm event having a prescribed recurrence interval will not be equaled or exceeded during a specified period is given in Table I-6. For example, a design based on a 10-year storm event has a 59 percent chance of not being exceeded during a 5-year period.

Table I-6
Probability of Non-Exceedance

Design Storm (years)	Period, years							
	1	5	10	20	50	100	200	500
1	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
2	0.50	0.03	0.01	(1)	(1)	(1)	(1)	(1)
5	0.80	0.33	0.12	0.01	(1)	(1)	(1)	(1)
10	0.90	0.59	0.35	0.12	(1)	(1)	(1)	(1)
50	0.98	0.90	0.82	0.67	0.36	0.13	0.02	(1)
100	0.99	0.95	0.90	0.78	0.61	0.37	0.13	0.01
200	0.995	.975	0.95	0.90	0.78	0.61	0.37	0.08
500	0.998	.989	0.98	0.96	0.90	0.82	0.67	0.37

(1) Values are near 0.

3.2.2 Analysis of Rainfall Data

The normal annual average rainfall for the Lawrence area is 39.28 inches. Historical data on average monthly rainfall amounts and rainfall intensity-duration relationships are presented in Tables I-7 and I-8 and shown graphically on Figure I-10 using the Lawrence, Kansas, area rainfall intensity-duration relationships. The annual and monthly normal rainfall values were obtained from the National Weather Service, San Francisco, based on 1961-1990 data for Lawrence, Kansas.

Rainfall intensities were evaluated to allow correlation of peak rain intensity to the peak flow rate in the sewers. The highest flow for a given storm event is generated when the storm duration has reached the travel time from the farthest point in the system to the flow meter location.

During the flow metering period of April 17, 2000 to June 14, 2000, the recorded total average rainfall was 6.66 inches, as shown in Table I-9. The actual rainfall that occurred during the monitoring period was much less than the historical Mid-April to Mid-June average of 9.60 inches. The importance of using a network of rainfall gauges is evidence of the varying amounts of total rainfall between gauges shown in Table I-9.

Rainfall was recorded on 19 of the 59 days in the monitoring period. A storm event was defined as continuous recorded rainfall separated by a minimum of four hours of no rain. During the eight-week monitoring period, 6 significant storm events occurred, with at least 0.40 inch total depth each. Three storms of approximately 1 inch of total depth occurred, plus one storm of more than 1.20 inches in depth. The events for which a definable flow response occurred were selected for flow analysis to determine inflow into the system.

Table I-7 Historical Average Rainfall For the Lawrence, Kansas Area		
Month	Average Precipitation (in)	Cumulative Precipitation (in)
January	1.24	1.24
February	1.12	2.36
March	2.80	5.16
April	3.46	8.62
May	4.96	13.58
June	5.82	19.40
July	3.97	23.37
August	4.06	27.43
September	4.52	31.95
October	3.35	35.30
November	2.24	37.54
December	1.74	39.28

Table I-8 Rainfall Depth-Duration-Frequency Relationship					
Return Period	Total Rainfall (inches) for Duration Indicated				
Yrs	30 Min	60 Min	2 Hrs	3 Hrs	12 Hrs
1	1.02	1.32	1.63	1.81	2.50
2	1.27	1.63	2.02	2.25	3.10
5	1.61	2.07	2.56	2.85	3.93
10	1.88	2.42	2.99	3.33	4.58
25	2.24	2.89	3.57	3.98	5.48
50	2.54	3.27	4.04	4.50	6.20
100	2.84	3.66	4.52	5.04	6.93

Figure I-10
Rainfall Intensity Duration Curve

Table I-9 Total Monitoring Period Recorded Rainfall 4/17/00 – 6/14/00		
Rainfall Gauge No.	Gauge Location	Rainfall (inches)
RG01	6th and Wakarusa	6.91
RG02	31st and Kasold	6.04
RG03	Haskell INU	7.08
RG04	8th and Haskell	6.61
Average		6.66

For the analysis of inflow versus rainfall (Q vs. i relationship), it was necessary to determine the rainfall pattern for each rain event applicable to each flow meter's tributary area. Thiessen polygons were drawn around each rainfall gauge to indicate the areas most influenced by each gauge, and the percentage of the total area tributary to each metering site within each rainfall gauge polygon was determined. For each flow meter, these percentages were applied to the rainfall data recorded at each rainfall gauge. This procedure resulted in a rainfall pattern specific to each flow meter and each storm event, in 15-minute intervals, based on the data collected at the four rain gauges. Table I-10 shows the rainfall gauge allocations used in the Thiessen analysis. Each rainfall event was further analyzed to determine the return interval for the selected rainfall duration by comparing the recorded data with the rainfall intensity-duration-frequency curves for Lawrence.

Table I-10 Rain Gauge Allocation (Theissen Analysis)					
		Recorded Rainfall Assignment (%)			
Basin	Flow Meter	RG01	RG02	RG03	RG04
Wakarusa	FM01	41	41	18	-
Wakarusa	FM02	41	41	18	-
Wakarusa	FM03	-	-	100	-
Kansas	FM04	-	25	75	-
Kansas	FM05	-	25	75	-
Kansas	FM06	-	25	75	-
WWTP	WWTP	35	12	23	30

Summaries of the observed daily total rain at each rain gauge, and the rainfall depth/duration relationship during each storm event are given in Tables I-11 and I-12.

Table I-11
Monitored Daily Rainfall Totals

Rain Date	Total Rain at Rain Gauge (in)			
	RG01	RG02	RG03	RG04
17-Apr-00	0.00	0.00	0.01	0.00
20-Apr-00	0.09	0.06	0.06	0.06
23-Apr-00	0.30	0.32	0.43	0.44
25-Apr-00	0.36	0.48	0.97	0.21
26-Apr-00	0.01	0.01	0.01	0.01
30-Apr-00	0.14	0.15	0.09	0.11
1-May-00	0.01	0.05	0.00	0.00
2-May-00	0.04	0.08	0.00	0.00
9-May-00	0.55	0.40	0.55	0.52
17-May-00	0.00	0.01	0.00	0.00
21-May-00	0.05	0.14	0.10	0.12
24-May-00	0.14	0.10	0.13	0.14
26-May-00	1.30	1.31	1.62	1.67
27-May-00	0.07	0.07	0.14	0.06
1-Jun-00	0.46	0.32	0.91	0.85
2-Jun-00	0.03	0.02	0.02	0.03
11-Jun-00	0.01	0.28	0.47	0.22
13-Jun-00	2.85	1.82	1.09	1.72
14-Jun-00	0.50	0.42	0.48	0.45
TOTAL	**6.91**	**6.04**	**7.08**	**6.61**

Table I-12
Monitored Peak Rainfall Depth vs. Duration

Storm Event	Peak Rainfall Depth (in.) For Duration Indicated					
	30 (min)	60 (min)	120 (min)	180 (min)	240 (min)	600 (min)
Standard 1-Year Storm						
-	1.15	1.50	1.66	1.80	1.92	2.31
Observed Storm Events						
25-Apr-00	0.01	0.69	0.85	0.96	0.97	0.97
9-May-00	0.05	0.26	0.47	0.53	0.54	0.55
26-May-00	0.70	0.84	1.01	1.20	1.21	1.21
26-May-00	0.36	0.41	0.41	0.41	0.41	0.41
1-Jun-00	0.25	0.71	0.81	0.91	0.93	0.93
13-Jun-00	0.01	0.25	0.53	0.54	0.68	1.15

Note: Only the significant rain dates selected for the inflow analyses are listed. This table shows representative data for rain gauge RG03. Some rain events continued into the next date, but were considered one storm event. That is why some high rainfall dates are not included in this list. The actual rain distribution applied to the flow analysis for a given flow meter utilizes the data observed at the rain gauges assigned as listed in Table 2-6, Theissen Analysis.

3.3 Wastewater Flow Data Analysis

3.3.1 Service Area Background Information

3.3.1.1 Flow Metering Program and Distribution

Continuous flow metering was performed at 7 sites, including the WWTP flow meter. FM01, FM02, and FM03 collected the flow information for the area tributary to PS05, which is the Wakarusa River Basin area. FM04, FM05, and FM06 collected flow information for the area tributary to PS08, which is the Kansas River Basin area. In addition, flow data was collected at the WWTP for the same time period as the flow meters and rain gauges. Using the WWTP and tributary Wakarusa River Basin flow data, flows were calculated for the Kansas River Basin tributary area.

The flow meter data collected at PS05, PS08, and the WWTP was analyzed to determine the 2001 flows for the Kansas and Wakarusa River Basins. Using the new Basin flows, current subbasin information, and the 1994 Wastewater Master Plan flow distribution to subbasins, a new flow distribution was generated for the current subbasins. In the succeeding tables, cumulative KR-5 values reflect the flows that would be seen at the wastewater treatment plant (WWTP), since all subbasins are tributary to KR-5 and KR-5 is directly tributary to the wastewater treatment plant.

3.3.1.2 Area Data

The developed acreage for each subbasin was determined from the GIS data provided by the City. The developed acreage for allocated to each subbasin and to each basin is in Table I-13. The subbasin area is used to identify which subbasins contribute large amounts of I/I. Figure I-11 is a schematic drawing ("bubble diagram") of the relationship between the subbasins. The total developed area that is sewered by the City of Lawrence is 18,396 acres.

3.3.1.3 Population Data

The 2000 total population being served by sewer was estimated to be 79,817. The average number of persons per acre is 4.34.

Figure I-11 Subbasin Schematic

Table I-13 Developed Area by Subbasin and Basin-Year 2000		
Subbasin Designation	Subbasin Area (acres)	CumulativeTributary Area (acres)
C-1	763	1,432
C-2	534	534
C-3	135	135
EL-1	897	897
KR-1	517	517
KR-2	1,681	2,199
KR-3	412	412
KR-4	722	3,333
KR-5	1,447	18,396
KR-6	1,245	1,245
NL-1	1,118	1,118
WR-2	1,892	1,892
WR-3	913	913
WR-4	1,404	1,404
WR-5	226	7,046
WR-6	1,879	8,925
YTC-1	***554***	***2,610***
YTC-2	953	953
YTC-3	***1,103***	***1,103***
Total	**18,396**	
Basin	Tributary Area (acres)	
Wakarusa	9,822	
Kansas	8,574	
Total	18,396	

3.3.2 Determination of Average Daily Dry Weather Flow

Daily fluctuations in flow are attributable to variations in domestic, industrial, and commercial wastewater production. Average Daily Dry Weather Flow (ADDF) is measured directly by flow metering and includes wastewater production (WWP) plus the portion of total infiltration that occurs during low groundwater conditions. The ADDF for each monitoring location was determined using the average flow at the monitor for the selected 7 days. The days selected for determining the ADDF were preceded by several days of no significant rainfall.

A mass balance was performed using the ADDF recorded at each metering site. The mass balance is an accounting procedure for balancing flows recorded throughout the system. At the same time, flows were checked against the population tributary to each meter (to determine the per capita use rate (gpcd) for each subbasin. Any metering site for which unrealistic per capita rates were obtained from the preliminary data was rechecked.

Dry weather peaking factors (the ratio of the peak 60-minute flow to average daily flow measured during dry weather/low groundwater conditions) were determined for each basin as the average of the factors observed for each day of the selected period. The system-wide average dry weather peaking factor was 1.22, based on total ADDF and Peak Dry Weather Flow. Peaking factors for the individual subbasins were assigned based on the cumulative acres for that subbasin. A summary for the subbasin ADDF, dry weather flow peaking factor, and diurnal peak flow rate is given in Table I-14.

Table I-14
Subbasin ADDF and Peak Flow Summary

Subbasin	Subbasin ADDF (mgd)	Cumulative ADDF (mgd)	Peaking Factor[1] (Qp/Qa)	Diurnal Peak Flow Rate[2] Subbasin (mgd)	Diurnal Peak Flow Rate[2] Cumulative (mgd)
C-1	0.482	1.242	1.308	0.630	1.625
C-2	0.607	0.607	1.308	0.794	0.794
C-3	0.154	0.154	1.308	0.201	0.201
EL-1	0.197	0.197	1.381	0.272	0.272
KR-1	0.078	0.078	1.135	0.089	0.089
KR-2	0.632	0.710	1.135	0.717	0.806
KR-3	0.380	0.380	1.135	0.431	0.431
KR-4	0.711	1.801	1.135	0.808	2.044
KR-5	1.555	8.533	1.135	1.765	9.685
KR-6	0.172	0.172	1.135	0.195	0.195
NL-1	0.085	0.085	1.135	0.096	0.096
WR-2	0.934	0.934	1.308	1.222	1.222
WR-3	0.486	0.486	1.308	0.636	0.636
WR-4	0.890	0.890	1.308	1.164	1.164
WR-5	0.231	2.758	1.308	0.303	3.607
WR-6	0.724	3.482	1.308	0.947	4.554
YTC-1	***0.158***	***0. 215***	***1.308***	***0. 206***	***0. 281***
YTC-2	0.040	0.040	1.308	0.053	0.053
YTC-3	***0.017***	***0.017***	***1.308***	***0.022***	***0.022***
TOTAL	**8.533**			**10.551**	

(1) Peaking factor is the ratio of peak flow rate to average flow rate.
(2) ADDF times peaking factor.

3.3.3 Determination of Infiltration

Infiltration consists of dry weather-low groundwater infiltration and dry weather-high groundwater infiltration (as indicated on Figure I-9). Infiltration during high groundwater is observed on the days after the end of significant rainfall events. The total flow measured during these periods includes WWP flow plus both base and high groundwater infiltration flows. High groundwater infiltration flow is determined from flow monitoring data by subtracting the minimum nighttime flow during dry weather/low groundwater periods from the minimum nighttime flow during high groundwater periods. Using night-time flow readings is the most reliable method for determining these infiltration flows. A summary of infiltration, including rankings based on this parameter are given in Table I-15.

The net system-wide infiltration flow rate for the area, which excludes WWP, is 1.267 mgd, which is equivalent to 68.8 gpd per acre. The subbasin infiltration rate ranged from 8.6 gpd per acre to 221.9 gpd per acre. Subbasins with high infiltration rates have higher priority for I/I removal.

