Report on

Integrated 2012 Water Utilities Plan

City of Lawrence, Kansas

Project No. 59410

2012

INDEX AND CERTIFICATION

Water Facilities Master Plan
City of Lawrence, Kansas

Project 59410

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Certification

I hereby certify, as a Professional Engineer in the state of Kansas, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the City of Lawrence, Kansas or others without specific verification or adaptation by the Engineer. This certification is made in accordance with the provisions of the laws and rules of the Kansas under Kansas Administrative Code.

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17377

3/28/2013

L. Jeffrey Klein, P.E.
Date: 3/28/2013
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Technical Memorandum No. 1
Initial Services

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 1

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REPORT ACRONYM AND ABBREVIATION SUMMARY

µg/L	Micrograms per liter (parts per billion)
0.25-log	43.8% removed (56.2% remain)
0.50-log	68.4% removed (31.6% remain)
1-log	90% removed (10% remain)
2-log	99% removed (1% remain)
3-log	99.9% removed (0.1% remain)
4-log	99.99% removed (0.01% remain)
AOC	Assimilable organic carbon
CaCO3	Calcium carbonate
ClO2	Chlorine dioxide
Co	Initial residual
CO	Commercial
CT	Disinfection credit (product of concentration and contact time)
CT	City (metered but provided at no charge)
D/DBPR	Disinfection/Disinfection Byproduct Rule
DBP	Disinfection byproducts
DOC	Dissolved organic carbon
EDC	Endocrine disrupting compound
GAC	Granular activated carbon
gpm	Gallons per minute
gpmd	Gallons per meter day
GWUDI	Groundwater under the direct influence
HAA	Haloacetic Acids (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid)
HOCL	Hypochlorous acid
HPC	Heterotrophic plate count (bacteria)
IDSE	Initial Distribution System Evaluation
IN	Industrial
KDHE	Kansas Department of Health and Environment
KU	University of Kansas
LRAA	Locational running annual average
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum contaminant level
MF	Microfiltration
MF	Multi-family
mg/L	Milligrams per liter (parts per million)
MGD	Million gallons per day
MIEX	Magnetic Ion Exchange Resin
mJ/cm2	Milijoules per square centimeter (UV dose)
MRDL	Maximum residual disinfectant level
NF	Nanofiltration
ng/L	Nanograms per liter (parts per trillion)
NH3-N	Ammonia as nitrogen
NOM	Natural Organic Matter
NTU	Nephelometric Turbidity Units
PAC	Powdered activated carbon
PPCP	Pharmaceuticals and personal care products
psi	Pounds per square inch
RO	Reverse Osmosis
RS	Residential
RW	Rural Water System
SWTR	Surface water treatment rule
TM	Technical memorandum
TOC	Total organic carbon
TTHM	Total Trihalomethanes (chloroform, bromoform, bromodichloromethane, and dibromochloromethane)
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
UV	Ultraviolet radiation
UVA	Ultraviolet light absorbance
UVT	Ultraviolet radiation transmittance
WTP	Water treatment plant

TECHNICAL MEMORANDUM NO. 1
Lawrence, Kansas Water Master Plan
December 20, 2012

A. Purpose

The purpose of these technical memos is to update the Lawrence Water Master Plan (WMP) based on the City-provided land use plan and population projections for years 2020 and 2030 and build-out. The WMP will focus on additional water sources and plant capacity, condition assessment and associated improvements at the Kaw Water Treatment Plant, and water distribution system improvements culminating in a new capital improvement plan.

B. Scope

The following defines the scope of work for the Lawrence WMP:

- Review and evaluate available data from City on the water system;
- Using customer data from the Wastewater Master Plan (WWMP), develop water demand projections for years 2020, 2030 and build-out of the City defined city limits/service area;
- Summarize existing water rights based on City provided data and compare to projected water demand;
- Summarize existing diversion capacity and compare to projected water need;
- Summarize diversion alternatives based on water need and the recent diversion alternative report;
- Complete a regulatory review of the Clinton and Kaw Water Treatment Plants (WTPs);
- Complete a condition assessment of the Kaw WTP;
- Determine net water need for water rights, diversion, and treatment based on years 2020, 2030 and build-out demand projections;
- Construct the water distribution model from City provided GIS files;
- Calibrate and verify the model to the field test data collected in summer 2010;
- Complete water distribution system modeling for the existing system, years 2020, 2030 and build-out systems;
- Complete extended period simulation (EPS) modeling to evaluate storage and water age for years 2020, 2030 and build-out;
- Determine trigger flows for major improvements;
- Develop preliminary concept design for Oread storage and booster pump station (BPS);
- Prepare opinion of probable cost;

- Develop a capital improvement plan (CIP);
- Prepare draft and final report sections for City review and comment;
- Distribute the complete final report;
- Deliver water system model to City;
- Provide training on model and GIS integration, customer projections, demand allocation, and improvement prioritization for City staff.

Technical Memorandum No. 2
Existing Water System

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

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Water Master Plan Technical Memorandum No. 2

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A. Introduction

Technical Memo (TM) No. 2 summarizes the components of the existing water system including water rights, diversion facilities, raw water pumping, water treatment plants (WTP), high service pumping, distribution system piping, storage, and booster pump stations (BPS). Locations of key facilities and the distribution system are shown in Figure TM2.1.

Lawrence obtains water from three distinct sources: the Kansas River, groundwater in the alluvium adjacent to Kansas River, and Clinton Lake. These sources serve Lawrence and multiple wholesale customers. Water rights only serving Lawrence allow a total average daily withdrawal of 35.7 MGD and total maximum day withdrawal of 69.9 MGD. In addition, Lawrence's wholesale customers have rights allowing a total average day withdrawal of 2.3 MGD and total maximum day withdrawal of 4.95 MGD. The average daily withdrawal of each water source and the City's wholesale customers under the current water rights is listed below:

- Kansas River Total – 20.5 MGD
- Kansas River Alluvium Total – 1.9 MGD
- Clinton Lake Total – 13.3 MGD
- Wholesale Customer Total – 2.3 MGD

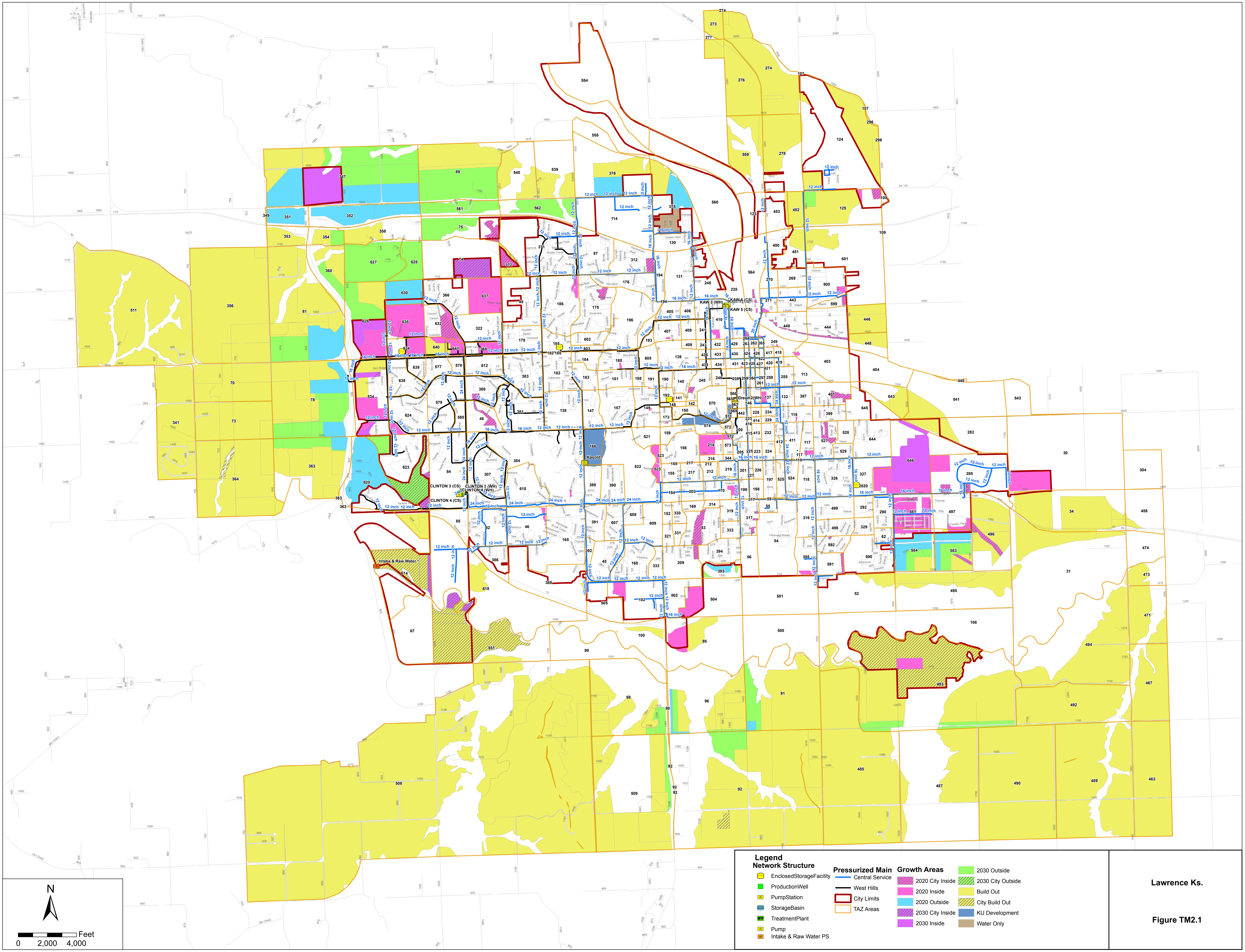
The Kansas River and alluvium supply the Kaw WTP and Clinton Lake supplies Clinton WTP. Currently, these plants have a combined treatment capacity of 36.0 MGD with 16.0 MGD at Kaw WTP and 20.0 MGD at Clinton WTP. If the Clinton WTP were able to sustain a treatment capacity of 25 MGD as intended and Kaw WTP were operating at its rated capacity of 17.5 MGD, then the combined rated capacity of both WTPs would be 42.5 MGD. Water supply for City's wholesale customers can be provided by either WTP.

B. Kansas River and Kaw WTP

The Kansas River is the primary supply for the Kaw WTP. Operation of the upstream reservoirs, use of existing water rights, and adequacy of flow are overseen by the Kansas River Water Assurance District for Lawrence and its other members.

B.1 Water Rights

Water rights for the Kansas River are summarized in Table TM2.1 and allow an average daily withdrawal of 20.5 MGD and a maximum day withdrawal of 44.9 MGD from the river. Additionally, the six existing



Lawrence Ks.

Figure TM2.1

wells at Burcham Park have a water right of 1.9 MGD, increasing the total average daily diversion rate to 22.4 MGD from the Kansas River and the alluvium.

Table TM2.1: Kansas River Water Right Summary

Source	Water Right	Permit Status	Allocation			Maximum Day Diversion Rate (MGD)
			(acre-ft/year)	(MGD)	(MGY)	
Kansas River	DG-2	Vested	1804.3	1.6	588.0	6.6[2]
	2019	Appropriated	5574.6	5.0	1816.7	10.0[2]
	44594	Approved	15,556.0[1]	13.9	5069.6	44.9[2]
Subtotal			**22,934.8**	**20.5**	**7474.3**	
Alluvium						
Well No. 3 & 4	DG-1	Vested	773.4	0.7	252.0	--
Well No.7	2019-A	Appropriated	652.1	0.6	212.5	--
Well No.5	9811	Appropriated	306.9	0.3	100.0	--
Well No.6 & 8	26315	Appropriated	350.4	0.3	114.2	--
Subtotal			**2082.8**	**1.9**	**678.8**	**44.9**
Kansas River Total			**25,017.6**	**22.4**	**8153.0**	**44.9**

Notes:

[1] Net additional quantity for a total water right of 25,017.6 acre-feet per year.

[2] Maximum at a point in time - water right 44594 increased maximum to 44.9 MGD.

B.2 Diversion Facilities

Diversion from the Kansas River includes a single surface water intake and groundwater from six wells located in Burcham Park on the west bank of the river south of the I-70 Kansas Turnpike. Surface water diversion is conveyed to the raw water pumping system and then pumped to the Kaw WTP. Groundwater diversion is collected from the river alluvium by the wells and pumped directly to the Kaw WTP.

B.2.a Surface Water Diversion

The Kansas River supplies surface water through a single crib type intake and a 30-inch siphon line to the raw water pumping system. Surface water diversion is dependent on the Kansas River elevation, which is set by the Bowersock Dam flashboards. When the flashboards are in the “up” position the normal river elevation is 813.5 feet (ft) and in the “down” position the normal river elevation is 807.5 ft.

B.2.b Groundwater Diversion

Currently, the only groundwater available to the City is collected by six wells that were constructed in the 1940s and 1950s. The wells are shallow at approximately 60 feet deep, but they could be re-drilled and the well field renovated to deliver the groundwater right on an annual basis. Groundwater can be effectively used to blend with surface water during the winter months to increase water temperature. This practice is used by other utilities in the area to reduce water main breaks in the distribution system.

Wells along the Kansas River offer a number of advantages for future water supply. Groundwater, or groundwater under the direct influence of surface water, will undergo bank filtration thereby minimizing solids issues reducing TOC, and provides consistent temperatures in the 55 degree range. High or low river conditions will have minimal impact on well performance.

Diversion alternatives include horizontal collector wells (HCW) and vertical wells. HCWs offer the advantage of minimizing the number of facilities and land requirements while maximizing supply capacity. HCWs require a mix of water rights. This mix is typically 90 percent surface water and 10 percent groundwater. Based on previous studies, alternate diversion sources are available to provide water to Kaw and Clinton WTPs or provide a redundant water supply to enhance reliability. These concepts are discussed in further detail in TM No. 5 – Diversion Alternatives.

B.3 Raw Water Pumping System

The raw water pumping system consists of the Low Service Pump Station (LSPS) No. 1, LSPS No. 2, and six wells near Burcham Park. LSPS No. 2 is the primary pumping facility that delivers raw water to the treatment process. LSPS No. 2 includes one traveling debris screen installed during the original booster pump station (BPS) construction and five vertical turbine pumps which were installed in 2008 with a firm capacity of 20.5 MGD. Each vertical turbine pump has a rated capacity of 5.1 MGD at 83 feet of head; Pump No. 3 and No. 4 are equipped with variable frequency drives (VFD).

LSPS No. 1 has a rated firm capacity of 4.0 MGD with two pumps rated for 2.0 MGD and another rated for 2.7 MGD at 80 feet of head. This station is not currently used and was last operated just for the raw water supply stress testing conducted in 2007.

When all six wells are operational, they can supply about 1.0 MGD to Kaw WTP. Each well is about 60 feet deep and includes a crows-nest housing a vertical turbine pump with oil lubrication. Two years ago the west bank of two wells was disabled by weather. The electrical power system restoration for Well

No.'s 3, 5, 6, and 7 was completed in 2011 and generally included relocating the power supply system underground. There are no current plans for similar improvements at Well No.'s 4 and 8.

B.4 Water Treatment

Kaw WTP is a lime softening plant treating Kansas River water. Prior to September 2009, the plant was an excess lime softening plant and the WTP can be run in softening mode or excess lime softening mode. The plant was built in 1917 and has been expanded over the years to a rated capacity of 17.5 MGD. The plant has two trains of equal capacity. Capacity is limited to 16 MGD by a hydraulic bottleneck at the effluent of the carbon contact chamber. An 8-inch curb was added in late 2010 to the influent, but has not been flow tested. Based on the results of the future flow testing, treatment capacity could be increased up to 17.5 MGD. As the water source is the Kansas River, influent water quality is highly variable. Hardness can be as high as 330 mg/L and turbidity can range from 5 to >1000 NTU. Typical potable water hardness is 140 mg/L and alkalinity is > 40 mg/L.

