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SECTION III– WATER TREATMENT

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Appendices

Executive Summary

1. Purpose

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

2. Study Area and Scope

The Study Area is shown in Section I on Figure I-1 of this report. The various components of the Study Area have been delineated by the City of Lawrence Planning Department and are described below:

- Existing City Limits: The boundaries 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 its *2025 Transportation Plan*.

The study period for this investigation is from year 2000 through year 2025. Detailed evaluation of water demands by class and service level, and hydraulic analyses, were conducted for base year 2000 and for design years 2010 and 2025. Overall, total system demands were extrapolated to year 2050 to evaluate long-term supply requirements.

The principal elements of this study include the following:

- Evaluate historical water use trends and prepare projections of future water requirements based on population projections provided by the Lawrence-Douglas County Metropolitan Planning Office.
- Evaluate the adequacy of existing supply, treatment, and distribution system components.

- Perform a Safe Drinking Water Act (SDWA) evaluation and regulatory review of the existing treatment processes at the Kaw and Clinton Water Treatment Plants and evaluate modifications needed to meet anticipated future regulations.

- Update the existing computer model of the Lawrence water distribution system and expand the capabilities of the model to include extended-period simulations (EPS). Perform hydraulic analyses to determine the capacity of the distribution system to meet present and future water demands and deliver the updated model to the City.

- Develop a master plan of recommended water system improvements, including a phased construction program and opinions of probable cost.

3. Population and Water Demands

Actual year 2000 and projected retail water service populations used for this report are summarized in Table ES-1.

Table ES-1
Population

Year	Population	Population Growth	
		Number of Persons	Annual Growth Rate, %
2000	79,817[1]		
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 and including all population within assumed year 2010 retail water 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 from 2025 through 2050.

Projected total system water requirements are summarized in Table ES-2.

Table ES-2
Projected Water Requirements (Total System)

	Base Year [1]	Design Year 2010	Design Year 2025	Design Year 2050
Population	79,817	99,600	149,278	244,906
AD (mgd)	12.5	15.6	22.5	35.9
MD (mgd)	27.5	34.4	49.6	79.1
MH (mgd)	38.7	48.5	69.8	111.4

(1) Base year demands are calculated using design water demand projection criteria and the Year 2000 population. Base year demands are similar to recent historical demand.

4. Findings

4.1 Water Supply

Raw water supply to the Kaw WTP consists of surface water from the Kansas River and groundwater from the Kansas River alluvium. The City recently obtained approval to develop a new water right on the Kansas River. This new right plus the existing water rights would limit the total amount of water diverted under the surface and groundwater water rights to a maximum annual volume of 8,152 million gallons (22.3 mgd), with a maximum diversion rate of 31,202 gpm (44.9 mgd).

Normal river water levels limit the supply capacity to the Kaw WTP from the Kansas River intake to approximately 16.5 mgd. The firm supply capacity to the Clinton WTP from the Clinton Reservoir intake is 20 mgd at conservation pool elevation (USGS 875.50) and 15 mgd at the projected drought water surface elevation (USGS 853.50).

The City has two contracts with the Kansas Water Office (KWO) that allow diversion of water from Clinton Reservoir. The original Contract 77-1 allowed the diversion of 3,650 million gallons per year (10 mgd) at a maximum diversion rate of 25 mgd, and the original Contract 90-5 provided for an additional annual diversion of 1,460 million gallons per year (4 mgd) while maintaining the maximum diversion rate of 25 mgd. The total annual diversion allowed under contract 77-1 has now been reduced to 3,468,957,286 gallons (9.5 mgd), and the total annual diversion allowed under contract 90-5 has been reduced to 1,287,481,489 gallons (3.52 mgd). Therefore, the total average annual yield available from the reservoir is 13.02 mgd and the maximum diversion rate is 25 mgd.

The total water rights of 35.32 mgd are sufficient to meet average day demands through year the planning year 2025 but will result in a shortfall of 0.6 mgd by year 2050.

As a result of a request by the Tri-counties water districts for a diversion of 200 million gallons per year (0.55 mgd), the KWO is considering a further reduction in the available supply to the City. Other users may also apply for water from Clinton Reservoir. The State has the right to consider the overall needs of all potential users of the reservoir and could further reduce the supply available to Lawrence. The City is discussing the KWO's plans for the Clinton Reservoir supply, as the State's decisions will have immediate impacts on the City's water system.

4.2 Water Treatment

The City of Lawrence is served by two water treatment plants (WTPs). Both use conventional lime softening treatment with flocculation, sedimentation, and filtration followed by chlorine disinfection. The Clinton WTP is located along Wakarusa Drive north of Clinton Parkway, and the Kaw WTP is at the intersection of 3rd and Indiana Streets. The Kaw WTP, originally constructed in 1917, has been expanded over the years. The treatment capacity of the Kaw WTP is currently restricted by a hydraulic bottleneck to about 16.5 mgd. Improvements are currently being implemented to remove the hydraulic bottleneck and allow the plant to produce at its rated capacity of 17.5 mgd. The Clinton WTP was recently expanded to 15 mgd.

Both plants consistently comply with all current state and federal water quality and treatment requirements. Several rules are scheduled for promulgation and implementation within the next few years. Because these rules have not yet been formally proposed or promulgated, their relative impact on current treatment operations is difficult to predict at this time. However, the information presented in this report reflects the latest thinking with regard to anticipated regulations.

It is currently anticipated that Stage 2 of the Disinfection By-products Rule will be finalized during July 2004. Stage 2A of the rule is expected to become effective by July 2007. It will add site specific maximum contaminate levels (MCLs) for disinfection by-products (TTHM and HAA5) to the existing average MCL required for the entire system. Stage 2B of the rule is expected to become effective by July 2010 and will set even lower site specific MCLs for DPBs, at revised locations based a one-year sampling program. Review of historical data indicates that both plants should be able to comply with the requirements of the Stage 2 Disinfection By-Products Rule without significant difficulty. The only significant impact is expected to be increased analytical costs during the initial one-year period of expanded system monitoring.

The Long-Term Stage 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) is expected to be promulgated during July 2004. The main focus of the LT2ESWTR is to require a two-year monitoring program to determine average *Cryptosporidium* concentrations in the source waters, and additional treatment if concentrations exceed certain levels. It is anticipated that both plants may be able to meet additional treatment requirements if the monitoring results place them in the middle "Bin 2" category. However, if future monitoring places either of the plants in the most severe "Bin 3" category, primary disinfection using ultraviolet radiation or physical removal using a membrane process could be required. It is not prudent to make any firm recommendations regarding what the City should do to prepare for compliance with this regulation because additional treatment requirements cannot be determined with any certainty until the required monitoring of the source water for *Cryptosporidium* is completed and submitted to the Kansas Department of Health and Environment (KDHE) by January 2007.

A particular emphasis with conventional treatment processes with regards to the regulations is the concept of "narrowing the margin" for error within the operations of a facility. As the regulations continue to get more restrictive the knowledge, training, supervision, and response of staff become more critical. The utility will be continually faced with the dilemmas of 1) simply meeting the regulations, which is required, versus providing enhanced treatment technologies (such as ozone disinfection, ultraviolet disinfection, and membrane filtration) to gain some of that "lost margin" back and 2) the cost to provide this enhanced level of treatment. This report is written around the concept of meeting the regulations. The governing body may elect to make a policy decision that meeting the regulations is not sufficient, and additional treatment processes may be needed to provide a higher level of treatment.

4.3 Distribution System

The existing service area of the Lawrence water system is divided into two service levels designated as Central Service and West Hills. Water to both service levels can be delivered from both treatment plants. Storage facilities in the Central Service Level consist of the Oread Reservoirs, the Kasold Reservoir, and the Harper Elevated

Tank. Storage facilities in the West Hills service level consist of the Sixth Street Elevated Tank and the Stratford Elevated Tank. Booster pumping stations located adjacent to the Oread and Kasold reservoirs can be used to pump to the West Hills service level.

Because the year 2025 service area will extend considerably beyond the current service area, new service levels will need to be added.

The Lawrence distribution system was evaluated by hydraulic analyses and various improvements were investigated to identify those most effective in meeting the projected water demands. Criteria used in developing the improvement program include increasing the system reliability, simplifying system operations, more effectively utilizing system storage to meet peak demands, and maintaining adequate pressures (at least 35 psi) under maximum hour demand conditions.

The analyses revealed localized pressure problems under maximum hour conditions in the vicinity of the Harper Elevated Tank and in the Santa Fe Industrial Park area. Ground elevations in the vicinity reach 980 feet in isolated areas. With the Harper Elevated Tank full (elevation 1015), the maximum pressure provided to this high ground elevation is only about 37 psi. These problems have been reported in previous hydraulic modeling and master planning for the Lawrence distribution system, but are not reported to be a significant concern at this time.

The existing facilities, and storage area for the distribution system crews and administrative staff are currently located at the Kaw WTP and do not meet their current needs.

5. Recommendations

Two alternatives to meet the year 2025 demand of 50 mgd were developed in detail. Both alternatives are based on expanding the existing water treatment plants since they constitute a large portion of the City's capital investment. A third water treatment plant, to be located in the vicinity of the Kansas River, northeast and west of the city, was considered, but was dropped from further consideration because of the cost to provide infrastructure to a new site and because it would involve staffing a third plant.

Table ES-3 summarizes the existing WTP capacities for the two alternatives.

Table ES-3
WTP Capacities For Alternatives

Facility	Existing Capacity (mgd)	Alternative 1 (mgd)	Alternative 2 (mgd)
Kaw WTP	17.5[(1)]	25	17.5
Clinton WTP	15	25	32.5
Total	**32.5**	**50**	**50**

[(1)]Existing capacity of 17.5 mgd is the rated treatment capacity. However, plant hydraulics currently limit the plant to 16.5 mgd.

Alternative 1 would involve the expansion of both the Kaw and Clinton WTPs to 25 mgd each to meet the future demands. Alternative 2 would involve the expansion of only the Clinton WTP to meet the projected year 2025 maximum day demand of 50 mgd. The Kaw WTP would remain at its current capacity of 17.5 mgd, whereas the Clinton WTP would be expanded from 15 mgd to 32.5 mgd.

Table ES-4 shows the comparison of the estimated capital costs of Alternative 1 and Alternative 2.

Table ES-4
Cost Comparison of Alternatives

Alternative	Capital Cost ($)
Alternative 1	74,489,000
Alternative 2	73,660,000

A discussion of the relative merits and detriments of the two alternatives are summarized below:

- The cost for Alternative 1 about 1-percent higher than Alternative2, however, considering the relative accuracy of master-plan level estimating, the costs of the two alternatives are essentially the same.

- Both Alternative 1 and 2 would reliably meet the projected demands while maintaining compliance with existing drinking water regulations.

- Either alternative could be impacted by the requirement for additional source water treatment for *Cryptosporidium* removal or inactivation, but such impact cannot be determined until testing (which will start in July 2004) is completed in January 2007.

- The redundancy and security of having two plants of equal size provides an additional factor of safety in terms of meeting system demands if one of the two plants were out-of-service.

After careful consideration and review with City staff, it is recommended that the City of Lawrence proceed with implementing the water supply, treatment, and distribution system improvements identified as Alternative 1. The two plants of similar size arrangement has well served the City in recent years.

Additional information on recommended improvements under Alternative 1 is presented below.

5.1 Water Supply

The firm capacity of the existing river intake and the vertical wells at the Kaw WTP is approximately 16 mgd. Therefore, the firm capacity of the raw water supply system has to be increased to 17.5 mgd to be compatible with the plant's rated treatment capacity. The firm capacity of the intake system should be increased by installing a 30-inch parallel siphon. In addition, a program should be implemented for replacing all of the pumps at Low Service Pumping Station 2 (LSPS No. 2) with five units rated 3,050 gpm at approximately 75 feet head, to provide the required firm pumping capacity with one unit out-of-service. Other options for pump replacement capacities (such as two or three pump replacements with different rated capacities) may be considered during detailed design.

Additional surface water supply or a new groundwater supply is needed to expand the Kaw WTP raw water supply from 22.3 mgd to 25 mgd. A second intake crib should be constructed and a 24-inch raw water supply line installed to convey water to the trash well. From there, the water would be pumped through an upgraded Low Service Pumping Station 1 (LSPS No. 1) through a new 24-inch raw water transmission line to convey the water to the new treatment train. The upgrading at LSPS No. 1 would include replacement of the pumps, electrical equipment, HVAC system, and instrumentation and controls.

The Bowersock Dam has recently undergone significant maintenance and repairs. The City should plan on routinely inspecting the dam and budgeting for repairs to the more than 100 year old structure to ensure that the dam remains a viable component of the City's raw water supply system.

Improvements required to develop a firm supply capacity of 25 mgd to the Clinton WTP at the projected drought water pool elevation, include replacement of all existing pumping units with higher head units rated at approximately 180 feet. Three 10 mgd units and one 5 mgd unit should be installed.

5.2 Water Treatment

In order to expand the Kaw WTP from 17.5 mgd to 25 mgd, a new 7.5 mgd treatment train should be added and new presedimentation, primary, and secondary basins should be constructed. Circular basins are considered preferable to rectangular basins because circular softening equipment is more efficient in reducing hardness and settling out precipitate. Circular basins would provide treatment similar to that used at the Clinton WTP.

Additional filtration capacity is also needed at the Kaw WTP. It appears that the most viable option would be to construct two additional filters west of existing filters 5 through 8. For reliability, the two new filters should be of the same size as the adjacent filters, which would increase the filtration capacity by 7.8 mgd at a loading rate of 4 gpm/sf.

A new treated water reservoir with a minimum volume of 1 million gallons should be constructed to provide additional storage capacity at the site, allowing plant operation to vary from production rates. In addition to these improvements, new chemical feed facilities would need to be constructed to accommodate the increased capacity.

Expanding the Clinton WTP from 15 mgd to 25 mgd would involve the construction of a new basin train consisting of a presedimentation, a primary, and a secondary basin, and the installation of new chemical feed equipment for the new basin train; and construction of additional high service pumping facilities. Recommended high service pump station improvements are described in the following section about the distribution system. The Clinton WTP expansion project completed in 2002 already includes the filtration and transfer pump improvements necessary to process 25 mgd.

Depending upon the results of the monitoring for source water *Cryptosporidium* under LT2ESWTR, additional provisions for oocyst removal and/or inactivation may be required at the Kaw and the Clinton WTP. Depending on the severity of the *Cryptosporidium* infestation in the raw water, post-filtration UV disinfection may be required.

5.3 Distribution System

Service Levels: Much of the area west of Kansas Highway 10 (K-10) includes ground elevations that cannot be served at adequate pressures from the existing West Hills Service Level. A new Kanwaka Booster District is recommended to serve the entire area west of K-10. The Kanwaka Booster District would be supplied by booster pumping from the existing West Hills Service Level.

A South Service Level should be established for the future service area south of the Wakarusa River. The South Service level would have a maximum static hydraulic gradient of 1050, or about 30 feet higher than the existing Central Service Level.

Two areas of high ground that are expected to have a sizable future population could not be served by the future South Service Level. South 1 Booster District would be located in the southwest corner of the service area, along the south shore of Clinton Reservoir, and South 2 Booster District would be located on a ridge between Wakarusa Drive and Kasold Drive.

Storage Facilities: The City has been planning to construct additional storage in the West Hills Service Level along 6th Street, west of Wakarusa Drive. Based on the evaluations conducted for this report, this storage should have a minimum total volume of 1.0 million gallons.

No additional storage is recommended for the Central Service Level.

The additional storage volumes needed for each service level and booster district to meet projected demands through year 2025 are summarized in Table ES-5.

Table ES-5
Recommended Additional Storage Facilities

Service Level	Facility Designation	Volume (MGal)
West Hills Service Level	Sixth Street West Elevated Tank	1.0
Kanwaka Booster District	Kanwaka Elevated Tank	1.0
South Service Level	Central South Ground Storage	1.0
South 1 Booster District	South 1 Elevated Tank	0.25
South 2 Booster District	South 2 Elevated Tank	0.25

Pumping Facilities: Recommended pumping facilities are summarized below:

- The Kawaka Booster District should be supplied by two pumping stations for reliability and redundancy. The major pumping station should be located along Sixth Street, at the same location as the recommended 6th Street West Elevated Tank.

- The future South Service Level (including South 1 and South 2 Booster Districts) should receive the majority of its supply through a booster pumping station located in the vicinity of O'Connell Road and N 1100 Road (O'Connell Road Booster Station). Additional supplemental supply of about 2.0 mgd would be delivered directly from the Clinton WTP. A flow control valve should be installed on the existing 24-inch Central Service Level main near the intersection of 23rd Street and Wakarusa Drive to allow the Clinton WTP high service pumps to pump directly to the future South Service Level and to concurrently deliver water to the Central Service Level.

- The South 1 and South 2 Booster Districts should each be supplied by a single booster pumping station and elevated tank.

- High service pumping improvements are required for both the Kaw and the Clinton WTP as summarized below:

    - All four "old" Kaw WTP high service pumps to the Central Service Level should be replaced with 3.5 mgd units to meet year 2025 demands.

- The Kaw WTP high service pumps to the West Hills Service Level deliver only about 1.2 mgd, which is less than their reported capacity of 1.5 mgd. For reliability, the pumps should be replaced with units that would 1.5 mgd at a rated head of 350 feet.

- The Clinton WTP high service pumping capacity to the Central Service Level is not adequate to meet projected year 2025 demands. One of the existing 2.8 mgd units should be replaced with a 5.0 mgd unit.

- The firm rated capacity of 10 mgd from Clinton WTP high service pumping building to the West Hills Service Level is inadequate to meet the projected year 2025 demands. Two additional pumps rated at 4.5 mgd should be installed in the high service pumping building when the water treatment plant is expanded.

Distribution Mains: Significant distribution main improvements are required to deliver water from the expanded water treatment plants and to supply the expanded service area. Distribution main improvements are shown, with the locations of the other distribution system improvements discussed above, on Exhibit IV-1 in Section IV of this report.

Distribution main improvements are recommended to help sustain the water level in the Harper Elevated Tank. While a recommendation for a new “Harper Booster District” is not included in this report, additional consideration should be given to this concept if pressure concerns continue to be an issue in the area.

5.4 Operations and Maintenance Building

New operations and maintenance building space should be constructed at a location that can be separated from the water processing areas to provide a consolidated area for all Utilities Department administrative staff. An isolated site would enhance the security of the water processes as there would be no reason for the general public to require access to the plant sites. Public access is currently required at the Kaw WTP because the administrative staff is located there.

6. Capital Costs and Implementation Plan

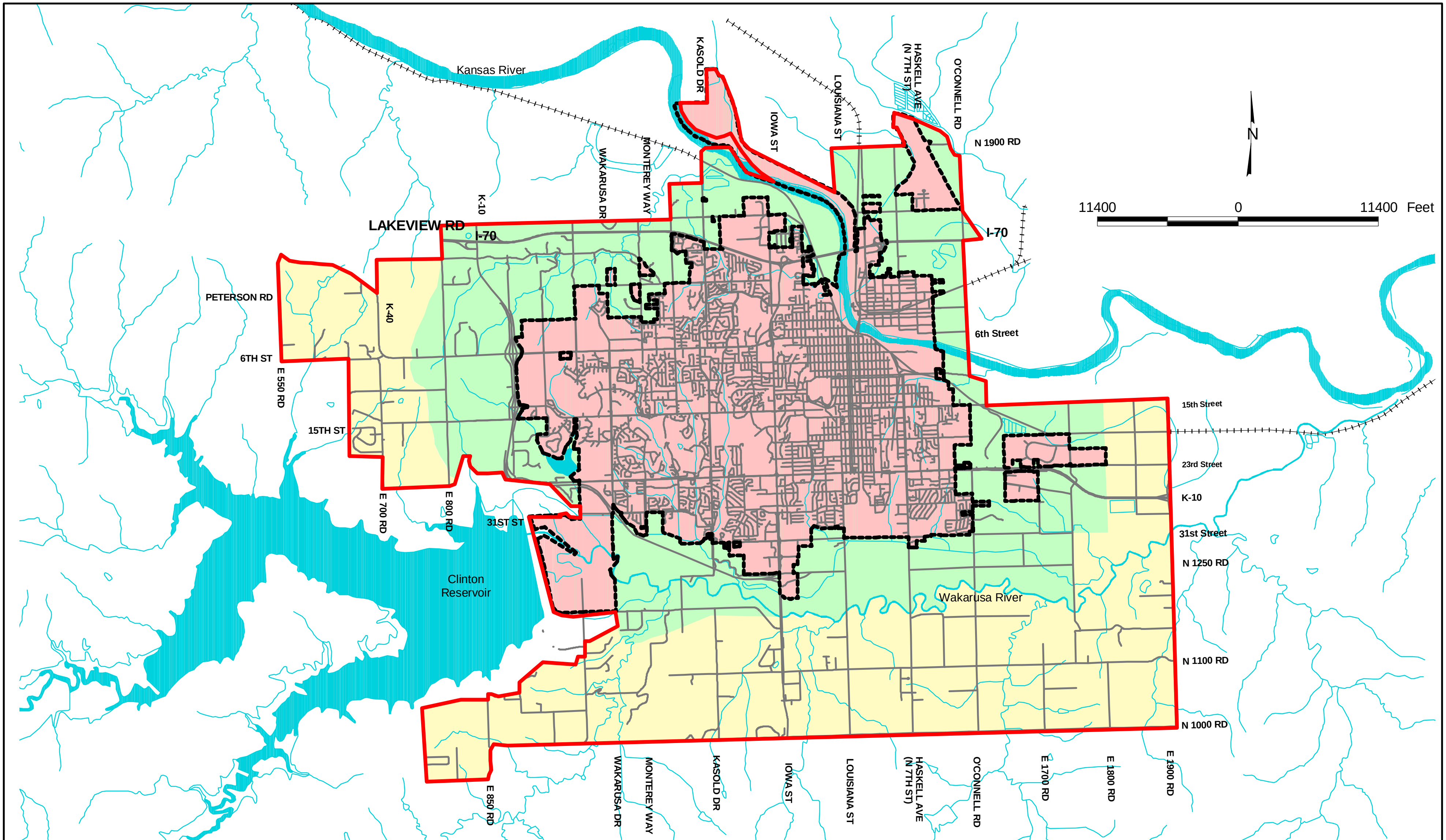
All costs presented in this report are capital costs and have been developed from previous Black & Veatch projects of similar size and scope. All capital costs for distribution-related improvements, including pipelines, storage facilities, and pumping stations, include a 20 percent allowance for contingencies and a 20 percent allowance for engineering, legal, and administrative (ELA) costs. All capital costs for supply and treatment related improvements include a 25 percent allowance for contingencies and a 20 percent allowance for ELA. The overall water system capital costs, in 2003 dollars, for the 2025 planning period are summarized in Table ES-6.

Table ES-6
Capital Cost Summary of Recommended Improvements

Component	Capital Cost ($)
Kaw Raw Water Supply Improvements	
Reliability	756,000
Growth	4,009,000
Clinton Raw Water Supply Improvement	
Reliability	--
Growth	1,151,000
Kaw WTP Improvements	
Reliability	--[1]
Growth	14,561,000
Regulatory	2,476,000
Clinton WTP Improvements	
Reliability	--
Growth	7,901,000
Regulatory[2]	2,476,000
Distribution System Improvements	36,440,000
New Operations and Maintenance Building	4,719,000
Total Improvements	**74,489,000**

[1] Reliability improvements are in the current year budget and are not included in this table for construction of a parallel header between the raw water flow splitter and presettling Basins 4 and 5, to remove a hydraulic restriction that currently limits the plant to about 16.5 mgd.
[2] UV post-filtration irradiation for Cryptosporidium inactivation may or may not be required depending upon the results of source water monitoring under the LT2ESWTR.

An implementation plan showing 10-year capital improvements was developed and is shown Table VI-1 of the report. The phasing schedule for the Clinton WTP expansion is shown on Figure VI-1 in Section IV of this report.



Legend

Service Limits

- Existing
- Year 2010
- Year 2025
- Lawrence 2000 City Limits
- Year 2025 Urban Growth Area

City of Lawrence, Kansas
Water System Master Plan
2003

STUDY AREA

BLACK & VEATCH
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Figure I - 1

1.0 Introduction

1.1 Purpose

This report has been prepared to provide the City of Lawrence with a comprehensive master planning evaluation of the City’s water system. The recommended improvements plan presented herein will serve as a basis for the design, construction, and financing of facilities to meet the City's anticipated population growth and commercial development. The purpose of the recommended improvements is to provide an adequate and dependable supply of water to existing and future customers.

1.2 Scope

The Study Area for this investigation and report is shown on Figure I-1. The various components of the Study Area have been delineated by the City of Lawrence Planning Department. These components are described below:

- 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 evaluation of water demands by class and service level, and computer hydraulic analyses, were conducted for base year 2000 and design years 2010 and 2025. Overall total system demands were extrapolated to year 2050 to evaluate long-term supply requirements.

The principal elements of this study include the following:

- Evaluate historical water use trends and prepare projections of future water requirements based on population projections provided by the Lawrence-Douglas County Metropolitan Planning Office.
- Evaluate the adequacy of existing supply, treatment and distribution system components.

Figure I-1 Study Area

- Perform a Safe Drinking Water Act (SDWA) evaluation and regulatory review of the existing treatment processes at the Kaw and Clinton Water Treatment Plants and evaluate modifications to meet future regulations.

- Update the existing computer model of the Lawrence water distribution system in WaterCAD hydraulic analysis software, to include most pipes within the distribution system, and to expand the capabilities of the model to include extended period simulations (EPS). Provide the updated model to the City.

- Perform steady state hydraulic analyses to determine the capacity of the distribution system to meet present and future water demands. Evaluate the impact of meeting maximum hour demands by high service pumping at the water treatment plants versus additional distribution system storage.

- Develop a master plan of recommended water system improvements, including a phased construction program and opinions of probable cost. The distribution system improvements recommended in this report are staged to address existing system deficiencies and to coincide with anticipated development.

1.3 Abbreviations

Abbreviations used in this report are as follows:

AD	(Annual) Average Day
BAT	Best Available Technology
BPS	Booster Pumping Station
$CaCO_3$	Calcium carbonate
CCL	Drinking Water Contaminant Candidate List
CIP	Capital Improvements Program
CPE	Comprehensive Performance Evaluation
DBP(s)	Disinfection by-product(s)
DBPR	Disinfection By-Products Rule
DOC	Dissolved organic carbon
EPA	United States Environmental Protection Agency
EPS	Extended Period Simulation (distribution hydraulic analysis)
FBRR	Filter Backwash Recycling Rule
ft	Feet
GAC	Granular activated carbon
gals/sq ft	Gallons per square foot
GIS	Geographical Information System

gpcd	gallons per capita per day
gpm	gallons per minute
GWR	Ground Water Rule
HAA5	Haloacetic acids
HGL	Hydraulic Grade Line
Hp	Horsepower
ICI	Industrial/Commercial/Institutional
ICR	Information Collection Rule
IDSE	Initial Distribution System Evaluation
IESWTR	Interim Enhanced Surface Water Treatment Rule
in	Inch
IOC(s)	Inorganic chemical(s)
ISO	Insurance Services Office
KDHE	Kansas Department of Health and Environment
KWRAD	Kansas River Water Assurance District
L	Liter
LRAA	Locational Running Annual Average
LT1ESWTR	Stage 1 Long-Term Enhanced Surface Water Treatment Rule
LT2ESWTR	Stage 2 Long-Term Enhanced Surface Water Treatment Rule
MCL(s)	Maximum contaminant level(s)
MCLG(s)	Maximum contaminant level goal(s)
MD	Maximum Day
MF	Microfiltration
MGal	Million gallons
mg/L	Milligrams per liter
mgd	Million gallons per day
MH	Maximum Hour
MRDL	Maximum Residual Disinfectant Level
MRDLG	Maximum Residual Disinfectant Level Goal
NF	Nanofiltration
NTU	Nephelometric turbidity unit
PAC	Powdered activated carbon
pCi/L	Picocuries per liter
PRV	Pressure Reducing Valve
psi	Pounds per square inch
psig	Pounds per square inch gauge
rpm	Revolutions per minute
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SMCL(s)	Secondary maximum contaminant level(s)

SOC	Synthetic organic chemical
SUVA	Specific Ultraviolet Absorbance
SWTR	Surface Water Treatment Rule
TAZ	Traffic Analysis Zone
TCAA	Trichloroacetic acid
TDH	Total Dynamic Head
TOC	Total organic carbon
TTHM(s)	Total trihalomethane(s)
UF	Ultrafiltration
UFW	Unaccounted-for Water
UGA	(Year 2025) Urban Growth Area
USGS	United States Geological Survey
WSE	Water Surface Elevation
WTP	Water 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, consideration was given to long-term growth to year 2050 in the development of recommended water supply improvements.

2.2 Population

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

Table I-1
City of Lawrence Population[(1)]

Year	Population	Population Growth	
		Persons	% (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.

2.1.1 Water Service Population

The City of Lawrence provides water service to retail customers within the City Limits. In addition, they provide wholesale service to a number of rural water districts that lie outside the City Limits. The service populations shown in this report refer to the retail water service customers within the City Limits and do not include population served by rural water districts.

The Lawrence-Douglas County Metropolitan Planning Office (Lawrence Planning Office) provided the overall UGA population projections used in this report.

They also provided housing unit counts and population per household data by traffic analysis zone (TAZ) for years 2000, 2010, and 2025. Determination of service population for years 2000, 2010, and 2025 was based on this data.

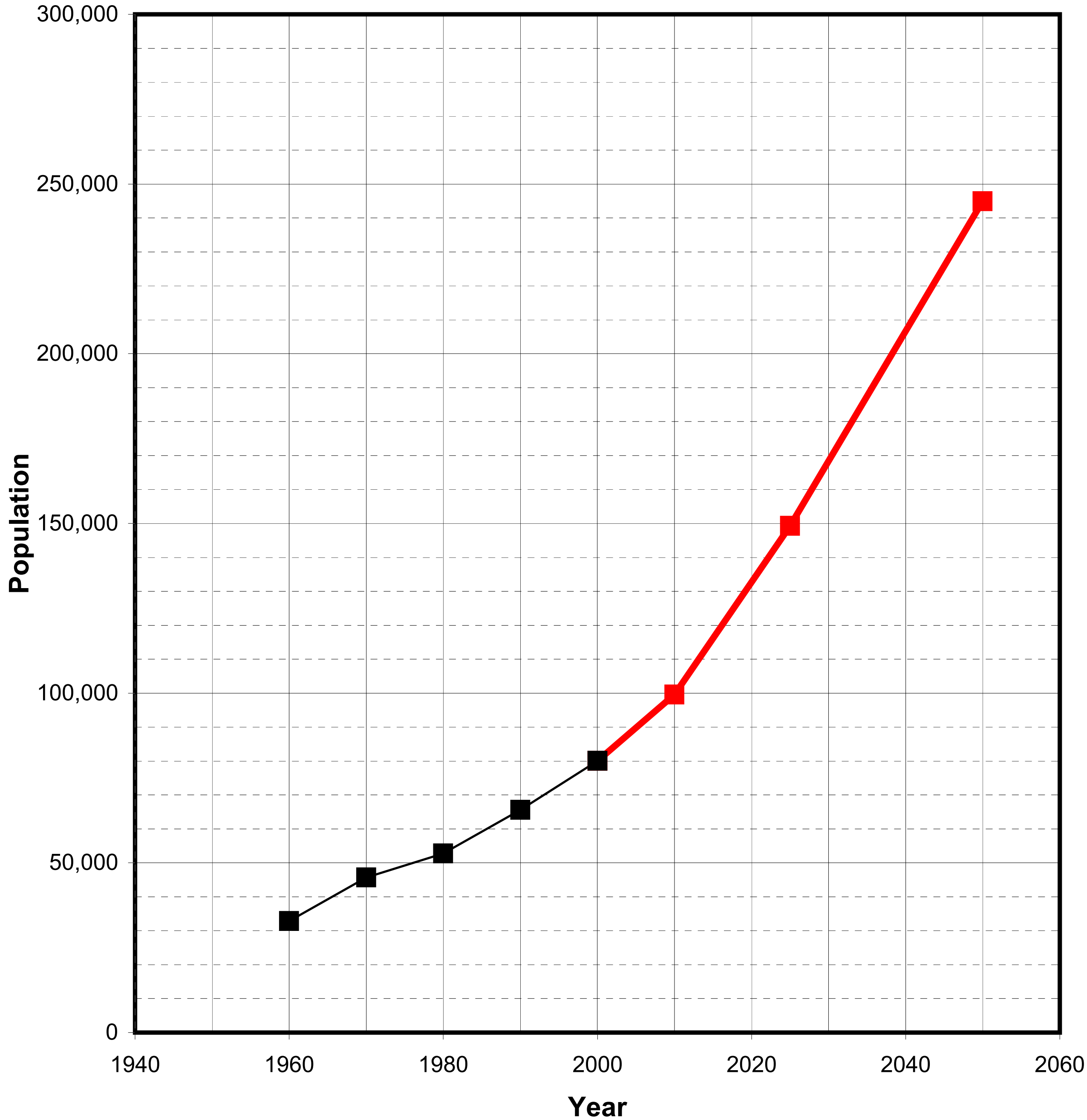
For this study, the 2010 retail water service area was assumed to extend to the Wakarusa River on the south and to coincide with drainage basin extents at approximately E 800 Road on the west. Eastern and northern boundaries coincide with the Urban Growth Area (UGA) boundary. The 2025 retail water service boundary was assumed to be the UGA boundary. Retail water service limits for each design year were previously shown on Figure I-1 Study Area.

Estimated year 2000 and projected retail water service population are summarized in Table I-2. Historical and projected populations are shown on Figure I-2.

Table I-2
Projected Retail Water Service Population

Year	Population	Population Growth	
		Persons	% (Annual)
2000	79,817(1)		
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 retail water service limits and excluding population within wholesale water districts
(2) Projection by Lawrence-Douglas County Metropolitan Planning Office for UGA
(3) Projection developed for this report based on 2% per year growth rate



Legend

Projected City Population

Historical City Population

City of Lawrence, Kansas
Water System Master Plan
2003

Historical and Future Population

BLACK & VEATCH
Corporation

Figure I-2

2.2.1 Population by Service Level

A spatial analysis of the population by TAZ was performed using GIS techniques to determine existing and projected population by service level.

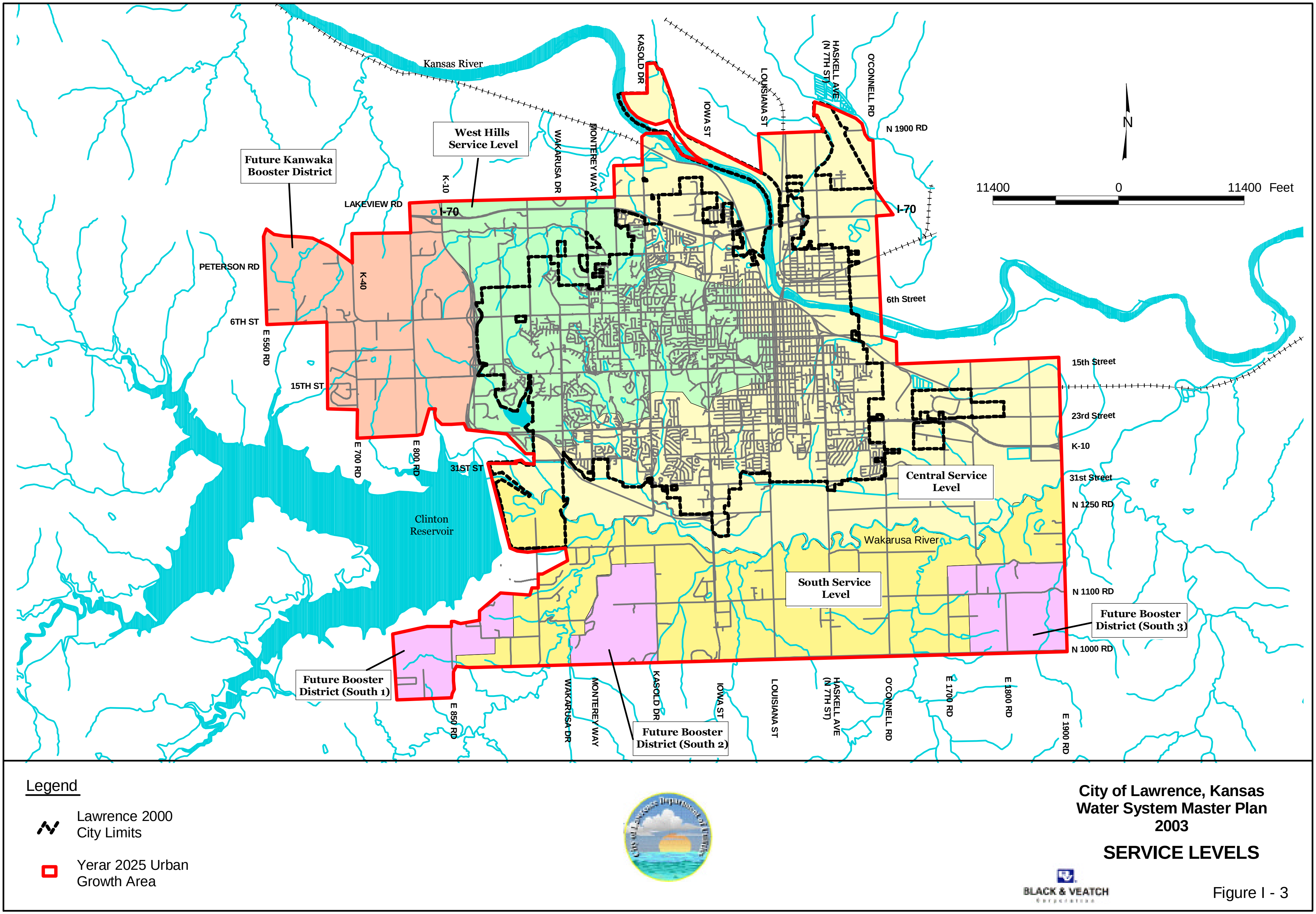
Service pressures based on ground elevations were evaluated for the expanded retail water service boundaries for years 2010 and 2025. The area within the 2010 service area boundary can be provided adequate pressures by the existing service levels (Central and West Hills) and the proposed Kanwaka Booster District. Additional booster districts will be needed to provide adequate service to the entire UGA. The proposed Kanwaka Booster District encompasses the entire area west of Highway K-10. The proposed South Service Level will encompass much of the area south of the Wakarusa River. Future booster districts South 1, South 2 will serve high ground elevation along the extreme southern boundary of the UGA.

Service level boundaries for the entire UGA are shown on Figure I-3. Table I-3 presents a summary of projected population by service level.

Table I-3
Population by Service Level[(1)]

Service Level	Base Year 2000		Design Year 2010		Design Year 2025	
	Total UGA	Water Service	Total UGA	Water Service	Total UGA	Water Service
West Hills	29,648	29,648	37,750	37,750	51,570	51,570
Central Service	50,450	50,169	56,800	56,800	66,784	66,784
Future Kanwaka Booster District	633	0	5,192	5,050	10,827	10,827
Future South Service Level	1,269	0	6,601	0	14,612	14,612
Future South 1 Booster District	121	0	1,425	0	3,082	3,082
Future South 2 Booster District	178	0	1,090	0	2,403	2,403
Total	**82,299**	**79,817**	**108,858**	**99,600**	**149,278**	**149,278**

[(1)]Based on population distribution by TAZ provided by Lawrence Planning Office.



City of Lawrence, Kansas
Water System Master Plan
2003

SERVICE LEVELS

BLACK & VEATCH

Figure I - 3

2.3 Employment

Employment data is used to aid in the spatial distribution of future ICI (Industrial/Commercial/Institutional) water demands in the computer model. Areas with high concentrations of employment have a higher ICI water demand. The Lawrence Planning Office provided employment data by TAZ within the UGA. A spatial analysis of the TAZ data was performed using GIS techniques to determine employment by service level. Employment by service level for years 2000, 2010, and 2025 is summarized in Table I-4.

Table I-4
Employment by Service Level[1]

Service Level	Base Year 2000		Design Year 2010		Design Year 2025	
	Total UGA	Service Area	Total UGA	Service Area	Total UGA	Service Area
West Hills Service Level	14,470	14,470	16,093	16,093	18,603	18,603
Central Service Level	28,775	28,775	33,987	33,987	40,986	40,986
Future Kanwaka Booster District	90	0	428	400	861	861
Future South Service Level	464	0	565	0	733	733
Future South 1 Booster District	5	0	5	0	7	7
Future South 2 Booster District	31	0	31	0	31	31
Total	**43,834**	**43,245**	**51,110**	**50,480**	**61,221**	**61,221**

[1]Based on employment distribution by TAZ provided by Lawrence Planning Office.

The projected population growth in the UGA from year 2000 to year 2025 of 69,180 is a total growth of about 86 percent, and an annual growth rate of 2.5 percent. Over the same time period, the total increase in employment of 17,976 amounts to an increase of only about 42 percent and an annual increase of 1.4 percent. The implication of this data is that employment will not keep pace with population growth. That is, much of the increase in population will commute to jobs located outside the UGA.

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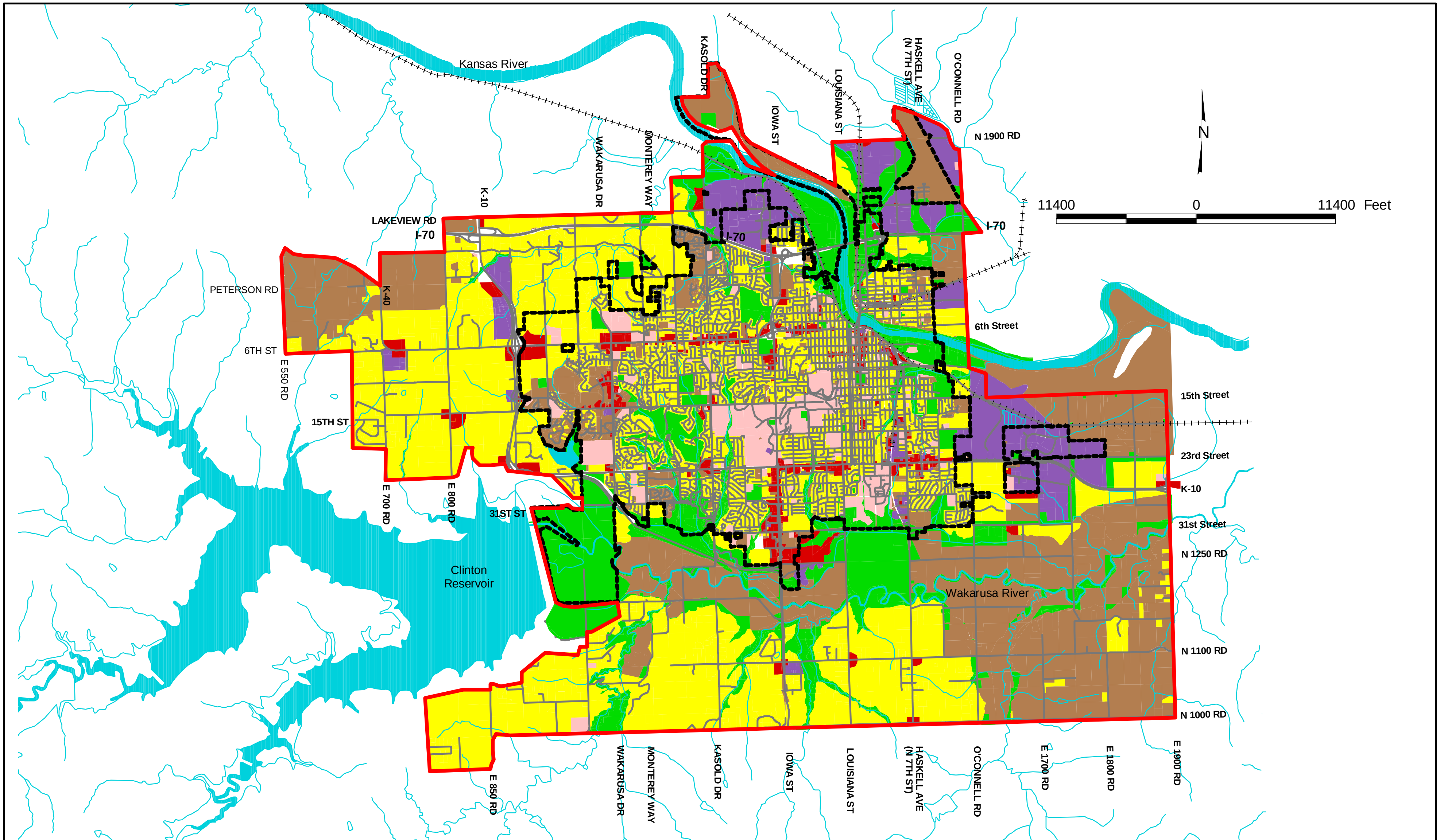
2.4 Land Use

Employment data by TAZ provides a measure and general indication of the location of future ICI demands. The assignment of future ICI demand to the computer model is based on the future land use plan. The land use plan for year 2025 was provided by the Lawrence Planning Office and is shown in Figure I-4.



Legend

Land Use Classifications

- Residential
- Commercial
- Public/Institutional
- Industrial
- Parks / Open Space
- Farm / Vacant
- Lawrence 2000 City Limits
- Year 2025 Urban Growth Area

City of Lawrence, Kansas
Water System Master Plan
2003

2025 LAND USE

BLACK & VEATCH

Figure I - 4

3.0 Water Requirements

3.1 General

A water utility must be able to supply water at rates that fluctuate over a wide range. Yearly, monthly, daily, and hourly variations in water use occur, with higher use during dry years and in hot months. Also, water use typically follows a diurnal pattern, being low at night and peaking in the early morning and late afternoon. Rates most important to the hydraulic design and operation of a water treatment plant and distribution system are average day (AD), maximum day (MD), and maximum hour (MH). Minimum day (ND) usage is becoming increasingly significant relative to water quality issues in the distribution system as these conditions provide the longest residence time within the distribution system (greatest water age).

Average day use is the total annual water use divided by the number of days in the year. The average day rate is used primarily as a basis for estimating maximum day and maximum hour demands. The average day rate is also used to estimate future revenues and operating costs.

Maximum day use is the maximum quantity of water used on any one day of the year. The maximum day rate is used to size water supply hydraulics, treatment facilities, and pumping stations. The raw water facilities must be adequate to supply water at the maximum day rate, and the treatment facilities must be capable of processing this quantity of water.

Maximum hour use is the peak rate at which water is required during any one hour of the year. Since minimum distribution system pressures are usually experienced during maximum hour, the sizes and locations of distribution facilities are generally determined on the basis of this condition. Maximum hour water requirements are partially met through the use of strategically located system storage. The use of system storage minimizes the required capacity of transmission mains and permits a more uniform and economical operation of the water supply, treatment, and pumping facilities.

Minimum day use is minimum quantity of water used on any one day. It is used as a basis for evaluating the maximum water age in the distribution system.

Because water use characteristics vary between water systems, historical production and sales records serve as the primary basis for predicting future requirements.

3.2 Historical Water Production

"Water Production Reports" were received from the City for the years 1995 through 2001. The Water Production Reports include monthly information on raw pumping from the water supply sources (Kansas River, Clinton Reservoir), finished water pumping at the treatment plants (Kaw and Clinton) to the two service levels (Central and West Hills), and metered city usage by class (Residential, Multi-Family, Commercial, Industrial, City Meters, KU, and RWD-Baldwin). Yearly and monthly totals are provided on the reports.

Finished production at the water treatment plants is summarized in Table I-5.

Table I-5
Historical Finished Production

Year	Total Annual Production		Total Finished Production (mgd)
	Kaw WTP (mgd)	Clinton WTP (mgd)	
1995	5.3	4.6	9.8
1996	5.3	4.8	10.1
1997	6.0	4.8	10.8
1998	5.9	5.7	11.6
1999	6.4	5.2	11.6
2000	6.8	6.0	12.8
2001	6.3	5.9	12.2

The difference between total finished production (Kaw WTP plus Clinton WTP) and the metered city usage was evaluated for this study. This difference is referred to as Unaccounted for Water (UFW). Historical production, metered usage, and UFW for 1995 to 2001 are summarized in Table I-6. Metered sales were compared to historical total finished production to evaluate the amount of unaccounted-for water in the distribution system. Over the past 7 years, unaccounted-for water in the distribution system has averaged approximately 5 percent of the total average day finished production. The design value for UFW for this study is 5.0 percent.

Table I-6 Historical Production, Metered Usage, and Unaccounted For Water				
Year	Total Finished Production (mgd)	Metered City Usage (mgd)	Unaccounted For Water (UFW)	
			(mgd)	(%)
1995	9.8	10.1	-0.3	-3.0
1996	10.1	9.5	0.6	5.8
1997	10.8	9.8	0.9	8.7
1998	11.6	10.7	0.9	7.8
1999	11.6	11.1	0.5	4.7
2000	12.8	12.0	0.7	5.8
2001	12.2	11.5	0.7	5.7
Average	**11.3**	**10.7**	**0.6**	**5.1**

3.3 Historical Distribution Usage

3.3.1 Total System

The City provided data including flow, water level, and pressure in the form of circular charts. Hourly use was calculated for the maximum days for 1995 through 1997 and the day before, the day of, and day after maximum days for 1998 through 2001. Hourly use was calculated for the day before, the day of, and day after minimum days for 2000 and 2001. This data comprised a total of fifteen days of record for peak demand conditions and six days for minimum demand conditions. For the days of provided data, the total daily and hourly water demands were calculated taking into account the various changes in the storage tank and reservoir levels throughout the day.

The peak demand diurnal curves consistently indicate that the peak hour demand occurs during the morning hours, with a second, lower peak hour demand in the evening hours. The diurnal curves for peak demand conditions are shown in Appendix A to this report.

In Lawrence, minimum demand conditions typically occur during the Christmas holidays. The minimum demand diurnal curves indicate lowest usage during the early morning hours. The diurnal curves for the minimum demand conditions are shown in Appendix B to this report.

Historical average day, maximum day, maximum hour, and minimum day water use is summarized in Table I-7. Also shown in Table I-7 are the maximum day to average day (MD/AD), maximum hour to maximum day (MH/MD), maximum hour to average day (MH/AD), and minimum day to average day (ND/AD) demand ratios.

Table I-7
Historical Water Demands

Year	Water Use (mgd)				Demand Ratios			
	AD[3]	MD[4]	MH[4]	ND[4]	MD/AD	MH/MD	MH/AD	ND:AD
1980[1]	7.4	17.6	-	-	2.38	-	-	-
1981[1]	8.9	13.2	-	-	1.48	-	-	-
1982[1]	8.4	12.8	-	-	1.52	-	-	-
1983[1]	8.3	20.6	-	-	2.48	-	-	-
1984[1]	7.7	18.3	-	-	2.38	-	-	-
1985[1]	8.0	13.8	-	-	1.73	-	-	-
1986[2]	8.2	16.2	21.0	-	1.98	1.30	2.56	-
1987[2]	8.8	16.3	21.5	-	1.85	1.32	2.44	-
1988[2]	8.9	21.6	34.1	-	2.43	1.58	3.83	-
1989[2]	9.8	17.9	23.8	-	1.83	1.33	2.43	-
1990[2]	9.7	17.7	25.4	-	1.82	1.44	2.62	-
1991[2]	10.6	20.0	23.4	-	1.89	1.17	2.21	-
1992[2]	9.8	15.5	23.0	-	1.58	1.48	2.35	-
1993[2]	9.5	19.9	25.6	-	2.09	1.29	2.69	-
1994[2]	10.6	17.8	22.8	-	1.68	1.28	2.15	-
1995	9.8	18.8	24.0	-	1.91	1.28	2.44	-
1996	10.1	18.2	23.3	6.6	1.80	1.28	2.30	0.65
1997	10.8	18.6	25.8	7.1	1.72	1.39	2.39	0.66
1998	11.6	22.2	28.3	7.4	1.92	1.27	2.44	0.64
1999	11.6	22.3	30.3		1.92	1.36	2.60	
2000	12.8	25.6	38.6	7.2	2.01	1.51	3.02	0.56
2001	12.2	21.9	31.9	7.7	1.79	1.46	2.61	0.63
Average	**9.7**	**18.5**	**26.4**	**7.2**	**1.92**	**1.36**	**2.57**	**0.63**

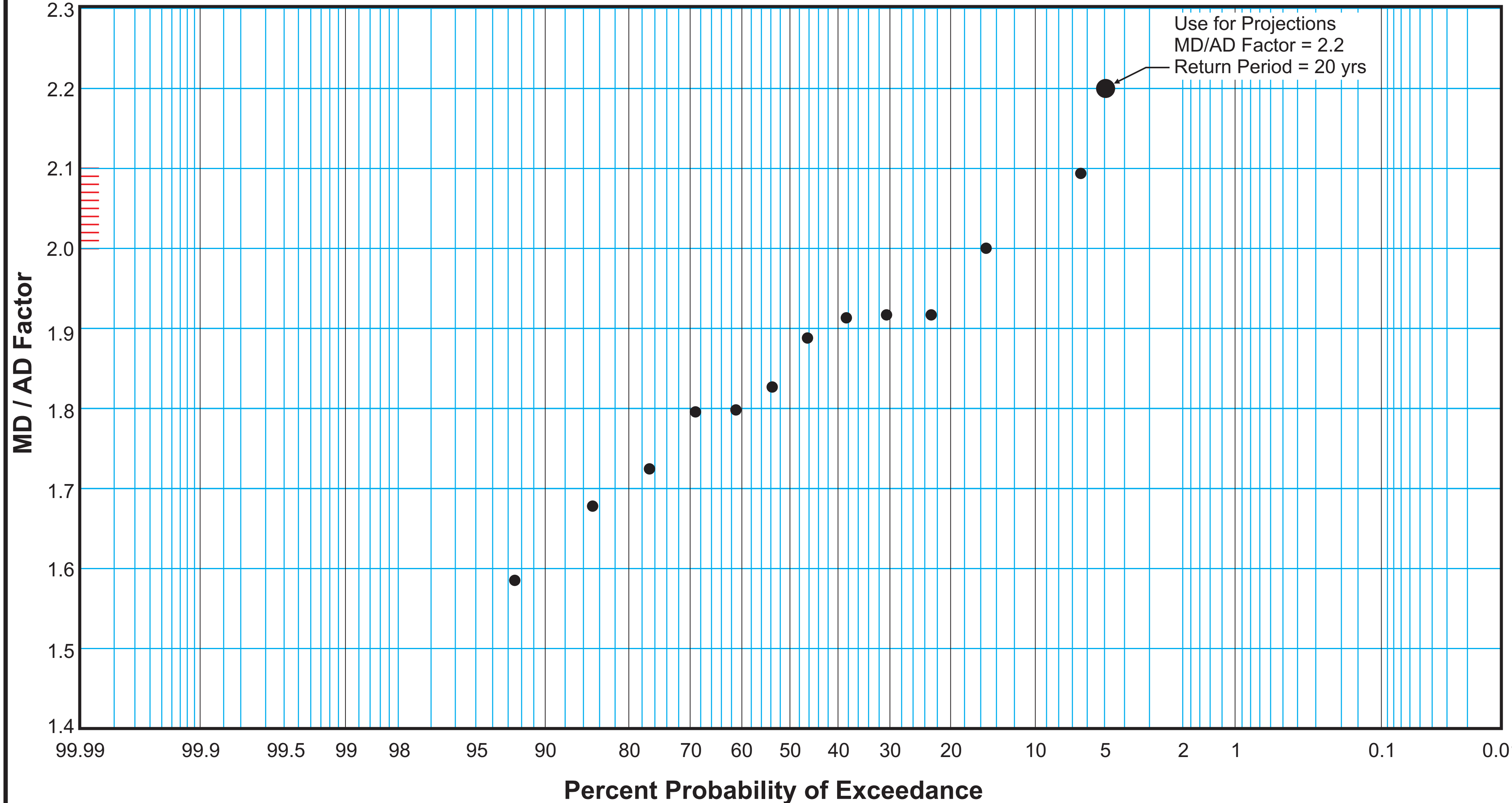
(1) All 1980 through 1985 data is from 1986 Master Plan by Black & Veatch.
(2) All 1986 through 1994 data is from 1995 Master Plan by Black & Veatch.
(3) 1995 through 2001 AD was calculated for this study by summarizing the City's Water Production Reports.
(4) 1995 through 2001 MD, MH, and ND were calculated for this study from circular chart data.

3.3.1.1 Demand Factor Risk Analysis

A risk analysis was performed to determine the appropriate return period desired for peaking factor development for maximum day and maximum hour demands, and to aid in understanding the implications of these factors. If a water system improvements program is planned based on subjectively low design peaking factors, it would be anticipated that the future peak demands would exceed the capacity of the system, and water restrictions would need to be imposed too often. Conversely, if an improvements program is planned based on high peaking factors, the additional and premature cost of capital improvements may not be warranted. The return period of historical peaking factors was evaluated to aid in the selection of peaking factors used for water demand projections.

The water use data in Table I-7 shows that over the past 22 years, the maximum day to average day peaking factor averaged 1.92, and the maximum hour to average day peaking factor averaged 2.57. These ratios represent a 50 percent chance of being exceeded. That is, they would theoretically be exceeded every two years and represent a two-year return period.

Frequency distribution plots were prepared using the data in Table I-7 and are shown on Figure I-5 and Figure I-6. The figures also show the design peaking factors to be used for this study. Design MD/AD and MH/AD peaking factors of 2.2 and 3.1 respectively will be used. The selected factors represent a return period of 20 years. Statistically, based on a 20-year return period, the risk of being exceeded in any year would be about 5 percent.



City of Lawrence
Water System Master Plan - 2003

MD / AD Peaking Factor
Frequency Distribution (1990 - 2001)

Figure I-5

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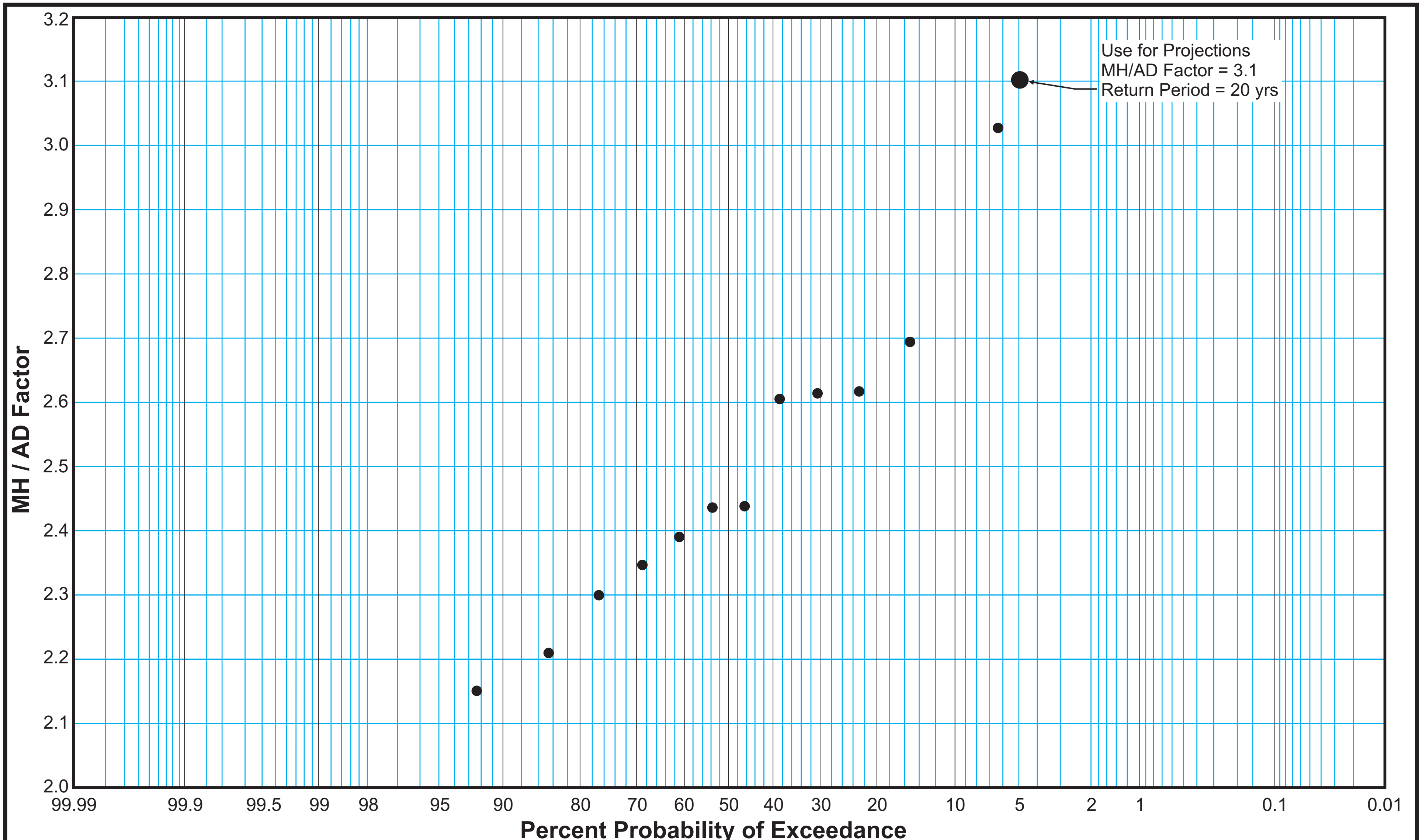
Corporation

132093.800-2 ADI 8/8/03



City of Lawrence
Water System Master Plan - 2003

MH / AD Peaking Factor
Frequency Distribution (1990 - 2001)

Figure I-6

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Corporation

132093.800-3 ADI 8/8/03

3.3.2 Use by Service Level

Daily and hourly demands were calculated for each service level for each of the days of record provided for this study. Historical demands by service level are shown in Table I-8 and I-9.

Table I-8
West Hills Service Level – Historical Demands

Date	Water Use (mgd)				Demand Ratios			
	AD	MD	MH	ND	MD/AD	MH/MD	MH/AD	ND:AD
1995	3.25	8.00	9.79	-	2.46	1.22	3.01	-
1996	3.47	7.49	10.98	-	2.16	1.46	3.16	-
1997	3.67	7.45	10.42	-	2.03	1.40	2.84	-
1998	4.07	9.84	14.79	-	2.42	1.50	3.63	-
1999	4.13	10.14	14.76	-	2.45	1.46	3.57	-
2000	4.32	11.72	20.82	2.18	2.72	1.78	4.82	0.50
2001	3.90	10.04	15.73	1.49	2.57	1.57	4.03	0.38
Average	**3.83**	**9.24**	**13.90**	**1.84**	**2.40**	**1.48**	**3.58**	**0.44**

Table I-9
Central Service Level – Historical Demands

Date	Water Use (mgd)				Demand Ratios			
	AD	MD	MH	ND	MD/AD	MH/MD	MH/AD	ND:AD
1995	6.59	11.46	14.74	-	1.74	1.29	2.24	-
1996	6.66	10.22	13.33	-	1.53	1.30	2.00	-
1997	7.11	11.48	15.89	-	1.61	1.38	2.23	-
1998	7.52	12.97	17.15	-	1.72	1.32	2.28	-
1999	7.51	13.19	16.93	-	1.76	1.28	2.25	-
2000	8.45	14.06	18.73	4.79	1.66	1.33	2.22	0.57
2001	8.32	12.83	18.30	6.10	1.54	1.43	2.20	0.73
Average	**7.45**	**12.31**	**16.44**	**5.44**	**1.65**	**1.33**	**2.20**	**0.65**

3.4 Historical Metered Sales

3.4.1 Total System

Annual water sales were reviewed to determine the mix of residential and non-residential water use, and per capita water use rates. This information provides a basis for the breakdown and distribution of projected water demands.

Total metered sales for years 1995 through 2001 were summarized in the "Water Production Reports." The "Metered City Usage" report provides metered sales summarized by Residential, Multi-Family, Commercial, Industrial, City Meters, KU, and RWD categories. For this study, the Commercial, Industrial, and City Meters categories were combined to create the ICI (Industrial/Commercial/Institutional) user class.

Historical metered sales categorized by user class and the respective percentages of total metered sales are summarized in Table I-10.

Table I-10
Historical Metered Sales

Year	Residential		ICI[1]		KU		RWD		Total
	(mgd)	%	(mgd)	%	(mgd)	%	(mgd)	%	(mgd)
1995	5.1	50	3.2	31	0.7	7	1.2	12	10.1
1996	4.9	51	2.9	30	0.7	7	1.2	12	9.6
1997	5.1	52	3.0	30	0.7	7	1.1	11	9.8
1998	5.3	50	3.3	31	0.7	7	1.3	12	10.7
1999	5.7	51	3.5	32	0.7	6	1.2	11	11.1
2000	6.2	51	3.8	31	0.7	6	1.4	11	12.1
2001	5.8	50	3.5	31	0.7	6	1.5	13	11.5
Average	**5.4**	**51**	**3.3**	**31**	**0.7**	**6**	**1.3**	**12**	**10.7**

(1) ICI (Industrial/Commercial/Institutional) includes Commercial, Industrial, and City Meters categories.