Table I-15
Subbasin Infiltration Rate

Subbasin	Subbasin Area (acres)	Infiltration (mgd)	Subbasin Infiltration Rate (gpd/acre)	Rank[2]
C-1	763	0.048	63.0	12
C-2	534	0.053	100.0	9
C-3	135	0.030	221.9	1
EL-1	897	0.021	23.3	18
KR-1	517	0.063	121.8	3
KR-2	1,681	0.152	90.4	10
KR-3	412	0.045	108.9	5
KR-4	722	0.075	103.7	8
KR-5	1,447	0.158	109.3	4
KR-6	1,245	0.131	105.3	7
NL-1	1,118	0.096	85.6	11
WR-2	1,892	0.082	43.4	13
WR-3	913	0.039	43.0	15
WR-4	1,404	0.060	43.0	14
WR-5	226	0.024	107.4	6
WR-6	1,879	0.077	41.0	16
YTC-1	***554***	***0.079***	***143.5***	***2***
YTC-2	953	0.022	23.5	17
YTC-3	***1,103***	***0.010***	***8.6***	***19***
TOTAL	**18,396**	**1.267**		

(1) Total Infiltration is Wet Weather Infiltration + Dry Weather Infiltration
(2) Ranking from highest to lowest infiltration rate, with 1 being the highest rate.

3.3.4 Determination of Inflow

Inflow for a specific storm event includes all rainfall-induced flow, direct storm water inflow, and rapid infiltration. Inflow can be measured during wet weather as illustrated on Figure I-9. The flow data for each significant rainfall event were analyzed for inflow. The total peak flow measured during inflow periods includes wastewater production flow, infiltration, and inflow. Inflow for a particular rainfall event is determined by subtracting the wastewater production and infiltration flow from the measured peak flow. Normally, the wastewater production and infiltration flows at the time of peak inflow are estimated as the dry weather flow data 24 hours previous.

The magnitude of peak inflow depends on rainfall distribution, intensity, antecedent groundwater conditions, types and locations of inflow sources, and time of concentration of the system to the monitoring point. The time of concentration is the time from initiation of peak rainfall to the time of peak inflow. An inflow coefficient "K" was determined for each rainfall event for each metered basin. The inflow coefficient is an attempt to combine all system variables into a single parameter, and is analogous to the runoff coefficient in the rational formula for storm water flow. The cumulative inflow coefficient for each metered basin was determined by dividing the peak inflow rate by developed tributary land area and by the peak rainfall intensity corresponding to the system time of concentration as determined from field measurements. Inflow coefficients for the individual subbasins were based on the 1995 Master Plan information, developed in a similar way as the ADDF and peaking factors. Generally, the time of concentration increases as the total tributary area increases and the inflow coefficient increases with the age of the system.

A summary of inflow parameters is presented in Appendix C.

Cumulative inflows and subbasin inflows were determined for a ten-year storm event, as shown in Table I-16. A comparison of cumulative inflow and subbasin-generated inflow rates shows that the cumulative inflow for interior subbasins is less than the sum of individual subbasin-generated inflows. This is consistent with expected system dynamics and is critical for any comparison of projected I/I source flow with monitored flow.

Table I-16
Inflow Summary

Subbasin	10-Yr. Inflow (mgd)		Cumulative Area (acres)	***Cumulative*** 10-Yr. Inflow Rate (gpd/acre)	Ranking
	Subbasin	Cumulative			
C-1	3.36	7.83	1,432	5,470	4
C-2	5.29	5.20	534	9,730	2
C-3	1.46	1.46	135	10,830	1
EL-1	4.23	4.23	897	4,720	7
KR-1	0.59	0.59	517	1,140	19
KR-2	4.13	4.28	2,199	1,950	18
KR-3	1.10	1.10	412	2,660	14
KR-4	3.54	7.30	3,333	2,190	17
KR-5	11.54	45.37	18,396	2,470	16
KR-6	3.62	3.62	1,245	2,910	11
NL-1	8.32	8.32	1,118	7,440	3
WR-2	6.74	6.74	1,892	3,560	10
WR-3	4.40	4.40	913	4,820	6
WR-4	3.71	3.71	1,404	2,640	15
WR-5	1.30	18.99	7,046	2,700	13
WR-6	8.00	24.45	8,925	2,740	12
YTC-1	***3.25***	***10.98***	***2,610***	***4,210***	***9***
YTC-2	4.02	4.02	953	4,220	8
YTC-3	***5.45***	***5.45***	***1,103***	***4,940***	***5***

3.3.5 Subbasin Distribution of I / I

The distribution of I/I based on a 10-Year storm event is summarized in Table I-17. Figure I-12 is a graph of the calculated system I/I versus the total system acreage. Figure I-13 shows the I/I rate by subbasin. The data indicates that 52.9 percent of the total I/I is produced in 36.7 percent of the area. The City's efforts to reduce I/I has produced positive results. Many of the subbasins have shown a decrease in inflow and infiltration into the collections system during storm events. For future collection system analysis, the continuing efforts of the City to reduce I/I will be considered and the I/I reduction goal adjusted.

Table I-17 Subbasin Distribution of I / I							
				Percent Total I/I By Subbasin		Percent Total Size By Subbasin (acre)	
Subbasin	10-Yr. Storm I/I (mgd)	Area (acre)	10-Year I/I Rate (gpd/acre)	Subbasin %	Cum. %	Subbasin %	Cum. %
C-3	1.49	135	11,050	1.8	1.8	0.7	
C-2	5.34	534	10,000	6.3	8.0	2.9	
KR-5	11.70	1,447	8,080	13.7	21.7	7.9	11.5
NL-1	8.41	1,118	7,530	9.9	31.6	6.1	17.6
YTC-1	3.33	554	6,020	3.9	35.5	3.0	20.6
WR-5	1.32	226	5,860	1.6	37.0	1.2	21.8
KR-4	3.62	722	5,010	4.2	41.3	3.9	25.7
YTC-3	5.46	1,103	4,950	6.4	47.7	6.0	31.7
WR-3	4.44	913	4,870	5.2	52.9	5.0	36.7
EL-1	4.25	897	4,740	5.0	57.9	4.9	41.6
C-1	3.41	763	4,470	4.0	61.9	4.1	45.7
WR-6	8.08	1,879	4,300	9.5	71.3	10.2	55.9
YTC-2	4.04	953	4,240	4.7	76.1	5.2	61.1
WR-2	6.83	1,892	3,610	8.0	84.1	10.3	71.4
KR-6	3.75	1,245	3,010	4.4	88.5	6.8	78.2
KR-3	1.14	412	2,770	1.3	89.8	2.2	80.4
WR-4	3.77	1,404	2,690	4.4	94.2	7.6	88.0
KR-2	4.29	1,681	2,550	5.0	99.2	9.1	97.2
KR-1	0.65	517	1,270	0.8	100.0	2.8	100.0
TOTAL	**85.34**	**18396**	**4,640**				
Note: Table sorted based on 10-year I/I rate.							

3.3.6 Future Flows

Future flows were derived from the City of Lawrence design curve using future projected developed area. The future flow criteria used, and City of Lawrence Design Curve for growth areas are presented in Table I-18. Table I-19 presents a summary of cumulative peak 10-year flows for years 2000, 2010, and 2025. The future average daily dry weather flows (ADDF) by subbasin are presented in Appendix D.

Table I-18 – Future Flow Criteria

Table I-19
2000, 2010, and 2025 Cumulative Peak 10-year Flows

Basin / Subbasin	Year 2000						Cumulative Peak 10-yr flow (mgd)		
	ADDF (mgd)		Infiltration (mgd)		10-yr Inflow (mgd)				
	Subbasin	Cumulative	Subbasin	Cumulative	Subbasin	Cumulative	2000	2010	2025
Yankee Tank Creek Basin									
YTC-1	0.158	0.215	0.079	0.111	3.250	3.625	4.017	8.901	16.400
YTC-2	0.040	0.040	0.022	0.022	0.660	0.660	0.735	3.193	6.155
YTC-3	0.017	0.017	0.010	0.010	0.333	0.333	0.364	4.031	10.198
YTC-4								1.510	3.224
YTC-5								0.018	1.886
YTC-6									1.039
Wakarusa River Basin									
WR-1								0.570	1.270
WR-2	0.934	0.934	0.082	0.082	6.740	6.740	7.674	9.330	10.060
WR-3	0.486	0.486	0.039	0.039	4.400	4.400	4.886	6.060	6.210
WR-4	0.890	0.890	0.060	0.060	3.710	3.710	4.600	5.830	6.030
WR-5	0.231	2.758	0.024	0.234	1.300	18.990	21.748	11.160	11.540
WR-6	0.724	3.482	0.077	0.311	8.000	24.450	27.932	22.650	24.030
Baldwin Creek Basin									
BC-1								4.750	9.410
BC-2								1.080	2.120
BC-3								0.990	2.260
BC-4									0.350
Kansas River Basin									
KR-1	0.078	0.078	0.063	0.063	0.590	0.590	0.668	0.790	1.330
KR-2	0.632	0.710	0.152	0.215	4.130	4.280	4.990	9.800	15.410
KR-3	0.380	0.380	0.045	0.045	1.100	1.100	1.480	1.860	1.920
KR-4	0.711	1.801	0.075	0.335	3.540	7.300	9.101	14.310	20.460
KR-5	1.555	8.533	0.158	0.752	11.540	45.370	53.903	50.910	55.780
KR-6	0.172	0.172	0.131	0.131	3.620	3.620	3.792	5.350	5.160
Central Basin									
C-1	0.482	1.242	0.048	0.131	3.360	7.830	9.072	6.180	6.250
C-2	0.607	0.607	0.053	0.053	5.290	5.200	5.807	6.120	6.280
C-3	0.154	0.154	0.030	0.030	1.460	1.460	1.614	1.950	1.970
East Lawrence Basin									
EL-1	0.197	0.197	0.021	0.021	4.230	4.230	4.427	5.870	7.180
EL-2								1.190	2.800
North Lawrence Basin									
NL-1	0.085	0.085	0.096	0.096	8.320	8.320	8.405	5.200	6.110
NL-2								0.710	1.430
NL-3								0.620	1.250
New Wakarusa River Basin									
WRS-1									0.470
WRS-2									2.570
WRS-3									3.790
WRS-4									6.460
WRS-5								12.200	25.430
WRS-6								1.490	7.760
WRS-7									1.620
WRS-8									4.120
WRS-9									0.640

Figure I-12
Percent I/I by Percent Area

Figure I-13 I/I rate

SECTION II – WASTEWATER COLLECTION AND TREATMENT ALTERNATIVES

1.0 Description of Alternatives

1.1 Introduction

This section summarizes the comparison of wastewater collection and treatment alternatives, based on wastewater treatment plant location, and recommends the best collection and treatment configuration for final basis of the Wastewater Master Plan. Three wastewater treatment plant (WWTP) locations were considered for this evaluation to determine the recommended wastewater system configuration. The evaluation was based on design year 2025 population and land use projections and includes all projected wastewater flows for the study area. Treatment systems were based on anticipated future regulatory requirements obtained from the Kansas Department of Health and Environment (KDHE).

Alternative 1 consists of routing all wastewater flow for the study area to the existing Kansas River WWTP. Alternative 2 is based on dividing the study area and conveying part of the flow to the existing Kansas River WWTP and the remaining flow to a proposed Wakarusa River WWTP (Site A). Alternative 3 is similar to Alternative 2, however, a different site (Site B) was used for the proposed Wakarusa River WWTP. The selection of two Wakarusa WWTP sites was made to allow consideration of differing project costs due to site location, however, a Wakarusa WWTP could be located in many different locations along the Wakarusa River.

1.2 Alternative 1 – All Flow to Existing Kansas River WWTP

Alternative 1 consists of collecting and routing all wastewater flow to the existing Kansas River WWTP. Wastewater flow for west Lawrence would continue to be conveyed to Wakarusa Pumping Stations 5A and 5B and routed north through the Haskell Avenue corridor to the Kansas River WWTP. West Lawrence wastewater flow would be comprised of flow from the following subbasins: Part of Baldwin Creek (via new pumping stations BC-01 and BC-02), Yankee Tank, and Wakarusa River. East Lawrence flow would also be conveyed to the Wakarusa Pumping Stations and routed through a force main in the Haskell Avenue corridor. All existing and future growth areas south of the Wakarusa River would require wastewater flow to be collected and pumped directly to the Kansas River WWTP through a force main in the Haskell Avenue corridor. The remaining flow for central Lawrence, north Baldwin Creek, and all Kansas River Subbasins would be conveyed to the Kansas River WWTP through existing interceptor sewers.

The existing Kansas River WWTP would need to be upgraded and expanded to treat flow for the entire study area and meet all anticipated future regulatory requirements.

1.3 Alternative 2 – Wakarusa River WWTP (Site A) & Kansas River WWTP

Alternative 2 consists of dividing the study area and routing wastewater flow to both the existing Kansas River WWTP and a proposed Wakarusa River WWTP (Site A). Wastewater flow for west Lawrence would be pumped from the Four Seasons Pumping Station at south Kasold Street directly to a new interceptor sewer located south of the Wakarusa River. This west Lawrence flow includes flow from the following subbasins: Part of Baldwin Creek (via the new pumping stations BC-01 and BC-02), Yankee Tank, and Wakarusa River Subbasin 2. Flow for the Wakarusa South Subbasins and flow from the Four Seasons Pumping Station would be collected in an interceptor sewer located south and parallel to the Wakarusa River and pumped to a new Wakarusa River WWTP (Site A) through a large pumping station located near Louisiana Street. The new Wakarusa WWTP (Site A) would be located south of the Wakarusa River in the Coal Creek watershed. The remaining flow for central Lawrence, north Baldwin Creek, and all Kansas River Subbasins would be conveyed to the Kansas River WWTP through existing interceptor sewers.

The existing Kansas River WWTP would need to be upgraded to meet all anticipated future regulatory requirements. The Wakarusa River WWTP would meet all anticipated future regulatory requirements and account for all growth capacity in the study area that could not be handled by the existing Kansas River WWTP.

1.4 Alternative 3 – Wakarusa River WWTP (Site B) & Kansas River WWTP

Alternative 3 would consist of routing wastewater flow to both the existing Kansas River WWTP and a proposed Wakarusa River WWTP (Site B). Wastewater flow for west Lawrence would be pumped from the Four Seasons Pumping Station at south Kasold Street directly to a new Wakarusa River WWTP (Site B) located south of the Wakarusa River in the Highway 59 watershed. The west Lawrence area flow pumped from Four Seasons would be from the same subbasins described in Alternative 2. The Wakarusa South Subbasins flow would be collected in an interceptor sewer located south and parallel to the Wakarusa River and conveyed to a new Wakarusa River WWTP. The remaining flow for central Lawrence, north Baldwin Creek, and all Kansas River Subbasins would be conveyed to the Kansas River WWTP through existing interceptor sewers.