A general process overview of the water treatment system from river diversion to high service pumping is described below:

- Water is conveyed from the intake crib in the Kansas River to LSPS No. 2, which includes a single traveling debris screen upstream of five vertical turbine pumps;
- LSPS No. 2 pumps water to the pre-sedimentation basin – a small dose of Nalco 8201 Plus cationic polymer is added, <0.5 mg/L only when influent turbidity load is at an NTU greater than 400;
- Pre-sedimentation residuals are flushed back to the river;
- Water flows by gravity through the carbon contact basin; powder activated carbon (PAC) is added via side stream injection into a 36-inch diameter pipe at one of two injection points at 4 to 24 mg/L;
- A splitter structure diverts flow to train 1, train 2, or both;

Table TM2.2: Kaw WTP – Rapid Mix Chamber Chemical Addition

Chemical	Dose Range (mg/L)	Typical Dose (mg/L)
Lime	100 to 170	130
Alum	5 to 10	6
Polymer	3.0 to 4.0	3.5

- Water flows to the rapid mix chamber where the chemicals listed in Table TM2.2 are added. Solids can be recycled from the primary basin to the rapid mix;
- Each flocculation basin includes three sets of two countercurrent paddle wheel flocculators. Speed can be adjusted based on the weight of the floc and horizontal velocity to keep solids from settling out in the flocculation basin (fast for heavy floc and slow for light floc);
- Softening is accomplished in the primary basin and baffle walls are used to separate the softening and settling zones. The City monitors pH, alkalinity and turbidity leaving the primary basin;
- Chlorine and carbon dioxide are added in the secondary basin rapid mix. Chlorine dose varies based on biological demand but can be as high as 5 mg/L. Carbon dioxide is added with a target alkalinity goal of 50 mg/L. The carbon dioxide lacks detention time and is inefficient compared to newer pressure systems;
- Disinfection and Ct occur in the secondary basin. Ct goals are 0.8 to 1.0 in winter and 0.3 to 0.4 in summer;
- Ammonia is applied at the end of the secondary basin to create chloramines. The free ammonia goal is <0.1 mg/L;
- Upstream of the filters, chlorine, orthophosphate, fluoride and a filter aid polymer are added. This results in a chloramine dose of 3 to 4 mg/L with some free ammonia residual;
- Turbidity from the secondary basins is typically 1.3 NTU;
- Water flows to four dual media filters each with a capacity of 4 MGD at 4 gpm/sqft. The original WTP includes four filters each with a capacity of 1.5 MGD at 4 gpm/sqft that are used during high demand periods. Filtered water is typically 0.03 to 0.04 NTU in the summer and 0.1 NTU in the winter;
- Filtered water from the 1954 filters flows to the 0.574 MG clearwell and filtered water from the 1917 filters flows to the 0.17 MG clearwell;
- The plant includes ten high service pumps fed off a common pump suction pipeline between the filters. Seven pumps supply the Central Service (CS) pressure zone and three pumps supply the West Hills (WH) pressure zone;
- Lime solids are conveyed to lagoons at the wastewater treatment plant;
- Filters backwash is dechlorinated with sodium bisulfite and directly discharged to the river.

Filters are backwashed about every 96 hours of operation. However, headloss is minimal and the filter's effluent turbidities are still good. The City will evaluate extending the filter run time.

B.5 Current Issues

Current issues with respect to the Kansas River, river diversion, and raw water pumping include the following:

- Zebra mussels are present in the river and are cleaned out of the pre-sedimentation basin annually;
- Gravity intake is the single surface water supply and is about 37 years old – this presents redundancy and reliability issues;
- Sand bar located upstream of the intake allows large quantities of sand to enter the LSPS No. 2. Debris and algae from the river will also clog the intake, raw water piping near bends, and the debris screen inside the LSPS No. 2 wetwell;
- Age and condition of the six wells require planning for renovation of the well field or construction of a new well field. Similar electrical systems improvements completed in 2011 on Well No.'s 3, 5, 6 and 7 should be considered for Well No.'s 4 and 8 for added protection from overhead obstructions, such has falling branches and aging trees, and to limit the potential for vandalism;
- LSPS No. 1 is in need of modernization or full replacement;
- City staff wants to relocate the phosphate feed downstream of the filters;
- Taste and odor issues need to be evaluated in detail and a control system designed and installed;
- Microcystin species need to be evaluated in detail and a control system designed and installed.

C. Clinton Lake and Clinton WTP

Clinton Lake is operated by the U.S. Army Corps of Engineers (COE) and is the only water source for Clinton WTP. The lake is also used for flood control, industrial supply, recreation, fish and wildlife, and maintaining minimum stream flow conditions on the Wakarusa and Kansas rivers.

C.1 Water Rights

Water rights for the City at Clinton Lake were increased in to an average annual of 13.3 MGD and a maximum diversion rate of 25 MGD. Table TM2.3 includes a description of each water right and expiration date.

Lawrence's wholesale customers also have water rights in Clinton Lake as listed in Table TM2.4. This includes the City of Baldwin and RWD No.s 1, 2, 4, 5, and 6 for a total of 846.8 million gallons per year

(MGY) and an average of 2.3 MGD. There are no additional rights available at Clinton and future diversions must come from the Kansas River.

Table TM2.3: Clinton Lake Water Right Allocation

Clinton Lake	Water Right	Allocation			Maximum Day Diversion Rate (MGD)
		(acre-ft/year)	(MGD)	(MGY)	
Expires 12/29/2019	77-1	10,646.0	9.5	3469.5	--
Expires 1/1/2031	90-5	4258.0	3.8	1387.7	--
Clinton Lake Total		**14,904.0**	**13.3**	**4857.2**	**25.0**

The contract with the Kansas Water Office (KWO) requires Lawrence to pay for water used at Clinton Lake as follows:

- Minimum use is 50% of the contracted amount of each contract;
- The 90-5 contract is on a sliding scale with full implementation in 2014, and is a variable rate calculated by the Kansas Water Office each year;
- The 77-1 contract is a Fixed Fee of $0.10/1000 gallons;
- 100% of the 77-1 Contract must be used before any water is counted against the 90-5 contract;
- The City will need to renegotiate these contracts prior to the expiration dates shown in Table TM2.3.

Table TM2.4: Wholesale Customer Water Right Allocation

Wholesale Customer	Water Right	Water Right Allocation			
		(acre-ft/year)	(MGD)	(MGY)	Max. Day (MGD)
Baldwin City	77-3	991.5	0.9	323.1	2.0
RWD #1	77-4 & 90-1	189.6	0.2	61.8	0.18
RWD #2	90-3	247.9	0.2	80.8	0.47
RWD #4	77-5 & 95-2	533.7	0.5	173.9	1.0
RWD #5	77-2 & 95-3	533.7	0.5	173.9	1.0
RWD #6	79-2 & 90-2	102.1	0.1	33.3	0.30
Wholesale Total		**2598.4**	**2.3**	**846.8**	**4.95**

Notes:
City has an emergency contract with Jefferson County RWD #13.
RWD #13 has no water rights in Clinton Lake.

C.2 Diversion Facilities

Diversion from Clinton Lake includes an intake that was constructed as part of the reservoir by the COE in 1977. The intake structure is owned and operated by the COE. The multipurpose pool elevation in Clinton Lake is 875.5 feet and provides storage of 111,400 acre-feet.

C.3 Raw Water Pumping System

The raw water pump station is owned and operated by the City and includes four pumps with a total pumping capacity of approximately 30 MGD. The rated firm capacity of the pump station is approximately 20 MGD. Pump No. 1 and No. 2 are each rated for 4.6 MGD at 137 feet of head and Pump No. 3 and No. 4 are each rated for 10.2 MGD at 137 feet of head. Pump No. 2 and No. 3 are constant speed and Pump No. 1 and No. 4 are equipped with VFDs. Raw water is pump to the Clinton WTP through a 36-inch concrete transmission main. Currently there is no infrastructure in place for transmission redundancy between the pump station and the WTP.

C.4 Water Treatment

Clinton WTP is a lime softening plant and was expanded in 2009 from 10 MGD to 25 MGD with the addition of a 15 MGD treatment train. However, City staff is working with the Kansas Department of Health and Environment (KDHE) to recognize the 25 MGD filter capacity rating. The expanded plant can meet current demands most of the year without Kaw WTP and met recent high demands with some restrictions. The treatment process is described below:

- PAC is added in the raw water line prior to the flow splitter structure where water is diverted to the 10 MGD, 15 MGD or both trains;
- PAC can be added to the secondary;
- Water flows from the splitter structure to the pre-sedimentation basin;
- Lime and polymer are added at the head of the primary settling basin;
- Ferric can be added at the pre-sedimentation or primary settling basins;
- Polymer and chlorine are added at the head of the secondary basin. This is where disinfection and Ct occur;
- Chlorine, ammonia, and fluoride are added at the effluent of the secondary basin;
- Eight dual media filters are available to finalize water treatment;
- Water is then pumped from a clearwell below the filters to two 1.5 MG above-grade steel storage tanks;
- Orthophosphate is added at these pumps to stabilize the water;

- Treated water is conveyed to the distribution system by two high service pump stations;
- Lime solids and backwash water are conveyed to the lagoons. Backwash water is de-chlorinated in the pipe to the lagoons.

The City will finalize filter re-rating at a later date with KDHE to increase the filter capacity from 20 to 25 MGD. This will increase the filtration rate to 5.65 gpm/sf based on running seven of the eight filters.

C.5 Current Issues

Current issues with respect to Clinton Lake diversion, raw water pumping, and water treatment include the following:

- Reliability issue associated with a single 36" concrete water main;
- Need for 25 MGD of firm pumping capacity at the intake. Operational problems associated with overheating MCCs and other systems have stalled pumping capability in the past. Therefore, any pump replacement that is done in order to increase the firm capacity must consider ancillary electrical and mechanical upgrades for proper protection and uninterrupted service capability – further review of these improvements is not included in this Water Master Plan;
- Increase in the water right maximum diversion rate water to account for water losses associated with the treatment process at the Clinton WTP;
- Taste and odor issues need to be evaluated in detail and a control system designed and installed;
- Microcystin species need to be evaluated in detail and a control system designed and installed;
- Zebra mussels are inevitable and planning needs to consider mature zebra mussels and veligers;
- Need for back-up power generator to operate the WTP at 15 MGD.

There are no additional rights available at Clinton and future diversions must come from the Kansas River. Additional water supply and expansion concepts at Clinton WTP are discussed in TM No. 5 – Diversion Alternatives.

D. Existing Water Distribution System

The distribution system covers about 30 square miles, includes two pressure zones, approximately 463 miles of pipe ranging from 2-inch to 24-inch diameter, 19 high service pumps, six storage sites, and two BPSs. A schematic of the existing system is shown in Figure TM2.2 and illustrates the CS pressure zone the WH pressure zone relationship with the Kaw and Clinton WTPs, the Oread reservoir and BPS, and the

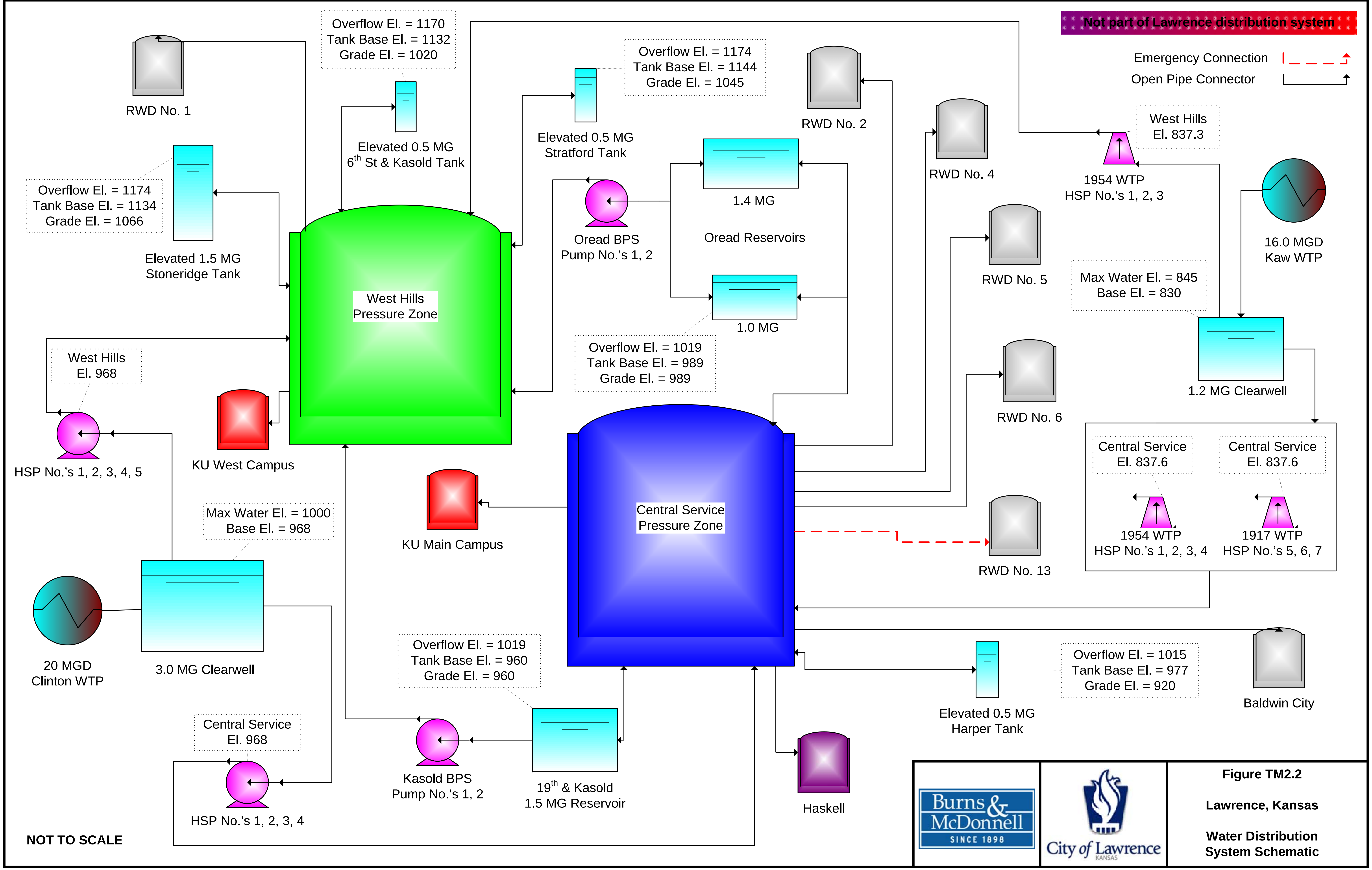


Figure TM2.2

Lawrence, Kansas

Water Distribution System Schematic

19th and Kasold reservoir and BPS. The Oread and Kasold reservoirs supply the CS pressure zone by gravity and can pump into WH pressure zone. The other tanks are elevated and dedicated to a specific pressure zone. The CS pressure zone ranges in elevation from 810 feet to 950 feet, while the WH pressure zone ranges from 870 feet to 1060 feet.

D.1 High Service Pumps

The Kaw and Clinton WTPs can pump to both the CS and WH pressure zones as listed in Table TM2.5. Review of the table indicates Kaw and Clinton WTPs can deliver a firm capacity of 24.5 MGD into the WH pressure zone and a firm capacity of 30.6 MGD into the CS pressure zone. The firm capacity definition for each pressure zone is calculated with the largest pump out of service. For the two pressure zones this is calculated as follows:

- WH Pressure Zone – one 5.0 MGD pump out of service at Clinton WTP
- CS Pressure Zone – one 5.0 MGD pump out of service at Clinton WTP

Kaw WTP has a total pumping capacity of 24.5 MGD with 20.0 MGD dedicated to the CS pressure zone and 4.5 MGD dedicated to the WH pressure zone. Clinton WTP has a total pumping capacity of 40.7 MGD with 15.7 MGD dedicated to the CS pressure zone and 25.0 MGD dedicated to the WH pressure zone.

D.2 Storage and Booster Pump Stations

The Lawrence water distribution system includes six tank sites with a total capacity of 6.9 MG. Tank data is summarized in Table TM2.6 and lists the tank location, capacity and elevation data. The Oread Tank includes two above-grade steel tanks. The distribution system also includes two BPSs and is summarized in Table TM2.7. The firm capacity of Oread BPS is 1.8 MGD and the firm capacity of Kasold BPS is 1.9 MG. The Kasold BPS includes a VFD to run either pump, but can only run one at a time.

D.3 Distribution System Piping

The distribution system includes approximately 463 miles of 2-inch through 24-inch pipe that is maintained by the City. Private water lines such as KU, Haskell, and others comprise an additional 20 miles. The piping inventory is sorted by diameter and material in Table TM2.8 and consists of cast iron, concrete, copper, ductile iron, galvanized, PVC, steel, and transite Private water lines are not included in Table TM2.8. About 85 percent of the distribution system consists of 6-, 8-, and 12-inch diameter pipe.

Table TM2.5

High Service Pump Summary
Lawrence, Kansas

Pressure Zone	Pump No.	Year Installed	WTP / Location	Drive	Type	Manufacturer	Flow		Head (ft)	Motor	
							(gpm)	(MGD)		(Hp)	(rpm)
West Hills	1	2008	Kaw - 2nd Floor	Constant	Vertical	Weir, Floway	1050	1.5	350	125	1785
	2	2004	Kaw - 2nd Floor	Constant	Vertical	Layne Christensen	1050	1.5	350	125	1785
	3	2008	Kaw - 2nd Floor	Constant	Vertical	Weir, Floway	1050	1.5	350	125	1785
	1	2001[1]	Clinton - HSPS 1	Constant	Horizontal	Patterson	3500	5.0	245	300	1800
	2	2001[1]	Clinton - HSPS 1	Constant	Horizontal	Patterson	3500	5.0	245	300	1800
	3	1997	Clinton - HSPS 1	VFD	Horizontal	ITT Goulds	3500	5.0	245	300	1785
	4	2008	Clinton - HSPS 2	VFD	Horizontal	ITT Goulds	3500	5.0	245	300	1785
	5	2008	Clinton - HSPS 2	VFD	Horizontal	ITT Goulds	3500	5.0	245	300	1785
						West Hills Firm Capacity =		**24.5**			
Central Service	1	2008	Kaw - 2nd Floor	Constant	Vertical	Weir, Floway	2100	3.0	220	150	1780
	2	2008	Kaw - 2nd Floor	Constant	Vertical	Weir, Floway	2100	3.0	220	150	1780
	3	2008	Kaw - 2nd Floor	Constant	Vertical	Weir, Floway	2100	3.0	220	150	1780
	4	2008	Kaw - 2nd Floor	Constant	Vertical	Weir, Floway	2100	3.0	220	150	1780
	5	2010[2]	Kaw - East Shop	Constant	Horizontal	Peerless	2000	2.9	220	125	1780
	6	2002[3]	Kaw - East Shop	Constant	Horizontal	Fairbanks Morse	900	1.3	210	60	1470
	7	2011[4]	Kaw - East Shop	Constant	Vertical	Layne Western	2650	3.8	220	200	1185
	1	2008	Clinton - HSPS 1	Constant	Horizontal	Weinman	1900	2.8	80	50	1750
	2	1978[5]	Clinton - HSPS 1	Constant	Horizontal	Weinman	1900	2.8	80	50	1750
	3	1997	Clinton - HSPS 1	VFD	Horizontal	ITT Goulds	3500	5.0	80	100	1180
	4	2008	Clinton - HSPS 2	VFD	Horizontal	ITT Goulds	3500	5.0	80	100	1785
						Central Service Firm Capacity (with original Kaw WTP pumps) =		**30.6**			

Notes:

[1] New motors installed in 2008.