The summation of residential and ICI metered sales is referred to as "Lawrence Metered Sales" for this report. Historical metered sales by Residential and ICI and the respective percentage of Lawrence Metered Sales are summarized in Table I-11.

Table I-11
Historical Lawrence Metered Sales

Year	Historical Metered Sales				Lawrence Metered Sales[1]
	Residential		ICI		
	(mgd)	(%)	(mgd)	(%)	(mgd)
1995	5.1	61	3.2	39	8.2
1996	4.9	63	2.9	37	7.8
1997	5.1	63	3.0	37	8.1
1998	5.3	61	3.3	39	8.7
1999	5.7	62	3.5	38	9.2
2000	6.2	62	3.8	38	10.0
2001	5.8	62	3.5	38	9.3
Average	**5.4**	**62**	**3.3**	**38**	**8.8**

(1) Lawrence Metered Sales refers to the sum of Residential and ICI metered sales and excludes KU and RWD sales.

Metered sales data was related to historical population to provide an indication of historical per capita uses. For purposes of this evaluation, the population was assumed to grow in even increments between census years. Per-capita residential usage rates are summarized in Table I-12.

Table I-12
Historical Residential Per-Capita Usage

Year	Population[1] [2]	Total (mgd)	Per-Capita (gcd)
1995	67,878	5.1	74.4
1996	69,322	4.9	70.5
1997	70,766	5.1	72.0
1998	72,210	5.3	73.9
1999	73,654	5.7	77.3
2000	75,098	6.2	82.0
2001	76,542	5.8	75.7
Average		**5.4**	**75.1**

(1) Population assumed to grow in even increments between 1990 and 2000 based on U.S. Census population for 1990 and 2000. 2001 population assumed at same growth rate.
(2) Residential service population assumed to consist of City population less an estimated 5,000 persons residing in KU dormitories and Jayhawker Towers. Water demands for this housing is included in the KU water usage and not the residential usage in this table.

The metered sales data in Table I-11 demonstrates that the residential metered sales as a percentage of Lawrence Metered Sales; and the average per-capita residential sales, as shown in Table I-12; have remained fairly constant over the past seven years. For projected water demands for this study, it is assumed that per-capita residential use will remain constant, and that residential sales will continue to account for about 62 percent of the Lawrence metered sales.

The City of Lawrence provides water to several rural water districts and the City of Baldwin. A summary of RWD water use is tabulated in Table I-13.

Table I-13 Historical Rural Water District Usage					
Name	Address	Service Level	Water Use (mgd)		
			2000	2001	Average
Rural Water District #1	600 Wakarusa Dr	West Hills	0.107	0.102	0.104
Rural Water District #2	3400 Iowa	Central	0.119	0.113	0.116
Rural Water District #4	3000 Haskell Ave	Central	0.207	0.186	0.197
Rural Water District #5	3400 Iowa	Central	0.182	0.164	0.173
Rural Water District #6	3130 Lakeview Rd	Central	0.053	0.053	0.053
City of Baldwin	3100 Haskell Ave	Central	0.638	0.905	0.771
Rural Water District #1	600 Folks Rd	West Hills	0.014	0.012	0.013
Rural Water District #1	River Ridge Rd & Lonetree	Central	0.011	0.005	0.008
Rural Water District #1	Clinton Pkwy & Yankee Tk	West Hills	0.001	0.002	0.002
		Total	**1.332**	**1.544**	**1.438**

The City of Lawrence also provides water to the University of Kansas (KU). A summary of University of Kansas water use is tabulated in Table I-14.

Table I-14 Historical University of Kansas Usage			
Description	Water Use (mgd)		
	2000	2001	Average
Power Plant(1)	0.43	0.39	0.41
Dormitories (2)	0.25	0.23	0.24
Miscellaneous(3)	0.10	0.09	0.10
Total	**0.78**	**0.71**	**0.75**

(1) Includes "KU Power Plant" and "Power Plant Boiler" meters.
(2) Includes Jayhawker Towers and eight dormitories.
(3) Includes 21 meters at various locations.

3.5 Water Use Projections

Water use projections were developed for the total system (in aggregate) for each design year. In addition, water demand projections by service level were determined for the base year (year 2000) and years 2010 and 2025. The base year demand represents the theoretical demand that would have occurred in year 2000, using the same criteria as for the projected water requirements.

3.5.1 Total System

The residential per capita water use, percentage residential and ICI use, and unaccounted-for water were used to determine the base year 2000 and design years 2010 and 2025 water demands. Residential and ICI water use is calculated on a per capita basis. For this study, residential use is considered to be water used by domestic customers in houses and apartments. ICI use includes water used by businesses, industries, hotels, hospitals, and similar establishments. Future water requirements for the University of Kansas and the (wholesale customer) City of Baldwin were determined separately and added to the per capita sales to determine the total water sales. Unaccounted-for water is calculated as 5-percent of the total metered sales.

Projected water requirements for the University of Kansas were estimated to increase from about 0.7 mgd currently, to about 0.8 mgd by 2025. Information provided by the University indicated that they are projecting growth in the area referred to as “west campus”.

Unlike main campus, the approx. 600-acres located on the west side of Iowa (15th street to 23rd street) is relatively undeveloped as yet. It is expected that most of the university's future growth in water demand will come from development of west campus. In general, this property is owned by the University Endowment Association. The Endowment Assoc., with some technical support from University Facilities Management and planning staff, is planning this development; but, these plans are not complete and are not being widely distributed. It is expected that an increase in water demand will occur on this property. All water demand increase for KU was projected to occur on the west campus property.

Water use for the City of Baldwin has increased significantly over the past several years. They are currently negotiating a new wholesale delivery contract with the City of Lawrence. The new contracted maximum daily deliveries to the City of Baldwin are expected to be 1.3 mgd for year 2003, and 2 mgd for year 2010. For this report, it was assumed that the amount of water sold to the City of Baldwin would increase from about 0.9 mgd currently, to about 2.0 mgd by year 2025.

Other than the University of Kansas and City of Baldwin, future water requirements for wholesales customers were assumed to remain at current levels. As the City expands into areas currently served by wholesale agencies, the associated wholesale demand may decrease. However, growth in other parts of the wholesale areas would likely be increasing during the same time. The design values for wholesale water use projections are summarized in Table I-15.

Table I-15 Projected Wholesale Water Requirements			
Name	Base Year	2010	2025
Rural Water District # 1	0.12	0.12	0.12
Rural Water District # 2	0.10	0.10	0.10
Rural Water District # 4	0.18	0.18	0.18
Rural Water District # 5	0.15	0.15	0.15
Rural Water District # 6	0.05	0.05	0.05
City of Baldwin	0.90	1.50	2.00
Subtotal RWD Sales	**1.50**	**2.10**	**2.60**
University of Kansas	0.70	0.75	0.80
Total Wholesale Sales	**2.20**	**2.85**	**3.40**

Design values for projections of water requirements are summarized in Table I-16.

Table I-16 Design Criteria for Projected Water Requirements	
Per-Capita Residential Metered Sales	75 gcd
Residential / ICI Ratio (1)	62% / 38%
Per-Capita ICI Metered Sales (1)	46 gcd
KU Metered Sales	0.7 mgd increasing to 0.8 mgd
RWD Metered Sales	1.5 mgd increasing to 2.6 mgd
Unaccounted-For Water (Percent of Total Distribution Usage(2))	5 %
Peaking Factor Return Ratio	9 years
MD/AD Peaking Factor	2.2
MH/AD Peaking Factor	3.1
ND/AD Peaking Factor	0.75
(1)Exclusive of RWD and KU water requirements. (2) Including RWD and KU usage.	

Projected average day water demand requirements by user class are summarized in Table I-17.

Table I-17
Projected AD Water Requirements by Class

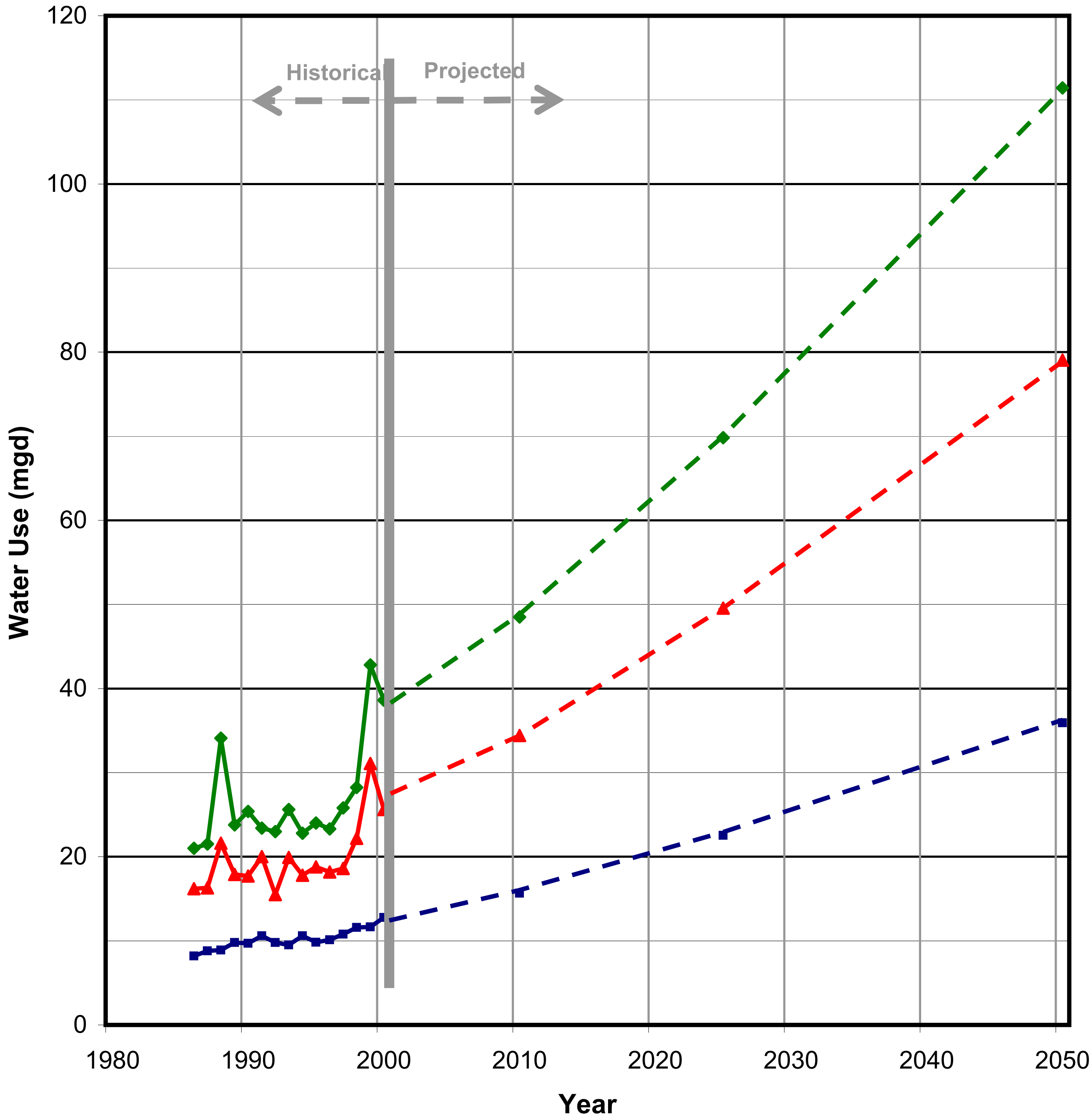
	Base Year		2010		2025		2050	
	(mgd)	(%)	(mgd)	(%)	(mgd)	(%)	(mgd)	(%)
Residential	6.0	48	7.5	48	11.2	50	18.4	51
ICI	3.7	29	4.6	29	6.9	30	11.3	31
KU	0.7	6	0.75	5	0.8	4	1.0	3
RWD	1.5	12	2.1	13	2.6	12	3.6	10
Subtotal	11.9	95	14.9	95	21.5	95	34.2	95
UFW	0.6	5	0.7	5	1.1	5	1.7	5
Total	**12.5**	**100**	15.6	**100**	22.5	**100**	35.9	**100**

Historical and projected water requirements are shown on Figure I-7. Projected total system water requirements are summarized in Table I-18.

Table I-18
Projected Water Requirements (Total System)

	Base Year [1]	Design Year		
		2010	2025	2050
Population	79,817	99,600	149,278	244,906
AD (mgd)	12.5	15.6	22.5	35.9
MD (mgd)	27.5	34.4	49.6	79.1
MH (mgd)	38.7	48.5	69.8	111.4

[1] Base year demands are calculated using design water demand projection criteria and the Year 2000 population. Base year demands are similar to recent historical demand.



Legend

- Average Day
- Maximum Day
- Maximum Hour

City of Lawrence, Kansas
Water System Master Plan
2003

Historical and Projected Water Requirements

BLACK & VEATCH
Corporation

Figure I-7

3.5.2 Projections by Service Level

Based on the total system demands by class and historical uses, base year and future year 2010 and 2025 average day water requirements were determined as shown in Table I-19. The base year demands and projected year 2010 and 2025 demands by service level were allocated and used for computer hydraulic analyses as described later in this report.

Table I-19
Projected AD Water Demands by Class and Service Level

Service Level	Res. Sales (mgd)	Res./Total Ratio (%)	ICI Sales (mgd)	KU (mgd)	RWD (mgd)	Total Sales (mgd)	UNF (mgd)	AD (mgd)
Base Year								
Central	3.32	0.55	2.67	0.44	1.38	7.82	0.39	8.21
West Hills	2.68	0.72	1.03	0.26	0.12	4.08	0.21	4.29
Total	**6.00**	**0.62**	**3.70**	**0.70**	**1.50**	**11.90**	**0.60**	**12.50**
Design Year 2010								
Central	3.79	0.44	3.02	0.44	1.98	9.24	0.43	**9.67**
West Hills	3.29	0.70	1.41	0.31	0.00	5.01	0.25	**5.26**
Kanwaka	0.38	0.72	0.15	0.00	0.12	0.64	0.03	**0.67**
Total	**7.46**	**0.62**	**4.57**	**0.75**	**2.10**	**14.89**	**0.71**	**15.60**
Design Year 2025								
Central	4.54	0.44	3.63	0.44	0.00	8.61	0.43	9.04
West Hills	4.33	0.65	2.33	0.36	0.00	7.01	0.35	7.36
Kanwaka	0.81	0.72	0.32	0.00	0.12	1.24	0.06	1.31
South SL	1.10	0.72	0.43	0.00	2.48	4.01	0.20	4.21
South 1	0.23	0.72	0.09	0.00	0.00	0.32	0.02	0.34
South 2	0.18	0.72	0.07	0.00	0.00	0.25	0.01	0.26
Total	**11.19**	**0.62**	**6.86**	**0.80**	**2.60**	**21.45**	**1.07**	**22.52**

Maximum day and maximum hour demands projections for each service level were evaluated based on historical peak demands and comparison to the criteria used in the previous reports. Peaking factors by class within each service level were calculated for each design year and adjusted slightly so that the sum of the demands by service level would match the total system demands. Design peaking factors by class and service level are summarized in Table I-20.

Table I-20 Design Peaking Factors by Class by Service Level												
	Residential Peaking Factors						ICI Peaking Factors					
	Maximum Day			Maximum Hour			Max Day			Max Hour		
Service Level	Base	2010	2025	Base	2010	2025	Base	2010	2025	Base	2010	2025
Central	2.50	2.50	2.40	3.50	3.50	3.40	2.00	1.90	1.90	2.80	2.80	2.50
West Hills	3.10	3.10	2.90	4.60	4.60	4.40	2.20	2.20	2.10	3.30	3.10	3.00
Kanwaka	-	3.20	3.00	-	4.60	4.50	-	2.30	2.10	-	3.20	3.10
South SL	-	-	3.00	-	-	4.40	-	-	2.20	-	-	3.10
South 1	-	-	3.10	-	-	4.50	-	-	2.20	-	-	3.10
South 2	-	-	3.10	-	-	4.50	-	-	2.20	-	-	3.10
Overall System Average	2.77	2.80	2.72	3.99	4.04	4.00	2.06	2.01	2.00	2.94	2.91	2.75

1. Unaccounted-for water peaking factor = 1.0 for all conditions and all design years.
2. KU peaking factor equal to ICI factor for all design years and conditions.
3. For all years, RWD peaking factor equal to 1.35 and 1.5 for maximum day and maximum hour, respectively.

Projected water requirements by service level are summarized in Table I-21.

Table I-21 Projected Water Requirements by Service Level			
Service Level	Average Day (mgd)	Maximum Day (mgd)	Maximum Hour (mgd)
Design Base Year (2000)			
Central	8.21	16.35	22.23
West Hills	4.29	11.19	16.49
Total	**12.50**	**27.50**	**38.70**
Design Year 2010			
Central	9.67	18.77	25.80
West Hills	5.26	13.86	20.32
Kanwaka	0.67	1.73	2.41
Total	**15.60**	**34.40**	**48.50**
Design Year 2025			
Central	9.04	18.67	25.61
West Hills	7.36	18.15	26.91
Kanwaka	1.31	3.32	4.87
South	4.21	7.78	10.07
South 1	0.34	0.93	1.33
South 2	0.26	0.73	1.04
Total	**22.50**	**49.60**	**69.80**

SECTION II – WATER SUPPLY

1.0 General

The City obtains its raw water supply from the Kansas River, Kansas River alluvium, and Clinton Reservoir. The Kansas River has long been a consistent source of raw water supply to the City. To ensure the future long-term water supply reliability of the river, the State of Kansas purchased water supply storage in Tuttle Creek, Milford, and Perry reservoirs from the federal government in the 1980's. The Kansas River Water Assurance District (KRWAD) was formed in 1989 to operate the reservoirs to ensure adequate raw water supply to its members. Lawrence participates in KRWAD and this will allow the City to rely on the Kansas River as a long-term raw water supply source.

The City also has six wells that tap the Kansas River alluvium near the Kaw Water Treatment Plant.

Clinton Reservoir is the other primary source of raw water supply. The City has signed two water marketing contracts with the State to allow diversion of water from the reservoir. The contracts allow the City to divert water for a period of 40 years from their effective date. When the contract period expires, the City has the first right to renegotiate the contracts.

2.0 Existing Water Rights

2.1 Surface Water

2.1.1 Kansas River

The City recently obtained approval for a new water right #44954 on the Kansas River. This water right allows an annual diversion of 8,152 million gallons (25,017.57 ac-ft/year). This is equal to an average day demand of 22.3 mgd. The maximum permitted diversion rate is 31,202 gpm, which is equal to 44.9 mgd. The permitted point of diversion is the existing intake on the Kansas River that supplies the Kaw WTP.

The City also has two other existing water rights permits to divert surface water from the Kansas River. Surface water rights are summarized in Table II-1.

Table II-1
Kansas River Surface Water Rights

Water Right Permit Number	Date of Permit	Status of Permit	Annual Quantity ac-ft	Annual Quantity mgd	Maximum Diversion Rate cfs	Maximum Diversion Rate mgd
DG002	02/07/55	Vested	1,712.56	1.53	10.25	6.62
2019	11/30/53	Appropriated	8,961.00	8.00	15.47	10.00
44954	01/18/02	Approved	25,017.57	22.30	69.52	44.90

The new water right includes a provision that limits the total water diverted under the existing surface water right, existing groundwater rights summarized later in this Chapter, and the new surface water right to the maximum annual volume of 8,152 million gallons (22.3 mgd) and the maximum diversion rate of 31,202 gpm (44.9 mgd).

2.1.2 Clinton Reservoir

The City has two contracts with the Kansas Water Office (KWO) which allow diversion of water from Clinton Reservoir. Contract 77-1 was signed December 29, 1977. The length of the contract is 40 years, so the City will need to renegotiate the contract by December 2017. Provisions in the contract allow the State to reduce the amount available to the City to "best provide for the health, safety, and general welfare of the people of this state as determined by the State" (1977 Contract). The Contract allows for the diversion of 3,650 million gallons per year (10 mgd) at a maximum diversion rate of 25 mgd.

On August 9, 1990, the City entered into Contract 90-5 with the State of Kansas for additional diversions from Clinton Reservoir. The contract allows for an annual diversion of 1,460 million gallons (4 mgd) at a maximum diversion rate of 25 mgd. The contract period is for 40 years beginning on January 1, 1991. The contract contains the following requirement:

> "The Purchaser is obligated to utilize 100 percent of the water supply under its contract number 77-1 before any use can be made of water under this contract."

According to staff correspondence, the total annual diversion allowed under contract 77-1 has been reduced to 3,468,957,286 gallons (9.5 mgd). Similarly, the total annual diversion allowed under contract 90-5 has been reduced to 1,287,481,489 gallons (3.52 mgd). Therefore, the total average annual yield of the reservoir is 13.02 mgd and the maximum diversion rate is 25 mgd.

It should be noted that the State is considering a further reduction in the available supply to the City due to a request made by the Tri-counties water districts. Their application is for 200 million gallons per year (0.55 mgd). Other users may also apply to divert water from Clinton Reservoir. The State has the right to consider the overall needs of the potential users of the reservoir and could reduce the supply available to Lawrence further. City staff is actively discussing the KWO's plans for Clinton Reservoir as the State's decisions have immediate impacts on the City's water supply system.

2.2 Groundwater Supplies

The City owns four groundwater rights permits to divert water from the Kansas River alluvium. Table II-2 summarizes the existing water rights.

Table II-2
Existing Groundwater Rights

Water Rights Permit Number	Permit Date	Source	Permit Status	Annual Quantity ac-ft	Annual Quantity, mgd	Maximum Diversion Rate cfs	Maximum Diversion Rate mgd
DG-001	02/03/99	Wells 3 and 4	Vested	774.00	0.69	1.78	1.15
2019-A	02/03/99	Well 7	Appropriated	652.00	0.58	1.34	0.87
9811	02/03/99	Well 5	Appropriated	307.00	0.27	0.82	0.53
26315	02/02/99	Well 6	Appropriated	443.65	0.39	0.71	0.46
26315	02/02/99	Well 8	Appropriated	414.72	0.37	0.75	0.48
Total	**2082.75[(1)]**				**1.86[(1)]**	**4.40**	**3.49**

[(1)] Water right number 26315 limits the annual quantity diverted from water rights DG001, 2019-A, 9811, and 26315 to 2082.75 ac-ft/yr.

2.3 Summary of Water Rights

The new water right (No. 44954) includes a provision that limits the total water diverted under the existing surface water right, existing groundwater rights, and the new surface water right to the maximum annual volume of 8,152 million gallons (22.3 mgd) and the maximum diversion rate of 31,202 gpm (44.9 mgd).

3.0 Existing Water Supply Infrastructure

3.1 Kaw Water Treatment Plant

Raw water supply to the Kaw WTP consists of surface water from the Kansas River and groundwater from the Kansas River alluvium. The surface water is withdrawn from the river with the use of a crib intake and siphon line that conveys the raw water to two pumping stations. The firm pumping capacity at Low Service Pumping Station (LSPS) No. 1 is approximately 4.0 mgd at 80 feet of total dynamic head (TDH), with an installed capacity of 6.7 mgd. The total capacity at LSPS No. 2 is approximately 25 mgd; while the firm capacity is 19.5 mgd. The following table summarizes the capacity of the pumping units installed in the Low Service Pumping Stations:

Table II-3
KAW WWTP Low Service Pumping Capacities

Low Service Pump Station No. 1		Low Service Pump Station No. 2	
Pump No.	Capacity, gpm/mgd at 80' TDH	Pump No.	Capacity, gpm/mgd at 60' TDH
1	1,900/2.7	1	3,000/4.3
2	1,400/2.0	2	3,000/4.3
3	1,400/2.0	3	3,800/5.5
		4	3,800/5.5
		5	3,750/5.4

At normal river levels with the Bowersock flap gates in their upright position, when all pumps at LSPS No. 2 are operating, the water level at LSPS No. 1 is drawn down such that when the pumps are turned on at LSPS No. 1, the trashwell is rapidly drained, and the pumps shut-off at their low water cut-off set point. In addition, the maximum raw water flow rate that can be attained with all pumps operating at LSPS No. 2 including all the vertical wells is approximately 16.5 mgd. This is approximately 8.5 mgd below the total rated capacity of LSPS No. 2, and does not include the contribution of the vertical wells.

The primary raw water route through the intake system is from the river intake, through the 30-inch siphon to LSPS No. 2. Hydraulic analysis of this route indicates that at the design low river elevation of EL 807.5, and low wetwell elevation in LSPS No. 2 of El. 802 is between 13 and 14 mgd. At these levels, the hydraulic gradient at the tee that connects the 30 inch siphon to LSPS No. 1 is approximately at the same elevation as the bottom of the down-turned elbow for the 24-inch supply pipe in the trash well. Therefore, sufficient head is not available to transfer flow to LSPS No. 1. Subsequently, there is insufficient head to transfer flow through the 24” siphon from LSPS No. 1 to LSPS No. 2. Therefore, the 30-inch siphon is conveying all flow to LSPS No. 2, and the 24-inch interconnecting siphon between the trashwell at LSPS No. 1 and LSPS No. 2 is not contributing any flow.

The current capacity of the vertical well system is approximately 1.5 to 2.0 mgd, depending on the condition of the wells. Only six of the eight wells are currently operable.

Raw water is conveyed from LSPS No. 2 to the plant influent at the treatment plant site by a 24-inch raw transmission main.

3.2 Clinton Water Treatment Plant

The Clinton Reservoir Raw Water Pumping Station, which was constructed as a portion of the reservoir by the Army Corps of Engineers, currently contains two 5.0 mgd pumps and two 10.0 mgd horizontal double suction pumps which provide a firm pumping capacity of 20.0 mgd and a total installed capacity of 30.0 mgd. The following table summarizes the pumping units installed:

Table II-4
Clinton WTP Raw Water Pumps

Pump No.	Capacity mgd	Rated head ft	Horsepower hp	Drive
1	4.6	137	150	Adjustable
2	4.6	137	150	Constant
3	10.2	137	300	Constant
4	10.2	137	300	Adjustable

The pumps discharge to a 36-inch raw water supply pipeline which conveys the raw water to the Clinton WTP.

4.0 Kansas River Water Assurance District

The Kansas River Water Assurance District (KRWAD) was created in December 1989 to clearly define water management along the Kansas River. The objective of the KRWAD is to assure that each of its members has adequate supply to meet current water rights and to plan for future projected water rights for long-term needs.

Every five years the KWO, the Division of Water Resources, and the members of KRWAD update an operations agreement defining the rules for making releases from Milford, Tuttle Creek, and Perry reservoirs to meet member demands. The operations agreement is currently being updated. The most recent version is titled draft August 19, 2002, but includes the status as of September 30, 2002. The remainder of this section is based on this most recent version of the operation's agreement.

Within the agreement, each member provides records of current use and estimates of projected use in 2020. The current use of members is approximately 95 mgd and the projected use is approximately 194 mgd. It should be noted that the City's projected demand for year 2020 is 12,546 ac-ft/year (11.2 mgd). This is much lower than permitted in the recently approved water right for the Kansas River.

The operations agreement also provides estimates of the reliable yield of current KRWAD controlled storage as well as projections for the future yield once the sediment allocations are filled. The following table summarizes the yield estimates.

Table II-5
Assurance District Yield

Reservoir	Current Yield	Yield after Sediment Allocation is Filled mgd
Milford	25	20
Tuttle Creek	216	89
Perry	18	13
Totals	**259**	**122**

The table indicates that current KRWAD storage is adequate to meet current demands, but as sediment allocations fill and demands increase KRWAD may need additional storage to meet member demands. This indicates that it is critical to periodically update the estimated rate and volume of sedimentation in the reservoirs.

Three pools of water within the reservoirs are available for purchase by KRWAD. The set-aside pool is included in the operation's agreement and KRWAD has first right to this water. If the set-aside storage is not purchased by KRWAD by December 31, 2020, the State then has sole discretion on its use. The table below summarizes the yield of the available set aside storage.

Table II-6
Set-Aside Storage Yield, mgd

Reservoir	Current Yield Mgd	Yield after Sediment Allocation is Filled Mgd
Milford	27	22
Tuttle Creek	0	0
Perry	11	8
Totals	**38**	**30**

Assuming sediment allocations are filled, the total available yield is 152 mgd, when the set-aside storage is combined with the current storage yield. The table below summarizes the yield from future use or uncommitted storage that is also available. Because KRWAD membership includes all of the major water users in the Kansas River basin, this water should be available for use by KRWAD, even though it is presently uncommitted.

Table II-7
Future Use or Uncommitted Storage Yield, mgd

Reservoir	Current Yield	Yield after Sediment Allocation is Filled
Milford	63	51
Tuttle Creek	46	19
Perry	79	58
Totals	**188**	**128**

This table indicates that the yield of future use or uncommitted storage is adequate to meet projected member demands beyond year 2020 when combined with the yield from existing and set-aside storage even after sediment allocations have filled. Marketing storage that is available would add another 17 mgd of yield to the system after sediment allocations have filled, if purchased by KRWAD. It will be important for the City to work with the KRWAD board to ensure that the future use or uncommitted storage is available to KRWAD as demands grow and sediment allocations fill.

Based on the current operations agreement, the Kansas River should be a reliable source of water supply for the City for the foreseeable future.

SECTION III– WATER TREATMENT

1.0 Existing Water Treatment Facilities

The City of Lawrence is served by two water treatment facilities, Clinton and Kaw. The Clinton WTP is located along Wakarusa Drive north of Clinton Parkway, and the Kaw treatment facility is at the intersection of 3rd and Indiana.

1.1 Kaw Water Treatment Plant

The Kaw Water Treatment Facility was originally constructed in 1917 and has been expanded throughout the years to its current treatment capacity of 17.5 mgd. The Kaw WTP is bounded by residential development on the south, east, and west sides which will make future expansions difficult. The site is also within 500 feet of a historical landmark and any work on the site requires review by the Historical Society to ensure the landmark is protected.

As outlined in the Water Supply Section, the source of supply for the Kaw WTP is the Kansas River. Two lift stations, LSPS No. 1, which contains 3 pumps, and LSPS No. 2 which contains 5 pumps, convey raw water from a single intake in the Kansas River to the plant site through a 24 inch pipeline. Normal river water levels limit the supply capacity to approximately 16.5 mgd due to pump submergence conditions despite having excess treatment capacity.

The first step in the treatment process is at the presedimentation basin where polymer is dosed to aid in particle removal. Powdered Activated Carbon (PAC) is added to the presettling basins influent for taste and odor control. The flow is then split into parallel trains of primary settling, rapid mix, and secondary settling basins. The flow combines immediately following the secondary settling basin where ammonia, soda ash, phosphate, fluoride, and chlorine are dosed. Eight dual media gravity filters further polish the water. Two clearwells are located on-site with a total capacity of 748,000 gallons. Four filters have a clearwell located directly underneath with a combined capacity of 174,000 gallons. Clearwell 2E was placed into service in 1954 and has a volume of 574,000. Treated water is conveyed to the distribution system by use of the high service pumps which are discussed in Section IV of this report.

1.2 Clinton Water Treatment Plant

The Clinton Water Treatment Plant has recently been expanded to a 15 mgd facility.

Raw water is pumped from the Clinton Reservoir by two five mgd and two ten mgd pumps into a single 36 inch raw water pipeline. Powdered activated carbon is added to the raw water prior to flow splitting for taste and odor control. In the future, the existing flow splitter will divide the flow into two process trains, but currently, only one treatment train exists. The raw water first begins treatment at the rapid mix basin followed by presedimenation and primary settling. Lime and polymer are dosed at the primary settling basin. A second rapid mix and settling basin further aid in removal of suspended solids. Polymer and chlorine are added at the secondary settling basins. On the secondary basin effluent, fluoride, chlorine, and ammonia are dosed. Eight dual medial filters further remove remaining suspended solids particles. Two sets of three 1.5 mgd transfer pumps convey the water form the clearwell located beneath the filters and transfer it to the two 1.5 MGal on-site, above grade steel reservoirs. Phosphate is added to the transfer pump effluent prior to the reservoirs as a corrosion inhibitor in the distribution system. A wash water recovery basin is also present on-site to store the filter backwash water. The wash water is transferred from the basin by two 500 gpm submersible pumps to the head of the plant. Treated water is conveyed to the distribution system as outlined in Section IV of this report.

2.0 SDWA Evaluation

This section presents an assessment of the City's ability to comply with current, impending, and potential future water quality and treatment regulations. A detailed discussion of current and impending regulations under the 1986 and 1996 Amendments to the Safe Drinking Water Act (SDWA) is presented in Appendix C. Aspects of these regulations that may affect current treatment practices are discussed below. It is emphasized that the United States Environmental Protection Agency (EPA) is continuously modifying and revising many of these regulations in response to public and water industry comments and results of new research regarding the potential adverse impacts of the compounds to be regulated. The discussion that follows reflects the present position of EPA on various water quality and treatment issues. Major changes to this position prior to final promulgation of the regulations may require revision of the conclusions and opinions presented in this report.

2.1 Current Regulations

2.1.1 General

As discussed in the paragraphs that follow, the existing treatment facilities consistently comply with all current state and federal water quality and treatment requirements. Filtered water turbidity complies with the 0.5 NTU maximum level under the current Surface Water Treatment Rule. Samples routinely collected from within the distribution system for bacteriological analysis are consistently negative with respect to presence of coliform organisms. Fluoride concentrations in the distribution system are well below the current MCL of 4.0 mg/L and the secondary MCL of 2.0 mg/L.

The City is in compliance with all aspects of the Lead and Copper Rule. Lead and copper concentrations at consumer taps were below the EPA-specified Action Levels (0.015 mg/L for lead, 1.3 mg/L for copper) during the initial round of monitoring and subsequent follow-up monitoring. The treated water also complies with the Phase II and Phase V Synthetic Organic Contaminant / Inorganic Contaminant Regulations.

Prior to initiating a detailed review of regulatory compliance issues, operating records for January through December 2001 were reviewed to assess typical source water and treated water quality and plant operating characteristics; a summary of this data is presented in Tables III-1 and III-2.

Table III-1
Water Quality Monitoring Data Summary
(January 2001 – December 2001)

Constituent	Kaw River WTP		Clinton WTP	
	Average	Range[(1)]	Average	Range[(1)]
Turbidity, NTU				
Raw Water	213	5 – 3234	14.8	4.4 – 82.7
Finished Water	0.09	0.05 – 0.21	0.06	0.05 – 0.13
PH, units				
Raw Water	8.22	7.48 – 8.86	8.38	7.80 – 8.70
Finished Water	9.01	7.90 – 9.28	8.51	8.00 – 9.10
Total Hardness, mg/L as $CaCO_3$				
Raw Water	227	128 – 354	135	112 – 158
Finished Water	116	73 – 171	109	84 – 144
Total Alkalinity, mg/L as $CaCO_3$				
Raw Water	171	103 – 274	120	102 – 139
Finished Water	53	44 – 109	90	52 – 121
Temperature, degrees C				
Raw Water	15.7	2.0 – 30.9	15.7	2.2 - 30.0
Chloramine Residual, mg/L				
Finished Water	3.45	3.13 – 3.94	3.58	3.10 – 4.00

(1)From "Monthly Reports" for Kaw River & Clinton WTPs: values may not reflect "instantaneous" minimum/maximum conditions.

Table III-2
Plant Production, Chemical Feed Data
(January 2001 – December 2001)

Constituent	Kaw River WTP		Clinton WTP	
	Average	Range	Average	Range
Raw Water Treated, mgd	6.723	3.228 – 12.356	6.843	0.897 – 12.434
Finished Water Pumped, mgd	6.339	2.710 – 11.959	6.137	0.731 – 10.825
Chemicals Fed, mg/L[(1)]				
Lime	165	80 – 265	22.5	12.9 – 34.8
Chlorine	6.8	2.7 – 16.0	5.47	2.94 – 9.65
Carbon Dioxide	25.7	8.0 – 68.9	-	-
Alum	13.4	7.3 – 34.9	-	-
Polymer	2.72	1.64 – 5.85	7.15	4.00 – 12.63
Powdered Activated Carbon	6.7	2.7 – 13.9	13.0	4.7 – 30.8
Ammonia	1.54	0.99 – 3.74	1.52	0.66 – 1.95
Fluoride	0.97	0.33 – 1.52	0.82	0.15 – 1.54
Sodium Hexametaphosphate	-	-	0.98	0.43 – 1.66
Zinc Orthophosphate	1.17[(2)]	0.70 – 1.50	-	-
AquaMag	1.88[(3)]	0.12 – 3.03	-	-
Potassium Permanganate	0.81[(4)]	0.26 – 0.99	-	-

(1)Dosage based on daily chemical consumption and raw water treated.
(2)Zinc orthophosphate fed 65 days during 2001.
(3)AquaMag fed 220 days during 2001.
(4)Permanganate fed 7 days during 2001.

2.2 Surface Water Treatment Rule

2.2.1 Turbidity

Finished water turbidities for January through December 2001 (as reported to the Kansas Department of Health and Environment (KDHE) for Surface Water Treatment Rule compliance purposes, based on monitoring of the filtered water at the plant lab tap every 2 hours) are summarized in Table III-3. As the turbidity of the finished water during the period evaluated did not exceed 0.5 NTU in more than 5 percent of the total monthly samples, the City was in full compliance with the turbidity requirements of the SWTR. (Monitoring data indicate that the filtered water turbidity did not exceed 0.5 NTU at any time during the period evaluated.)

Table III-3
Treated Water Turbidity

Month / Year	Turbidity, NTU[1]			
	Kaw River WTP		Clinton WTP	
	Average	Max. Single Sample[2]	Average	Max. Single Sample[2]
January 2001	0.08	0.29	0.07	0.14
February 2000	0.10	0.29	0.06	0.08
March 2000	0.12	0.24	0.06	0.09
April 2001	0.10	0.19	0.06	0.09
May 2001	0.09	0.14	0.07	0.14
June 2001	0.09	0.25	0.07	0.14
July 2001	0.10	0.32	0.07	0.09
August 2001	0.10	0.30	0.06	0.08
September 2001	0.10	0.19	0.06	0.08
October 2001	0.09	0.18	0.06	0.08
November 2001	0.08	0.17	0.06	0.08
December 2001	0.07	0.15	0.06	0.12

(1)Combined treated water from all filters.
(2)Based on samples collected at 2-hour intervals.

2.2.2 Disinfection

Current disinfection practice consists of maintaining a free chlorine residual across the secondary softening basins, and a chloramine residual across the filters and treated water storage facilities. (A free chlorine residual of 1 to 2 mg/L is typically maintained at the secondary softening basin discharge at the Kaw River plant, and a 0.5 to 0.8 mg/L free chlorine residual is typically maintained at the Clinton plant secondary basin discharge.)

The City complies with the KDHE requirement that a minimum combined chlorine residual of 1.0 mg/L be maintained within the distribution system, and also the SWTR requirement that a detectable chlorine residual be maintained in at least 95 percent of the monthly distribution system samples. For the period of January through December 2001, the minimum monthly chloramine residual at the plant discharge was 1.3 mg/L at the Kaw River plant, and 2.7 mg/L at the Clinton plant, as shown in Table III-4. During this same period, chlorine was detectable in the distribution system in 100 percent of the samples collected.

Table III-4
Minimum Chloramine Residuals at Plant Discharge(1)

Month / Year	Minimum Residual, mg/L	
	Kaw River WTP	Clinton WTP
January 2001	2.5	3.3
February 2001	2.8	3.0
March 2001	1.8	3.3
April 2001	1.7	3.1
May 2001	1.9	2.6
June 2001	1.3(2)	2.8
July 2001	2.2	3.25
August 2001	2.6	3.1
September 2001	2.5	3.05
October 2001	1.5	2.7
November 2001	1.6	3.3
December 2001	2.5	3.3

(1)As reported to KDHE for SWTR compliance monitoring.
(2)Attributable to ammonia feed problems.

The City meets the disinfection CT requirements for *Giardia* and viruses through a combination of free chlorine and chloramine contact time, in accordance with current KDHE requirements. Disinfection CT data for *Giardia* cysts, as reported to KDHE for the period of January through December 2001 are summarized in Table III-5. This information indicates that the City complied with the minimum CT requirements for each day of the period evaluated. Therefore, the City is in compliance with current SWTR disinfection CT requirements for both *Giardia* and viruses, and typically maintains conditions which provide inactivation levels well in excess of current minimum requirements. (When free chlorine is used as the primary disinfectant, compliance with *Giardia* inactivation requirements also results in compliance with inactivation requirements for enteric viruses.)

Table III-5
Disinfection CT Ratios for *Giardia* Cysts

Month / Year	CT Ratios Provided[1]			
	Kaw River WTP		Clinton WTP	
	Average	Range	Average	Range
January 2001	2.37	1.10 – 4.10	2.35	1.44 – 3.40
February 2001	2.36	1.75 – 3.11	2.22	1.40 – 3.18
March 2001	3.34	2.00 – 4.77	2.46	1.18 – 3.63
April 2001	4.62	2.21 – 6.57	3.61	2.02 – 6.04
May 2001	6.23	4.09 – 9.35	6.38	2.91 – 16.83
June 2001	7.40	4.25 – 10.78	6.10	2.45 – 10.90
July 2001	8.49	4.43 – 14.73	5.58	2.76 – 13.14
August 2001	7.78	3.60 – 12.78	6.33	3.01 – 9.79
September 2001	5.20	2.56 – 8.76	4.80	1.94 – 6.66
October 2001	3.76	2.58 – 5.48	3.68	2.56 – 5.94
November 2001	2.99	1.80 – 4.62	3.85	1.96 – 7.00
December 2001	2.76	1.63 – 4.20	3.18	2.04 – 5.31

[1]Ratio of CT provided to CT required; values greater than or equal to 1.0 indicate compliance with SWTR disinfection requirements for *Giardia* inactivation.

2.3 Coliform Rule

Under the revised Coliform Rule promulgated in 1989, the City currently collects 90 distribution system samples per month for analysis of total coliforms, and a maximum of 5 percent of these samples may exhibit the presence of total coliform organisms. Water Department staff report that during 2000 and 2001, all distribution system coliform samples were negative with respect to presence of coliform. These data indicate that the City is in full compliance with the Coliform Rule requirements.

2.4 Lead and Copper Rule

Lead and copper monitoring results for the City's distribution system are summarized in Table III-6. Both lead and copper concentrations at consumer taps have consistently been below the EPA "Action Levels" of 0.015 mg/L and 1.3 mg/L, respectively. Based on this performance, the City has been placed on reduced monitoring status, and must now monitor lead and copper concentrations at consumer taps every three years. (The City's next monitoring period will be 2002.)

Table III-6 Lead and Copper Monitoring Results			
Monitoring Period	90th Percentile Lead Conc. (mg/L)	90th Percentile Copper Conc. (mg/L)	Number of Samples
1992	0.014	0.157	105
1997	0.0076	0.219	60
1998	0.0051	0.186	30
1999	0.0045	0.093	30

2.5 Stage 1 Disinfection By-Products Rule

Stage 1 of the Disinfection By-Products Rule (DBPR) was finalized during late November 1998, and became effective on January 1, 2002 for systems serving 10,000 or more consumers. An assessment of the City's ability to comply with the new DBPR requirements is presented below.

2.5.1 Compliance with Revised MCLs

TTHM and HAA5 monitoring results for the City's distribution system for 1999 through 2001 are summarized in Tables III-7 and III-8, respectively, and summaries of TTHM and HAA5 concentrations for portions of the system served by the Kaw River and Clinton WTPs are presented in Tables III-9 and III-10, respectively. Review of this historical DBP monitoring data suggests that compliance with the revised TTHM MCL of 0.080 mg/L and the new HAA5 MCL of 0.060 mg/L should not present any difficulties. (The maximum 4-quarter running annual average TTHM concentration during the period evaluated was 0.0596 mg/L, which is well below the revised MCL. Likewise, the maximum 4-quarter running annual average HAA5 concentration during this period was 0.0373 mg/L, which is well below the new 0.060 mg/L MCL.)

Table III-7
Total Trihalomethane Concentrations for Lawrence Distribution System

Month / Year	Total Trihalomethanes Concentration, mg/L		
	Average	Range[1]	4-Quarter Average[2]
February 1999	0.0416	0.0201 – 0.0596	-
May 1999	0.0708	0.0416 – 0.0848	-
August 1999	0.0612	0.0469 – 0.0692	-
October 1999	0.0336	0.0266 – 0.0403	0.0518
February 2000	0.0318	0.0251 – 0.0383	0.0493
May 2000	0.0456	0.0391 – 0.0541	0.0430
August 2000	0.0628	0.0567 – 0.0729	0.0434
October 2000	0.0402	0.0379 – 0.0423	0.0451
February 2001	0.0313	0.0282 – 0.0376	0.0450
April 2001	0.0621	0.0497 – 0.0747	0.0491
August 2001	0.0953	0.0808 – 0.1080	0.0572
October 2001	0.0497	0.0347 – 0.0640	0.0596

(1) 8 samples collected per monitoring period.
(2) Four-quarter running annual average values.

Table III-8
Haloacetic Acid Concentrations for Lawrence Distribution System

Month / Year	HAA5 Concentration, mg/L		
	Average	Range[1]	4-Quarter Average[2]
February 1999	0.0235	0.0070 – 0.0330	-
May 1999	0.0548	0.0250 – 0.0760	-
August 1999	0.0255	0.0150 – 0.0400	-
October 1999	0.0220	0.0140 – 0.0320	0.0314
February 2000	0.0255	0.0180 – 0.0360	0.0319
May 2000	0.0431	0.0240 – 0.0670	0.0290
August 2000	0.0281	0.0240 – 0.0340	0.0297
October 2000	0.0336	0.0240 – 0.0400	0.0326
February 2001	0.0254	0.0210 – 0.0300	0.0326
April 2001	0.0396	0.0200 – 0.0550	0.0317
August 2001	0.0504	0.0450 – 0.0590	0.0373
October 2001	0.0290	0.0160 – 0.0450	0.0361

(1) 8 samples collected per monitoring period.
(2) Four-quarter running annual average values.

Table III-9
Total Trihalomethane Concentrations vs. Distribution System Served

Month / Year	TTHM Concentration, mg/L			
	4-Sample Average		Maximum Concentration[1]	
	Kaw System	Clinton System	Kaw System	Clinton System
February 1999	0.0289	0.0542	0.0436	0.0596
May 1999	0.0578	0.0839	0.0744	0.0848
August 1999	0.0655	0.0569	0.0692	0.0664
October 1999	0.0327	0.0345	0.0362	0.0393
February 2000	0.0318	0.0319	0.0379	0.0383
May 2000	0.0424	0.0488	0.0481	0.0541
August 2000	0.0649	0.0606	0.0729	0.0644
October 2000	0.0400	0.0404	0.0406	0.0423
February 2001	0.0308	0.0318	0.0336	0.0376
April 2001	0.0612	0.0630	0.0697	0.0747
August 2001	0.0942	0.0965	0.1070	0.1080
October 2001	0.0496	0.0498	0.0640	0.0639

[1]Maximum single-sample concentration

Table III-10
Total HAA5 Concentrations vs. Distribution System Served

Month / Year	HAA5 Concentration, mg/L			
	4-Sample Average		Maximum Concentration[1]	
	Kaw System	Clinton System	Kaw System	Clinton System
February 1999	0.0175	0.0295	0.0220	0.0330
May 1999	0.0405	0.0690	0.0590	0.0760
August 1999	0.0278	0.0233	0.0390	0.0400
October 1999	0.0195	0.0245	0.0270	0.0320
February 2000	0.0270	0.0240	0.0360	0.0300
May 2000	0.0258	0.0605	0.0290	0.0670
August 2000	0.0255	0.0308	0.0270	0.0340
October 2000	0.0323	0.0350	0.0400	0.0400
February 2001	0.0263	0.0245	0.0300	0.0280
April 2001	0.0393	0.0400	0.0490	0.0550
August 2001	0.0530	0.0478	0.0590	0.0530
October 2001	0.0285	0.0295	0.0350	0.0450

[1]Maximum single-sample concentration

2.5.2 Compliance with Maximum Residual Disinfectant Levels

Reported combined chlorine residuals in the finished water entering the distribution system are typically below the impending Maximum Residual Disinfectant Level (MRDL) of 4.0 mg/L, and therefore the City should not anticipate any difficulties in complying with this new requirement.

2.5.3 Compliance with Enhanced Softening Requirements

As discussed in Appendix C, under the Stage 1 DBPR, most systems with average source water total organic carbon (TOC) concentrations exceeding 2.0 mg/L will be required to operate in an "enhanced coagulation / enhanced softening" mode to achieve specified removals of TOC. The City has monitored source water and finished water TOC concentrations at their water treatment facilities monthly since early 1996. A summary of TOC removal performance for each treatment facility is presented below.

2.5.3.1 Kaw River Water Treatment Plant.

Reported monthly source water TOC between January 1996 and November 2001 averaged 5.2 mg/L and ranged from 2.6 to 11.0 mg/L. The TOC concentration in the treated water during this period averaged 2.5 mg/L and ranged from 0.5 to 5.6 mg/L. Average TOC removal during this period was approximately 51 percent, which exceeds the required Step 1 TOC removal percentage by a significant margin. (Systems practicing lime softening treatment will be required to achieve monthly TOC removals ranging from 15 percent to 30 percent.) The 12-month running annual average TOC removal ratio (i.e., the ratio of the TOC removal percentage achieved to the minimum TOC removal percentage required) during this period ranged from 1.71 to 4.72. (Values of 1.0 or greater indicate compliance with the Stage 1 DBPR enhanced coagulation/enhanced softening requirements.) Therefore, compliance with the new enhanced softening requirements at the Kaw River WTP should not present any significant difficulties.

The Stage 1 DBPR also includes provisions under which a system that cannot meet the specified TOC removals can be granted an exemption from the TOC removal requirements if it can demonstrate that it meets any of the eight alternative compliance criteria discussed in Appendix C. Two of the eight alternative compliance criteria apply specifically to systems practicing lime softening:

- Softening that results in removal of at least 10 mg/L of magnesium hardness (as $CaCO_3$), measured monthly and calculated quarterly as a running annual average.
- Softening that results in a reduction in the alkalinity of the treated water to less than 60 mg/L (as $CaCO_3$), measured monthly and calculated quarterly as a running annual average.

Quarterly treated water quality monitoring data for September 1999 through October 2001 indicate that magnesium hardness removal consistently exceeds 10 mg/L by a significant margin, while the alkalinity of the treated water is typically less than 60 mg/L. (As shown in Table III-1, the alkalinity of the treated water during 2001 averaged 53 mg/L.) This information suggests that the Kaw River WTP would have no difficulty in complying with either of the alternative performance criteria for lime softening facilities, should actual TOC removals be less than minimum specified levels. (Collection and reporting of monthly source water and filtered water TOC concentrations and source water alkalinity levels will still be required, however, under the Stage 1 DBPR regardless of the compliance basis utilized.)

2.5.3.2 Clinton Water Treatment Plant.

Reported monthly source water TOC between January 1996 and November 2001 averaged 4.3 mg/L and ranged from 0.5 to 10.0 mg/L. The TOC concentration in the treated water during this period averaged 3.1 mg/L and ranged from 0.5 to 7.2 mg/L. Average TOC removal during this period was approximately 29 percent. The 12-month running annual average TOC removal ratio (i.e., the ratio of the TOC removal percentage achieved to the minimum TOC removal percentage required) during this period ranged from 1.04 to 3.16. (Values of 1.0 or greater indicate compliance with the Stage 1 DBPR enhanced coagulation/enhanced softening requirements.) Therefore, compliance with the new enhanced softening requirements at the Clinton WTP would have been achieved, had the Stage 1 DBPR TOC removal requirements been in effect during this period. (TOC removals for 2000 and 2001 are summarized in Table III-11.) However, while annual average TOC removal ratios over the past 3 years have ranged from 1.25 to 3.16, the ratio has declined somewhat over the past year. While the plant currently complies with the new TOC removal requirements, future operational modifications could be required to ensure continued compliance. This would most likely involve expanded use of metal-salt coagulants (alum or ferric chloride/ferric sulfate) to remove additional TOC. Applicability of several alternative compliance criteria is discussed below.

Table III-11
TOC Removal for Clinton WTP (2000 – 2001)

Month	TOC, mg/L		TOC Removal %		TOC Removal Ratio	
	Raw	Treated	Achieved	Required	Monthly	12-Month[(1)]
Jan. 2000	3.8	2.6	31.6	15	2.11	-
Feb. 2000	4.2	2.7	35.7	25	1.43	-
Mar 2000	4.4	2.4	45.5	25	1.82	-
Apr 2000	3.2	2.2	31.3	15	2.08	-
May 2000	3.2	2.6	18.8	15	1.25	-
Jun 2000	3.4	2.3	32.4	15	2.16	-
Jul 2000	3.3	2.4	27.3	15	1.82	-
Aug 2000	3.6	2.3	27.8	15	1.85	-
Sep 2000	3.6	3.0	16.7	15	1.11	-
Oct 2000	3.1	2.4	22.6	15	1.51	-
Nov 2000	3.3	2.6	21.2	15	1.41	-
Dec 2000	3.5	3.1	11.4	15	0.76	1.61
Jan 2001	4.6	3.8	17.4	25	0.70	1.49
Feb 2001	4.2	3.1	26.2	25	1.05	1.46
Mar 2001	4.2	3.0	28.6	25	1.14	1.40
Apr 2001	4.2	3.4	19.0	25	0.76	1.29
May 2001	4.2	3.0	28.6	25	1.14	1.28
Jun 2001	3.5	2.6	25.7	15	1.71	1.25
Jul 2001	4.0	2.6	35.0	15	2.33	1.29
Aug 2001	3.9	2.8	28.2	15	1.88	1.29
Sep 2001	3.8	2.9	23.7	15	1.58	1.33
Oct 2001	3.7	3.2	13.5	15	0.90	1.28
Nov 2001	2.7	2.1	22.2	15	1.48	1.29

[(1)]Values $\geq$ 1.0 indicate compliance with enhanced softening requirement.

Current plant operating practices do not result in any significant removal of magnesium hardness. (As the magnesium hardness of the Clinton Reservoir supply is relatively low, excess-lime treatment at high pH to remove magnesium hardness is not required to achieve treated water total hardness goals.) Treatment modifications to increase magnesium hardness removal are considered neither cost-effective nor practical from a treated water quality perspective. Plant operating data for 2001 also indicate that the alkalinity of the treated water is typically much greater than 60 mg/L. (Treated water alkalinity averaged 90 mg/L during 2001.) Therefore, the Clinton WTP could not readily comply with either of the two softening-related alternative compliance criteria discussed above for the Kaw River WTP, should actual TOC removals be less than minimum specified levels.

As discussed in Appendix C, another potential alternative compliance criteria would be source water specific UV absorbance (SUVA, defined as the ratio of the water's ultraviolet absorbance at 254 nm (UV_{254}) to its dissolved organic carbon (DOC) concentration). If the source water SUVA value prior to any treatment is less than or equal to 2.0 L/mg-m, calculated quarterly as a running annual average of monthly monitoring data, the system would not be required to comply with the enhanced softening/TOC removal requirements. Reported source water specific UV absorbance (SUVA) values for the Clinton plant are summarized in Table III-12. As SUVA values for the source water from Clinton Reservoir are generally greater than 2.0 L/mg-m, this alternative compliance approach could not typically be utilized to achieve compliance with the Stage 1 enhanced coagulation requirements. However, should the TOC removal ratio for any month be less than 1.0, and the corresponding SUVA value be less than 2.0, the City can utilize the SUVA value as the compliance basis. A TOC removal ratio of 1.0 would then be reported for that month and utilized in the computation of the running annual average TOC removal ratio. (This approach is allowed under the federal Stage 1 DBPR regulation, and has been adopted by KDHE.)

Table III-12
Source Water SUVA Values for Clinton Water Treatment Plant

Date	Specific UV Absorbance, L/mg-m
January 8, 2001	2.0
February 5, 2001	1.8
March 12, 2001	2.0
April 9, 2001	2.4
May 9, 2001	2.6
June 13, 2001	2.7
July 11, 2001	3.2
August 8, 2001	2.4
September 12, 2001	2.0
October 3, 2001	2.9
November 8, 2001	2.7
2001 Average	2.4

2.6 Interim Enhanced Surface Water Treatment Rule

The Interim Enhanced Surface Water Treatment Rule (IESWTR) was finalized during late November 1998, and became effective on January 1, 2002 for systems serving 10,000 or more consumers. An assessment of the City's ability to comply with the new IESWTR requirements is presented below.

2.6.1 Compliance with Revised Turbidity Requirements

The City currently complies with the requirement that filtered water turbidity be monitored continuously for individual filters, and provisions for monitoring of turbidity for individual filters at 15 minute intervals and storage of the resulting data for a minimum of three years are in place.

As discussed in Appendix C, under the IESWTR, the turbidity of the combined filter effluent must be less than or equal to 0.3 NTU for a minimum of 95 percent of the monthly samples, and combined filtered turbidity cannot exceed 1.0 NTU at any time. Plant performance data for January through December 2001 suggest that difficulties in complying with the more restrictive 0.3 NTU requirement under the impending IESWTR should not be anticipated.

2.6.2 Compliance with *Cryptosporidium* Removal Requirements

The IESWTR states that systems that comply with the revised 0.3 NTU filtered water turbidity requirement are automatically assumed to be achieving the required 2-log removal of *Cryptosporidium*. As difficulties in complying with the revised 0.3 NTU requirement are not anticipated, the City should be granted the full 2-log *Cryptosporidium* removal credit under the IESWTR.

2.6.3 Compliance with Disinfection Benchmarking Requirements

As recent running annual average TTHM and HAA5 concentrations have not exceeded 80 percent of the Stage 1 DBPR MCLs of 0.080 mg/L and 0.060 mg/L, respectively, the City was not required to develop and submit a disinfection profile for *Giardia*. However, if future "significant changes" in disinfection practices are required, and if these plans include use of ozone for primary disinfection, preparation of a disinfection profile and determination of a disinfection "benchmark" for both *Giardia* and viruses will likely be required by KDHE. The City would then need to confer with KDHE to determine specific disinfection profile and disinfection benchmark development and submittal requirements. (Note: As discussed in Section 2.2 below, under Stage 2 of the Long-Term Enhanced Surface Water Treatment Rule, the City will likely be required to prepare *Giardia* and virus inactivation profiles, if this regulation is promulgated as currently recommended.)

2.7 Consumer Confidence Reports Rule

The City complied with the October 1999 deadline for publication of the first annual Consumer Confidence Report for their system, and indicates that continued compliance with this regulation should not present significant difficulties.

2.8 Arsenic

Quarterly treated water monitoring data for September 1999 through October 2001 (10 total monitoring periods) indicate that arsenic was not present in any of the samples at detectable levels (indicated detection level was 0.010 mg/L). These data suggest that the City should not anticipate difficulties in complying with the recently promulgated arsenic MCL of 0.010 mg/L.

2.9 Radionuclides

During December 2000, EPA promulgated a final rule for the radionuclides identified for regulation in a 1991 proposed rule (radium, alpha, beta, and photon emitters, and uranium). This regulation establishes a new MCL for uranium of 30 ug/L, but maintains MCLs for the remaining radionuclides at current levels. Radionuclides normally present problems for utilities that treat groundwater from deep wells or that utilize surface water supplies located downstream from an industrial source of radiation. As neither of these conditions currently exist for the source water utilized by the Kaw River and Clinton treatment facilites, it is not anticipated that these regulations will have any impact on current water treatment practices. (It is also emphasized that experience at other similar utilities has demonstrated that the high-pH lime softening treatment process employed by the City at the Kaw River plant would effectively remove the regulated radionuclides, should they be present in the source water.)

2.10 Phase II, Phase V Contaminants

The Phase II and Phase V Rules include MCLs or treatment techniques for a total of 45 synthetic organic chemicals (SOCs) and 14 inorganic chemicals (IOCs). Review of quarterly monitoring data for September 1999 through October 2001 (10 total monitoring periods) for the treated water produced by the Kaw River and Clinton treatment facilities indicate that none of these contaminants were present at levels approaching their respective MCLs. (In most cases, essentially all of SOCs, with the occasional exception of atrazine, were not present at detectable levels).

2.11 Filter Backwash Recycling Rule

Spent filter backwash currently discharges from the Kaw River WTP directly to the Kaw River, and from the Clinton WTP to offsite lagoons; no internal recycle of filter backwash or lagoon decant flows currently occurs. Therefore, provisions of the Filter Backwash Recycling Rule will not apply, and this rule will have no impact on current treatment practices.

2.12 Kansas Dept. of Health & Environment Requirements

The Safe Drinking Water Act allows some flexibility for states to develop their own regulations, and they are allowed to set standards that are more stringent than the federal regulations. In addition to the federal regulations, Kansas public water utilities are responsible for the following:

- If fluoridation is practiced, the fluoride concentration in the treated water must be maintained at less than the current Secondary Maximum Contaminant Level (SMCL) of 2.0 mg/L.
- All surface waters must receive pretreatment, including clarification (federal regulations allow use of direct filtration).
- Equalization must be provided for recycled process water to avoid disrupting coagulation and flocculation processes.
- Disinfection adequacy is to be determined using published CT criteria.
- When combined chlorine is used for residual maintenance in the distribution system, a combined residual of at least 1.0 mg/L must be maintained at the ends of the distribution system.

The City currently complies with all of these KDHE requirements.

3.0 Pending Regulations

3.1 General

Several rules are scheduled for promulgation and implementation within the next few years. Because these rules have not yet been formally proposed or promulgated, their relative impact on current treatment operations at the City's water treatment facility is difficult to predict with any certainty at this time. However, Black & Veatch maintains close contact with EPA officials involved in the preparation of these new regulations, and the information presented in this section reflects the latest thinking with regard to these regulations. The information presented herein should be reviewed and revised as necessary when the rules are proposed and finalized.

3.2 Stage 2 Disinfection By-Products Rule

It is currently anticipated that Stage 2 of the Disinfection By-Products Rule will be proposed during July 2003 and finalized during July 2004. The assessment summarized below is based on information presented in (1) the "Stage 2 M-DBP Agreement in Principle", which will serve as the basis for EPA's development of the Stage 2 DBPR, and (2) the November 2001 pre-proposal draft regulation issued by EPA for stakeholder review. (It is emphasized that EPA may elect to modify these regulatory provisions, based on public comment received following formal proposal of the regulation and/or new information developed during the regulatory promulgation process.) "Stage 2A" of this regulation, which will become effective three years after promulgation, i.e., by July 2007, will require that systems comply with running annual TTHM and HAA5 MCLs of 0.120 mg/L and 0.100 mg/L, respectively, at <u>each</u> of their <u>current</u> DBP monitoring locations. (Systems must also continue to comply with the impending Stage 1 MCLs for TTHMs and HAA5 of 0.080 mg/L and 0.060 mg/L, respectively, based on "system running annual average" values.) "Stage 2B" of this regulation, which will become effective six years after promulgation, i.e., by July 2010, will require compliance with running annual TTHM and HAA5 MCLs of 0.080 mg/L and 0.060 mg/L, respectively, at individual "revised" system monitoring locations. (KDHE may extend this compliance deadline by up to two years if significant capital expenditures will be required to achieve compliance.) As discussed in Appendix 3, these revised monitoring locations will be selected based on one year of system DBP monitoring at 60-day intervals at 16 locations (8 locations per plant) not currently included in the City's DBP monitoring program. The primary purpose of this additional monitoring is to identify areas within the distribution system where DBP levels are highest. This monitoring must be completed, and a report summarizing the testing results and the City's recommended revisions to current monitoring sites must be submitted to KDHE within two years of promulgation of the Stage 2 rule, i.e., by July 2006.

A summary of recent maximum quarterly running annual average DBP concentrations at each of the City's eight current monitoring locations is presented in Table III-13. These data suggest that the City should easily comply with the Stage 2A TTHM and HAA5 MCLs of 0.120 mg/L and 0.100 mg/L, respectively, at individual monitoring sites using current disinfection practices. These data also suggest that compliance with the more restrictive "Stage 2B" TTHM and HAA5 MCLs of 0.080 mg/L and 0.060 mg/L, respectively, at revised system monitoring locations should also be achieved. (As chloramines are utilized for residual maintenance within the distribution system, DBP concentrations throughout the system should be relatively consistent.)

Table III-13
Maximum 4-Quarter Running Average DBP Concentrations at Current System Monitoring Sites

Monitoring Location	Max. 4-Quarter Average DBP Concentration mg/L(1)	
	TTHM	HAA5
Westminster Inn	0.0544	0.0395
McDonalds (6th & Wakarusa)	0.0643	0.0445
Kwik Shop (1401 Kasold)	0.0659	0.0415
Village Inn (821 Iowa) Royal Crest Lanes (933 Iowa)	0.0569	0.0355
City Hall	0.0542	0.0385
Wal-Mart	0.0622	0.0408
JLE Building	0.0582	0.0308
KDHE (804 W. 24th Street)	0.0624	0.0410

(1)Based on quarterly monitoring results for 1999 through 2001.

Based on the above considerations, the only significant impact of this regulation on current treatment practices will be the increased analytical costs incurred during the initial 1-year period of expanded IDSE system monitoring.

3.3 Long-Term Enhanced Surface Water Treatment Rule

A long-term Enhanced Surface Water Treatment Rule which extends the IESWTR requirements to systems serving less than 10,000 consumers was promulgated during January 2002, and will become effective during January 2005. This regulation, referred to as the Stage 1 Long-Term Enhanced Surface Water Treatment Rule, or LT1ESWTR, will not have any impact on the City's current monitoring and treatment requirements.