The existing Kansas River WWTP would need to be upgraded to meet all anticipated future regulatory requirements. The Wakarusa River WWTP would meet all anticipated future regulatory requirements and account for all growth capacity in the study area that could not be handled by the existing Kansas River WWTP.

2.0 Required Collection System Improvements

This section describes the significant wastewater collection system improvements as they relate to the differences between Alternatives 1, 2, and 3. This evaluation compares only the collection system differences between alternatives and does not consider the total scope of improvements required for the study area that are equivalent for each alternative. In subsequent figures herein, the collection system differences used for cost comparison are shown in red and collection system facilities that are equivalent for each alternative are shown in green or black. All alternatives are based on maintaining the Alabama Pumping Station and not diverting this flow south to the Wakarusa Pumping Stations.

2.1 Alternative 1 – All Flow to Existing Kansas River WWTP

Collection system improvements required for Alternative 1 – All Flow to Existing Kansas River WWTP are shown in Figure II-1. Major new facility improvements used for differential cost comparison include the following:

New Facilities to Convey West Lawrence Flow

- 31st Street Relief Sewer (Kasold Street to Louisiana Street)
- Wakarusa Pumping Station 5C (Wet weather pumping station only)
- Wakarusa Pumping Station 5C Force Main (Wet weather force main only)

The 31st Street Relief Sewer would require difficult construction down an existing developed street. Wakarusa Pumping Station 5C (PS-5C) would have a firm capacity of 10.0 mgd and would serve as a wet-weather pumping station when the capacity of Wakarusa Pumping Stations 5A & 5B are exceeded. Site location requirements for this pumping station would be significant as it would be located near 31st Street and Louisiana Street adjacent to the Baker Wetlands, Haskell Indian Nations University, and the proposed South Lawrence Trafficway. As shown on Figure II-1, route location requirements for the 24-inch and 36-inch force main for Pumping Station 5C would also be significant as the alignment would be in the congested street routes of Louisiana Street, 23rd Street, and Haskell Avenue. The force main must be increased in size to 36-inches along Haskell Avenue from 23rd Street to the Kansas River WWTP to account for the additional flow from the force main serving areas south of the Wakarusa River. The 36-inch force main would have a downhill slope from 23rd Street to the Kansas River WWTP.

The 24-inch force main should not be routed along 31st Street between Louisiana Street and Haskell Avenue because Douglas County does not have right-of-way for the road in this area. The county only has a road easement which will revert back to Haskell Indian Nations University if 31st Street is relocated with the South Lawrence Trafficway extension.

Figure II-1 Alternative 1Wastewater Flows to Kansas WWTP

<u>New Facilities to Convey South Wakarusa Flow</u>

- Wakarusa South Interceptor Sewer (Parallel to Wakarusa River)
- Wakarusa South Pumping Stations WRS-1 & WRS-2
- Wakarusa South Pumping Station Force Mains (Convey to PS-5C force main)

As shown in Figure II-1, a new interceptor sewer is required south of the Wakarusa River from Kasold Street to Louisiana Street to collect flow from trunk sewers (shown in green) in the Wakarusa South watershed. The interceptor sewer would range in size from 30-inches to 42-inches in diameter.

Additionally, two pumping stations would be required to convey flow from south of the Wakarusa River to the PS-5C force main connection point at 23rd Street and Haskell Avenue. Pumping Station WRS-1, with a firm capacity of 11.0 mgd, would serve the majority of the Wakarusa South area and would be located south of the Wakarusa River just west of Lousiana Street. A 24-inch diameter force main would convey flow from this pumping station east to Haskell Avenue and north along Haskell Avenue to the connection point at 23rd Street. Pumping Station WRS-2 would have a firm capacity of 2.0 mgd and would serve the area east of Haskell Avenue and south of the Wakarusa River. It would be located just west of O'Connell Road. The 10-inch force main from this pumping station would be connected to the 24-inch force main at Haskell Avenue. Both Wakarusa South pumping stations would require similar designs for pump system curves and headloss in order to use the same 24-inch pipe along Haskell Avenue. Construction for these pumping stations and force mains would not be difficult as these areas are not developed at this time and the force mains would not need to be constructed within streets.

2.2 Alternative 2 – Wakarusa River WWTP (Site A) & Kansas River WWTP

Collection system improvements required for Alternative 2 – Wakarusa River WWTP (Site A) and Kansas River WWTP are shown in Figure II-2. Major new facility improvements used for differential cost comparison include the following:

<u>New Facilities to Convey West Lawrence Flow</u>

- Four Seasons Force Main Extension (South along Kasold Street)

The 20-inch diameter Four Season Force Main would be extended south along Kasold Street to the Wakarusa South Interceptor located south of the Wakarusa River.

<u>New Facilities to Convey South Wakarusa Flow</u>

- Wakarusa South Interceptor Sewer (Parallel to Wakarusa River)

- Wakarusa South Pumping Station WRS-1
- Wakarusa South Pumping Station Force Main (Convey to Wakarusa River WWTP)

As shown in Figure II-1, a new interceptor sewer is required south of the Wakarusa River from Kasold Street to Louisiana Street to collect flow from trunk sewers (shown in green) in the Wakarusa South watershed. The interceptor sewer would be approximately 42-inches in diameter.

The interceptor sewer would convey flow to the Wakarusa South Pumping Station WRS-1 located just west of Louisiana Street. This pumping station would have a firm capacity of 20.0 mgd and would serve as an influent pumping station to the Wakarusa WWTP (Site A). The force main would consist of a 30-inch diameter pipeline extending from Louisiana Street to approximately O'Connell Road.

It should be noted that a gravity interceptor sewer option was studied in lieu of pumping to a Wakarusa River WWTP (Site A). This option was not cost-competitive because it would require a long sewer tunnel from just west of Haskell Avenue to half-way between Haskell Avenue and O'Connell Road, due to the depth of the sewer. The significant cost for this sewer tunnel could not be economically justified due to the small amount of additional area that could be served by this sewer during the study period.

Figure II-2 Alternative 2 Wastewater Flows to Kansas WWTP and Wakarusa WWTP (Site A)

2.3 Alternative 3 – Wakarusa River WWTP (Site B) & Kansas River WWTP

Collection system improvements required for Alternative 3 – Wakarusa River WWTP (Site B) and Kansas River WWTP are shown in Figure II-3. Major new facility improvements used for differential cost comparison include the following:

<u>New Facilities to Convey West Lawrence Flow</u>

- Four Seasons Force Main Extension to West Wakarusa River WWTP

The 20-inch diameter Four Seasons Force Main would be extended south along Kasold Street directly to a Wakarusa River WWTP (Site B) located south of the Wakarusa River and west of Highway 59. The existing Four Seasons Pumping Station would serve as an influent pumping station to the Wakarusa River WWTP.

<u>New Facilities to Convey South Wakarusa Flow</u>

- Wakarusa South Interceptor Sewer (Parallel to Wakarusa River)
- Wakarusa South Pumping Station WRS-1 (For small eastern area)
- Wakarusa South Pumping Station Force Main (Convey to interceptor sewer)

As shown in Figure III-3, new west and east interceptor sewers are required south of the Wakarusa River to convey flow to a new Wakarusa River WWTP (Site B) located just west of Highway 59. The 30-inch diameter west interceptor would convey trunk line flow east to the WWTP. The east interceptor (21 to 27 inches in diameter) would convey trunk line flow west to the WWTP.

Wakarusa South Pumping Station WRS-1 would have a firm capacity of 2.0 mgd and serve the small eastern area south of the Wakarusa River. The flow would be conveyed through a 10-inch force main to the Wakarusa South Interceptor.

2.4 Four Seasons Excess Flow Holding Basins

All three alternatives require effective use of the Four Seasons Excess Flow Holding Basins. The evaluation is based on use of the holding basins to reduce peak flow that must be transported to the WWTP's in all alternatives. The Four Seasons Pumping Station and Holding Basins comprise a very important lynch pin to the collection system and it is anticipated that these facilities will need to be expanded in the future. The expansions are equivalent for each alternative and are not included in the cost evaluation.

Figure II-3 Alternative 3 Wastewater Flows to Kansas WWTP and Wakarusa WWTP (Site B)

2.5 Detailed Summary of Collection System Alternatives

A detailed summary of the major collection system differences between alternatives is shown in Table II-1. Table II-1 does not list all facility improvements required to implement a system-wide capital improvements plan, just the facilities improvements that differ between alternatives. The completion year indicated below is the year each facility should be completed and ready for service and is based on population projections for the study area. Table II-1 lists pumping station firm capacities as well as the size and length of interceptor sewers and force mains. A pumping station and force main requested by City Staff has also been indicated for each alternative to serve the Wakarusa South area for initial development requirements.

Table II-1
Detailed Summary of Collection System Alternatives

Description	Station Capacity (mgd)	Pipe Size (in)	Length (ft)	Completion Year
Alternative 1 – Kansas River WWTP				
31st Street Relief Sewer	-	30	12,000	2007
Wakarusa PS-5C	10.0	-	-	2006
Wakarusa PS-5C Force Main	-	24 & 36	21,300	2006
Wakarusa South Interceptor	-	30 to 42	12,100	2005
Wakarusa South PS-WRS-1	11.0	-	-	2011
Wakarusa South PS-WRS-1 FM	-	24	18,500	2011
Wakarusa South PS-WRS-2	2.0	-	-	2015
Wakarusa South PS-WRS-2 FM	-	10	4,700	2015
Initial Pumping Station and FM for Wakarusa South Area	0.65	6	7,400	2005
Alternative 2 – East Wakarusa River WWTP				
Four Seasons Force Main Extension	-	20	7,000	2011
Wakarusa South Interceptor	-	42	10,400	2005
Wakarusa South PS-WRS-1	20.0	-	-	2011
Wakarusa South PS-WRS-1 FM	-	30	11,400	2011
Initial Pumping Station and FM for Wakarusa South Area	0.65	6	7,400	2004
Description	Station Capacity	Pipe Size	Length	Completion Year
	(mgd)	(in)	(ft)	
Alternative 3 – West Wakarusa River WWTP				
Four Seasons Force Main Extension	-	20	11,300	2011
West Wakarusa South Interceptor	-	30	4,300	2005
East Wakarusa South Interceptor	-	21 to 27	9,000	2005
Wakarusa South PS-WRS-1	2.0	-	-	2015
Wakarusa South PS-WRS-1 FM	-	10	9,600	2015
Initial Pumping Station and FM for Wakarusa South Area	0.65	6	7,400	2005

3.0 Required Wastewater Treatment Plant Improvements

This section describes the primary wastewater treatment plant improvements required for alternatives 1, 2, and 3. The improvements include facilities to meet capacity expansion for growth as well as anticipated future regulatory requirements. All alternatives are based on 2025 population and land use projections for the study area. A 2025 population of 150,000 people was used as the basis of design for the study area. The design population for the existing Kansas River WWTP, including the expansion currently under construction, is 100,000 people.

Anticipated future regulatory requirements for the Kansas River and the Wakarusa River were received from KDHE. The requirements were based on the National Nutrient Strategy developed by the Environmental Protection Agency (EPA). The strategy presents recommended water quality on an Ecoregion basis, which for Region IX, includes the Kansas and Wakarusa Rivers. In order to meet the new EPA nutrient strategy, biological nutrient removal facilities will be required for wastewater treatment at both the Kansas and Wakarusa Rivers. In addition, the wastewater treatment requirements will be the same for discharges to either the Kansas River or the Wakarusa River. KDHE has indicated facilities for both the Kansas and Wakarusa Rivers must meet the following biological nutrient removal requirements:

<u>Biological Nutrient Removal Requirements</u>
Total Phosphorous < 1.5 mg/L
Total Nitrogen < 10.0 mg/L
Ammonia Nitrogen < 1.0 mg/L

An additional requirement for a Wakarusa River discharge is that an anti-degradation review process must be completed before a National Effluent Discharge Elimination (NPDES) permit is issued for the Wakarusa River. KDHE has indicated that this review process will most likely not prevent an NPDES permit from being issued to the City of Lawrence for the Wakarusa River. Therefore, it appears that wastewater treatment plant discharges to the Wakarusa River are viable from a regulatory standpoint.

3.1 Alternative 1 – All Flow to Existing Kansas River WWTP

All wastewater flow for the entire study area would be conveyed to the existing Kansas River WWTP for Alternative 1. The current design population and average flow capacity for the WWTP are 100,000 people and 12.5 mgd. The 2025 design population for Alternative 1 is 150,000 people, and therefore, would involve a capacity expansion as well as a biological nutrient removal (BNR) upgrade. Proposed design criteria for Alternative 1 are as follows:

Design Criteria for Alternative 1

- Design population = 150,000
- Average flow = 18.8 mgd
- Max month flow = 26.3 mgd
- Peak hydraulic flow = 37.6 mgd
- Provide capacity expansion
- Upgrade for BNR per KDHE limits

A summary of wastewater treatment process improvements required for Alternative 1 is shown in Table II-2

Table II-2
Alternative 1 Process Improvements at Kansas River WWTP

WWTP Modification	Alternative 1 – All flow to Kansas River WWTP	
	Circular Aeration Basin Train	Rectangular Aeration Basin Trains
New Primary Clarifier	Add 1 @ 100 ft. dia.	
Modify Flow Split to Process Trains	25% of total flow (1 train)	75% of total flow (3 trains)
New BNR Basins	1 basin per existing circular aeration basin (includes pre-anoxic, anaerobic, and anoxic zones). Total volume of each BNR basin = 36,560 cf.	1 basin w/ 3 trains to serve all rectangular AB's (includes pre-anoxic and anaerobic zones, total vol. = 137,080 cf) Anoxic zone incorporated into AB's, vol. ea. AB = 27,420 cf.
New Aeration Basin (AB)	N.A.	1 identical to existing rectangular (189,000 cf). Anoxic zone included, as above.
New Final Clarifier	N.A.	Add 1 @ 110' dia.
MLSS recycle	Provide flexibility for 2-4 Q	Provide flexibility for 2-4 Q
New Anaerobic Digesters	Use existing 80' primary and 55' secondary as primary digesters and add 1 primary @ 50 ft. dia. (51,375 cf). Convert 55' sludge storage basin to a secondary digester.	
New Fermentation Basin	1 @ 55' dia.	
Additional chlorine contact volume	Add 1 basin (17,000 cf)	
Additional dechlorination volume	Add 1 basin (1,500 cf)	

Note: AB = Aeration basin, Q = Ave. WWTP flow, N.A. = Not applicable

The BNR treatment zones were sized for the following detention times:

- 15 minutes for pre-anoxic zone
- 60 minutes for anaerobic zone
- 45 minutes for anoxic zone

Wastewater treatment plant improvements required for Alternative 1 – All Flow to Existing Kansas River WWTP are shown in Figure II-4.