[2] Motor was new in 2008.

[3] Motor was new in 1954; pump was either new or rehabbed in 2002.

[4] Motor was new in 2011; pump was either new or rehabbed in 2011.

[5] New motor installed in 1978; pump and motor serviced in 2008.

Table TM2.6

Distribution System Storage Summary
Lawrence, Kansas

Pressure Zone	Name	Year Installed	Type	Volume (MG)	Overflow Elevation (ft)	Bottom Elevation (ft)	Base Elevation (ft)	Head Range (ft)
West Hills	Stoneridge	2008	Elevated	1.5	1174	1134	1066	40
	Sixth Street	1967	Elevated	0.5	1170	1132	1060	38
	Stratford	1954	Elevated	0.5	1174	1144	1045	30
			West Hills Capacity =	**2.5**				
Central Service	Harper	1967	Elevated	0.5	1015	977	920	38
	Kasold	Note 2	Standpipe	1.5	1019	960	960	59
	Oread[1]	1931, 1954	Ground	2.4	1019	989	989	30
			Central Service Capacity =	**4.4**				

Notes:

1. Oread storage consists of two ground storage tanks - one 1.4 MG & one 1.0 MG.
2. Tank Installation year is unknown. Pump curves for the Kasold BPS include a date of March 2001.

Table TM2.7

Booster Pump Summary
Lawrence, Kansas

Name	Pump No.	Year Installed	Pressure Zone	Drive	Manufacturer	Flow		Head (ft)	Motor	
						(gpm)	(MGD)		(Hp)	(rpm)
Kasold	1	2001	West Hills	Constant	Fairbanks Morse	1310	1.9	235	125	1785
	2	2001	West Hills	Constant	Fairbanks Morse	1310	1.9	235	125	1785
Oread	1	1998	West Hills	Constant	Fairbanks Morse	1240	1.8	245	125	1750
	2	1998	West Hills	Constant	Fairbanks Morse	1240	1.8	245	125	1750
						West Hills Firm Capacity =	**3.7**			

Table TM2.8

Distribution System Piping Summary
Lawrence, Kansas

Diameter (in)	Total Length by Diameter (ft)	Total Length by Diameter (mi)	Material Breakdown (%)								
			Cast Iron	Concrete	Copper	Ductile Iron	Galvanized	PVC	Steel	Transite	Unknown
1	5,028	1	-	-	69.7	-	12.2	18.2	-	-	-
2	83,275	16	-	-	57.8	-	2.6	35.1	-	0.7	4.0
3	4,354	1	22.9	-	-	0.4	-	76.7	-	-	-
4	47,194	9	48.7	-	-	0.5	-	38.5	-	12.3	-
6	355,492	67	50.5	-	-	11.7	-	35.2	-	2.6	-
8	1,085,411	206	19.4	-	0.1	14.1	-	66.2	0.1	0.2	-
10	23,009	4	98.0	-	-	0.2	-	1.9	-	-	-
12	380,260	72	24.3	-	-	51.2	-	24.2	-	0.3	-
14	10,018	2	99.6	-	-	0.1	0.2	-	0.1	-	-
15	909	-	100.0	-	-	-	-	-	-	-	-
16	84,374	16	9.1	38.7	-	48.5	-	-	0.1	3.6	-
18	832	-	92.8	-	-	-	-	-	7.2	-	-
20	5,577	1	-	54.8	-	17.5	-	-	27.7	-	-
24	46,245	9	1.3	44.3	-	54.4	-	-	-	-	-
All Sizes	**Total Length (ft)**	**Total Length (mi)**	**Total Length by Material (mi)**								
	2,131,979	**403.5**	104.1	10.6	9.9	86.5	0.5	187.0	0.5	4.2	0.5

Notes:

1. The values presented in this table only reflect potable water lines maintained by the City of Lawrence. No private lines within the City's water service area are included (i.e. KU, Haskel, etc.). Individual service connections are not included either.

Additionally, about 94 percent of the distribution system consists of cast iron, ductile iron, and PVC pipe, with PVC equal to about half of all pipe material. A timeline of distribution system growth by pipe material is included in Figures TM2.3A and TM2.3B.

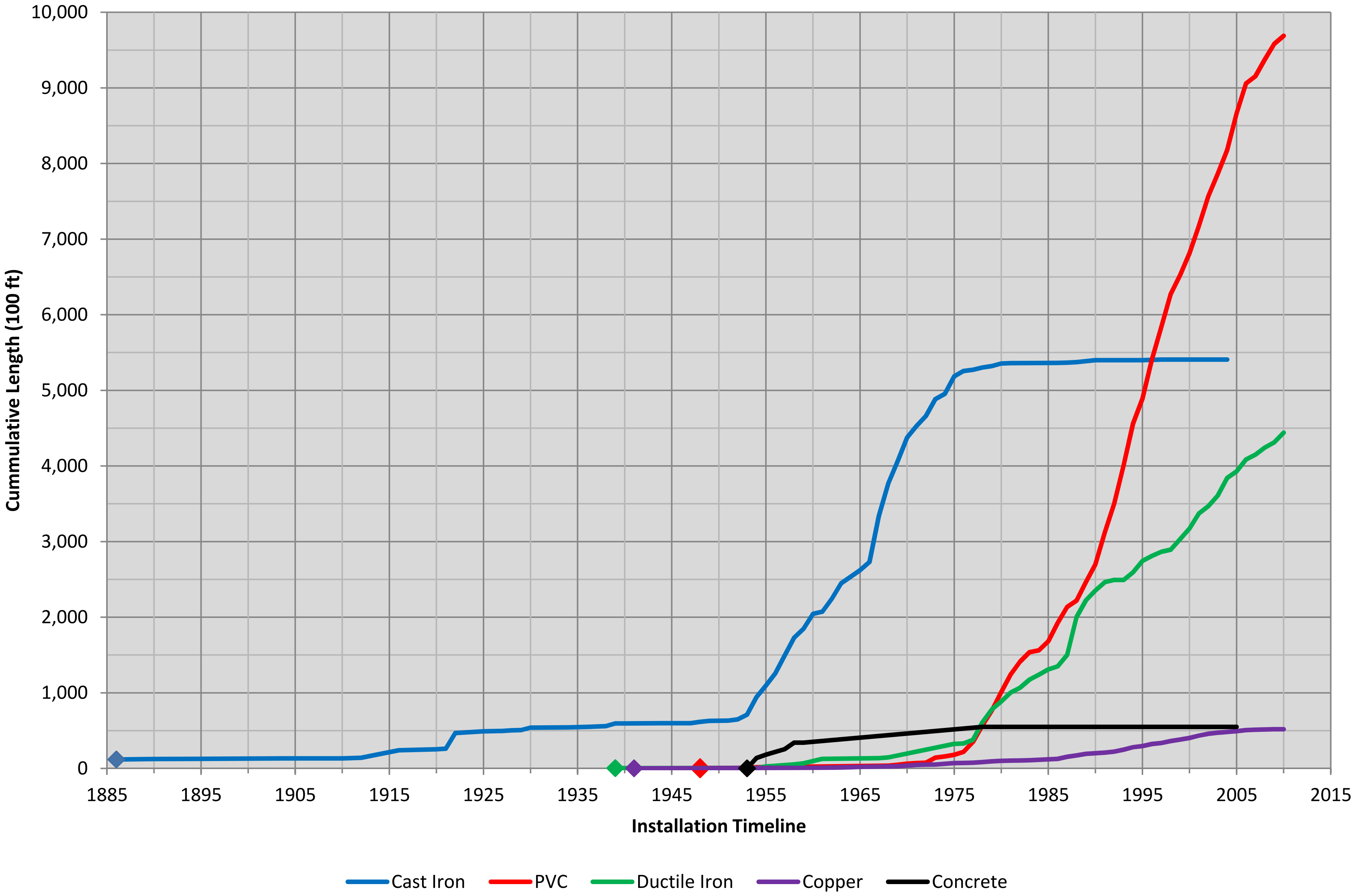
A number of programs have been implemented by the City to maintain and update distribution system piping as follows:

- Since 2008 the City has replaced about 34,000 feet of 2-inch and 4-inch diameter pipelines with 8-inch C900 pipe. This represents about one third of the old smaller diameter pipe;
- In addition to the pipeline, fire hydrants are installed every 400 feet and isolation valves are installed such that water service interruption is limited to 25 homes or fewer;
- A significant portion of the pipe replacement budget is used to relocate low-priority pipelines associated with road projects. Although this is timely and important, it extends the cost and schedule of the priority-based pipeline replacement program;
- Critical valves are exercised annually;
- Small valves are exercised every four years;
- City flushes key dead-ends due to lack of use – this is required to comply with disinfection byproduct regulations and maintain an adequate water age and chloramine residual. This is accomplished with six auto-flushers and other manual locations – additional auto-flushers and looping dead-end pipelines will reduce manpower demands from flushing;
- City uses thickness class vs. pressure class pipe;
- City is considering a cathodic protection system on existing mains without polyethylene wrap;
- City is wrapping all ductile iron pipe (DIP) with polyethylene starting in 2008;
- City had 104 breaks/leaks in 2010 and 102 in 2009;
- Meters are less than 15 years old;
- In 2009, the City replaced 2400 meters;
- Large meters, 6-inches and greater, are tested annually;
- Rural water wholesale meters are tested annually;
- WTP meters are tested annually.

City of Lawrence
KANSAS

Figure TM2.3-A
Pipe Material Timeline
Lawrence, Kansas

Burns & McDonnell
SINCE 1898



City of Lawrence
KANSAS

Burns & McDonnell
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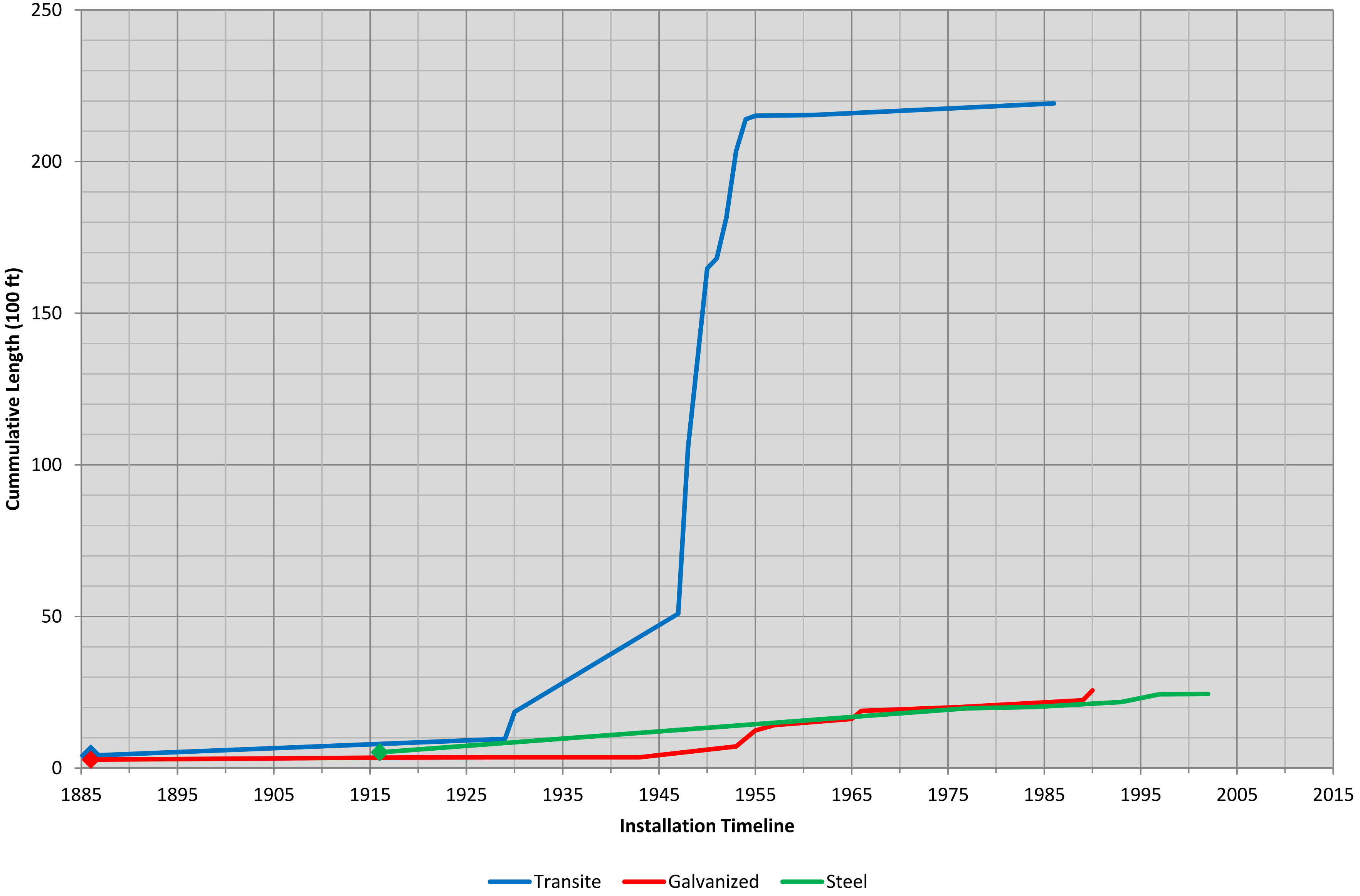
Figure TM2.3-B
Pipe Material Timeline
Lawrence, Kansas



Review of water use data shows the City’s non-revenue water, water lost in the distribution system, is typically less than 5 percent. This is an outstanding value as the accepted norm ranges from 10 to 15 percent. This low value equates to reduced operating costs for water treatment and distribution of water and minimizes waste. An adequately funded pipeline replacement program is essential in maintaining a low non-revenue percentage and minimizing supply, treatment, and distribution system capital and operating costs.

D.4 Current Issues

Current issues with respect to the water distribution system include the following:

- Booster station improvement at 19th and Kasold;
- Replacement of Oread tanks and pump station;
- Tank maintenance coatings;
- Large valve replacement program:
- Concrete main assessment;
- Ductile iron pipe corrosion issue due to “hot” soils.

Technical Memorandum No. 3
Demand Projections

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 3

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TECHNICAL MEMORANDUM NO. 3
Lawrence, Kansas Water Master Plan
December 20, 2012

A. General

Technical Memo (TM) No. 3 discusses conversion of City provided population and land use projections to projected number of customers and water demand for years 2020, 2030 and build-out. The existing and projected service areas for water are illustrated in Figure TM3.1 and are the same as the wastewater service areas and City limits. Review of the figure also shows existing parcels and roads as well as existing land use for the City's 27 different land use classes.