As discussed in Appendix C, a long-term Stage 2 ESWTR (currently being referred to as the LT2ESWTR) is expected to be proposed during June 2003 and finalized during July 2004. As this rule has not been formally proposed, it is not prudent to make any firm recommendations regarding what the City should do to prepare to comply with specific requirements of this regulation. However, the "Stage 2 M-DBP Agreement in Principle", which will serve as the basis for EPA's development of the LT2ESWTR, and the November 2001 pre-proposal draft rule provide some indications as to how the Agency will proceed in developing the regulation. The discussion that follows assumes that the LT2ESWTR will be proposed and promulgated as recommended by the regulatory negotiating committee that drafted the "Agreement in Principle", and as summarized in the pre-proposal draft. (It is emphasized, however, that EPA may elect to modify these regulatory provisions, based on public comment received following formal proposal of the regulation and/or new information developed during the regulatory promulgation process.)

Specific treatment requirements under this regulation would be determined based on results from two years of monthly monitoring to assess average source water *Cryptosporidium* concentrations. Source water monitoring would need to be completed, and a report summarizing the resulting data would need to be submitted to KDHE within 2 and one-half years of promulgation of the LT2ESWTR, i.e., by January 2007. If this monitoring reveals that 12-month running average source water *Cryptosporidium* concentrations equal or exceed 0.075 oocysts per Liter, the City would be required to provide increasingly-stringent levels of oocyst physical removal, in addition to a minimum 1-log inactivation by disinfection if average oocyst concentrations exceed 1.0 per Liter. Compliance with these more stringent treatment requirements would be required by July 2010 at the earliest, and KDHE could grant compliance extensions of up to two years if significant capital improvements are required to achieve compliance.

The City has conducted quarterly source water and treated water monitoring to assess removals of *Cryptosporidium*-sized particles across the treatment process at the Kaw River and Clinton treatment facilities since mid-1996. These analyses indicate that historical average removal of particles in the 5 – 10 micron size range is approximately 4.7-log for the Clinton plant and 3.6-log for the Kaw River Plant. (The overall range of particle removals during this period was 2.4-log to 8.8-log for the Clinton Plant, and 0.67-log to 5.3-log for the Kaw River plant.) However, source water *Cryptosporidium* monitoring data using EPA Method 1623 (the analytical method that will be required for source water monitoring under the LT2ESWTR) are not currently available. Therefore, firm conclusions regarding potential compliance requirements cannot be developed until the required *Cryptosporidium* monitoring has been completed. Comments on potential compliance requirements presented in this report should be regarded as preliminary, and a reassessment of compliance requirements should therefore be conducted following completion of source water *Cryptosporidium* monitoring in January 2007. However, as discussed in Section VI.D below, the City may be able to comply with the "Bin 2" additional treatment requirements (1-log additional treatment required, based on a maximum 12-month running average source water *Cryptosporidium* concentration between 0.075/L and 1.0/L) by obtaining credit for *Cryptosporidium* removal achieved by (1) presedimentation, (2) two-stage lime softening, and/or (3) maintaining filtered water turbidities at 0.15 NTU or lower for a minimum of 95 percent of the monthly samples collected.

Should future monitoring of source water *Cryptosporidium* concentrations indicate that the City may be classified in "Bin 3" (2-log additional treatment required, based on a maximum 12-month running average source water *Cryptosporidium* concentration between 1.0/L and 3.0/L), provisions for primary disinfection using an alternative disinfection process such as ultraviolet (UV) irradiation could be required. (As discussed in Appendix C, utilities will be able to chose from a wide range of treatment methodologies in order to achieve the required level of *Cryptosporidium* removal/inactivation.) Another treatment option would be use of membrane processes such as microfiltration and ultrafiltration, which provide positive physical removal of both *Giardia* cysts and *Cryptosporidium* oocysts. The "Agreement in Principle" states that membrane filtration processes would be an acceptable substitute for oocyst inactivation processes, and that "EPA believes that ultraviolet (UV) disinfection is available and feasible", based on currently available information. Treatment facilities that could be required to comply with this regulation are discussed in Section X. D below.

All systems which are required to monitor source water *Cryptosporidium* oocyst concentrations would also be required to prepare *Giardia* and virus inactivation profiles under the LT2ESWTR, if promulgated as currently recommended. The City would be required to document the total level of *Giardia* and virus inactivation achieved at least once per week over a period of at least one year, beginning two years after promulgation of the LT2ESWTR (i.e., by July 2006, if this regulation is promulgated as currently scheduled). The disinfection profiling requirement could be waived by KDHE if the system's request for approval of existing disinfection data (referred to as "grandfathered" data) is approved in writing by the Department prior to the date that the City would be required to begin disinfection profiling. The City could therefore create the profile by either conducting new weekly monitoring, or by using historical, grandfathered data, if approved by KDHE. It is emphasized that the City would be required to document and incorporate disinfection achieved throughout the entire treatment facility (free chlorine across the secondary basins, and chloramine across the filters and the treated water storage facilities) in preparing the disinfection profile.

3.4 Radon

As discussed in Appendix C, EPA has proposed a new MCL for radon of 300 pCi/L, and an alternative MCL of 4,000 pCi/L when a multimedia radon mitigation program is put in place by state regulatory agencies. Radon normally presents problems for utilities that treat groundwater from deep wells; as the City does not utilize deep well supplies, it is anticipated that this regulation will not have any impact on current water treatment practices.

4.0 Regulatory Compliance Schedule

The City's current position with respect to ability to comply with both recently-enacted and impending/future regulations using existing water treatment processes is summarized in Table III-14. A summary of key compliance dates is presented in Table III-15.

Table III-14
Regulatory Compliance Assessment Summary:
City of Lawrence w/Current Treatment

Requirement	Standard	Existing System Performance	Compliance Status
Interim ESWTR (Effective January 2002)			
Filtered Water Turbidity	0.3 NTU for > 95% of monthly samples	< 0.3 NTU	Compliance Expected
	1 NTU Maximum	< 1 NTU	Compliance Expected
Cryptosporidium Removal	2 log	-	Compliance Expected
Microbial Benchmarking/ Disinfection Profiling	TTHM > 0.064 mg/L(1) HAA5 > 0.048 mg/L(1)	< 0.064 mg/L < 0.048 mg/L	Not Required by KDHE
Stage 1 DBPR (Effective January 2002)			
TTHM MCL (system avg.)	0.080 mg/L	0.043 – 0.060 mg/L	Compliance Expected
HAA5 MCL (system avg.)	0.060 mg/L	0.029 – 0.037 mg/L	Compliance Expected
Chloramine MRDL	4.0 mg/L maximum	Avg. 3.5 mg/L	Compliance Expected
Enhanced Coagulation	15-30% TOC Removal	30% - 50% Avg. TOC Removal	Compliance Expected
Stage 2 DBPR Phase 1 (Effective July 2007)			
TTHM MCL(2)	0.120 mg/L	0.034 – 0.066 mg/L	Compliance Expected
HAA5 MCL(2)	0.100 mg/L	0.017 – 0.045 mg/L	Compliance Expected
Stage 2 DBPR Phase 2 (Effective July 2010)			
TTHM MCL(3)	0.080 mg/L	0.034 – 0.066 mg/L	Compliance Expected
HAA5 MCL(3)	0.060 mg/L	0.017 – 0.045 mg/L	Compliance Expected
Filter Backwash Rule (Effective June 2004)	Governs in-plant waste stream recycling.	No in-plant recycling	Compliance Expected
LTESWTR, Stage 2 (Effective July 2010)	*Cryptosporidium* removal, inactivation(4)	*Cryptosporidium* inactivation not Provided	Possible non-compliance if inactivation is required.

(1)Not an MCL. Criteria used to determine if microbial benchmarking and/or disinfection profiling is req'd.
(2)MCLs based on 4-quarter running annual average at "current" individual monitoring sites.
(3)MCLs based on 4-quarter running annual average at "revised" individual monitoring sites.
(4)*Cryptosporidium* removal may be required, based on source water monitoring results

Table III-15
Key Dates for SDWA Regulations

Date	Regulation	Activity / Compliance Requirements
Jan. 1, 2002	IESWTR	Combined Filter Effluent Turbidity: 0.3 NTU max for minimum of 95% of monthly measurements Performance requirements for individual filters Monitor individual filters @ 15 minute intervals
Jan. 1, 2002	Stage 1 DBPR	Revised MCL for TTHM New MCLs for HAA5, chlorite, chlorine dioxide MRDLs for chloramines, chlorine dioxide TOC removal requirements
Jan. 2002	Stage 1 DBPR	Initiate monthly source water, finished water TOC monitoring
Dec. 2003	Radionuclides	Revised MCLs for radionuclides effective
July 2004	LT2ESWTR, Stage 2 DBPR	Projected regulatory promulgation date.
Oct. 2004(1)	LT2ESWTR	Deadline for submittal of source water monitoring schedule to KDHE
Jan. 2005(2)	Stage 1 DBPR	Recommended deadline for initiating IDSE monitoring
Jan. 2005(1)	LT2ESWTR	Deadline for initiating 2-year source water *Cryptosporidium*, *E. coli*, & turbidity monitoring program
July 2006(2)	Stage 2 DBPR	Deadline for submittal of report to KDHE summarizing IDSE monitoring results
July 2006(1)	LT2ESWTR	Begin disinfection profiling[3]
Jan. 2007(1)	LT2ESWTR	Deadline for submittal of results of 2-year source water monitoring program to KDHE
July 2007(2)	Stage 2 DBPR	Compliance with "Stage 2A" MCLs at individual system monitoring sites
July 2007(1)	LT2ESWTR	KDHE determines *Cryptosporidium* bin classification Complete disinfection profiling with one year of data[3]
July 2010(1)	LT2ESWTR	Deadline for compliance with additional *Cryptosporidium* treatment requirements(4) Deadline for submittal of documentation for utilization of microbial toolbox options to KDHE
July 2010(2)	Stage 2 DBPR	Compliance with "Stage 2B" MCLs at individual system monitoring sites(4)

(1)Assumes promulgation of LT2ESWTR during May 2004.
(2)Assumes promulgation of Stage 2 DBPR during May 2004.
(3)Unless KDHE approves use of existing disinfection profiling data.
(4)Extension of up to two years can be granted by KDHE if capital improvements are required to achieve compliance.

5.0 Regulatory Compliance Alternatives

As discussed above, provisions for increased removal of, and potentially for inactivation of *Cryptosporidium* oocysts may be required under the impending LT2ESWTR. The following discusses treatment requirements and associated probable costs for several potential *Cryptosporidium* treatment scenarios, based on information presented in the November 2001 preproposal draft of the LT2ESWTR. It is emphasized that EPA has requested comment on the proposed microbial toolbox options and criteria, and that the information presented in the LT2ESWTR preproposal draft could be modified prior to promulgation of this regulation during July 2004.

5.1 *Cryptosporidium* Removal (Bin 1 Classification)

Should raw water monitoring conducted under the impending LT2ESWTR indicate the presence of *Cryptosporidium* at average annual concentrations of less than 0.075 oocysts per Liter ("Bin 1" classification), no additional treatment to address *Cryptosporidium* oocyst removal/inactivation would be required.

5.2 *Cryptosporidium* Removal (Bin 2 Classification)

Should raw water monitoring conducted under the impending LT2ESWTR indicate the presence of *Cryptosporidium* at average annual concentrations of 0.075 to 1.0 oocysts per Liter, the City would be required to provide an additional 1.0-log of treatment ("Bin 2" classification). (This would be in addition to the 3.0-log *Cryptosporidium* removal credit granted for well-operated conventional treatment.)

Review of the microbial toolbox options presented in the recently-published LT2ESWTR preproposal draft suggests that the City could achieve the required Bin 2 1-log total additional *Cryptosporidium* removal credit for the existing treatment facilities by utilizing available credits for any of the following:

- 0.5-log credit for presedimentation
- 0.5-log credit for two-stage softening
- 0.5-log or 1.0-log credit for maintaining low treated water turbidity levels.
- 1.0-log credit for demonstration of performance (aerobic spore removal).

Proposed design and implementation criteria for each of the above are discussed below.

5.2.1 Presedimentation

A 0.5-log *Cryptosporidium* removal credit will be granted to systems utilizing presedimentation prior to clarification or softening treatment. To receive this credit, the presedimentation facilities must operate continuously with addition of coagulant. Maximum allowable effective surface loading rate is 1.6 gpm/sq ft and (1) mean influent turbidity must be greater than or equal to 10 NTU, or (2) maximum influent turbidity must be greater than or equal to 100 NTU. All flow must pass through the presedimentation basin(s), and systems with existing presedimentation basins may conduct required *Cryptosporidium* monitoring at either the presedimention inlet or discharge.

The City's existing Kaw River and Clinton Reservoir presedimentation facilities should comply with these requirements. Both facilities currently have polymer feed capability at the presedimentation basins, and design hydraulic surface loading rates are less than 1.6 gpm/sq ft. (However, as polymer is not routinely fed at the presedimentation basins, operational changes would be required to obtain this removal credit.)

5.2.2 Two-Stage Lime Softening

A 0.5-log *Cryptosporidium* removal credit will be granted to systems utilizing two-stage softening with a coagulant added at the inlet to the secondary softening basin(s). Coagulant is defined as either metal salts (alum, ferric) or polymers, or formation and subsequent precipitation of magnesium hydroxide. All flow must pass through the secondary softening basin(s).

The Clinton WTP currently has provisions for feeding polymer at the secondary softening basins. The Kaw River plant does not currently have provisions for feeding a coagulant at the secondary softening basins, but plant staff indicate that this capability could be readily added if necessary without significant difficulty. (Coagulant feed piping to the secondary basin inlet is currently in place, and the existing polymer system could be readily modified to feed to the secondary basins.) However, as discussed above for presedimentation, polymer is not routinely added at the secondary softening basins; operational changes would therefore be required to obtain this removal credit.

5.2.3 Reduced Finished Water Turbidity

A 0.5-log *Cryptosporidium* removal credit will be granted to systems with a combined filtered turbidity less than or equal to 0.15 NTU in at least 95 percent of the measurements taken each month. Compliance with this criterion would be determined based on measurements of the combined filter effluent at intervals of no longer than 4 hours. A 1.0-log *Cryptosporidium* removal credit will be granted to systems that achieve a turbidity level in each individual filter effluent less than or equal to 0.15 NTU in at least 95 percent of the measurements taken each month. Compliance with this criterion would be determined based on measurements of the individual filter effluent at 15-minute intervals.

Plant performance data for January through December 2001 suggest that the Clinton treatment facility should comply with the 0.15 NTU combined filtered water turbidity criterion without significant difficulty. (The combined filtered water turbidity for the Clinton plant during 2001 did not exceed 0.15 NTU in any of the more than 4,200 compliance samples collected.) For the period from January 2000 through December 2001, the turbidity of the combined filter effluent at the Kaw WTP was less than 0.15 NTU for more than 95 percent of the monthly measurements during 20 of the 24 months evaluated, as shown in Table III-16. However, the elevated turbidities recorded during February and March 2001 can be attributed to rapid and severe variations in the Kaw River turbidity levels. During late February 2001, raw water turbidity exceeded 4200 NTU, and raw water hardness and alkalinity concentrations dropped to 128 mg/L and 107 mg/L, respectively. It is emphasized that during this period, the turbidity of the combined filter discharge did not exceed 0.30 NTU, and in fact, the majority of the samples with turbidities exceeding 0.15 NTU exhibited turbidities in the 0.16 NTU to 0.20 NTU range. Likewise, during August and September 2001, the majority of the samples with turbidities exceeding 0.15 NTU exhibited turbidities in the 0.16 NTU to 0.20 NTU range. It was also noted that many of the samples with turbidity exceeding 0.15 NTU were collected from the lower level filters. (These filters are used primarily during periods of high treated water demand, and are generally operated only a few hours per week.)

This performance suggests that the Kaw River plant should be able to comply with the maximum 0.15 NTU / 95 percent criteria through expanded use of filter aid polymer, operational modifications such as more frequent backwashing during periods of high source water turbidity, and/or improvements to the lower-level filters to yield performance similar to that of the upstairs filters

Table III-16
Combined Filtered Turbidity Values (January 2000 – December 2001)

Month/Year	Kaw River WTP		Clinton WTP	
	Total Samples	% ≤ 0.15 NTU	Total Samples	% ≤ 0.15 NTU
January 2000	339	99.7	-	-
February 2000	348	100	-	-
March 2000	372	99.7	-	-
April 2000	360	100	-	-
May 2000	372	100	-	-
June 2000	360	99.7	-	-
July 2000	372	99.5	-	-
August 2000	513	95.1	-	-
September 2000	358	96.4	-	-
October 2000	372	100	-	-
November 2000	360	99.7	-	-
December 2000	371	100	-	-
January 2001	366	99.7	348	100
February 2001	334	92.5	336	100
March 2001	371	82.5	372	100
April 2001	358	97.5	359	100
May 2001	372	100	357	100
June 2001	360	98.9	300	100
July 2001	399	97.2	372	100
August 2001	379	93.7	372	100
September 2001	359	94.7	360	100
October 2001	371	98.4	371	100
November 2001	360	99.4	360	100
December 2001	372	100	340	100

Note: Shaded areas represent potential noncompliance, had IESWTR been in effect.

It is expected that maintaining turbidities for individual filters of 0.15 NTU or less for a minimum of 95 percent of the monthly samples will be difficult for most utilities to consistently achieve, particularly for lime softening facilities treating surface supplies. The Kaw River and Clinton plants typically produce finished water with a turbidity of less than 0.10 NTU, which is indicative of excellent process operation and performance. However, review of current filter operating data suggests that obtaining the 1.0-log *Cryptosporidium* removal credit based on maintaining turbidities for individual filters at 0.15 NTU or less would likely be difficult.

5.2.4 Performance Demonstration

EPA recognizes that some treatment facilities can achieve mean log removals of *Cryptosporidium* oocysts greater than the average 3-log value that will be granted under the LT2ESWTR. However, it is generally not considered practical for systems to directly quantify log removals for *Cryptosporidium* across the treatment process due to finished water oocyst concentrations at below the detection limit for available methods. Studies have demonstrated that aerobic spores are a conservative indicator of *Cryptosporidium* removal by sedimentation and filtration when a coagulant is used. Therefore, a 1.0-log *Cryptosporidium* removalcredit will be granted to systems that demonstrate an annual mean removal of at least 4-log (99.99 percent) of aerobic spore forming bacteria (or other parameter approved by KDHE). Compliance with this criterion would be determined based on results of weekly plant influent and combined filter effluent monitoring conducted over a minimum 1-year period. (However, systems that receive the 1-log credit would not be eligible to receive additional credit for reductions in finished water turbidity, or for existing pretreatment processes (presedimentation, two-stage lime softening) located after the influent monitoring point.)

5.3 *Cryptosporidium* Removal/Inactivation (Bin 3 Classification)

Should raw water monitoring conducted under the impending LT2ESWTR indicate the presence of *Cryptosporidium* at average annual concentrations of 1.0 to 3.0 oocysts per Liter, the City would be required to provide an additional 2.0-log of treatment ("Bin 3" classification). (This would be in addition to the 3.0-log *Cryptosporidium* removal credit granted for well-operated conventional treatment.) The City would be required to achieve at least 1.0-log of this additional treatment using ozone, chlorine dioxide, UV, membrane treatment, bag/cartridge filtration, or in-bank filtration processes. Disinfection CT requirements for chlorine dioxide presented in the November 2001 LT2ESWTR preproposal draft are high enough to eliminate it from serious consideration as a viable *Cryptosporidium* inactivation process, while bag filtration / cartridge filtration processes are generally applicable only to relatively small-capacity treatment facilities. Membrane processes, ozonation, UV disinfection treatment, and in-bank filtration are discussed below.

5.3.1 Microfiltration/Ultrafiltration

Microfiltration (MF) and ultrafiltration (UF) are physical processes in which colloidal particles are removed from the water supply by straining through a porous medium. Both processes provide exceptional removal of turbidity (most operating facilities routinely produce treated water with turbidities of less than 0.05 NTU). MF membranes typically used for treatment of surface water supplies are hollow-fiber with a nominal pore size of 0.2 microns. UF membranes used in surface water treatment applications typically exhibit a nominal pore size of 0.04 microns. As these pore sizes are significantly smaller than *Cryptosporidium* oocysts (2 to 7 microns) and Giardia cysts (5 to 15 microns), MF and UF provide excellent removal of these microbial contaminants. Removal of *Giardia* cyst-sized particles in excess of 6 to 8 logs (99.9999 to 99.999999 percent) have been demonstrated during pilot-scale testing, and therefore many states grant 3-log, and, in some cases 4-log removal credits for MF and UF treatment. (KDHE currently does not have a specific position with regard to allowable removal credits for MF/UF.)

Typical “average” feedwater pressures for conventional “encased” membrane configurations are 15 to 20 psi. Backwashing of MF/UF modules is typically initiated every 18 to 20 minutes (up to 30 minutes for exceptionally clean feedwaters), and the backwash cycle typically lasts for 2.5 to 3 minutes. Backwashing typically uses approximately 5 to 7 percent of the feedwater pumped to an MF system; however, recycling of the backwash flow to the plant influent following treatment to remove settleable solids can reduce overall losses to 1 to 2 percent of plant production. Periodic cleaning with citric acid, caustic/hypochlorite solution, and/or proprietary detergent solutions may be required when conventional backwashing can no longer restore differential pressures across the membranes to original levels. Chemical cleaning is typically conducted at 4 week to 6 week intervals.

A relatively new development in MF/UF treatment is the “immersed” membrane configuration. Immersed membrane systems consist of “modules” of membrane fibers suspended in conventional concrete or steel tanks containing the water to be treated. Unlike conventional membrane systems, where the feedwater is pressurized to force the feedwater through the membranes, immersed membranes operate under a slight vacuum (typically 6 to 8 psig). Vacuum is produced by pumps located on the product water side of the membranes. The membranes are periodically “backpulsed” using product water to remove deposits on the membrane surfaces; this typically occurs every 15 to 20 minutes for a period of approximately 30 seconds. Immersed membrane system employs injection of air at the floor of the membrane chamber to scour the membrane surfaces and to maintain a homogeneous concentration of suspended solids within the chamber. Periodic chemical cleaning is required to maintain membrane flux rates; this is typically accomplished by backpulsing the membranes at a reduced rate with the concentrated cleaning solutions. Cleaning solutions typically include sodium hypochlorite and proprietary detergent solutions. The cleaning process is typically automated to reduce operator labor required. Most existing immersed membrane systems operate at raw-to-product recovery rates of approximately 90 percent. However, through recycling of the membrane reject stream and /or use of "secondary" membrane treatment systems, overall treatment process losses can typically be reduced to 1 to 2 percent of the raw water treated.

As MF and UF treated water exhibits extremely low turbidities, which are difficult to monitor consistently, provisions for continuous monitoring of treated water particle counts are required to ensure that the membranes are operating properly. It is also typically recommended that an air integrity test be conducted at least once per day to ensure that the membranes and associated gaskets/seals are functioning properly, and that individual membrane fibers have not failed. (At least one state currently requires that membrane integrity testing be conducted every 4 hours.)

A potential advantage of immersed membranes is their ability to be located in existing plant structures, such as filter boxes (the membranes would replace the conventional granular media). Minimum required basin depth for the immersed membranes is 10 to 11 feet, and membrane production rates at "conservative" hydraulic loading (flux) rates are approximately 3 to 6 gpm per square foot of basin plan area. (A new product released this year may allow a higher equivalent loading rate.)

For the Kaw River and Clinton treatment facilities, immersed MF/UF membranes could potentially be located within the existing granular media filter structures. Pilot-scale evaluation to assess feasible loading rates, operating pressures, and membrane cleaning requirements would be recommended prior to any decision to consider full-scale MF/UF implementation. A brief contact period (5 to 8 minutes) with free chlorine should be provided prior to or following membrane treatment to ensure effective inactivation of viruses. (Viruses are considerably smaller than *Giardia* cysts and *Cryptosporidium* oocysts, and therefore may not be effectively removed by MF/UF.)

5.3.2 Ozonation

Ozone has been used with increasing frequency in U.S. treatment facilities over the past 10 to 15 years. In addition to disinfection, potential direct benefits associated with the use of ozone include the following:

- Improvement in filtered water turbidity when applied immediately preceding filtration.
- "Microcoagulation" of dissolved organic contaminants (transformation of soluble organic contaminants into insoluble forms that can be removed by conventional treatment techniques).
- Reduction of tastes and odors.
- Oxidation of iron and manganese.

Ozone oxidation must precede filtration to ensure effective removal of the flocculated particles resulting from the partial oxidation of dissolved organic materials. Ozone is applied to the process stream in gaseous form, and because of its instability, is generated onsite. A baffled contact chamber is typically required to achieve optimum ozone utilization and effectiveness, and to satisfy disinfection contact time requirements. As ozone treatment does not yield a sustainable disinfectant residual, a secondary disinfectant (chloramine) must continue to be added to prevent microbial regrowth within the distribution system. Because of its highly reactive nature, ozone should be applied prior to filtration at a point where water quality is highest (typically just prior to filtration.) This results in maximum disinfection efficiency, lower ozone demands, and minimum formation of potentially undesirable by-products.

Disadvantages of ozone include high construction costs for the ozone generation and contact equipment and high operating costs attributable to high energy consumption rates. Continuing concerns regarding the potential health impacts of bromate (a by-product of ozone oxidation of waters containing low levels of bromide) may also limit application of ozone in some cases, unless effective bromate control measures can be implemented. Required ozone CT values presented in the November 2001 LT2ESWTR pre-proposal draft also suggest that inactivation of *Cryptosporidium* will likely require significantly higher ozone dosages and longer ozone contact periods than originally anticipated (particularly under cold-water conditions), which would greatly reduce it's attractiveness for inactivation of this microbial contaminant. (CT values for inactivation of *Cryptosporidium* oocysts are approximately 20 to 40 times higher than CT values for inactivation of *Giardia* cysts published in the Surface Water Treatment Rule "Guidance Manual".)

While ozonation would provide positive inactivation of many microbial pathogens (and could assist in controlling undesirable tastes and odors at the Clinton plant), implementation as the primary disinfectant is not considered cost-effective, based on the following considerations:

- The low water temperatures typically experienced during the winter months at both of the City's treatment facilities would require that high applied ozone dosages and long ozone contact times be employed to ensure positive inactivation of *Cryptosporidium* oocysts. (At this time, ability to maintain required ozone residuals for periods sufficient to meet required CT values cannot be determined with any certainty.)
- Construction of ozone generation and contact facilities within the confines of the existing Kaw River plant site would be relatively difficult.

5.3.3 Ultraviolet Disinfection

Ultraviolet (UV) irradiation, historically used in this country primarily to disinfect wastewater effluents, is rapidly emerging as a viable disinfectant in the drinking water industry. While use in the U.S. is currently limited, there are reportedly more than 2,000 facilities in Europe currently utilizing UV for disinfection of public drinking water supplies. Current research is focused primarily on inactivation of *Cryptosporidium* and *Giardia*, and preliminary results suggest that 3-log to 5-log inactivation of these microbial pathogens is readily achievable.

Benefits of UV disinfection include: (1) significantly lower costs than for comparable microbial control processes (ozone, microfiltration); (2) small facility area requirements; (3) ability to cost-effectively retrofit existing plant facilities; (4) significant reductions in formation of halogenated disinfection by-products (as required free chlorine contact times for disinfection are greatly reduced); and (5) high levels of achievable pathogen inactivation. Potential disadvantages include: (1) the potential for fouling/plating of the quartz sleeves which house the UV lamps; (2) reliability/accuracy of the UV sensors used to monitor process effectiveness; and (3) difficulties in securing State Regulatory approval for disinfection of surface water supplies due to the lack of full-scale U.S. operating experience. Utilities should also be aware that one manufacturer of UV systems (Calgon Carbon Corporation) recently obtained a patent for inactivation of *Cryptosporidium* using UV, and has announced its intention to charge users a licensing fee equivalent to $0.015 per thousand gallons of water treated using UV. This licensing fee will apply to all utilities that install UV for inactivation of *Cryptosporidium*, regardless of the supplier selected to provide the UV equipment.

Several states have approved use of UV for disinfection of groundwater supplies, but none have approved its use for utilities treating surface water supplies. EPA intends to address this potential problem by publishing the following concurrent with proposal of the LT2ESWTR:

- Tables specifying required UV dosages to achieve up to 3-log inactivation of *Giardia*, up to 3-log inactivation of *Cryptosporidium*, and up to 4-log inactivation of viruses.
- Minimum standards to determine if UV systems are acceptable for compliance with drinking water disinfection requirements.
- A UV Guidance Manual, the purpose of which is to facilitate design and planning of UV installations by familiarizing State/Primacy agencies and utilities with UV system design and operational issues.

UV systems currently being designed include provisions for periodic automated cleaning of the lamp sleeves. It is expected that as additional experience is acquired, state regulatory agencies will be increasingly supportive of use of UV technology as an alternative to conventional disinfection processes.

Newer UV system designs typically utilize medium-pressure or low-pressure high-intensity lamps enclosed in a stainless steel pipe-type reactor vessel, which facilitates incorporation into existing treatment facilities. Multiple units operating in parallel are typically specified to provide reliability and to ensure continued plant operation should a single unit require servicing. As UV should be applied to the cleanest possible water in order to maximize effectiveness and minimize operating costs, it would typically be used to treat the filtered water prior to storage/distribution. UV has also been shown to be relatively ineffective for inactivation of enteric viruses at dosages typically considered cost-effective for inactivation of *Giardia* and *Cryptosporidium*; therefore, a brief free chlorine contact period either prior to or following UV would be required to ensure that conditions for positive inactivation of viruses are provided.

Evaluation of *Cryptosporidium* control requirements for other similar facilities indicates that both probable construction and annual operating costs associated with UV disinfection would be considerably less than for MF/UF membrane treatment or ozone disinfection. For the City's water treatment facilities, UV disinfection facilities could potentially be retrofitted between the existing filters and the treated water reservoirs.

5.3.4 In-Bank Filtration

"Bank filtration" is a process that utilizes surface water that has naturally infiltrated into a subsurface aquifer and is recovered by one or more pumping wells. Microorganisms and other particles are removed by contact with aquifer materials as the water progresses through the aquifer. The November 2001 preproposal draft of the LT2ESWTR indicates that EPA will propose that *Cryptosporidium* removal credits be granted to systems that utilize "in-bank filtration" with either vertical wells or horizontal collector wells. In-bank filtration wells would be required to be drilled in unconsolidated, predominantly granular/sandy aquifers, and the utility would be required to characterize the aquifer at the well site in order to receive *Cryptosporidium* removal credit. A vertical or horizontal well located adjacent to a surface water body would be eligible for bank filtration credit if there is sufficient grondwater flow path length to ensure effective removal of oocysts. *Cryptosporidium* removal credits presented in the preproposal draft are as follows:

- 0.5-log credit for vertical wells located greater than 25 feet from the surface water source, and 1.0-log credit for vertical wells located greater than 50 feet from the surface water source. (Measured from the edge of the surface water source under high flow conditions.)
- 0.5-log credit for horizontal collector wells with laterals no closer than 25 feet to the bottom of the river channel, and 1.0-log credit when laterals are no closer than 50 feet to the river channel.

Utilities would be required to monitor the turbidity of the wells continuously to detect any system failure. If the monthly average turbidity (based on daily maximum values) exceeded 1 NTU, the utility would be required to determine if microbial removal had been compromised, and then report the exceedance to KDHE, along with an explanation of the basis for concluding that microbial removal had not been compromised. If KDHE determined that microbial removal had indeed been compromised, the utility would not receive the *Cryptosporidium* removal credit until the problem had been resolved.

Implementation of bank filtration as an alternative to the City's current surface water supplies would be a relatively costly compliance option strictly for *Cryptosporidium* control, particularly when potential removal credits that may be obtained for other processes at substantially lower costs are considered. However, when other potential benefits (reduction in chemical coagulant/pretreatment requirements, protection against contaminant spills upstream of the existing Kansas River intake, improved overall microbial quality, attenuation of turbidity and temperature extremes) are also considered, bank filtration could represent a viable long-term alternative to the City's current supplies.

5.4 Summary

The City is well positioned in most respects regarding compliance with pending and anticipated future water quality and treatment requirements. Based on review of historical system monitoring data for disinfection by-products, the City should comply with the more restrictive requirements of the Stage 2 Disinfection By-Products Rule without significant difficulty. However, treatment requirements to address the microbial control criteria of the Long-Term 2 Enhanced Surface Water Treatment Rule (effective July 2010, based on current projected regulation promulgation schedules) cannot be determined with any certainty until the required source water *Cryptosporidium* monitoring is completed in January 2007. However, should monitoring under the LT2ESWTR reveal annual average source water *Cryptosporidium* oocyst concentrations exceeding 1.0 per Liter, the City could be required to install provisions for additional oocyst removal and/or inactivation. The most cost-effective treatment technology for meeting this requirement would be UV irradiation following filtration.

The ability to consistently maintain low filtered water turbidities will be a key factor in ensuring compliance with future regulatory requirements. To ensure continued compliance, the City should consider improvements to the existing lower level filters at the Kaw River WTP to provide performance similar to that of the upper level filters. Expanded use of coagulants at the presedimentation basins and secondary softening basins may also allow the City to obtain additional *Cryptosporidium* removal credit under the LT2ESWTR, should this be required based on source water *Cryptosporidium* monitoring results.

The City may want to consider initiating some preliminary monitoring of source water *Cryptosporidium* concentrations using EPA Method 1622/23. Consideration should also be given to conducting simultaneous monitoring of both the raw water supply and the presedimentation basin discharge to assess potential benefits of post-presedimentation monitoring with respect to future *Cryptosporidium* bin placement under the LT2ESWTR. (The November 2001 LT2ESWTR pre-proposal draft states that systems "with existing pre-sed basins may monitor effluent to determine bin classification.").

SECTION IV –DISTRIBUTION SYSTEM

1.0 Existing Distribution Facilities

1.1 Service Levels

The service area is divided into two service levels designated as Central Service and West Hills. The Central Service level is supplied by low service pumps located at the Clinton and Kaw Water Treatment Plants and includes ground ranging in elevation from 810 to 950. The static hydraulic gradient in the Central Service level of elevation 1019 is established by the overflow of the Oread and Kasold Reservoirs. The West Hills service level is supplied by high service pumps at the Clinton and Kaw Water Treatment Plants and includes ground ranging in elevation from 870 to 1060. The static hydraulic gradient in the West Hills service level of elevation 1174 is established by the overflow of the Stratford elevated tank. Two booster pumping stations are located adjacent to the Oread and Kasold reservoirs and can be used to pump to the West Hills service level. A schematic of the distribution system is shown in Figure IV-1.

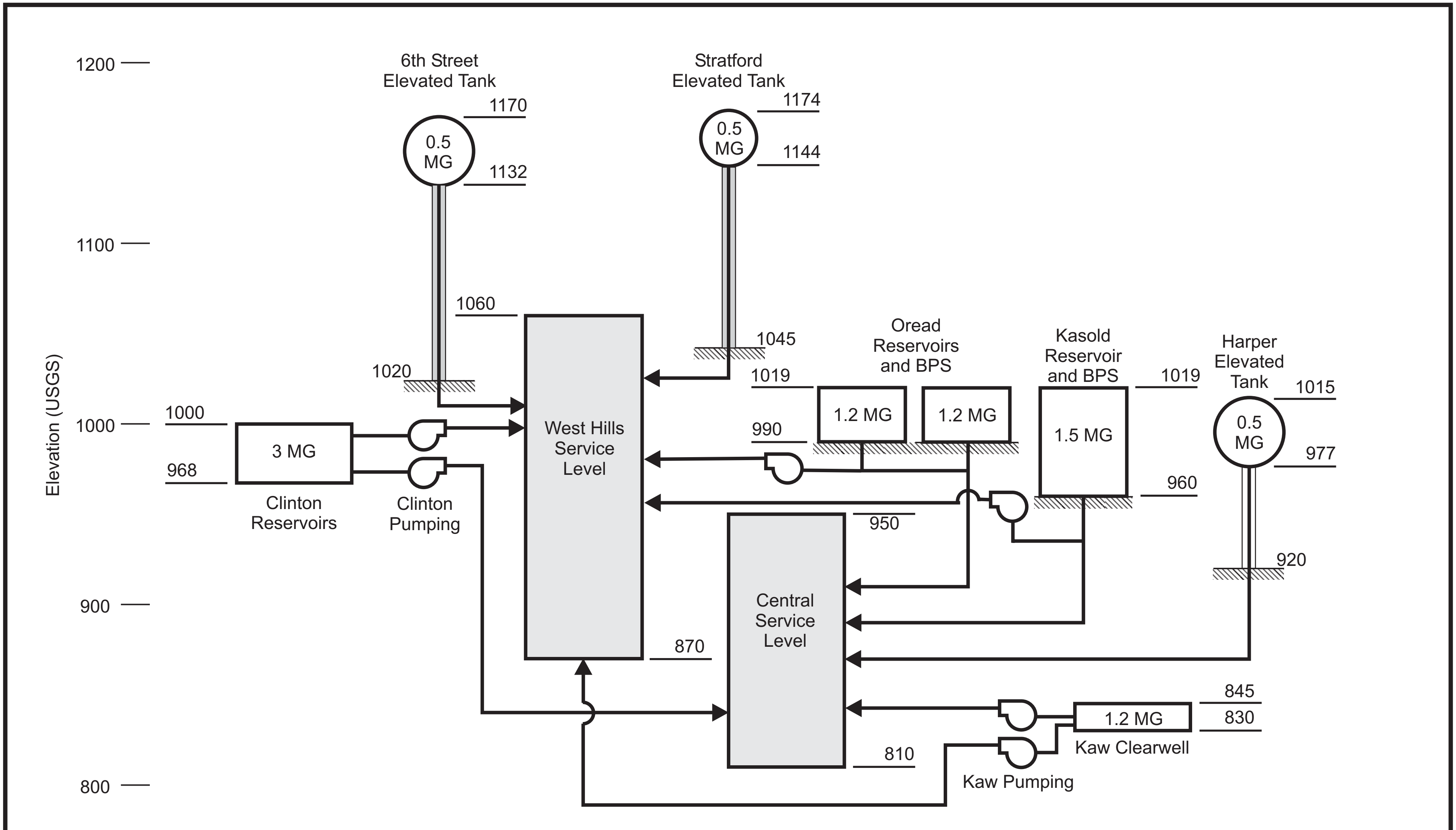
1.2 System Storage

Storage reservoirs in the distribution system are listed in Table IV-1.

Table IV-1
Distribution Storage Reservoirs

Name	Service Level	Type	Volume (MGal)	Sidewater Depth (feet)	Overflow Elevation (USGS)
Harper	Central Service	Elevated	0.5	38	1,015
Kasold	Central Service	Ground	1.5	59	1,019
Oread [(1)]	Central Service	Ground	2.4	30	1,019
Sixth Street	West Hills	Elevated	0.5	38	1,170
Stratford	West Hills	Elevated	0.5	30	1,174

[(1)] Includes two separate reservoirs at 1.2 MGal each



City of Lawrence
Water System Master Plan - 2003

Distribution System Schematic

Figure IV-1

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1.3 Distribution System Pumping

1.3.1 High Service Pumping

The Central Service level is served by two sets of pumps at the Kaw Water Treatment Plant. One set consists of four 3.0 mgd pumps located in the 1954 addition to the plant; the other consists of four pumps totaling 10.6 mgd capacity located in the "old" section of the plant. In addition, the Clinton Plant services the Central service level with two 2.75 mgd pumps and one 5.0 mgd pump. The total high service pumping capacity to the Central service level is 33.2 mgd. The firm pumping capacity, with the largest unit out of service, is 28.2 mgd.

Three 1.5 mgd pumps located at the Kaw Water Treatment Plant serve the West Hills service level. In addition, the Clinton Plant services the West Hills service level with three 5.0 mgd pumps. The total high service pumping capacity to the West Hills service level is 19.5 mgd. The firm pumping capacity, with the largest unit out of service, is 14.5 mgd.

The total high service pumping capacity at the Kaw WTP is 27.1 mgd. The total high service pumping capacity at the Clinton WTP is 25.6 mgd.

Data on the pumping units are summarized in Table IV-2.

1.3.2 Booster Pumping Stations

The distribution system contains two booster pumping stations. The Kasold and Oread Booster Pumping Stations are reportedly used only in emergency situations and therefore operate infrequently.

The Kasold Booster Pumping Station is located below grade at the Kasold Reservoir site and pumps from the Central Service Level to the West Hills Service Level using two 1,310 gpm centrifugal pumps rated at 235 TDH. One variable frequency drive is provided for the operation of only one pump at a time.

The Oread Booster Pumping Station is located at the Oread Reservoirs site. Two 1,240 gpm pumps rated at 245 TDH pump from the Central Service Level to the West Hills Service Level. Data on the booster pumping units are summarized in Table IV-3.

Table IV-2 Water Treatment Plant High Service Pumping Units								
No.	Installed	Location	Manufacturer	Rated Capacity		Rated Head	Pump Motor	
				gpm	mgd	ft	hp	rpm
West Hills Service Level								
1	1954	Kaw Plant	Layne & Bowler	1,050	1.5	350	116	1,760
2	1954	Kaw Plant	Layne & Bowler	1,050	1.5	350	116	1,760
3	1954	Kaw Plant	Layne & Bowler	1,050	1.5	359	116	1,760
1	1992	Clinton Plant	Patterson	3,500	5.0	245	300	3,500
2	1992	Clinton Plant	Patterson	3,500	5.0	245	300	3,500
3 (1)	1997	Clinton Plant	Allis Chalmers	3,500	5.0	245	300	1,785
			Total	**13,650**	**19.5**			
Central Service Level								
1	1954	Kaw Plant	Layne & Bowler	2,100	3.0	220	144	1,750
2	1954	Kaw Plant	Layne & Bowler	2,100	3.0	220	144	1,750
3	1954	Kaw Plant	Layne & Bowler	2,100	3.0	220	144	1,750
4	1954	Kaw Plant	Layne & Bowler	2,100	3.0	220	144	1,750
1	1917	Kaw Plant "Old"	-	2,000	2.8	220	-	-
2	1917	Kaw Plant "Old"	-	2,000	2.8	220	-	-
3	1917	Kaw Plant "Old"	-	2,650	3.8	-	-	-
4	1917	Kaw Plant "Old"	-	900	1.2	210	-	1,750
1	1989	Clinton Plant	Weinman	1,900	2.8	80	50	1,750
2	1989	Clinton Plant	Weinman	1,900	2.8	80	50	1,750
3 (1)	1997	Clinton Plant	Allis Chalmers	3,500	5.0	80	100	1,185
			Total	**23,250**	**33.2**			
(1) Adjustable Frequency Drive								

Table IV-3 Booster Pumping Units								
No.	Installed	Service Level	Manufacturer	Rated Capacity		Rated Head	Pump Motor	
				gpm	mgd	ft	hp	rpm
Kasold								
1	2001	West Hills	Fairbanks Morse	1,310	1.9	235	125	1785
2	2001	West Hills	Fairbanks Morse	1,310	1.9	235	125	1785
			Total	**2,620**	**3.8**			
Oread								
1	1998	West Hills	Fairbanks Morse	1,240	1.8	245	125	1750
2	1998	West Hills	Fairbanks Morse	1,240	1.8	245	125	1750
			Total	**2,480**	**3.6**			

1.4 Distribution Mains

The distribution network includes mains up to 24 inches in diameter. The major distribution grid is considered to include mains from 8 to 24 inches. Local distribution is provided by mains 6 inches or less in diameter.

2.0 Distribution System Computer Model

2.1 General

As part of this investigation the Lawrence water distribution system was evaluated using the network analysis program, WaterCad v4.0.

The physical characteristics of the water distribution system included in the computer model include ground topography, reservoir elevations, pump characteristics, and pipe diameter, length, and interior roughness. Historical and projected water demands are also assigned to the computer model. The model contains all gridded, or looped, mains of 8-inch diameter and greater. Dead-end mains and mains 6-inch diameter and smaller were not included in the model.

The computer model of the Lawrence water distribution system was updated from an earlier WaterCad model that was created in 1996. The 1996 model included only 12-inch main gridding with numerous equivalent pipes and a limited number of 8-inch mains. An extensive quality control checking process was undertaken to verify diameters and connectivity by comparison to the previous WaterCad computer model and to current water system maps of the Lawrence Water Distribution System.

The final “calibrated” computer model of the Lawrence transmission and distribution system contains about 1,500 pipe elements and 980 node elements. All distribution system reservoirs and all pumps which discharge to the distribution system or boost water from one service level to another were incorporated into the model.

2.2 Model Development

2.2.1 Pipe Friction Coefficient (C-value)

The pipe friction coefficient, "C" value in the Hazen-Williams empirical equation for pipe flow, is an index of pipe hydraulic capacity. The "C" value is dependent upon a number of factors including pipe material, type of lining, pipe age, cross-sectional area, amount of tuberculation, and thickness of calcium carbonate deposits. High "C" values represent smoother interior surfaces. The typical "C" value for a new cement-lined ductile iron pipe is about 130, and for a 20-year old pipe it is about 100. Prior to the 1960's mains were generally not lined with cement mortar, typically resulting in greater tuberculation and lower "C" values.

The mains in the Lawrence water distribution system are mostly lined cast or ductile iron and are generally in good condition. The "C" values assigned used in the previous WaterCadd computer model were transferred to the new model. Smaller diameter mains that were not included in the previous model were assigned "C" values on the basis of their vicinity to larger mains with previously assigned "C" values. In general, the "C" values for the smaller mains were dropped by about 10 from the nearby larger mains. "C" values ranged from 120 for newer large diameter transmission mains, to 70 for older and smaller mains in the distribution system. All future mains were modeled with a conservative "C" value of 120.

2.2.2 Demand Allocation

A demand spreadsheet was created to enable peaking of demands at each junction based on up to eleven classes or fields. Base year demands were allocated to the computer model using the first five user class fields (designated as residential, non-residential, University of Kansas, rural water district and unaccounted-for). Additive incremental future long-term demands (2010 and 2025) were allocated to the model using three separate user class fields (residential, non-residential, and unaccounted-for). The demands can be factored based on geographical variations in water use, allowing a broad range of demand conditions to be simulated.

2.2.2.1 Base Year Allocation

Base year "design" average day demands of 12.5 mgd were allocated to the model of the existing distribution system. Actual year 2001 historical sales were greater than the base year average day demand, so the historical year 2000 sales were summarized by service level and adjusted to match the base year demand. This allocation method precisely reflects the actual distribution of metered water sales in year 2000.

The City of Lawrence provided year 2001 metered sales information for every account in the Lawrence Distribution System. The information included account address, user classification code, annual sales in gallons (gal), and parcel number. The data consisted of a total of 28,376 accounts. A total of 170 records accounting for 0.68 percent (0.08 mgd) of the total year 2001 metered sales were not "geocoded" due to no address, or un-located street addresses. The "geocoded" sales (99.32 percent of total sales) were summarized by user class and then factored to match the "design" base year sales. After quality control checks and adjustment of the metered sales to match the "design" demands, the base year demands were allocated to the computer model.

The top 5 large user accounts (2001 sales greater than 0.1 mgd) and all rural water district sales were separately identified in the metered sales data for direct allocation to the computer model to ensure accuracy. The remaining "geocoded" sales by user class were then allocated to the appropriate computer model junctions using spatial GIS techniques.

Base year "design" unaccounted-for water of 0.6 mgd was then allocated to each node in the model based on the percent of total demand at each node.

2.2.2.2 Year 2010 and 2025 Allocation of Increased Demands

Future residential demand increases were allocated to the model based on incremental 2000-2010 and 2010-2025 population increases using population projections by census block as provided by the Lawrence – Douglas County Planning Office. A per-capita water use rate of 75 gpcd was then applied to the incremental growth to produce incremental residential demands.

Service level specific residential to non-residential ratios were used to calculate the increase in non-residential demands in each service level. Future non-residential demand increases were then allocated to the model by consulting land use maps provided by the City in combination with previously discussed assumptions and anticipated development patterns. Incremental non-residential demand increases by service level were distributed strictly to nodes within that same service level.

Future unaccounted-for demand increases were allocated to the model based on a design unaccounted-for demand of 5 percent of the total water use. Unaccounted-for water increases were allocated to nodes with residential on non-residential demand increases at a value equal to 5 percent of the total increased demand.

2.3 Model Calibration

2.3.1 Steady State Calibration

The maximum hour demand that occurred between 7:00 am and 8:00 am on August 28, 2000 was selected for steady state calibration of the water distribution system computer model.

Historical peaking factors by user class were determined for the two service levels for the calibration hour. Peaking factors by use class for each service level were then applied (in the demand allocation spreadsheet) to the base year allocation to achieve the calibration maximum hour condition. The peaking factors used, the resulting comparison of modeled maximum hour demands by service level to actual maximum hour demands by service level, are provided in Appendix D – Model Calibration Memorandum. The computer model was run with the allocated demands and peaking factors. The results of the calibration analysis are also provided in the Appendix D memorandum.

2.3.1.1 Kaw WTP High Service Pumps to West Hills

The Kaw WTP high service pumps that pump to the West Hills Service Level are rated 1.5 mgd at 350-feet of total dynamic head (TDH). Field test pump curves dated September 1956 were provided by the City for these pumps.

Review of circular chart data revealed that typically with one pump operating, only about 1.2 mgd is delivered to the West Hills distribution system. With two pumps operating about 2.4 mgd is typically delivered, and with three pumps operating, about 3.5 mgd is typically delivered.

The pump suction conditions are established by the Kaw WTP clearwell which has an overflow elevation of 845 feet and a bottom elevation of 830 feet. The typical discharge pressure is 140 psi to 145 psi at the discharge header which has an elevation of about 835 feet. The typical discharge hydraulic gradient is about 1170 feet. Therefore, the pumps are typically operating at a TDH of about 325 feet.

It appears that the Kaw WTP high service pumps to West Hills do not have the capacity shown on the 1956 field test pump curves. A modified pump curve was used in the computer model to represent the Kaw WTP to West Hills high service pumps. A comparison of the field test data and the curve used in the computer model is shown on Figure IV-2.

2.3.2 Extended Period Simulation (EPS) Analysis

The computer hydraulic model was configured to conduct extended period simulation (EPS) analyses. The EPS model was verified by simulating the conditions that occurred on August 28, 2000.

The EPS model was calibrated to a 24-hour period, in 1-hour increments, to simulate demand and operational conditions that occurred on August 28, 2000. The steps for developing the EPS model are provided in Appendix D – Model Calibration Memorandum.

Hourly peaking factors were developed for each service level and were applied (in the computer model) to the allocated "design" sales and unaccounted-for water to achieve the hourly demands for each hour during the August 28, 2000 Maximum Day scenario.

The same peaking factor was used for all demand classes in the computer model. The diurnal curves used for the EPS analysis are also provided in Appendix D.

The pump curve data used in for the final steady state analysis was also used for the EPS calibration analysis. In addition, operational and demand controls were used to simulate the conditions that occurred over the 24-hour period. The operational and demand controls are discussed in detail in Appendix D.

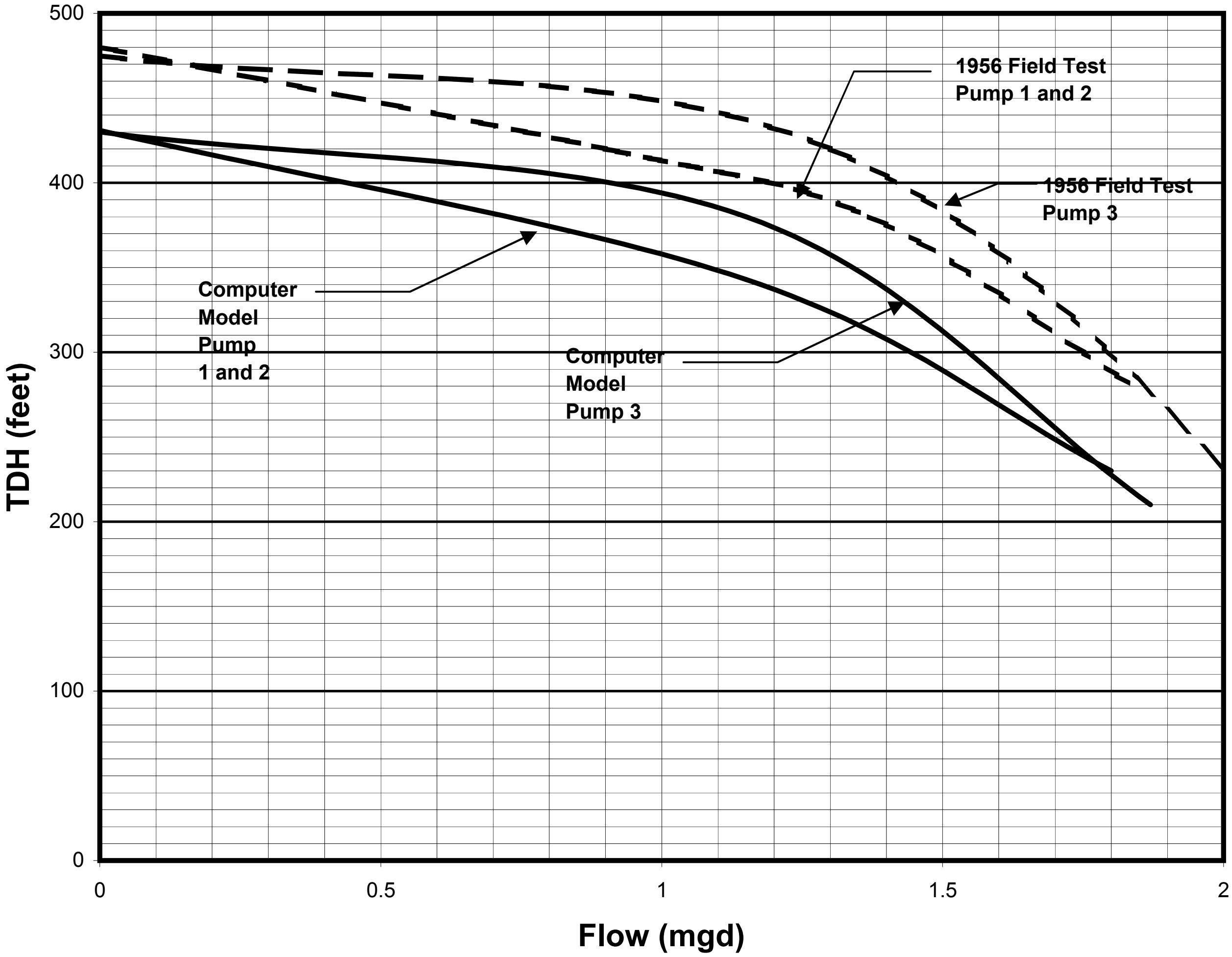
The modeled operation of each facility was reviewed for reasonableness and compared with SCADA data. Adjustments or corrections to the operations control statements were made as necessary. The final model closely simulated actual operation and resulted in normal pump operations and fluctuations in reservoir levels during the day.

Graphs showing the comparison of model results to the SCADA data for the day of the verification analysis are provided in Appendix D. The graphs show recorded flows and tank levels versus recorded data for the 24-hour period. The graphs indicate a good correlation between the recorded (circular chart) and modeled flows and water levels.

2.3.3 Conclusion

The steady state calibration analysis closely matched the recorded conditions that occurred in the distribution system. The EPS verified that the computer model is able to simulate the variable system hydraulics that occur over extended time periods.

The results of these analyses verify that the computer model created for this project is accurate and should prove to be a reliable tool for evaluating existing and projected conditions in the distribution system.



NOTES:

Field test data for Kaw WTP to West Hills high service pumps provided by City. Field tests dated September 1956.

Pump curves used in computer model for Kaw WTP to West Hills based on review of historical circular chart data.

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Kaw WTP to West Hills High Service Pumps

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Figure IV-2

2.4 Analyses of Future Conditions

The calibrated hydraulic model was used to evaluate a number of future condition scenarios. These included the maximum day, maximum and storage replenishment for existing "base year" conditions, and plan years 2010, and 2025. Vulnerability and fire flow analyses were also conducted.

A discussion of the analyses of future conditions in a separate chapter. Hydraulic analyses results plots, tables and an electronic copy of the hydraulic model data files are provided as a separately bound appendix "WaterCAD Hydraulic Model".

2.5 Future Use of EPS Model

The EPS model is a detailed system model containing most of the pipe volume within the distribution system. As such, the model should be useful for City personnel for identifying areas of potential high water age, and for evaluated future customer specific issues. The EPS model prepared for this study is the next step in developing an accurate hydraulic analysis tool that can be further enhanced and used to evaluate system operations, energy use, water quality, and vulnerability assessments.

Water age is defined as the time it takes the water to reach the customer's tap after leaving the initial source of supply. Water age can be modeled with computer model running in EPS mode. The water age at a certain point in the distribution system is calculated from the flow-weighted average of travel times along the various flow paths from the source. Water age is also affected by retention of water in storage reservoirs. Since high water age corresponds to extended periods of time in the distribution system for various reactions to occur, water age is modeled as a general parameter to evaluate potential water quality deterioration in the water networks.

2.5.1 Minimum Day Demands

The historical minimum day demands were evaluated for this study. Design minimum day demands can be used to evaluate maximum water age in the distribution system.

Diurnal curves were developed for each service level, for the day before, the day of and the day after minimum system demand for 2000 and 2001. These curves were used to create a normalized system curve to be used for future extended period simulation (EPS) computer modeling. The EPS analysis can be used to calculate maximum water age in the distribution system. Minimum day diurnal demand curves for each of the six days of minimum demand, for each service level, and for the total system, are provided in Appendix 2.

The average demand for each service level over the twelve days of minimum demand was calculated as shown in Table IV-4.

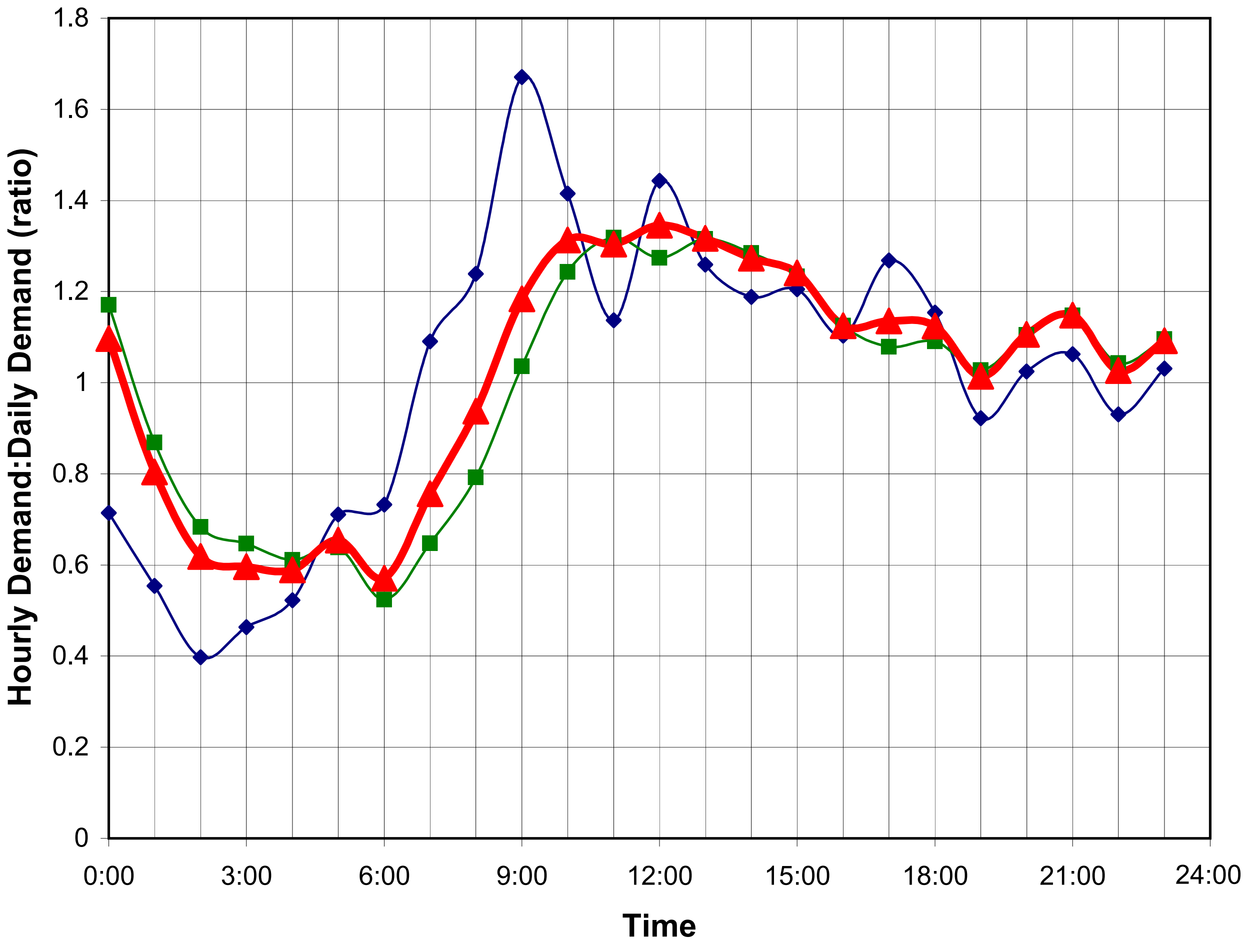
Table IV-4
Average Minimum Demand by Service Level (mgd)

Central Service	West Hills	Total
6.13	2.17	8.30

Average minimum demand for 6 days of minimum demand including the day before, the day of, and the day after the day of minimum demand for 2000 and 2001.

A single design demand curve was developed by averaging the hourly-normalized demands for each service level. Average normalized diurnal minimum day curves are shown on Figure IV-3. The design hourly-demand to daily-demand ratios (minimum day hourly peaking factors) for future EPS analysis are shown on Figure IV-4.

The design hourly demand ratios can be applied to the average of the minimum demands for each service level to determine the hourly minimum demands by service level. The calculated design minimum day hourly demands by service level are shown on Figure IV-5.



Normalized curves for each service level were created by averaging the normalized demand for each hour for six days of record consisting of the day before, the day of, and the day after minimum day demand for 2000 and 2001.

Normalized curve for system total reflects a wieghted average of the normalized curves for each service level.