3.2 Alternative 2 – Wakarusa River WWTP (Site A) and Kansas River WWTP

Alternative 2 involves dividing the study area and conveying part of the flow to the Kansas River WWTP and the remaining flow to a proposed Wakarusa River WWTP (Site A). Proposed design criteria and plant improvements for each WWTP are summarized below.

Kansas River WWTP Design Criteria and Improvements
Proposed design criteria for the Kansas River WWTP would be as follows:

Alternative 2 Design Criteria at Kansas River WWTP

- Design population = 95,000
- Average flow = 11.9 mgd
- Max month flow = 16.6 mgd
- Peak hydraulic flow = 23.8 mgd
- Upgrade for BNR per KDHE limits
- Capacity expansion is not required
- Remaining flow is to Wakarusa River WWTP

A summary of Kansas River wastewater treatment process improvements required for Alternative 2 is shown in Table II-3.

Figure II-4

Table II-3
Alternative 2 Process Improvements at KS River WWTP

WWTP Modification	Alternative 2 – Partial flow to Kansas River WWTP	
	Circular Aeration Basin Train	Rectangular Aeration Basin Trains
New Primary Clarifier	N.A.	N.A.
Modify Flow Split to Process Trains	Stays at 40% of total flow (1 train)	Stays at 60% of total flow (2 trains)
New BNR Basins	1 basin per existing circular aeration basin (includes pre-anoxic, anaerobic, and anoxic zones). Total volume of each BNR basin = 36,990 cf.	BNR vol. (pre-anoxic, anaerobic, and anoxic zones) incorporated into existing AB's. Total BNR vol. per AB = 55,480 cf.
New Aeration Basin (AB)	N.A.	N.A.
New Final Clarifier	N.A.	N.A.
MLSS recycle	Provide flexibility for 2-4 Q	Provide flexibility for 2-4 Q
New Anaerobic Digesters	Use existing 80' primary and 55' secondary as primary digesters. Convert 55' sludge storage basin to a secondary digester.	
New Fermentation Basin	1 @ 45' dia.	
Additional chlorine contact volume	N.A.	
Additional dechlorination volume	N.A.	

AB = Aeration Basin, N.A. = Not applicable, Q = Ave. WWTP flow

Wastewater treatment plant improvements required for the Kansas River WWTP with Alternative 2 are shown in Figure II-5.

Wakarusa River WWTP Design Criteria and Improvements

Proposed design criteria for the Wakarusa River WWTP would be as follows:

Alternative 2 Design Criteria at Wakarusa River WWTP

- Design population = 55,000
- Average flow = 6.9 mgd
- Max month flow = 9.7 mgd
- Peak hydraulic flow = 13.8 mgd
- Provide BNR per KDHE limits
- Allow for future filtration

The Wakarusa River WWTP would include the following treatment units and support facilities:

- Influent pumping and screening
- Grit removal
- Primary clarification
- Aeration and biological nutrient removal
- Secondary clarification
- Effluent disinfection
- Excess flow handling facilities
- Fermentation basin
- Anaerobic digestion facilities
- Biosolids dewatering facilities
- Administration building

3.3 Alternative 3 - Wakarusa River WWTP (Site B) and Kansas River WWTP

Wastewater flow for the study area with Alternative 3 would be conveyed to both the Kansas River WWTP and a proposed Wakarusa River WWTP (Site B), similar to Alternative 2. Proposed design criteria and plant improvements for each treatment plant would be identical to Alternative 2 with the exception of the following:

- The influent pumping station for the Wakarusa WWTP (Site B) would be larger than the influent pumping station for Wakarusa WWTP (Site A). This is due to less flow being pumped to the Site B plant by a remote pumping station than would be pumped to the Site A plant. (Refer to collection system figures.)

- More provisions for future odor control facilities would likely be included with Wakarusa WWTP (Site B) than with Wakarusa WWTP (Site A) due to the probable proximity to future City development.

Figure II-5

4.0 Cost-Effectiveness Evaluation

4.1 Basis of Evaluation

Each alternative was evaluated for the planning period from January 1, 2003 to December 31, 2025. Capital costs for wastewater treatment and collection were based on data from previous projects and cost curves developed by Black & Veatch. All previous project costs were indexed to 4th quarter 2002 dollars using Engineering News Record indexes. Operation and maintenance costs were developed from City Utilities Department data for wastewater treatment and Black & Veatch data for wastewater collection.

Capital costs for the cost-effectiveness evaluation are based on year 2002 dollars and do not include allowances for inflation. Capital costs include costs for construction, a 20 percent service factor for collection system contingencies, a 25 percent service factor for treatment system contingencies, and a 20 percent service factor for engineering and administration. A discount rate of 5 7/8 percent was used for present worth calculations.

4.2 Cost-Effectiveness Analysis

A cost-effectiveness analysis was performed to compare the life cycle costs of the three alternatives during the planning period. The present worth of capital and operation and maintenance costs for the alternative differences shown in “red” in the collection and treatment system figures was calculated to determine the most cost-effective alternative for the planning period. The analysis does not include the majority of the collection system improvements that are identical to each alternative. A full capital improvements plan for the entire collection system is provided in a subsequent chapter of the Master Plan based on the selected wastewater system alternative.

The present worth of capital and operation and maintenance costs for the three collection and treatment system alternatives is summarized in Table II-4.

Table II-4 Cost-Effectiveness Analysis Design Year 2025			
Present Worth	Alternative 1 All Flow to Kansas River WWTP	Alternative 2 Wakarusa River WWTP (Site A)	Alternative 3 Wakarusa River WWTP (Site B)
Capital Costs: WWTP and Collection	$56,600,000	$52,000,000	$48,400,000
O&M Costs: WWTP and Collection	$25,400,000	$26,200,000	$25,900,000
Total Present Worth	**$82,000,000**	**$78,200,000**	**$74,300,000**

A detailed summary of the cost-effectiveness analysis showing individual project capital costs, project implementation year, operation and maintenance costs, and present worth for each alternative is shown in Appendix E, Cost Effectiveness Analysis.

5.0 Consideration of Additional Issues

A review of additional issues relating to the collection and treatment system alternatives was also considered. The lowest present worth alternative may not always be the best option or the best fit based on extenuating additional issues in the study area. Criteria were selected for consideration relating to additional local issues that may affect implementation of future wastewater system alternatives.

The topics presented herein provide an initial global look at additional issues to be considered by City staff and the City Commission in evaluating the alternatives. The topics are not all-inclusive and should only be used as a starting point for discussion purposes. Detailed studies of these additional issues should be conducted as necessary for major treatment plant facilities and pumping stations or pipelines in sensitive locations. The review of additional issues for each alternative included the following criteria:

- Environmental Issues – Potential adverse impacts or beneficial effects may result from the alternatives under consideration. Issues for consideration include wetlands, protected lands, federally listed species, state or other federal sensitive species, wildlife, aquatic life, and existing hazardous wastes or contaminated soil. An Environmental Impact Assessment would be required to provide a detailed assessment of these issues.

- Cultural Issues – Cultural resources may impact the feasibility of acquiring land or easements for wastewater facilities or pipelines. Both pre-historic and historic sites would need to be researched, documented, and evaluated in a detailed study.

- Socio-Economic Issues – Social and economic diversity is typically a major issue with water reservoir projects, however, some adverse impacts or beneficial effects may result from major wastewater system facilities. Issues for consideration include tourism, recreation, industrial and commercial development, residential development, and agricultural interests.

- Initial Permitting and Regulatory Issues – Initial permitting and regulatory issues must be met for the following agencies: EPA, KDHE, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Kansas Division of Water Resources, and City of Lawrence (zoning and flood plain development restrictions).

- Long-Term Wastewater Regulatory Issues – Wastewater regulatory issues beyond the 2025 planning year should be considered relative to the impacts on existing or proposed treatment facilities. The existing Kansas River WWTP is limited by facility site constraints and an existing hydraulic profile with regards to addition of new process units for long-term regulatory requirements.

- Long-Term Capacity Expansion Issues – Wastewater treatment plant capacity expansion beyond the 2025 planning year is a long-term feasibility consideration that could affect future costs. A long-term view of space requirements for additional treatment units and support facilities on the plant site and hydraulic profile availability should be conducted.

- Plant Access Roadways – Adequate access roadways to wastewater treatment facilities are necessary for safe and efficient delivery of chemicals and supplies, efficient access for plant personnel and solids disposal trucks, and quick access for fire and medical vehicles. The most favorable access roadways are paved major arterial streets and paved highways. Possible future roadways such as the South Lawrence Trafficway extension and the Eastern Parkway should be considered.

- Public Perception and Acceptance – The public's perception and acceptance of an alternative is based on the inherent community value system that exists in the area. The extent of the community boundary may be defined by the study area or extend well beyond the 2025 urban growth area boundary. Public perception and acceptance are often influenced by issues such as public health and welfare, safety, land-use development, property values, odor potential, truck traffic, and aesthetics.

- A matrix was developed to summarize the review of additional issues considered for each alternative. The matrix is shown in Table II-5 and includes commentary for each alternative relating to each particular issue. As indicated previously, the matrix of additional issues is not all-inclusive and is only intended as a beginning point of consideration of additional issues by City staff and the City Commission. Detailed studies of these additional issues should be conducted as necessary for major treatment plant facilities and pumping stations or pipelines in sensitive locations.

Table II-5 Consideraton of Additional Issues for Alternatives

6.0 Recommendations

6.1 Cost Factors

Alternative 3 has the lowest capital cost and the lowest present worth as shown in the cost-effectiveness analysis. A distinct difference is shown for the present worth of the capital costs. The ranking of alternatives by present worth of capital costs is shown below.

Ranking by Present Worth of Capital Costs

Ranking	Alternative Description	Present Worth	Difference from Alt. 3
1	Alt. 3 – Wakarusa WWTP (Site B)	$48,400,000	
2	Alt. 2 – Wakarusa WWTP (Site A)	$52,000,000	7.4%
3	Alt. 1 – Kansas River WWTP	$56,600,000	16.9%

From a cost standpoint, master planning alternatives may be considered similar if the difference in present worth is less than 10 percent. Based on capital costs only, Alternative 1 is not equivalent to the Wakarusa Alternatives 2 and 3. Alternative 3 has the lowest capital cost, however, Alternative 2 should be given consideration since the capital cost difference is less than 10 percent.

Alternative 3 has the lowest total present worth considering both capital and operation and maintenance costs. The ranking of alternatives by present worth cost of both capital and operation and maintenance costs is shown below:

Ranking by Present Worth of Capital and O&M Costs

Ranking	Alternative Description	Present Worth	Difference from Alt. 3
1	Alt. 3 – Wakarusa WWTP (Site B)	$74,300,000	
2	Alt. 2 – Wakarusa WWTP (Site A)	$78,200,000	5.3%
3	Alt. 1 – Kansas River WWTP	$82,000,000	10.4%

The difference in total present worth cost between Alternatives 1 and 3 is larger than 10 percent, so Alternative 1 would still not be considered similar to Alternative 3. The difference in present worth between Alternatives 2 and 3, at 5.3 percent, is close enough that both plant locations should be given consideration, however, Alternative 3 is the best option from a cost standpoint.

6.2 Additional Issues

The present worth analysis indicates the cost of Alternatives 2 and 3 is similar. With this in mind, consideration of additional issues may aid in the ultimate selection of an alternative.

If Alternative 1 is screened out due to cost reasons, a review of Alternatives 2 and 3 may provide some differences that may influence the selected location of a Wakarusa WWTP. As shown in the issues matrix, the two Wakarusa River WWTP alternatives have similar requirements relating to the evaluation and study of environmental, cultural, protected species, and flood plain issues. Wakarusa River WWTP (Site B) would have the benefit of better plant access roadways than would Site A. Public perception and acceptance of a Wakarusa River WWTP location should be evaluated and studied in more detail to provide input for selecting a site for a Wakarusa River WWTP.

Based on this initial review, the overall impact of additional issues is similar for both Wakarusa plant locations. Further study of the additional issues for potential Wakarusa River WWTP locations will provide more insight into the most favorable plant site.

6.3 Recommended Alternative

Alternative 3 – Wakarusa WWTP (Site B) is the most cost-effective option for the City of Lawrence and, at present, does not appear to have any fatal flaws with respect to additional issues.

Consideration should also be given to the long-term expansion of the City wastewater system. After the year 2025, further expansion of the Kansas River WWTP beyond that shown for Alternative 1 would be extremely difficult. Additional space for expansion within the existing plant layout would not be available, therefore, any future expansion after 2025 would likely require a separate treatment plant located adjacent to the existing plant. The collection system would also need to be expanded with parallel pipelines in congested areas to route flow from west and south Lawrence to the existing plant.

In a similar fashion, consideration should also be given to the impact of implementing a Wakarusa River WWTP after 2025 if Alternative 1 – Kansas River WWTP is selected now. If a Wakarusa River WWTP is implemented after 2025, a significant amount of collection system infrastructure would be constructed for Alternative 1 that would not be needed after the year 2025. Alternative 1 collection system improvements that would be unused after 2025 include the 31st Street Relief Sewer, Wakarusa Pumping Station 5C and Force Main 5C, and most of the force main for Wakarusa South Pumping Station WRS-1. The capital cost for these collection system facilities which would not be used after 2025 is $19,200,000.

Based on capital and present worth costs, review of additional issues, and long-term wastewater expansion issues beyond 2025, the recommended plan is Alternative 3 – Wakarusa River WWTP (Site B). It is recommended that collection system improvements proceed on the basis of routing flow for part of the collection system to a future Wakarusa River WWTP. The Four Seasons Holding Basins should be used as a wet-weather handling facility for all Wakarusa River WWTP service area flow originating north of the Wakarusa River. It is also recommended that studies be conducted of the additional issues including environmental, cultural resource, and flood plain impact assessments to determine the best and most favorable location for a Wakarusa River WWTP site.