A process was developed to condense City population forecasts for years 2020, 2030, build-out and for the 27 land use classes to the number of customers and demand for the City's meter classifications with a goal of projecting customers and associated water demand as follows:

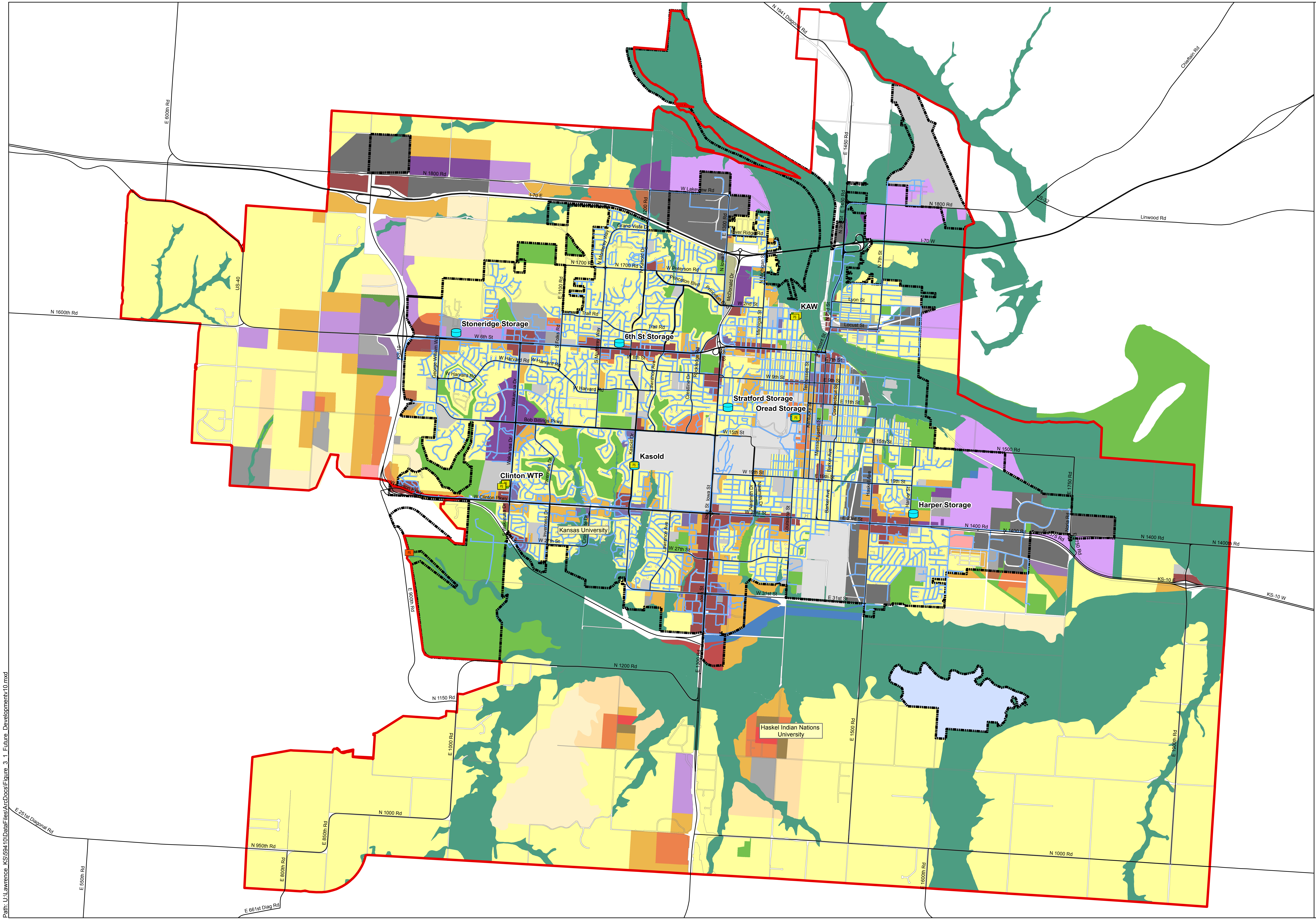
- RS = residential
- MF = multi-family
- CO = commercial
- IN = industrial
- CT = City (metered but provided at no charge)

These meter classes are used by the City to account for the water demands that are distributed across the existing system and used for future land use areas. Two other classes exist and include the University of Kansas (KU), which has 37 separate meters, and rural water (RW) districts, which have master meters. City staff used information provided by the wholesale customers to determine future demands and their timing. This information is incorporated into the water demands and the hydraulic model. City staff also met with KU to discuss their future water needs at the main campus and the west campus. This data is also incorporated into the water demands and hydraulic model. As these are either a point demand via wholesale meters or allocated within a set area like KU, they will not directly impact the global allocation of demand for the model and are kept separate from the other five meter classes.

B. Historical Population, Customer, and Water Use Data

Available historical population, customers, raw water pumpage, WTP pumpage, and sales data are summarized in Table TM3.1 and shown in Figure TM3.2 for years 1990 through 2010. Water use includes all eight customer classes. This data and associated trends are used to develop customer and demand projections for years 2020, 2030 and build-out. Average day and maximum day pumpage and sales are highly influenced by the timing and amount of rainfall as seen by the variations in water use.

City of Lawrence, Kansas
Water Master Plan



Legend

- 🟦 Storage Facility
- WTP Treatment Plant
- PS PumpStation
- PS Intake & Raw Water PS
- — Pipes
- ▭ Project Limit
- ▭ City Limits
- ▭ Parcel Boundary
- ▨ Existing Land Use

Future Land Use

- 🟥 Commercial
- 🟥 Auto-Related Commercial
- 🟥 Mixed Use Commercial Center
- 🟫 Neighborhood Commercial
- 🟥 Community Commercial
- ▨ Community Facility
- ▨ Public/Institutional
- 🟩 Green Space Buffer
- 🟩 Open Space/Floodplain
- 🟩 Parks/Open Space
- 🟫 Live/Work Units
- 🟧 High Density Residential
- 🟧 Medium Density Residential
- 🟨 Low-Density Residential
- 🟨 TND Low Density Residential
- 🟨 Very Low Density Residential
- 🟪 Office
- 🟪 Office Research
- 🟪 Office/Industrial/Warehouse
- 🟪 Office/Multiple Family Mix
- 🟪 Office/Research/Industrial
- ⬛ Industrial
- ▨ Warehouse/Distribution
- ▨ Quarry
- 🟦 Proposed Treatment Plant Site
- 🟦 Transport/Communication/Utility

N

1,000 0 5,000 Feet

Scale in Feet
1 inch = 2000 feet

Figure 3.1

Future Development
and
Land Use

Table TM3.1

Historical Population, Customer, and Water Use Summary
Lawrence, Kansas

Year	Population	No. of Customers	Potable AD Pumped (MGD)	Maximum Day (MGD)	Maximum Hour (MGD)	MD/AD Ratio	MH/AD Ratio	Raw Pumped (MGD)	Average Day Sales (MGD)	Water Loss(%)	Use^1 (gpmd)	Use^1 (gpcd)
1990			8.9	17.7	25.4	2.00	2.87					
1991			10.4	20.0	23.4	1.93	2.26					
1992			9.2	15.5	23.0	1.68	2.49					
1993			9.4	19.9	23.9	2.12	2.55					
1994			10.1	17.8	22.8	1.76	2.26					
1995	67,878		9.8	18.8	25.8	1.91	2.62					145
1996	69,322		10.2	18.2	23.3	1.79	2.29					147
1997	70,766		10.8	18.6	25.8	1.73	2.39					152
1998	72,210		11.6	22.2	28.3	1.92	2.44					161
1999	73,654		11.6	22.3	30.3	1.92	2.61					157
2000	80,508	27,671	12.8	25.6	38.6	2.00	3.02	13.8	11.9	6.7%	463	159
2001	81,780	28,319	12.2	21.9	30.9	1.79	2.53	13.3	11.5	5.7%	432	149
2002	83,310	29,008	12.7	24.5	26.1	1.93	2.05	14.0	11.8	7.4%	438	153
2003	84,844	29,583	12.5	25.4	39.3	2.03	3.14	13.8	11.7	6.5%	423	148
2004	86,448	30,223	10.9	18.6	30.0	1.71	2.76	11.9	9.9	8.7%	360	126
2005	88,664	30,763	11.6	24.5	34.4	2.11	2.96	12.6	11.2	3.7%	378	131
2006	89,110	31,232	12.2	24.0	36.9	1.97	3.03	13.0	11.8	3.0%	390	137
2007	90,311	31,471	11.4	23.9	37.6	2.10	3.31	12.2	11.0	3.7%	361	126
2008	90,866	31,742	10.4	20.5	30.3	1.98	2.92	11.2	9.9	5.0%	327	114
2009	91,464	31,922	9.5	18.6	25.2	1.96	2.66	10.3	9.1	4.3%	297	104
2010	92,727	31,937	9.9	19.5	35.9	1.97	3.63	11.1	9.7	1.7%	310	107
Average 1995 to 1999			10.2	19.1	25.2	1.88	2.48					152
Average 2000 to 2010			11.5	22.5	33.2	1.96	2.91	12.5	10.9	5.1%	380	132
Average 1990 to 2010			10.9	20.9	29.4	1.92	2.70					138
Maximum 1990 to 2010			12.8	25.6	39.3	2.12	3.63	14.0	11.9	8.7%	463	161

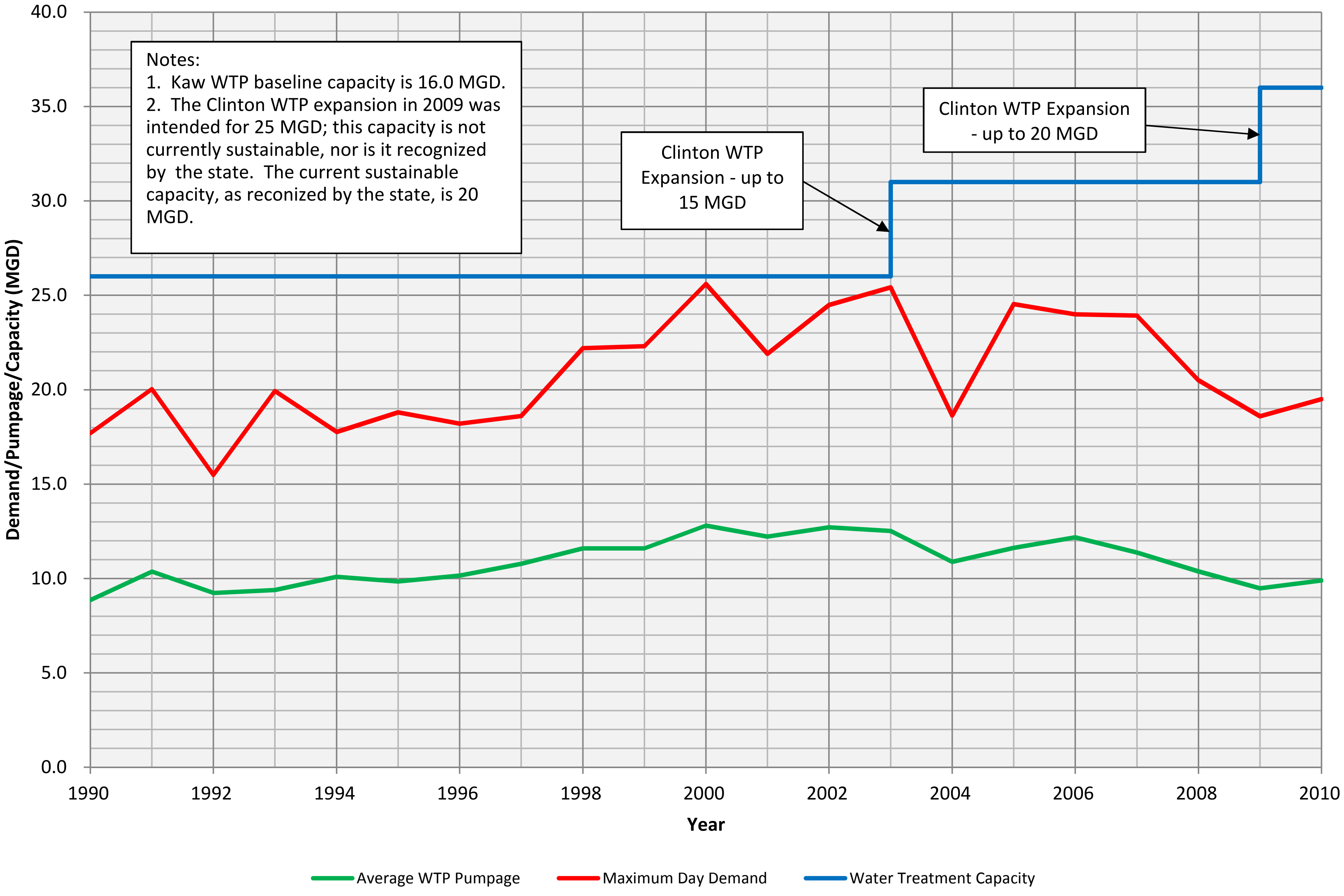
Notes:

1. Use is based on Potable Pumped quantities.

Figure TM3.2

Historical Water Demand and WTP Pumpage

Lawrence, Kansas



Notes:
1. Kaw WTP baseline capacity is 16.0 MGD.
2. The Clinton WTP expansion in 2009 was intended for 25 MGD; this capacity is not currently sustainable, nor is it recognized by the state. The current sustainable capacity, as reconized by the state, is 20 MGD.

Clinton WTP Expansion - up to 15 MGD

Clinton WTP Expansion - up to 20 MGD

Wet and cooler summers equate to lower than normal water sales and dryer, hot summers equate to higher than normal water use. Weather patterns have been relatively normal over the last 15 plus years with no extended dry periods or drought; in fact, years 2008 through 2010 were very wet. Review of the data shows the following:

- Water use for the total system averaged 380 gallon per meter day (gpmd) and 132 gpcd for the last 11 years with respective maximums of 463 gpmd and 161 gpcd:
    - these values include KU water use, meters, and student population,
    - these values include wholesale customer water use, but not the population and exclude meters that had no use;
- Maximum day to average day ratios averaged 1.92 over the last 21 years with a maximum of 2.12;
    - Average and maximum day demands over the last 5 years have been trending downward at nearly the same rate and are reflected as such in the ratios which range between 1.96 and 2.10. The average for this ratio between 2000 and 2010 is 1.96.
- Maximum hour to average day ratios averaged 2.70 over the last 21 years with a maximum of 3.63;
    - Ratios have varied over the last five years, with a low of 2.66 occurring in 2009 and a high of 3.63 occurring in 2010; the average for this ratio between 2000 and 2010 is 2.91.
- Non-revenue water percentage has been less than or equal to 5 percent since 2005.

Lawrence also tracks number of customers and water use by class as summarized in Table TM3.2 and shown in Figure TM3.3. Data from year 2000 forward is used as it reflects the impacts of low water use plumbing fixtures and continued integration of water conservation measures, such as public education. In 2005 the City switched from a declining rate structure to a flat rate structure which also supports water conservation and the reduced water use since 2005.

The gpmd data during this period reflects the normal to wet rainfall years that occurred and does not include any years of extended dry weather periods. Residential use ranges from 149 to 209 with an average of 183 gpmd. Multi-family use ranges from 1,138 to 1,410 with an average of 1,262 gpmd. Industrial use ranges from 5,385 to 13,514 with an average of 8,283 gpmd. Commercial use ranges from 965 to 1,486 with an average of 1,226 gpmd. City use ranges from 1,100 to 2,243 with an average of 1,651 gpmd. Rural water use ranges from 111,111 to 160,000 with an average of 132,456 gpmd. The total use for these five customer classes ranges from 285 to 434 with an average of 360 gpmd.

Table TM3.2

Historical Water Consumption by Class
Lawrence, Kansas

Year	Commercial (CO)			City (CT)			Industrial (IN)[2]			Multi-Family (MF)			Residential (RS)			KU			Rural Water (RW)			Total		
	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD	Meters	Avg Day[1]	GPMD
2000	1,686	2.5	1,486	145	0.32	2,186	74	1.00	13,514	687	0.93	1,354	25,037	5.2	209	31	0.74	23,882	11	1.3	118,182	27,671	12.0	434
2001	1,706	2.1	1,231	144	0.24	1,667	78	0.99	12,692	688	0.97	1,410	25,660	4.8	187	32	0.67	20,983	11	1.6	145,455	28,319	11.4	402
2002	1,732	2.4	1,401	151	0.29	1,918	74	0.94	12,703	700	0.91	1,300	26,306	5.4	205	34	0.70	20,508	11	1.2	105,562	29,008	11.8	408
2003	1,759	2.4	1,354	163	0.29	1,809	73	0.56	7,671	713	0.91	1,276	26,831	5.4	203	34	0.67	19,780	10	1.3	130,000	29,583	11.6	391
2004	1,779	2.0	1,132	145	0.21	1,448	74	0.46	6,209	714	0.88	1,227	27,468	4.6	168	32	0.58	18,155	11	1.3	118,182	30,223	10.1	333
2005	1,782	2.2	1,240	158	0.28	1,751	76	0.53	6,974	715	0.88	1,231	27,988	5.2	186	34	0.66	19,412	10	1.2	122,995	30,763	11.0	357
2006	1,793	2.5	1,399	166	0.37	2,243	74	0.53	7,162	712	0.90	1,261	28,443	5.6	197	34	0.69	20,294	10	1.3	133,987	31,232	11.9	382
2007	1,788	2.1	1,173	192	0.33	1,699	74	0.48	6,486	710	0.90	1,274	28,665	5.2	181	32	0.66	20,625	10	1.3	125,008	31,471	10.9	346
2008	1,781	1.9	1,049	183	0.22	1,198	75	0.51	6,800	707	0.86	1,220	28,952	4.7	162	34	0.56	16,471	10	1.2	116,389	31,742	9.9	311
2009	1,787	1.7	965	179	0.20	1,100	78	0.43	5,513	747	0.85	1,138	29,086	4.3	149	35	0.55	15,714	10	1.0	100,429	31,922	9.1	285
2010	1,798	1.9	1,057	185	0.21	1,135	78	0.42	5,385	741	0.88	1,188	29,138	4.8	165	35	0.58	16,571	10	1.0	100,000	31,985	9.8	306
Average			1,226			1,651			8,283			1,262			183			19,309			119,653			360
Minimum			965			1,100			5,385			1,138			149			15,714			100,000			285
Maximum			1,486			2,243			13,514			1,410			209			23,882			145,455			434