Legend

- West Hills
- Central Service
- System Total

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Minimum Day Normalized Hourly Demand Curves

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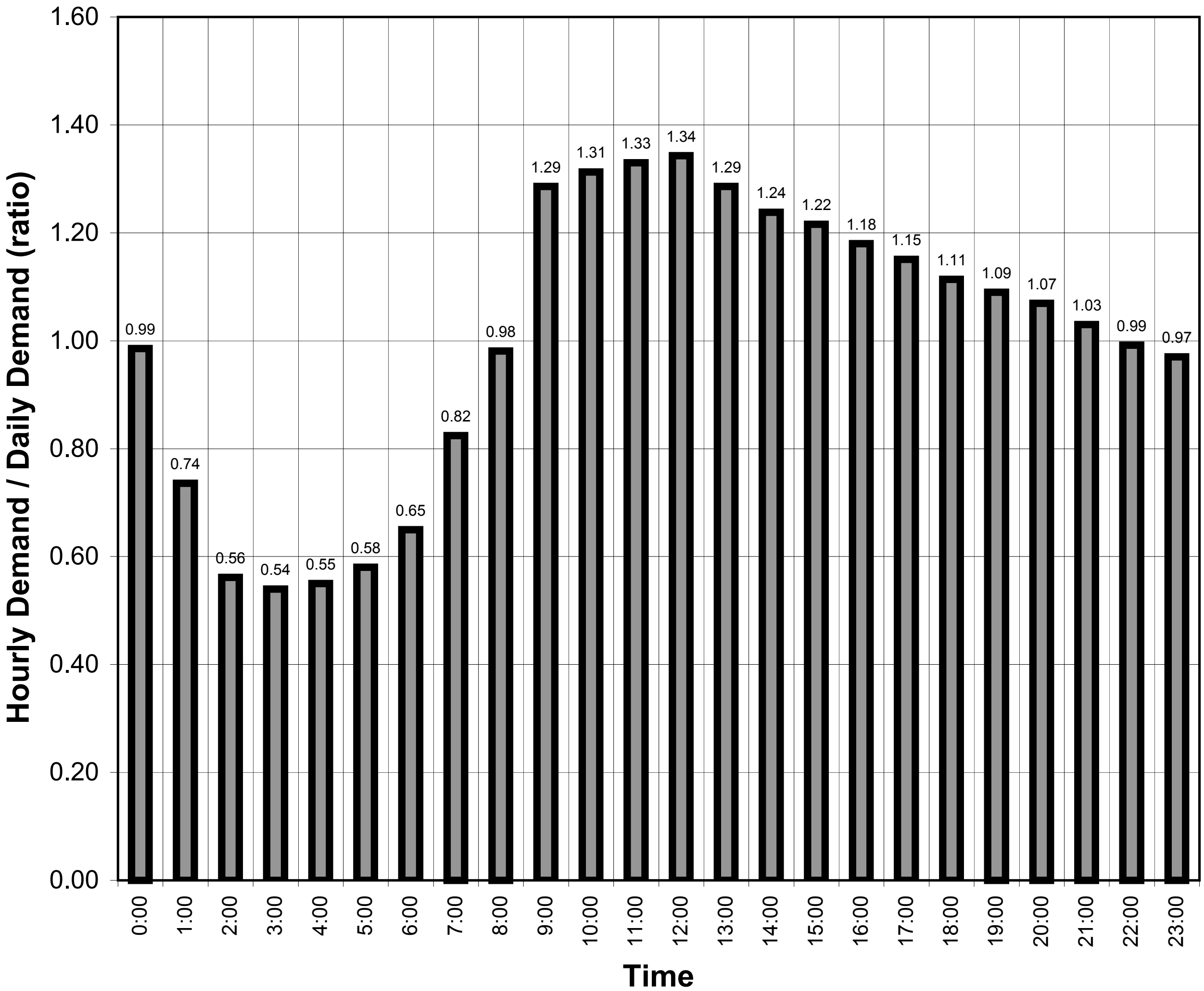
Figure IV-3



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Minimum Day Design Hourly Peaking Factors

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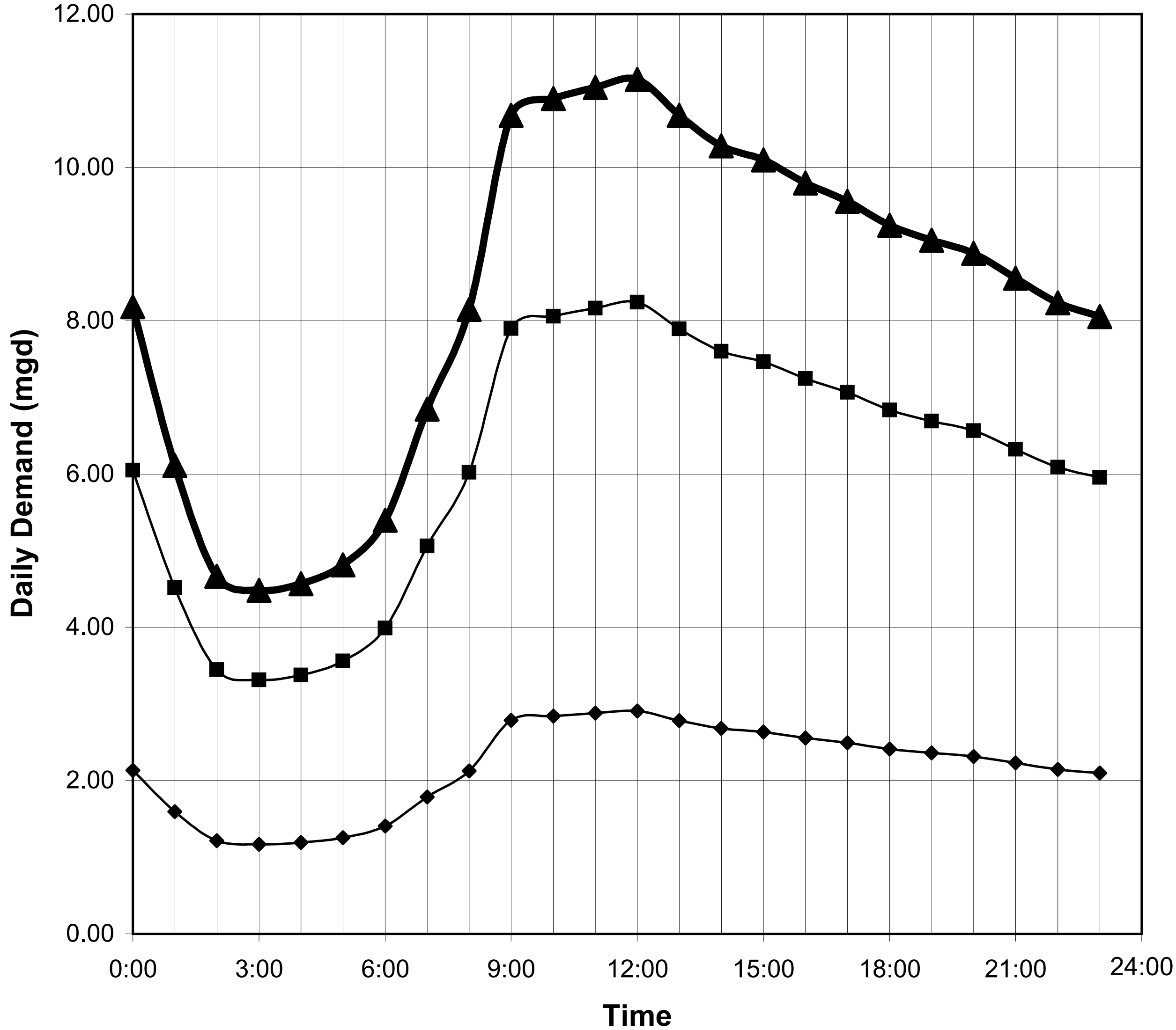
Figure IV-4



Legend

- System Total
- Central Service
- West Hills

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Water System Master Plan
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Minimum Day
Design Hourly Demands

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Figure IV-5

SECTION V - ALTERNATIVES EVALUATION

1.0 Alternatives Evaluation

1.1 Introduction

This section addresses the water supply, treatment, and distribution system improvements required for the City of Lawrence's water system to reliably meet the increased demands and regulatory requirements through the Year 2025.

Section I of this report identifies the need to produce 49.6 mgd on a maximum day basis to meet system demands. For constructability purposes, a demand of 50 mgd will be utilized. This 50 mgd includes unaccounted-for water in the distribution system, or the difference between finished production and metered metered sales. The water supply systems may need to be expanded slightly ahead of the demand curve due to an additional estimated 5 percent to 10 percent water loss during production. This loss is due to internal plant uses such as basin blowdown.

The development of alternatives to meet this demand was based on expansion of the existing water treatment facilities, since they comprise a large portion of the sunk capital costs invested by the City of Lawrence as it has grown over the years. Other alternatives, including consideration of a third water treatment plant located in the vicinity of the Kansas River northeast and west of the City were considered, but were discounted and are not included in this report due to the need to develop a new site and staff a third plant.

Table V-1 summarizes the existing WTP capacities and alternatives analyzed.

Table V-1
WTP Capacities and Alternatives

Facility	Existing Capacity (mgd)	Alternative 1 (mgd)	Alternative 2 (mgd)
Kaw WTP	17.5	25	17.5
Clinton WTP	15	25	32.5
Total	**32.5**	**50**	**50**

These alternatives were selected to optimize the use of the existing facilities and the remaining portions of this section address the improvements and costs necessary for the City of Lawrence to supply, treat, and distribute water to the Year 2025 study area.

1.2 Capital Costs Development

All capital costs presented within this report have been developed from previous Black & Veatch projects of similar size and scope. All capital cost for distribution 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 supply and treatment related improvements include a 25 percent allowance for contingencies and 20 percent allowance for engineering, legal and administrative costs.

1.3 Alternative 1

Alternative 1 focuses on the expansion of both the Kaw and Clinton WTP to 25 mgd each to meet the future demands.

1.3.1 Water Supply

The following paragraphs summarize the raw water supply improvements required to provide 25 mgd of firm capacity to the Kaw and Clinton WTP's respectively.

1.3.1.1 Kaw WTP

As discussed in Section II, the firm capacity of the existing intake and vertical wells at Kaw WTP is approximately 16 mgd. Therefore, reliability improvements are required to upgrade the firm capacity of the raw water supply system to 17.5 mgd to be compatible with the WTP capacity. In May 2000, Black & Veatch completed an evaluation of the River Intake System Reliability. The letter report identified a 30-inch parallel siphon, as shown on Figure V-1, to increase the firm capacity of the intake system. In addition, all of the pumps at Low Service Pumping Station No. 2 (LSPS No. 2) should be replaced with five units rated at 3,050 gpm at approximately 75 feet head to provide total and firm pumping capacity. We have also evaluated replacing the section of 24 inch raw water piping in the alley leading to the chemical dock, but that section of piping only provides approximately three to five feet of additional head loss. Therefore, replacing this piping doesn't appear to provide a significant benefit since the pumps need to be replaced. Table V-2 summarizes the capital cost for the recommended improvements.

Figure V-1 Kaw WTP Siphon

Table V-2 Kaw WTP Parallel Supply Siphon Costs (reliability)	
Component	Cost ($)
General Requirements (10%)	34,000
30 inch Siphon Pipe	186,000
Pump Replacements	150,000
Subtotal	370,000
Contingency (25%)	93,000
Subtotal	463,000
ELA (20%)	93,000
Total	**556,000**

City staff has been planning to install a 16-inch raw water line on the planned replacement of the U.S. Interstate 70 (I-70) bridge over the Kansas River. This main would allow for connection to possible future wells on the north side of the Kansas River near the airport, as would provide for increased supply reliability. Table V-3 summarizes the capital costs for this reliability improvement.

Table V-3 Kaw WTP Bridge Crossing for North Supply Costs (reliability)	
Component	Cost ($)
General Requirements (10%)	14,000
16 inch Raw Water Pipeline on I-70 bridge	125,000
Subtotal	139,000
Contingency (20%)	28,000
Subtotal	167,000
ELA (20%)	33,000
Total	**200,000**

The Bowersock Dam has recently undergone significant maintenance repair. However there are still voids at the southern end of the dam that should be monitored on a routine basis to observe the rate of erosion of the concrete face. The condition of the maintenance work and movement of the riprap providing downstream support to the new sheet piling driven on the downstream face of the dam should also be monitored. Several benchmarks should also be established on the dam to monitor if there is any horizontal or vertical movement of the dam. The City should plan on inspecting the dam on a routine basis and plan budgeting for miscellaneous repairs of the 100+ year old structure on a routine basis to ensure that the dam remains as a viable feature of the City's raw water supply system. Additional surface water supply or a new groundwater supply would be required at the Kaw WTP to expand the raw water supply system to 25 mgd.

During review meetings with Staff, the potential for new vertical wells in the vicinity of the airport were discussed. This appears to be the only viable locations for new wells in the vicinity of the Kaw WTP. A highly productive aquifer is located in this area (Fader, 1974). However, the DWR has indicated that no addition water rights are available. To develop a new wellfield, existing water rights would need to be purchased; therefore, this alternative was not developed further since the City already has established a new surface water right on the Kansas River.

The May 2000 River Intake Reliability study evaluated the feasibility of replacing one of the out-of-service crib intakes with a new one to expand the reliability of the raw water system. This alternative has been modified to add 7.5 mgd of firm capacity to the raw water supply system to increase the total reliable water supply to 25 mgd. This alternative includes constructing a second intake crib with a new 24-inch raw water supply line to convey water to the trash well. From there, the water would be pumped through the upgraded Low Service Pumping Station No. 1 (LSPS No. 1) through a new 24-inch raw water transmission line to convey the water to the new treatment train. Required upgrades at LSPS #1 include replacing the pumps, electrical equipment, HVAC, and instrumentation and controls. Table V-4 summarizes the capital costs to expand the Kaw raw water supply system.

Table V-4
Kaw WTP Supply Expansion Costs (growth)

Component	Cost ($)
General Requirements (10%)	191,000
Intake Crib and Raw Water Line	1,716,000
LSPS #1 Pumps	90,000
24 inch Raw Water Supply Line	108,000
Subtotal	2,105,000
HVAC (7%)	147,000
Electrical & I&C (20%)	421,000
Subtotal	2,673,000
Contingency (25%)	668,000
Subtotal	3,341,000
ELA (20%)	668,000
Total	**4,009,000**

1.3.1.2 Clinton WTP

No reliability improvements are currently required for the Clinton WTP supply. Growth related improvements are required to develop a firm supply to the plant of 25 mgd.

The firm capacity of the raw water pumping station is 20 mgd at conservation pool elevation and 15 mgd at the projected drought water surface elevation. This pumping configuration maximizes the use of the existing power feed to the pumping station. In order to provide a firm pumping capacity of 25 mgd at the projected drought water surface elevation, all of the pumping units would need to be replaced with units rated at approximately 180 feet of head. Therefore, three 10 mgd units and one 5 mgd unit would be required. It was also assumed that one of the 10 mgd units and the 5 mgd unit would be equipped with adjustable frequency drives to provide pumping flexibility in meeting demands.

Table V-5 summarizes the capital cost to increase the pumping capacity and electrical improvements needed at the raw water pumping station.

Table V-5
Clinton WTP Supply Expansion Costs (growth)
Three New Pumps

Component	Cost ($)
General Requirements (10%)	55,000
Pump Replacement	224,000
Adjustable Frequency Drives	75,000
Electrical Gear Replacement	250,000
Subtotal	604,000
HVAC (7%)	42,000
Electrical & I&C (20%)	121,000
Subtotal	767,000
Contingency (25%)	192,000
Subtotal	959,000
ELA (20%)	192,000
Total	**1,151,000**

Another option for providing 25 mgd firm pumping capacity would be to remove one of the 5 mgd pumps and install a third 10 mgd pumping unit, along with a parallel raw water supply line from the raw water pumping station to the Clinton WTP. The parallel line would reduce the dynamic system losses and potentially allow the use of the existing pumping units. This option provides more redundancy and reliability as the

Clinton WTP capacity is expanded and relied upon more heavily to meet demands. Table V-6 summarizes the capital cost for this alternative.

Table V-6
Clinton WTP Supply Expansion Costs (growth)
New Supply Line

Component	Cost ($)
General Requirements (10%)	165,000
Pump Replacement	48,000
24" Raw Water Supply Line	1,620,000
Subtotal	1,833,000
HVAC (7% of Pump Costs)	4,000
Electrical & I&C (20% of Pump Costs)	10,000
Subtotal	1,847,000
Contingency (20%)	369,000
Subtotal	2,216,000
ELA (20%)	443,000
Total	**2,659,000**

Since the pump removal and replacement option summarized in Table V-5 is more economical, it is the recommended supply improvement.

As discussed in Section II, the City should also monitor the Kansas Water Office's evaluations of other applications for use of water from Clinton Reservoir. If they further reduce the permitted withdrawals for the City, the ability of the reservoir to supply 25 mgd during peak demand periods could be limited.

1.3.2 Water Treatment

1.3.2.1 Kaw WTP

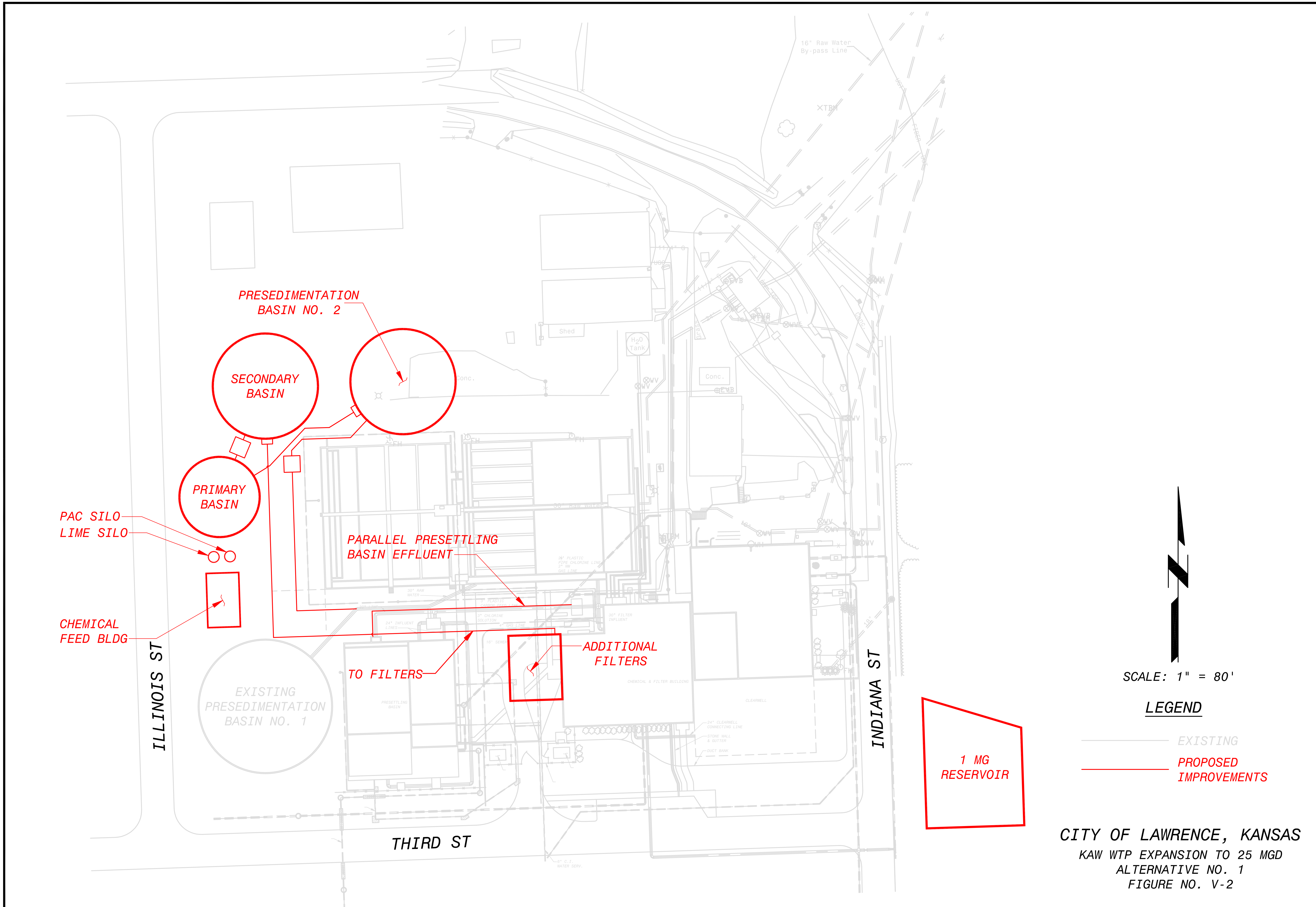
The following outlines the necessary improvements to expand the Kaw WTP by 7.5 mgd to 25 mgd. The improvements are broken down by reliability, growth, and regulatory improvements.

In order to expand the Kaw WTP from 17.5 mgd to 25 mgd, a new 7.5 mgd treatment train could be added to the north of the existing basins. New circular presedimentation, primary, and secondary basins could be utilized to provide the additional treatment processes similar to the facilities utilized at the Clinton WTP. Circular basins were selected over rectangular basins because circular softening equipment is more efficient at reducing hardness and settling out precipitate than rectangular basins.

Additional filtration capacity is also needed to increase the plant capacity. It appears that the most viable option to increasing the filter capacity is to construct two more filters west of the existing filters 5 through 8. The filter boxes could be sized to provide the exact capacity, but for reliability purposes, it would be prudent to construct the two new filters as the same size as the adjacent filters, providing an additional capacity of 7.8 mgd at a loading rate of 4 gpm/sf.

A new 1 MGal below grade treated water storage reservoir should also be constructed to provide additional storage capacity at the site to allow for plant operations to vary from production rates. In addition to these improvements, new chemical feed facilities would need to be constructed to accommodate the increased capacity. The powdered activated carbon and lime would be housed in exterior silos while the other chemicals would be stored and fed from a new Chemical Building. Figure V-2 illustrates the proposed site plan improvements and Figure V-3 reflects the proposed treatment schematic at the Kaw WTP.

In the Water Treatment Section of this report, the Kaw "old" filters were reviewed. These filters are currently used infrequently, but produce high quality water. As the Kaw WTP capacity is increased, additional stress may be added to the "old" filter operation, which may require some modifications including removal and replacement of the media and controls. However, based upon their current performance, this report does not include any costs to upgrade the "old" filters.


PRESEDIMENTATION BASIN NO. 2
SECONDARY BASIN
PRIMARY BASIN
PAC SILO
LIME SILO
CHEMICAL FEED BLDG
PARALLEL PRESETTLING BASIN EFFLUENT
ADDITIONAL FILTERS
TO FILTERS
EXISTING PRESEDIMENTATION BASIN NO. 1
ILLINOIS ST
THIRD ST
INDIANA ST
1 MG RESERVOIR
SCALE: 1" = 80'
LEGEND
EXISTING
PROPOSED IMPROVEMENTS
CITY OF LAWRENCE, KANSAS
KAW WTP EXPANSION TO 25 MGD
ALTERNATIVE NO. 1
FIGURE NO. V-2

STUDY5.DWG

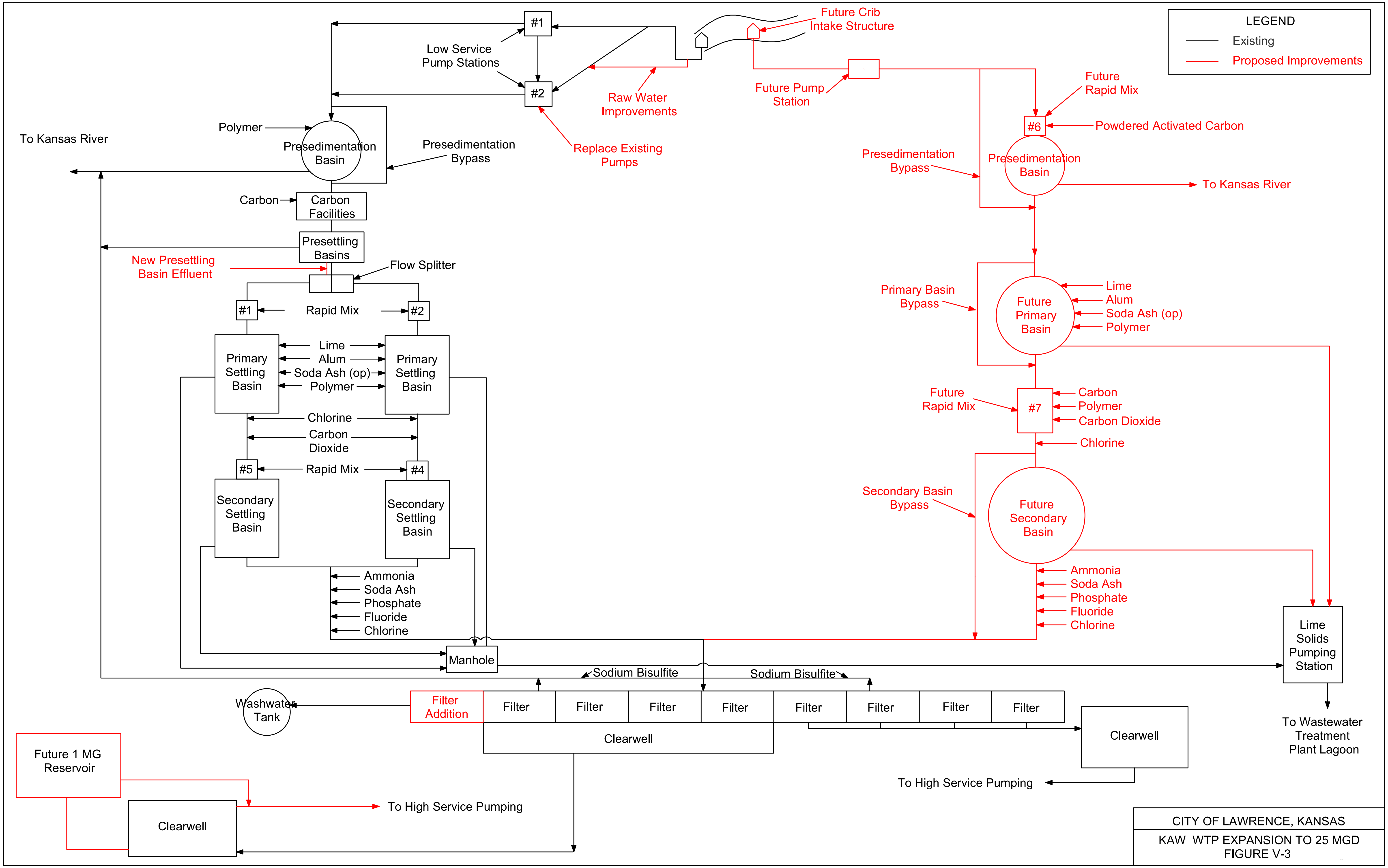

LEGEND
Existing
Proposed Improvements
Future Crib Intake Structure
#1
#2
Low Service Pump Stations
Raw Water Improvements
Replace Existing Pumps
Future Pump Station
Future Rapid Mix
#6
Powdered Activated Carbon
Presedimentation Bypass
Presedimentation Basin
To Kansas River
Polymer
Presedimentation Basin
Presedimentation Bypass
To Kansas River
Carbon
Carbon Facilities
Presettling Basins
New Presettling Basin Effluent
Flow Splitter
#1
Rapid Mix
#2
Primary Settling Basin
Lime
Alum
Soda Ash (op)
Polymer
Primary Settling Basin
Chlorine
Carbon Dioxide
#5
Rapid Mix
#4
Secondary Settling Basin
Secondary Settling Basin
Ammonia
Soda Ash
Phosphate
Fluoride
Chlorine
Primary Basin Bypass
Future Primary Basin
Lime
Alum
Soda Ash (op)
Polymer
Future Rapid Mix
#7
Carbon
Polymer
Carbon Dioxide
Chlorine
Secondary Basin Bypass
Future Secondary Basin
Ammonia
Soda Ash
Phosphate
Fluoride
Chlorine
Manhole
Sodium Bisulfite
Sodium Bisulfite
Lime Solids Pumping Station
To Wastewater Treatment Plant Lagoon
Washwater Tank
Filter Addition
Filter
Filter
Filter
Filter
Filter
Filter
Filter
Filter
Clearwell
Clearwell
To High Service Pumping
Future 1 MG Reservoir
Clearwell
To High Service Pumping
CITY OF LAWRENCE, KANSAS
KAW WTP EXPANSION TO 25 MGD
FIGURE V-3

Table V-7 provides the capital cost for expansion of the Kaw WTP from 17.5 mgd to 25 mgd.

Table V-7
Kaw WTP Expansion Costs (growth)

Component	Cost ($)
General Requirements (10%)	695,000
Sitework	890,000
Presedimentation Basin	743,000
Primary & Secondary Basins	1,650,000
Filters	795,000
Chemical Feed	1,710,000
1 MG Reservoir	1,160,000
Subtotal	7,643,000
HVAC (7%)	535,000
Electrical & I&C (20%)	1,529,000
Subtotal	9,707,000
Contingency (25%)	2,427,000
Subtotal	12,134,000
ELA (20%)	2,427,000
Total	**14,561,000**

As indicated in Section III, the Kaw WTP is well suited to meet the pending and anticipated future regulatory requirements. Depending upon the results of the source water monitoring under the LT2ESWTR for *Cryptosporidium*, additional provisions for oocyst removal and/or inactivation may be required if the concentration exceeds 1.0 cyst per liter. For the purposes of development of a long-term capital improvement program, this report is based upon the assumption that *Cryptosporidium* exceeding 1.0 cyst per liter is found in the Kansas River and UV irradiation following filtration is required to comply with the regulations.

Table V-8 summarizes the capital cost for the addition of UV at the 25 mgd Kaw WTP.

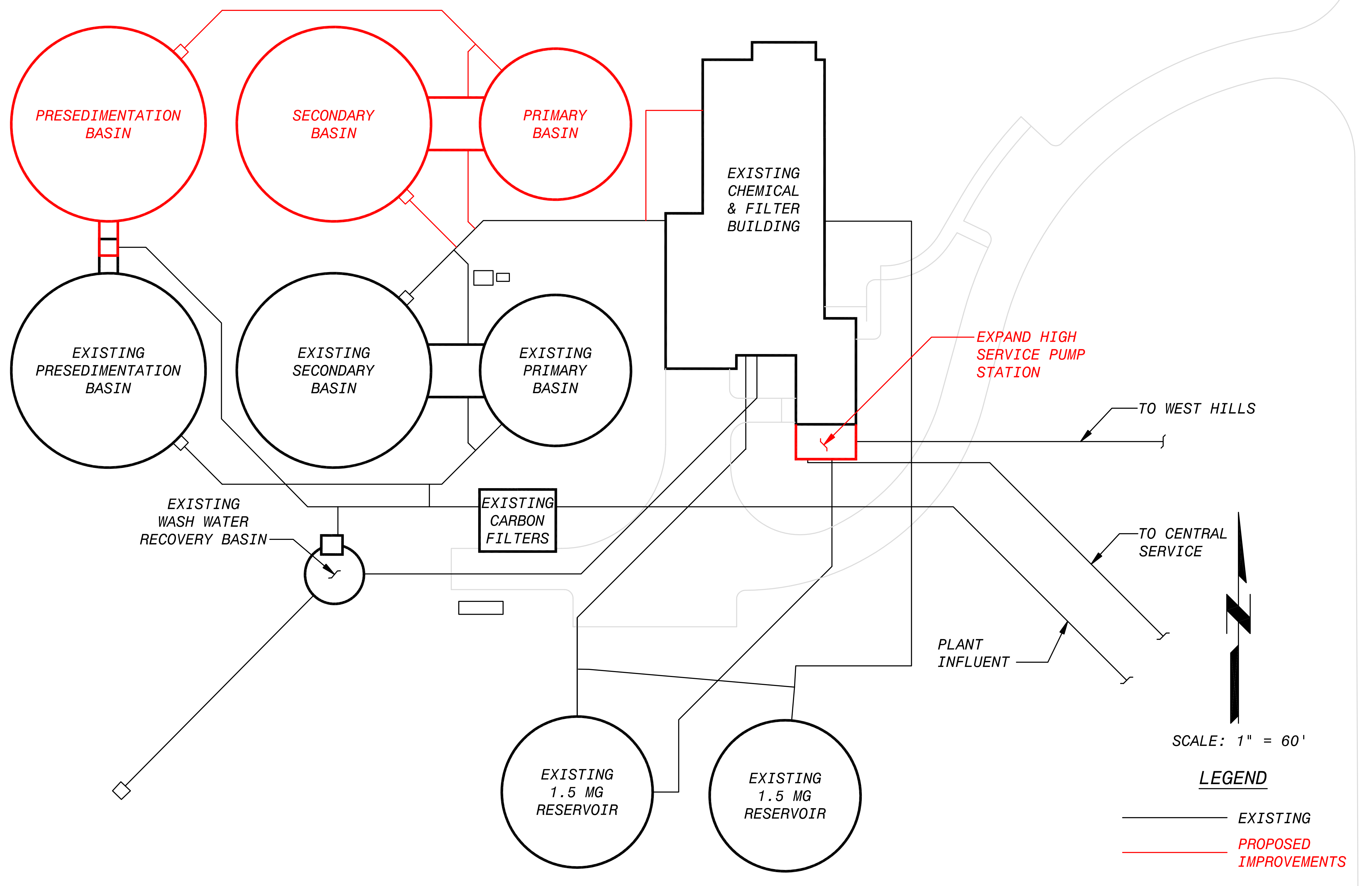
Table V-8 Kaw WTP UV Disinfection Costs (regulatory)	
Component	Cost ($)
General Requirements (10%)	125,000
UV Irradiation	1,250,000
Subtotal	1,375,000
Electrical & I&C (20%)	275,000
Subtotal	1,650,000
Contingency (25%)	413,000
Subtotal	2,063,000
ELA (20%)	413,000
Total	**2,476,000**

1.3.2.2 Clinton Water Treatment Plant

The following outlines the necessary improvements to expand the Clinton WTP from 15 mgd to 25 mgd. The improvements are broken down by reliability, growth, and regulatory costs.

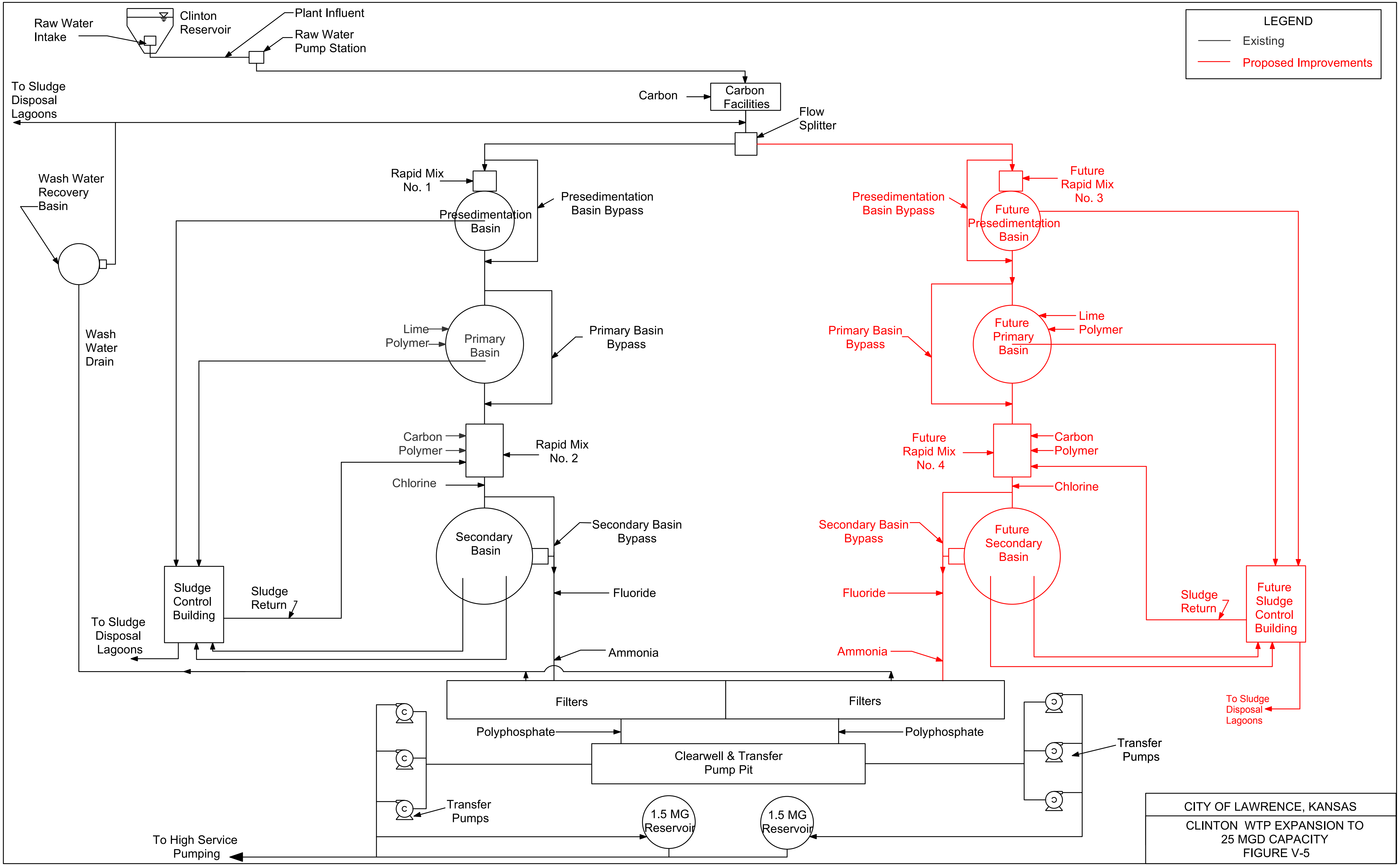
The Clinton WTP was recently expanded and can produce 15 mgd without additional reliability related improvements.

In order to expand the Clinton WTP from 15 mgd to 25 mgd, the only improvements necessary are to construct a new presedimentation basin, primary basin, and secondary basin. The Clinton WTP Expansion project completed in 2002 has already addressed the filtration and transfer pump improvements necessary to process 25 mgd through the WTP. Figure V-4 illustrates the proposed site plan improvements and Figure V-5 reflects the proposed treatment schematic at the Clinton WTP.



CITY OF LAWRENCE, KANSAS
CLINTON WTP EXPANSION TO 25 MGD
ALTERNATIVE NO. 1
FIGURE NO. V-4

STUDY3.DWG



CITY OF LAWRENCE, KANSAS

CLINTON WTP EXPANSION TO 25 MGD CAPACITY

FIGURE V-5

Table V-9 provides the capital cost for expansion of the Clinton WTP from 15 mgd to 25 mgd.

Table V-9
Clinton WTP Expansion Costs (growth)

Component	Cost ($)
General Requirements (10%)	399,000
Sitework	760,000
Presedimentation Basin	910,000
Primary & Secondary Basins	2,320,000
Subtotal	4,389,000
Electrical & I&C (20%)	878,000
Subtotal	5,267,000
Contingency (25%)	1,317,000
Subtotal	6,584,000
ELA (20%)	1,317,000
Total	**7,901,000**

Expansion of the high service pumping building is included separately in the table of distribution system costs.

As indicated in Section III, the Clinton WTP is also well suited to meet the pending and the anticipated future regulatory requirements. Depending upon the results of the monitoring requirements under the LT2ESWTR for source water *Cryptosporidium*, additional provisions for oocyst removal and/or inactivation may be required if the source water concentration exceeds 1.0 cyst per liter. For the purposes of development of a long-term capital improvement program, this report is based upon the assumption that *Cryptosporidium* exceeding 1.0 cysts per liter is found in Clinton Reservoir and UV irradiation following filtration is required to comply with the regulations.

Table V-10 summarizes the capital cost for the addition of UV at the 25 mgd Clinton WTP.

Table V-10 Clinton WTP UV Disinfection Costs (regulatory)	
Component	Cost ($)
General Requirements (10%)	125,000
UV Irradiation	1,250,000
Subtotal	1,375,000
Electrical & I&C (20%)	275,000
Subtotal	1,650,000
Contingency (25%)	413,000
Subtotal	2,063,000
ELA (20%)	413,000
Total	**2,476,000**

1.3.3 Distribution System

An initial series of analyses was conducted under year 2025 design demands, and including main improvements required serving the year 2025 service limits. Preliminary distribution system improvements were developed for each of the treatment plant expansion alternatives on the basis of meeting year 2025 maximum day demands. Preliminary costs were developed for each alternative.

For analyses of both alternatives, there were similarities as summarized below:

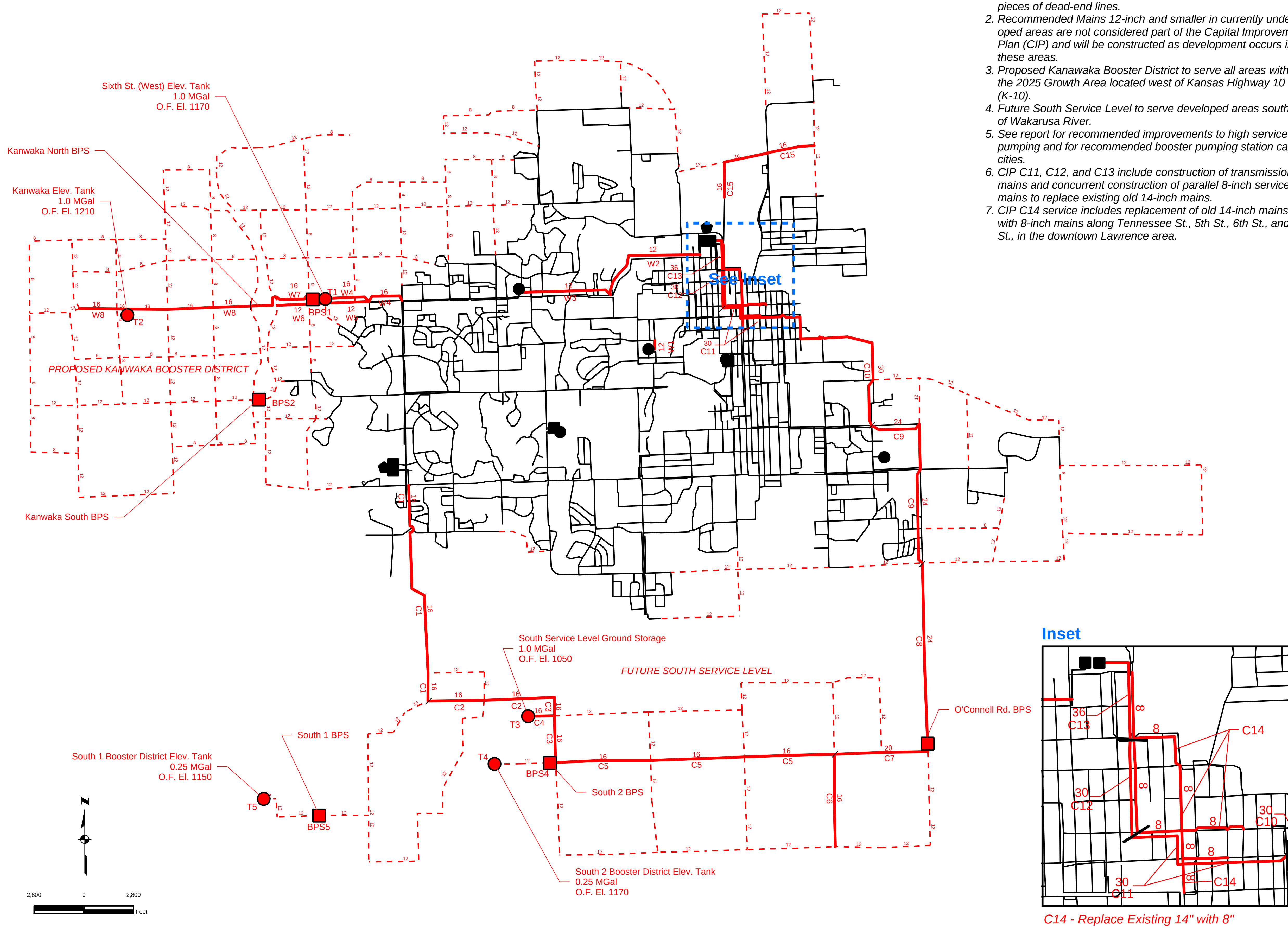
- Storage requirements by service level are identical for both alternatives.
- The Kawaka Booster District would be supplied by two pumping stations for reliability and redundancy. For both alternatives, a major pumping station capable of delivering the entire year 2025 maximum day demand of 3.3 mgd would be located along 6th Street and is referred to as the "Kanwaka North BPS", and a second smaller pumping station with a firm capacity of about 0.75 mgd would be located along 15th Street and is referred to as the "Kanwaka South BPS".
- As discussed in the Section IV, the Kaw WTP high service pumps to the West Hills Service Level do not appear to have the capacity identified in the 1956 field tests. For these analyses, it was assumed that for reliability, the pumps would be replaced with units that would provide 1.5 mgd capacity each, for a total capacity at Kaw WTP to West Hills Service Level of 4.5 mgd.

The Alternative 1 analysis was based on expanding the Clinton WTP to 25 mgd and the Kaw WTP to 25 mgd to meet year 2025 maximum day demands. The major components of the distribution system improvements required for this alternative are summarized below:

- The future South Service Level (including South 1 and South 2 Booster Districts) would receive a majority of supply (about 7 mgd) from a booster pumping station located along O'Connell Road near the Wakarusa River (O'Connell Road Booster Pumping Station). Additional supply of about 2.5 mgd would be delivered by new 16-inch main (Main C1) running south from the Clinton WTP. Other required main improvements to serve the South Service Level are shown on Figure V-6.
- Additional transmission capacity as summarized below is required to deliver water from the Kaw WTP to the distribution system.
  - For the Central Service Level, analyses showed that a major new transmission main would be required from the expanded Kaw WTP. A new 36-inch main should be constructed from the Kaw WTP south to 5th Street (Main C13), continuing as a 30-inch main south to 8th Street (Main C12), from 5th and Indiana south and east to 9th and New York (Main C11), continuing south and east to 19th Street and Harper Street (Main C10). At 19th and Harper, the main would be reduced to a 24-inch and continue south and east to supply the O'Connell Road Booster Pumping Station (Mains C9 and C8).
  - There are several old 14-inch water mains in the downtown area that were installed between 1886 and 1916 that the City has indicated need to be replaced. Several of these mains would be replaced with 8-inch mains concurrently with the new transmission main from the Kaw Plant. Others would be replaced with new 8-inch mains as a separate project
  - In order to deliver water to the West Hills Service Level without using either the Oread BPS or Kasold BPS, a new 12-inch main would be required from the Kaw WTP to the existing 6th Street Elevated Tank (Main W2 and W3). However, analyses showed that pumping from the Kaw WTP to West Hills could be reduced by utilizing the Oread BPS to deliver about 2 mgd of the maximum day demand to West Hills. The reduced flows from the Kaw WTP of about 2.4 mgd could be delivered through the existing 16-inch main. This mode of operation would eliminate the need to construct approximately 12,500 feet of 12-inch main through existing developed areas and reduce the cost of Alternative 1 by about $1,730,000.
  - A main improvement would be required in the vicinity of the Stratford Elevated Tank (Main W1), to support the Stratford Elevated Tank.

Notes:

1. *Existing mains shown on this exhibit include most 8-inch and larger mains and some 6-inch mains, but may not include short pieces of dead-end lines.*
2. *Recommended Mains 12-inch and smaller in currently undeveloped areas are not considered part of the Capital Improvement Plan (CIP) and will be constructed as development occurs in these areas.*
3. *Proposed Kanawaka Booster District to serve all areas within the 2025 Growth Area located west of Kansas Highway 10 (K-10).*
4. *Future South Service Level to serve developed areas south of Wakarusa River.*
5. *See report for recommended improvements to high service pumping and for recommended booster pumping station capacities.*
6. *CIP C11, C12, and C13 include construction of transmission mains and concurrent construction of parallel 8-inch service mains to replace existing old 14-inch mains.*
7. *CIP C14 service includes replacement of old 14-inch mains with 8-inch mains along Tennessee St., 5th St., 6th St., and 8th St., in the downtown Lawrence area.*



C14 - Replace Existing 14" with 8"

City of Lawrence, Kansas
Water Master Plan
2003

Legend

Recommended Improvements

- 16 / C10 — CIP Main with Number and Diameter (see note 2)
- 12 — Development Main and Diameter
- T1 — Storage Facility with CIP Number
- BPS1 — Pumping Station with CIP Number

Existing Pipes and Facilities

- Water Main
- Storage Facility
- Pumping Station
- Water Treatment Plant

WATER SYSTEM
ALTERNATIVE 1 IMPROVEMENTS
EXPAND KAW WTP

Modified Version - Existing Infrastructure Not Shown

BLACK & VEATCH
Corporation

Figure V-6

- A parallel 16-inch main (Mains W4 and W7) and 12-inch main (Mains W5 and W6) would be located along W. 6th Street to supply the northwest portion of the Central Service Level, and support the proposed 6th Street (West) Elevated Tank and the Kanwaka North BPS (located at the elevated tank site).

- Additional main improvements are shown on Figure V-6.

- High service pumping improvements are required for both the Kaw and Clinton WTP as summarized below:

  - The Kaw WTP to Central high service pumps consists of eight pumps with a firm capacity of 18.8 mgd. Under this alternative, about 22 mgd would be required to be delivered from the Kaw WTP to the Central Service Level. To increase the high service pumping capacity to the Central Service Level, the existing "old" pumps should be replaced with new 3.5 mgd pumps. The resulting installed capacity to the Central Service Level at Kaw WTP would be 26 mgd and the firm rated capacity would be 22.5 mgd.
  - If the Oread BPS or Kasold BPS is not used to help meet maximum day demands in the West Hills Service Level, the Kaw WTP required pumping to West Hills would be about 4.5 mgd. However, use of either of the booster pumping stations would reduce the required flow. Using the Oread BPS reduces the required pumping from the Kaw WTP to West Hills, to about 2.2 mgd. Reducing the flow from Kaw to West Hills also reduces the required main improvements out of Kaw as discussed above. Because of the ability to use the booster pumping stations, and the reduction in main improvements, no additional pumping capacity would be required for the Kaw WTP high service pumping to West Hill Service Level as a growth related improvement. As explained in Chapter IV-2.0, the three units currently deliver only about 1.2 mgd each. For reliability, all three units should be replaced with new units rated 1.5 mgd at 350 feet of total dynamic head.
  - The Clinton WTP high service pumps to the Central Service Level consist of two units rated 2.8 mgd and one unit rated 5.0 mgd. To provide the required firm capacity of about 7.8 mgd, one of the 2.8 mgd units should be replaced with a 5.0 mgd unit.
  - The Clinton WTP high service pumps to the West Hills Service Level consist of three units, each rated 5.0 mgd, providing a firm rated capacity of 10 mgd. A minimum additional capacity of about 8 mgd is required to provide a firm capacity of 18 mgd. Based on review of the existing high service pumping building, a building expansion to the south would be required to house new pumping units. Two new 4 mgd units should be

installed to provide a total rated capacity of 23 mgd and a firm rated capacity of 18 mgd.

Distribution improvements for Alternative 1 are shown on Figure V-6 and summarized in Table V-11.

Table V-11
Alternative I Distribution System Improvements

Water Mains						
CIP	Description	Dia (in.)	Length (ft)	Unit Cost ($/dia*in)	Const. Cost ($)	Capital Cost ($)
C1	Wakarusa Dr	16	12,500	6	1,200,000	1,730,000
C2	N 1170 Road/Kasold Dr	16	7,200	6	690,000	990,000
C3	Kasold Dr	16	3,700	6	360,000	520,000
C4	Supply to Reservoir T3	16	1,500	6	140,000	200,000
C5	N 1100 Road	16	15,900	6	1,530,000	2,200,000
C6	Haskell Ave	16	5,300	6	510,000	730,000
C7	N 1100 Road	20	5,300	6	640,000	920,000
C8	O'Connell Road	24	10,600	6	1,530,000	2,200,000
C9	19th/O'Connell	24	10,600	6	1,530,000	2,200,000
C10	Ninth/Delaware/11th/Harper Rd	30	11,100	6	2,000,000	2,880,000
C11	Eighth/Tennessee/Ninth	30	3,700	8	890,000	1,280,000
C11a	Replace 14" w 8" (with C11)	8	2,500	6	120,000	170,000
C12	Indiana - 5th to 8th	30	1,900	8	460,000	660,000
C12a	Replace 14" w 8" (with C12)	8	1,900	6	90,000	130,000
C13	South From KAW WTP	36	1,700	8	490,000	710,000
C13a	Replace 14" w 8" (with C13)	8	1,500	6	70,000	100,000
C14	Replace 14” w 8" (5th/6th/8th/Tenn)	8	6,500	9	470,000	680,000
C15	Second River Crossing	16	7,200	8	920,000	1,320,000
W1	Stafford ET Support	12	700	8	70,000	100,000
W2	West From Kaw WTP	12	7,100	8	680,000	980,000
W3	To Sixth St (East) ET	12	5,400	8	520,000	750,000
W4	Sixth St - Wakarusa to West ET	16	4,400	6	420,000	600,000
W5	Sixth St - Deer Run to West ET	12	2,600	6	190,000	270,000
W6	Sixth St - West ET to K-10	12	3,500	6	250,000	360,000
W7	Sixth St- West ET to K-10	16	3,900	6	370,000	530,000
W8	Sixth St - Kan Booster	16	9,700	6	930,000	1,340,000
				Total Mains	**17,070,000**	**24,550,000**

Table V-11 Alternative I Distribution System Improvements				
Pumping Stations				
CIP	Description	Installed Capacity (mgd)	Const.Cost ($)	Capital Cost ($)
BPS1	Kanwaka North BPS	5.10	770,000	1,110,000
BPS2	Kanwaka South BPS	1.50	230,000	330,000
BPS3	Haskell Ave BPS	10.50	1,580,000	2,280,000
BPS4	South 1 BPS	2.00	300,000	430,000
BPS5	South 2 BPS	1.50	230,000	330,000
HSKC	Kaw HSP - Central (Old)	14.00	420,000	600,000
HSKW	Kaw HSP – West Hills	4.50	90,000	130,000
HSCW	Clinton HSP - West Hills	8.00	200,000	290,000
HSCC	Clinton HSP – Central/South	5.00	130,000	190,000
HSBA	HSP Building Addition		710,000	1,020,000
		Total Pump Stations	**4,660,000**	**6,710,000**
Flow Control Facilities				
CIP	Description		Const.Cost ($)	Capital Cost ($)
FCV1	Clinton Parkway FCV		200,000	290,000
		Total Flow Control Valves	**200,000**	**290,000**
Storage Facilities				
CIP	Description	Volume (MGal)	Const. Cost ($)	Capital Cost ($)
T1	Sixth Street West ET	1.00	1,000,000	1,440,000
T2	Kanwaka ET	1.00	1,000,000	1,440,000
T3	Central South Ground Storage	1.00	800,000	1,150,000
T4	South 1 Elev Tank	0.25	300,000	430,000
T5	South 2 Elev Tank	0.25	300,000	430,000
		Total Storage	**3,400,000**	**4,890,000**
		Total Alternative 1 Distribution Improvements	**25,330,000**	**36,440,000**

1.3.4 Operations and Maintenance Building

Staff has indicated that a new Operations and Maintenance Building may be required in the future to consolidate distribution system crew activities at a location that is not directly adjacent to a water processing facility, such as the existing situation at the Kaw Water Treatment Plant. A spatial program has not been outlined at this time; however, the following summarizes the space and materials of construction envisioned for the facility at a master planning level of effort:

- Offices, Crew Quarters and Storage (5,000 square feet) – Space for 14 offices in a single level building with a maximum wall height of 20 feet. The structure was assumed to be constructed with a concrete strip foundation and slab-on grade concrete flooring with structural steel framing. The exterior walls would be precast concrete panels. The interior walls would be metal lath with drywall construction for office portioning. The roofing would be a single-ply roofing system on a metal deck supported by open web joists.

- Heated Warehouse Storage (10,000 square feet) – The warehouse storage area would be a stand-alone pre-engineered metal building with metal wall panels and a metal roof with a cast-in-place concrete floor slab supported on strip footings.
- Covered Storage Area for PVC Materials (8,000 square feet) – The covered storage area would consist of a pre-engineered metal building without the wall panels to enclose the storage area with a cast-in-place concrete floor slab supported on strip footings.
- Covered Storage Area for Equipment, Vehicles, and Barricades (8,000 square feet) – The covered storage area would be a pre-engineered metal building with metal wall panels to enclose the storage area with a cast-in-place concrete floor slab supported on strip footings. The building would be approximately 35' tall with a bridge crane to facilitate truck loading and unloading and two drive though truck bays with rolling overhead doors.
- Paved Outdoor Storage (25,000 square feet) – A paved area with a cast-in-place concrete finish would be required for outdoor storage.

The following table provides a summary of the capital cost opinion for this structure. This type of construction is significantly different than municipal water treatment construction; therefore, the multipliers have been adjusted downward to reflect a less complex facility.

Table V-12 Operations and Maintenance Facility Costs	
Component	Cost ($)
General Requirements (8%)	280,000
Sitework (3%)	110,000
Offices, Crew Quarters and Storage	810,000
Heated Warehouse Storage	850,000
Covered Storage Area for PVC Materials	600,000
Covered Storage Area for Equipment, Vehicles, and Barricades	1,120,000
Paved Outdoor Storage	130,000
Electrical, HVAC, & Plumbing	Included Above
Subtotal	3,900,000
Contingency (10%)	390,000
Subtotal	4,290,000
ELA (10%)	429,000
Total	**4,719,000**

1.3.5 Alternative 1 Summary of Costs

Table V-13 summarizes the capital costs for Alternative 1.

Table V-13 Alternative 1 Capital Cost Summary	
Component	Cost ($)
Kaw Raw Water Supply Improvements	
Reliability	756,000
Growth	4,009,000
Clinton Raw Water Supply Improvement	
Reliability	--
Growth	1,151,000
Kaw WTP Improvements	
Reliability	--
Growth	14,561,000
Regulatory	2,476,000
Clinton WTP Improvements	
Reliability	--
Growth	7,901,000
Regulatory	2,476,000
Distribution System Improvements	36,440,000
Operations and Maintenance Building	4,719,000
Total Improvements	**74,489,000**

1.4 Alternative 2

Alternative 2 involves the expansion of only the Clinton WTP to meet the projected demand of 50 mgd. The Kaw WTP would remain at its current capacity of 17.5 mgd, which requires the Clinton WTP to be expanded from 15 mgd to 32.5 mgd.

1.4.1 Water Supply

1.4.1.1 Kaw WTP

The required reliability improvements to expand the firm capacity of the raw water supply system for the Kaw WTP to 17.5 mgd are identical to those described for Alternative 1. The opinion of probable project cost for a 30-inch parallel siphon is $556,000.

1.4.1.2 Clinton WTP

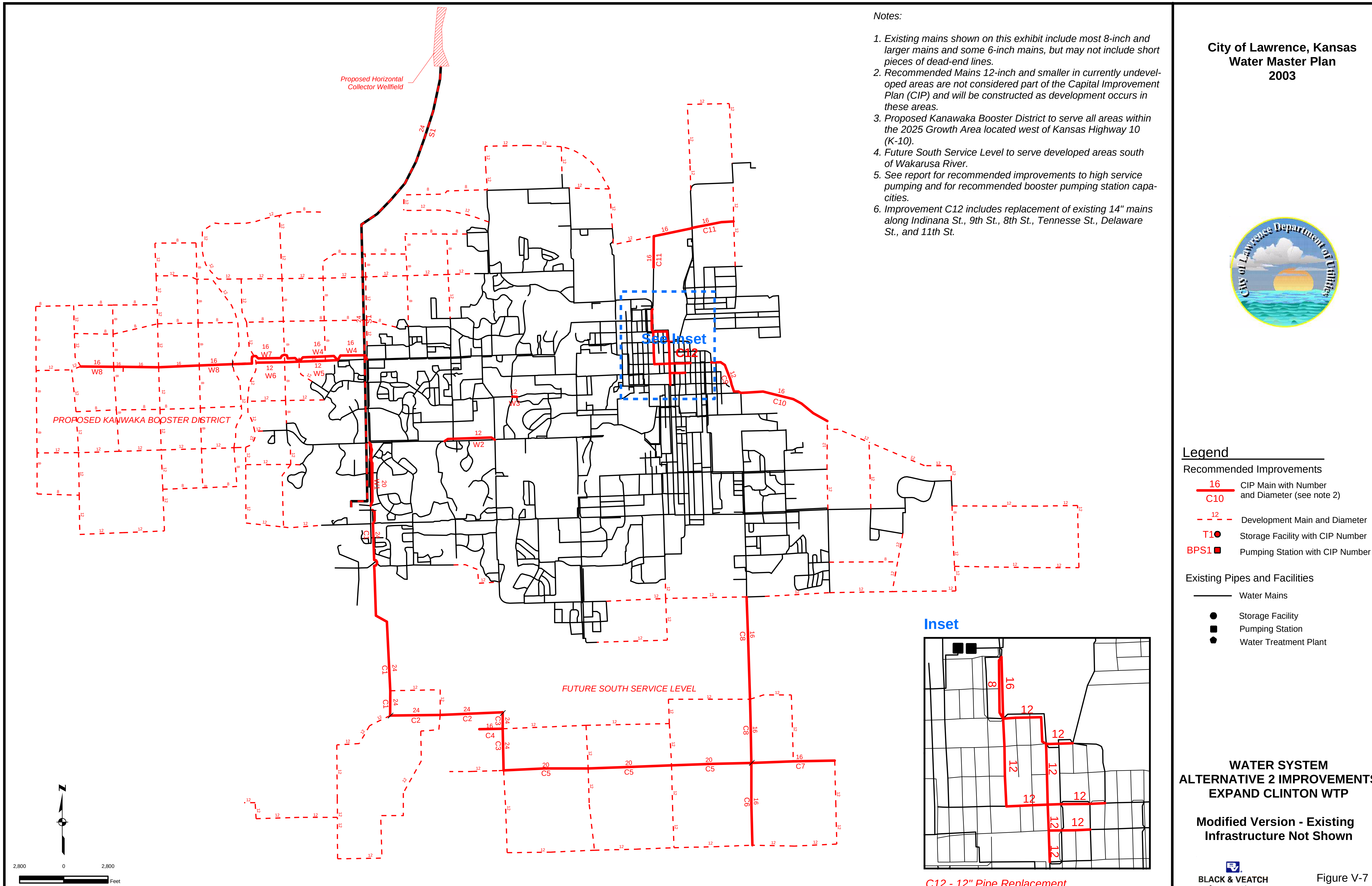
The expansion of the Clinton WTP from 25 mgd to 32.5 mgd will require a two phased expansion to align with the water supplies available to the WTP. As outlined in Section II, the City is currently limited to a maximum diversion of 25 mgd from the Clinton Reservoir. Therefore, the improvements outlined for the Clinton WTP in Alternative 1 would be required to match the treatment capacity with the current maximum diversion of 25 mgd. An additional 7.5 mgd of Kansas River water would need to be conveyed to the Clinton site for treatment.

As previously discussed for Alternative 1, in order to provide a firm pumping capacity of 25 mgd at the projected drought water surface elevation, all of the pumping units would need to be replaced. Three 10 mgd units and one 5 mgd unit would be required. It was also assumed that one of the 10 mgd units and the 5 mgd unit would be equipped with adjustable frequency drives to provide pumping flexibility in meeting demands. The opinion of probable project cost for this alternative is $1,151,000. Also, the City should monitor the State's review of other applications to purchase water from Clinton Reservoir. If approved, the State could reduce the volume of water available to Lawrence and additional surface water may be required.

Several options were considered for providing 7.5 mgd of raw water supply from the Kansas River to the Clinton WTP. Various sites were considered for the supply. Figure V-7 shows a site that is suitable for development of both groundwater and surface water supplies.

Notes:

1. Existing mains shown on this exhibit include most 8-inch and larger mains and some 6-inch mains, but may not include short pieces of dead-end lines.
2. Recommended Mains 12-inch and smaller in currently undeveloped areas are not considered part of the Capital Improvement Plan (CIP) and will be constructed as development occurs in these areas.
3. Proposed Kanawaka Booster District to serve all areas within the 2025 Growth Area located west of Kansas Highway 10 (K-10).
4. Future South Service Level to serve developed areas south of Wakarusa River.
5. See report for recommended improvements to high service pumping and for recommended booster pumping station capacities.
6. Improvement C12 includes replacement of existing 14" mains along Indinana St., 9th St., 8th St., Tennesse St., Delaware St., and 11th St.



City of Lawrence, Kansas
Water Master Plan
2003

WATER SYSTEM
ALTERNATIVE 2 IMPROVEMENTS
EXPAND CLINTON WTP

Modified Version - Existing Infrastructure Not Shown

BLACK & VEATCH Corporation

Figure V-7

Several options are available to divert Kansas River water for conveyance to the Clinton WTP to obtain the additional 7.5 mgd to meet the demand of 32.5 mgd. All options include a 24 inch transmission main to convey water from the raw water supply expansion area to the Clinton WTP. All are located in the expansion area shown on Figure V-7.

- Crib Intake System and Jetty
- Riverbank Intake and Jetty
- Vertical Wellfield
- Collector Wellfield

1.4.1.2.1 Crib Intake System and Jetty. This option would be similar to the existing crib intake systems at the Kaw WTP. The crib would be constructed in a deep portion of the river using cofferdam construction to protect the siphon piping form scour damage. The intake would convey water to a raw water pumping station by gravity. The head required at the raw water pumping station would be approximately 250 feet.

Because the river is shallow, carries a heavy silt load, and is subject to a wide range of flows, a jetty in the river would be required to ensure adequate submergence of the intake and pumps. Recent experience in evaluating a potential new intake for WaterOne of Johnson County has indicated that obtaining a Corps of Engineers permit to build a jetty is very unlikely. Threatened and endangered species' habitats would likely be submerged by a jetty and flood levels would likely increase. Both of these conditions would make obtaining a permit from the Corps of Engineers very difficult and consideration of other options would be required before the Corps would grant a permit.

Table V-14 Clinton WTP Supply - Crib Intake and Jetty Costs (growth)	
Component	Cost ($)
General Requirements (10%)	1,298,000
New Crib and Cofferdam	1,716,000
Jetty	5,200,000
7.5 mgd Pumping Station	1,125,000
24-inch Raw Water Transmission Main	4,942,000
Subtotal	14,281,000
HVAC (7%) (Pump Station Only)	79,000
Electrical & I&C (20%) (Pump Station Only)	225,000
Subtotal	14,585,000
Contingency (25%)	3,646,000
Subtotal	18,231,000
ELA (20%)	3,646,000
Total	**21,877,000**

1.4.1.2.2 River Intake and Jetty. This option would also divert surface water from the Kansas River to the Clinton WTP. An intake on the banks of the river would be constructed instead of a crib. The intake superstructure would house the pumping station. A jetty would still be required to ensure adequate submergence and the water would be conveyed to the Clinton WTP through a 24-inch transmission main. Similar to the crib option, obtaining a permit to construct the jetty is unlikely. The capital costs are summarized in Table V-15**.**

Table V-15 Clinton WTP Supply – Riverbank Intake and Jetty Costs (growth)	
Component	Cost ($)
General Requirements (10%)	1,392,000
Riverbank Intake	3,783,000
Jetty	5,200,000
24-inch Raw Water Transmission Main	4,942,000
Subtotal	15,317,000
HVAC (7%) (Intake Only)	265,000
Electrical & I&C (20%) (Intake Only)	757,000
Subtotal	16,339,000
Contingency (20%)	3,268,000
Subtotal	19,607,000
ELA (20%)	3,921,000
Total	**23,528,000**

1.4.1.2.3 Vertical Wells. The area shown on Figure V-7 appears to be suitable for installation of multiple high capacity vertical wells. Greater than 40 feet of saturated thickness of coarse aquifer materials are present in this area (Fader 1974). Existing wells in the vicinity have capacities of up to 1,000 gpm. However, according to the Division of Water Resources, existing water rights in the area would limit the capacity available. DWR indicated that approximately 1,375 ac-ft (average diversion rate of 1.22 mgd) of water rights remain in this area. Therefore, for a supply of 7.5 mgd to be developed, existing water rights would need to be purchased.