SECTION III – COLLECTION SYSTEM EVALUATION

1.0 Existing Collection System

1.1 General Description of Collection System

The existing collection system includes sanitary sewers, pumping stations, force mains, and a wet weather holding basin. The Lawrence collection system consists of lines ranging in size from 6 to 48 inches in diameter and some lines constructed as early as 1886. A general description of the collection system is given in the following sections.

1.1.1 Trunk Sewer Inventory

The system is constructed primarily of vitrified clay pipe (VCP), plastic (PVC), reinforced concrete pipe (RCP), and cast iron pipe with some older pipe joints consisting of poured mortar and wiped cement. Older manholes were typically constructed of brick and mortar with newer manholes typically made of pre-cast concrete riser sections with rubber o-ring gaskets.

The City provided Black & Veatch with GIS databases that contained information on every sewer line and manhole within the City limits. However for purposes of this wastewater master plan, only the trunk sewers, which range in size from 10 inch to 48 inch, and 8 inch lines connecting pump stations to the system, were analyzed. The trunk sewer inventory data was imported into Black & Veatch's Sanitary Sewer Management System (SSMS) to create a computerized hydraulic model. SSMS also has built-in quality control measures to check the integrity of the data entered. Sewer information from the 1995 Wastewater Master Plan was used where gaps in the City's current GIS databases existed.

The trunk sanitary sewer collection system computer model consists of approximately 87.9 miles (464,000 feet) of sewer pipe ranging in size from 8 to 48 inches in diameter. The average depth of the gravity lines is approximately 10 feet. Table III-1 shows the trunk sewer length used in the computer model and total sewer length by basin for the City of Lawrence.

Table III-1
Summary of Existing Trunk Sewer and Related Data by Basin

Basin Name	Trunk Sewer Length[1] (ft)	Total Length in GIS (ft)	Largest Diameter (in)	No. of Pumping Stations	Gross Tributary Area[2] (acres)	Current Developed Area (acres)
Yankee Tank Creek	25,196	107,509	27	0	2,794	697
Wakarusa River	154,669	694,528	48	7	8,465	6,868
Kansas River	206,449	696,759	48	17	9,434	5,678
Central	28,814	184,795	18	2	1,430	1,430
East Lawrence	21,624	95,489	18	7	3,765	897
North Lawrence	27,917	93,067	15	5	1,680	450
Baldwin Creek	-	13,260	8	4	5,048	-
Total	**464,669**	**1,885,407**	**-**	**42**	**32,616**	**16,020**
Total (mi)	**88.0**	**357.1**	**-**	**-**	**-**	

(1) Length of trunk sewer in hydraulic model.
(2) Gross area based on natural watershed boundaries.

Figure III-1 shows the existing system modeled trunk sewer inventory for the City of Lawrence.

Figure III-1 Trunk Sewers

1.1.2 Pumping Stations and Force Mains

The sanitary sewer system includes 42 wastewater pumping stations. Seventeen of these stations are located in the Kansas River Basin, seven in the Wakarusa Basin, two in the Central Basin, seven in the East Lawrence Basin, five in the North Lawrence Basin, and four in the Baldwin Creek Basin. These facilities were constructed to pump wastewater across watershed boundaries as the City grew, or to allow development in areas that were located long distances from existing gravity sewers. A summary of pumping stations and force main data is presented in Table III-2.

Table III-2
Pumping Station and Forcemain Summary

Subbasin	Pump Station Name	Pump Station Ref.	Total Capacity (mgd)	Firm Capacity (mgd)	Forcemain size (in)	Forcemain length (ft)
North Lawrence Basin						
NL-1	North St.	PS_01	0.58	0.29	8	1,349
NL-1	Walnut St.	PS_02	0.58	0.29	6	2,487
NL-1	Grant St.	PS_03	1.73	0.86	8	3,300
NL-1	Oak St.	PS_04	2.02	1.01	18	1,300
NL-1	North 3rd St.	PS_12	0.86	0.43	6	2,171
Wakarusa River Basin						
WR-6	Wakarusa Old	PS_05A	7.20	4.32	12	2,472
WR-6	Wakarusa New	PS_05B	15.56	10.37	24	2,704
WR-2	Four Seasons	PS_09	8.85	4.42	20	10,969
			4.63	0.00	20	310
WR-5	Maple St.	PS_24	0.29	0.14	4	220
WR-2	Clinton Pkwy.	PS_33	0.23	0.12	4	529
Central Basin						
C-2	Alabama St.	PS_08	3.46	2.31	12	1,878
Baldwin Creek Basin						
BC-2		PS_10	0.86		8	3,210
			0.86		8	3,210
BC-1		PS_14	0.90		10	16,495
			0.90		10	16,495
BC-1		PS_18	no data	no data	6	2,582
BC-1		PS_40	no data	no data	4	495
Kansas River Basin						
KR-1	Harris Ind. Park	PS_11	0.86	0.43	6	1,220
KR-6	Knights of Columbus	PS_13	0.23	0.12	4	353
KR-4	Kentucky St.	PS_16	11.53	7.93	24	1,638
KR-1	Santa Fe St.	PS_17	2.31	1.15	10	1,095
KR-6	East Hills Business Park	PS_25	2.93	1.95	8	11,000
KR-2	Sherwood Dr.	PS_27	0.86	0.43	6	1,479
KR-1	River Ridge Rd.	PS_28	0.23	0.12	6	1,596
KR-2		PS_42	no data	no data	8	523
East Lawrence Basin						
EL-1		PS_19	3.89	1.94	12	7,133
EL-1		PS_23	no data	no data	4	508
EL-1	Prairie Park	PS_32	1.30	0.65	6	3,505

1.1.3 Wet Weather Holding Facility

A 3.75 million gallon wet weather holding facility is located adjacent to the Four Seasons Pumping Station (PS-9). Wastewater can be diverted to the holding facility by gravity or through the Four Seasons Pumping Station. During high flows, wastewater is diverted from the 24-inch and 36-inch Lawrence Avenue sewers into the facility on the upstream side of the pumping station. Flow is returned to the pumping station by gravity after peak flows have subsided. Odor control is provided for the holding basin with diffused aeration and ferrous chloride facilities.

1.2 Description of Sewered Drainage Basins

This Master Plan addresses the entire City wastewater service area and incorporates data from the 1995 Wastewater Master Plan prepared by Black & Veatch and new data collected as part of this project. The City wastewater service area is divided into sewered drainage basins. These sewered drainage basins are further divided into subbasins.

The current sewered drainage basins for the City of Lawrence are as follows:

- Baldwin Creek Basin
- Central Basin
- East Lawrence Basin
- Kansas River Basin
- North Lawrence Basin
- Wakarusa River Basin
- Yankee Tank Creek Basin

Existing collection system facilities and drainage basins for the current wastewater service area are shown on Figure III-2.

A general description of each basin is presented in the following paragraphs.

1.2.1 Baldwin Creek Basin

The Baldwin Creek Basin consists of four subbasins (BC-1 through BC-4). This basin serves Northwest Lawrence. The Basin contains 13,260 feet of sewer at present, but significant growth is expected in this basin by 2025.

1.2.2 Central Basin

The Central Basin consists of three subbasins (C-l through C-3) and contains the area for the main campus of the University of Kansas. The basin serves areas tributary to the Alabama Street Pumping Station (PS-8, firm capacity = 1600 gpm), Massachusetts Street Pumping Station (PS-6, firm capacity = 350 gpm), and the majority of flows from the University of Kansas. The largest pumping station is the Alabama Street Pumping Station, which serves residential areas and a portion of the University. Flows may be diverted from the Central Basin by means of an overflow weir in the l5-inch sewer that extends to the Alabama station and conveyed by gravity to the 15-inch Naismith relief line in the Wakarusa Basin. Flow diversion occurs during rainstorm events if the peak flows exceed the capacity of this pumping station and upstream sewer.

1.2.3 East Lawrence Basin

The East Lawrence Basin is divided into two subbasins (EL-1 and EL-2) and serves the area south of 23rd Street and generally east of Haskell Avenue. PS-19 pumps to the Kansas River Basin, while other flows from the East Lawrence Basin are received at the Wakarusa Pumping Station (PS-5A and PS-5B). Pumping stations in the East Lawrence Basin that have a firm capacity of 200 gpm or less include Knights of Columbus (PS-13) and 31st St. (PS-22). Prairie Park (PS-32) and Anderson Acres (PS-19) have firm capacities greater than 200 gpm.

1.2.4 Kansas River Basin

The north region, historic district, downtown, and parts of central and east Lawrence are served by the Kansas River Basin which consists of six subbasins (KR-1 through KR-6). The Basin currently receives flow at the wastewater treatment plant from all other basins in the service area. Flows from the Northwest Relief Sewer are tributary to the Kentucky Street Pumping Station (PS-16, firm capacity = 6900 gpm). Flows from the Wakarusa Pumping Stations (PS-5A, PS-5B), Alabama Street Pumping Station (PS-8), Massachusetts Street Pumping Station (PS-6), and the area generally east of Massachusetts Street are tributary to the East Lawrence Relief Sewer. Six of the eleven pumping stations in the Kansas River Basin have a firm capacity of 100 gpm or less: Woodcreek (PS-15), Graystone Apts. (PS-20), Armory (PS-21), Trail Rd. (PS-26), River Ridge Rd. (PS-28), and Kimos Circle (PS-29). The remaining four pumping stations have a firm capacity of 800 gpm or less: Harris Industrial Park (PS-11), Rockledge Apts. (PS-14), Santa Fe St. (PS-17), and Sherwood Dr. (PS- 27).

1.2.5 North Lawrence Basin

The North Lawrence Basin (NL-l, NL-2, and NL-3) serves the areas north of the Kansas River. The Oak Street Pumping Station (PS-4) is the largest station, serving all areas in North Lawrence except for the area served by the Walnut Street Pumping Station (PS-2). These two stations pump wastewater to the wastewater treatment plant through parallel 8-inch and 18-inch force mains. The 18-inch force main has deteriorated and is currently being rehabilitated by the installation of a 16.5-inch inside diameter CIPP (cured-in-place pipe) lining.

1.2.6 Wakarusa River Basin

The Wakarusa River Basin contains six subbasins (WR-l through WR-6) and serves south Lawrence and the portion of west Lawrence that is not included in the Yankee Tank Creek Basin. There are two main sewers in this basin which are both tributary to the Wakarusa Pumping

Station: the 24-inch Lawrence Avenue sewer which is continued as the 24-inch Lower Wakarusa Sewer, and the 36-inch Lawrence Avenue Sewer which is continued as the 36-inch Upper Wakarusa Sewer. The 36- inch Upper Wakarusa Sewer increases in size to 48 inches about 5000 feet before discharging into the wet well of the Wakarusa Pumping Station. All wastewater flow in this basin is tributary to the Wakarusa Pumping Stations (PS-5A and PS-5B). Pumping Stations 5A and 5B have firm capacities of 3420 gpm and 7000 gpm, respectively. Flow from Pumping Stations 5A and 5B is discharged through 12-inch and 24-inch force mains, respectively, to the Kansas River Basin. A 3.75 million gallon wet-weather holding facility is located at the Four-Seasons Pumping Station (PS-9). PS-9 has a dry weather firm capacity of 3070 gpm, which pumps wastewater from the Yankee Tank Creek basin into the Wakarusa Basin. PS-9 also has a wet weather total capacity of 3210 gpm, which diverts flow from the Yankee Tank Creek Basin in to the wet weather holding facility. There are three other pumping stations in the Wakarusa River Basin which have a firm capacity of 350 gpm or less: Maple St. (PS-24), Somerset Ct. (PS-30), and Kasold St. (PS-31).

1.2.7 Yankee Tank Creek Basin

The Yankee Tank Creek Basin contains three sewered subbasins (YTC-1 through YTC-3) and serves west and southwest Lawrence, in the area generally west of Wakarusa Drive. The 27-inch trunk line serving this area, generally referred to as the Yankee Tank Sewer, is tributary to the Four Seasons Pumping Station (PS-9). All flow from this basin is pumped by PS-9 to the 24-inch Lawrence Avenue sewer located in the Wakarusa River Basin. The Yankee Tank Creek Basin currently serves 697 developed acres, and is expected to experience significant population growth in the future.

Figure III-2 Existing Collection System Facilities and Drainage Basins

1.3 Hydraulic Model Description and Calibration

1.3.1 Description of Hydraulic Model

Hydraulic models are valuable tools for conducting system-wide master planning studies such as the City of Lawrence's Wastewater Master Plan. A dynamic hydraulic model was used for this project to evaluate the collection system for current and future conditions. A dynamic model is capable of simulating unsteady state flow conditions under both open channel and surcharged conditions for varying time periods. Additionally, dynamic models allow simulation of both looped and dendritic networks, backwater profiles, flow reversals, pumps, weirs, siphons, gates, orifices, parallel pipes, and other diversion structures necessary to simulate a large and complex collection system such as the City of Lawrence.

The computerized capacity model of the sanitary sewer system was developed utilizing sewer network data, flow data, and a hydraulic modeling program. The model incorporated system parameters such as ADDF, population, developed acres, and rainfall duration and intensity to determine system peak flows. The model was developed using the HydroWorks hydraulic modeling software. Sewer system data was processed using Sanitary Sewer Management System (SSMS) support modules developed by Black & Veatch to write data to and read from HydroWorks.

Flows can be generated externally and directly loaded into the model or can be internally generated by the software using monitored data. For this project, flows were generated internally by the model. Data required by the model for internal flow generation include rainfall hyetographs, basin area, percent pervious and impervious surfaces, infiltration flows, and dry weather flows.

The drainage areas tributary to each monitoring point in the system, and developed acres for each drainage area were obtained from a GIS analysis of the sewered areas in the basins, crosschecked with the developed acres from the 1995 Wastewater Facility Master Plan. The ADDF determined by the flow monitoring was input to the model as a monitored diurnal flow variation observed at each flow meter.

Infiltration was input to the hydraulic model as a constant flow, as observed infiltration flows were relatively constant over several days.

The inflow flow component is highly variable over short periods, requiring dynamic analysis and modeling for accurate measurement and simulation. The inflow component was input to the model in a manner reflecting the dynamic nature of the flow. Data required to generate the inflow includes the following:

- Subbasin inflow parameters determined from flow monitoring data.
- Developed acres for each basin area.
- A design rainfall event.

1.3.2 Model Inventory

Trunk sewer and pump station inventory was provided by the City in shapefile format. Differences between this inventory and the 1995 Master Plan inventory were corrected after consultation with the City. The existing modeled sewer inventory includes trunk sewers modeled in the 1995 Master Plan and sewer lines that had been constructed prior to commencement of work on this Master Plan. Appendix F, Network Inventory, is a complete listing of all existing pipes in the computer model. Appendix F is located in a separate binder.