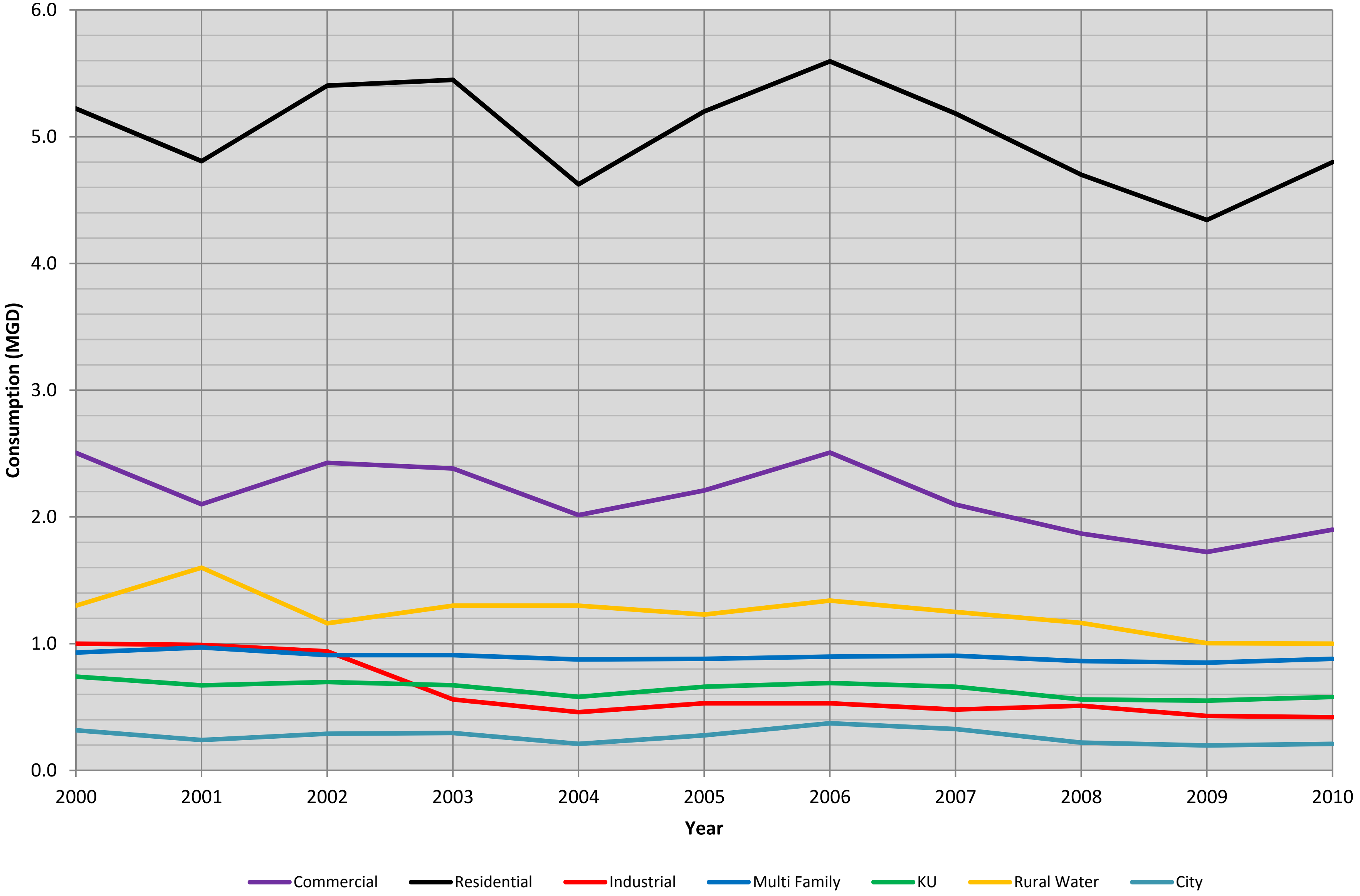
Notes:

1. Average Day consumption is annual average day in MGD.
2. Farmland cut water use in 2004 and FMC was sold to Astaris about year 2003 and reduced water use - reduced water use about 140 MGY.
3. Flat rate went into effect starting in 2005.

City of Lawrence
KANSAS

Figure TM3.3
Consumption by Customer Class
Lawrence, Kansas

Burns & McDonnell
SINCE 1898



Dry weather water use for each customer class is listed in Table TM3.3 and is used in the customer projections in Section C and the demand projections in Section E. Dry year water use values are based on the historical values from year 2000 through 2010 and the downward trend of water use due to conservation-based changes in the plumbing codes, water conserving appliances, and wet weather. For instance, high efficiency clothes washers are the new norm and dramatically decrease water use by 35 to 50 percent. This reduction in use has an estimated savings of 5,000 gallons per household per year. Dry weather gpmd values assure future water treatment and supply capacities are met and are fiscally reasonable. This means the values are conservative enough to meet extended dry periods but not so high that they cover a severe drought that would otherwise dramatically increase the City's investment in the water system for facilities that are rarely or never used. Moderately conservative water use values combined with additional water conservation measures are generally adequate to meet demands during extended dry periods or those periods when the City's drought contingency plan can be implemented.

Table TM3.3: 2010 Water Use Adjusted for Dry Year by Class

Meter Class	2010 Water Use[1] (gpmd)	Dry Year Water Use Adder (gpmd)	Future Dry Year Water Use (gpmd)	Non-revenue Amount[2] (gpmd)	Total Dry Year Water Use[3] (gpmd)
CO	1,057	243	1,300	65	**1,365**
CT	1,135	665	1,800	90	**1,890**
IN	5,385	615	6,000	300	**6,300**
MF	1,188	12	1,200	60	**1,260**
RS	165	20	185	9	**194**

Notes:
1. Water use by meter class in 2010 as listed Table TM3.2.
2. Non-revenue amount is 5 percent of the future dry year water use.
3. Total dry year water use is the summation of the future dry year water use and non-revenue amount.

C. Population Projection

Population data was provided by City staff within the Master Plan boundaries for years 2010, 2020, 2030 and build-out, and is included in Appendix A. As growth is gradual, population within the water utility service area is less than Master Plan boundary and is summarized below in Table TM3.4. Review of the data projects a 29 percent increase in population from 2010 to 2030 and a 172 percent increase from 2010 to build-out.

Table TM3.4: Water Utility Service Area and Master Planning Area Population Forecasts

Year	Utility Service Area	Master Planning Area
2010	92,727	94,564
2020	106,667	113,051
2030	119,529	129,176
Buildout	251,971	251,971

D. Customer Projection

The population projections are used to distribute water use in years 2020, 2030 and build-out. The conversion process described in the paragraphs below is used to develop the number and class of future customers through buildout.

Lawrence provided water meter sales records and physical meter data to allocate current water usage across the system. Data was provided for 2005 through 2010 in both spreadsheet and GIS shapefiles and included the sales for each of twelve (12) billing periods for each of these years by meter ID, address, and parcel ID.

A meter class code was assigned to each water meter. Several of these meters were modified as there were a number of parcels with multiple meters in which all of the meters were not of the same class. Additionally, there were a number of residential class meters that were more appropriately assigned to the multi-family class based off their parcel acreage. These modifications made the classifications consistent. These basic meter classes were then used to assign a simplified land use category to each meter as follows:

- RS = Residential
- MF = Multi-family
- CO = Commercial
- IN = Industrial
- CT = City

The meter class percentages and dry year water use, which includes non-revenue water, are listed in Table TM3.5 and used to determine a total dry year average day demand of 10.4 MGD based 2010 population and number of meters. The 2010 population of 92,727 people and 31,937 existing meters results in a density of 2.9 people per meter and is also listed in Table TM3.5. Water demand is added for other customer classes including KU and wholesale.

Table TM3.5: Water Use Data for Demand Projections

Meter Class	No. of Meters	Meter Class Percentage[1]	Dry Year Water Use[2] (gpmd)	Avg Day Demand[3] (MGD)
CO	1,797	5.6%	1,365	2.5
CT	185	0.6%	1,890	0.3
IN	78	0.2%	6,300	0.5
MF	743	2.3%	1,260	0.9
RS	29,134	91.2%	194	5.7
Total	**31,937**	**100.0%**	**--**	**9.9**
Average gpmd[4]	**--**	**--**	**310**	**--**
2010 Population[5]	**88,000**		**People/Meter**	**2.8**

Notes:
1. Meter class percentage will remain fixed throughout the study.
2. Dry year water use includes water loss.
3. The average day demand does not include KU or wholesale customers.
4. The average gpmd is based on the average day demand of 10.4 MGD and a total of 31,937 meters.
5. 2010 Population does not include KU student housing.

The people per meter density of 2.9 are used with the City provided population to develop RS and MF meter counts for 2020, 2030, and buildout. Since populations for CO, CT, and IN meter classes are not associated with full time occupancy like RS and MF meter classes, the total meter count listed in Table TM3.6 are calculated as the meter count divided by the meter class percentage for RS and MF.

Table TM3.6: Customer Meter Count Projections

Year	Population	Density (people/meter)	RS & MF Meter Count	RS + MF Meter Class Percentage[1]	Total Meter Count[2]
2020	106,667	2.8	38,712	93.5%	41,381
2030	119,529	2.8	43,380	93.5%	46,371
Buildout	251,971	2.8	91,445	93.5%	97,751

Notes:

1. This percentage is equivalent to 91.2 + 2.3 = 93.5%, from Table TM3.5.
2. Total meter count includes RS, MF, CO, IN, and CT meter classes.

E. Water Demand Projection

Demand projections are based on the water usage discussed in Section B and the customer projections discussed in Section D. Water usage by meter class and the average day demand projections for 2020, 2030, and buildout for the customer meter count projections are summarized in Table TM3.7.

Table TM3.7: Average Day Water Demand Projection Excluding Wholesale

Water Usage Summary			2020		2030		Buildout	
Meter Class	**Dry Year Water Use (gpmd)**	**Meter Class Percentage**	**Meter Count**	**Avg Day Demand[1] (MGD)**	**Meter Count**	**Avg Day Demand[1] (MGD)**	**Meter Count**	**Avg Day Demand[1] (MGD)**
CO	1,365	5.6%	2,328	3.2	2,609	3.6	5,500	7.5
CT	1,890	0.6%	240	0.5	269	0.5	566	1.1
IN	6,300	0.2%	101	0.6	113	0.7	239	1.5
MF	1,260	2.3%	963	1.2	1,079	1.4	2,274	2.9
RS	194	91.2%	37,749	7.3	42,301	8.2	89,171	17.3
		Totals	**41,381**	**12.8**	**46,371**	**14.4**	**97,751**	**30.3**

Notes:
1. Average day demand projections listed do not include KU or wholesale customers.

Key numbers and factors used in Lawrence's demand projections and hydraulic modeling as presented in Table TM3.8 include the following:

- Existing Customers:
  - 2010 metered water use
  - Additions to the metered usage are as follows to conform to projected WTP pumpage for dry weather year conditions:
    - Unallocated demand from the GIS – demand without an address or parcel or an incorrect address;
    - Average dry year water use adder;
    - Non-revenue water at 5 percent of the total demand.
- Future Customers:
  - Projected customer meter counts as listed in Table TM3.6;
  - Information provided by KU and wholesale customers;

- Average dry year water use adder;
- Non-revenue water at 5 percent of the total demand.

Table TM3.8: Gallon per Capita Day Check

Year	Population / Projection	Avg Day Demand[2, 3] (MGD)	GPCD
2006	89,110	12.2	137
2007	90,311	11.4	126
2008	90,866	10.4	114
2009	91,464	9.5	104
2010	92,727	9.9	107
2020	106,667	12.8	**120**
2030	119,529	14.4	**120**
Buildout	251,971	30.3	**120**

Notes:
1. Population from 2006 to 2010 includes KU.
2. Average day demand from 2006 to 2010 is total potable pumped quantities which includes KU and wholesale customers.
3. Average day demand for 2020, 2030, and buildout does not include KU or wholesale customers.

- MD/AD ratio of 2.2
- MH/AD ratio of 3.5

KU and the City discussed water use projections for KU's Main and West Campuses as listed in Table TM3.9. Water use has been very stable over the last five years. Review of the table shows KU increasing 110,000 gallons per day (gpd) at the Main Campus and 90,000 gpd at the West Campus by year 2030.

Wholesale and rural water districts are also projecting increases in water use as listed in Table TM3.9. Review of the table shows the RWD meter class totals 1.0 MGD in 2010 and is projected to increase to 1.37 MGD in 2020 and 1.63 MGD in 2030.

Projected water demands for all seven meter classes are summarized in Table TM3.10 for years 2020, 2030 and buildout. Review of the table shows the maximum day demand is projected to be 32.7, 36.9, and 71.7 MGD respectively for year 2020, year 2030, and buildout. These values have been approved by the City and are the basis for all water supply, water treatment, and distribution system evaluations. Any changes to these values require reevaluation of the water system.

Table TM3.9: KU and Wholesale Water User Summary

Water User	Max Contract Amount (MGD)	Year 2010 (MGD)	Year 2020 (MGD)	Year 2030 (MGD)	Buildout (MGD)
KU Main Campus[1]	NA	0.56	0.62	0.67	0.67
KU West Campus[1]	NA	0.026	0.073	0.12	0.12
Baldwin City[2]	0.89	0.54	0.66	0.80	0.89
RWD #1[2]	0.17	0.11	0.13	0.13	0.17
RWD #2[3]	0.34	0.08	0.10	0.12	0.34
RWD #4[2]	0.48	0.07	0.13	0.14	0.48
RWD #5[3]	0.62	0.19	0.28	0.34	0.62
RWD #6[4]	0.09	0.04	0.07	0.09	0.16
Total	2.59	1.616	2.063	2.41	3.45

Notes:
1. Based on information provided by KU.
2. Maximum contract amount allowed by KWO.
3. Maximum contract amount allowed by a City revised contract to sell raw water in addition to the KWO amount.
4. The current amendment under consideration for the maximum contract amount of RWD #6 is 0.16 MGD and will be used for the buildout demand projection. No agreement has been executed with the City for additional water.

F. Demand Allocation and Growth Strategy

The demand allocation for future customers is a holistic approach and is based on a gpd/acre value. The City's Land Use Plan provides a total of 28,731 acres of undeveloped land within the study area and the difference between the buildout system demand and the existing system demand represents the demand for this undeveloped land area. This represents a demand allocation of 691.24 gpd/acre for future customers as shown in Table TM3.11. This value is less than the value for the current City limits of 778.9 gpd/acre. The primary differences are as follows:

- Much of the older City development is small lot, greater density, narrow road and little green space, and older appliances and fixtures;
- Newer and anticipated development is larger lot, wider roads, more green space, larger footprint for schools and commercial facilities, and all water efficient appliances and fixtures.

Table TM3.10

Projected Water Demands
Lawrence, Kansas

Year	Average Day Demand (MGD)								Maximum Day[1] (MGD)	Maximum Hour[2] (MGD)
	RS	MF	CO	IN	CT	KU	RWD	Total		
2010	**5.83**	**0.98**	**2.64**	**0.57**	**0.38**	**0.58**	**1.00**	**12.0**	**19.5**	**41.9**
2011	5.96	1.00	2.70	0.58	0.39	0.59	1.04	12.3	27.0	42.9
2012	6.10	1.03	2.76	0.60	0.40	0.60	1.07	12.6	27.6	44.0
2013	6.23	1.05	2.82	0.61	0.41	0.61	1.11	12.8	28.3	45.0
2014	6.37	1.07	2.88	0.62	0.41	0.63	1.15	13.1	28.9	46.0
2015	6.50	1.10	2.95	0.64	0.42	0.64	1.19	13.4	29.5	47.0
2016	6.64	1.12	3.01	0.65	0.43	0.65	1.22	13.7	30.2	48.0
2017	6.77	1.14	3.07	0.67	0.44	0.66	1.26	14.0	30.8	49.0
2018	6.90	1.17	3.13	0.68	0.45	0.67	1.30	14.3	31.4	50.0
2019	7.04	1.19	3.19	0.69	0.46	0.68	1.33	14.6	32.1	51.0
2020	**7.17**	**1.21**	**3.25**	**0.71**	**0.47**	**0.69**	**1.37**	**14.9**	**32.7**	**52.1**
2021	7.26	1.23	3.29	0.71	0.47	0.70	1.40	15.1	33.1	52.7
2022	7.35	1.24	3.33	0.72	0.48	0.71	1.42	15.3	33.6	53.4
2023	7.43	1.26	3.37	0.73	0.48	0.72	1.45	15.4	34.0	54.1
2024	7.52	1.27	3.41	0.74	0.49	0.73	1.47	15.6	34.4	54.7
2025	7.61	1.29	3.45	0.75	0.50	0.74	1.50	15.8	34.8	55.4
2026	7.69	1.30	3.49	0.76	0.50	0.75	1.53	16.0	35.2	56.0
2027	7.78	1.31	3.53	0.77	0.51	0.76	1.55	16.2	35.6	56.7
2028	7.87	1.33	3.57	0.77	0.51	0.77	1.58	16.4	36.1	57.4
2029	7.95	1.34	3.60	0.78	0.52	0.78	1.60	16.6	36.5	58.0
2030	**8.04**	**1.36**	**3.64**	**0.79**	**0.52**	**0.79**	**1.63**	**16.8**	**36.9**	**58.7**
Build-out	**16.32**	**2.76**	**7.40**	**1.61**	**1.06**	**0.79**	**2.66**	**32.6**	**71.7**	**114.1**

Notes:

[1] Maximum day to average day ratio is 2.2 for 2011 through buildout.

[2] Maximum hour to average hour ratio is 3.5 for 2011 through buildout.

Table TM3.11

Water Demand Distribution for Hydraulic Modeling
Lawrence, Kansas

No.	Item	Amount	Units	Commments
1	Buildout System Demand[1]	30.26	MGD	--
2	Year 2010 System Demand[2]	10.40	MGD	--
3	Demand for Undeveloped Buildout System	19.86	MGD	--
4	Undeveloped Land Area for Buildout System	28,731	Acres	Summation from GIS data
5	**Demand Distribution**	**691.24**	**gpd/acre**	**See Note 3**

Notes:

[1] Buildout system demand does not include KU and RWD; their demand projections are applied directly to the model based on current and historical water demands. This approach increases the accuracy demand distribution for the buildout system.