Eight vertical wells would be needed to develop a firm supply of 7.5 mgd. The vertical well pumps would be sized to pump directly to the Clinton WTP without re-pumping. One of the major advantages of vertical wells is that the raw water supply capacity can be expanded incrementally to match demands, which postpones major capital expenditures.

Table V-16 summarizes the capital costs to develop this option.

Table V-16
Clinton WTP Supply - Vertical Wellfield Costs (growth)

Component	Cost ($)
General Requirements (10%)	695,000
Eight Vertical Wells	1,232,000
24-inch Raw Water Transmission Main	5,722,000
Subtotal	7,649,000
HVAC (7%) (Wells Only)	86,000
Electrical & I&C (20%) (Wells Only)	246,000
Subtotal	7,981,000
Contingency (25%)	1,995,000
Subtotal	9,976,000
ELA (20%)	1,995,000
Total	**11,971,000**[(1)]

[(1)]Costs for additional rights not included.

1.4.1.2.4 Collector Wells. The area shown on Figure V-7 also appears to be suitable for installation of multiple horizontal collector wells. Based on the available information, it appears that a single collector could supply the needed 7.5 mgd. The geology appears to be similar to that in the City of Olathe's wellfield and in highly productive areas tested for WaterOne of Johnson County. In these areas, the deposits are coarse sand and gravel with 40 feet or more of saturated thickness. When these conditions are present, yields of 10 mgd can be obtained from a single collector well.

Collector wells typically derive 75 percent or more of their water from infiltrated surface water. Because they derive their water from both groundwater and infiltrated surface water, DWR has permitted collector wells as both surface and groundwater rights. This is advantageous to the City. First, the excess water rights at the Kaw intake could be transferred to this area. This was accomplished in a similar situation for the BPU of Kansas City, Kansas. Second, because most of the water pumped from the collector will be surface water, only a small groundwater right is needed. As previously discussed, the availability of groundwater rights in this area is somewhat limited, but should be adequate to support a 7.5 mgd collector well. Finally, DWR has indicated that a collector well would fall within the KRWAD operating agreements; and therefore, would be assured of having an adequate source of recharge. Table V-17 summarizes the capital costs.

Table V-17
Clinton WTP Supply- Collector Well Costs (growth)

Component	Cost ($)
General Requirements (10%)	677,000
Collector Well	1,825,000
24-inch Raw Water Transmission Main	4,942,000
Subtotal	7,444,000
HVAC (7%) (Collector Only)	175,000
Electrical & I&C (20%) (Collector Only)	500,000
Subtotal	8,119,000
Contingency (25%)	2,030,000
Subtotal	10,149,000
ELA (20%)	2,030,000
Total	**12,179,000**

Since the cost of the multiple vertical wells and one collector well is almost identical, the use of a collector well is recommended because of similar costs and the lack of the need to purchase additional groundwater rights.

1.4.2 Water Treatment

1.4.2.1 Kaw Water Treatment Plant

The Kaw WTP capacity would remain at 17.5. The improvements are broken down by reliability, growth, and regulatory.

The Bowersock Dam has recently undergone significant maintenance repair. However, there are still voids at the southern end of the dam that should be monitored on a routine basis to observe the rate of erosion of the concrete face. The condition of the maintenance work and movement of the riprap providing downstream support to the new sheet piling driven on the downstream face of the dam should also be monitored. Several benchmarks should also be established on the dam to monitor if there is any horizontal or vertical movement of the dam. The City should plan on inspecting the dam on a routine basis and plan budgeting for miscellaneous repairs of the 100+ year old structure.

There are no growth improvements associated with this alternative at the Kaw WTP. As previously noted for Alternative 1, no costs for enhancing the “old” filters at the Kaw WTP have been included based upon current performance.

As previously noted, there may be a need to install UV at the Kaw WTP for compliance with the LT2ESWTR. Table V-18 summarizes the capital cost for the addition of UV at the 17.5 mgd Kaw WTP.

Table V-18
Kaw WTP – UV Disinfection Costs (regulatory)

Component	Cost ($)
General Requirements (10%)	88,000
UV Irradiation	875,000
Subtotal	963,000
Electrical & I&C (20%)	193,000
Subtotal	1,156,000
Contingency (25%)	289,000
Subtotal	1,445,000
ELA (20%)	289,000
Total	**1,734,000**

1.4.2.2 Clinton Water Treatment Plant

The following outlines the necessary improvements to expand the Clinton WTP from 15 mgd to 32.5 mgd. The improvements are broken down by reliability, growth, and regulatory costs. The Clinton WTP was recently expanded and can reliably produce 15 mgd now without additional improvements.

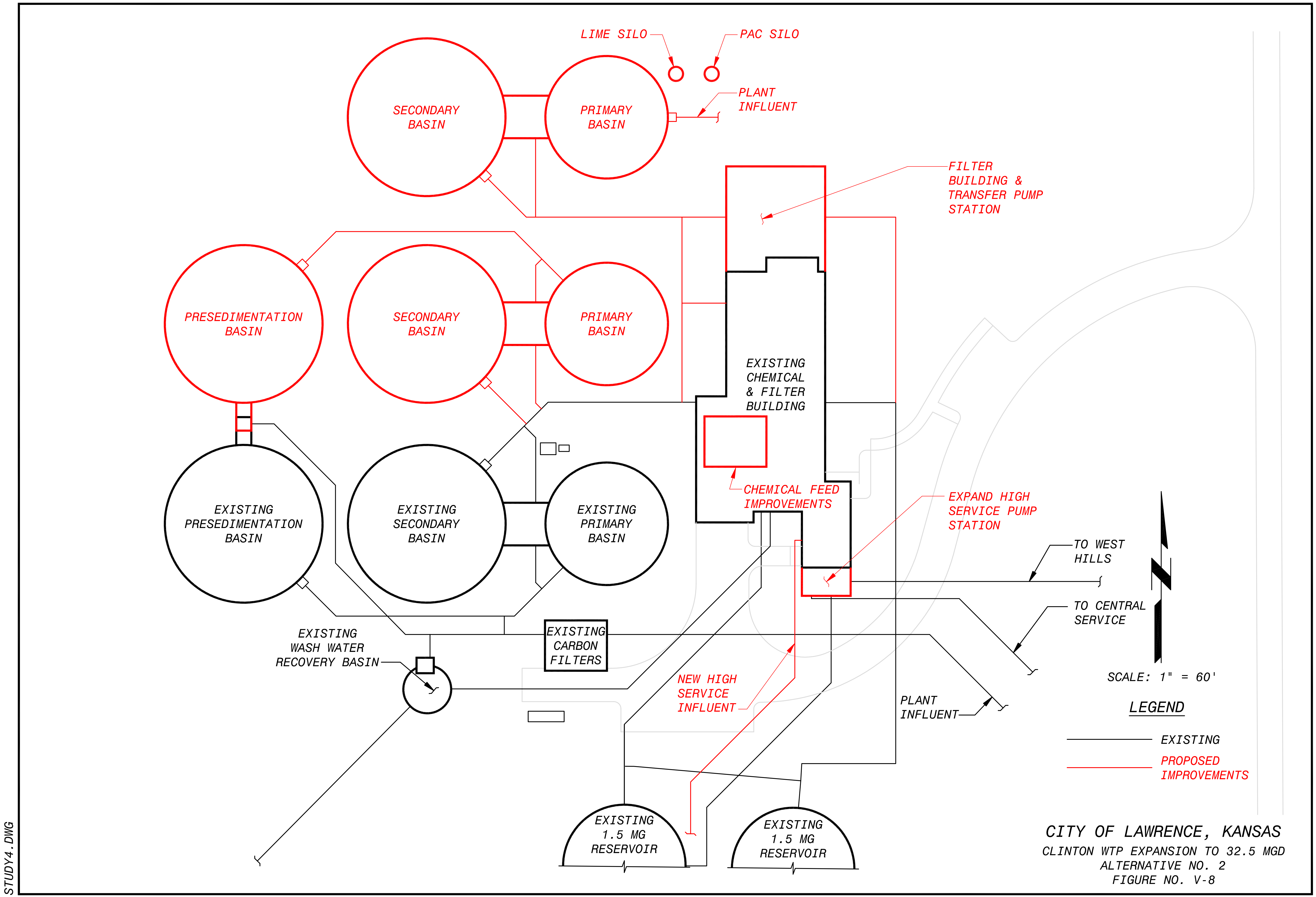
Clinton Reservoir and Kansas River water quality will be substantially different and require significantly different chemical feed dosages to produce a compatible water quality. Therefore, the WTP should be expanded as identified in Alternative 1 to 25 mgd to align the treatment capacity with the supply. A third treatment train should be constructed to allow the river water to be treated separately from the reservoir water. The new river treatment train would include a primary basin, secondary basin, four filters, clearwell, low head transfer pumps, and chemical storage and feed capacity. It was assumed that the expanded chemical feed equipment would be incorporated within the existing building space, with the exception of the powdered activated carbon feed system which would be a silo system similar to Alternative 1. The use of a collector well would offset the need for a presedimentation basin for this treatment train since the water would be withdrawn from the river alluvium.

The Clinton WTP currently has 3.0 MG of treated water storage at the facility, which is approximately 9 percent of the MD design capacity of the WTP. In new designs for treatment facilities where the WTP is designed to meet MD demands, B&V typically includes 5 to 10 percent of the maximum daily plant flow through the WTP. Therefore, this alternative does not include additional storage.

Figure V-8 illustrates the proposed site plan improvements and Figure V-9 reflects the proposed treatment schematic at the Clinton WTP. Table V-19 provides the capital cost for expanding the Clinton WTP to 32.5 mgd.

Table V-19
Clinton WTP Expansion Costs (growth)

Component	Cost ($)
General Requirements (10%)	582,000
Sitework	890,000
Primary & Secondary Basins	1,740,000
Filters, Clearwell, & Transfer Pumps	1,590,000
Chemical Feed	856,000
Subtotal	5,658,000
HVAC (7%)	396,000
Electrical & I&C (20%)	1,132,000
Subtotal	7,186,000
Contingency (25%)	1,797,000
Subtotal	8,983,000
ELA (20%)	1,797,000
Subtotal	10,780,000
Clinton WTP Expansion to 25 mgd	7,901,000
Total	**18,681,000**

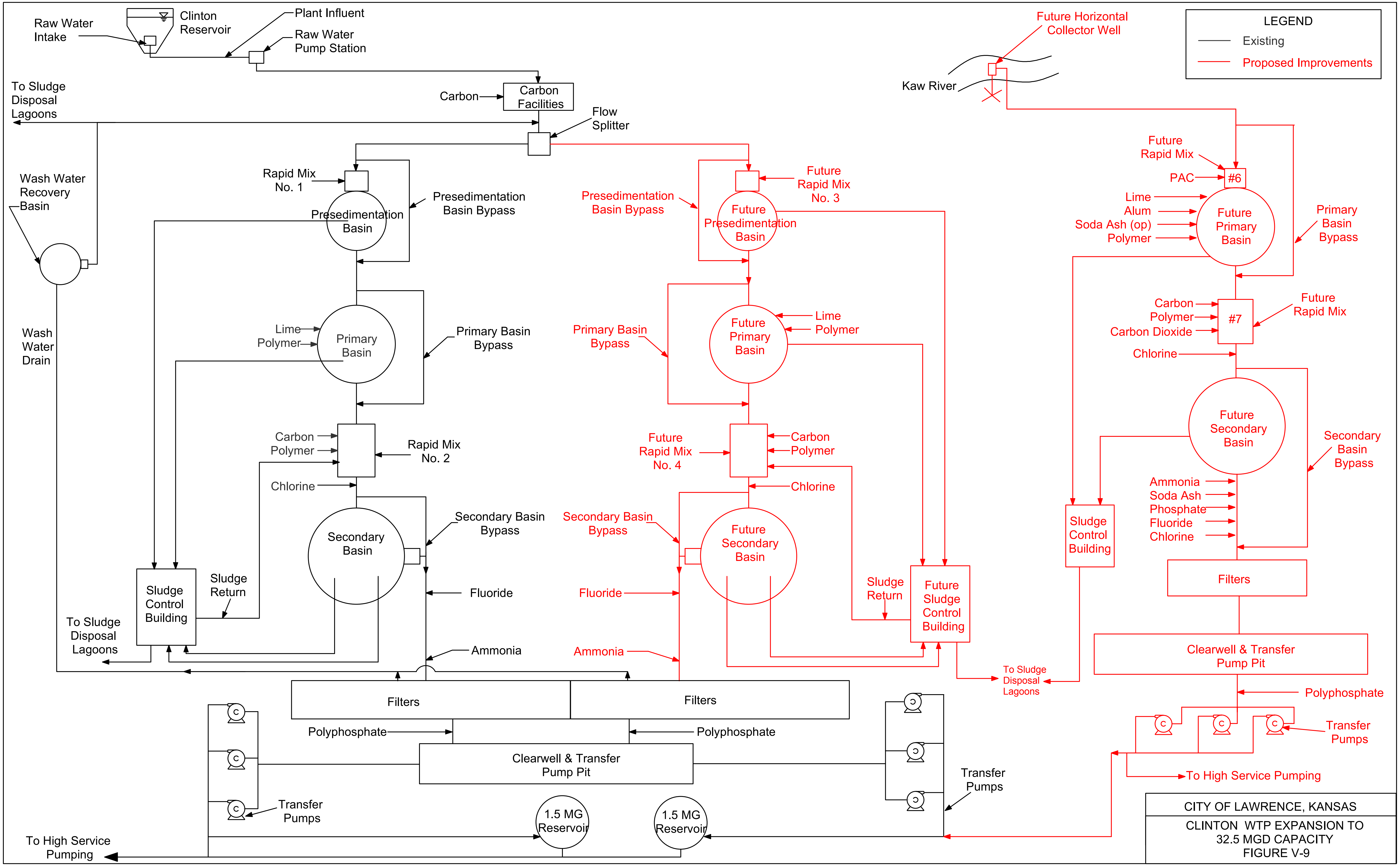


CITY OF LAWRENCE, KANSAS

CLINTON WTP EXPANSION TO 32.5 MGD

ALTERNATIVE NO. 2

FIGURE NO. V-8



CITY OF LAWRENCE, KANSAS
CLINTON WTP EXPANSION TO 32.5 MGD CAPACITY
FIGURE V-9

As previously noted, there may be a need to install UV at the Clinton WTP for compliance with the LT2ESWTR. Table V-20 summarizes the capital cost for the addition of UV at the 32.5 mgd Clinton WTP.

Table V-20
Clinton WTP UV Disinfection Costs (regulatory)

Component	Cost ($)
General Requirements (10%)	163,000
UV Irradiation	1,625,000
Subtotal	1,788,000
Electrical & I&C (20%)	358,000
Subtotal	2,146,000
Contingency (25%)	537,000
Subtotal	2,683,000
ELA (20%)	537,000
Total	**3,220,000**

1.4.3 Distribution System

The Alternative 2 analysis was based on expanding the Clinton WTP to 32.5 mgd and maintaining the Kaw WTP at 17.5 mgd. As discussed in Section 1.3.3 of this chapter, there are similar improvements required for Alternative 1 and Alternative 2. The additional major components of the distribution system improvements required for Alternative 2 are summarized below:

- The future South Service Level (including South 1 and South 2 Booster Districts) would receive a majority of supply (about 7.5 mgd) from a 24-inch main running south from the Clinton WTP. Additional supply of about 2.0 mgd would be delivered by a booster pumping station located along Haskell Avenue near the Wakarusa River (Haskell Avenue Booster Station). Additional main improvements to serve the South Service Level are shown on Figure V-7.

- Additional transmission capacity is required to deliver water from the Clinton WTP to the distribution system.

  - For the West Hills Service Level, a new 20-inch main would be required from the Clinton WTP north to about 15th Street (Main W1). Additional main improvements would be required in the West Hills Service Level along 15th Street (Main W2) and on Harvard Road between S. Lawrence Ave. and Wellington Rd. (Main W3) to support the Stratford Elevated

Tank. Additional main improvements to serve the West Hills Service Level and the future Kanwaka Booster District are shown of Figure V-7.

- For the South Service Level, a new 24-inch main would be required to run south from the Clinton WTP (Main C1).

- Main improvements out of the Kaw WTP would be minimized. A new 12-inch main would be constructed from about 8th and New Jersey to 10th and Haskell (Main C9). A new 16-inch main would run from 10th and Haskell south and east along the railroad tracks to about O'Connell Road (Main C10). These mains would help to supply to Santa Fe Industrial Park and maintain water levels in the Harper Elevated Tank.

- As previously discussed in the explanation of Alternative 1, there are several old 14-inch mains in the downtown area that were installed between 1886 and 1916 that the City has indicated need to be replaced. For Alternative 1, these mains would be replaced with 8-inch mains in conjunction and coordination with construction of a new transmission main out of the Kaw WTP. However, the transmission main is not required for Alternative 2. Therefore, in order to maintain adequate distribution capacity in the downtown area, these old 14-inch mains are recommended to be replaced with 12-inch mains for Alternative 2. Along Indiana St. between 5th and 8th, two parallel 12-inch lines are required to replace the parallel 14-inch mains. For Alternative 1, one of these mains would be replaced with the new transmission main. As a result, the total length of replacement main shown for Alternative 2 is greater than that shown for Alternative 1.

- High service pumping improvements are required for both the Kaw and Clinton WTP as summarized below:

  - The Kaw WTP to Central high service pumps consists of eight pumps with a firm capacity of 18.8 mgd. This capacity is sufficient to meet the required pumping capacity of 14.5 mgd. However, for reliability, two of the "old" 1917 units should be replace with new 3.0 mgd units to provide a "reliable" rated capacity of 18 mgd, and a "reliable" firm capacity of 15 mgd.
  - As previously discussed, the Kaw WTP to West Hills high service pumps do not deliver their rated capacity of 1.5 mgd. Hydraulic analyses showed that all three units, operating at a combined capacity of 4.5 mgd would be needed to help maintain water levels in the existing 6th Street Elevated Tank and the Stratford Elevated Tank under maximum hour conditions. All three of the existing units should be replace with new units rated 1.5 mgd at 350 feet of TDH.
  - The Clinton WTP high service pumps to the Central Service Level consist of two units rated 2.8 mgd and one unit rated 5.0 mgd. To provide firm capacity of 15.1 mgd, two additional 5.0 mgd units should be installed.

As described for Alternative 1, the existing high service pumping building should be expanded to the south to house the new units. The resulting total capacity to the Central Service Level from the Clinton WTP would be 20.6 mgd and the firm capacity would be 15.6 mgd.

- The Clinton WTP high service pumps to the West Hills Service Level consist of three units, each rated 5.0 mgd, providing a firm rated capacity of 10 mgd. Two additional pumps rated at 4.5 mgd would be installed in the high service pumping building expansion, to provide a total rated capacity of 24 mgd and a firm rated capacity of 19 mgd.

Distribution improvements for Alternative 2 are shown on Figure V-6 and summarized in Table V-21.

Table V-21
Alternative 2 Distribution System Improvements

Water Mains						
CIP	Description	Dia (in.)	Length (ft)	Unit Cost ($/dia*in)	Const. Cost ($)	Capital Cost ($)
C1	Wakarusa Dr	24	13,600	6	1,960,000	2,820,000
C2	N 1170 Road	24	7,200	6	1,040,000	1,500,000
C3	Kasold Dr	24	3,800	6	530,000	760,000
C4	Supply to Reservoir T3	16	1,500	6	140,000	200,000
C5	N 1100 Road	20	15,900	6	1,910,000	2,750,000
C6	Haskell Ave	16	5,300	6	510,000	730,000
C7	N 1100 Road	16	5,300	6	510,000	730,000
C8	Haskell Ave	16	10,600	6	1,020,000	1,470,000
C9	8th & NJ to 10th & Haskell	12	3,200	8	310,000	450,000
C10	Along RR to O'Connell	16	6,600	6	630,000	910,000
C11	Second River Crossing	16	7,200	8	920,000	1,320,000
C12	Replace 14" w 12" in Downtown	12	14,300	9	1,540,000	2,220,000
W1a	Clinton WTP Discharge	24	250	6	40,000	60,000
W1	North From Clinton WTP	20	4,200	6	500,000	720,000
W2	15th Street	12	3,300	8	320,000	460,000
W3	Harvard Rd	12	300	8	30,000	40,000
W4	Sixth St - Wakarusa to West ET	16	4,400	6	420,000	600,000
W5	Sixth St - Deer Run to West ET	12	2,600	6	190,000	270,000
W6	Sixth St - West ET to K-10	12	3,500	6	250,000	360,000
W7	Sixth St- West ET to K-10	16	3,900	6	370,000	530,000
W8	Sixth St - Kan Booster	16	9,700	6	930,000	1,340,000
				Total Water Mains	**14,070,000**	**20,240,000**

Table V-21
Alternative 2 Distribution System Improvements

CIP	Description	Installed Capacity (mgd)	Const. Cost ($)	Capital Cost ($)
Pumping Stations				
BPS1	Kanwaka North BPS	5.10	770,000	1,050,000
BPS2	Kanwaka South BPS	1.50	230,000	320,000
BPS3	Haskell Ave BPS	4.00	600,000	840,000
BPS4	South 1 BPS	2.00	300,000	420,000
BPS5	South 2 BPS	1.50	230,000	320,000
HSKC	Kaw WTP - Central (Old)	6.00	180,000	170,000
HSKW	Kaw HSP - West Hills	4.50	90,000	130,000
HSCC	Clinton HSP – Central	10.00	250,000	280,000
HSCW	Clinton HSP - West Hills	9.00	230,000	250,000
HSBA	HSP Building Addition		1,150,000	1,610,000
		Total Pump Stations	**4,030,000**	**5,800,000**

CIP	Description	Const. Cost ($)	Capital Cost ($)
Flow Control Facilities			
FCV1	Clinton Parkway FCV	200,000	290,000
	Total Flow Control Valves	**200,000**	**290,000**

CIP	Description	Volume (MGal)	Const. Cost ($)	Capital Cost ($)
Storage Facilities				
T1	Sixth Street East ET	1.00	1,000,000	1,440,000
T2	Kanwaka ET	1.00	1,000,000	1,440,000
T3	Central South Ground Storage	1.00	800,000	1,150,000
T4	South 1 Elev Tank	0.25	300,000	430,000
T5	South 2 Elev Tank	0.25	300,000	430,000
		Total Storage	**3,400,000**	**4,890,000**
		Total Alternative 2 Distribution Improvements	**21,700,000**	**31,220,000**

1.4.4 Operations and Maintenance Building

The operations and maintenance building for this alternative would be identical to that described for Alternative 1. The opinion of capital cost for the facility is $4,719,000.

1.4.5 Alternative 2 Summary of Costs

Table V-22 summarizes the capital cost opinion for Alternative 2.

Table V-22
Alternative 2 Capital Cost Summary

Component	Cost ($)
KAW Raw Water Supply Improvements	
Reliability	776,000
Growth	--
Clinton Raw Water Supply Improvements	
Reliability	--
Growth	13,330,000
Kaw WTP Improvements	
Reliability	--
Growth	--
Regulatory	1,734,000
Clinton WTP Improvements	
Reliability	--
Growth	18,681,000
Regulatory	3,220,000
Distribution System Improvements	31,220,000
Operations and Maintenance Building	4,719,000
Total Improvements	**73,660,000**

1.5 Recommended Alternative

A discussion of the relative merits and detriments of the two alternatives are summarized below:

- The cost for Alternative 1 about 1-percent higher than Alternative2, however, considering the relative accuracy of master-plan level estimating, the costs of the two alternatives are essentially the same.
- Both Alternative 1 and 2 would reliably meet the projected demands while maintaining compliance with existing drinking water regulations.
- Either alternative could be impacted by the requirement for additional source water treatment for *Cryptosporidium* removal or deactivation, but such impact cannot be determined until testing (which will start in July 2004) is completed in January 2007.

- The redundancy and security of having two plants of equal size provides an additional factor of safety in terms of meeting system demands if one of the two plants were out-of-service.

After careful consideration and review with City staff, it is recommended that the City of Lawrence proceed with implementing the water supply, treatment, and distribution system improvements identified as Alternative 1.The two plants of similar size arrangement has well served the City in recent years.

2.0 Distribution System Evaluations

2.1 Service Levels and Pressures

The year 2025 service area covers a large amount of land outside the current service area. Maximum and minimum pressures were reviewed to evaluate the development of future service levels.

Distribution system service levels were evaluated on the basis of maintaining a desired minimum pressure of 40 psi. A minimum pressure of 35 psi was judged acceptable if it was caused by high ground in a small area that could not be supplied from another service level with a higher operating hydraulic gradient. For evaluation of minimum pressures it was assumed that storage facilities would be at 20-feet below overflow, or about half-depleted, resulting in the lowest pressures to high ground elevation.

In addition to evaluating minimum pressures to high ground, high pressures to low ground were also evaluated. Service district boundaries were developed to minimize high pressure areas. The goal of this evaluation was to minimize pressures above 110 psi. For evaluation of maximum pressures it was assumed that storage facilities would be full, resulting in the highest pressures to low ground elevation.

Based on these criteria and the results of additional computer hydraulic analyses (as described later in this chapter), future service levels were developed. Maximum and minimum ground elevations for existing and proposed service levels are shown in Table IV-23.

Table V-23
Service Level Ground Elevations

Service Level	Overflow Elevation	Max Ground Elev For 40 psi	Min Ground Elev For 110 psi
Central Service Level	1,019	910	760[(1)]
West Hills Service Level	1,170	1,060	920
Kanwaka Booster District	1,210	1,100	960
South Service Level	1,050	940	830
South 1 Booster District	1,150	1,040	900
South 2 Booster District	1,170	1,060	920

(1) Minimum ground elevation in Central Service Level is about 800 feet. Therefore, maximum pressure is 94.8 psi.

2.1.1 Kanwaka Booster District

The area west of Kansas Highway 10 (K-10) contains ground elevations up to about elevation 1100. Much of this area cannot be served by the existing west service level at adequate pressures. Therefore, for this master plan a proposed Kanwaka Booster District was evaluated to serve the entire area west of K-10.

The Kanwaka Booster District would be supplied by booster pumping from the existing West Hills Service Level.

2.1.2 South Service Level and Booster Districts

The future service area south of the Wakarusa River contains ground elevations that range from about 800 up to a maximum of 1060. Much of the low ground between elevation 800 and 830 lies within the 100-year flood plain. A detailed review of ground elevations resulted in evaluation of a future South Service Level with a maximum static hydraulic gradient of 1050, about 30-feet higher than the existing Central Service Level.

The increased gradient will allow service at 40-psi up to about ground elevation 940. Ground up to about elevation 950 could be provided pressures at up to about 35-psi.

Review of the existing high service pumps at the Clinton WTP showed that they could deliver water directly to increased gradient of the proposed South Service Level. The Clinton WTP high service pumps are rated at 80-feet of total dynamic head. Hydraulic analyses showed that the required pumping head under maximum day conditions to a future South Service Level, from the Clinton WTP, would be about 65-feet.

Two areas of high ground with significant projected future population could not be served by the future South Service Level. Ground elevation above 940 should be provided service from booster districts that pump from the future South Service Level. For this master plan, two booster districts referred to hereafter as the South 1 and South 2 Booster Districts were developed for this report.

The South 1 Booster District is located in the southwest corner of the year 2025 service area, along the south side of the Clinton Reservoir. High ground elevation reaches a maximum of about 1040 in this area. Based on the criteria presented above, this high ground elevation requires a minimum static hydraulic gradient of about 1150 to provide minimum pressures of about 40-psi.

The South 2 Booster District is located on a ridge of high ground on the south side of the year 2025 service area, between Wakarusa Drive and Kasold Drive. High ground elevation reaches a maximum of about 1160 in this area. Based on the criteria presented above, this high ground elevation requires a minimum static hydraulic gradient of about 1170 to provide minimum pressures of about 40-psi.

2.2 Storage Evaluation

To determine the optimum amount of water storage for a distribution system, the three major considerations are (1) the demand ratio between maximum hourly and maximum daily water use rates; (2) the fire fighting storage requirements; and (3) the cost-effectiveness relationship between system facility options. Other factors that should be considered before determining storage capacities include system reliability, pressure limitations and operational flexibility. Additionally, the adequacy of system storage is dependent on, and is interrelated with (1) requirements for high-service pumping, (2) distribution system residual pressures, (3) sizing of transmission and feeder mains, and (4) operation and maintenance costs.

Existing total storage volumes were previously summarized in Chapter IV-1 of this report.

2.2.1 Operational Storage

Experience with numerous water distribution system studies indicates that storage for supplying the maximum hourly rate in excess of the maximum daily rate for a four-hour period, without depleting storage by more than one-half, will provide adequate storage capacity for most systems. Required operational storage volumes based on the projected demands developed for this report are summarized in Table IV-24.

Table V-24
Required Operational Storage Volumes

Service Level	Year 2010			Year 2025		
	2010 MD (MGal)	2010 MH (MGal)	Reqd. Volume[1] (MGal)	2025 MD (MGal)	2025 MH (MGal)	Reqd. Volume[1] (MGal)
Central Service Level[2]	18.77	25.80	1.17	18.67	25.61	1.16
West Hills Service Level	13.86	20.32	1.08	18.15	26.91	1.46
Kanwaka Booster District	1.73	2.41	0.11	7.78	10.07	0.38
South Service Level	--	--	--	3.32	4.87	0.26
South 1 Booster District	--	--	--	0.93	1.33	0.07
South 2 Booster District	--	--	--	0.73	1.04	0.05
Total	**34.4**	**48.5**	**2.36**	**49.6**	**69.8**	**3.38**

(1) Operational storage volume is based on meeting maximum hour in excess of maximum day for a period of 4 hours.
(2) Total demands in Central Service Level decline from year 2010 to 2025 because existing wholesale users will be relocated to future South Service Level upon expansion of City of Lawrence water service area.

2.2.2 Fire Storage

Fire storage is based on supplying fire flow for required durations. The system should be capable of supplying the required fire flow during the maximum day demand conditions.

Part of an ISO evaluation consists of determining needed and available fire flows at various locations throughout a water utility. The needed fire flow is calculated based on the size, construction, occupancy, and exposure of each building or complex. Needed fire flows can range from 500 to 12,000 gpm. The fire flow is required for a specified duration, generally 2 to 3 hours, at a residual pressure of 20 psi. Fire flow requirements in excess of 3500 gpm that cannot be met by the water system may affect the rating of the individual building. However, the overall municipal rating will not be affected.

A flow of 1,500 gpm for 2-hours is the maximum required for fighting fires in single-family residential structures. This would require fire storage of 0.18 MGal. For insurance rating purposes, 3500 gpm for a 3-hour duration is the maximum fire flow required to be supplied by a municipal water system. This rate would require fire storage of 0.63 MGal.

2.2.3 Required Storage Volumes

Required storage volumes for each service level and booster district were determined based on an evaluation of required operational storage and required fire storage volumes, or twice the operation storage, whichever is greater. For this report it was assumed that a residential fire volume of 0.18 would be the maximum required for the future South 1 and South 2 Booster Districts. The other service levels were all evaluated based on the need to provide a required fire volume of 0.63 MGal. Required storage volumes are summarized in Table IV-25.

Table V-25
Required Storage Volumes

Service Level	Year 2010			Year 2025		
	Opertional[(1)] (MGal)	Fire (MGal)	Total[(2)] (MGal)	Opertional[(1)] (MGal)	Fire (MGal)	Total[(2)] (MGal)
Central Service Level[(3)]	1.17	0.63	2.34	1.16	0.63	2.32
West Hills Service Level	1.08	0.63	2.16	1.46	0.63	2.92
Kanwaka Booster District	0.11	0.63	0.74	0.38	0.63	1.01
South Service Level	--	--	--	0.26	0.63	0.89
South 1 Booster District	--	--	--	0.07	0.18	0.25
South 2 Booster District	--	--	--	0.05	0.18	0.23
Total	**2.36**	**--**	**6.62**	**3.38**	**--**	**7.62**

(1) Operational storage volume is based on meeting maximum hour in excess of maximum day for a period of 4 hours.
(2) Total storage requirement determined as the sum of operational and fire storage, or twice the operational storage; whichever is greater.
(3) Total demands in Central Service Level decline from year 2010 to 2025 because existing wholesale users will be relocated to future South Service Level upon expansion of City of Lawrence water service area.

Storage volumes for the future service levels and booster districts are based on the storage requirements shown above.

The Central Service Level has excess operational storage available through year 2025. The total available volume of 4.4 MGal exceeds the year 2025 requirement.

The West Hills Service Level is currently deficient in floating storage capacity. The existing available operational storage is only 0.5 MGal, while the existing operation storage requirement is about 0.9 MGal. Excess high service pumping capacity at the Clinton WTP is currently being used to supply maximum hour demands in excess of maximum day. The Clinton WTP clearwell has a total volume of 3.0 MGal, equaling 20-percent of the existing treatment capacity of 15 mgd. Assuming that 0.4 MGal of this storage is used for operational storage in West Hills, there remains 2.6 MGal of WTP storage, or about 17-percent of the existing treatment capacity.

The City has been planning to construct additional storage in the West Hills Service Level along 6th Street, west of Wakarusa Drive. Based on the storage evaluations presented above, this storage should be constructed with a total volume of 1.0 MGal. Hydraulic analyses conducted for this report determined that this volume of storage could be effectively utilized at the proposed location.

The addition of a 1.0 MGal elevated tank in the West Hills Service Level will increase the available operational storage to 1.0 MGal. There will still remain an operational storage deficiency in West Hill by year 2010. The deficiency of 0.2 MGal would be available from the Clinton WTP. Alternatively, the recent booster stations constructed at the Oread and Kasold Reservoirs may be used to meet maximum hour demands in West Hills and to utilize excess storage in the Central Service Level.

For year 2025, there will be an operational storage deficiency in West Hills of nearly 0.5 MGal. The Oread and Kasold Booster Pumping Stations can be used to deliver excess storage volumes in the Central Service Level to the West Hills Service Level. Hydraulic analyses verified that this mode of operation would sufficiently meet maximum hour demands in the West Hills Service Level.

2.3 Computer Hydraulic Analyses

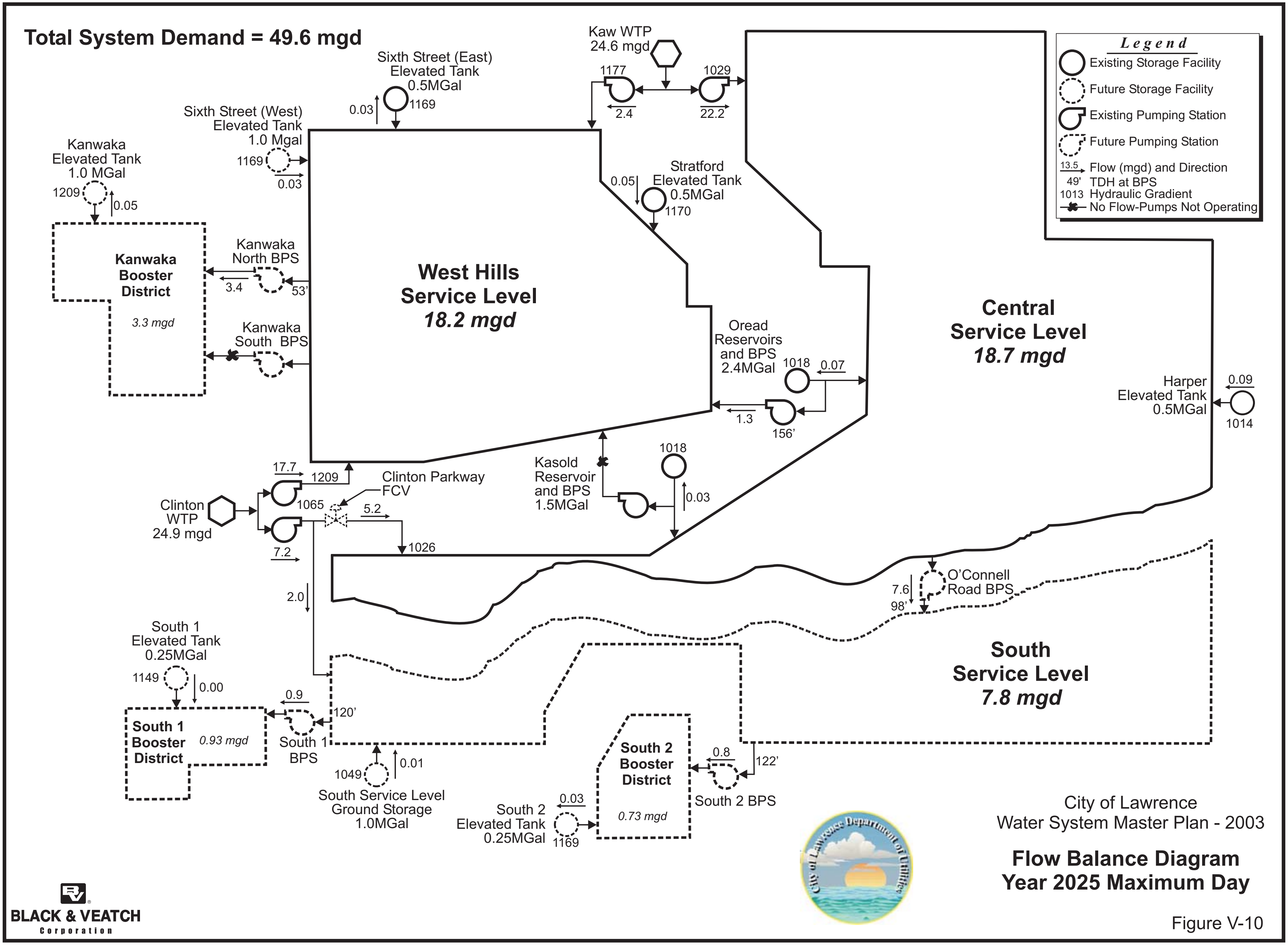
Computer hydraulic analysis is a method of predicting the hydraulic gradient pattern, pressures, and flows across the water distribution network under a given set of conditions. The hydraulic gradient pattern depends upon the magnitude and location of system demands, the characteristics of the pipes in the distribution system, and the flows and gradients at network boundaries such as reservoirs and pumping stations. The head loss through each pipe is a function of flow rate, pipe diameter, length, and internal roughness. The available pressure or head, at any point in the network is the difference between the hydraulic gradient and the ground elevation.

Hydraulic analyses were conducted to evaluate the Lawrence distribution system, and to establish an improvement program to reinforce the existing system and allow expansion to meet projected water demands through the year 2025. Alternative improvements were investigated to identify those most effective in meeting projected water demands. Criteria used to develop the improvement program include increasing system reliability, simplifying system operations, more effectively utilizing system storage to meet peak demands, and maintaining pressures of 35 psi under maximum hour demand conditions. This section discusses development of the hydraulic computer model and results of the analyses performed.

Hydraulic analyses plots, tables and graphs are provided as a separately bound document titled “WaterCAD Hydraulic Model”.

2.4 Year 2025 Analyses

Year 2025 maximum day analyses were conducted for each of the water treatment plant alternatives, as discussed in Chapter V-1.0 Alternatives Evaluation. Additional year 2025 analyses were conducted for the recommended alternative of expanding both the Clinton and Kaw WTPs. In addition to the maximum day analysis, maximum hour and storage replenishment analyses were conducted for this alternative. Figure IV-10 shows the distribution system flow balance for the year 2025 maximum day. Figure IV-11 shows the flow balance for the year 2025 maximum hour. The storage replenishment analysis verified that the storage facilities could be refilled adequately during off-peak hours in the night. All three of these analyses incorporated the Alternative 1 Recommended Improvements (as previously shown on Figure IV-7) in the distribution system model.



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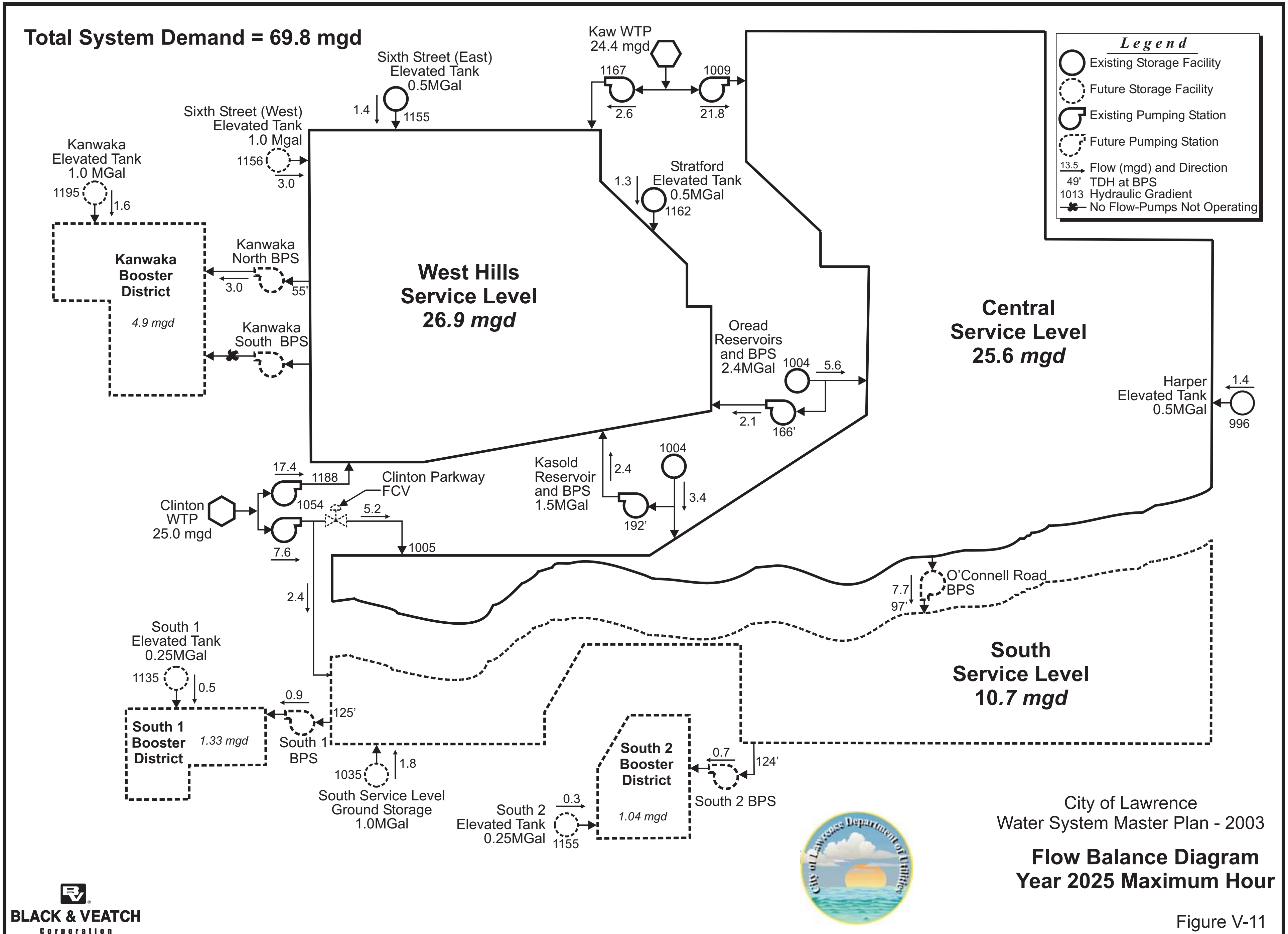

City of Lawrence
Water System Master Plan - 2003

Flow Balance Diagram
Year 2025 Maximum Hour

Figure V-11

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The year 2025 analyses included facilities for the proposed Kanwaka Booster District, and the future South Service Level, South 1 Booster District and South 2 Booster District. The model included the following proposed facilities:

- The Kawaka Booster District was supplied by two pumping stations for reliability and redundancy.
  - Under maximum day conditions, the entire demand of about 3.4 mgd was delivered from a "Kanwaka North BPS". Review of the site currently owned by the City and planned for the 6th Street West elevated tank, and discussion with City personnel, indicate that there is sufficient area to locate the Kanwaka North BPS at the same site. Location of the pumping station at this location will allow the ridge of high ground along 6th Street, but east of K-10 to be served by the higher gradient of the Kanwaka Booster District. Pressures to this ridge would be less than 40 psi, under conditions with the planned 6th Street West elevated tank half depleted, if served by the West Hills Service Level.
  - A smaller "Kanwaka South BPS" located along 15th Street, would serve for reliability and backup. This station is sized at about 0.75 mgd firm capacity to provide service to areas in the southeast portion of the Kanwaka Booster District should they develop in advance of completion of improvements along 6th Street (including the north BPS, the elevated tank, or mains required to connect the two areas of potential development).
- The future South Service Level (including South 1 and South 2 Booster Districts) would receive a majority of supply (about 7.5 mgd) from a booster pumping station located near the intersection of O'Connell Road and N 1100 Road (O'Connell Road Booster Station). Additional supply of about 2.0 mgd would be delivered directly from the Clinton WTP.
- A flow control valve would be installed on the existing 24-inch Central Service Level main near the intersection of 23rd Street and Wakarusa Drive. This valve would be an electronically controlled, remotely operated valve that would allow the Clinton WTP high service pumps to pump directly to the future South Service Level and concurrently deliver water to the Central Service Level. The analyses showed that the existing pumps which are rated for 80 feet of TDH could adequately deliver flows to a future South Service Level ground storage reservoir at overflow elevation 1049. The hydraulic analyses show that the flow control valve can be used to control flow to the Central Service Level while delivering required amounts to the future South Service Level. The flow can be restricted to force water at the Kasold Reservoir to be supplied to the distribution system, therefore increasing turnover in the reservoir and reducing water age.

- The South 1 Booster District would each be supplied by a single booster pumping station and elevated tank.
- A third elevated tank would be located in the West Hills Service Level. For the analyses, the tank was located along 6th Street at a location that has been identified in previous reports and for which the City has already purchased property. The analyses showed that with the recommended main improvements, a 1.0 MGal elevated tank would operate adequately at this location with the other two elevated tanks in the West Service Level. The analyses further showed that the water level in the elevated tanks could be maintained without the use of the Oread or Kasold Booster Pumping Stations (pumping from the Central Service Level to the West Hills Service Level).
- High service pumping improvements are required for both the Kaw and Clinton WTP as summarized below:
  - The Kaw WTP to Central high service firm capacity of 18.8 mgd. Under maximum day conditions., in order to have the reliable capacity to deliver water to the Central Service Level, and to simultaneously use the Oread BPS to deliver water to West Hills, the hydraulic analyses about 22 mgd of firm high service pumping would be required at the Kaw WTP to Central.
  - As previously discussed, the Kaw WTP to West Hills high service pumps do not deliver their rated capacity of 1.5 mgd. Hydraulic analyses showed that if neither the Oread BPS or Kasold BPS are used to transfer water from the Central Service Level to the West Hills Service Level, thereby helping to maintain the water levels in the West Hills tanks, all three West Hills high service units, operating at a combined capacity of 4.5 mgd would be needed to help maintain water levels in the existing 6th Street Elevated Tank and the Stratford Elevated Tank under maximum hour conditions.
  - The Clinton WTP high service pumps to the Central Service Level installed firm capacity of 5.6 mgd is not adequate to meet required pumping of 7.8 mgd under maximum hour conditions. To provide firm capacity of 7.8 mgd, one of the existing 2.8 mgd units should be replaced with a 5.0 mgd unit.
  - The Clinton WTP high service pumps to the West Hills Service Level firm rated capacity of 10 mgd is inadequate to meet the required maximum hour pumping requirement. Two additional pumps rated at 4.0 mgd would be installed in the high service pumping building expansion, to provide a total rated capacity of 23 mgd and a firm rated capacity of 18 mgd.

2.5 Year 2010 Analyses

Maximum day, maximum hour and storage replenishment analyses were conducted under year 2010 design demands, and including main improvements required to serve the year 2010 service limits.

Figure IV-12 shows the distribution system flow balance for the year 2010 maximum day. Figure IV-13 shows the distribution system flow balance for the year 2010 maximum hour. The storage replenishment analysis verified that the storage facilities could be refilled adequately during off-peak hours in the night.

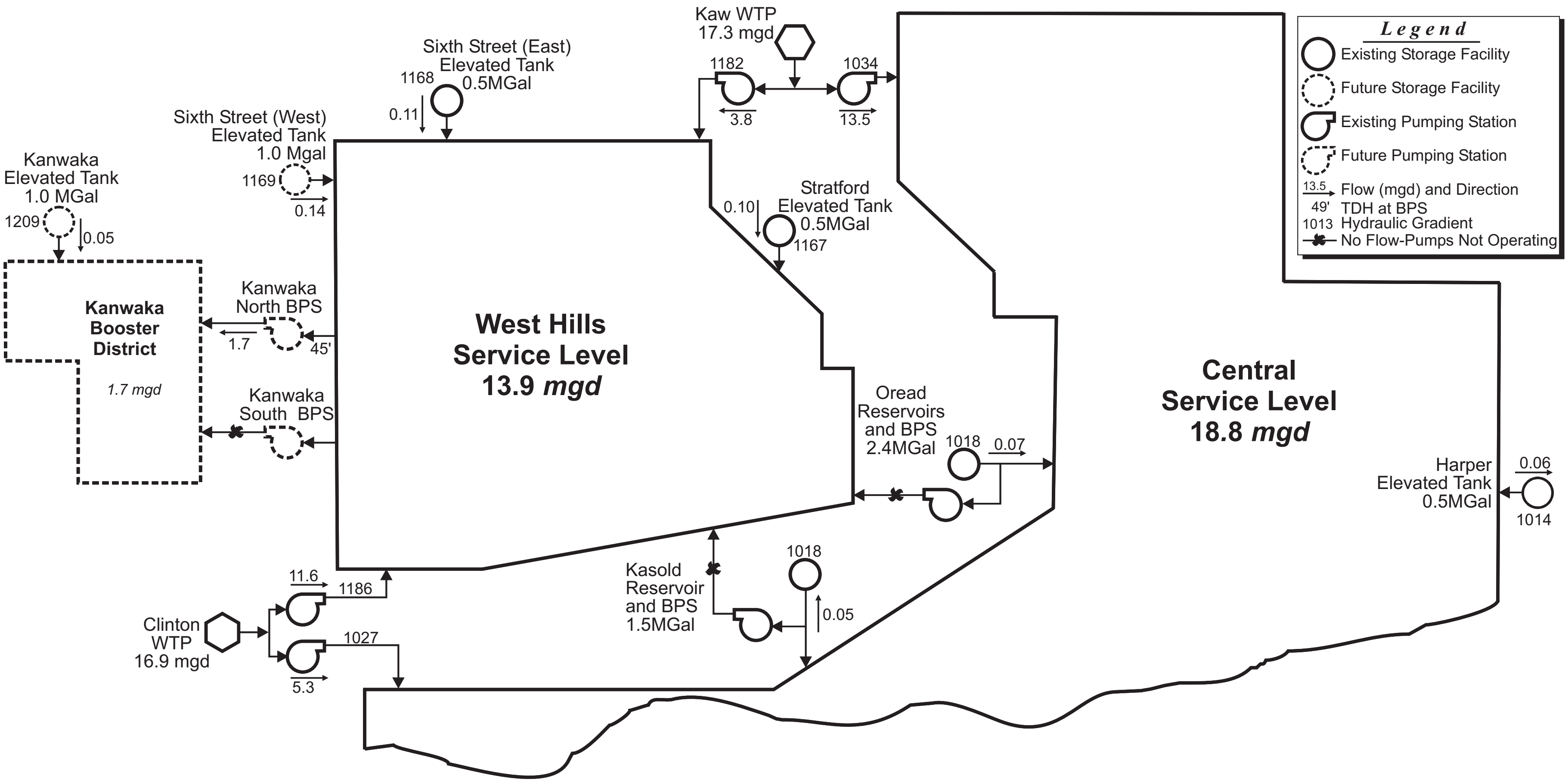
For the year 2010 analyses, the proposed Kanwaka Booster District was modeled including the two booster pumping stations and elevated tank. The new elevated tank along 6th Street in the West Hills Service Level was also included. The future South Service Level (and South 1 and South 2 Booster Districts) was not included in the year 2010 analyses. The analyses showed that the proposed Kanwaka North BPS should be used to deliver most of the water to the Kanwaka Booster District to facilitate adequate turnover in the new elevated tank along 6th Street.

For year 2010, additional treatment and high service pumping capacity is required from the Clinton WTP to meet projected demands of 34.4 mgd in the distribution system. For these analyses, the Kaw WTP was delivering its maximum flow of 17.5 mgd and the Clinton WTP was delivering about 17 mgd under maximum day conditions.

The year 2010 maximum hour analyses assumed that the Clinton WTP continued to deliver water to the distribution system at the maximum day rate. This analysis showed the storage facilities in the Central Service Level were contributing flow to the distribution system at rates which slightly exceeded the theoretical maximum recommended delivery (based on one-half the volume for a period of four hours). In order to reduce the volume being delivered from the storage facilities, the Clinton WTP could deliver additional flow to meet some of the maximum hour demand. About 0.5 mgd would be required, and would require less than 0.1 MGal of storage at the Clinton WTP. Expansion of the Clinton WTP to 25 mgd (Phase 1), including additional high service pumping to West Hills would readily allow this operation.

The analyses showed that the water levels in the storage facilities in the West Hills Service Level could be maintained without operation of the booster pumping facilities located at the Kasold Reservoir and the Oread Reservoirs. However, the analyses did show that there is sufficient capacity in these reservoirs to help meet maximum hour demands in the West Hills Service Level, if needed.

Total System Demand = 34.4 mgd



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Flow Balance Diagram
Year 2010 Maximum Day

Figure V-12

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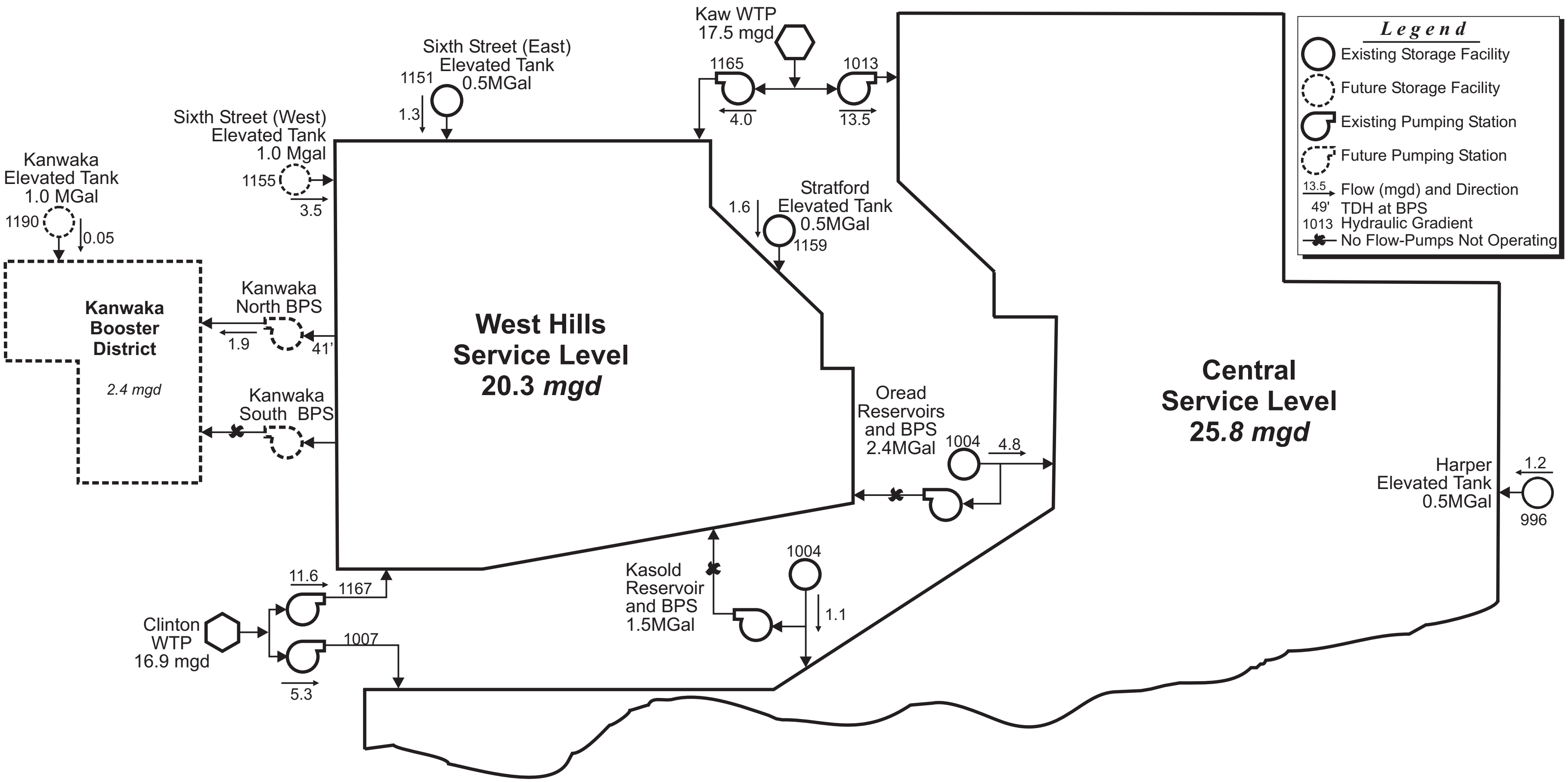
Total System Demand = 48.5 mgd



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Water System Master Plan - 2003

Flow Balance Diagram
Year 2010 Maximum Hour

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Figure V-13

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Historically, the water level in the Kasold Reservoir does not fluctuate as much as desired. That is, it does not deliver as much water to the distribution system as it is capable of delivering. Hydraulic analyses verified that operation of the booster pumps at the Kasold Reservoir would increase flows from the reservoir, improving turnover and water quality. Operation of the Kasold booster pumps also helps to support water levels in the Stratford Elevated Tank. The Kasold booster pumps could be operated in lieu of increasing pumping from the Clinton WTP. There is sufficient storage capacity in the Central Service Level to support this operation.

2.6 Base Year Analyses

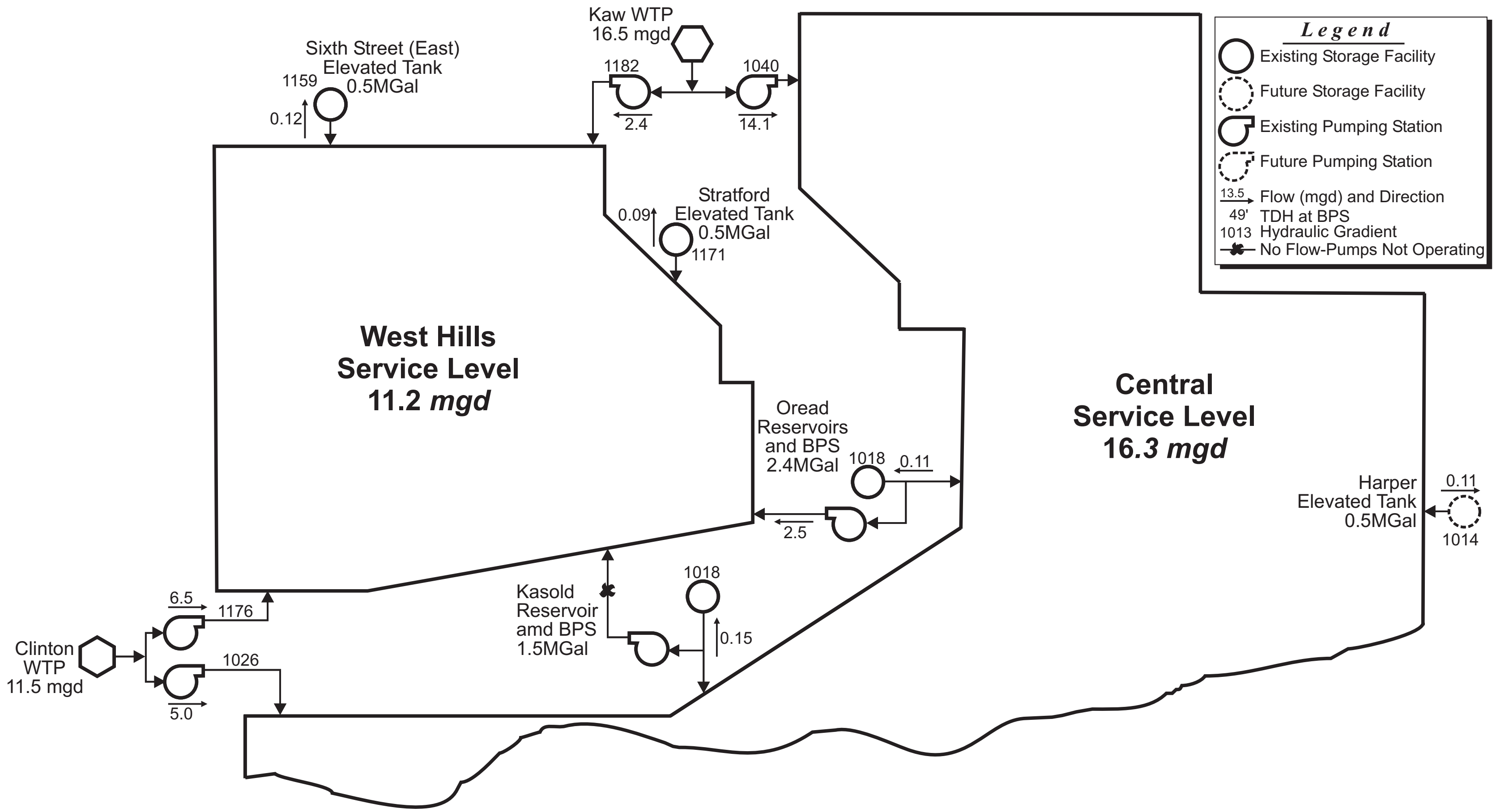
A series of analyses was conducted under base year design demands, representing the current level of demands. Figure IV-14 shows the distribution system flow balance for the base year maximum day. Figure IV-15 shows the distribution system flow balance for the base year maximum hour. The storage replenishment analysis verified that the storage facilities could be refilled adequately during off-peak hours in the night.

The maximum day analysis showed that operation of the existing Oread BPS helps to maintain water levels in the Stratford and 6th Street Elevated Tanks. This operation provides adequate service without any required main improvements.

There is a deficiency in storage volume in the West Hills Service Level to meet maximum hour demands which exceed the maximum day demands. The Base Year analyses verified that this deficiency can be adequately met by pumping from the Clinton WTP. The maximum hour analysis included an additional 3.0 mgd of pumping from the Clinton WTP. The analysis showed that this operation can be maintained without any additional main improvements. Additionally, there is sufficient pumping storage capacity and Clinton WTP to support this operation.

Alternative to using the Clinton WTP pumping and storage to meet maximum hour demands in the Central Service Level, the Kasold or Oread BPS could also be used. The final Base Year analyses do not show this operation. However, preliminary analyses showed that this operation would help meet maximum hour demands in the Central Service Level and would improve turnover in the West Hills reserviors. .