1.3.3 Model Calibration

Model calibration was performed using peak flow projections developed from monitored data. Parameters used in model calibration included unit per capita dry weather flow rates, infiltration rates, and area for pervious and impervious soil as a surrogate for inflow.

The model was calibrated against the projected 1-year peak flows determined from flow monitoring data. The hydraulic model peak flows were also checked against flow data from actual rainfall events that occurred during the flow monitoring period. Hydraulic model calibration showed most modeled peak flows within 10% of projected 1-year peak flows as shown in Table III-3.

Table III-3
Model Calibration Results

Subbasin	Projected Peak 1-yr Flow (mgd)	Modeled Peak 1-yr Flow (mgd)	Difference (%)
Yankee Tank Creek Basin			
YTC-1	2.18	2.10	-3.5
YTC-2	0.44	0.44	0.7
YTC-3	0.21	0.21	-1.4
Wakarusa River Basin			
WR-2	4.84	4.98	2.9
WR-3	2.99	3.04	1.9
WR-4	3.17	3.36	6.1
WR-5	12.62	12.12	-4.0
WR-6	14.81	14.32	-3.3
Kansas River Basin			
KR-1	0.28	0.34	21.8
KR-2	3.27	3.51	7.2
KR-3	1.07	1.00	-6.3
KR-4	6.07	5.80	-4.4
KR-5 (WWTP)	31.53	31.14	-1.2
KR-6	2.22	2.13	-4.3
Central Basin			
C-1	5.85	5.87	0.4
C-2	3.66	3.76	2.7
C-3	1.04	1.03	-1.0
East Lawrence Basin			
El-1	2.53	2.52	-0.3
North Lawrence Basin			
NL-1	2.65	2.57	-3.1

1.3.4 Collection System Improvement Criteria

The collection system improvement criteria, including the parameters used in the model for peak flow analyses, are included in Appendix G, Sewer Design Criteria. The model improvement criteria include evaluation of information on existing sewers, relief sewers, force-mains and pumping stations. Replacement relief sewers were sized and costs assigned for all pipes with a peak flow greater than 100 percent of the pipe capacity. Proposed replacement relief sewers less than 18-inches in diameter were sized for a design flow-to-capacity ratio of 0.65. Proposed relief sewers 18-inches in diameter or larger were sized for a design flow-to-capacity ratio of 0.78. All improvements were sized as replacement relief sewers. The improvement cost basis information is presented in Appendix H, Construction Cost Basis.

1.4 Adequacy of Existing Collection System

1.4.1 Current Design Conditions

The number of overloaded sewers is determined based on the selected level of system protection for a design storm event. The lower the level of protection, the greater the risk of sewer overloading and subsequent sewage bypassing or basement flooding. Selection of a design storm is a balance between an acceptable level of protection and acceptable cost. A 10-year storm event level of protection has been selected by the City of Lawrence and was used for analysis.

System analyses were performed to evaluate sewer line and pumping station capacity against peak flow rates for current design conditions (2002, 10-year rainfall event). Analyses were performed for existing conditions without removal of any infiltration and inflow (I/I). An evaluation of the existing City of Lawrence collection system shows that relatively high levels of I/I are experienced during wet weather conditions. The average ratio of average daily dry weather flow (ADDF) to peak 10-year flow within the City's system is about 10 with a range of 2.40 to 32.55. High ratios indicate the presence of excessive I/I. The highest ratios are in the East Lawrence and North Lawrence Basins, although it should be noted that ratios greater than typical design norms exist throughout the system. Table III-4 shows the ratio of the existing peak flow to ADDF by subbasin.

Table III-4
Ratio of Existing Peak Flow to ADDF

2002, 10-year rainfall event

Existing Subbasin	Peak Flow (mgd)	ADDF (mgd)	Ratio Peak Flow/ADDF
C-1	8.82	1.37	6.44
C-2	6.47	0.66	9.80
C-3	1.75	0.18	9.72
EL-1	4.63	0.22	21.05
KR-1	0.40	0.14	2.86
KR-2	5.76	0.93	6.19
KR-3	1.50	0.42	3.57
KR-4	9.41	2.14	4.40
KR-5 (WWTP)	53.51	9.80	5.46
KR-6	3.76	0.30	12.53
NL-1	4.65	0.18	25.83
WR-2	8.27	1.02	8.11
WR-3	5.39	0.53	10.17
WR-4	5.38	0.95	5.66
WR-5	18.54	3.08	6.02
WR-6	24.82	3.88	6.40
YTC-1	3.92	0.33	11.88
YTC-2	0.83	0.06	13.83
YTC-3	0.31	0.03	10.33

Based on the results of the analyses, the existing collection system has adequate capacity to convey dry weather flow. During peak flow conditions (10-year rainfall event) 24 percent of the trunk system is overloaded, but using the total system length of 1,885,407 ft, only 6% of the total system is overloaded. Trunk sewers are more likely to overload than collector sewers, so this is considered a reasonable estimate of the actual overloading during peak flow conditions. Table III-5 shows the length and number of overloaded pipes for a 1-year and a 10-year rainfall event.

Table III-5
Design Event Comparison – Overloaded Trunk Sewer Pipe

Design Event	Length of Overloaded Pipe (feet)	Model Length of Pipe (feet)	Percent of Overloaded Pipes Based on Length %	Number of Overloaded Pipes	No. of Modeled Pipes	Percent of Overloaded Pipes Based on No. of Modeled Pipes %
DW/HG	1,129	464,669	0.2	4	1,618	0.2
1-year	48,225	464,669	10.3	171	1,618	10.6
10-year	111,168	464,669	23.9	392	1,618	24.2
DW/HG - Dry Weather, High Groundwater						

The lengths of existing overloaded sewer lines by drainage basin are summarized in Table III-6 and shown on Figure III-3.

Table III-6
Length of existing (2002) Overloaded Sewers by Subbasin - 10-Year Event

Subbasin	Length of Overloaded Pipe (ft)	Total Number of Sewer Segments	Number of Overloaded Segments	Subbasin Percent of Pipes Overloaded (%)	Total System Percent of Pipes Overloaded (%)
C-1	7,236	69	28	40.6	7.1
C-2	5,736	32	20	62.5	5.1
C-3	0	1	0	0.0	0.0
EL-1	13,824	77	53	68.8	13.5
KR-1	0	31	0	0.0	0.0
KR-2	3,909	195	15	7.7	3.8
KR-3	339	55	1	1.8	0.3
KR-4	1,832	98	9	9.2	2.3
KR-5	27,005	320	87	27.2	22.2
KR-6	247	57	1	1.8	0.3
NL-1	6,885	90	27	30.0	6.9
WR-2	15,111	147	50	34.0	12.7
WR-3	6,497	43	29	67.4	7.4
WR-4	562	121	2	1.7	0.5
WR-5	1,218	63	5	7.9	1.3
WR-6	20,767	161	65	40.4	16.6
YTC-1	0	19	0	0.0	0.0
YTC-2	0	17	0	0.0	0.0
YTC-3	0	22	0	0.0	0.0
Total	**111,168**	**1618**	**392**		**100.0**

Figure III-3 Existing overloaded sewers during 10-year rainfall event

Key observations from the computer analyses for 2002 peak flows are summarized in the following paragraphs.

1.4.2 Central Basin

The Alabama (PS-8) Pumping Station is overloaded. Sewer lines upstream and immediately downstream of the Alabama Pumping Station are also overloaded.

1.4.3 Kansas River Basin

PS-13, PS-16, PS-25, and PS-27 are overloaded.

1.4.4 North Lawrence Basin

The North Street (PS-1), Walnut Street (PS-2), and Grand Street (PS-3) Pumping Stations are overloaded. Most sewer lines immediately upstream and downstream of Pumping Stations 1, 3, and 4 are also overloaded.

1.4.5 Wakarusa River Basin

The Wakarusa (PS-5A & 5B) Pumping Station is overloaded. The 24 inch diameter Lower Wakarusa interceptor is overloaded. Segments upstream and downstream of the Four Seasons Pumping Station are overloaded. Clinton Parkway (PS-33) Pumping Station is also overloaded.

The major trunk line in the WR-3 subbasin is overloaded, as is the major trunk line in the WR-2 subbasin.

1.4.6 Yankee Tank Creek Basin

There are no significant reaches of sewer that are overloaded.

2.0 Future Collection System Evaluation

2.1 Future Design Conditions

The existing model inventory, planned improvements, and future wastewater service extension sewers comprise the future model inventory. Hydraulic capacity analyses were performed to identify sewers, pump stations, and force mains with insufficient capacity for future growth peak flows. Projected future growth peak flows assume the successful completion of a 20 percent I/I removal program. The analyses were then used to develop a Capital Improvement Plan to address these hydraulic concerns.

Projected future growth peak flows comprise growth within existing subbasins and growth which is tributary to the existing subbasins and the existing wastewater collection system. The growth areas which are tributary to the existing subbasin are called extension areas. Sewers were preliminarily placed in extension areas, based on topography, so costs can be estimated for providing sewer service to these areas.

The hydraulic analyses highlighted areas where pipes are overloaded at future growth conditions. Where the degree of overloading is small (existing pipe capacity is exceeded by 15 percent or less) or the length of overloaded pipe is small and isolated, these sections of sewer were placed on a Wastewater Collection Sewer Watch List. The sewers on the Watch List should be monitored for deterioration, backups, and overloading. The Wastewater Collection System Watch List is presented in Appendix I.

2.2 Year 2010 Hydraulic Capacity Evaluation

The year 2010 sewer network inventory includes sewer improvements which are currently in design or near to construction completion and the sewer extensions needed to serve 2010 projected growth. It should be noted that the new Wakarusa River WWTP will not be operational until 2011. Table III-7 shows the trunk sewer inventory by basin for year 2010. Table III-8 shows the additional pump stations and their force mains needed by 2010 to serve the extension areas.

Table III-7
Summary of 2010 Collection System Facilities and Related Data by Basin

Basin Name	Trunk Sewer Length[1] (ft)	Largest Diameter (in)	No. of Pumping Stations	Gross Tributary Area[2] (acres)	2010 Developed Area (acres)
Yankee Tank Creek	67,852	27	2	4152	1597
Wakarusa River	160,691	48	7	7058	6400
Kansas River	206,449	60	17	10741	6026
Central	28,613	24	2	1430	1430
East Lawrence	22,323	18	8	4325	1076
North Lawrence	30,754	21	6	3803	549
Baldwin Creek	88,674	27	5	4786	810
Wakarusa River South	32,842	30	0	2426	204
Total	**638,198**			**38,721**	**18,092**
Total (mi)		-	-	-	

[1] Length of trunk sewer in hydraulic model.
[2] Gross area based on natural watershed boundaries.

Table III-8
2010 New Pumping Stations and Associated Force Mains

Subbasin	Pump Station Name	Firm Capacity (mgd)	Forcemain size (in)	Forcemain length (ft)
North Lawrence Basin				
NL-3	NL3PS1	2.00	10	5,174
Baldwin Creek Basin				
BC-1	BC1PS1	10.00	10	6,750
Yankee Tank Creek Basin				
YTC-4	YTC4PS1	2.00	10	8,181
YTC-4	YTC4PS2	3.00	10	10,742
East Lawrence Basin				
YTC-6	YTC6PS1	2.00	8	13,403

2.2.1 Yankee Tank Creek Basin

Two additional subbasins (YTC-4 and 5) are included in the 2010 planning year analysis. The sewers have been sized to adequately convey peak 10 year flows for year 2025 and therefore there is no predicted sewer overloading for the 2010 planning year analysis.

Significant growth is expected through year 2010 in subbasins YTC-3, YTC-2, and YTC-4.

The existing Yankee Tank Sewer tributary to the Four Seasons Pumping Station (PS-09) is shown to be overloaded for the 2010 planning year analysis. The degree of overloading is larger in the upper reaches of subbasins YTC-2 and 3, where the sewers are shown to be overloaded by 150 percent or more for the 2010 year analysis.

2.2.2 Wakarusa River Basin

The Wakarusa River Basin does not incorporate additional subbasins in the future 2010 year analysis. The only future growth predicted for this basin is in subbasin WR-1. There are three subbasins (WR-2, WR-3, and WR-6) which show overloading for the 2010 planning year. The majority of overloaded sewers are overloaded by up to 125 percent, although there are several isolated segments of sewer with up to 150 percent overloading or more.

2.2.3 Baldwin Creek Basin

There are three additional subbasins (BC-1 through 3) included in the future 2010 planning year analysis. The 2010 future year analysis indicates that there are no pipe overloading problems in this basin.

2.2.4 Kansas River Basin

The future 2010 planning year analysis incorporates future growth within subbasins KR-1, KR-2, and KR-6.

KR-4 has a few isolated sewer overloads of 150 percent or more. Sewers along Peterson Road in subbasin KR-2 are shown to be overloaded by up to 150 percent. Several segments of this sewer are at 150 percent utilization or more.

2.2.5 Central Basin

There is no future growth predicted for this basin. Of the three subbasins that comprise the Central Basin, two show minor isolated segments of overloaded sewers. Subbasin C-2 shows significant segments of sewer to be overloaded by more than 150 percent.

2.2.6 East Lawrence Basin

There is one additional subbasin (EL-2) included in the future 2010 planning year analysis. Subbasin EL-1 shows overloading upstream of the Prairie Park Pump Station (PS-32).

2.2.7 North Lawrence Basin

Two additional subbasins (NL-2 and 3) are included in the future 2010 planning year analysis. All future growth identified is within these two subbasins. Subbasin NL-1 shows sewers to be overloaded by up to 150 percent in isolated areas south of I-70.

2.2.8 Wakarusa River South Basin

This is a new basin for areas of future extensions. The proposed sewer sizes have been sized to adequately convey peak 10 year flows for the basin. Therefore there is no predicted sewer overloading for the 2010 planning year analysis.

Figure III-4 presents the overloaded sewers for the design year of 2010. Table III-9 is a summary of the 2010 overloaded sewers.