[2] Existing system demand shares the same approach indicated in Note 1 for the buildout system.

[3] For comparison, the existing system area includes 13,352 acres with an average day dry year demand of 10.4 MGD and represents a demand distribution of 778.9 gpd/acre.

The demand allocation is further refined in Table TM3.12 as it relates to the undeveloped land areas inside and outside the existing system in 2020, 2030, and buildout and reflects the growth strategy provided by City staff. Between 2010 and 2020 there are a total of 3,340 acres planned for development which represents a water demand increase of 2.4 MGD based on the demand allocation. Between 2020 and 2030 there are a total of 2,315 acres which represents a water demand increase of 1.6 MGD and in buildout there are a total of 23,002 acres which represents a water demand increase of 15.9 MGD. All of these areas combined equate to the total area of undeveloped land within the study area of 28,731 acres discussed in the first paragraph of this section.

A growth strategy provided by City staff illustrates where growth is anticipated to occur by 2020, 2030, and buildout for the areas inside and outside the existing system. This approach for the demand allocation is conservative because it allows the City to adjust with any changes in the growth strategy. The water demands in hydraulic model are easily adaptable depending on where growth actually occurs. The growth strategy is illustrated in Figure TM3.4.

G. Demand Management

Lawrence’s water loss is typically less than 5 percent. This is outstanding as most systems consider 10 to 15 percent acceptable. Demand management, or water conservation, is used to reduce or control demand. Projections used in this study do not reflect any additional demand management activities beyond those currently in place. Current practices and ongoing programs are maintaining a very low value. Typical recommended demand management activities for systems serving more than 10,000 people include the following (per EPA Guidelines for Conservation Planning):

- Universal metering – meter all water users to provide a complete account of use;
- Control water loses – perform leak detection surveys and associated repairs;
- Costing – institute an inverted water rate to encourage the water conservation. An inverted rate is a higher volume charge, usually 200 to 500 percent of the current volume charge for water use in excess of 110 to 125 percent of average winter use or average system winter use (whichever is higher);
- Distribute information and education material on water conservation with water bills, at schools, special city functions, etc.;
- Water-use audits – help customers realize how much water they use and where;

- Retrofits – provide plumbing retrofits kits to decrease water use from showers, toilet flushing, and faucets;
- Pressure management – lower system pressure to decrease the amount of water people can use in comparable time periods and to reduce leakage;
- Xeriscape – plant water efficient trees, shrubs, flowers, and grass. Tall fescue, zoysia, loccul, and buffalo grasses use much less water and fewer chemicals than rye and blue grass varieties;
- Pipeline replacement – replacement of old and small-diameter pipelines are key to controlling water loss and provide an opportunity to improve system efficiency and fire flow.

Generally, implementation of the first four conservation guidelines detailed above can reduce average day and maximum day water demands 10 to 30 percent. Implementation of the remaining conservation guidelines can save an additional 5 to 20 percent. The impacts of additional demand management are not included in the demand analysis. Additional data on residential and commercial water use should be evaluated before selecting demand management measures. For Lawrence, continuation of current practices and keeping pace with the replacement of old water mains will allow the water distribution system to continue to operate at these low water losses. A 5 percent water loss is used in the demand projections.

Table TM3.12

Water Demand Projections and Land Development Area by Improvement Year
Lawrence, Kansas

Year 2010				
Location	Avdy[1] (MGD)	TAZ/Land Area (acres)	Demand Allocation (gpd/acre)	Progressive City Growth / Population[3]
Existing System	10.40	NA	NA	92,727
Undeveloped Area Inside Existing System	--	--	--	NA
Undeveloped Area Outside Existing System	--	--	--	NA
Total	**10.40**	**--**	**--**	**92,727**

Year 2020				
Location	Avdy[1] (MGD)	Land Area[2] (acres)	Demand Allocation (gpd/acre)	Progressive City Growth / Population[3]
Existing System	10.40	--	NA	92,727
Undeveloped Area Inside Existing System	1.01	1,460	691.24	NA
Undeveloped Area Outside Existing System	1.39	1,880	691.24	NA
Total	**12.80**	**3,340**	**--**	**106,667**

Year 2030				
Location	Avdy[1] (MGD)	Land Area[2] (acres)	Demand Allocation (gpd/acre)	Progressive City Growth / Population[3]
Existing System	12.80	--	--	106,667
Undeveloped Area Inside Existing System	0.45	650	691.24	NA
Undeveloped Area Outside Existing System	1.15	1,664	691.24	NA
Total	**14.40**	**2,315**	**--**	**119,529**

Buildout				
Location	Avdy[1] (MGD)	Land Area[2] (acres)	Demand Allocation (gpd/acre)	Progressive City Growth / Population[3]
Existing System	14.40	--	--	119,529
Undeveloped Area Inside Existing System	0.68	987	691.24	NA
Undeveloped Area Outside Existing System	15.22	22,015	691.24	NA
Total	**30.30**	**23,002**	**--**	**251,971**

Notes:

1. The average day demand (AD) totals are the water demand projections for 2020, 2030, and build-out. The demand projections are based on 2.9 people/meter and represent a water use of 120 gpcd which is consistent with recent trends.
2. The "Undeveloped Area Outside Existing System" for each year is calculated as the "AD" divided by the "Demand Allocation". The meter percentage will remain fixed throughout the study period.
3. The "Population / Growth" totals for 2010, 2020, & 2030 are provided by City staff; buildout population from TAZ.

Technical Memorandum No. 4
Net Water Needs

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 4

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A. General

Technical Memo No. 4 summarizes the net water needs for water rights, diversions, and water plant components of Lawrence. The net water need is the difference between projected demand and diversion capacities allowed by the current water rights and are listed in Tables TM4.1 and TM4.2.

Table 4.1: Maximum Day Water Rights Needs Assessment

Water Component	**Year 2020**	**Year 2030**	**Buildout**
	Amount (MGD)	**Amount (MGD)**	**Amount (MGD)**
Maximum Day Demand Projection[1]	35.3	39.9	77.4
Maximum Day Water Right Diversion[2]	74.9	74.9	74.9
Maximum Day Net Water Need	**39.5**	**35.0**	**-2.6**

Notes:
1. Maximum day demand projections include 8 percent water loss for treatment through the WTPs and demands for KU and wholesale customers.
2. Maximum day diversion right includes rights of the wholesale customers.

Table TM4.2: Average Day Water Right Needs Assessment

Water Component	**Year 2020**	**Year 2030**	**Buildout**
	Amount (MGD)	**Amount (MGD)**	**Amount (MGD)**
Average Day Demand Projection[1]	16.1	18.1	35.2
Average Day Water Right Diversion[2]	38.0	38.0	38.0
Average Day Net Water Need	**21.9**	**19.9**	**2.8**

Notes:
1. Average day demand projections include 8 percent water loss for treatment through the WTPs and demands for KU and wholesale customers.
2. Average day diversion right includes rights of the wholesale customers.

B. Diversion

The two Lawrence WTPs currently have the capacity to divert and treat 36.0 MGD, with Kaw WTP supplying 16.0 MGD and Clinton WTP supplying 20.0 MGD. Table TM4.3 shows an additional diversion capacity of 3.9 MGD by 2030 and 41.4 MGD by buildout is required to meet maximum day demands. This is illustrated in Figure TM4.1 and shows a deficit starting in year 2028. Maximum day demand is the highest daily demand of the year. Maximum day and high demands near the maximum day occur about five to ten times a year and may or may not be contiguous. Additional conservation or water management / emergency water management can be effectively used to limit demand and minimize these peak demands.

Table TM4.3: Diversion Capacity Needs

Water Component	Year 2020	Year 2030	Buildout
	Amount (MGD)	Amount (MGD)	Amount (MGD)
Required Diversion Capacity[1]	35.3	39.9	77.4
Current Diversion Capacity	36.0	36.0	36.0
Net Water Need	**0.7**	**-3.9**	**-41.4**

Note:
1. Required diversion capacity is the maximum day demand projection plus an 8 percent adder for WTP losses.

Currently, the diversions for both plants lack redundancy. One intake serves the Kaw WTP and a single 36-inch pipeline conveys water from the Clinton Lake intake to the WTP. Based on this information, the BMcD 2011 Kaw WTP Water Supply and Transmission Main report, City population projections by TAZ, and discussions with City staff, the following diversion alternatives are planned for use in the hydraulic model:

- Utilize water rights on the Kansas River and transfer these rights to horizontal collector wells (HCW) in the Kansas River alluvium to supply a Clinton WTP expansion;
- Add a pipeline from proposed HCW to feed Kaw WTP for supply redundancy. If this interconnection is utilized, then Kaw WTP must be capable of treating water from this source or a blend with the Kaw intake water;
- Add a second raw water intake to supply Kaw WTP for redundancy or connect the proposed raw pipeline from the HCWs to Kaw WTP;
- Increase firm capacity of Clinton Intake to 25 MGD.

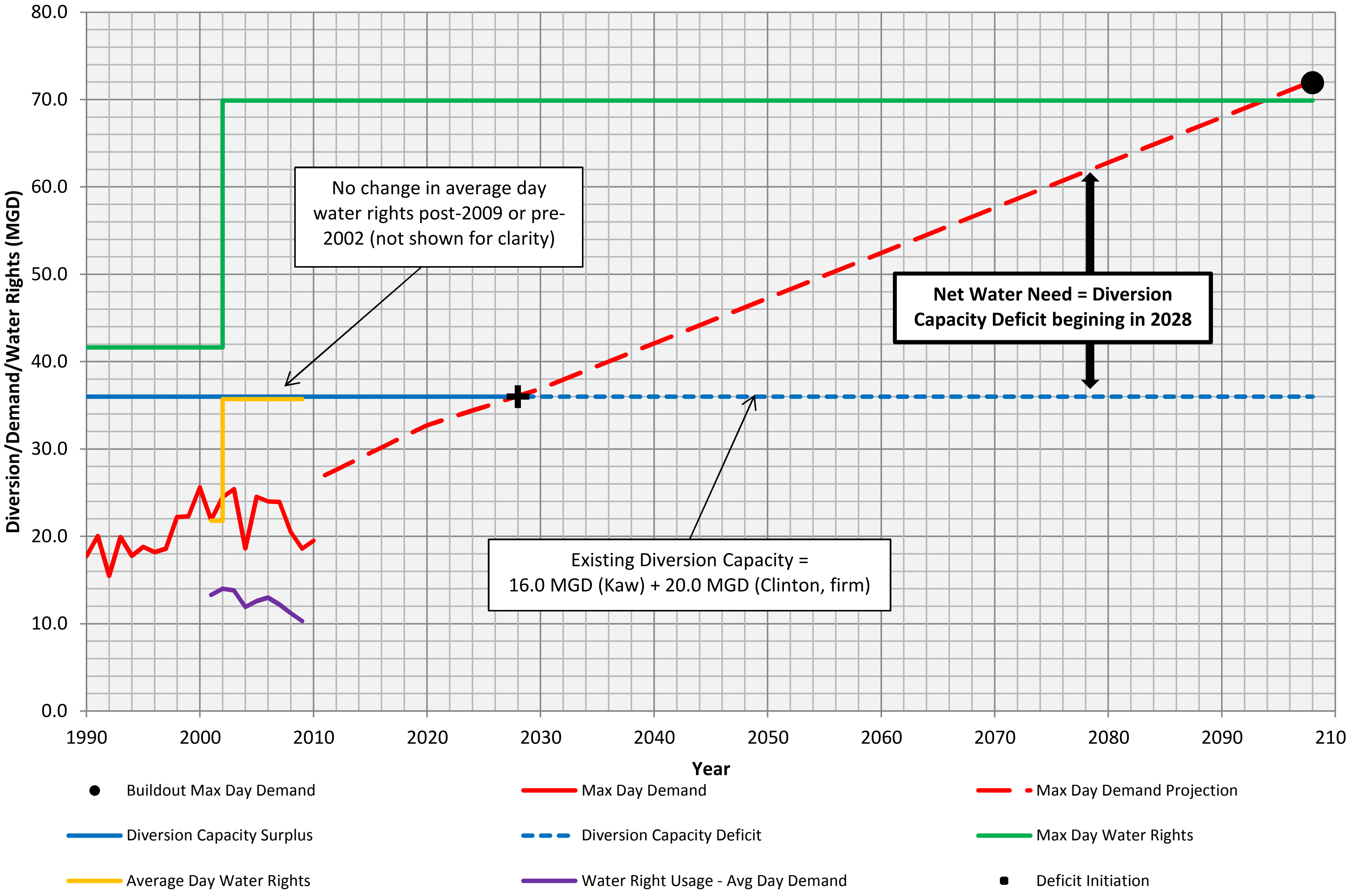
C. Treatment

The current WTP capacity is 36.0 MGD with 20.0 MGD from Clinton WTP and 16.0 MGD from Kaw WTP. This capacity can potentially be maximized to 42.5 MGD based on 25 MGD from Clinton WTP and 17.5 MGD from Kaw WTP. Filter testing and plant improvements are required

City of Lawrence
KANSAS

Figure TM4.1
Net Water Needs - Diversion Capacity
Lawrence, Kansas

Burns & McDonnell
SINCE 1898


No change in average day water rights post-2009 or pre-2002 (not shown for clarity)

Net Water Need = Diversion Capacity Deficit begining in 2028

Existing Diversion Capacity = 16.0 MGD (Kaw) + 20.0 MGD (Clinton, firm) at both plants to meet these capacities. Additional water treatment capacity of 41.4 MGD is required to meet the buildout demand of 77.4 MGD based on the existing WTP capacity of 36.0 MGD as shown in Table TM4.4. If the existing WTPs capacity is increased to the maximum potential of 42.5 MGD, only an additional 34.9 MGD would be required to meet buildout demands. This is illustrated in Figure TM4.2 and shows a deficit starting in year 2028 for the existing WTP capacity and 2041 for the maximized potential existing WTP capacity.

Table TM4.4: Treatment Capacity Needs (Maximum Day)

Water Component	**Year 2020**	**Year 2030**	**Buildout**
	Amount (MGD)	**Amount (MGD)**	**Amount (MGD)**
Required WTP Capacity[1]	35.3	39.9	77.4
Maximum Potential Existing WTP Capacity	42.5	42.5	42.5
Net Water Need (Potential Existing WTP Capacity)	**7.2**	**2.6**	**-34.9**
Required WTP Capacity[1]	35.3	39.9	77.4
Current WTP Capacity	36.0	36.0	36.0
Net Water Need (Current WTP Capacity)	**0.7**	**-3.9**	**-41.4**

[1] Required treatment capacity is the maximum day demand projection, including KU and wholesale users, plus an 8 percent adder for WTP losses.

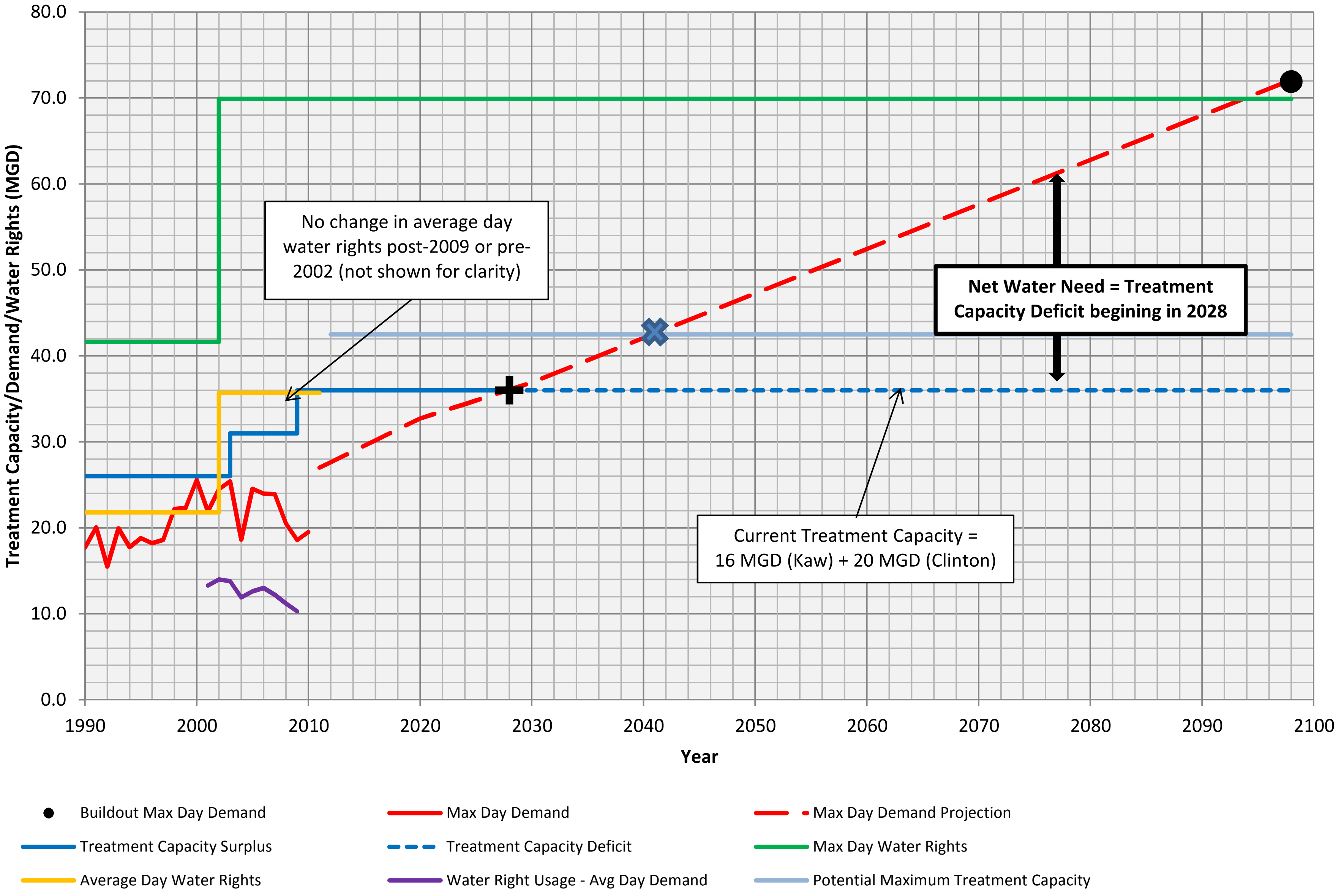
D. Distribution

Based on the future WTP location, capacities discussed above, and approximately 89 square miles of future growth areas, a substantial amount of pipelines and storage volume are required to serve the build-out future growth area. The hydraulic model is used to determine the need for additional pressure zones, size and location of additional transmission pipelines, pump station, and storage for buildout, and years 2020 and 2030.