Total System Demand = 27.5 mgd



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Flow Balance Diagram
Base Year Maximum Day

Figure V-14

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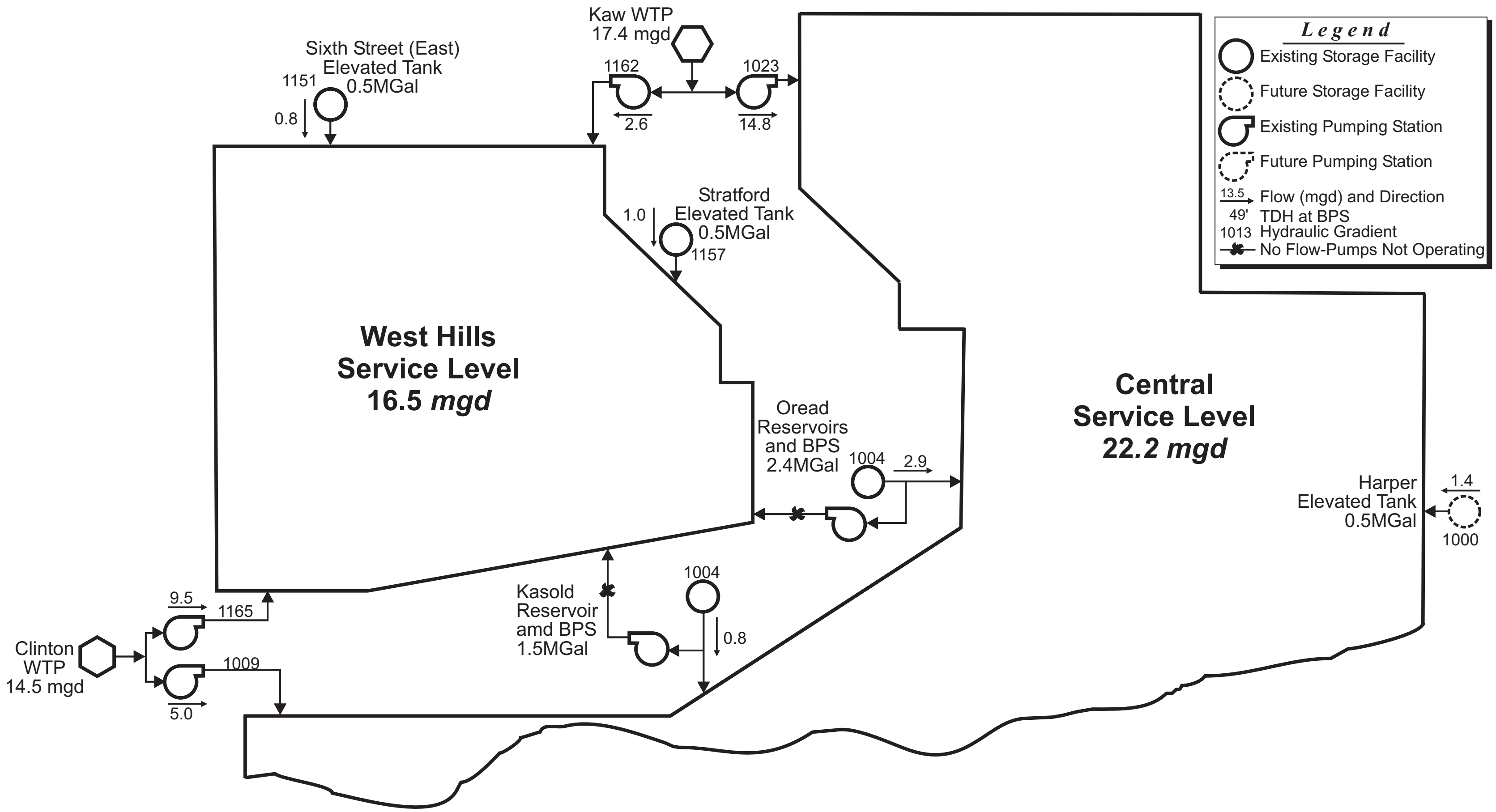
Total System Demand = 38.7 mgd



City of Lawrence
Water System Master Plan - 2003

Flow Balance Diagram
Base Year Maximum Hour

Figure V-15

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2.7 Hydraulic Analyses Observations

2.7.1 Harper Elevated Tank

The analyses indicated that the existing system cannot keep the Harper Elevated Tank full during maximum day demands. The analyses also indicated pressure problems in the vicinity of the tank and in the Santa Fe Industrial Park area under maximum hour conditions. These conditions have been reported in previous hydraulic modeling and master planning for the Lawrence water distribution system.

The 1995 *Water Distribution System Master Plan Update* (1995 Update) by Black & Veatch recommended installation of an electronically controlled, remotely operated throttling valve on the 20-inch main near the Oread Reservoirs. The throttling valve would allow a higher discharge gradient at the Kaw WTP which would increase pressures to the east side of the City during peak demands. Alternatively, an altitude valve could be installed on the fill line to the Oread Reservoirs. Because of concerns with raising the hydraulic gradient in the distribution system between the Oread Reservoirs and the Kaw WTP, and the age of the distribution mains in this area, neither the remote operated valve nor the altitude valve have been installed and are not recommended.

For this study, distribution main improvements are recommended to help support the water level in the Harper Elevated Tank. However, hydraulic analyses show that under all design year conditions (Base Year, Year 2010 and Year 2025), with the Harper Elevated Tank about half depleted (about 19 feet below overflow) pressures between 32 and 35 psi would be experienced on high ground in the vicinity of the elevated tank. Furthermore, it is difficult to maintain water levels in the Harper Elevated Tank above this half depleted level without reducing the effectiveness of the other storage facilities in the Central Service Level.

The 1995 *Water Distribution System Master Plan Update* (1995 Update) by Black & Veatch evaluated creation of a booster district surrounding the Harper Elevated Tank. This alternative was not recommended in lieu of the recommendation to install the throttling valve discussed in the previous paragraph. While recommendation of a new "Harper Booster District" is not included in this report, additional consideration should be given the concept if pressure concerns continue to be an issue in the area.

2.7.2 Booster Pumping Station Capacities

Hydraulic analyses conducted for this report included booster pumping stations to serve the Kanwaka Booster District, South Service Level, South 1 Booster District and South 2 Booster District. Based on the results of the analyses, the capacities as shown in Table V-26 are recommended for each of the booster pumping stations.

Table V-26
Booster Pumping Station Recommendations

CIP	Name	No. of Pumps	Rated Capacity (mgd)		Rated Head (ft)
			Total	Firm	
BPS1	Kanwaka North BPS	2	7.0	3.5	50
BPS2	Kanwaka South BPS	2	1.5	0.75	40
BPS3	O'Connell Road BPS	2	10.5	7.0	45
BPS4	South 1 BPS	2	2.0	1.0	110
BPS4	South 2 BPS	2	1.5	0.75	125

2.7.3 Kaw WTP Discharge Piping Modifications

Black & Veatch completed an evaluation of modifications to Central Service Level discharge piping at the Kaw WTP in 1998. That evaluation recommended replacement and simplification of yard discharge piping directly at the Kaw WTP and in Indiana Street in front of the plant. Those recommendations are carried through in this report and included as a line item in the CIP in the following section.

2.8 Fire Flow Analyses

In addition to supplying water for domestic, commercial, and industrial uses, a municipal distribution system should be capable of supplying an adequate and dependable flow for fire fighting. Although the annual volume of water used for fire fighting is relatively small, the rate of use may be quite high during fires. These high rates may impose critical demands on transmission, pumping, and storage facilities.

The Insurance Services Office (ISO) grades municipal fire defense capabilities for insurance rating purposes. The 1980 ISO Fire Suppression Rating Schedule considers three areas of evaluation: Receiving and Handling Fire Alarms, Fire Department, and Water Supply.

Part of an ISO evaluation consists of determining needed and available fire flows at various locations throughout a water utility. The needed fire flow is calculated based on the size, construction, occupancy, and exposure of each building or complex. Needed fire flows can range from 500 gpm to 12,000 gpm. A flow of 1,000 gpm is generally sufficient for fighting fires in residential structures no higher than two stories if they are more than 10 feet apart. The fire flow is required for a specified duration, generally 2 to 3 hours, at a residual pressure of 20 psi. The system should be capable of supplying the required fire flow during the maximum day demand condition.

For insurance rating purposes, 3,500 gpm is the maximum fire flow required to be supplied by a municipal water system. Fire flow requirements in excess of 3,500 gpm which cannot be met by the water system may affect the rating of the individual building. However, the overall municipal rating will not be affected.

Fire flow analyses were conducted under the 2010 maximum day demand condition of 34.4 mgd, with year 2010 improvements as previously described in this chapter. The analyses included all nodes in the hydraulic model with the exception of a few nodes on the suction side of pumping facilities. The computer model was configured to calculate the available fire flow at 25 psi (20 psi residual pressure plus 5 psi local hydrant loss) for each of the nodes. All but three system nodes were able to deliver a fire flow of at least 1000 gpm (1.44 mgd) under these conditions. These three nodes were located on dead-end lines near service level boundaries. A color-coded figure showing the available fire flow at each node is provided in Appendix E.

SECTION VI – CAPITAL IMPROVEMENTS PLAN

1.0 Recommended Improvements

1.1 Recommended Alternative

As described in Chapter V-1.0 Alternatives Evaluation, we recommend that the City of Lawrence proceed with implementing the water supply, treatment, and distribution system improvements identified for Alternative 1.

Alternative 1 involves the expansion of the Clinton WTP and the Kaw WTP to 25 mgd each to meet the projected year 2025 maximum day demand of 50 mgd. A summary of costs associated with this recommendation is shown in Table VI-1.

Table VI-1
Capital Cost Summary of Recommended Improvements

Component	Capital Cost ($)
Kaw Raw Water Supply Improvements	
Reliability	756,000
Growth	4,009,000
Clinton Raw Water Supply Improvement	
Reliability	--
Growth	1,151,000
Kaw WTP Improvements	
Reliability	--(1)
Growth	14,561,000
Regulatory	2,476,000
Clinton WTP Improvements	
Reliability	--
Growth	7,901,000
Regulatory(2)	2,476,000
Distribution System Improvements	36,440,000
New Operations and Maintenance Building	4,719,000
Total Improvements	**74,489,000**

(1) Reliability improvements are in the current year budget and are not included in this table for construction of a parallel header between the raw water flow splitter and presettling Basins 4 and 5, to remove a hydraulic restriction that currently limits the plant to about 16 mgd.
(2) UV post-filtration irradiation for Cryptosporidium inactivation may or may not be required depending upon the results of source water monitoring under the LT2ESWTR.

Additional information on recommended improvements for Alternative 1 is provided in the following paragraphs.

1.1.1 Water Supply

The firm capacity of the existing intake and vertical wells at Kaw WTP is approximately 16 mgd. Therefore, improvements are required to upgrade the firm capacity of the raw water supply system to 17.5 mgd to be compatible with the existing WTP capacity. A 30-inch parallel siphon should be constructed to increase the firm capacity of the intake system. In addition, all of the pumps at Low Service Pumping Station No. 2 (LSPS No. 2) should be replaced with five units rated at 3,050 gpm at approximately 75 feet head to provide the required pumping capacity. Other options for pump replacement capacities (such as two or three pump replacements with different rated capacities) may be considered during detailed design.

Additional surface water supply or a new groundwater supply is required at the Kaw WTP to expand the raw water supply system to 25 mgd. A second intake crib would be constructed and a new 24-inch raw water supply line would convey water to the trash well. From there, the water would be pumped through an upgraded Low Service Pumping Station No. 1 (LSPS No. 1) through a new 24-inch raw water transmission line to convey the water to the new treatment train. Required upgrades at LSPS No. 1 include replacing the pumps, electrical equipment, HVAC, and instrumentation and controls.

The Bowersock Dam has recently undergone significant maintenance repair. The City should plan on inspecting the dam and budgeting for miscellaneous repairs of the 100+ year old structure on a routine basis to ensure that the dam remains as a viable feature of the City's raw water supply system.

Improvements are required to develop a firm supply of 25 mgd to the Clinton WTP. In order to provide the firm capacity at projected drought water pool elevation in the Clinton Reservoir, all of the existing pumping units should be replaced with higher head units rated at approximately 180 feet. Three 10 mgd units and one 5 mgd unit should be installed and for flexibility, equipped with adjustable frequency drives.

1.1.2 Water Treatment

In order to expand the Kaw WTP from 17.5 mgd to 25 mgd, a new 7.5 mgd treatment train should be added and new presedimentation, primary, and secondary basins should be constructed. Circular basins are considered preferable to rectangular basins because circular softening equipment is more efficient in reducing hardness and settling out precipitate. Circular basins would provide treatment similar to that used at the Clinton WTP.

Additional filtration capacity is also needed at the Kaw WTP. It appears that the most viable option would be to construct two additional filters west of existing filters 5 through 8. For reliability, the two new filters should be of the same size as the adjacent filters, which would increase the filtration capacity by 7.8 mgd at a loading rate of 4 gpm/sf.

A new treated water reservoir with a minimum volume of 1 million gallons should be constructed to provide additional storage capacity at the site, allowing plant operation to vary from production rates. In addition to these improvements, new chemical feed facilities would need to be constructed to accommodate the increased capacity.

Expanding the Clinton WTP from 15 mgd to 25 mgd would involve the construction of a new basin train consisting of a presedimentation, a primary, and a secondary basin, and the installation of new chemical feed equipment for the new basin train; and construction of additional high service pumping facilities. Recommended high service pump station improvements are described in the following section about the distribution system. The Clinton WTP expansion project completed in 2002 already includes the filtration and transfer pump improvements necessary to process 25 mgd.

Depending upon the results of the monitoring for source water Cryptosporidium under LT2ESWTR, additional provisions for oocyst removal and/or inactivation may be required at the Kaw and the Clinton WTP. Depending on the severity of the Cryptosporidium infestation in the raw water, post-filtration UV disinfection may be required.

1.1.3 Distribution System

Service Levels: Much of the area west of Kansas Highway 10 (K-10) includes ground elevations that cannot be served at adequate pressures from the existing West Hills Service Level. A new Kanwaka Booster District is recommended to serve the entire area west of K-10. The Kanwaka Booster District would be supplied by booster pumping from the existing West Hills Service Level.

A South Service Level should be established for the future service area south of the Wakarusa River. The South Service level would have a maximum static hydraulic gradient of 1050, or about 30 feet higher than the existing Central Service Level.

Two areas of high ground that are expected to have a sizable future population could not be served by the future South Service Level. South 1 Booster District would be located in the southwest corner of the service area, along the south shore of Clinton

Reservoir, and South 2 Booster District would be located on a ridge between Wakarusa Drive and Kasold Drive.

*Storage Facilities: T*he City has been planning to construct additional storage in the West Hills Service Level along 6th Street, west of Wakarusa Drive. Based on the evaluations conducted for this report, this storage should have a minimum total volume of 1.0 million gallons.

No additional storage is recommended for the Central Service Level.

Recommended additional storage facilities to meet projected demands through year 2025 are summarized in Table VI-2.

Table VI-2
Recommended Additional Storage Facilities

Service Level	Facility Name	Volume (MGal)
West Hills Service Level	Sixth Street East Elevated Tank	1.0
Kanwaka Booster District	Kanwaka Elevated Tank	1.0
South Service Level	Central South Ground Storage	1.0
South 1 Booster District	South 1 Elevated Tank	0.25
South 2 Booster District	South 2 Elevated Tank	0.25

Pumping Facilities: Recommended pumping facilities are summarized below:

- The Kawaka Booster District should be supplied by two pumping stations for reliability and redundancy. The major pumping station should be located along Sixth Street, at the same location as the recommended 6th Street West Elevated Tank.

- The future South Service Level (including South 1 and South 2 Booster Districts) should receive the majority of its supply through a booster pumping station located in the vicinity of O'Connell Road and N 1100 Road (O'Connell Road Booster Station). Additional supplemental supply of about 2.0 mgd would be delivered directly from the Clinton WTP. A flow control valve should be installed on the existing 24-inch Central Service Level main near the intersection of 23rd Street and Wakarusa Drive to allow the Clinton WTP high service pumps to pump directly to the future South Service Level and to concurrently deliver water to the Central Service Level.

- The South 1 and South 2 Booster Districts should each be supplied by a single booster pumping station and elevated tank.

- High service pumping improvements are required for both the Kaw and the Clinton WTP as summarized below:

  - All four "old" Kaw WTP high service pumps to the Central Service Level should be replaced with 3.5 mgd units to meet year 2025 demands.

  - The Kaw WTP high service pumps to the West Hills Service Level deliver only about 1.2 mgd, which is less than their reported capacity of 1.5 mgd. For reliability, the pumps should be replaced with units that would 1.5 mgd at a rated head of 350 feet.

  - The Clinton WTP high service pumping capacity to the Central Service Level is not adequate to meet projected year 2025 demands. Two additional 5.0 mgd units should be installed.

  - The firm rated capacity of 10 mgd from Clinton WTP high service pumping building to the West Hills Service Level is inadequate to meet the projected year 2025 demands. Two additional pumps rated at 4.5 mgd should be installed in the high service pumping building when the water treatment plant is expanded.

Distribution Mains: Significant distribution main improvements are required to deliver water from the expanded water treatment plants and to supply the expanded service area. Distribution main improvements are shown, with the locations of the other distribution system improvements discussed above, on Exhibit IV-1 in Section IV of this report.

Distribution main improvements are recommended to help sustain the water level in the Harper Elevated Tank. While a recommendation for a new "Harper Booster District" is not included in this report, additional consideration should be given to this concept if pressure concerns continue to be an issue in the area.

1.1.4 Operations and Maintenance Building

New operations and maintenance building space should be constructed at a location that can be separated from the water processing areas to provide a consolidated area for all Utilities Department administrative staff. An isolated site would enhance the security of the water processes as there would be no reason for the general public to require access to the plant sites. Public access is currently required at the Kaw WTP because the administrative staff is located there.

1.2 Implementation Plan

Detailed discussions of cost for the recommended improvements are provided in Section V of this report. An implementation plan showing 10-year capital improvements was developed on the basis of the recommended improvements and is shown on Table VI-3. The phasing schedule for the Clinton WTP expansions is shown on Figure VI-1. Recommended improvements are shown on Figure VI-2.

Revised JAE 02/26/04

Corrected Error with Summation of 1st Subtotal

Water System Facility Project Name	Reason for Improvement	Year 2003 Project Cost (1) Short Term 2004 -2013	Long Range Through 2027	Project Cost by Year Including 4% Annual Inflation 2004 ($)	2005 ($)	2006 ($)	2007 ($)	2008 ($)	2009 ($)	2010 ($)	2011 ($)	2012 ($)	2013 ($)
Water Supply Improvements													
Kaw WTP Improvements - Parallel Supply Siphon & Pump Replacement (ELA)	(C)	$93,000		$96,720	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP Improvements - Parallel Supply Siphon & Pump Replacement (const)	(C)	$463,000		$0	$500,781	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP Supply Expansion - Intake, LSPS #1, Raw Water Lines (ELA)	(A)		$668,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP Supply Expansion - Intake, LSPS #1, Raw Water Lines (Const)	(A)		$3,341,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Clinton WTP Supply Expansion - Three New Pumps (ELA)	(A)	$192,000		$0	$0	$0	$0	$0	$0	$0	$262,771	$0	$0
Clinton WTP Supply Expansion - Three New Pumps (ELA)	(A)	$959,000		$0	$0	$0	$0	$0	$0	$0	$0	$1,364,945	$0
16-inch Raw Water Line on New I-70 Bridge - for future wells (const +ELA)	(C)		$200,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Bowersock Dam Maintenance and Improvements (const + ELA)	(C)	$2,000,000	$2,500,000	$0	$0	$0	$1,169,900	$0	$0	$0	$0	$0	$1,480,200
Water Treatment Improvements													
Residuals Monofill	(B)	$1,000,000		$1,040,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP - Central Service Level Discharge Piping Modifications (const +ELA)	(C)	$750,000		$0	$811,200	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP Expansion (ELA) (3)	(A)		$2,427,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP Expansion (Const) (3)	(A)		$12,134,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP - High Service HSKC - Replace All Four "Old" Central Service Pumps (const + ELA)	(A)		$600,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kaw WTP - High Service HSKW - Replace All Three West Hills Pumps (const + ELA)	(C)	$130,000		$0	$0	$0	$0	$158,171	$0	$0	$0	$0	$0
Clinton WTP Expansion - (ELA) (3)	(A)	$1,317,000		$547,872	$569,787	$296,299	$0	$0	$0	$0	$0	$0	$0
Clinton WTP Expansion - (const) (3)	(A)	$6,584,000		$0	$2,350,014	$4,962,249	$0	$0	$0	$0	$0	$0	$0
Clinton WTP - High Service HSCW - Add Two West Hills High Service Pumps (const + ELA)	(A)	$290,000		$0	$0	$326,221	$0	$0	$0	$0	$0	$0	$0
Clinton WTP - High Service HSCS - Replace Central/South High Service Pump (const + ELA)	(A)		$190,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Clinton WTP - High Service HSBA - High Service Pumping Station Building Addition (ELA)	(A)	$145,000		$150,800	$0	$0	$0	$0	$0	$0	$0	$0	$0
Clinton WTP - High Service HSBA - High Service Pumping Station Building Addition (const)	(A)	$875,000		$0	$473,200	$492,144	$0	$0	$0	$0	$0	$0	$0
Operations and Maintenance Building	(C)	$4,680,000		$0	$0	$0	$0	$1,138,831	$4,737,283	$0	$0	$0	$0
Distribution System Improvements (const + ELA) (2)													
Main C1 - 16" - Wakarusa Dr South from Clinton WTP to Wakarusa River	(A)		$1,730,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C2 - 16" - N 1170 Road in South Service Level	(A)		$990,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C3 - 16" - Kasold Drive in South Service Level	(A)		$520,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C4 - 16" - Supply Line to New South Service Level Reservoir	(A)		$200,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C5 - 16" - N 1100 Road in South Service Level	(A)		$2,200,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C6 - 16" - Haskell Ave in South Service Level	(A)		$730,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C7 - 20" - N 1100 Road in South Service Level	(A)		$920,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C8 - 24" - O'Connell Road from 31st Street to N 1100 Road	(A)		$2,200,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C9 - 24" - 19th & Harper to 31st & O'Connell	(A)		$2,200,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C10 - 30" - 9th & New York to 19th & Harper	(A)	$2,880,000		$0	$0	$0	$0	$0	$0	$0	$0	$2,049,552	$2,131,488
Main C11 - 30" - 8th St / Tennessee St / 9th St with Replace of 14" w/ 8"	(A,C)	$1,450,000		$0	$0	$0	$0	$441,054	$1,376,014	$0	$0	$0	$0
Main C12 - 30" - Indiana St from 5th St to 8th St with Replace of 14" w/ 8"	(A,C)	$790,000		$0	$0	$0	$231,055	$720,895	$0	$0	$0	$0	$0
Main C13 - 36" - Indiana St from Kaw WTP to 5th St with Replace of 14" w/ 8"	(A,C)	$810,000		$0	$0	$0	$236,905	$739,145	$0	$0	$0	$0	$0
Main C14 - 8" - Replace Additional old 14" Mains in Downtown Lawrence (5th,6th,8th,Tenn.)	(C)		$680,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main C15 - 16" - Second River Crossing to North Lawrence	(C)		$1,320,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W1 - 12" - Sunset Drive to Stratford Elevated Tank	(C)		$100,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W2 - 12" - From Kaw WTP to W 6th St & Rockledge Road	(C)		$980,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W3 - 12" - W 6th St from Rockledge Road to Sixth Street (East) Elevated Tank	(C)		$750,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W4 - 16" - W 6th St from Wakarusa Dr to Sixth St. (West) Elevated Tank	(A)	$600,000		$624,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W5 - 12" - W 6th St from Deer Run to to Sixth St (West) Elevated Tank	(A)	$270,000		$280,800	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W6 - 12" - W 6th St from Sixth St (West) Elevated Tank to K-10 (SLT)	(A)	$360,000		$374,400	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W7 - 16" - W 6th St from Sixth St (West) Elevated Tank to K-10 (SLT)	(A)	$530,000		$551,200	$0	$0	$0	$0	$0	$0	$0	$0	$0
Main W8 - 16" - W 6th St from K-10 (SLT) to Kanwaka Elevated Tank	(A)	$1,340,000		$0	$0	$0	$0	$0	$0	$881,653	$916,962	$0	$0
Valve FCV1 - Clinton Parkway Flow Control Valve to Central Service Level	(A)		$290,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pumping Station BPS1 - Kanwaka North BPS	(A)	$1,110,000		$0	$0	$0	$0	$0	$0	$730,325	$759,573	$0	$0
Pumping Station BPS2 - Kanwaka South BPS	(A)	$330,000		$0	$0	$0	$0	$0	$0	$434,247	$0	$0	$0
Pumping Station BPS3 - O'Connell Road BPS	(A)		$2,280,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pumping Station BPS4 - South 1 Booster District BPS	(A)		$430,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pumping Station BPS5 - South 2 Booster District BPS	(A)		$330,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Storage Facility T1 - Sixth Street (West) Elevated Tank	(A)	$1,440,000		$0	$0	$0	$1,684,656	$0	$0	$0	$0	$0	$0
Storage Facility T2 - Kanwaka Elevated Tank	(A)	$1,440,000		$0	$0	$0	$0	$0	$0	$0	$0	$2,049,552	$0
Storage Facility T3 - South Service Level Ground Storage Tank	(A)		$1,150,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Storage Faciltiy T5 - South 1 Booster District Elevated Tank	(A)		$430,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Storage Faciltiy T5 - South 2 Booster District Elevated Tank	(A)		$430,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Repaint Kasold Ground Storage Tank	(C)	$380,000		$395,200	$0	$0	$0	$0	$0	$0	$0	$0	$0
Repaint Clinton WTP Ground Storage Tanks	(C)	$680,000		$0	$0	$0	$795,532	$0	$0	$0	$0	$0	$0
Replace 1931 Oread Tank - 1.0 MGal	(C)	$1,440,000		$0	$0	$0	$0	$0	$0	$0	$1,970,784	$0	$0
Replace 1954 Oread Tank - 1.4 MGal	(C)		$2,020,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Waterline Rehabilitation and Replacement Program	(A,C)	$10,000,000	$15,000,000	$1,040,000	$1,081,600	$1,124,900	$1,169,900	$1,216,700	$1,265,300	$1,315,900	$1,368,600	$1,423,300	$1,480,200
Security Improvements	(B)	$2,500,000		$416,000	$540,800	$562,450	$584,950	$730,020	$0	$0	$0	$0	$0
Misc. Water System Improvements	(B,C)	$10,000,000	$15,000,000	$1,040,000	$1,081,600	$1,124,900	$1,169,900	$1,216,700	$1,265,300	$1,315,900	$1,368,600	$1,423,300	$1,480,200
Subtotal (Recommended Plan) (3)		**$57,828,000**	**$74,940,000**	**$6,556,992**	**$7,408,982**	**$8,889,162**	**$7,042,798**	**$6,361,516**	**$8,643,897**	**$4,678,025**	**$6,647,290**	**$8,310,649**	**$6,572,088**
Modifications due to Pending and Future Regulations													
Kaw WTP - LT2ESWTR - UV (eng)	(B)	$413,000		$0	$0	$0	$0	$0	$522,569	$0	$0	$0	$0
Kaw WTP - LT2ESWTR - UV (const)	(B)	$2,063,000		$0	$0	$0	$0	$0	$0	$2,714,702	$0	$0	$0
Clinton WTP - LT2ESWTR - UV (eng)	(B)	$413,000		$0	$0	$0	$0	$0	$522,569	$0	$0	$0	$0
Clinton WTP - LT2ESWTR - UV (const)	(B)	$2,063,000		$0	$0	$0	$0	$0	$0	$2,714,702	$0	$0	$0
Subtotal (Regulations) (3)		**$4,952,000**		**$0**	**$0**	**$0**	**$0**	**$0**	**$1,045,138**	**$5,429,403**	**$0**	**$0**	**$0**
Total (All Projects) (3)		**$62,780,000**	**$74,940,000**	**$6,556,992**	**$7,408,982**	**$8,889,162**	**$7,042,798**	**$6,361,516**	**$9,689,035**	**$10,107,428**	**$6,647,290**	**$8,310,649**	**$6,572,088**

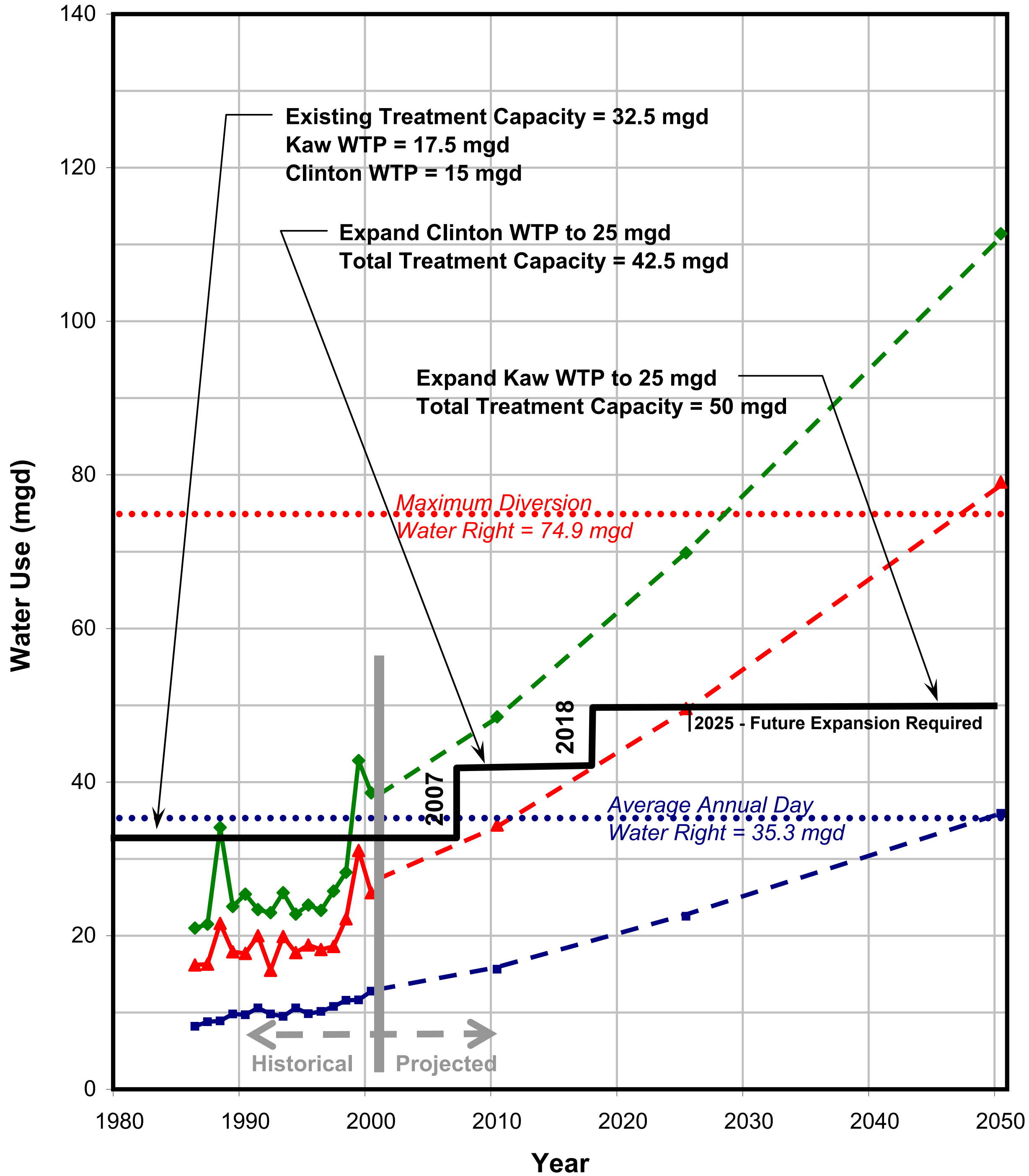
(1) Project costs include construction costs plus a service factor for contingencies, engineeering, legal, and admininstration costs as noted in report text.
(2) Distribution system improvements 12-inch diameter and smaller in growth areas are to be funded by developers and are not included in this CIP.
(3) Costs do not include bond or financing costs.
(4) Project Costs for Planning Years include 4 percent inflation per year
(5) Exact timing of impprovements is uncertain and will be dependant on City funding availability and physical condition of equipemnt.
(6) Project costs identified in this table are identified also as capital cost throughout report text.

Reason for Improvement
(A) - Growth Related Improvement
(B) - Regulatory related improvement.
(C) - Reliability related improvement.

City of Lawrence, Kansas
Water System Master Plan - 2003

Implementation Plan

Table VI-3



Legend

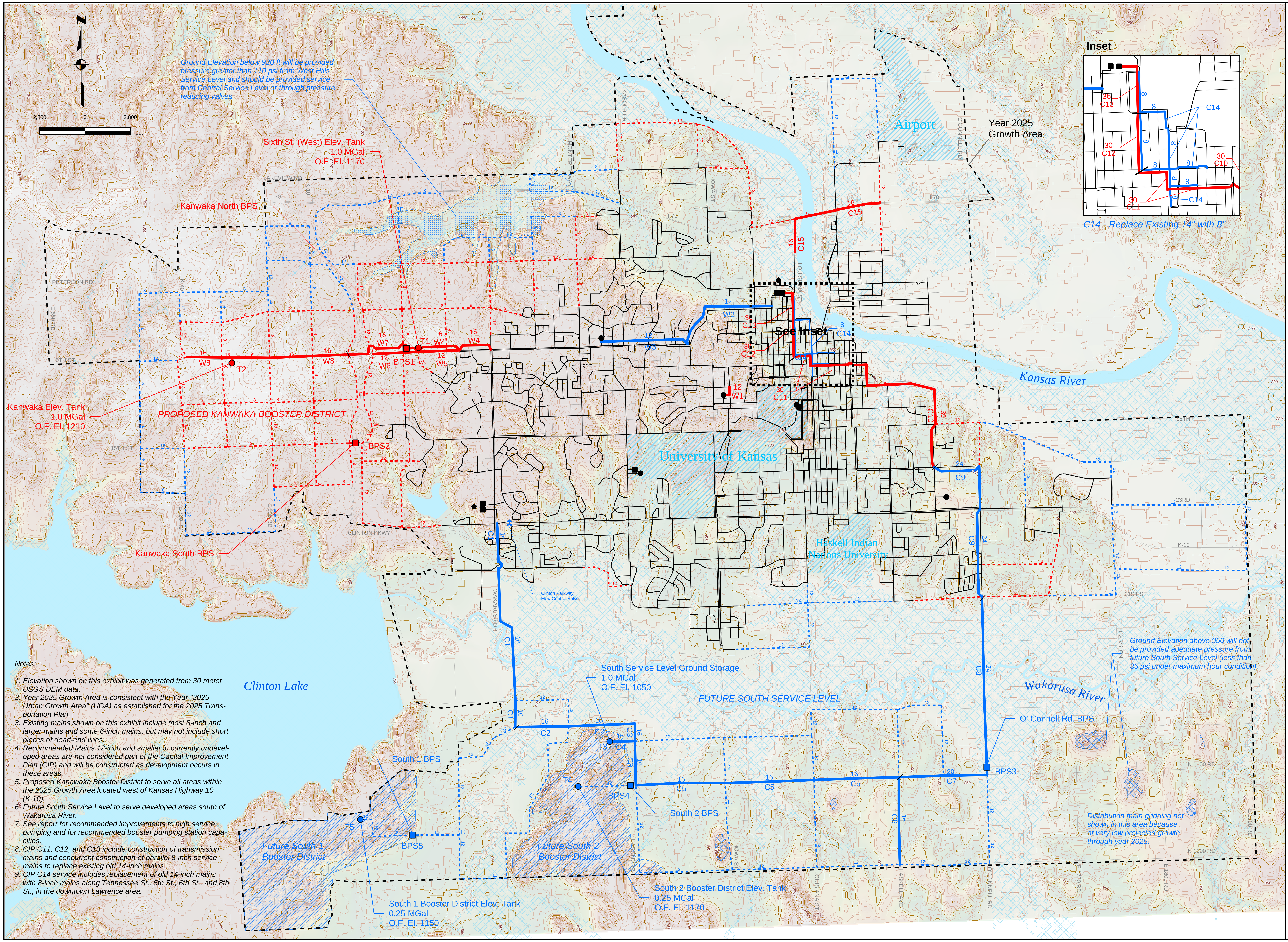
- Average Day
- Maximum Day
- Maximum Hour

City of Lawrence, Kansas
Water System Master Plan
2003

WTP Expansion Phasing

BLACK & VEATCH Corporation

Figure VI-1



City of Lawrence, Kansas
Water Master Plan
2003

Legend

Recommended Improvements

2010	2025	
16 C10	16 C8	CIP Main with Number and Diameter (see note)
12	12	Development Main and Diameter
T1	T3	Storage Facility with CIP Number
BPS1	BPS3	Pumping Station with CIP Number

Existing Pipes and Facilities

- Water Main
- Water Treatment Plant
- Storage Facility
- Pumping Station

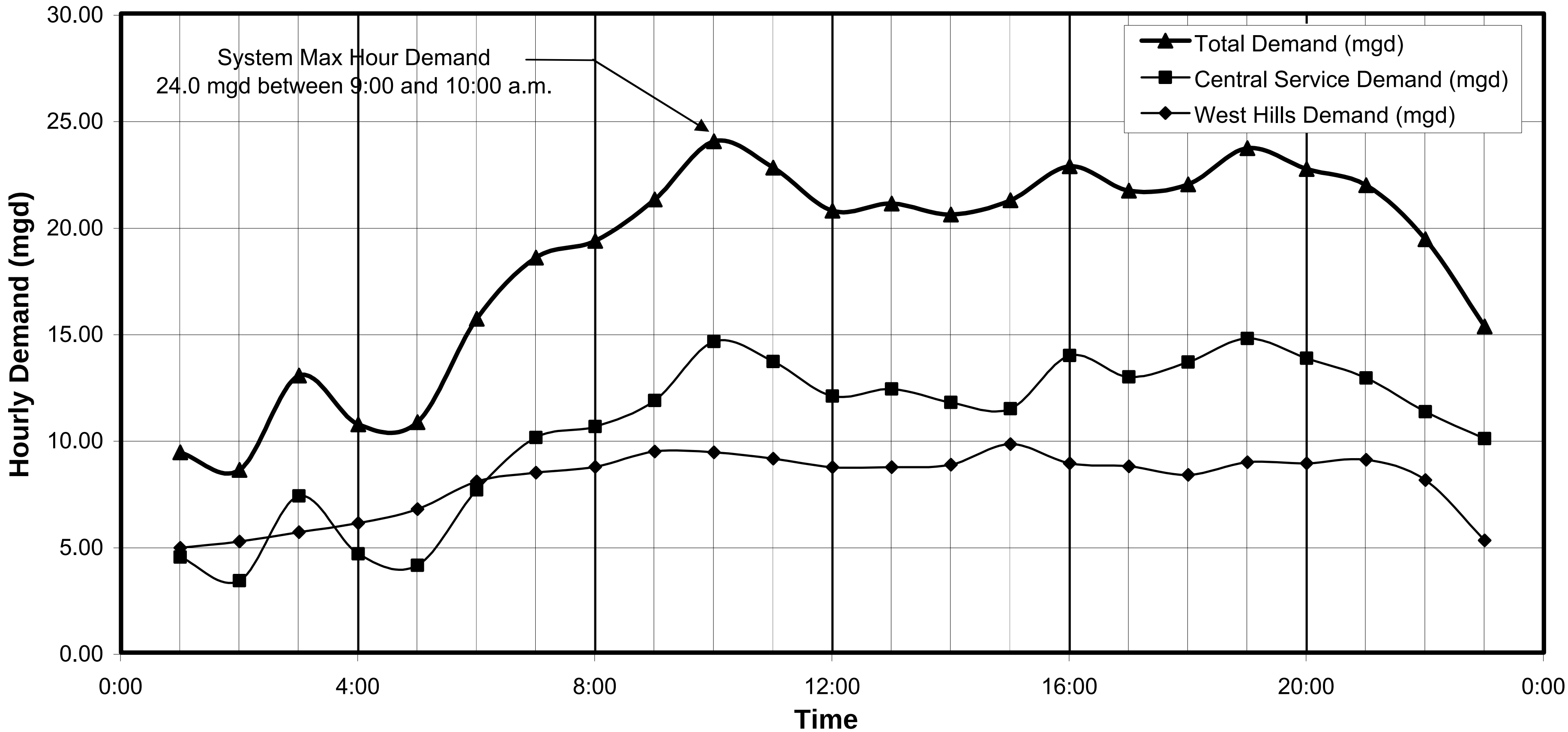
Miscellaneous

- 100-Year Floodplain
- River and Lake

Recommended Improvements

BLACK & VEATCH Corporation

Figure VI-2



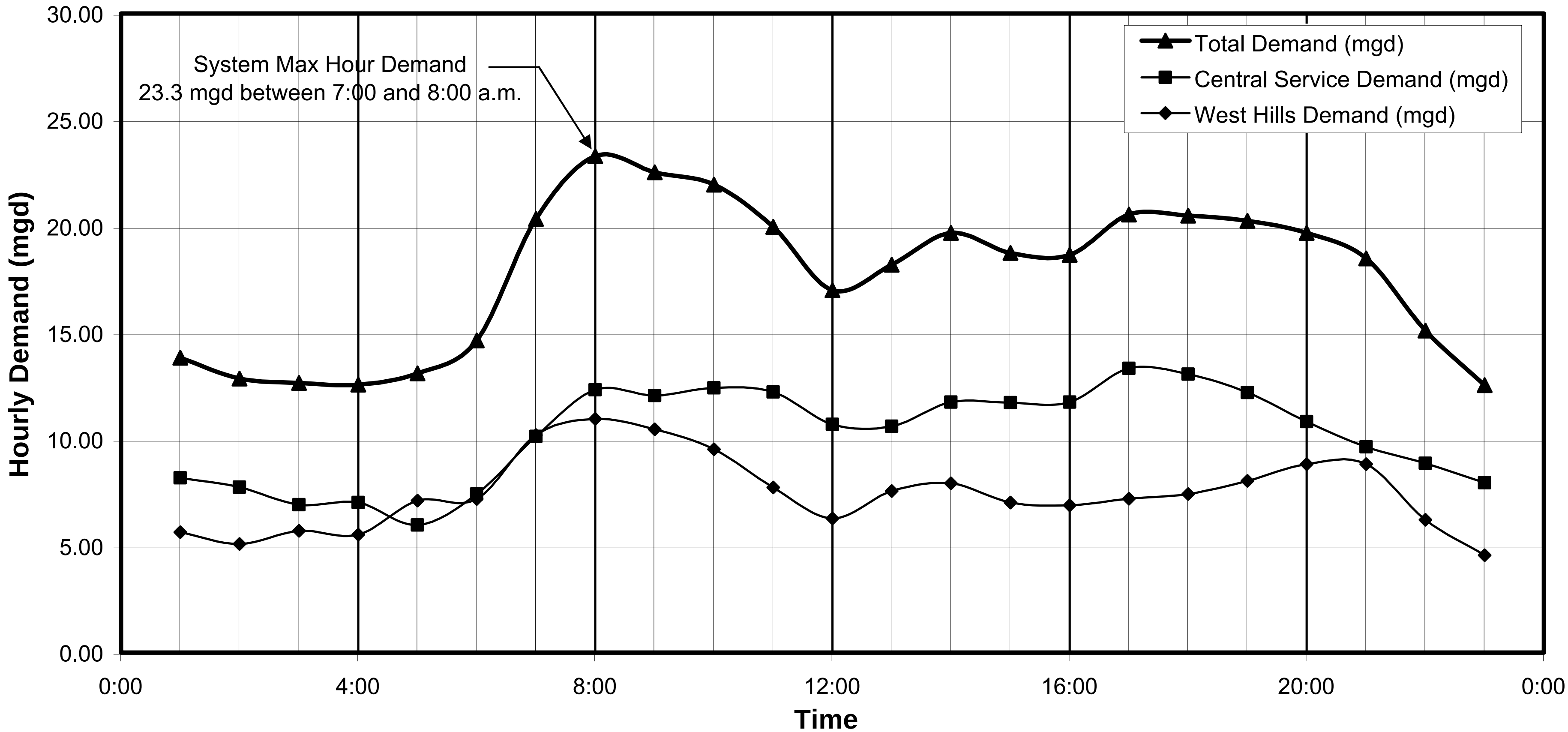
Saturday, July 15, 1995
Total Day Demand = 18.6 mgd

City of Lawrence
Water System Master Plan - 2003

Maximum Day 1995
Hourly Demands

Figure A-1

BLACK & VEATCH
Corporation



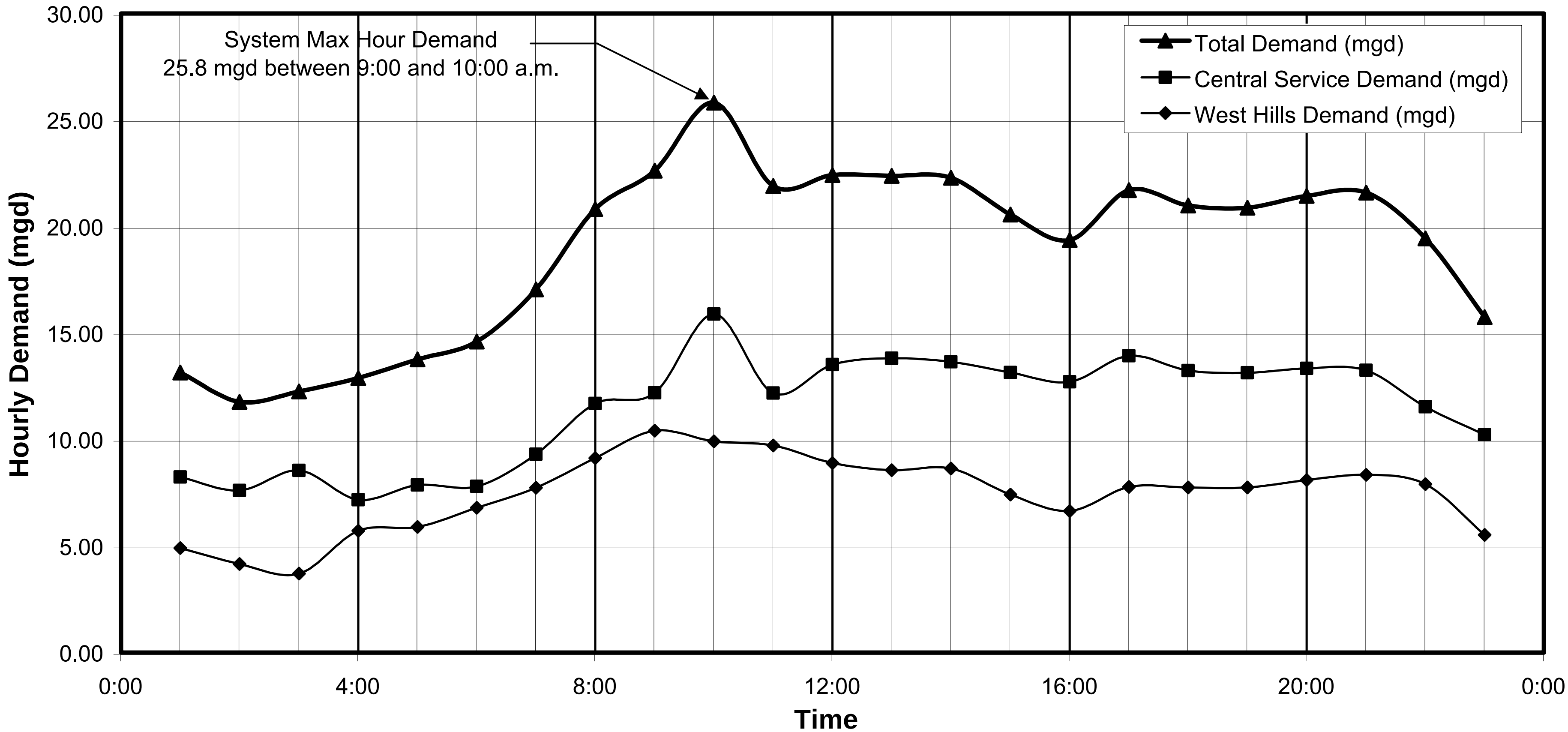
Friday, July 19, 1996
Total Day Demand = 17.7 mgd

City of Lawrence
Water System Master Plan - 2003

Maximum Day 1996
Hourly Demands

BLACK & VEATCH
Corporation

Figure A-2



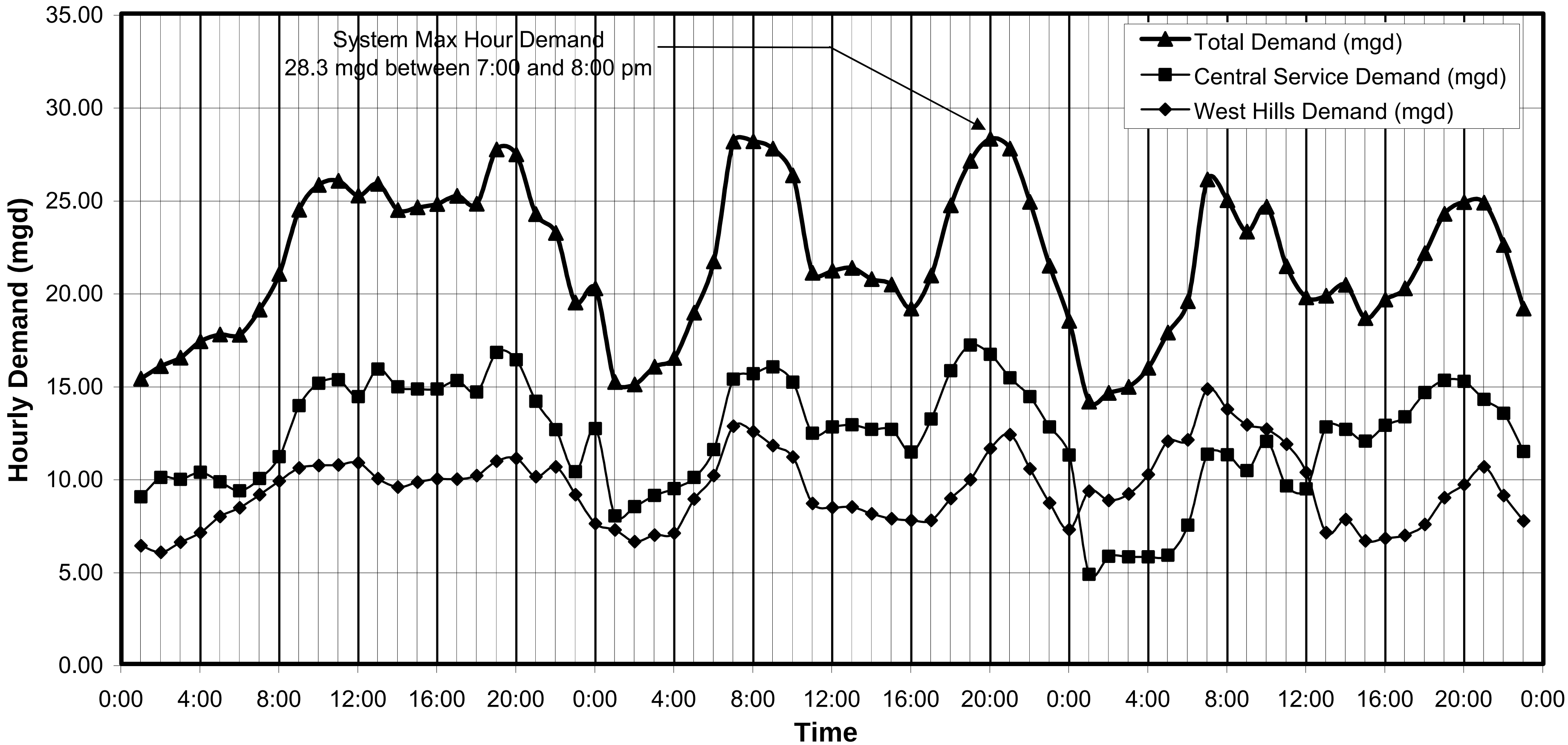
Saturday, July 26, 1997
Total Day Demand = 18.9 mgd

City of Lawrence
Water System Master Plan - 2003

Maximum Day 1997
Hourly Demands

Figure A- 3

BLACK & VEATCH
Corporation



Sunday, August 23, 1998
Total Day Demand = 22.2 mgd

Monday, August 24, 1998
Total Day Demand = 22.1 mgd

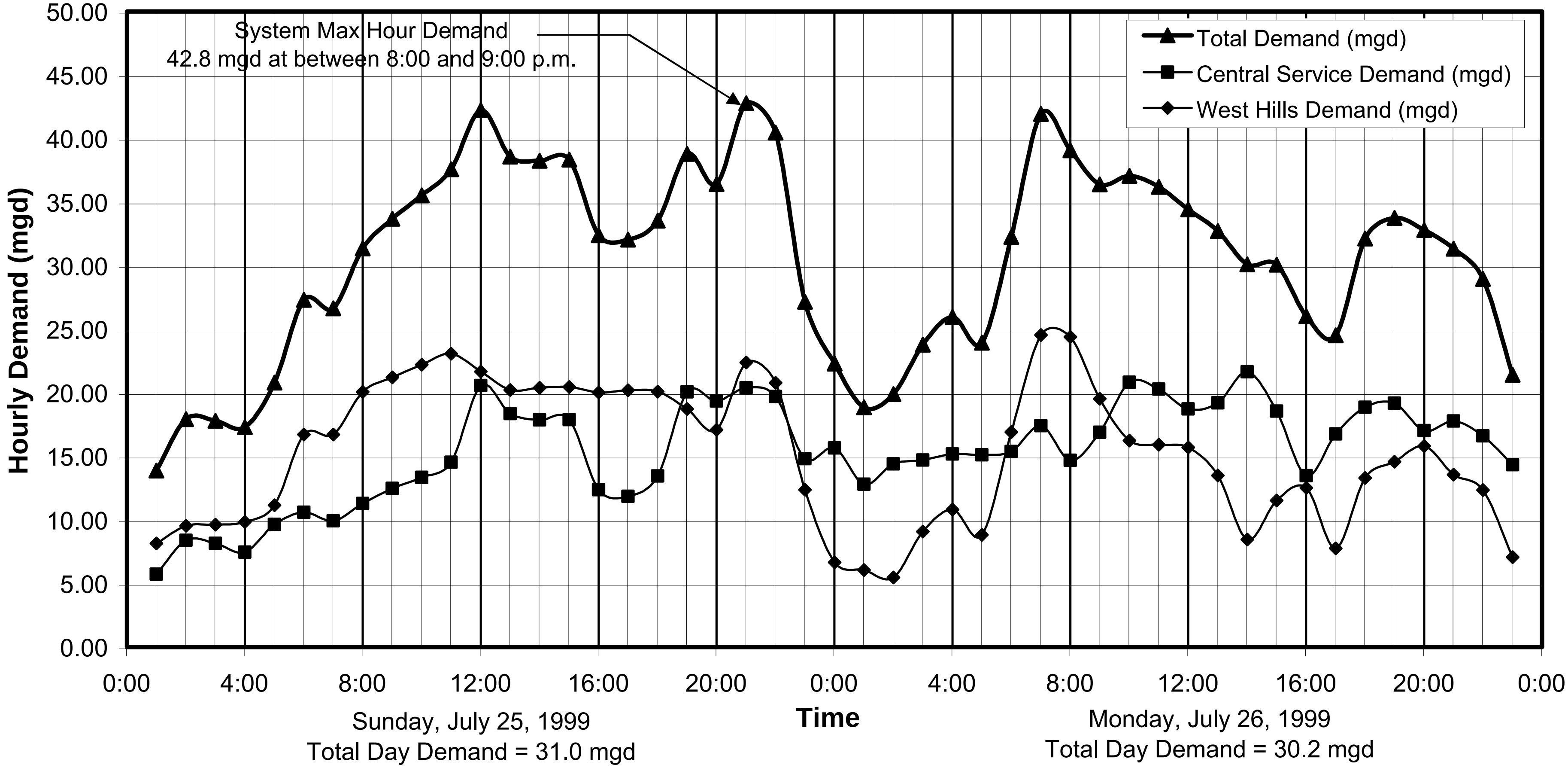
Tuesday, August 25, 1998
Total Day Demand = 20.6 mgd

City of Lawrence
Water System Master Plan - 2003

Maximum Day 1998
Hourly Demands

BLACK & VEATCH
Corporation

Figure A-4

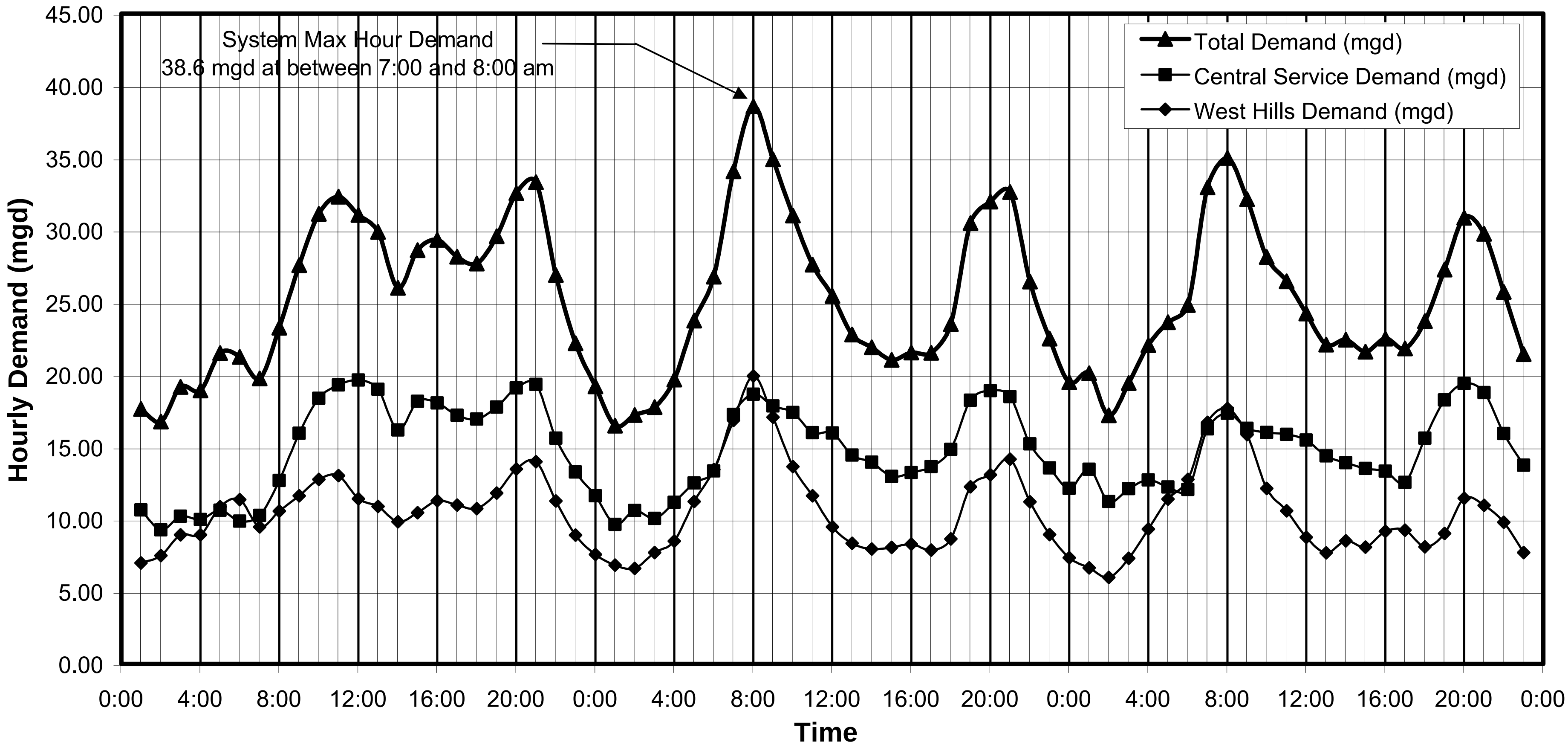


City of Lawrence
Water System Master Plan - 2003

Maximum Day 1999
Hourly Demands

Figure A-5

BLACK & VEATCH
Corporation



Sunday, August 27, 2000
Total Day Demand = 25.6 mgd

Monday, August 28, 2000
Total Day Demand = 25.4 mgd

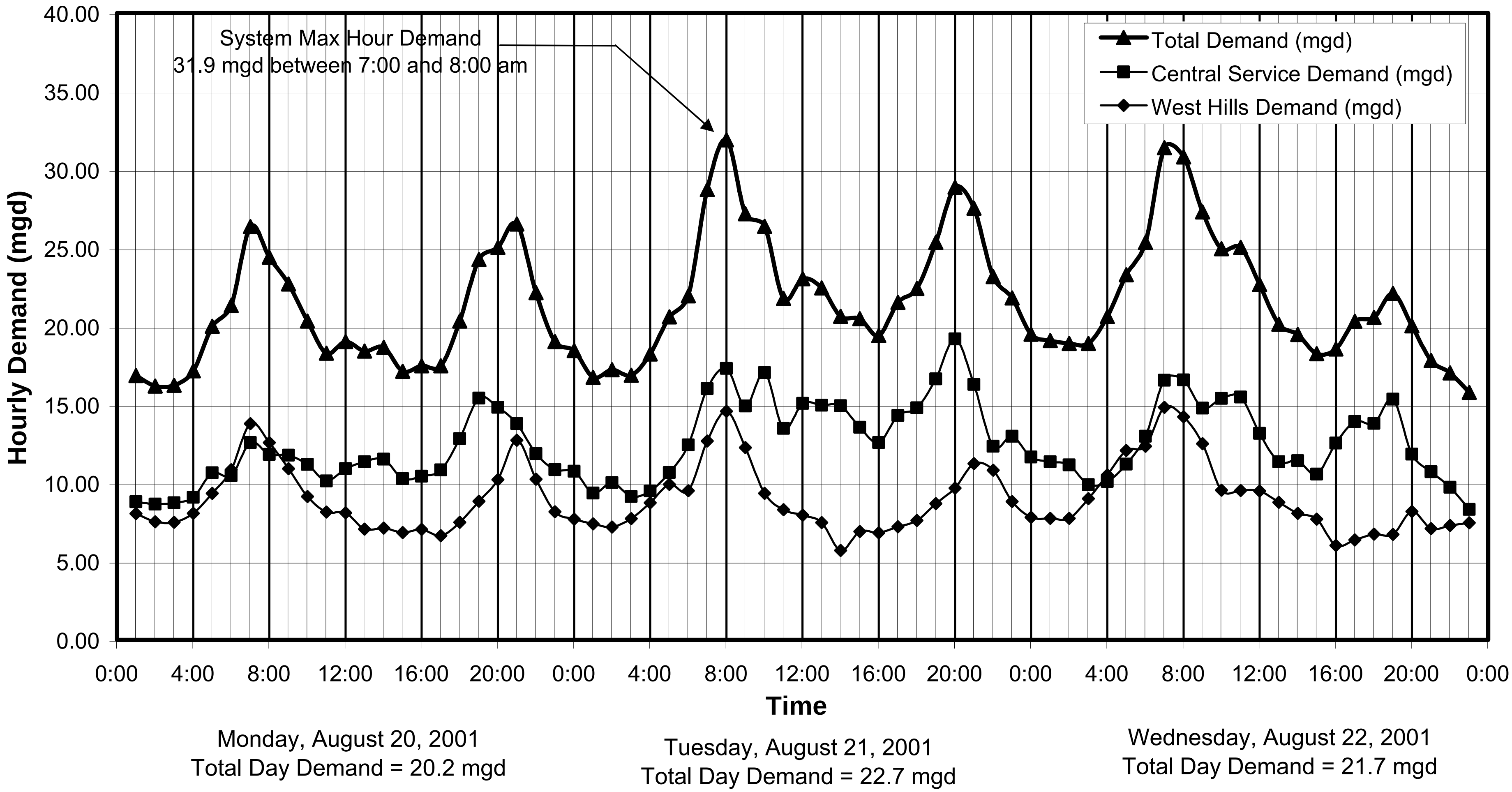
Tuesday, August 29, 2000
Total Day Demand = 25.0 mgd

City of Lawrence
Water System Master Plan - 2003

Maximum Day 2000
Hourly Demands

BLACK & VEATCH
Corporation

Figure A-6

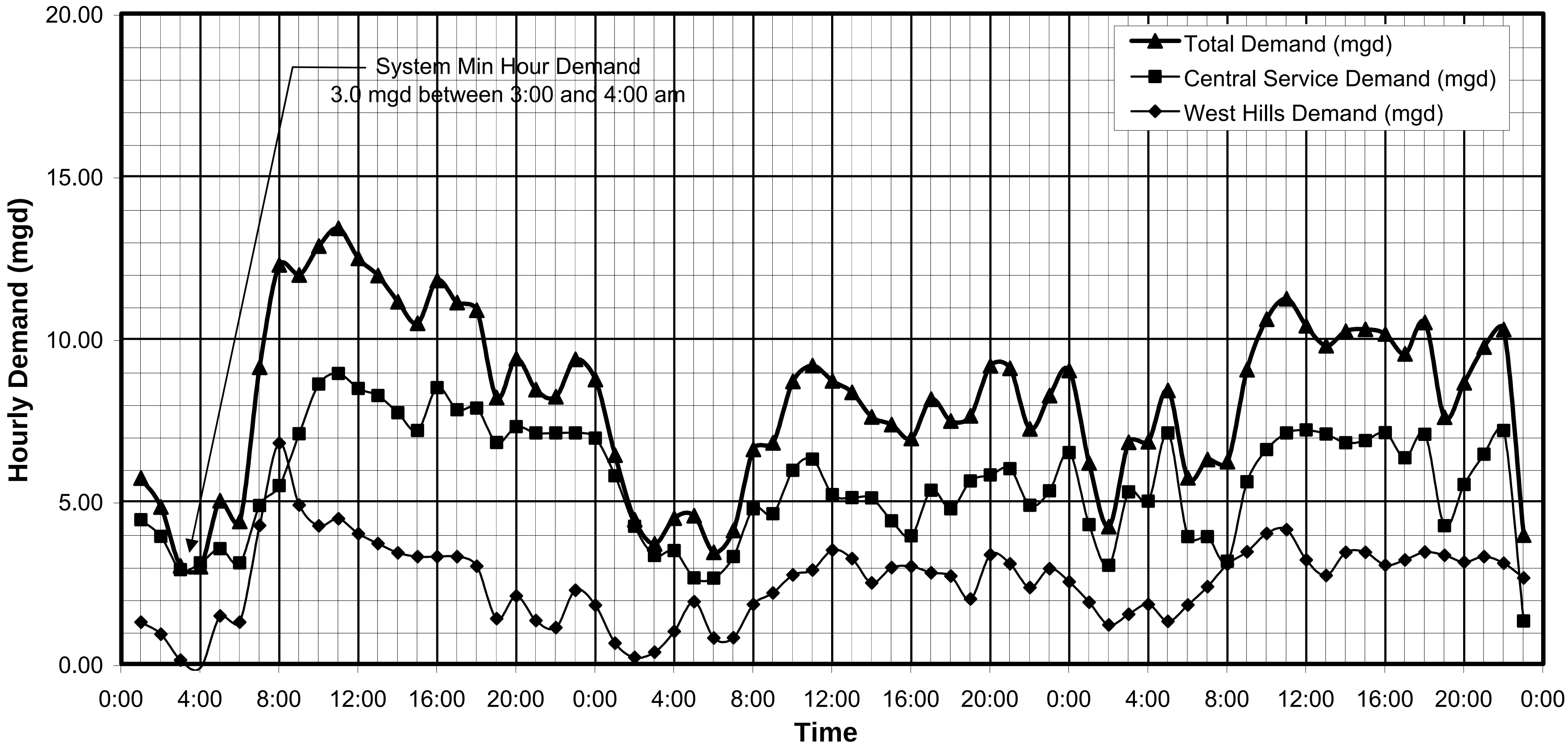


City of Lawrence
Water System Master Plan - 2003

Maximum Day 2001
Hourly Demands

BLACK & VEATCH
Corporation

Figure A-7



Sunday, December 24, 2000
Total Day Demand = 9.1 mgd

Monday, December 25, 2000
Total Day Demand = 7.0 mgd

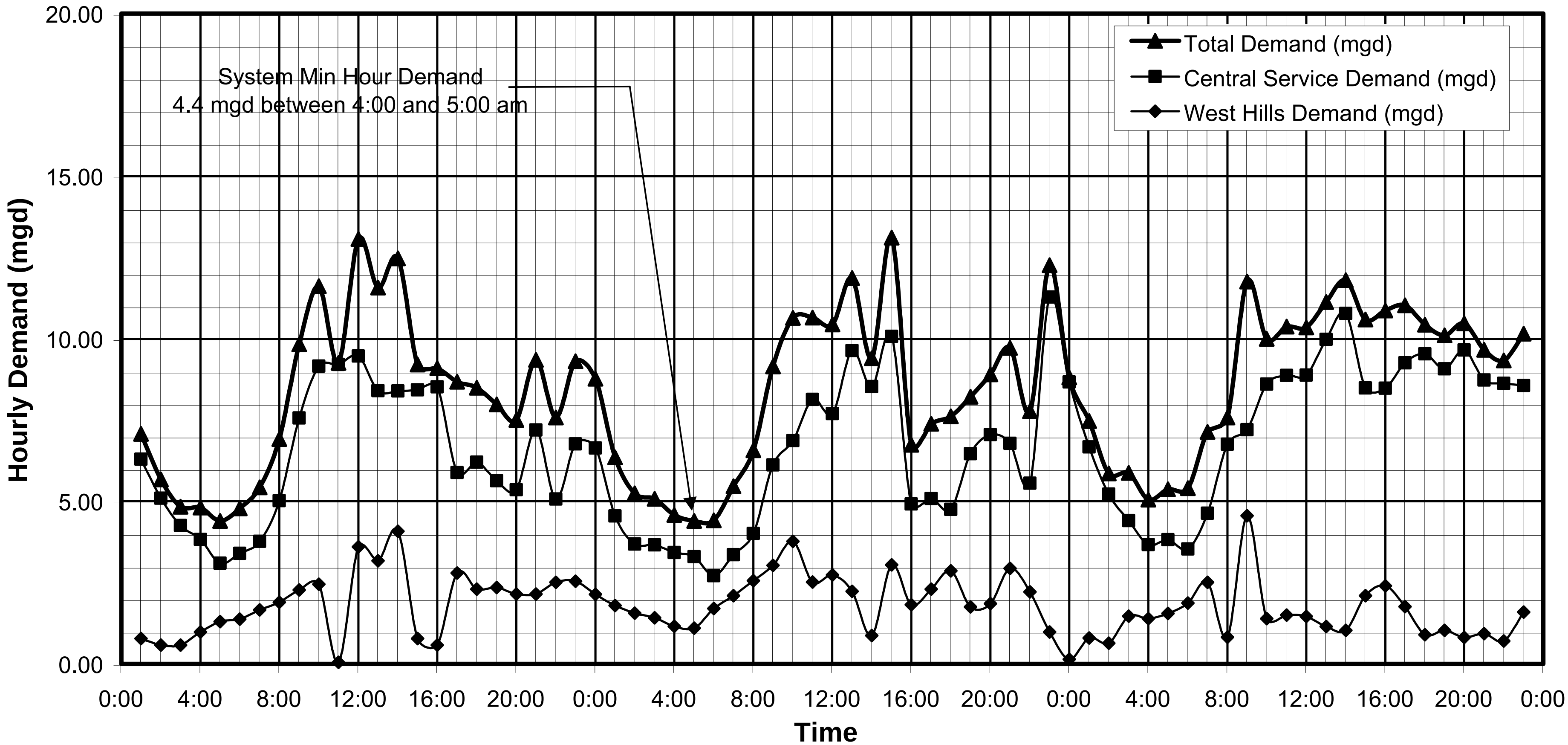
Tuesday, December 26, 2000
Total Day Demand = 8.4 mgd

City of Lawrence
Water System Master Plan - 2003

Minimum Day 2000
Hourly Demands

Figure B-1

BLACK & VEATCH
Corporation



Monday, December 24, 2001
Total Day Demand = 8.2 mgd

Tuesday, December 25, 2001
Total Day Demand = 8.1 mgd

Wednesday, December 26, 2001
Total Day Demand = 9.0 mgd

City of Lawrence
Water System Master Plan - 2003

Minimum Day 2001
Hourly Demands

Figure B-2

BLACK & VEATCH
Corporation

Appendix C

Water Treatment Regulatory Requirements

The first national regulatory standards for drinking water quality were established by the U.S. Public Health Service in 1914. The standards were revised in 1925, 1942, 1946, and 1962. In 1974, the Safe Drinking Water Act (SDWA) transferred responsibility for public water supplies to the U. S. Environmental Protection Agency (EPA). EPA later revised the SDWA to regulate a broad spectrum of contaminants. This section discusses current, pending, and anticipated future drinking water regulations.