Table III-9
2010 Overloaded Sewers – 10 Year Event

Basin Name	Sewer Pipes Modeled	Length of Pipes Modeled (ft)	Number of Pipes Overloaded	Length of Overloaded Pipes (ft)	Percent Overloaded by Length (%)
Yankee Tank Creek	112	67,852	51	23,244	34
Wakarusa River	535	160,691	97	25,306	16
Kansas River	756	206,449	86	24,842	12
Central	103	28,613	26	7,921	28
East Lawrence	78	22,323	32	7,924	35
North Lawrence	100	30,754	23	5,567	18
Baldwin Creek	75	88,674	0	0	0
Wakarusa South River	68	32,842	0	0	0
Total	**1,827**	**638,198**	**315**	**94,804**	15

Figure III-4 2010 overloaded sewers

2.3 Year 2025 Hydraulic Capacity Evaluation

The year 2025 sewer network inventory includes sewer improvements that were in the 2010 sewer network inventory and sewer extensions needed for 2025 projected growth. Table III-10 shows the trunk sewer inventory by Basin for year 2025. Table III-11 shows the additional pump stations and their force mains needed by 2025 to serve the extension areas added from 2010 to 2025. A sewer capacity analysis is presented in Appendix J, and a pump station and force main capacity analysis is presented in Appendix K. Peak flows generated by the model are presented in Appendix L, Modeled Peak Wastewater Flows. Appendix L is located in a separate binder.

Table III-10
Summary of 2025 Collection System Facilities and Related Data by Basin

Basin Name	Trunk Sewer Length[1] (ft)	Largest Diameter (in)	No. of Pumping Stations	Gross Tributary Area[2] (acres)	2025 Developed Area (acres)
Yankee Tank Creek	124,489	27	4	6,506	3,255
Wakarusa River	176,621	48	7	8,123	6,714
Kansas River	198,174	60	17	10,741	6,522
Central	26,867	24	2	1,430	1,432
East Lawrence	36,048	18	8	4,325	1,393
North Lawrence	35,795	21	6	3,803	653
Baldwin Creek	99,703	27	6	5,048	1,886
Wakarusa River South	190,811	33	1	15,053	3,205
Total	**888,508**		**51**	**55,029**	**25,060**
Total (mi)		-	-	-	

[1] Length of trunk sewer in hydraulic model.
[2] Gross area based on natural watershed boundaries.

Table III-11
2025 Additional Pumping Stations and Associated Force Mains

Subbasin	Pump Station Name	Firm Capacity (mgd)	Forcemain size (in)	Forcemain length (ft)
Wakarusa River South Basin				
WRS-2	WRS2PS1	2.00	10	8,081
Baldwin Creek Basin				
BC-4	BC4PS1	1.00	4	7,411
Yankee Tank Creek				
YTC-5	YTC5PS1	3.00	10	10,153
YTC-6	YTC6PS1	2.00	8	13,403

2.3.1 Yankee Tank Creek Basin

Three additional subbasins are included in the future 2025 planning year analysis (YTC-4 through 6) serving West Lawrence between E 550 Road and E 800 Road. The existing Yankee Tank Sewer tributary to the Four Seasons Pumping Station (PS-09) is shown to be overloaded by 150 percent or more for the 2025 planning year.

There are no overloaded sewers in subbasins YTC-4 through 6. These subbasins are for areas of future extensions. The sewers have been sized to adequately convey peak 10 year flows for year 2025 and therefore there is no predicted sewer overloading for the 2025 planning year analysis.

2.3.2 Wakarusa River Basin

The Wakarusa River Basin does not incorporate additional subbasins in the future 2025 year analysis. All future growth is within the existing six subbasins (WR-1 through WR-6). There are three subbasins (WR-2, WR-3, and WR-6) which show overloading for the 2025 planning year. The majority of overloaded sewers are overloaded by up to 150 percent.

2.3.3 Baldwin Creek Basin

The future 2025 planning year analysis incorporates future growth within all existing subbasins. Significant growth is expected within subbasins BC-3 and BC-4. The 2025 future year analysis indicates that there are no pipe overloading problems in this basin.

2.3.4 Kansas River Basin

The future 2025 planning year analysis incorporates future growth within all existing subbasins. Significant growth is expected within all subbasins. KR-4 has a few isolated sewer overloading.

Sewers along Peterson Road in subbasin KR-2 are shown to be overloaded by up to 150 percent.

2.3.5 Central Basin

The future 2025 planning year analysis incorporates future growth within all existing subbasins. The Alabama pump station (PS_08) is abandoned. Of the three subbasins that comprise the Central Basin, two show minor isolated segments of overloaded sewers. Subbasin C-2 shows significant segments of sewer to be overloaded by more than 150 percent.

2.3.6 East Lawrence Basin

The future 2025 planning year analysis incorporates future growth within all existing subbasins. Subbasin EL-1 shows overloading upstream of the Prairie Park Pump Station (PS-32).

2.3.7 North Lawrence Basin

The future 2025 planning year analysis incorporates future growth within all existing subbasins. Subbasin NL-1 shows sewers to be overloaded by up to 150 percent in isolated areas south of I-70.

2.3.8 Wakarusa River South Basin

This is a new basin for areas of future extensions. The sewer sizes have been sized to adequately convey peak 10 year flows for the basin. Therefore there is no predicted sewer overloading for the 2025 planning year analysis.

Figure III-5 presents the overloaded sewers for the design year of 2025. Table III-12 is a summary of the 2025 overloaded sewers.

Table III-12
2025 Overloaded Sewers – 10 Year Event

Basin Name	Sewer Pipes Modeled	Length of Pipes Modeled (ft)	Number of Pipes Overloaded	Length of Overloaded Pipes (ft)	Percent Overloaded by Length (%)
Yankee Tank Creek	199	124,489	57	24,897	20
Wakarusa River	555	176,621	106	28,171	16
Kansas River	749	198,174	105	30,643	15
Central	102	26,867	26	7,921	29
East Lawrence	82	36,048	27	6,906	19
North Lawrence	103	35,795	23	5,567	16
Baldwin Creek	87	99,703	0	0	0
Wakarusa River South	365	190,811	0	0	0
Total	**2242**	**888,508**	**344**	**104,105**	12

Figure III-5 2025 overloaded Sewers

2.4 Ultimate Buildout

With the City of Lawrence expected to grow by 96,000 people in the next 50 years, it is reasonable to determine the growth expansion boundaries of the City. This ultimate buildout boundary provides the City a general road map of the direction in which the City's growth and development will occur.

Figure III-6 presents the results of the ultimate build-out analysis. The ultimate trunk sewer and pumping station sizes and potential routes were identified to allow the City to conduct long-range collection system planning. The trunk sewers were sized to adequately convey flow during a 10-year storm event based on the flow design curve. As shown on the figure, some extension sewer pipes installed by 2025 will have to be upsized to adequately convey the ultimate build-out flow. The ultimate buildout trunk sewers and pump stations were not considered for improvements by 2025, therefore, costs were not considered as part of this project scope.

Figure III-6 Ultimate Growth Boundary

SECTION IV - RECOMMENDED IMPROVEMENTS AND PROBABLE COST

1.0 Recommended Improvements

1.1 Introduction

An implementation plan and schedule of the recommended improvements was prepared using information from the flow monitoring, existing and future collection system inventory, growth and development projections from the City, and from hydraulic modeling results. The recommended improvements for the City of Lawrence wastewater system include the following:

- Remove I/I sources to achieve 20 percent reduction in peak storm flows
- Collection system relief and pumping station improvements to meet existing and future capacity requirements of a 10-Year rain event
- Additional wastewater treatment capacity to meet future growth wastewater treatment needs

In addition to the recommended improvements to the wastewater system the Implementation Plan also includes:

- Conduct and develop a Capacity, Management, Operations, and Maintenance (CMOM) Audit and Program.
- Continue general improvements to the collection system.

1.2 Collection System

1.2.1 Cost-Effective Infiltration and Inflow Removal

The City of Lawrence has been undertaking an effective infiltration and inflow (I/I) removal program since the 1995 Master Plan. The 1995 Master Plan recommended a target I/I removal of 30 percent; because of the progress made to date the I/I removal target for this project has been revised to 20 percent removal. This revised goal takes into account the progress made, and represents a reasonable target for future I/I removal. However, it is recommended that the City maintain budgetary funding for their I/I removal program at current levels. The following recommended collection system improvements assume the successful completion of the City's I/I removal program.

1.2.2 Relief Sewer and Pumping Station Improvements

The hydraulic computer model indicates that there are 27 gravity relief sewer improvement projects required as summarized in Table IV-1. The capital costs shown in Table IV-1 are shown by planning year. The relief improvements will be phased in the final Implementation Plan schedule. Wastewater service extension lines are required to service future developed area but are considered development costs and not City improvement cost.

A total of 12 existing pumping stations and four force mains are identified for upgrade in various years with an estimated cost of $12 million. Lift station and force main improvements are presented in Table IV-2.

A detailed listing of each relief improvement is presented in Appendix M.

Table IV-1
Gravity Sewer Improvement Summary[1]

Improvement Name	Existing Size (in)	Improvement Size (in)	Total Pipe Length (ft.)	Improvement Type	Construction Cost ($)	Capital Cost ($)	Planning Year Needed
Central							
C-2-1	12-15	21	1,498	Replacement	$171,000	$240,000	2000
C-2-2	10-12	18	3,727	Replacement	$391,000	$548,000	2000
				Subtotal	$562,000	$788,000	
East Lawrence							
EL-1-1	8	10	2,186	Replacement	$253,000	$354,000	2000
				Subtotal	$253,000	$354,000	
Kansas River							
KR-2-1	24-27	33	1,732	Replacement	$304,000	$426,000	2025
KR-2-2	24	30	5,937	Replacement	$1,277,000	$1,787,000	2025
KR-2-3	15	21	4,004	Replacement	$552,000	$773,000	2025
KR-4-1	8	8	778	Replacement	$52,000	$73,000	2000
KR-4-2	8	8	1,431	Replacement	$179,000	$250,000	2000
KR-5-1	10-12	15	1,160	Replacement	$169,000	$236,000	2000
KR-5-2	8-12	15	1,700	Replacement	$166,000	$233,000	2000
KR-6-1	18	24	583	Replacement	$103,000	$144,000	2025
				Subtotal	$2,802,000	$3,922,000	
North Lawrence							
NL-1-1	8-12	12	2,220	Replacement	$174,000	$244,000	2025
NL-1-2	8-15	15	1,550	Replacement	$140,000	$195,000	2025
				Subtotal	$314,000	$439,000	
Wakarusa River							
WR-2-1	21	24	2,475	Replacement	$336,000	$471,000	2000
WR-2-2	8-10	12	3,982	Replacement	$308,000	$431,000	2000
WR-3-1	24	30	2,358	Replacement	$508,000	$712,000	2000
WR-3-2	21-24	27	1,642	Replacement	$247,000	$346,000	2025
WR-3-3	10-15	18	4,732	Replacement	$632,000	$884,000	2000
WR-6-1	24	36	2,792	Replacement	$504,000	$705,000	2000
WR-6-2	12	18	1,384	Replacement	$137,000	$191,000	2000
WR-6-3	24	24	8,088	Replacement	$1,063,000	$1,489,000	2000
				Subtotal	$3,735,000	$5,229,000	
Yankee Tank Creek							
YTC-1-1	24-30	42	11,685	Replacement	$2,948,000	$4,127,000	2025
YTC-2-1	18	36	3,279	Replacement	$623,000	$872,000	2025
YTC-2-2	12	30	2,815	Replacement	$454,000	$635,000	2010
YTC-3-1	15-21	30	2,738	Replacement	$485,000	$679,000	2025
YTC-3-2	18	27	1,595	Replacement	$227,000	$318,000	2025
YTC-3-3	10-15	24	4,195	Replacement	$497,000	$696,000	2010
				Subtotal	$5,234,000	$7,327,000	
				Total	**$12,900,000**	**$18,059,000**	

[1] All costs are Year 2003 costs.

Table IV-2
Pump Station and Force Main Improvement Summary

Improve-ment Name	Facility Type	Improve-ment Type	Existing Size (in) or Firm Capacity (mgd)	Improve-ment Size (in) or (mgd)	Construction Cost [(1)] ($)	Capital Cost ($)	Planning Year Needed
East Lawrence							
PS_32	Pump Station	Expansion	0.65	1.00	$196,000	$274,000	2025
FM-PS_32	Force Main	Replacement	6	8	$93,000	$130,000	2000
				Subtotal	$289,000	$404,000	
Kansas River							
PS_16	Pump Station	Expansion	7.93	10.00	$1,001,000	$1,401,000	2000
PS_25	Pump Station	Expansion	1.95	4.00	$552,000	$773,000	2010
FM-PS_25	Force Main	Parallel	8	12	$444,000	$622,000	2025
PS_26, PS_33	Pump Station	Improve or Replace	0.23, 0.12	0	$357,000	$500,000	2000
PS_27	Pump Station	Expansion	0.43	1.00	$196,000	$274,000	2000
PS_28	Pump Station	Replacement	0.12	1.00	$392,000	$549,000	2010
				Subtotal	$2,942,000	$4,119,000	
North Lawrence							
PS_01	Pump Station	Replacement	0.29	2.00	$678,000	$949,000	2025
PS_02	Pump Station	Expansion	0.29	0.50	$117,000	$164,000	2025
PS_03	Pump Station	Expansion	0.86	3.00	$474,000	$664,000	2025
FM-PS_03	Force Main	Replacement	8	12	$115,000	$162,000	2025
				Subtotal	$1,384,000	$1,939,000	
Wakarusa River							
PS_08	Pump Station	Abandon	2.31	0	$143,000	$200,000	2000
PS-09 (HB3)	Holding Basin	Expansion	0	2.5 MG	$1,428,000	$2,000,000	2025
PS_09A	Pump Station	Expansion	4.42	5.00	$616,000	$862,000	2010
FM-PS_09	Force Main	Reroute	20	24	$872,000	$1,221,000	2010
PS_09B	Pump Station	Expansion	0.00	5.00	$616,000	$862,000	2025
				Subtotal	$3,675,000	$5,145,000	
				Total	**$8,290,000**	**$11,607,000**	

[(1)] All costs are Year 2003 costs.

The new trunk sewers, pumping stations, and force mains identified for extension areas in Year 2025 and build-out are summarized in Table IV-3. The costs shown are not included in the overall improvement costs. Extension costs are normally funded by developers or benefit districts. If an extension project is built depends on the growth in that particular area.