City of Lawrence
KANSAS

Figure TM4.2
Net Water Needs - Water Treatment Capacity
Lawrence, Kansas

Burns & McDonnell
SINCE 1898



Technical Memorandum No. 5
Diversion Alternatives

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

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Water Master Plan Technical Memorandum No. 5

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A. General

Technical Memo (TM) No. 5 discusses diversion alternatives for the Kaw and Clinton WTPs to meet the maximum day demand projected through buildout. The Kaw site is limited, and additional land area is required to expand the plant beyond 25 MGD. The other limiting factor is transmission capacity from the Kaw WTP to customers. New transmission mains will be at a higher cost than a greenfield expansion but allows the City to replace older transmission mains which will be required before buildout occurs.

Clinton WTP has ample area to expand and is well situated for distribution of future demands. However, there are no available water rights at Clinton reservoir and all future diversion must come from the Kansas River. Another factor for consideration is that raw water costs from Clinton Reservoir are much higher than at Kaw WTP. Currently, raw water costs from Clinton are approximately $340,000 per year and rising versus approximately $24,000 per year at Kaw WTP. The cost of treatment is lower at Clinton WTP.

B. KAW WTP

Raw water pump station and piping improvements required to reach a 25 MGD firm capacity were evaluated in the 2011 BMcD report and presented surface water and groundwater options. Major improvements associated with a surface water diversion alternative include the following:

- Replace LSPS No. 1;
- Construct a new intake and raw waterline for the ultimate capacity of the WTP capacity plus process losses;
- The total low service pumping capacity needs to include the ultimate capacity of the WTP capacity plus process losses. This can be split with the existing LSPS No. 2 and can constructed in an expandable manner; and
- Presedimentation basin.

For the purposes of this master plan, the raw water improvements listed above are evaluated in the model as providing a diversion capacity of 27 MGD to account for an 8 percent treatment process loss which equates to a treated water high service pumping capacity of 25 MGD.

Groundwater diversion was also evaluated in the 2011 BMcD report and included alternate locations at Burcham Park and at the North Well Field. The Burcham Park groundwater diversion alternative concluded that nine HCWs would be required to deliver 25 MGD to the Kaw WTP. However, due to the saturated thickness of the well field, it is unlikely that more than four 3.1-MGD HCWs could be supported, as interference between the wells would be too great. Ultimately, the use of HCWs for diversion at this location cannot provide the entire water supply.

The North Well Field diversion alternative concluded that three HCWs are required to deliver 25 MGD to the Kaw WTP. HCWs at this location require approximately five miles of 36-inch transmission from the well field to the Kaw WTP. Figure TM5.1, from the 2011 BMcD report, illustrates the general location for this diversion alternative adjacent to the Kansas River approximately 4.5 miles upstream of Burcham Park.

C. Clinton WTP

Clinton Lake has no additional water rights available. Therefore, all future diversion must come from the Kansas River. Clinton WTP will also have to be expanded to supply the remainder of the projected buildout demand that Kaw WTP cannot provide. Expansion at Clinton WTP is more conducive by nature of its location to the existing distribution system, land availability, and future growth areas determined by City staff.

Based on previous studies, alternate diversion sources are available to provide water to Kaw and Clinton WTPs or provide a redundant water supply to enhance reliability as illustrated in Figure TM5.2. A primary location for a single or series of HCWs is the oxbow located northwest of Kaw WTPs as illustrated in Figure TM5.1. A second alternate location is the Farmland site on the east side of Lawrence and could be developed with vertical wells. An additional evaluation of the hydrogeology and water right issues with these sites is required to refine capacity, spacing, water quality, supply, transmission lines crossing the City core, permitting, and process treatability issues.

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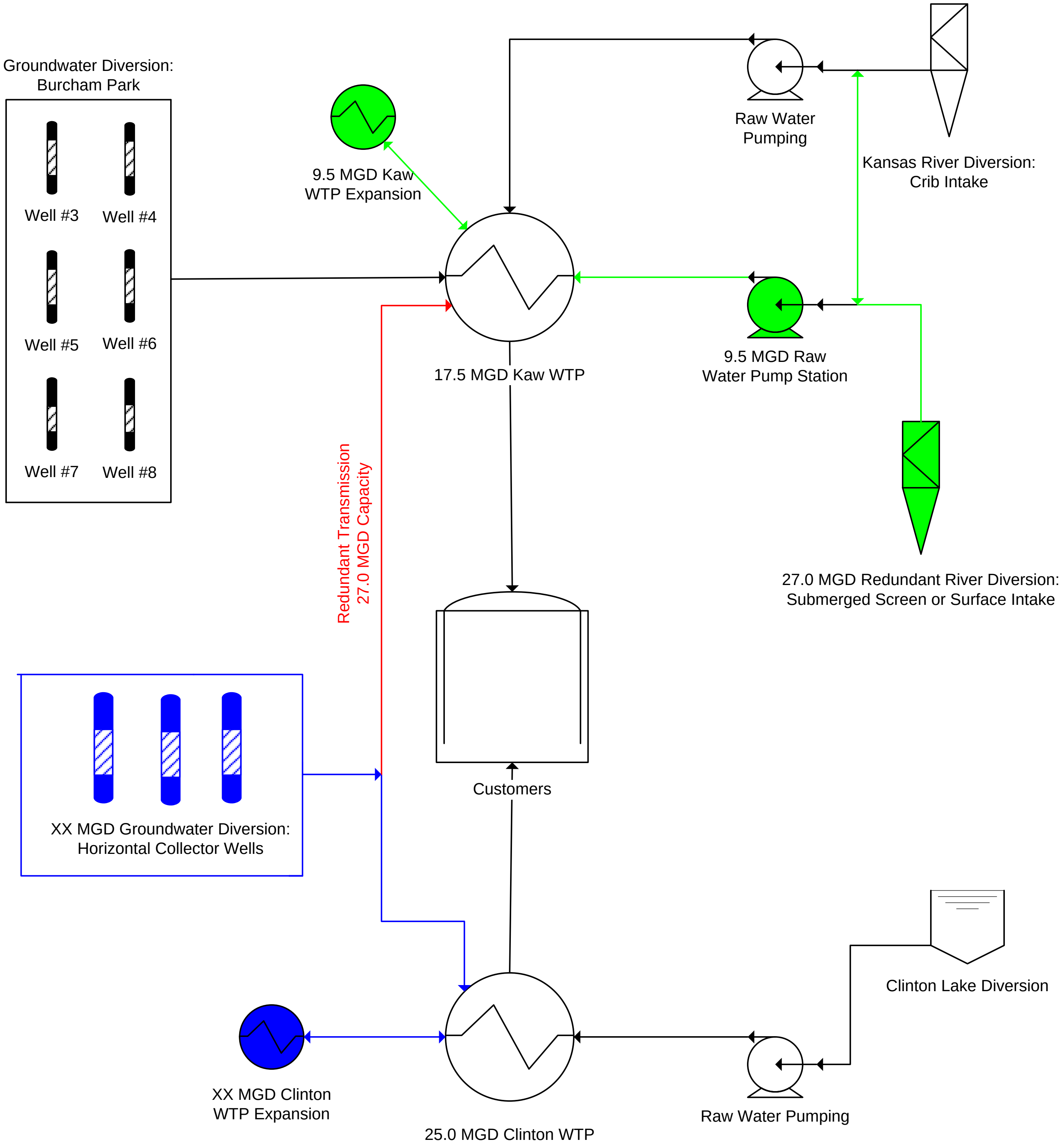
Figure TM5.1

NORTH WELL FIELD
LOCATION MAP

J:\LAWRENCE\41658\COLLECTORWELLMAPS\SITE2.DWG 11/1/2011 9:40 AM D_LAIRMO



Legend

Kaw WTP Diversion	🟩
Clinton WTP Diversion	🟦
Transmission Redundancy	🟥

NOT TO SCALE

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City of Lawrence
KANSAS

Figure TM5.2

Lawrence, Kansas

Alternate Diversion Sources for Water Supply

Technical Memorandum No. 6
Regulatory Evaluation

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 6

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A. General

This section of the report provides a summary of the current and anticipated future State and Federal drinking water quality regulations and their potential impact on the City of Lawrence.

Lawrence obtains water from three distinct water sources; the Kansas River, groundwater adjacent to Kansas River, and Clinton Lake. The Kansas River is a primary water source for the Kaw Water Treatment Plant (WTP). Wells adjacent to the Kansas River provide minimal supply during peak periods. Clinton Lake is the other primary water source and supplies the Clinton Lake WTP.

A WTP with surface water or groundwater under the direct influence of surface water must produce water that meets State and Federal mandated regulations for drinking water. In general, States are primarily concerned with the administration of Federal drinking water requirements, but on some topics, they may add additional or stricter requirements. The primary State and Federal requirements that guide drinking water treatment in Kansas are summarized in this document. Supplementary data referenced in this section is presented in Appendix B and C.

A.1 Regulatory Background

The regulatory evaluation includes a review of current and anticipated water quality regulations that may impact the City of Lawrence. The review was performed in consideration of the following current and anticipated drinking water regulations:

- Safe Drinking Water Act (SDWA) and its amendments
  - National Primary Drinking Water Regulations (NPDWRs)
    - Microorganisms
    - Disinfection Byproducts
    - Organic Contaminants
    - Inorganic Chemicals
    - Radionuclides
    - Disinfectants
  - National Secondary Drinking Water Regulations (NSDWRs)
  - Arsenic Rule
  - Lead and Copper Rule

  - Radionuclide Rule
  - Radon Rule
  - Filter Backwash Recycling Rule
  - Surface Water Treatment Rule (SWTR)
- Total Coliform Rule (TCR)
- Microbial/Disinfection Byproduct Rules
  - Interim Enhanced Surface Water Treatment Rule (IESWTR)
  - Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)
  - Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)
  - Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 D/DBPR)
  - Stage 2 Disinfectants/Disinfection Byproducts Rule (Stage 2 D/DBPR).
- Unregulated Contaminant Monitoring (UCM) for large and small utilities

B. Existing Water Quality Regulations

B.1 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) of 1974 established primary drinking water regulations to ensure the distribution of safe drinking water. These regulations were the first to be implemented to public water supplies (PWSs) in the United States (US), covering both chemical and microbial contaminants. They remained in place for more than 10 years with minor revisions, including a revised fluoride standard, addition of a total trihalomethanes standard, and interim regulations for radionuclides in potable water.

The SDWA authorized the United States Environmental Protection Agency (USEPA) to promulgate regulations regarding water supply. In 1986, Congress passed widespread amendments to the SDWA, which significantly altered the rate at which the USEPA was to set drinking water standards. These amendments resulted in a three-fold increase in the number of contaminants regulated. The National Interim and revised Primary Drinking Water Regulations promulgated prior to 1986 were redefined as National Primary Drinking Water Regulations.

The 1996 amendments to the SDWA greatly enhanced the existing law by recognizing source water protection, operator training, funding for water system improvements, and public information as important components of safe drinking water. Among others, the 1996 amendments required the USEPA to develop rules to balance risks between microbial pathogens and disinfection by-products (DBP), named the Microbial/Disinfection Byproduct (M/DBP) Rules. Several rules emerged from this requirement, including the Interim Enhanced Surface Water Treatment Rule (IESWTR), the Stage 1 and Stage 2

Disinfectants and Disinfection By-Products Rules (Stage 1 D/DBPR and Stage 2 D/DBPR), and the Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules (LT1ESWTR and LT2ESWTR).

Since the passage of the 1996 amendments, numerous regulations specific to surface water and ground water sources have been finalized by the USEPA including: Total Coliform Rule, Lead and Copper Rule, Radionuclide, Arsenic, and additional standards for various organic and inorganic chemicals. The EPA is currently engaged in a process for proposing and promulgating additional rules associated with these amendments.

B.2 Primary and Secondary Drinking Water Regulations

The National Primary Drinking Water Regulations (NPDWRs) of the Safe Drinking Water Act, legislated by Congress and adopted by the State of Kansas, are currently set for 83 contaminants, including turbidity, six indicator microorganisms, four radionuclides, 16 inorganic contaminants, and 57 organic contaminants. MCLs and maximum contaminant level goals (MCLGs) have been set for 73 contaminants and three disinfectants. Ten other contaminants have treatment technique (TT) requirements. The Federal and State MCLs for the contaminants listed in the NPDWR are summarized in Table B.1 of Appendix B.

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Federal and Kansas secondary standards are recommended for 15 contaminants to ensure aesthetic quality of drinking water. The Federal and State secondary standards for the contaminants listed in the Secondary Drinking Water Standards are summarized in Table B.2 of Appendix B. It should be noted that Kansas has a public notification requirement for fluoride.

B.2.a Inorganic Compounds

Inorganic compounds (IOC) consist of substances that do not have organic carbon in their composition. The K.A.R. 28-15a-62 set maximum contaminant levels (MCLs) for eight metals and two non-metal contaminants, as listed in Table TM6.1. Most of these IOCs occur naturally in the environment and are soluble in water. Because of this, they are potential contaminants of drinking water. Not all IOCs originate from natural mineral deposits. Industrial activities such as metal finishing, textile manufacturing, mining operations, electroplating, and manufacturing of fertilizers, paints, and glass also generate these contaminants.

Table TM6.1: Inorganic Compounds

Compound Name	MCL (mg/L)	Kaw (2010) Tap (mg/L)	Clinton (2010) Tap (mg/L)
Antimony	0.006	<0.001	<0.001
Arsenic	0.01	<0.0034	<0.002
Barium	2	0.02 - 0.12	0.03 - 0.05
Beryllium	0.004	<0.030	<0.030
Cadmium	0.005	<0.001	<0.001
Chromium	0.1	<0.002	<0.002
Cyanide	0.2	No data	No data
Fluoride	4	<1.5	<1.5
Mercury	0.002	<0.0001	<0.0001
Nickel	0.1	<0.0024	<0.0013
Selenium	0.05	<0.002	<0.002
Thallium	0.002	<0.0004	<0.0004

These IOC contaminants are toxic to humans at various levels. Cadmium, chromium, and selenium can cause damage to the kidneys, liver, and nervous and circulatory systems. Barium has been associated with high blood pressure and mercury has been shown to damage kidneys. Antimony, beryllium, cyanide, nickel and thallium have been shown to damage the brain, lungs, kidneys, heart, spleen and liver. This class of drinking water contaminants can be removed from drinking water using various available technologies such as coagulation/filtration, lime softening, reverse osmosis, ion exchange, chlorine oxidation, activated alumina, and granular activated carbon.

Data collected on six different days in 2009 and 2010 for the Kaw and Clinton WTPs showed non-detect for most inorganic samples. The samples that had detection were well below the MCL. For example, barium was detected at both plants. The Clinton WTP raw water had between 66 and 77 µg/L and was reduced to less than 50 µg/L in the finished water, which is 40-times lower than the regulatory limit.