A. Current Regulations

1. Safe Drinking Water Act of 1974.

The Safe Drinking Water Act was promulgated in 1974. It mandated that National Primary Drinking Water Regulations be established for a number of chemical, physical, and biological contaminants. The regulations set maximum contaminant levels (MCLs) for individual contaminants and identified treatment technologies that could be used to remove the contaminants.

Following passage of this law, EPA promulgated National Interim Primary Drinking Water Regulations, which became effective in June 1977. These regulations established MCLs for ten inorganic chemicals, six organic chemicals, two radioactive categories, turbidity, and coliforms. In 1979, an MCL for trihalomethanes of 0.10 mg/L was added, and in April 1986, EPA promulgated an MCL for fluoride of 4.0 mg/L, and a Secondary MCL (SMCL) of 2.0 mg/L. (While the fluoride SMCL is not a federally enforceable standard, individual State Regulatory Agencies are free to make the SMCL mandatory for public water supplies. However, EPA requires water systems which exceed the SMCL to notify their consumers.)

2. 1986 Amendments to the Safe Drinking Water Act

In June 1986, Congress passed comprehensive Amendments to the SDWA which have affected the operation of virtually every public water system in the United States. The Amendments empowered EPA to set enforceable standards for contaminants in drinking water based on the degree of removal that could be achieved using the “best available technology”. EPA was also granted enforcement powers through the use of administrative orders. Thus, EPA is no longer limited to the legal system in its efforts to correct deficiencies in water supply systems.

The Amendments required EPA to initially develop regulations for 83 contaminants. Additional contaminants were to be added every three years (although the subsequent 1996 Amendments modified this requirement). Specific aspects of several existing regulations promulgated under the 1986 SDWA Amendments are discussed below.

a. Surface Water Treatment Rule.

The Surface Water Treatment Rule (SWTR) pertains to utilities which use surface water sources or groundwater sources "under the direct influence of surface water". Major provisions of the SWTR are as follows:

- Filtered water turbidity is to be equal to or less than 0.5 NTU in 95 percent of the monthly samples collected. The maximum allowable interval between turbidity measurements is four hours.
- The disinfectant concentration in the water entering the distribution system must be at least 0.2 mg/L
- The disinfectant residual within the distribution system must be "detectable" in at least 95 percent of the monthly monitoring samples.
- Removal and/or inactivation of *Giardia* cysts must be at least 3.0 logs (99.9 percent), and removal and/or inactivation of enteric viruses must be at least 4.0 logs (99.99 percent).

b. Lead and Copper Rule.

The Lead and Copper Rule, promulgated during May 1991, establishes "Action Levels" for lead and copper. Based on first-draw samples collected at taps within the distribution system, lead and copper concentrations must be less than 0.015 mg/L and 1.3 mg/L, respectively, in ninety percent of the samples. Selected sample sites must consist of single-family residences which contain copper pipes with lead solder installed after 1982, which contain lead pipes, or which are served by a lead service line. Following implementation of state-specified "optimal" treatment to minimize lead and copper concentrations at consumer taps, annual follow-up monitoring is required. If the results of follow-up monitoring indicated that the system is consistently in compliance with the lead and copper Action Levels, the state may elect to reduce the annual monitoring requirements. Should follow-up monitoring indicate noncompliance, the utility is required to initiate a public education program, collect additional water quality samples, and possibly begin a program of replacing lead service lines.

c. Phase II, Phase V SOC / IOC Regulations.

The Phase II regulation for synthetic organic chemicals (SOCs) and inorganic chemicals (IOCs) lists MCLs and Maximum Contaminant Level Goals (MCLGs) for 30

SOCs and 9 IOCs. Establishment of limits for three Phase II SOCs (aldicarb, aldicarb sulfone, and aldicarb sulfoxide) has been delayed. (A final rule for aldicarb is not expected to be promulgated until August 2005.) The Phase V regulation lists MCLs and MCLGs for an additional 23 contaminants (18 SOCs and 5 IOCs). The MCL and MCLG for nickel included in the Phase V regulation were remanded by the US District Court during February 1995; therefore. Therefore, while utilities must continue to monitor for nickel in their treated water supplies, there currently is no EPA legal limit on the amount of nickel in drinking water supplies. Contaminants regulated under the Phase II and Phase V regulations are primarily volatile organic compounds and pesticides/herbicides.

d. Total Coliform Rule.

During June 1989, EPA promulgated revisions to the current regulation governing total coliform levels in water distribution systems. The revised rule expands current coliform monitoring requirements and specifies new MCLs. Compliance with the monthly MCL under the Coliform Rule is determined based on the presence or absence of coliform organisms. The Coliform Rule allows for up to 5 percent of the monthly water quality samples collected within the distribution system to test positive for coliforms. Fecal or *Escherichia* coliform levels are to be monitored for each sample where the presence of total coliforms is indicated. Public notification by electronic media (TV or radio) is required within 72 hours if a positive result indicates the presence of either fecal or *Escherichia* coliforms.

EPA subsequently modified the Total Coliform Rule to allow states to used a variance procedure for utilities encountering nonfecal biofilm problems in their distribution systems. Some coliform species, which are not classified as fecal, produce positive analytical results in total coliform and fecal coliform tests. Under the revised rule, states are allowed to disregard any coliform-positive analytical results that are speciated and not found to be of fecal origin.

3. 1996 Amendments to the Safe Drinking Water Act

The Safe Drinking Water Act was further amended in 1996, primarily to:

- Strengthen preventive approaches such as protecting source waters and providing operator certification.
- Provide consumers with more and better information about their water systems.
- Implement regulatory improvements regarding contaminant selection, cost-benefits, and application of regulations to small systems.

- Establish a Drinking Water State Revolving Fund to assist communities in installing and upgrading drinking water treatment facilities.

Under the 1986 SDWA Amendments, utilities typically were allowed 18 months to comply with new regulations following final promulgation. The 1996 Amendments extend the compliance period following promulgation to three years; EPA or individual states may grant an additional 2 years if necessary to implement significant capital improvements. The 1996 Amendments establish specific schedules for promulgation of new regulations governing disinfection by-products (DBPs), microbial contaminants, arsenic, radon, and disinfection of groundwater supplies, and require EPA and the Centers for Disease Control to conduct a joint study of the potential health impacts of sulfate in drinking water supplies.

4. Stage 1 Disinfection By-Products Rule

Stage 1 of the Disinfection By-Products Rule (DBPR) was finalized during late November 1998, and became effective during January 2002 for systems serving 10,000 or more consumers. The primary objective of this rule is to protect human health by reducing the concentrations of disinfection by-products (DBPs) in drinking water. Major provisions of the Stage 1 DBPR are as follows:

- The MCL for total trihalomethanes has been reduced to 0.080 mg/L.
- New MCLs have been established for total haloacetic acids, bromate (a by-product of disinfection using ozone), and chlorite ion (a by-product of disinfection using chlorine dioxide).
- Maximum Residual Disinfectant Levels (MRDLs) and MRDL Goals (MRDLGs) have been established for free chlorine, chloramine, and chlorine dioxide.
- A treatment technique has been established which requires that surface water systems (or groundwater systems under direct surface water influence) operate in either an enhanced coagulation or enhanced softening mode to achieve specified removals of total organic carbon (TOC).

As stated above, under the Stage 1 DBPR, the MCL for total trihalomethanes has been reduced to 0.080 mg/L. In addition, a new MCL of 0.060 mg/L has been established for total haloacetic acids (referred to as HAA5, as 5 of the 9 known haloacetic acid compounds are regulated under the Stage 1 rule). New MCLs for bromate and chlorite ion of 0.010 mg/L and 1.0 mg/L, respectively, have also been established. Compliance with these MCLs is assessed based on the “running annual average” of quarterly monitoring data.

Under the Stage 1 DBPR, the maximum allowable disinfectant residual in the water leaving the treatment facility, based on a running annual average of monthly monitoring data, is 4.0 mg/L for free chlorine and chloramines, and 0.8 mg/L for chlorine dioxide. (Higher residuals are permissible on a short-term basis if necessary to address specific water quality problems, providing that running annual average concentrations do not exceed the MRDLs.)

A primary goal of the DBPR is to reduce the levels of organic/humic compounds (collectively referred to as DBP precursors) which react with chlorine-based disinfectants to form DBPs. This is to be accomplished through operation of treatment facilities in an "enhanced coagulation" or "enhanced softening" mode, which will typically involve increases in coagulant dosages and/or adjustment of operating pH to optimize the removal of the precursor compounds. Precursor removal is to be quantified by measuring the removal of TOC across the treatment process. In general, for systems with average source water TOC concentrations exceeding 2.0 mg/L, enhanced coagulation/enhanced softening treatment will be required. Minimum TOC removal levels are summarized in Table A-1. TOC removals must be determined monthly, and compliance is assessed quarterly based on a running annual average of monthly TOC removals.

Table A-1
Step 1 TOC Removal Requirements for Enhanced Coagulation/Enhanced Softening

Source Water TOC, mg/L	Percent TOC Removal Required at Indicated Source Water Alkalinity		
	0 – 60 mg/L	>60 – 120 mg/L	>120 mg/L[(1)]
>2.0 – 4.0	35%	25%	15%
>4.0 – 8.0	45%	35%	25%
>8.0	50%	40%	30%

[(1)]Systems practicing softening must meet the TOC removals shown in this column.

The Stage 1 DBP rule also provides alternative compliance criteria that are independent of the criteria discussed above. Systems can be exempted from the enhanced coagulation/enhanced softening requirements if any of the following conditions are met:

- The system's source water TOC is less than 2.0 mg/L (calculated quarterly as a running annual average of monthly monitoring data).
- The system's treated water TOC is less than 2.0 mg/L (calculated quarterly as a running annual average of monthly monitoring data).
- The system's source water TOC is less than 4.0 mg/L, the source water alkalinity is greater than 60 mg/L (as $CaCO_3$), and the system is achieving TTHM concentrations less than 0.040 mg/L and HAA5 concentrations less than 0.030 mg/L.

- The system's running annual average TTHM concentration is less than 0.040 mg/L, and annual average HAA5 concentration is less than 0.030 mg/L, when only free chlorine is used for disinfection and maintenance of a residual in the distribution system. (Systems using chloramines would not comply with these conditions.)
- The system's source water specific UV absorbance (SUVA, defined as the ratio of the water's ultraviolet absorbance at 254 nm (UV_{254}) to its dissolved organic carbon (DOC) concentration) prior to any treatment is less than or equal to 2.0 L/mg-m, calculated quarterly as a running annual average of monthly monitoring data.
- The system's finished water SUVA is less than or equal to 2.0 L/mg-m, calculated quarterly as a running annual average of monthly monitoring data. (This measurement must be made prior to the addition of a chemical oxidant, which will likely be problematic for most utilities).

Systems that elect to utilize one of these alternative criteria must still conduct monthly monitoring of source water TOC and alkalinity concentrations, and treated water TOC concentrations. Systems practicing lime softening may demonstrate compliance if they meet any of the six alternative compliance criteria listed above, or one of the following criteria:

- Softening that results in a reduction in the alkalinity of the treated water to less than 60 mg/L (as $CaCO_3$), measured monthly and calculated quarterly as a running annual average.
- Softening that results in removal of at least 10 mg/L of magnesium hardness (as $CaCO_3$), measured monthly and calculated quarterly as a running annual average.

Following the first 12 months of TOC removal monitoring, if a system determines that it cannot achieve the TOC removals specified in Table A-1 on a running annual average basis, and it does not meet any of the alternative compliance criteria listed above, it will be required to perform bench-scale or pilot-scale testing to set an alternative TOC removal requirement. (This is referred to as Step 2 testing.) Results of this testing must be reported to the state within three months of failing to achieve the TOC removal percentages presented in Table A-1.

Under the Stage 1 DBPR, utilities serving more than 10,000 consumers must collect four DBP samples per quarter per treatment plant, and at least 25 percent of these samples must be collected at locations which reflect maximum system residence time. The Stage 1 rule also includes provisions for reduced monitoring if the following conditions are met:

- Source water TOC concentration (prior to any treatment) is less than or equal to 4.0 mg/L (based on a running annual average of monthly TOC data).
- The system annual average TTHM and HAA5 concentrations are less than or equal to 0.040 mg/L and 0.030 mg/L, respectively.

Systems that meet these requirements will be required to collect only one TTHM/HAA5 sample per quarter per plant at a distribution system location considered to reflect maximum residence time. Systems on a reduced monitoring schedule may remain on that schedule as long as running annual TTHM and HAA5 concentrations remain at 0.060 mg/L and 0.045 mg/L, respectively, and the annual average source water TOC concentration remains at 4.0 mg/L or less.

5. Interim Enhanced Surface Water Treatment Rule

The Interim Enhanced Surface Water Treatment Rule (IESWTR) was finalized during late November 1998, and became effective during January 2002 for systems serving 10,000 or more consumers. The rule applies to systems using surface water, or groundwater supplies under the influence of surface water. The primary objectives of this rule are to improve the control of microbial pathogens in drinking water (particularly *Cryptosporidium*), and to guard against significant increases in microbial risk that might occur when systems implement the Stage 1 DBPR. Primary requirements of the IESWTR are as follows:

- Systems with DBP levels exceeding or approaching the Stage 1 MCLs for trihalomethanes and haloacetic acids (0.080 mg/L and 0.060 mg/L, as discussed above) may consider changing their disinfection practices in order to comply with the new limits. However, in an effort to avoid increasing the risk from microbial contaminants while attempting to lower DBPs, EPA will require systems which have annual average DBP concentrations within 80% of the new MCLs (i.e., >0.064 mg/L for TTHMs or 0.048 mg/L for HAA5) for the most recent 12-month monitoring period to prepare a "disinfection profile" for state review prior to altering disinfection practices. The disinfection profile is a compilation of daily criteria that affect the overall efficacy of the disinfection process, collected over a minimum of one year. The average level of microbial inactivation for each month is developed from the disinfection profile, and the lowest monthly average inactivation becomes the disinfection benchmark. A minimum of one year, and a maximum of three years of daily disinfection performance data must be used to develop the disinfection profile. If the State does not approve changes in disinfection, systems must develop alternate ways of reducing DBPs to meet the new MCLs.

- For those systems that do not have four quarters of distribution system HAA5 monitoring data available by the end of February 1999, HAA5 monitoring must be conducted for four quarters beginning in March 1999.
- Allowable finished water turbidity is reduced from the present 0.5 NTU allowed under the SWTR to 0.3 NTU. This standard applies to the combined filtered water, and a minimum of 95 percent of the monthly turbidity measurements must meet the revised turbidity criteria. The turbidity of the combined filter effluent cannot exceed 1 NTU at any time. (The current SWTR allows for a maximum filter effluent turbidity of 5 NTU.)
- Continuous turbidity monitoring is required for each filter, and specific performance criteria will apply to each filter. Systems must record the results of individual filter turbidity monitoring at 15-minute intervals, and must maintain records of individual filter performance for a minimum of three years.
- Systems treating surface water (or groundwater under direct surface water influence) and serving more than 10,000 consumers must achieve at least a 2-log (99%) removal of *Cryptosporidium*. (The regulation states that systems that comply with the revised turbidity requirement of 0.3 NTU are assumed to be achieving compliance with the 2-log *Cryptosporidium* removal requirement.)
- States will be required to conduct sanitary surveys for all public water systems (regardless of size) no less frequently than every 3 years.

Under the IESWTR, systems are required to provide "an exceptions report to the State on a monthly basis". Exceptions to be reported consist of the following:

- Any individual filter with a turbidity level greater than 1.0 NTU based on 2 consecutive measurements 15 minutes apart.
- Any individual filter with a turbidity level greater than 0.5 NTU at the end of the first 4 hours of operation, based on 2 consecutive measurements 15 minutes apart.

A "filter profile" is to be produced if "no obvious reason for the abnormal filter performance can be identified". Other requirements are as follows:

- If an individual filter has turbidity levels greater than 1.0 NTU, based on 2 consecutive measurements 15 minutes apart at any time in each of three consecutive months, the water system is required to conduct a self-assessment of the filter utilizing "relevant portions" of guidance issued by EPA under its Comprehensive Performance Evaluation (CPE) program.
- If an individual filter has turbidity levels greater than 2.0 NTU based on 2 consecutive measurements 15 minutes apart at any time in each of two

> consecutive months, the water system must arrange for a CPE to be conducted by the State or a third party approved by the State. The State will ensure that the recommendations resulting from the CPE are implemented.

Methods for conducting CPEs and individual filter performance assessments are detailed in the April 1999 EPA publication “Guidance Manual for Compliance with the Interim Enhanced Surface Water Treatment Rule: Turbidity Provisions”.

6. Consumer Confidence Reports Rule

As directed by the 1996 SDWA Amendments, all Public Water Systems serving more than 500 consumers will need to prepare annual reports (beginning no later than October 1999) to advise their users of the quality of the distributed water. The reports must contain a specific list of material such as information on the source water, an explanation of terms such as MCLs and MCLGs, data on levels of currently-regulated contaminants in the treated water, and information regarding potential health effects of the contaminants.

7. Secondary MCLs

Secondary Maximum Contaminant Levels (SMCLs) for 13 contaminants were initially set in 1979. Contaminants included in these secondary regulations do not have a direct impact on consumer health; however, if present in excessive amounts, they may affect the palatability and aesthetic quality of the water. SMCLs are not federally enforceable, although state regulatory agencies may elect to promulgate enforceable MCLs for any of the contaminants included in the secondary regulations. The SMCL for fluoride was revised in 1986, and new SMCLs for aluminum and silver were added in 1991.

8. Arsenic

EPA proposed revisions to the current drinking water standard for arsenic during May 2000, and promulgated a new MCL of 0.010 mg/L during January 2001. The new MCL becomes effective 5 years after promulgation, i.e., during January 2006. Some aspects of the rule, such as monitoring and reporting requirements, will be effective prior to January 2006, but the original MCL of 0.05 mg/L will remain effective until January 2006. Utilities must begin providing health information and data on treated water arsenic concentrations in their annual Consumer Confidence Report by July 2002 if the water supply contains more than 0.005 mg/L of arsenic.

Considerable controversy currently surrounds the regulation of arsenic in drinking water supplies, and during March 2001, EPA announced its intention to withdraw this regulation as currently promulgated to allow further review. During July 2001, EPA requested additional comment on whether to set the new arsenic MCL at 0.003, 0.005, 0.010, or 0.020 mg/L. However, on October 31st, 2001, the EPA Administrator announced that the Agency would retain the 10 ug/L MCL, and that the original compliance date of January 2006 would not be altered.

9. **Radionuclides**

Radionuclides normally present problems for systems that treat groundwater from deep wells or that are located downstream from an industrial source of radiation. A proposed rule for several radionuclides (radon, radium, alpha, beta, and photon emitters, and radium) was released in 1991, but not finalized until December 2000. This rule established a new MCL for uranium of 30 ug/L; however, EPA elected to retain the MCLs for radium and alpha, beta, and photon emitters established under the original SDWA in 1976 with no modifications. (The new regulation does include separate monitoring requirements for radium-228 under the combined MCL for radium-226 and radium-228.)

10. Filter Backwash Recycling Rule

The Filter Backwash Recycling Rule (FBRR) was proposed concurrently with the LT1ESWTR during April 2000, but promulgated as a separate regulation during June 2001. Provisions of the FBRR addressing in-plant recycling of wastestreams apply to all systems. In addition to filter backwash flows, recycle streams covered under this regulation consist of sludge thickener supernatant, and flows associated with sludge dewatering processes. Plants practicing recycle of these streams within the treatment plant must return them to a location such that all unit processes of a system's conventional or direct filtration process are employed in the treatment of the recycle flow. (This location will typically be the plant headworks prior to the addition of coagulant.) All systems that recycle these flows must submit a plant process schematic to the state regulatory agency for review by December 2003 showing the current recycle return location and the proposed return location that will be used to establish compliance. Data on typical recycle flow rates, maximum recycle flow rates, and the plant design capacity and state-approved maximum operating capacity must also be submitted to the state regulatory agency by December 2003. Systems must also collect and maintain additional information on filter operating data, recycle flow treatment provided, physical dimensions of recycle flow equalization and/or treatment units, and recycle flow rate and frequency data for review and evaluation by the state regulatory agency beginning June 2004.

Systems must comply with the recycle return provisions of the FBRR no later than June 2004. If the system requires capital improvements to modify the location of the recycle return, these improvements must be in place and operational by June 2006.

The regulation does not address recycle of filter-to-waste flows. Process solids recycle flows from lime softening and contact clarification units are also not covered by the FBRR. However, softening systems may not return spent filter backwash, thickener supernatant, or liquids from solids dewatering processes to a location that does not incorporate all unit treatment processes.

11. KDHE Requirements

The majority of the drinking water regulations that govern public water systems in Kansas are based on the federal SDWA. However, the SDWA allows some flexibility for states to develop their own regulations, and they are allowed to set standards that are more stringent than the federal regulations. In addition to the federal regulations, Kansas public water utilities are responsible for the following:

- If fluoridation is practiced, the fluoride concentration in the treated water must be maintained at less than the current Secondary Maximum Contaminant Level (SMCL) of 2.0 mg/L.
- All surface waters must receive pretreatment, including clarification (federal regulations allow use of direct filtration).
- Equalization must be provided for recycled process water to avoid disrupting coagulation and flocculation processes.
- Disinfection adequacy is to be determined using published CT criteria.
- When combined chlorine is used for residual maintenance in the distribution system, a combined residual of at least 1.0 mg/L must be maintained at the ends of the distribution system.

12. Summary of Current MCLs and SMCLs

Current drinking water standards (MCLs and Maximum Contaminant Level Goals (MCLGs)) are summarized in Table A-2. (Table A-2 includes only currently effective, or "enforceable" MCLs.) Current Secondary Maximum Contaminant Levels are summarized in Table A-3.

Table A-2 Current Drinking Water Standards (as of 10/2002)			
Contaminant	Regulation	MCL, mg/L	MCLG, mg/L
Organic Substances			
Acrylamide	Phase II	Treatment Technique	Zero
Alachlor	Phase II	0.002	Zero
Atrazine	Phase II	0.003	0.003
Benzene	Phase I	0.005	Zero
Benzo(a)pyrene	Phase V	0.0002	Zero
Carbofuran	Phase II	0.04	0.04
Carbon tetrachloride	Phase I	0.005	Zero
Chlordane	Phase II	0.002	Zero
2,4-D	Phase II	0.07	0.07
Dalapon	Phase V	0.2	0.2
Di(2-ethylhexyl) adipate	Phase V	0.4	0.4
Di(2-ethylhexyl) phthalate	Phase V	0.006	Zero
Dibromochloropropane (DBCP)	Phase II	0.0002	Zero
p-dichlorobenzene	Phase I	0.075	0.075
o-dichlorobenzene	Phase II	0.6	0.6
1,2-dichloroethane	Phase I	0.005	Zero
1,1-dichloroethylene	Phase I	0.007	0.007
cis-1,2-dichloroethylene	Phase II	0.07	0.07
Trans-1,2-dichloroethylene	Phase II	0.1	0.1
Dichloromethane (methylene chloride)	Phase V	0.005	Zero
1,2-dichloropropane	Phase II	0.005	Zero
Dinoseb	Phase V	0.007	0.007
Diquat	Phase V	0.02	0.02
Endothall	Phase V	0.1	0.1
Endrin	Phase V	0.002	0.002
Epichlorohydrin	Phase II	Treatment Technique	Zero
Ethylbenzene	Phase II	0.7	0.7
Ethylene dibromide	Phase II	0.00005	Zero
Glyphosate	Phase V	0.7	0.7
Haloacetic Acids (total)	Stage 1 DBPR	0.060	-
Heptachlor	Phase II	0.0004	Zero
Heptachlor epoxide	Phase II	0.0002	Zero
Hexachlorobenzene	Phase V	0.001	Zero
Hexachlorocyclopentadiene	Phase V	0.05	0.05
Lindane	Phase II	0.0002	0.0002
Methoxychlor	Phase II	0.04	0.04
Monochlorobenzene	Phase II	0.1	0.1
Oxamyl (vydate)	Phase V	0.2	0.2
Pentachlorophenol	Phase II	0.001	Zero
Picloram	Phase V	0.5	0.5
Polychlorinated byphenols	Phase II	0.0005	Zero
Simazine	Phase V	0.004	0.004
Styrene	Phase II	0.1	0.1
2,3,7,8-TCDD (dioxin)	Phase V	3×10^{-8}	Zero
Tetrachloroethylene	Phase II	0.005	Zero
Toluene	Phase II	1	1
Toxaphene	Phase II	0.003	Zero
2,4,5-TP (silvex)	Phase II	0.05	0.05
1,2,4-trichlorobenzene	Phase V	0.07	0.07
1,1,1-trichloroethane	Phase I	0.2	0.20
1,1,2-trichloroethane	Phase V	0.005	0.003
Trichloroethylene	Phase I	0.005	Zero

Table A-2

Current Drinking Water Standards (as of 10/2002)

Contaminant	Regulation	MCL, mg/L	MCLG, mg/L
Trihalomethanes (total)	Stage 1 DBPR	0.080	NA
Vinyl chloride	Phase I	0.002	Zero
Xylenes (total)	Phase II	10	10
Inorganic Substances			
Antimony	Phase V	0.006	0.006
Arsenic	Interim	0.05	NA
Asbestos (fibers/L > 10 um)	Phase II	7 million	7 million
Barium	Phase II	2	2
Beryllium	Phase V	0.004	0.004
Bromate	Stage 1 DBPR	0.010	Zero
Cadmium	Phase II	0.005	0.005
Chlorite	Stage 1 DBPR	1.0	0.8
Chromium (total)	Phase II	0.1	0.1
Copper	LCR	Treatment Technique	1.3
Cyanide	Phase V	0.2	0.2
Fluoride	-	4	4
Lead	LCR	Treatment Technique	Zero
Mercury	Phase II	0.002	0.002
Nitrate (as N)	Phase II	10	10
Nitrite (as N)	Phase II	1	1
Nitrate + Nitrite (both as N)	Phase II	10	10
Selenium	Phase II	0.05	0.05
Thallium	Phase V	0.002	0.0005
Radionuclides			
Beta-particle and photon emitters	Interim	4 mrem	Zero
Alpha emitters	Interim	15 pCi/L	Zero
Radium 226 + 228	Interim	5 pCi/L	Zero
Microorganisms			
Cryptosporidium	IESWTR	2-log Removal	Zero
Escherichia coli	TCR	Treatment Technique	Zero
Fecal coliforms	TCR	Treatment Technique	Zero
Giardia lamblia	SWTR	Treatment Technique	Zero
Heterotrophic bacteria	SWTR	Treatment Technique	NA
Legionella	SWTR	Treatment Technique	Zero
Total coliforms	TCR	(1)	Zero
Turbidity	SWTR	0.3[2]	NA
Viruses	SWTR	Treatment Technique	Zero

[1]No more than 5 percent of monthly samples may be positive for presence of coliforms.
[2]Performance standard; no more than 5 percent of monthly samples may exceed 0.3 NTU.

DBPR = Disinfection By-Products Rule
IESWTR = Interim Enhanced Surface Water Treatment Rule
LCR = Lead and Copper Rule
SWTR = Surface Water Treatment Rule
TCR = Total Coliform Rule

Table A-3 Current Secondary Drinking Water Standards	
Contaminant	SMCL
Aluminum	0.05 - 0.2 mg/L
Chloride	250 mg/L
Color	15 Color Units
Copper	1.0 mg/L
Corrosivity	Non-corrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 Threshold Odor Units
pH	6.5 – 8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

B. Pending Regulations

1. Stage 2 Disinfection By-Products Rule

As part of the 1996 amendments to the SDWA, Congress established deadlines for promulgation of new regulations governing both disinfection by-products and microbial contaminants. These deadlined include a requirement that EPA promulgate a Stage 2 regulation for disinfection by-products, and a Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR, as discussed in the following section of this document) by May 2002. (These two rules are closely related, and are referred to collectively as the Stage 2 M-DBP). The Advisory Committee convened by EPA during early 1999 to develop recommendations for implementation of these regulations reached consensus during September 2000 on an agreement to be presented to EPA. The "Stage 2 M-DBP Agreement in Principle" summarizes the committee's recommendations for implementation of these rules, and will be the basis for EPA's development of the Stage 2 DBPR and the LT2ESWTR. A draft version of the proposed Stage 2 DBPR was made available for comment during November 2001. The LT2ESWTR and the Stage 2 DBR are currently scheduled to be proposed during June 2003 and July 2003, respectively, and promulgated during July 2004. The Stage 2 DBPR requirements will apply to all community water systems and non-transient non-community water systems that add a disinfectant (other than UV) or deliver water that has been disinfected. Key points pertaining to the Stage 2 DBPR are summarized below.

Review of disinfection by-products occurrence data obtained under the Information Collection Rule suggests that many systems have been achieving compliance with the original TTHM regulation by selecting quarterly monitoring dates to obtain samples that may not be representative of the actual variations in DBP formation that occur throughout the year. This was often accomplished by avoiding monitoring when water temperatures are warmest and when DBP formation rates are highest. The Advisory Committee has therefore developed recommendations regarding appropriate monitoring intervals to correct this problem under the Stage 2 rule. The Stage 2 MCLs would remain at the levels established under the Stage 1 rule, i.e., TTHMs = 0.080 mg/L and HAA5 = 0.060 mg/L. However, monitoring procedures and schedules would be modified to ensure that the data obtained more closely represent actual long-term exposure conditions. Initial compliance efforts will focus on identifying points within the system where DBP concentrations are typically highest, and would involve the following:

- For systems serving 10,000 or more consumers; one year of monitoring of TTHM and HAA5 concentrations at 60-day intervals (+/- 3 days) at 8 additional locations within the distribution system. (Systems served by more than one treatment facility would be required to monitor at 8 locations per treatment plant.) For systems that maintain a free chlorine residual within the distribution system, the 8 monitoring sites per plant would consist of (1) one sample near the distribution system entry point, (2) two sites considered to reflect "average" system DBP concentrations, and (3) five sites considered to reflect "maximum" system DBP concentrations. For systems that maintain a chloramine residual within the distribution system, the 8 monitoring sites per plant would consist of (1) two samples near the distribution system entry point, (2) two sites considered to reflect "average" system DBP concentrations, and (3) four sites considered to reflect "maximum" system DBP concentrations. This monitoring, referred to in the draft proposed regulation as the Initial Distribution System Evaluation (IDSE) monitoring study, would be conducted in addition to the quarterly compliance monitoring conducted under the current TTHM regulation and the impending Stage 1 DBPR. A report summarizing the IDSE monitoring results must be submitted to the State/Primacy Agency within two years of promulgation of the Stage 2 DBPR. (The draft proposed rule includes provisions for exemption from IDSE monitoring requirements, based on low historical system DBP concentrations.)
- Following completion of the IDSE, systems will recommend new or revised monitoring sites to their State/Primacy Agency based on their ISDE study. Monitoring site locations (four per system if served by a single treatment plant; four per system per plant if served by multiple treatment plants) are to be selected as follows:
  - One location representative of average conditions from among current Stage 1 DBPR monitoring locations.

- One location representative of highest HAA5 concentrations identified under the IDSE.
- Two locations representative of highest TTHM concentrations identified under the IDSE.

Quarterly monitoring of DBP concentrations at four locations per plant within the distribution system would continue to be conducted for compliance monitoring purposes. At least one quarterly monitoring period would be required to reflect "peak historical" DBP formation level periods, and systems will be required to monitor on a regular schedule of approximately every 90 days. MCL compliance will be determined based on a "Locational Running Annual Average" (LRAA) basis, i.e., a running annual average must be calculated at <u>each</u> monitoring location. Systems will be required to comply with the Stage 2 MCLs in two phases:

- 3 years after promulgation, all systems must comply with locational running annual average MCLs of 0.120 mg/L for TTHMs and 0.100 mg/L for HAA5 at current Stage 1 DBPR monitoring sites, while continuing to comply with the Stage 1 MCLs of 0.080 mg/L for TTHMs and 0.060 mg/L for HAA5. (These are currently being referred to as "Stage 2A" requirements.)
- 6 years after promulgation (with an additional two-year extension available if capital improvements are required), large and medium-sized systems must comply with locational running annual average MCLs of 0.080 mg/L for TTHMs and 0.060 mg/L for HAA5 at the approved sampling locations identified under the IDSE. (These are currently being referred to as "Stage 2B" requirements.)

Should an MCL be exceeded at one or more system monitoring points (based on annual running average DBP concentrations), the system would be considered to be in violation of the Stage 2 regulation, regardless of results for the remaining monitoring sites. This represents a major change from current TTHM and Stage 1 DBP regulations, as the "system averaging" concept would be eliminated under the Stage 2 regulation.

During Stage 2A, systems that maintain system running annual average TTHM and HAA5 concentrations of less than or equal to 0.040 mg/L and 0.030 mg/L, respectively, may reduce quarterly monitoring frequency for TTHMs and HAA5 to one sample per treatment plant at a site representative of maximum system residence time. Systems on a reduced monitoring schedule may remain on that reduced schedule as long as running annual average TTHM and HAA5 concentrations for all samples collected are no more than 0.060 mg/L and 0.045 mg/L, respectively. During Stage 2B, systems that have completed one year of routine monitoring at IDSE sites, and that exhibit TTHM and HAA5 locational running annual average concentrations of no more than 0.040 mg/L and 0.030 mg/L, respectively, and annual average source water TOC levels of 4.0 mg/L or less will be allowed to reduce the number of DBP samples collected to two per quarter per treatment plant. (For each quarterly sample pair, one sample would need to be collected at a location reflecting maximum TTHM levels, while the remaining sample would need to be collected at a location reflecting maximum HAA5 levels.)

The Advisory Committee also recommended that systems review peaks in TTHM and HAA5 concentrations that may occur in their distribution systems as part of the sanitary survey process, and EPA has adopted this recommendation in the draft proposed Stage 2 DBPR. EPA defines a peak as any individual sample with a TTHM concentration of 0.100 mg/L or greater, and/or with an HAA5 concentration of 0.075 mg/L or greater (these values exceed the Stage 2 MCLs by 25 percent). Utilities experiencing these peaks would be required to work with their state primacy agencies to reduce these severity of these excursions; EPA will be preparing guidance for systems and State primacy agencies on how to conduct peak excursion evaluations and how to reduce peaks.

The following is proposed by EPA in the draft Stage 2 DBPR as Best Available Technology (BAT) for compliance with the LRAA MCLs when free chlorine is used as the primary and secondary (system residual) disinfectant:

- GAC adsorbers with at least 10 minutes of empty bed contact time and an annual average carbon reactivation/replacement frequency no greater than 120 days.
- GAC adsorbers with at least 20 minutes of empty bed contact time and an annual average carbon reactivation/replacement frequency no greater than 240 days.
- Nanofiltration using a membrane with a molecular weight cutoff of 1000 Dalton or less (or demonstrated to reject at least 80% of the influent TOC concentration under typical operating conditions).

Considerable pressure to reduce the Stage 1 MCL for bromate to 0.005 mg/L or less currently exists, as ongoing research suggests that this contaminant may be more carcinogenic than originally believed. (This change would primarily impact utilities practicing ozonation for primary disinfection and/or utilities that employ high dosages of sodium hypochlorite.) However, the draft proposed Stage 2 DBPR recommends that the MCL for bromate remain at the current value of 0.010 mg/L. As recommended by the Advisory Committee, EPA would review the bromate MCL as part of the 6-year regulatory review process required under the Safe Drinking Water Act to determine whether the MCL should remain at 0.010 mg/L or be reduced to 0.005 mg/L or lower.

2. Long-Term Enhanced Surface Water Treatment Rule

A long-term Enhanced Surface Water Treatment Rule which extends the IESWTR requirements to systems serving less than 10,000 consumers was promulgated during January 2002 and will become effective during January 2005. (This regulation is referred to as the Stage 1 Long-Term Enhanced Surface Water Treatment Rule, or LT1ESWTR.)

A long-term Stage 2 ESWTR (currently being referred to as the LT2ESWTR) is expected to be promulgated during July 2004. This rule will apply to all public water systems that use surface water or groundwater under the direct influence of surface water. Recommendations presented in the Stage 2 M-DBP Agreement in Principle and a subsequent November 2001 draft proposed rule include an initial period of raw water microbial monitoring, with treatment requirements established based on microbial contaminant levels present in the supply. Utilities serving 10,000 or more consumers and practicing "conventional treatment" (coagulation, sedimentation, and filtration) would be required to conduct monthly monitoring of the raw water supply for *Cryptosporidium* (using EPA Method 1622/23 with minimum 10L samples), *E. coli*, and turbidity over a 24-month period. Specific regulatory compliance requirements would then be established based on the following:

- If monthly samples are collected, classification is to be based on the highest 12-month running annual average.
- If the system conducts monitoring twice per month, classification is to be based on a 2-year mean value of all monitoring data. (This increased monitoring must be conducted at evenly distributed time intervals over the 2-year period.)

Systems serving 10,000 or more consumers must complete this monitoring and submit a report summarizing the monitoring results to their State/Primacy Agency within two and one half years of promulgation of this regulation. Additional treatment requirements under the LT2ESWTR, based on average raw water *Cryptosporidium* oocyst concentrations, are summarized in Table A-4.

Under the recommendations presented in the Agreement in Principle, systems would chose technologies to comply with additional treatment requirements from a "toolbox" of options, including improved watershed control, improved treatment system and/or disinfection performance, and additional treatment barriers. Specific "tools" identified, and associated log treatment credits, as presented in the November 2001 pre-proposal draft rule, are summarized in Table A-5. It is emphasized that EPA has requested comment on the proposed log credits presented in Table A-5, and may modify assigned credits in the final rule based on comments received.

Table A-4 ***Cryptosporidium* Treatment Requirements under LT2ESWTR**	
Raw Water *Cryptosporidium* Conc., oocysts per Liter[1]	Additional Treatment Required for Conventional Treatment Systems in Full Compliance with IESWTR
Cryptosporidium < 0.075/L	No action required
0.075/L ≤ *Cryptosporidium* <1.0/L	1-log treatment[2]
1.0/L ≤ *Cryptosporidium* <3.0/L	2-log treatment[3]
Cryptosporidium ≥ 3.0/L	2.5-log treatment[3]

[1] Based on maximum value for 12-month running annual average, or 2-year mean if twice-monthly monitoring is conducted.
[2]Systems may use any combination of technologies to achieve 1-log credit.
[3]Systems must achieve at least 1.0-log of total treatment requirement using ozone, chlorine dioxide, UV, membranes, bag/cartridge filters, or in-bank filtration.

Table A-5 **Microbial Toolbox Options, Log Credits, and Design/Implementation Criteria**	
Toolbox Option	Proposed *Cryptosporidium* Log Credit
Watershed Control Program	0.5-log credit for State-approved program comprising EPA specified elements; Potential for additional credit based on *Cryptosporidium* reduction demonstrated through monitoring.
Alternative Source / Intake Management	No presumptive credit. Systems may be assigned to a lower bin based on *Cryptosporidium* monitoring at new intake location. Re-binning would occur after system begins using new intake location.
Off-Stream Raw Water Storage (1)	0.5-log credit for reservoir with hydraulic residence time (HRT) of at least 21 days: 1.0-log credit for reservoir with HRT of a least 60 days.
Presedimentation Basin (1)	0.5-log credit with continuous operation and coagulant addition. Max loading rate of 1.6 gpm/sq ft, mean influent turbidity = 10 NTU or max influent turbidity = 100 NTU.
Lime Softening	0.5-log credit for second stage softening with coagulant addition.
Bank Filtration (1)	0.5-log credit for 25 ft. setback; 1.0-log credit for 50 ft. setback.
Lower Finished Water Turbidity	0.5-log credit for combined filter effluent turbidity ≤ 0.15 NTU in 95% of samples each month. 1.0-log credit for individual filter effluent turbidity ≤ 0.15 NTU in 95% of samples each month.
Slow Sand Filters	2.5-log credit as add-on technology.
Second Stage Filtration	0.5-log credit for second separate filtration stage in treatment process.
Membranes (MF, UF, NF, RO)	Log credit equivalent to removal efficiency demonstrated in challenge test for device if supported by direct integrity testing.
Bag Filters	1-log credit with demonstration of at least 2-log removal efficiency in challenge test; State may award greater credit.
Cartridge Filters	2-log credit with demonstration of at least 3-log removal efficiency in challenge test; State may award greater credit.
Chlorine Dioxide	Log credit based on demonstration of compliance with CT table or alternative values approved by State.
Ozone	Log credit based on demonstration of compliance with CT table or alternative values approved by State.
UV	Log credit based on demonstration of compliance with UV dose table or alternative values approved by State.
Demonstration of Performance	1.0-log credit if average spore removal ≥ 4-log based on one year of weekly monitoring.

(1) Credit available only if source water *Cryptosporidium* monitoring conducted prior to Option.

Four years after completion of initial system classification, EPA will initiate a stakeholder process to review available microbial analytical methods and the classification structures. This process will develop the basis for a second round of national assessment monitoring. Six years after completion of initial system classification, systems will be required to conduct a second round of source water monitoring "equivalent or superior to the initial round from a statistical perspective".

This process could result in system reclassification (to determine additional treatment requirements for *Cryptosporidium*) under the current regulatory structure, or in promulgation of a revised regulation, which reflects recommended changes, developed during the stakeholder process.

Compliance schedules for the LT2ESWTR will be contingent upon (1) the availability of sufficient analytical capacity at approved laboratories to conduct the required *Cryptosporidium* and *E. coli* analyses, and (2) the availability of software for transferring, storing, and evaluating the results of all of the microbial analyses. If either of these 2 items is determined to be insufficient to support the level of analytical testing required, then monitoring, implementation, and compliance schedules for both the LT2ESWTR and the Stage 2 DBPR will be delayed by an equivalent time period. (Comments by EPA during December 2002 suggest that both analytical capacity and software availability will be adequate to allow promulgation of this regulation as currently scheduled.)

If the scenario discussed above is promulgated as currently recommended, many utilities practicing conventional treatment may need to begin to think in terms of having a process to provide an additional 1-log to 2.5-log removal/inactivation of *Cryptosporidium* oocysts in operation by July 2010. (July 2012, if significant capital improvements are required, with state regulatory agency approval). Based on current research results, it appears that only ozone and ultraviolet (UV) irradiation are serious contenders for inactivation of *Cryptosporidium* oocysts. (The recommended plan suggests that membrane filtration processes, such as microfiltration and ultrafiltration, would be an acceptable substitute for inactivation processes.)

The Agreement in Principle states that "Based on available information, EPA believes that ultraviolet (UV) disinfection is available and feasible", and that "The availability of UV disinfection is a fundamental premise of this Agreement in Principle". However, it is recognized that additional information is needed with regard to engineering issues and to assist Stage regulatory agencies in approving this technology. Concurrent with publication of the proposed LT2ESWTR, EPA therefore will publish the following:

- Information on UV doses and contact times required to achieve up to 3 logs inactivation of *Giardia* and *Cryptosporidium*, and up to 4 logs inactivation of viruses.
- Minimum standards to determine if UV systems are acceptable for compliance with drinking water requirements, including a Validation Protocol and a

description of onsite monitoring requirements to ensure ongoing compliance with required dosage levels.

- A UV Guidance Manual, which is to facilitate design and planning of UV systems and to familiarize State/Primacy Agencies and utilities with design and operational issues.

The November 2001 pre-proposal draft of the LT2ESWTR includes disinfection profiling and benchmarking requirements for *Giardia* cysts and viruses similar to those included in the Interim Enhanced Surface Water Treatment Rule. These requirements would apply only to surface water systems that are also required to monitor source water *Cryptosporidium* concentrations under the LT2ESWTR, or (for small systems) if disinfection by-product concentrations in the distribution system exceed specified levels. Disinfection profiles must be prepared using weekly *Giardia* and virus inactivation data over a one-year period; this data must be representative of inactivation levels provided through the entire treatment facility, and not just for certain treatment segments. Systems serving more than 10,000 consumers will need to begin collecting data needed to develop disinfection profiles within 24 months of promulgation of the LT2ESWTR. The draft proposed rule does include provisions for utilization of existing ("grandfathered") *Giardia* and virus inactivation data in preparing disinfection profiles, providing that the existing data meets specified requirements.

3. **Radon**

EPA proposed new regulations for radon during October 1999, and it is anticipated that a final rule will be issued by during December 2004. Two alternative compliance approaches were included in the proposed radon rule:

- States can elect to develop programs to address the health risks from radon in indoor air through adoption and implementation of a multimedia mitigation program. Under this approach, individual water systems would be required to reduce radon levels in the treated water to 4,000 pCi/L or lower. EPA will encourage States to adopt this approach, as it is considered the most cost-effective way to achieve the greatest reduction in radon exposure risk.
- If the State elects not to develop a multimedia radon mitigation program, individual water systems will be required to reduce radon levels in their system's treated water to 300 pCi/L, or to develop local multimedia mitigation programs and reduce radon levels in drinking water to 4,000 pCi/L.

Water systems with radon levels at or below 300 pCi/L would not be required to treat their water to remove radon. States will likely be granted fairly wide latitude in developing and implementing the multimedia mitigation programs, and it is expected that the programs will differ significantly from state to state. The need for radon treatment will be based on results of quarterly monitoring. If the state regulatory agency commits to the multimedia mitigation and alternative MCL compliance approach within 90 days of final promulgation of the rule, it will be granted an additional 18 months to achieve compliance. Considerable controversy currently surrounds the regulation of radon in drinking water supplies, and modification of this regulation as currently proposed could significantly alter the requirements contained in the final rule.

4. Ground Water Rule

The Ground Water Rule (GWR) was proposed in May 2000, and it is anticipated that a final rule will be issued during December 2003. Communities that use ground water as a source of drinking water (either for their entire supply or a portion of their supply) are covered under this regulation. (Public water systems that use ground water under the influence of surface water, or that blend ground water with surface water prior to treatment are not affected by this regulation.) A key aspect of the GWR is whether shallow ground water supplies are susceptible to microbial contamination. These supplies will be termed "vulnerable", and disinfection will be required. State-led sanitary surveys will determine if disinfection is necessary.

Other aspects of the proposed Ground Water Rule are as follows:

- Sanitary surveys; to be conducted by the State every 3 years.
- Hydrogeologic Sensitivity Assessment; will apply only to those systems that do not provide disinfection/treatment to achieve at least 4-log removal/inactivation.
- Source Water Monitoring; again, will apply only to those systems that do not provide disinfection/treatment to achieve at least 4-log removal/inactivation.
- Corrective Actions; necessary only for systems found to have significant deficiencies or fecal contamination in the source water.
- Compliance Monitoring; required reporting to the State regarding disinfection concentrations.

5. MTBE

EPA's most recent semi-annual rulemaking agenda (published in the May 13th 2002 *Federal Register*) indicates that the Agency plans to propose a Secondary Maximum Contaminant Level for MTBE. The schedule for proposal and promulgation of an SMCL for MTBE is uncertain at this time.

C. Future Regulations

1. General

In addition to the pending regulations discussed above, there are several additional regulations that will eventually be promulgated under the current SDWA agenda. These rules will be promulgated under the procedures established by the 1996 Amendments to the SDWA, meaning that EPA will no longer establish an MCL for a contaminant based solely on projected health related issues. The Amendments require the use of sound science, and allow for consideration of other factors such as cost, benefits, and competing risks.

2. Drinking Water Contaminants Candidate List

During March 1998, EPA finalized the first Drinking Water Contaminant Candidate List (CCL), which will be used to set regulatory, research, and occurrence-investigation priorities. This list included 19 chemicals and one microbial contaminant, which the Agency considered as "high priority" with respect to determination of the need to regulate. Since the March 1998 publication of the CCL, EPA narrowed the list of 20 contaminants to a total of 9; these contaminants are summarized in Table A-6. During June 2002, the Agency announced its preliminary decision that no regulatory action is needed for these 9 contaminants.

Table A-6 Contaminants to be Considered for Future Regulation
Acanthamoeba (guidance for contact lens wearers)
Naphthalene
Hexachlorobutadiene
Aldrin
Dieldrin
Metribuzin
Sodium (guidance)
Manganese
Sulfate

3. Total Coliform Rule Revisions / Distribution System Rule

As part of the mandated 6-year regulatory review process, EPA announced during August 2002 that it will decline to revise MCLs for 68 contaminants regulated prior to 1997, but that it is considering revisions to the 1989 Total Coliform Rule. These revisions may be expanded into a Distribution System Rule, and may consider issues such as cross connection control, nitrification, impact of biofilms, and the sanitary condition of storage tanks.

4. Other Rules

Additional rules are likely to be proposed by EPA, but these will primarily address administrative issues such as the reformatting of drinking water amendments, streamlining of public notification requirements, and analytical methods updates. EPA presently plans to defer action on regulation of contaminants such as nickel and atrazine, and has indicated that it likely will not propose a new regulation for aldicarb until August 2004, with a final regulation expected by August 2005.

D. Regulatory Schedule

EPA's current regulatory promulgation schedule is presented in Table A-7. Table A-7 includes both existing and pending/future SDWA regulations.

Table A-7
Schedule for Promulgation of SDWA Regulations (as of 06/2003)

Regulation	Proposed	Final	Effective
Fluoride	11/85	04/86	10/87
8 VOCs (Phase I)	11/85	07/87	01/89
Surface Water Treatment Rule	11/87	06/89	06/93
Coliform Rule[1]	11/87	06/89	12/90
Lead & Copper Minor Revisions	08/88 04/98	06/91 01/2000	01/92[2] 01/2001
26 Synthetic Organic Contaminants[3], 7 Inorganic Contaminants (Phase II)	05/89	01/91	07/92
MCLs for barium, pentachlorophenol (Phase II)	01/91	07/91	01/93
Phase V Organics, Inorganics	07/90	07/92	01/94
Information Collection Rule (ICR)	02/94	05/96	07/97
Consumer Confidence Reports Rule (CCR)	02/98	08/98	09/98
Unregulated Contaminants (monitoring)[4]	02/99	09/99	01/2001
Radionuclides (Phase III) – except radon Radon	07/91 11/99	12/2000 12/04	12/2003 12/07[5]
Disinfectants / Disinfection By-Products Stage 1 Stage 2	 07/94 07/2003	 12/98 07/2004	 01/2002[6,7] 07/2010[8]
Interim Enhanced SWTR Stage 1 – Long-Term Enhanced SWTR Stage 2 – Long-Term Enhanced SWTR	07/94 04/2000 07/2003	12/98 01/2002 07/2004	01/2002[6] 01/2005 07/2010[9]
Filter Backwash Recycling Rule (FBRR)	04/2000	06/2001	06/2004[10]
Ground Water Rule (GWR)	05/2000	12/2003	06/2006[5]
Arsenic	06/2000	01/2001	01/2006[11]
MCLs for aldicarb, aldicarb sulfoxide, aldicarb sulfone	08/2004	08/2005	08/2008[5]

1 Revisions expected by 2005; revised TCR may become Distribution System Rule.
2 Start date for tap monitoring; systems serving more than 50,000 consumers.
3 MCL, MCLG for atrazine to be reconsidered.
4 Tiered monitoring approach pending availability of analytical methods.
5 Assumes regulation in effect 3 years after final promulgation.
6 For systems serving more than 10,000 consumers.
7 Effective 01/2004 for groundwater and small surface water systems.
8 Phased compliance schedule; 07/2010 is projected deadline for compliance with locational TTHM and HAA5 values of 0.080 mg/L and 0.060 mg/L, respectively.
9 Phased compliance schedule; 07/2010 is projected deadline for compliance with additional C*ryptosporidium* treatment requirements.
10 Deadline for modifying recycle point location, if required. 2-year extension available if capital improvements required.
11 Deadline for compliance with revised arsenic MCL.

BLACK AND VEATCH CORPORATION

TECHNICAL MEMORANDUM | **B & V Project: 49768.310**
City of Lawrence, KS | **July 18, 2002**
Water Master Plan | **Updated December 3, 2002**
Model Calibration

To: Project File
From: Scott Cole, Jerry Edwards

A. PURPOSE

The purpose of this memorandum is to document the calibration of the Lawrence Steady State and Extended Period Simulation (EPS) hydraulic model scenarios. Assumptions that were made about the data that was supplied by the City are documented in this memorandum.

B. DEMAND ALLOCATION - BASE YEAR (2000)

1. Metered Sales

The City of Lawrence provided year 2001 metered sales information for every account in the Lawrence Distribution System. The information included account address, user classification code, an unknown three-digit numerical code, annual sales in gallons (gal), and parcel number.

The data consisted of a total of 28,376 records. Initially, 127 records were discarded due to the lack of any numerical street address. These records represented 0.49% of the total metered record sales. Using GIS techniques, the remaining records were "geocoded" to the most recent street centerline file provided by the Lawrence-Douglas County Metropolitan Planning Office. After the initial "geocoding" and subsequent use of other available maps and information to manually locate street addresses, 43 additional records remained unmatched to streets (no matching address was found). These 43 records had metered sales of about 7,880,900 gal (0.02 mgd). When combined with the original 127 records that were discarded, a total of 170 records accounting for 0.68% (0.08 mgd) of the total year 2001 metered sales were not "geocoded".

The top 11 large user accounts (2001 sales greater than 0.1 mgd) and all rural water district sales were separately identified in the metered sales data for direct allocation to the computer model to ensure accuracy. These records were removed from the overall "geocoded" metered sales data and placed in a separate file. The top 11 large users and rural water district allocation is summarized on the attached spreadsheet "Top 11 Allocation".

The remaining "geocoded" sales by user class were then allocated to the appropriate computer model junctions using spatial GIS techniques. Special quality control steps were taken in the allocation of metered records to computer model nodes near the service level boundary.

The "geocoded" sales (99.32% of total sales) were summarized by user class and then factored to match the design base year sales by user class as summarized in Table 1.

Table 1
"Geocoded" Metered Sales Adjustments
Base Year "Design" Allocation

User Class	Design Total Sales	"Geocoded" Sales	Adjustment Factor
	(mgd)	(mgd)	
RES	6.00	5.727129863	1.047645181
ICI (Excluding Top 5)	2.43	2.261690137	1.074417738
ICI (Top 5)	1.27	1.265051781	1.003911476
ICI Subtotal	3.70	3.526741918	
KU (Excluding Power Plant)	0.30	0.314421370	0.954133621
KU Power Plant	0.40	0.400046575	0.999883575
KU Subtotal	0.70	0.714467945	
RWD	1.50	1.490995890	1.00603899
Total	11.90	11.459335616	

2. Unaccounted-for water
Base year "design" unaccounted-for water of 0.6 mgd was then allocated. Unaccounted-for water was allocated to each node in the model based on the percent of total demand at each node.

3. Total Base Year "Design" Allocation
The total allocated demand including metered sales and unaccounted-for water for the base year "design" condition was 12.5 mgd. This is equal to the average annual day demand for base year, or existing conditions.

C. STEADY STATE MODEL CALIBRATION

1. Methodology

The maximum hour demand that occurred between 7:00 am and 8:00 am on August 28, 2000 was selected for steady state calibration.

The steps for calibrating the Steady State model were as follows:

1. Diurnal demand curves by service level were determined based on circular chart data provided by the City. See attached.
2. The maximum hour demand (7am-8am August 28, 2000) was selected for steady state calibration.
3. The status of facilities (pumps on/off, reservoir water levels) was determined from the data.
4. All the data parameters were added to the model.
5. The model results were compared to the original data to determine if the model closely represents the actual collected data.
6. Modifications were made to the model until most of the model was calibrated to the collected data.
7. Based on the results of trial analyses, the flow from the Oread Booster Pumping Station was estimated, diurnal curves were adjusted accordingly and the analysis was finalized based on the results of the EPS analysis.

2. Peaking Factors

Peaking factors by user class for each service level were applied (in the computer model) to the allocated "design" sales and unaccounted-for water to achieve the August 28, 2000 Maximum Hour condition. The peaking factors were selected based on historical trends.

During a meeting with City staff on June 28, 2002**,** it was determined that the Oread South Booster Pump was running all day. Flow data is not recorded for the Oread Pumping Station. Since no operational data was available, the percent speed was adjusted to 74% to balance the outflow from the Oread Reservoir to recorded conditions. The corresponding pumping rate from the Oread Booster was 0.9 mgd. The diurnal curves for August 28, 2000 were adjusted to reflect these modifications. The peaking factors were subsequently adjusted to match the modified demands by service level. The peaking factors used, and the resulting comparison of modeled maximum hour by service level to actual maximum hour by service level, are summarized in the attached spreadsheet "Peaking Factors" in Attachment A.

3. Harper Tank

In the trial steady state calibration analyses, the Harper Tank was not calibrating well. The model showed the tank draining at approximately 1.5 mgd while the circular chart data shows the tank water level as constant throughout the entire day. The City indicated that a valve exists at Harper Tank that controls the flow into the tank, but not out of the tank. During the year 2000, this valve was not on-line with the City's SCADA system. No data pertaining to the operation of this valve was available. The results of the EPS calibration analysis were used to adjust the initial water level at Harper tank from 36 ft. to 34 ft. The change in initial water level reduced the flow out of Harper Tank to about 0.6 mgd. All other tanks were set to the recorded level at 7:00 am.

4. Pumping

The following clarifies pump operational data used in the computer model for the final steady state calibration analysis. The final pump curves used in the steady state calibration analysis were modified based on the results of preliminary steady state trial analyses and the results of the final extended period simulation analyses.

1. Single design points (rated head and TDH) were used for the Kaw Plant Central Service Downstairs Pumps 1, 2, 3, and 4 since pump curves were not available. All other pumps curves were modeled as multiple points based on curves provided by the City.
2. The Kaw Plant West Hills Pumps 1, 2, and 3 were modified from the original shop curves provided by the City, to account for the age of the pumps (installed 1952). The curves were adjusted as follows:

	Original Points	Adjusted Points
Pumps 1&2	0 mgd @ 480 ft	0 mgd @ 430 ft
	1.37 mgd @ 370 ft	1.15 mgd @ 343 ft
	1.84 mgd @ 280 ft	1.51 mgd @ 280 ft
Pump 3	0 mgd @ 475 ft	0 mgd @ 430 ft
	1.30 mgd @ 420 ft	1.15 mgd @ 380 ft
	1.90 mgd @ 265 ft	1.87 mgd @ 210 ft

3. The Kaw Plant Central Service Downstairs Pumps 1, 2, 3, 4 were modified from the original single design points provided by the City to account for the age of the pumps (installed 1917). The points were adjusted as follows:

	Original Point	Adjusted Point
Pumps 1&2	2.2 mgd @ 220 ft	1.96 mgd @ 196 ft
Pump 3	3.6 mgd @ 220 ft	3.21 mgd @ 196 ft
Pump 4	1.4 mgd @ 210 ft	1.23 mgd @ 187 ft

4. The Kaw Plant Central Service Downstairs Pump 2 was set at 89% speed to account for operating only 50% of the hour.

5. The Clinton Plant Central Service Pump 3 speed was set at 68% (VFD)
6. The Clinton Plant West Hills Pump 3 speed was set at 77% (VFD)

5. Steady State Calibration Results

The computer model was run with the allocated demands and peaking factors. The results of the calibration analysis are summarized in the attached spreadsheet "Steady State Calibration Results" in Attachment A. Tank and pump tables from the computer model results are also attached.