Table IV-3
Extension Improvement Plan Summary(1)

Improvement Name	Facility Type	Improvement Type	Improvement Size (in) or (mgd)	Development Construction Cost ($)	Development Capital Cost ($)	Planning Year Needed
Baldwin Creek						
E-BC-1-01	Pipe	Extension	8-18	$428,000	$599,000	2010
E-BC-1-02	Pipe	Extension	18-27	$837,000	$1,172,000	2010
E-BC-2-01	Pipe	Extension	8	$212,000	$297,000	2010
E-BC-2-02	Pipe	Extension	15	$597,000	$835,000	2010
E-BC-2-03	Pipe	Extension	8	$205,000	$287,000	2010
E-BC-2-04	Pipe	Extension	8	$311,000	$436,000	2010
E-BC-3-01	Pipe	Extension	15-18	$1,027,000	$1,437,000	2010
E-BC-3-02	Pipe	Extension	8	$244,000	$342,000	2010
E-BC-3-03	Pipe	Extension	8-10	$330,000	$462,000	2010
E-BC-3-04	Pipe	Extension	8-12	$420,000	$587,000	2010
E-BC-4-01	Pipe	Extension	8	$187,000	$261,000	2025
E-BC-4-02	Pipe	Extension	8	$202,000	$283,000	2025
E-BC1PS1	Pump Station	Extension	10.00	$1,001,000	$1,402,000	2010
E-BC4PS1	Pump Station	Extension	1.00	$196,000	$274,000	2025
E-FM-BC1	Force Main	Extension	20	$451,000	$632,000	2010
E-FM-BC4	Force Main	Extension	4	$120,000	$167,000	2025
			Subtotal	$6,768,000	$9,473,000	
East Lawrence						
E-EL-2-01	Pipe	Extension	15-18	$194,000	$272,000	2010
E-EL2PS1	Pump Station	Extension	5.00	$616,000	$862,000	2010
E-FM-EL2	Force Main	Extension	16	$249,000	$348,000	2010
			Subtotal	$1,059,000	$1,482,000	
North Lawrence						
E-NL-2-01	Pipe	Extension	15	$13,000	$18,000	2010
E-NL-3-01	Pipe	Extension	10-15	$45,000	$63,000	2010
			Subtotal	$58,000	$81,000	
Wakarusa River South						
E-WRS-1-01	Pipe	Extension	10-12	$500,000	$700,000	2025
E-WRS-1-02	Pipe	Extension	8-10	$384,000	$538,000	2025
E-WRS-1-03	Pipe	Extension	8	$231,000	$323,000	2025
E-WRS-1-04	Pipe	Extension	8	$338,000	$473,000	2025
E-WRS-1-05	Pipe	Extension	8	$159,000	$223,000	2025
E-WRS-2-01	Pipe	Extension	18	$1,278,000	$1,789,000	2025
E-WRS-2-02	Pipe	Extension	12	$454,000	$635,000	2025
E-WRS-2-03	Pipe	Extension	15-18	$755,000	$1,057,000	2025
E-WRS-2-04	Pipe	Extension	8-15	$331,000	$463,000	2025
E-WRS-2-05	Pipe	Extension	8	$361,000	$506,000	2025
E-WRS-2-06	Pipe	Extension	8	$838,000	$1,173,000	2025
E-WRS-2-07	Pipe	Extension	8-10	$721,000	$1,010,000	2025
E-WRS-2-08	Pipe	Extension	8	$237,000	$332,000	2025
E-WRS-2-09	Pipe	Extension	8	$327,000	$458,000	2025
E-WRS-2-10	Pipe	Extension	8	$342,000	$478,000	2025
E-WRS-3-01	Pipe	Extension	21	$390,000	$546,000	2025
E-WRS-3-02	Pipe	Extension	10-15	$247,000	$346,000	2025
E-WRS-3-03	Pipe	Extension	8-12	$461,000	$646,000	2025

Table IV-3
Extension Improvement Plan Summary[1]

Improvement Name	Facility Type	Improvement Type	Improvement Size (in) or (mgd)	Development Construction Cost ($)	Development Capital Cost ($)	Planning Year Needed
E-WRS-4-01	Pipe	Extension	21-33	$393,000	$550,000	2025
E-WRS-4-02	Pipe	Extension	21-27	$360,000	$504,000	2025
E-WRS-4-03	Pipe	Extension	8-15	$497,000	$696,000	2025
E-WRS-4-04	Pipe	Extension	8-15	$477,000	$668,000	2025
E-WRS-5-01	Pipe	Extension	30	$1,002,000	$1,404,000	2010
E-WRS-5-02	Pipe	Extension	18	$688,000	$963,000	2025
E-WRS-5-03	Pipe	Extension	10	$193,000	$270,000	2025
E-WRS-5-04	Pipe	Extension	8-15	$411,000	$575,000	2025
E-WRS-5-05	Pipe	Extension	33	$732,000	$1,025,000	2025
E-WRS-5-06	Pipe	Extension	15	$824,000	$1,153,000	2025
E-WRS-5-07	Pipe	Extension	8-12	$392,000	$549,000	2025
E-WRS-6-01	Pipe	Extension	30	$1,682,000	$2,354,000	2010
E-WRS-6-02	Pipe	Extension	8-12	$222,000	$310,000	2010
E-WRS-6-03	Pipe	Extension	18	$189,000	$264,000	2010
E-WRS-6-04	Pipe	Extension	8-27	$995,000	$1,393,000	2010
E-WRS-7-01	Pipe	Extension	8-18	$369,000	$517,000	2025
E-WRS-7-02	Pipe	Extension	8	$166,000	$233,000	2025
E-WRS-8-01	Pipe	Extension	24	$622,000	$871,000	2025
E-WRS-8-02	Pipe	Extension	21-24	$496,000	$694,000	2025
E-WRS-8-03	Pipe	Extension	12	$158,000	$221,000	2025
E-WRS-8-04	Pipe	Extension	8-18	$453,000	$634,000	2025
E-WRS-9-01	Pipe	Extension	8-12	$332,000	$465,000	2025
E-WRS2PS1	Pump Station	Extension	2.00	$339,000	$475,000	2025
E-FM-WRS2	Force Main	Extension	10	$279,000	$391,000	2025
			Subtotal	$20,625,000	$28,875,000	
Yankee Tank Creek						
E-YTC-3-01	Pipe	Extension	8-18	$256,000	$358,000	2010
E-YTC-3-02	Pipe	Extension	21	$560,000	$784,000	2010
E-YTC-4-01	Pipe	Extension	8-15	$357,000	$499,000	2010
E-YTC-4-02	Pipe	Extension	8-10	$176,000	$247,000	2010
E-YTC-4-03	Pipe	Extension	8	$252,000	$353,000	2010
E-YTC-4-04	Pipe	Extension	8-18	$339,000	$474,000	2010
E-YTC-4-05	Pipe	Extension	8-15	$415,000	$580,000	2010
E-YTC-4-06	Pipe	Extension	8	$168,000	$236,000	2010
E-YTC-5-01	Pipe	Extension	8-18	$369,000	$517,000	2025
E-YTC-5-02	Pipe	Extension	8-15	$289,000	$405,000	2025
E-YTC-5-03	Pipe	Extension	8	$199,000	$279,000	2025
E-YTC-6-01	Pipe	Extension	8-12	$338,000	$473,000	2025
E-YTC-6-02	Pipe	Extension	8	$365,000	$511,000	2025
E-YTC-6-03	Pipe	Extension	8	$315,000	$442,000	2025
E-YTC-6-04	Pipe	Extension	8	$463,000	$648,000	2025
E-YTC-6-05	Pipe	Extension	8	$390,000	$546,000	2025
E-YTC4PS1	Pump Station	Extension	2.00	$339,000	$475,000	2010
E-YTC4PS2	Pump Station	Extension	3.00	$474,000	$663,000	2010
E-YTC5PS1	Pump Station	Extension	3.00	$474,000	$663,000	2025
E-YTC6PS1	Pump Station	Extension	2.00	$339,000	$475,000	2025
E-FM-YTC4-1	Force Main	Extension	10	$283,000	$396,000	2010
E-FM-YTC4-2	Force Main	Extension	10	$371,000	$520,000	2010
E-FM-YTC5	Force Main	Extension	10	$351,000	$491,000	2025
E-FM-YTC6	Force Main	Extension	8	$355,000	$497,000	2025
			Subtotal	$8,237,000	$11,532,000	
			Total	**$36,747,000**	**$51,443,000**	

(1) All costs are Year 2003 costs.

1.3 Wastewater Treatment System

1.3.1 Kansas River WWTP Improvements

Several improvements will be required for the Kansas River WWTP to meet regulatory requirements and maintain system reliability. Capacity expansion is not required for liquid treatment because City growth requirements will be accommodated with the implementation of a new Wakarusa River WWTP in the year 2011. Capacity expansion is required for solids treatment because the existing anaerobic digester capacity will be exceeded. Anaerobic digester improvements will consist of converting the existing anaerobic digester storage tank to a secondary digester with gas mixers and a floating cover, expanding the gas control building, and upgrading the digester SCADA system to current City standards.

The existing dissolved air flotation (DAF) thickener is designed to normally operate on a continuous 24-hour basis without polymer addition to thicken waste activated sludge (WAS). The DAF was sized for an annual average flow capacity of 12.5 mgd to the treatment plant. With polymer addition, the DAF is sized to process maximum month WAS quantities at 12.5 mgd design within an 8 hour period per day. Without polymer addition, it is anticipated that the DAF thickener will reach its design capacity by the year 2009. However, with polymer addition, the DAF should be capable of thickening WAS during the interim period of 2009 to 2011, prior to start-up of the new Wakarusa River WWTP in 2011. The existing DAF will have capacity to thicken WAS on a 24-hour basis, without polymer addition, during the design period of 2012 to 2025.

It is anticipated that future regulations will require the addition of biological nutrient removal (BNR) facilities for total nitrogen removal and phosphorous removal. KDHE indicated the liquid treatment facilities will need to be upgraded to meet a total nitrogen limit of 10 mg/L, an ammonia limit of 1 mg/L, and a phosphorous limit of 1.5 mg/L. The timetable for these regulatory improvements has not been dictated by KDHE at this time, therefore, a speculative timeframe for BNR improvements at the Kansas River WWTP is approximately the year 2015. BNR improvements would consist of external BNR basins for Aeration Basin No.s 1 and 2, BNR modifications internal to Aeration Basin No.s 3 and 4, and a fermentor/gravity thickener for primary sludge to produce volatile fatty acids for the BNR process.

New facility improvements required for the Kansas River WWTP are as follows:

- Anaerobic Digester Improvements
- Roof for Dewatered Biosolids Storage Basin
- Vehicle and Equipment Storage Building
- Biological Nutrient Removal Facilities

1.3.2 Wakarusa River WWTP Improvements

It is recommended to implement a new Wakarusa River WWTP to meet the growth requirements for the City of Lawrence and effectively comply with future regulatory requirements. As described in the WWTP evaluation section of this Master Plan, it is the best and most cost-effective solution to implement a Wakarusa River WWTP rather than conveying and treating all wastewater flow at the Kansas River WWTP. The Wakarusa River WWTP would be designed to accommodate all flow from west Lawrence that is pumped from the Four Seasons Pumping Station and all flow conveyed from south of the Wakarusa River.

Based on population projections, it is projected that a 6.9 mgd (annual average) WWTP will be required to meet 2025 growth projections for the service area. The WWTP should be designed with BNR facilities and contain space in the hydraulic profile for filtration facilities, if required in the future. The Four Seasons Pumping Station will pump flow directly to the WWTP for the west Lawrence service area. It is anticipated the design capacity of the existing Kansas River WWTP will be reached in the year 2011, therefore, the new Wakarusa River WWTP should be constructed and in service by the year 2011.

It is recommended that studies be conducted of plant site issues including environmental, cultural resource, and flood impact assessments to determine the best and most favorable location for a Wakarusa River WWTP site. These studies should commence immediately so that adequate time is allowed to study, identify, and purchase the land for the Wakarusa River WWTP site. Sufficient land should be procured to allow for future WWTP expansions and provide an adequate buffer zone to residential and commercial development.

1.4 Additional Implementation Plan Items

1.4.1 CMOM Audit and Program

Currently there is a proposal by the EPA, in legislation, that is intended to clarify and expand the National Discharge Elimination System (NPDES) permit requirements. The proposal addresses permit conditions on capacity, management, operations, and maintenance (CMOM); prohibiting overflows (Sanitary Sewer Overflows –SSOs); public notification; and recordkeeping. A CMOM audit and program will focus on preparing the City of Lawrence for pending regulation requirements by establishing a program that focuses on reducing the number of overflows in the system and providing an acceptable level of service to customers. In particular, the CMOM Program will focus on the following items:

- Capacity – Evaluate pipe relief sizes for current and future needs (20-Year Plan)
- Management – Implement a Management Information System (MIS) so as to become GASB 34 compliant. The MIS system should also be used to generate work orders and track those work orders.
- Operations and Maintenance – Establish operation and maintenance performance goals that allow the City to become proactive in preventing SSO's eg. establish a pipe cleaning routine that cleans 30 percent of the system yearly.

1.4.2 Collection System Improvements

The City currently maintains a budget for general collection system improvements that is not detailed in the 1995 Wastewater Master Plan. A budget of the general collection system improvements is included in the Implementation Plan costs and schedule.

1.5 Collection System Implementation Plan and Cost Summary

The Collection System Implementation Plan combines the gravity sewer improvements, pump station and force main improvements, and special items identified as part of this study.

The special items include continuation of the City's I/I reduction program, wastewater treatment plant upgrades, and continuation of the City's CMOM program.

The Collection System Implementation Plan for these items is presented in Table IV-4.

Table IV-5 presents a cost summary of recommendations.

Table IV-4 Implementation Plan

The cost of future extension sewers is normally borne by developers and are not included in the Implementation Plan. However, there are several extension sewer projects which the City will be financing. These have been included in the collection system Implementation Plan and are as follows; E-WRS-3-01, E-WRS-4-01, E-WRS-5-01, E-WRS-5-05, and E-WRS-6-01.

Figure IV-1 presents relief improvements for planning years 2000, 2010, and 2025. Sewers indicated are trunk sewers. Small collector sewers are not shown. “Developer Pipelines” are sewers to be provided by developers and Benefit Districts.

Cost Summary of Implementation Plan
Table IV-5

	Capital Cost ($)
Gravity Sewers	$18,059,000
Pump Stations and Force Mains	$11,607,000
Extensions (City Developed) (1)	$7,079,000
I/I Reduction Program	$650,000
Wastewater Treatment Plant Improvements	$70,570,000
CMOM	$200,000
General Improvements	$1,500,000
Total	$109,665,000

Figure IV-1 Relief Improvements Map
Bound in Volume II