Figure TM-1 in Attachment A, provides detailed information on the pipe diameters, direction and magnitude of flows in selected mains, and HGL values for selected nodes.

BLACK AND VEATCH CORPORATION

TECHNICAL MEMORANDUM — **B & V Project: 49768.310**
City of Lawrence, KS — **July 18, 2002**
Water Master Plan — **Updated December 3, 2002**
Model Calibration

D. EPS MODEL CALIBRATION

1. Methodology

The model was calibrated to a 24-hour period, in 1-hour increments, to simulate demand and operational conditions that occurred on August 28, 2000.

The steps for developing the EPS model were as follows:

1. Data was collected on base year maximum day (August 28, 200).
2. 24-hour diurnal demands and demand patterns were developed from the data. Diurnal Patterns can be found on the attached spreadsheet "Model Diurnal" Attachment B.
3. Operational controls and initial status of facilities were determined from the data.
4. All the data parameters were added to the model.
5. The model results were compared to the original data to determine if the model closely represents the actual collected data.
6. Modifications were made to the model until most of the model was calibrated to the collected data.

2. Peaking Factors

Hourly peaking factors were developed for each service level and were applied (in the computer model) to the allocated "design" sales and unaccounted-for water to achieve the hourly demands for each hour during the August 28, 2000 Maximum Day scenario. The same peaking factor was used for all demand classes in the computer model.

3. Operational Controls

The pump curve data used in for the final steady state analysis was also used for the EPS calibration analysis. In addition, the following operational and demand controls were used to simulate the conditions that occurred over the 24-hour period:

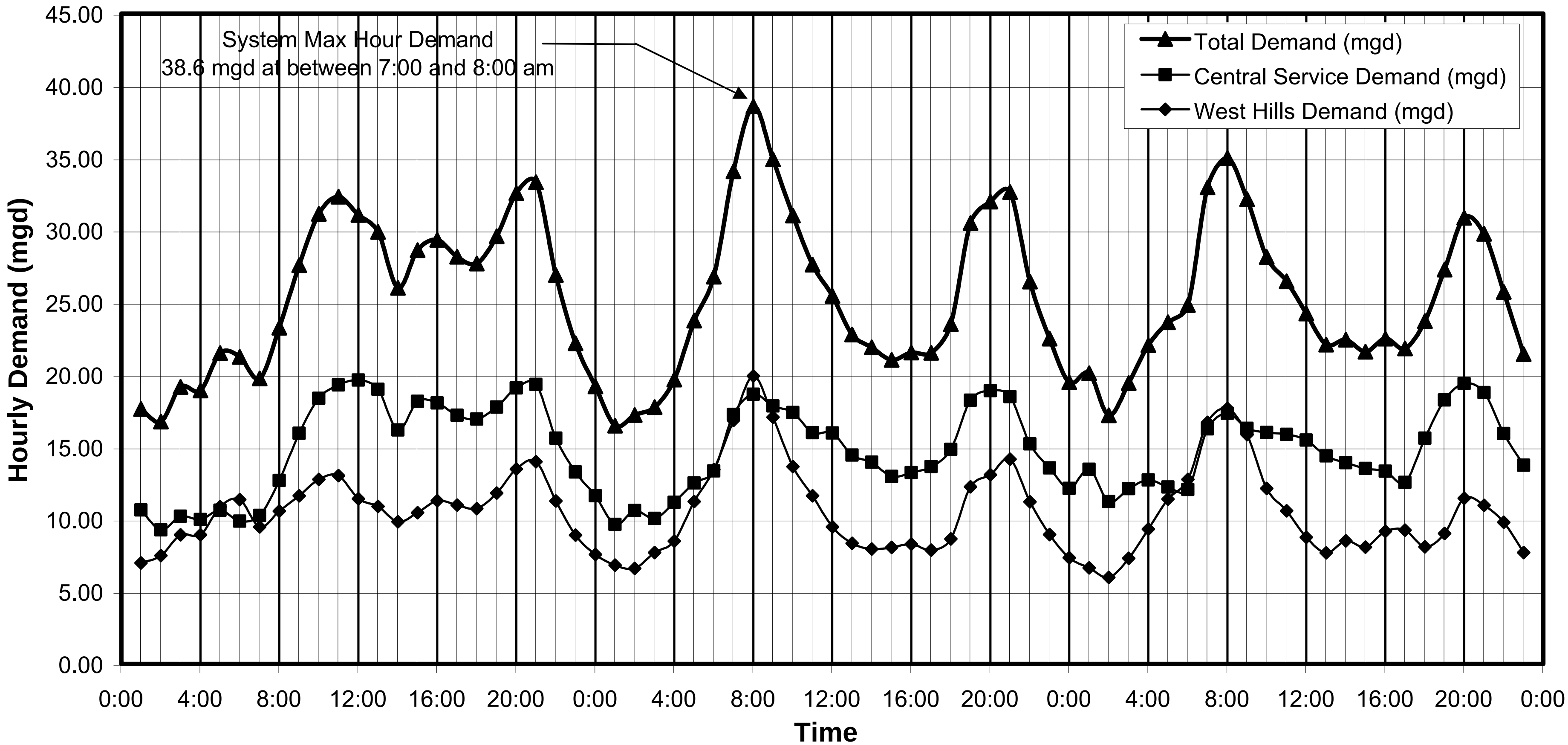
1. Initial tank levels were set from the data provided.
2. Clinton Plant West Hills Pump 3 percent speed was adjusted hourly to match recorded flows. The percent speed values can be found on attached table in Attachment B.
3. 0.9 mgd demand was placed on the suction side and 0.9 mgd input was placed on the discharge side of the Oread South Booster Pump to simulate constant pumping throughout the day.
4. Clinton Plant Central Service Pump 3 percent speed was adjusted hourly to match recorded flows. The percent speed values can be found on attached table in Attachment B.

5. 1.4 mgd demand was placed on the Kaw Plant Central Service Upstairs discharge header with a diurnal pattern to account for the wash water tank filling as indicated on the circular chart.

4. EPS Calibration Results

The results of the EPS calibration are summarized in the graphs included in the attached Attachment B. The graphs show recorded flows and tank levels versus recorded data for the 24-hour period. The graphs indicate a good correlation between the recorded (circular chart) and modeled flows and water levels.

The model shows a fluctuation throughout the day in the water level at Harper Tank while recorded data shows no variation. It is concluded that there may have been a problem with the recording equipment for the Harper Tank during the day of August 28, 2000.



Sunday, August 27, 2000
Total Day Demand = 25.6 mgd

Monday, August 28, 2000
Total Day Demand = 25.4 mgd

Tuesday, August 29, 2000
Total Day Demand = 25.0 mgd

City of Lawrence
Water System Master Plan - 2003

Maximum Day 2000
Hourly Demands

BLACK & VEATCH
Corporation

Figure A-6

ATTACHMENT A

STEADY STATE CALIBRATION RESULTS

Top 11 Allocation

SAC 06/10/02

Description	Address	Class	Service Level	USE_GAL	ACTUAL USE	Allocated Use
FMC Corp.	900 Lincoln St	ICI	Central	182,792,000	0.500800000	0.502758867
Western Resources	2900 Lakeview Rd	ICI	Central	80,006,000	0.219194521	0.220051895
Alvamar Golf Course	1800 Crossgate Dr	ICI	West Hills	79,232,700	0.217075890	0.217924977
Farmland industries	2499 E 19TH St	ICI	Central	77,767,000	0.213060274	0.213893654
Eagle Bend Golf Course	1250 E 902 Rd	ICI	Central	41,946,200	0.114921096	0.115370607
K U Power Plant	1600 Indiana St	KU	Central	146,017,000	0.400046575	0.400000000
City of Baldwin	3100 Haskell Ave	RWD	Central	330,476,000	0.905413699	0.910881483
Rural Water District #4	3000 Haskell Ave	RWD	Central	68,062,000	0.186471233	0.187597331
Rural Water District #5	3400 Iowa	RWD	Central	59,912,700	0.164144384	0.165135650
Rural Water District #2	3400 Iowa	RWD	Central	41,402,000	0.113430137	0.114115140
Rural Water District #1	600 Wakarusa Dr	RWD	West Hills	37,320,800	0.102248767	0.102866246
Rural Water District #1	600 FOLKS RD	RWD	West Hills	4,536,800	0.012429589	0.012504651
Rural Water District #6	RIVER RIDGE RD & LONETREE	RWD	Central	1,921,300	0.005263836	0.005295624
Rural Water District #1	CLINTON PKWY & YANKEE TK	RWD	West Hills	581,900	0.001594247	0.001603874
			Sum =	1,151,974,400	3.156094247	3.170000000

Sum ICI =	1.265051781
Design ICI =	1.27
ICI Factor =	1.003911476
Sum KU =	0.400046575
Design KU =	0.4
KU Factor =	0.999883575
Sum RWD =	1.490995890
Design RWD =	1.5
RWD Factor =	1.00603899

Sum of Allocated Use	Service Level		
Class	Central	West Hills	Grand Total
ICI	1.052075023	0.217924977	1.270000000
KU	0.400000000		0.400000000
RWD	1.383025228	0.116974772	1.500000000
Grand Total	2.835100251	0.334899749	3.170000000

Lawrence, KS
Water Master Plan
BV PN 49768.310

Calibration Peaking Factors

SAC 06/12/02
Checked JAE 07/29/02

Allocated (Adjusted to Design) Metered Sales and UNF (mgd)							
	Res	Non-Res	KU	RWD	Total Sales	UFW	AAD
Central	3.3180	2.6729	0.4431	1.3846	7.8186	0.3942	8.2128
West Hills	2.6820	1.0271	0.2569	0.1154	4.0814	0.2058	4.2872
Total	6.0000	3.7000	0.7000	1.5000	11.9000	0.6000	12.5000

Maximum Hour Peaking Factor Determination										
	AAD Class 1 Resid	PF1	AAD Class 2 Non-Res	PF2	AAD Class 3 KU	PF3	AAD Class 4 RWD	PF4	AAD Class 5 UFW	PF5
Central	3.3180	3.08	2.6729	2.09	0.4431	1.50	1.3846	1.30	0.3942	1.00
West Hills	2.6820	5.70	1.0271	3.79	0.2569	1.50	0.1154	1.30	0.2058	1.00
Total	6.0000	4.25	3.7000	2.56	0.7000	1.50	1.5000	1.30	0.6000	1.00

Maximum Hour Demands in Computer Model								
	AAD Class 1 RES	MH Class 2 Non-Res	AAD Class 3 KU	AAD Class 4 RWD	AAD Class 5 UNF	MH Total Calib Demand	Actual 6/28/00 8AM Demand	Delta
Central	10.2194	5.5863	0.6647	1.8000	0.3942	18.6646	18.6610	0.0036
West Hills	15.2875	3.8928	0.3853	0.1500	0.2058	19.9213	19.9192	0.0021
Total	25.5069	9.4791	1.0500	1.9500	0.6000	38.5860	38.5802	0.0058

Steady State Calibration Results

SAC 06/11/02

FACILITY	Measured Parameter	ACTUAL (mgd)	Model (mgd)	Model Difference (mgd)	Model Difference (%)	NOTES
Kaw Plant						
West Hills	Flow	3.8	3.93	0.13	3.42%	All Shop Curves adjusted for age (1952); 1,2,&3 "on"
West Hills	Discharge Pressure (psi)	143	146	3.00	2.10%	
Central Upstairs (New)	Flow	10.7	10.61	-0.09	-0.84%	Pumps 1,3,&4 "on"
Central Downstairs (Old)	Flow	2.63	2.58	-0.05	-1.98%	All Design Points adjusted for age (1917); Pump 4 at 89% due to half hour, 2&4 "on"
Central	Discharge Pressure (psi)	81	84	2.60	3.21%	
Clinton Plant						
West Hills	Flow	13.24	13.40	0.16	1.21%	Pump 3 at 77%; 1,2,3 "on"
West Hills	Discharge Pressure (psi)	NA	89	NA	NA	Pressure not provided
Central	Flow	4.6	4.62	0.02	0.43%	Pump 3 at 68%; 3 "on"
Central	Discharge Pressure (psi)	NA	12	NA	NA	Pressure not provided
Booster Pump Stations						
Kasold Booster	Flow	0	0.00	0.00	NA	Flow not recorded, not operating
	Discharge Pressure (psi)	NA	NA	NA	NA	Pressure not recorded, not operating
Oread Booster	Flow	0.9	0.93	NA	NA	Actual flow is assumed based on EPS results, Flow not recorded
	Discharge Pressure (psi)	NA	NA	NA	NA	Pressure not recorded
Water Storage Reservoirs						
6th Street Tank (WH)	Draft	0.38	0.39	0.01	2.85%	Set at actual 7:00 am tank level from circular charts
Stratford Tank (WH)	Draft	1.60	1.38	-0.22	-13.75%	Set at actual 7:00 am tank level from circular charts
Kasold Tank (CS)	Draft	0.06	0.08	0.02	31.15%	Set at actual 7:00 am tank level from circular charts
Oread Reservoirs (CS)	Draft	1.57	1.54	-0.03	-1.79%	Set at actual 7:00 am tank level from circular charts
Harper Tank (CS)	Draft	0.00	0.32	0.32	NA	Set tank at 34 ft. based on EPS results

Summary of West Hills Service Level Demand (mgd)		19.92	20.03	0.11	0.56%
Summary of Central Service Level Demand (mgd)		18.66	18.82	0.16	0.85%
Total System Demand (mgd)		38.58	38.85	0.27	0.70%

Scenario: MH Calibration Aug 28, 2000 8am
Steady State Analysis
Tank Report

Label	Zone	Minimum Elevation (ft)	Initial HGL (ft)	Maximum Elevation (ft)	Inflow (mgd)	Current Status	Calculated Hydraulic Grade (ft)	Calculated Percent Full (%)
T-HARPER	Central Servic	977.00	1,011.00	1,015.00	-0.32	Draining	1,011	90.6
T-6th St	Central Servic	1,132.50	1,164.20	1,170.00	-0.38	Draining	1,164	85.7
T-OREAD	Central Servic	990.00	1,016.50	1,019.00	-1.54	Draining	1,017	91.4
T-STRATFOR	Central Servic	1,144.00	1,166.60	1,174.00	-1.27	Draining	1,167	77.7
T-KASOLD	Central Servic	960.00	1,011.70	1,019.00	0.08	Filling	1,012	87.6

Scenario: MH Calibration Aug 28, 2000 8am
Steady State Analysis
Pump Report

Label	Elevation (ft)	Shutoff Head (ft)	Design Head (ft)	Design Discharge (mgd)	Maximum Operating Head (ft)	Maximum Operating Discharge (mgd)	Control Status	Intake Pump Grade (ft)	Discharge Pump Grade (ft)	Discharge (mgd)	Pump Head (ft)
CLINTON 1 (W	990.00	314	290	3.70	0	7.41	On	1,000	1,195	5.70	195
CLINTON 1(C	990.00	98	87	2.43	0	4.86	Off	1,000	1,019	0.00	0
CLINTON 2 (C	990.00	98	87	2.43	0	4.86	Off	1,000	1,019	0.00	0
CLINTON 2 (W	990.00	314	290	3.70	0	7.41	On	1,000	1,195	5.70	195
CLINTON 3 (C	990.00	107	94	3.98	0	7.95	On	1,000	1,019	4.62	19
CLINTON 3 (W	990.00	355	276	4.28	0	8.55	On	1,000	1,195	1.99	195
KASOLD_1	960.00	285	235	1.89	200	2.30	Off	1,012	1,160	0.00	0
KASOLD_2	960.00	285	235	1.89	200	2.30	Off	1,012	1,160	0.00	0
KAW (NEW) 1	835.00	263	241	2.50	0	5.01	On	845	1,032	3.54	187
KAW (NEW) 2	835.00	263	241	2.50	0	5.01	Off	845	1,032	0.00	0
KAW (NEW) 3	835.00	263	241	2.50	0	5.01	On	845	1,032	3.54	187
KAW (NEW) 4	835.00	263	241	2.50	0	5.01	On	845	1,032	3.54	187
KAW (OLD) 1	835.00	261	196	1.96	0	3.92	Off	845	1,032	0.00	0
KAW (OLD) 2	835.00	261	196	1.96	0	3.92	On	845	1,032	2.09	187
KAW (OLD) 3	835.00	261	196	3.21	0	6.42	Off	845	1,032	0.00	0
KAW (OLD) 4	835.00	249	187	1.23	0	2.46	On	845	1,032	0.50	187
KAW 1 (WH)	835.00	431	343	1.15	280	1.51	On	845	1,176	1.23	331
KAW 2 (WH)	835.00	431	343	1.15	280	1.51	On	845	1,176	1.23	331
KAW 3 (WH)	835.00	430	390	1.15	210	1.87	On	845	1,176	1.49	331
OREAD_1	990.00	288	250	1.79	204	2.30	Off	1,016	1,163	0.00	0
OREAD_2	990.00	288	250	1.79	204	2.30	On	1,016	1,163	0.93	147

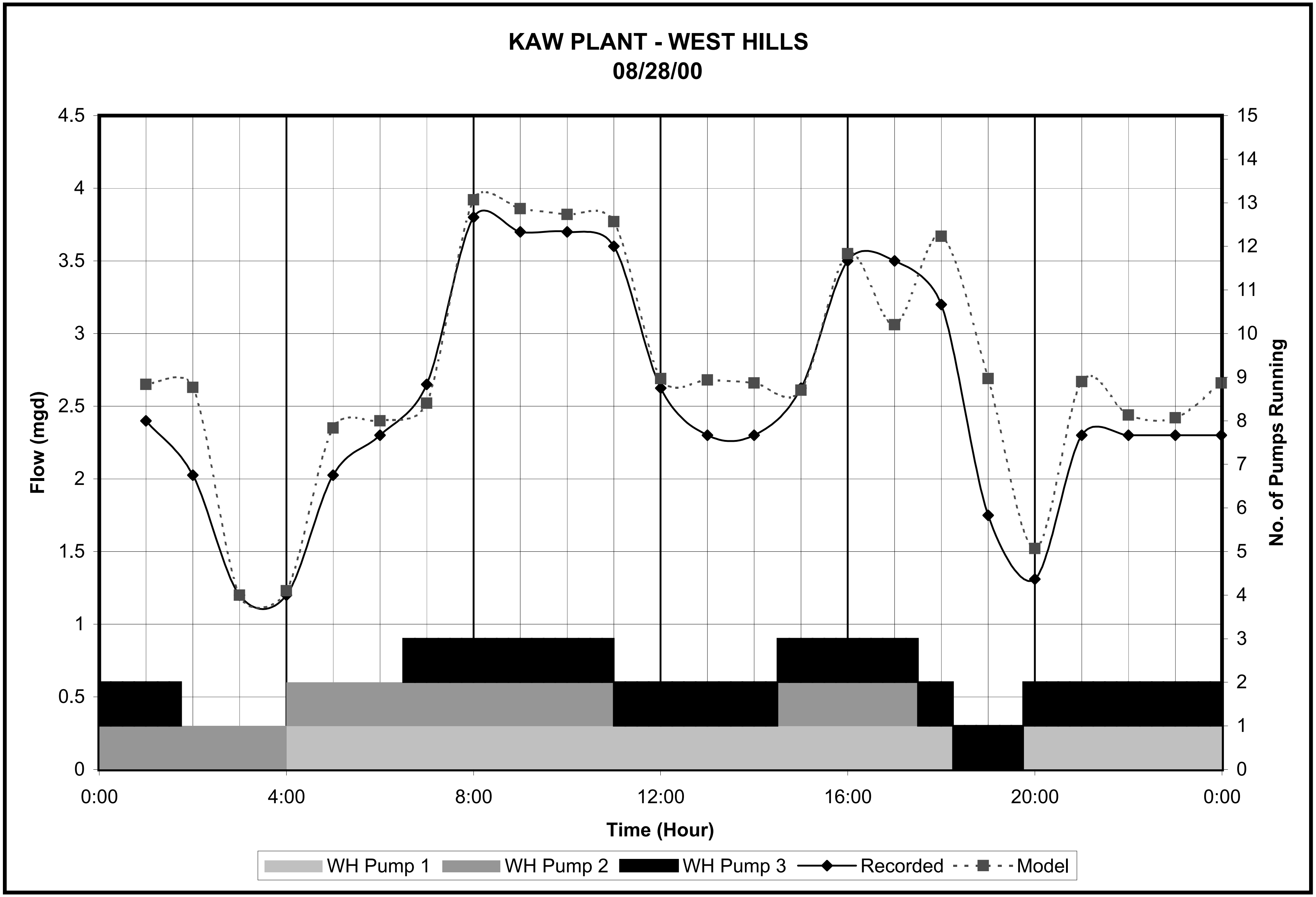
ATTACHMENT B

EPS CALIBRATION RESULTS

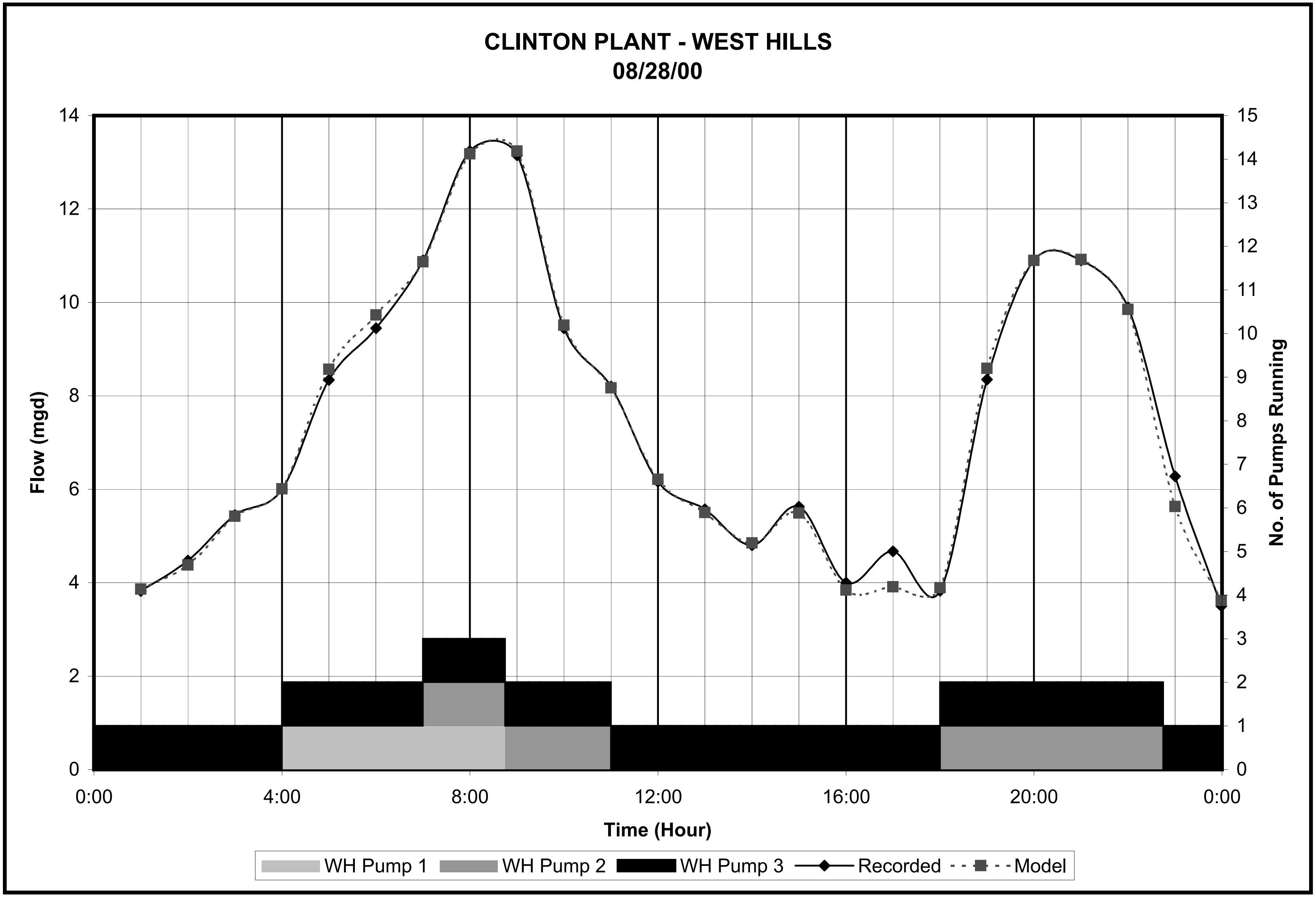
Model Diurnal

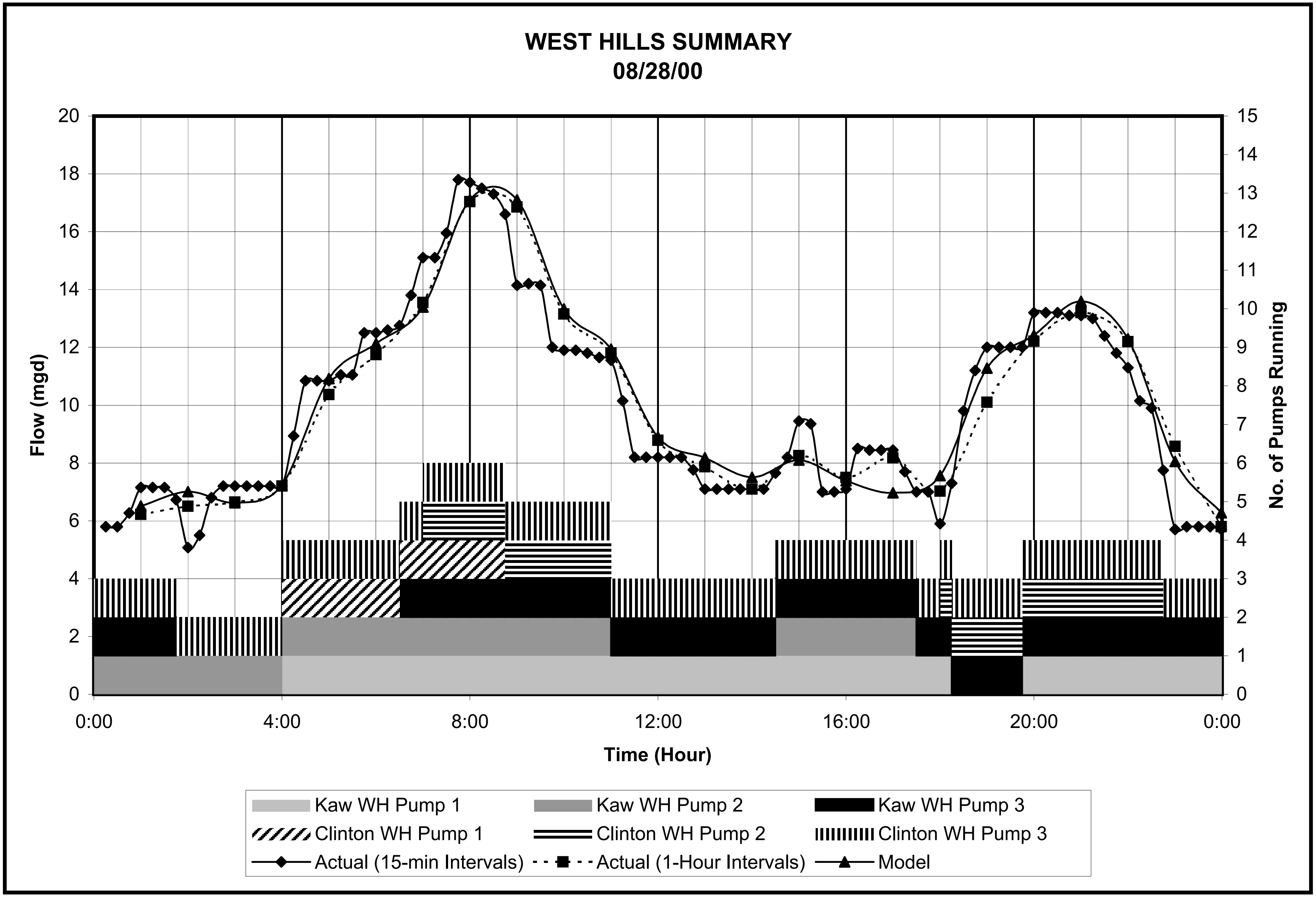
SAC 07/10/02

8/28/2000	WH	CS
AD	4.121657	7.953343
1:00	1.658556	1.214081
2:00	1.603336	1.334785
3:00	1.869879	1.264625
4:00	2.062277	1.404441
5:00	2.724972	1.573678
6:00	3.262765	1.678791
7:00	4.084765	2.169528
8:00	4.832813	2.346309
9:00	4.139985	2.243711
10:00	3.311775	2.185572
11:00	2.823719	2.010224
12:00	2.298639	2.008916
13:00	2.025593	1.816469
14:00	1.930777	1.753602
15:00	1.955815	1.630887
16:00	2.013559	1.664835
17:00	1.909329	1.717014
18:00	2.100078	1.86719
19:00	2.972785	2.292872
20:00	3.176101	2.376736
21:00	3.438326	2.324306
22:00	2.722934	1.914415
23:00	2.169661	1.705396
0:00	1.781905	1.526654

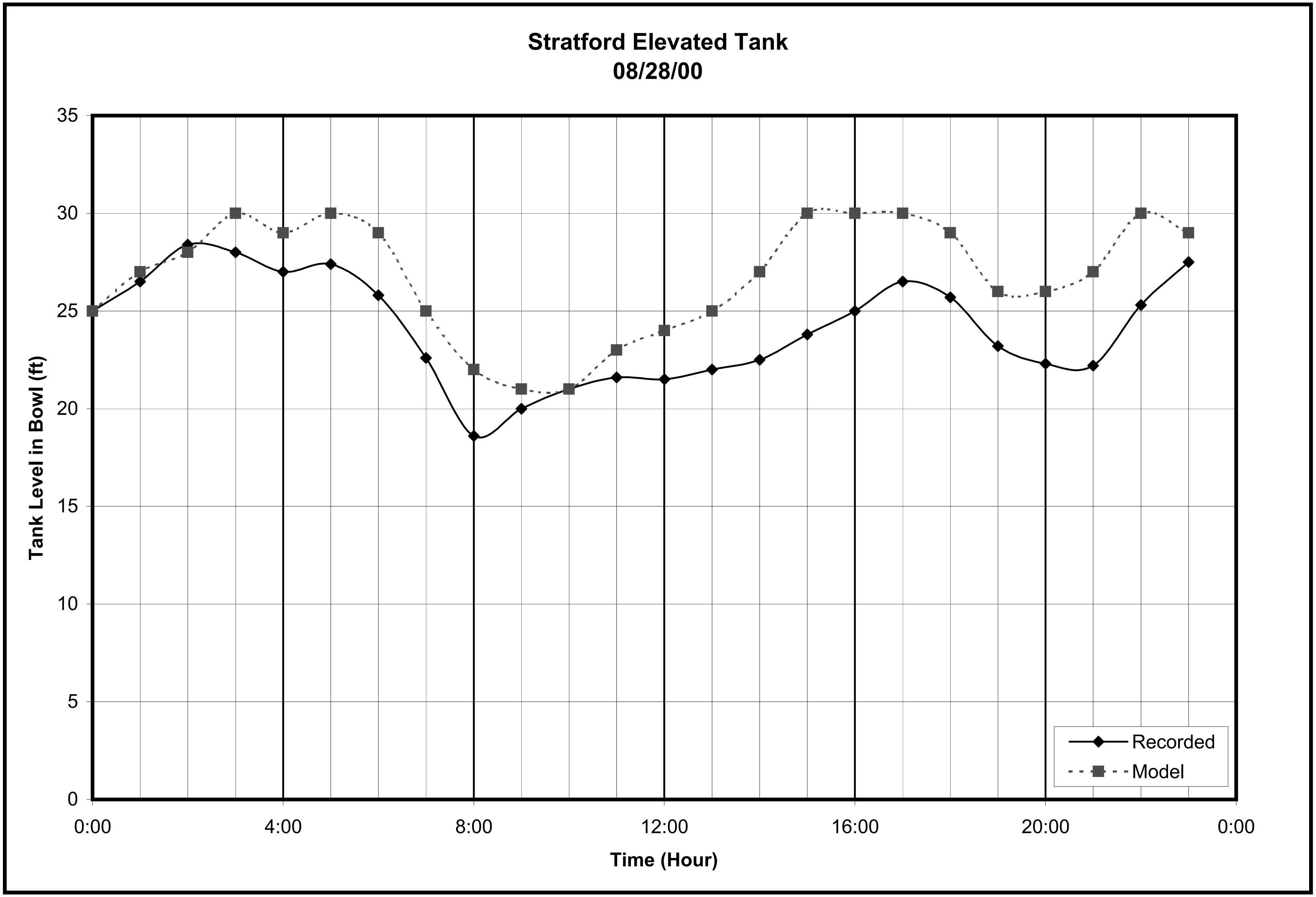


KAW PLANT - WEST HILLS
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
WH Pump 1
WH Pump 2
WH Pump 3
Recorded
Model

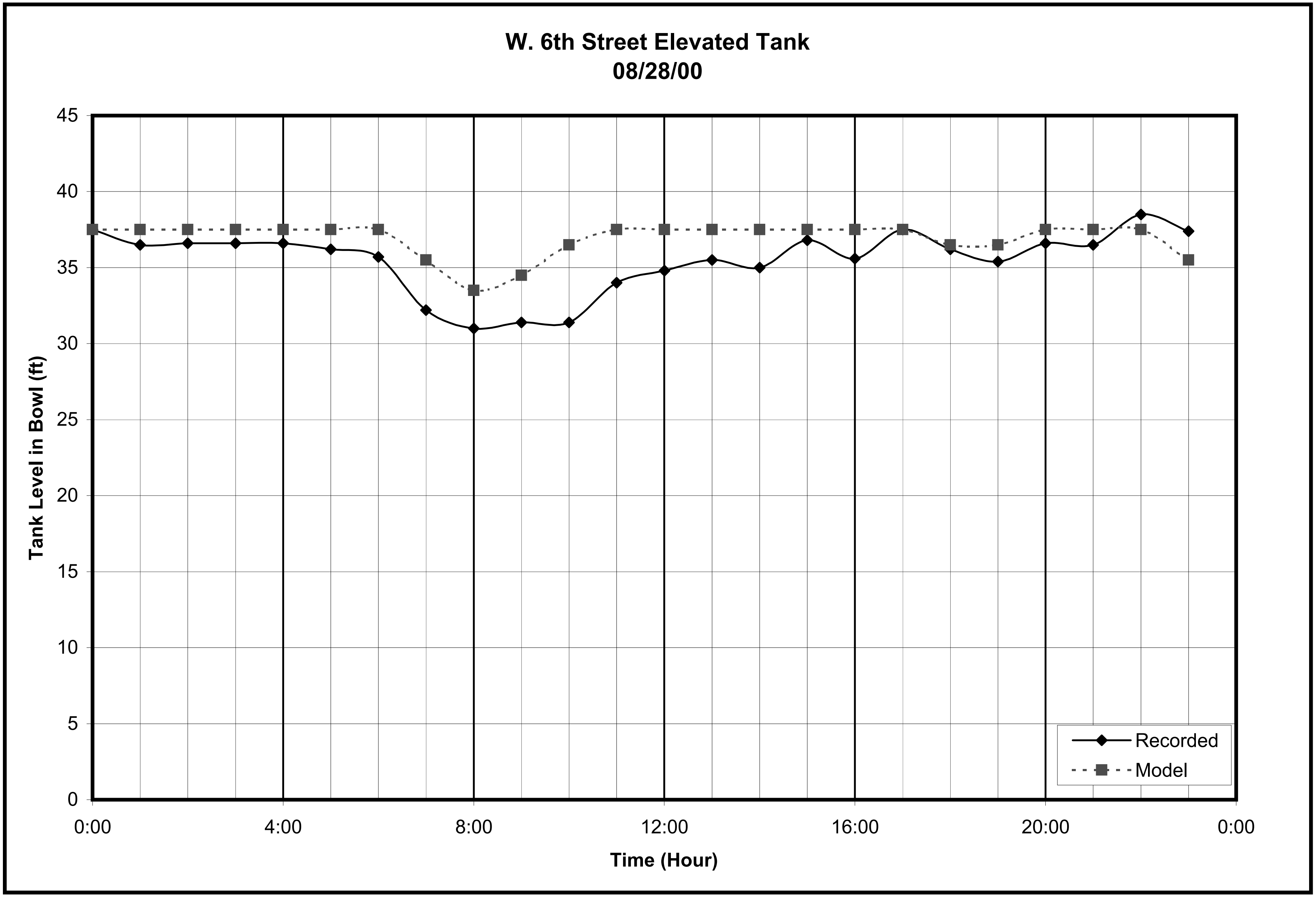

CLINTON PLANT - WEST HILLS
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
WH Pump 1
WH Pump 2
WH Pump 3
Recorded
Model

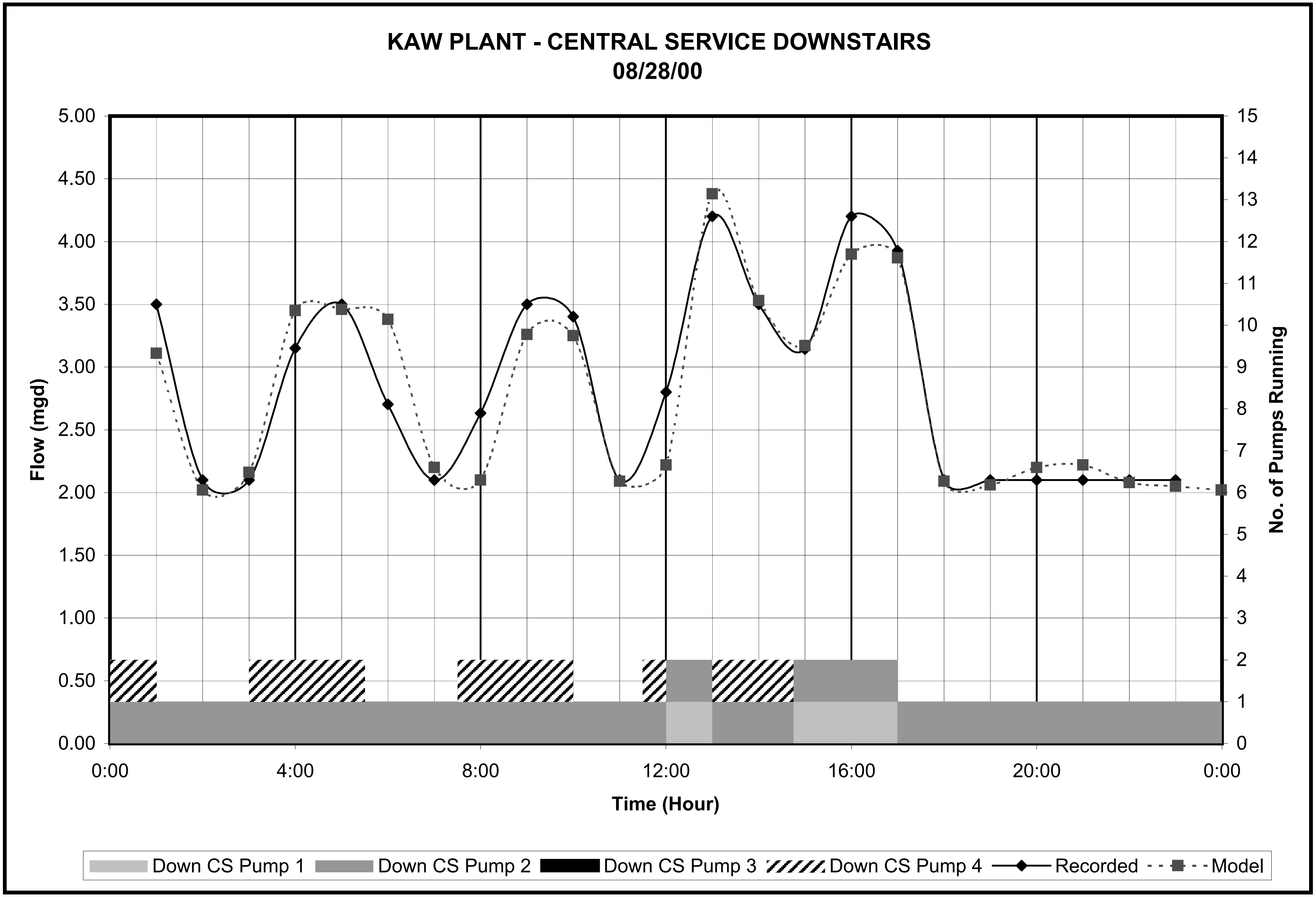


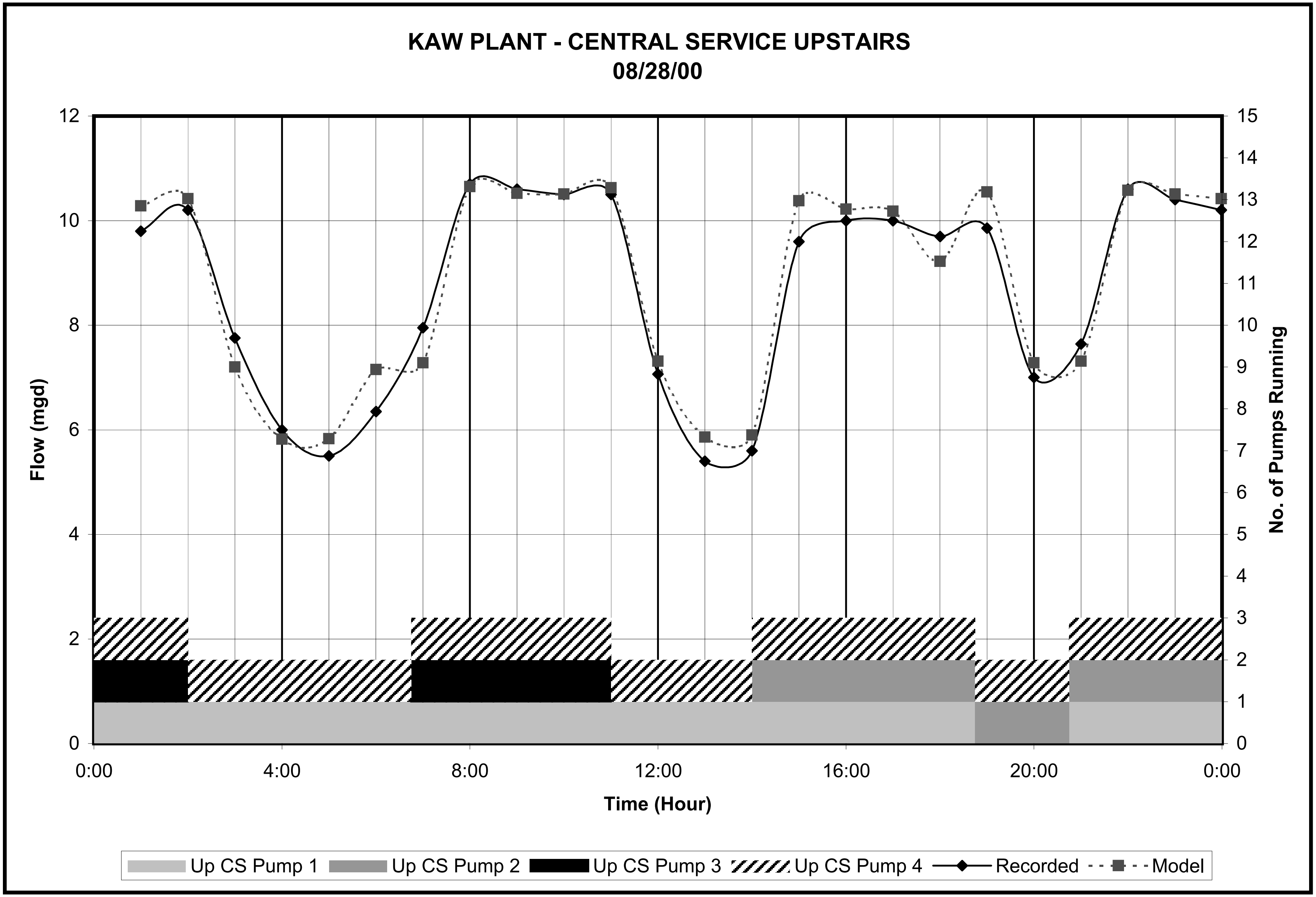
WEST HILLS SUMMARY
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Kaw WH Pump 1
Kaw WH Pump 2
Kaw WH Pump 3
Clinton WH Pump 1
Clinton WH Pump 2
Clinton WH Pump 3
Actual (15-min Intervals)
Actual (1-Hour Intervals)
Model

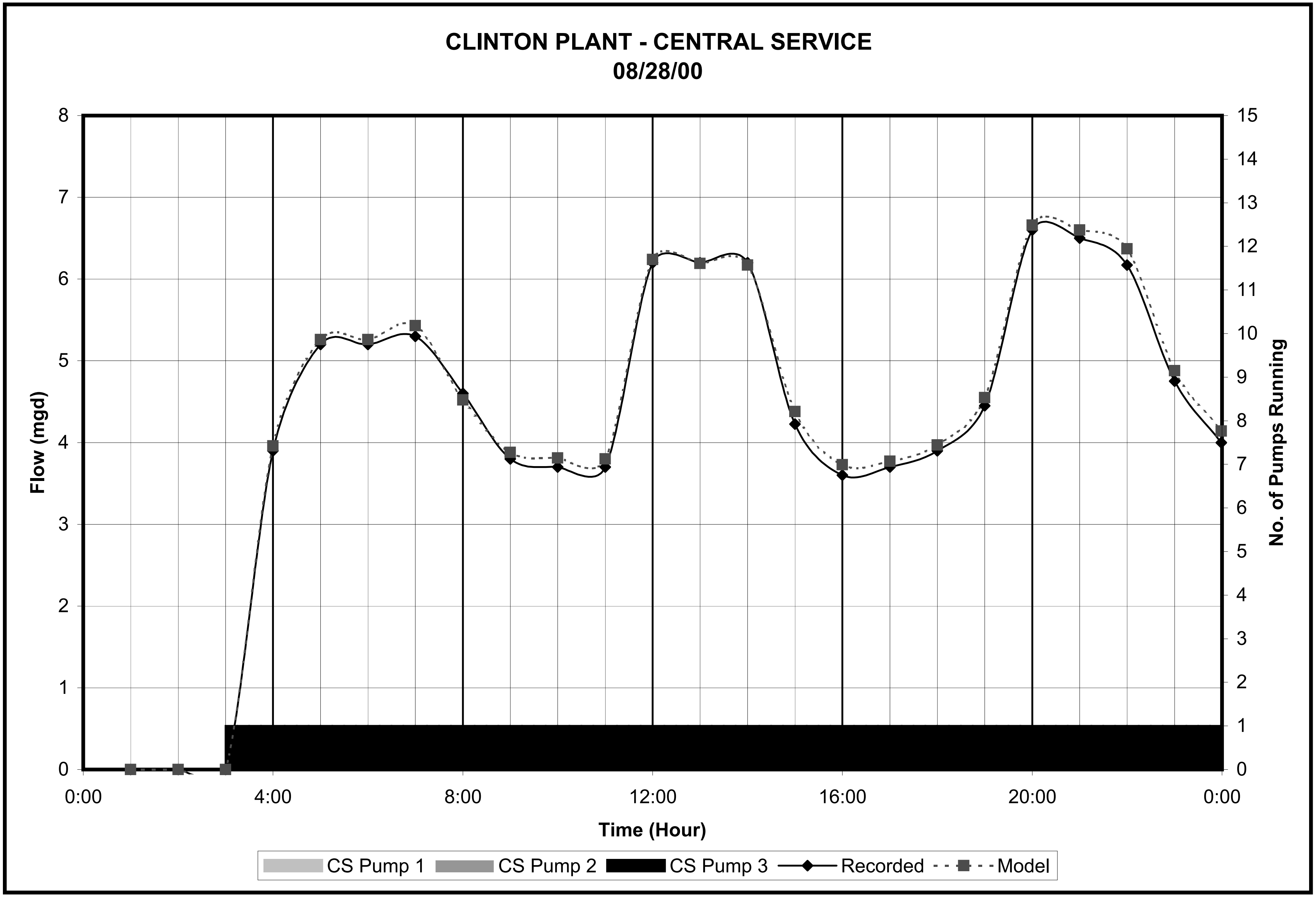


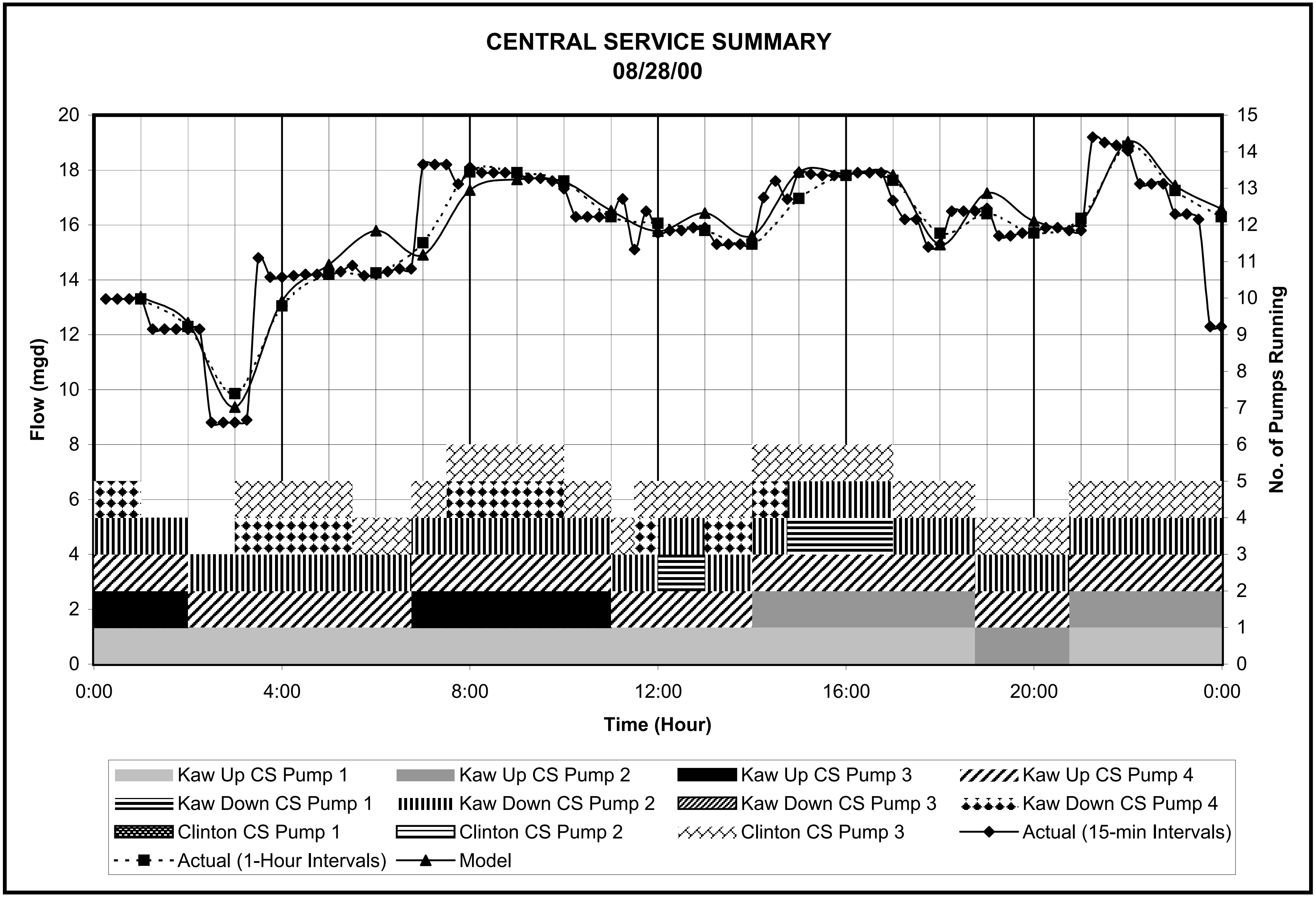
Stratford Elevated Tank
08/28/00
Tank Level in Bowl (ft)
35
30
25
20
15
10
5
0
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time (Hour)
Recorded
Model


W. 6th Street Elevated Tank
08/28/00
Tank Level in Bowl (ft)
45
40
35
30
25
20
15
10
5
0
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time (Hour)
Recorded
Model

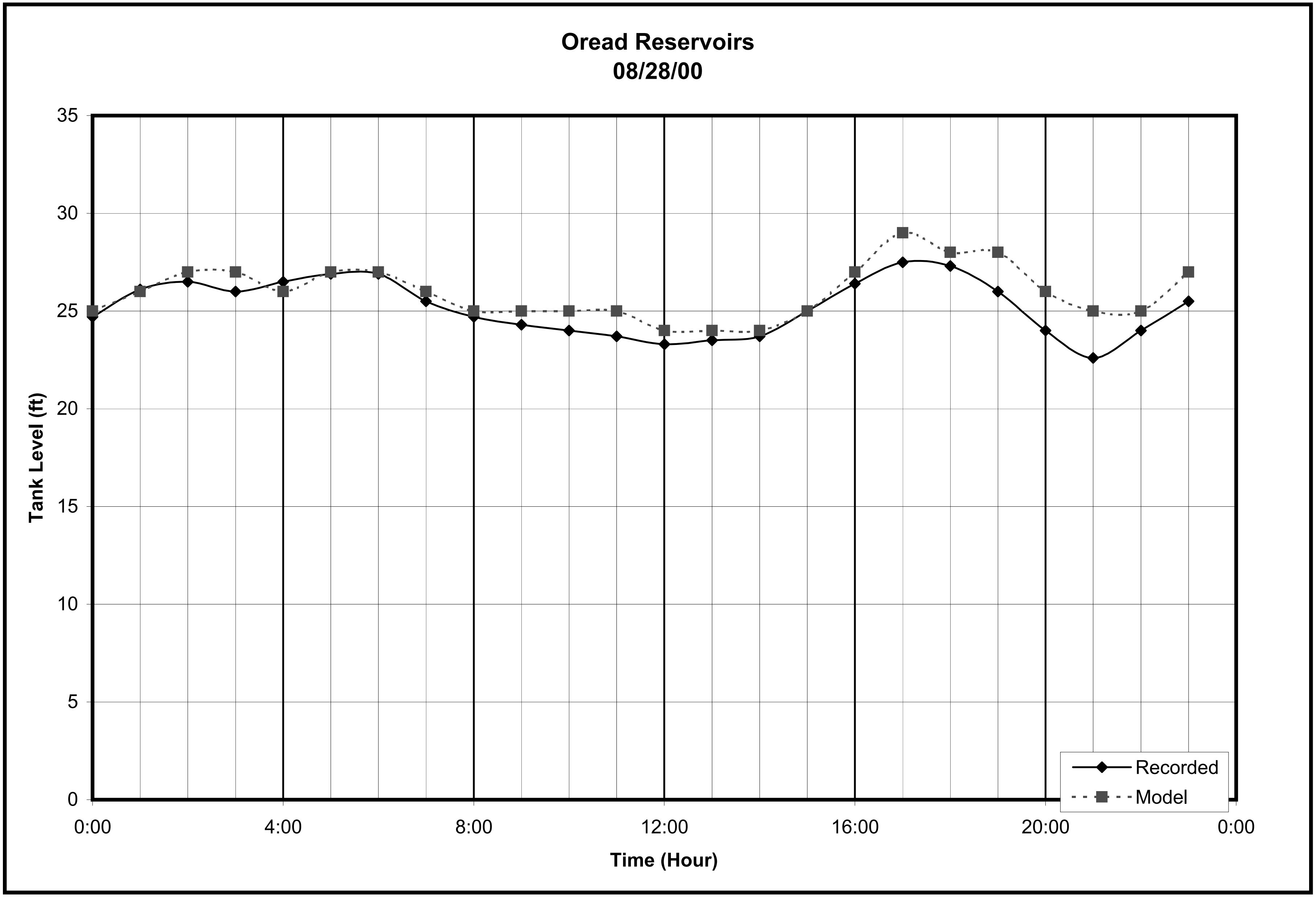

KAW PLANT - CENTRAL SERVICE DOWNSTAIRS
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Down CS Pump 1
Down CS Pump 2
Down CS Pump 3
Down CS Pump 4
Recorded
Model

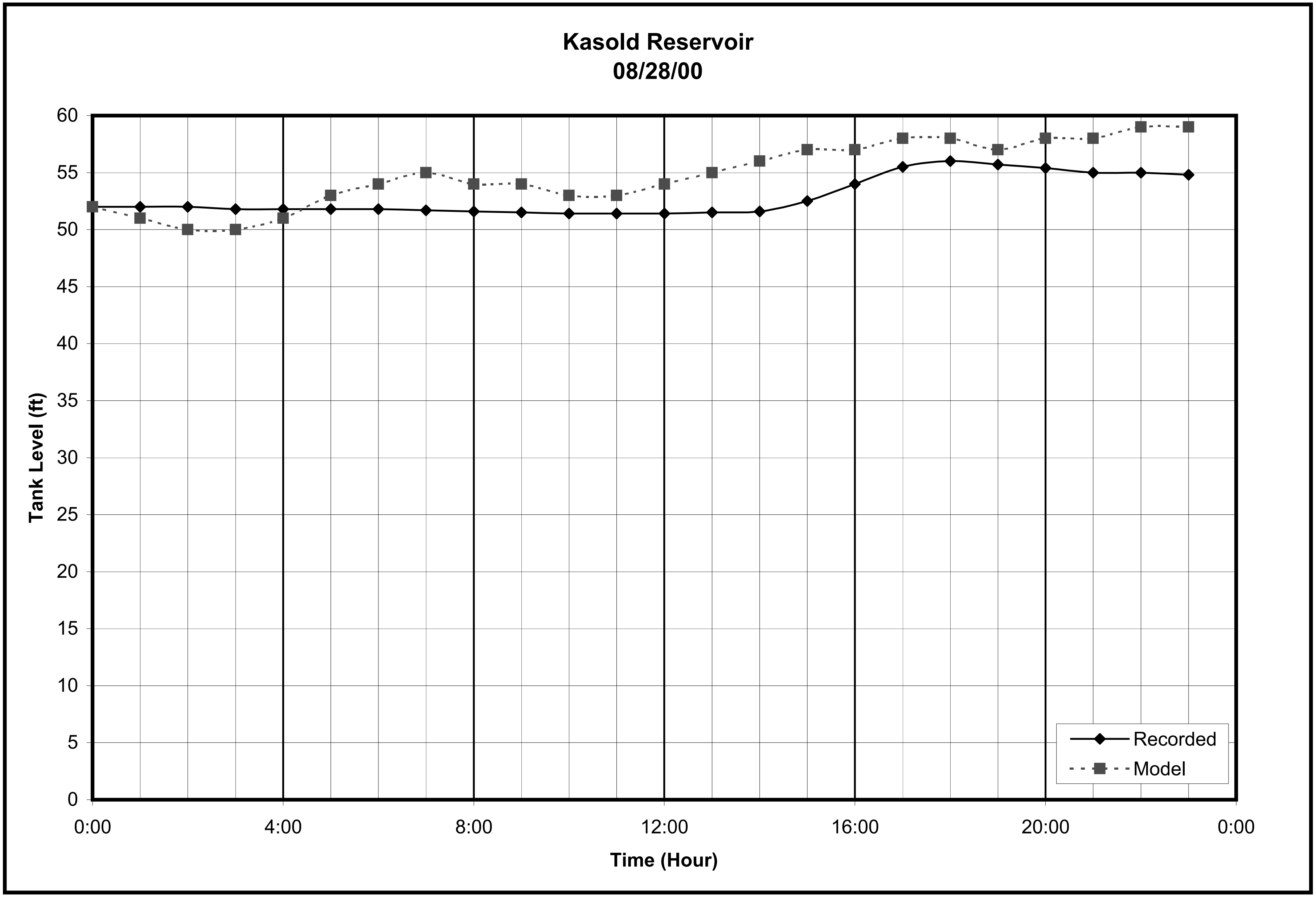

KAW PLANT - CENTRAL SERVICE UPSTAIRS
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
0
2
4
6
8
10
12
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Up CS Pump 1
Up CS Pump 2
Up CS Pump 3
Up CS Pump 4
Recorded
Model


CLINTON PLANT - CENTRAL SERVICE
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
CS Pump 1
CS Pump 2
CS Pump 3
Recorded
Model

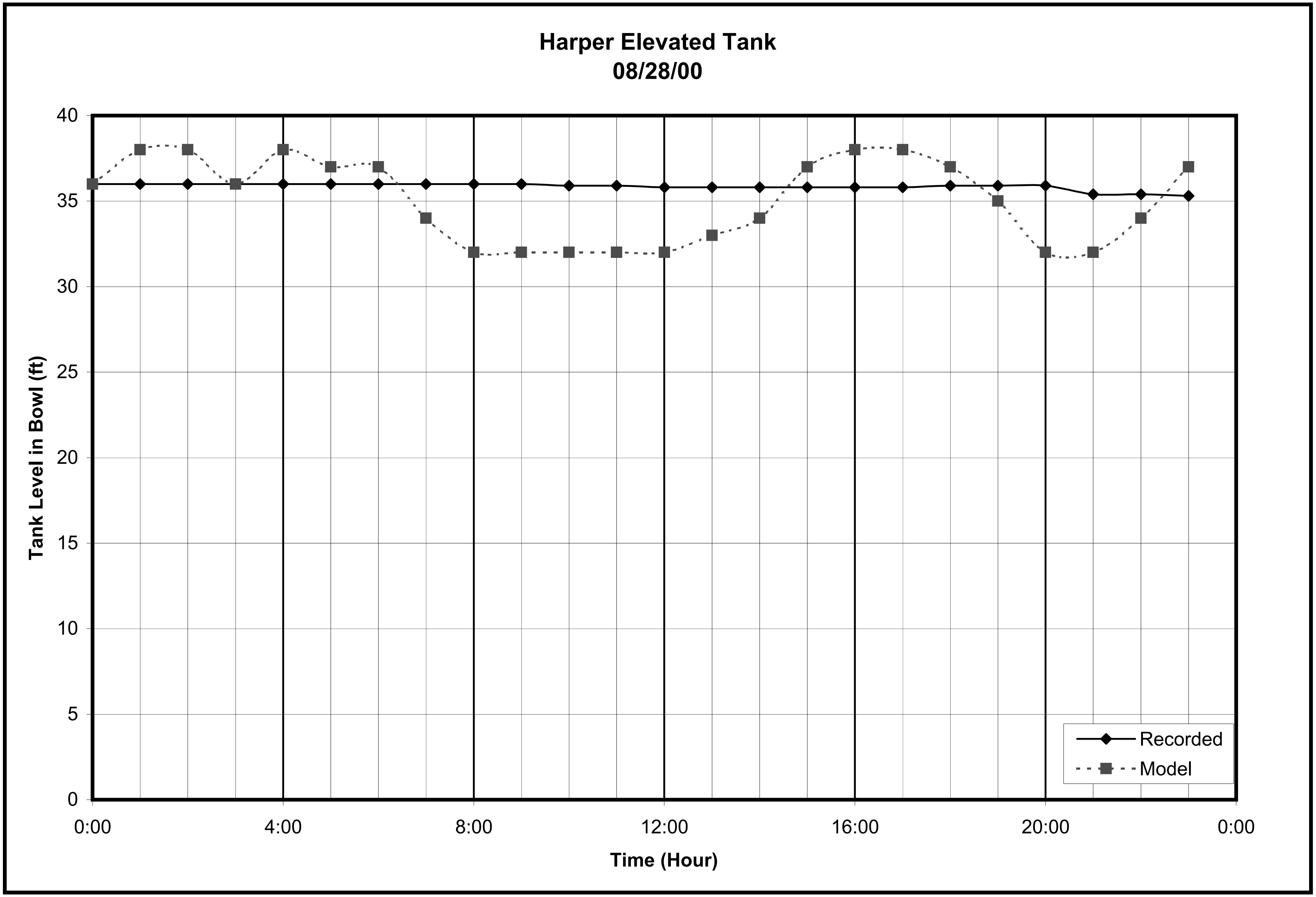


CENTRAL SERVICE SUMMARY
08/28/00
Flow (mgd)
No. of Pumps Running
Time (Hour)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Kaw Up CS Pump 1
Kaw Up CS Pump 2
Kaw Up CS Pump 3
Kaw Up CS Pump 4
Kaw Down CS Pump 1
Kaw Down CS Pump 2
Kaw Down CS Pump 3
Kaw Down CS Pump 4
Clinton CS Pump 1
Clinton CS Pump 2
Clinton CS Pump 3
Actual (15-min Intervals)
Actual (1-Hour Intervals)
Model


Oread Reservoirs
08/28/00
Tank Level (ft)
35
30
25
20
15
10
5
0
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time (Hour)
Recorded
Model



Kasold Reservoir
08/28/00
Tank Level (ft)
60
55
50
45
40
35
30
25
20
15
10
5
0
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time (Hour)
Recorded
Model



Harper Elevated Tank
08/28/00
Tank Level in Bowl (ft)
40
35
30
25
20
15
10
5
0
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time (Hour)
Recorded
Model