Table TM6.2: Volatile Organic Compounds

Compound Name	MCL (mg/L unless noted)	Uses
Benzene	0.005	fuels, pesticides, paints, pharmaceutical
Carbon tetrachloride	0.005	degreasing agents, fumigants
p-Dichlorobenzene	0.075	insecticides, moth balls
o-Dichlorobenzene	0.6	insecticides, industrial solvents
1,2 Dichloroethane	0.005	gasoline, insecticides
1,1 Dichloroethylene	0.007	paints, dyes, plastics
cis-1,2 Dichloroethylene	0.07	industrial solvents, chemical manufacturing
trans-1,2 Dichloroethylene	0.1	industrial solvents, chemical manufacturing
Dichloromethane	0.005	paint strippers, refrigerants, fumigants
1,2 Dichloropropane	0.005	soil fumigants, industrial solvents
Ethylbenzene	0.7	gasoline, insecticides
Monochlorobenzene	0.1	industrial solvents, pesticides
Styrene	0.1	plastics, synthetic rubber, resins
Tetrachloroethylene	0.005	dry cleaning/industrial solvents
Toluene	1	gasoline, industrial solvents
1,2,4 Trichlorobenzene	0.07	industrial solvents
1,1,1 Trichloroethane	0.2	metal cleaning/degreasing agent
1,1,2 Trichloroethane	0.005	industrial degreasing solvents
Trichloroethylene	0.005	paint strippers, dry cleaning, degreasers
Vinyl chloride	0.002	plastics/synthetic rubber, solvents
Xylenes	10	paints/inks solvent, synthetic fibers, dyes

B.2.b Volatile Organic Compounds

Volatile organic compounds (VOCs) are commonly referred to as organic solvents. These compounds are generally found as constituents of many degreasers, industrial cleaners, spot/stain removers, paint

Table TM6.3: Synthetic Organic Compounds

Compound Name	**MCL** (mg/L unless noted)	**Uses**
Alachlor (Lasso)	0.002	pesticide
Aldicarb	0.003	insecticide
Aldicarb sulfoxide	0.003	insecticide
Aldicarb sulfone	0.003	insecticide
Atrazine (Atranex, Crisazina)	0.003	weed control
Benzo(a)pyrene	0.0002	coal tar lining & sealants
Carbofuran (Furadan 4F)	0.04	rootworm, weevil control
Chlordane	0.002	termite control
Dalapon	0.2	herbicide
Dibromochloropropane(DBCP, Nemafume)	0.0002	pesticide, nematocide, soil fumigant
2,4-D (2,4-dichlorophenoxyacetic acid)	0.07	weed control, defoliant
2,4,5-TP (Silvex)	0.05	herbicide, defoliant
Di(diethylhexyl)adipate	0.4	plasticizer
Di(diethylhexyl)phthalate	0.006	plasticizer
Dinoseb (2,4-dinitro-6-sec-butylphenol)	0.007	insecticide, herbicide
Diquat	0.02	herbicide
Endothall	0.1	herbicide, defoliant
Endrin	0.002	insecticide
Ethylene Dibromide (EDB, Bromofume)	0.00005	gasoline additive, fumigants, & solvents
Glyphosate	0.7	herbicide
Heptachlor (H-34,Heptox)	0.0004	termite control
Heptachlor epoxide	0.0002	insecticide
Hexachlorobenzene	0.001	by-product of solvents & pesticides
Hexachlorocyclopentadiene	0.05	pesticide, fungicide
Lindane	0.0002	pesticide
Methoxychlor (DMDT, Marlate)	0.04	insecticide
Oxamyl (Vydate)	0.2	insecticide
Pentachlorophenol (PCP)	0.001	herbicide, fungicide, wood preservative
Picloram (Tordon)	0.5	herbicide, defoliant
Polychlorinated Biphenyls (PCB, Aroclors)	0.0005	herbicide
Simazine	0.004	herbicide
2,3,7,8 TCDD (Dioxin)	3E-8	pesticide byproduct
Toxaphene	0.003	pesticide

thinners, in some paints, varnishes and lacquers, in many paint removers/strippers, in many pesticides/herbicides, in most dry cleaning chemicals, in many printing inks and printing press chemicals, in most petroleum products including many types of fuels. These compounds can often be identified by their distinct aromatic smell. Most of these compounds are flammable and toxic to varying degrees. Because of this, they are also a potential source of environmental pollution and pose a health hazard.

The 21 volatile organic compounds regulated by K.A.R. 28-15a-61 are shown in Table TM6.2. Data collected in 2009 and 2010 for the Kaw and Clinton WTPs showed non-detect for each VOC sample.

B.2.c Synthetic Organic Compounds

Synthetic organic compounds (SOCs) are man-made compounds, many of which are chlorinated and used as herbicides, pesticides, fungicides, and insecticides. There are 33 synthetic organic compounds that are regulated in K.A.R. 28-15a-61 and summarized below in Table TM6.3. Systems failing to monitor or having a MCL violation must notify the public of such violation and provide proof of performing the public notice to the state.

The EPA conducted a six-year review of these compounds (published April 17, 2002) and concluded that it was not appropriate to revise any of the 68 currently regulated compounds.

Besides atrazine, data collected in 2009 and 2010 for the Kaw and Clinton WTPs showed non-detect for each SOC sample. Atrazine was detectable, but below the MCL.

Based on the review of Lawrence lab data, none of the aforementioned compounds have ever exceeded the maximum contaminant levels (MCLs) at the Kaw or Clinton WTPs. Most IOCs, VOCs, and SOCs measured at the Kaw or Clinton WTPs are near or below the non-detection levels.

Table TM6.4 summarizes the detectable barium and arsenic concentrations, showing that they are below the MCL and currently not a considerable concern for the City of Lawrence.

B.2.d Arsenic Rule

On January 22, 2001, the EPA proposed a reduction in the arsenic standard from 50 µg/L to 10 µg/L. Due to delays in the announcement of the proposed rule; the final rule was published on February 22, 2002 with a compliance date for all drinking water systems by January 23, 2006.

Table TM6.4: Detected Barium and Arsenic Compounds

Compound Name	MCL (µg/L)	Kaw		Clinton	
		2009	2010	2009	2010
Barium - Raw	---	220	250	66	77
Barium - Tap	2000	15	120	37	50
Arsenic - Raw	---	4.3	6.4	<2.0	4.1
Arsenic - Tap	10	<2.0	3.4	<2.0	1.0

Compliance Status

Raw water arsenic concentrations in the Kaw and Clinton WTP influent were found to be below the maximum contaminant level of 10 µg/L. The maximum recorded arsenic concentration in the Clinton and Kaw WTP raw water was 4.1 and 6.4 µg/L, respectively. Some arsenic will be removed by PAC and due to the interaction with aluminum-hydroxide floc that forms during flocculation. Additional removal can be achieved with a higher dose of PAC, or the addition of GAC or ozone.

B.2.e Lead and Copper Rule

The Lead and Copper rule requires PWS serving greater than 10,000 people to sample household taps for lead and copper and conduct distribution system sampling for certain water quality parameters (pH, alkalinity, calcium, etc.). Lead and copper samples must be collected from 100 "worst case" home sites (Tier 1) and water quality parameters must be collected from 25 sites in the distribution system.

On January 12, 2000, the USEPA republished the Lead and Copper Rule with minor changes, also known as the Lead and Copper Rule Minor Revisions (LCRMR). The LCRMR does not change the action levels for lead or copper, nor does it affect the rule's basic requirements. The modified rule addresses the following broad categories:

- Demonstration of optimal corrosion control
- Lead service line replacement requirements
- Public education requirements
- Monitoring requirements
- Analytical methods
- Reporting and record-keeping requirements

- Special primacy considerations

On October 10, 2007, USEPA published additional revisions and clarifications. These revisions were intended to enhance the implementation of the LCR in the areas of monitoring, treatment, customer awareness, lead service line replacement, and improving public education. The four new requirements are as follows:

- Water systems are not required to provide advanced notification and gain the approval of the primacy agency for intended changes in treatment or source water that could increase corrosion of lead. The State must approve the planned changes using a process that will allow regulators and water systems to take as much time as needed to consult about potential problems.
- All utilities must now provide a notification of tap water monitoring results for lead to owners and/or occupants of homes and buildings who consume water from the taps that are part of the utility's sampling program.
- Utilities are required to reconsider previously "tested-out" lines when resuming lead service line replacement programs. This provision applies to systems that had: (1) Initiated a lead service line replacement program; (2) Complied with the lead action level for two consecutive monitoring periods and discontinued the lead service line replacement program; and (3) Subsequently were re-triggered into lead service line replacement.
- The content, distribution methods, and timeframe of the public education materials that must be disseminated after a lead action level exceedance have been changed.

The USEPA has established the following action levels for lead and copper for the 90th percentile of home tap samples:

- Lead: 0.015 mg/L
- Copper: 1.3 mg/L

If the lead and copper concentrations in the 90th percentile of home tap samples is greater than these values, the utility must conduct a public education program.

The goal of the lead and copper regulation is for utilities to optimize their corrosion control treatment. Under this regulation, there are two ways in which a utility is considered to have "optimized" their corrosion control:

- Demonstrate to the regulatory agency that the utility has performed corrosion control steps "equivalent" to those required by USEPA.

- If the difference between the highest level of lead in the source water and the 90th percentile tap samples are less than the practical quantitation level (PQL) for lead (0.05 mg/L).

Compliance Status

According to the City of Lawrence's Water Quality Reports, the distribution system testing conducted in 2008 indicated compliance with the provisions of the Lead and Copper Rule based upon the 90th percentile of home tap samples. The data collected for this testing is summarized in Figure B.35 in Appendix B. The value for lead ranged from <0.001 to 0.0079 mg/L, with an average and 90th percentile of 0.0035 and 0.0055 mg/L, respectively. The value for copper ranged from 0.021 to 0.160 mg/L, with an average and 90th percentile of 0.061 and 0.097 mg/L, respectively. Both values are well below the action level for both constituents.

B.3 Radionuclides Rule

On December 7, 2000, the EPA announced updated standards for radionuclides and a new standard for uranium, as required in the 1986 amendments to the Safe Drinking Water Act (SDWA). The revised standards are as follows:

- Combined Radium 226/228: 5 pCi/L
- Total Beta Emitters: 4 mrem/yr
- Gross Alpha MCL: 15 pCi/L *
- Uranium MCL: 30 μg/L

* Excludes uranium and radon but includes Ra-226.

This rule became effective December 8, 2003. The monitoring requirements were phased between December 2000 and December 2003. Water systems will determine initial compliance under the new monitoring requirements using the average of four quarterly samples, or at state-direction, using appropriate grand fathered data.

Compliance Status

According to the City of Lawrence 2007 and 2008 Water Quality Reports, the following results were obtained for the Kaw and Clinton WTPs:

Radionuclide	Kaw WTP	Clinton WTP
Combined Radium	Below Detection	1.0 pCi/L
Total Beta Emitter	4.0 pCi/L	2.9 pCi/L

Radionuclide	Kaw WTP	Clinton WTP
Gross Alpha	3 pCi/L	Below Detection
Uranium	Below Detection	Below Detection

Compliance Status

The testing indicates current compliance with respect to all monitored radionuclides. The total beta emitter for the Kaw WTP tap was at the regulatory limit of 4.0 pCi/L in 2007 and should be retested.

B.3.a Radon Rule

The proposed Radon Rule was published on November 2, 1999. The regulation provides two options for the maximum level of radon that is allowable in community water supplies. The proposed MCL is 300 pCi/L, and the proposed alternative MCL is 4,000 pCi/L. The drinking water standard that would apply for a system depends on whether a state or community water system (CWS) develops a multi-media mitigation program. The lower alternative standard could be used in conjunction with an EPA approved program to reduce indoor air radon levels.

Compliance Status

Radon data collected for the Kaw and Clinton WTPs in 2009 and 2010 is shown in Figure B.34 in Appendix B. The values range between non-detect and 11 pCi/L. The City of Lawrence is therefore in compliance with the Radon Rule.

B.3.b Filter Backwash Recycling Rule

In May 2001, EPA released a rule governing the process of recycling waste water generated by the backwashing of drinking water filters. The Filter Backwash Recycling Rule (FBRR) is required by the Safe Drinking Water Act as one method of reducing the risks posed to consumers by microbial contaminants that may be present in public drinking water supplies.

The purpose of this rule is to minimize Cryptosporidium concentrations in the treated water due to the recycling of sludge supernatant and filter backwash wastewater to the head of the treatment plant. The major requirements of this rule are as follows:

- Systems that recycle backwash waste must do so prior to the point of application of primary coagulant.
- Direct Filtration plants could be required to provide detailed recycle treatment information to the State (which could then require modifications).

- Conventional treatment plants that practice direct recycle, employ 20 or fewer filters to meet production requirements during a selected month, and recycle spent filter backwash water, thickener supernatant, and/or liquids from dewatering processes within the treatment process must perform a one month, one-time recycle self assessment. The self-assessment requires hydraulic flow monitoring and that certain data be reported to the State, which may require that modifications be made to the recycling practices to protect public health.

Compliance Status

The Kaw and Clinton WTPs are currently in compliance with this rule.

B.4 Surface Water Treatment Rule (SWTR)

On June 29, 1989, the USEPA promulgated the SWTR, which became effective on December 31, 1990. Systems using surface water or GWUDI as a potable water source must provide treatment to reduce turbidity, *Giardia, Legionella*, viruses, and heterotrophic plate count (HPC) bacteria. Specifically, the SWTR establishes *treatment* and performance standards to provide a minimum reduction of 99.9 percent (3-log) for Giardia cysts, and 99.99 percent (4-log) reduction for viruses. The overall reduction of *Giardia* and viruses is to be achieved by multiple treatment barriers involving a combination of physical removal by pretreatment and filtration, and inactivation by disinfection.

The federal SWTR stipulates several specific requirements for turbidity and disinfection for filtration plants. For conventional filtration, the turbidity requirements are as follows:

- The turbidity of representative samples of a system's filtered water must be less than or equal to 0.5 NTU in at least 95 percent of the measurements taken each month.
- The turbidity level of representative samples of a system's filtered water must at no time exceed 5 NTU.

Well-operated conventional treatment plants, which meet or exceed (attain values lower than) the 0.5 NTU effluent turbidity standard, are credited with a 2.5-log removal of Giardia cysts and a 2-log removal of viruses. Given this, the disinfection treatment must be sufficient to ensure the following:

- The disinfection process achieves at least 0.5-log inactivation of Giardia cysts and at least a 2-log inactivation of viruses.
- Compliance with the disinfection requirement must be demonstrated by meeting minimum "CT" requirements, where "C" is the residual disinfectant concentration in mg/L, and "T" is the effective contact time in minutes with the disinfectant.

- The residual disinfectant concentration in the water entering the distribution system cannot be less than 0.2 mg/L of free chlorine or 0.5 mg/L of chloramine for more than four hours.
- The residual disinfectant concentration in the distribution system cannot be undetectable in more than 5 percent of the samples taken each month for any two consecutive months. Water in the distribution system with an HPC concentration less than or equal to 500 colony forming units (cfu)/mL is deemed to have a detectable disinfectant residual for purposes of determining compliance with this requirement.

Compliance Status

The Kaw and Clinton WTPs are currently in compliance with this rule.

B.4.a Disinfection

Disinfection at the Kaw WTP is achieved by contact with free chlorine. Sodium hypochlorite (NaOCl) and carbon dioxide (CO_2) are added in the rapid mix before the secondary basins. The chlorine dose varies based on biological demand and can be as high as 5 mg/L. Disinfection is achieved in the secondary basin with CT goals between 0.8 to 1.0 mg*min/L in the winter and between 0.3 to 0.4 mg*min/L in the summer. Ammonia is applied at the end of the secondary basin to create monochloramine for use as a secondary disinfectant with a free ammonia goal less than 0.1 mg/L. Free chlorine is added upstream of the filters in order to target a chloramines residual between 3 and 4 mg/L to the distribution system.

Table TM6.5: CT Values (mg/L-min) to Achieve 0.5 Log Giardia Lamblia Inactivation

Disinfectant	pH	Temperature			
		5°C	10°C	15°C	20°C
Free Chlorine [2]	6	20	15	10	8
	7	29	22	15	11
	7.5	36	27	18	13
	8	43	32	22	16
	9	63	47	31	24
Ozone	6-9	0.32	0.23	0.16	0.12
Chlorine Dioxide	6-9	4.3	4.0	3.2	2.5
Chloramines (preformed)	6-9	365	310	250	185

1. Adapted from EPA Guidance Manual.
2. CT values will vary depending on free chlorine concentration. Indicated CT values are for 2.6 mg/L free chlorine.

The necessary "CT" values to achieve 0.5-log inactivation of Giardia Lamblia and 2.0 log inactivation of viruses for various alternative disinfectants are summarized in Tables TM6.5 and TM6.6. These tables indicate that when using free chlorine as the primary disinfectant, the inactivation of Giardia is the controlling CT value. When using chlorine dioxide or ozone as the primary disinfectant, the inactivation of viruses is the controlling CT value. Temperature data for the Kaw and Clinton WTPs between January 2008 and December 2010 is summarized in Figure B.2 and B.11, with values ranging between 2 and 28°C for the Kaw WTP and between 2 and 32°C for the Clinton WTP.

Table TM6.6: CT Values (mg/L-min) to Achieve Virus Inactivation

Disinfectant	Log Inactivation	Temperature Winter			Summer
		5°C	10°C	15°C	20°C
Free Chlorine [2]	2.0	4	3	2	1
	3.0	6	4	3	2
	4.0	8	6	4	3
Ozone	2.0	0.6	0.5	0.3	0.25
	3.0	0.9	0.8	0.5	0.4
	4.0	1.2	1	0.6	0.5
Chlorine Dioxide	2.0	5.6	4.2	2.8	2.1
	3.0	17.1	12.8	8.6	6.4
	4.0	33.4	25.1	16.7	12.5
Chloramines (preformed)	2.0	857	643	428	321
	3.0	1423	1067	712	534
	4.0	1988	1491	994	746

1. Adapted from EPA Guidance Manual.
2. CT values will vary depending on free chlorine concentration. Indicated CT values are for 2.6 mg/L free chlorine.

Compliance Status

The Kaw and Clinton WTPs are able to achieve the required CT and are in compliance with Federal and State disinfection regulations.

B.5 Total Coliform Rule

On June 29, 1989, EPA promulgated a revised regulation for total coliforms. Where the previous regulation was based on the density of coliforms in a given volume of water, the revised rule is based on the presence/absence of coliforms. Under the TCR, utilities must develop a monitoring plan to collect samples representative of water throughout the distribution system.

The number of samples collected each month is based on population served. The City of Lawrence, with an estimated population of 92,000 in 2009, must collect at least 90 samples per month.

For systems that collect 40 or more samples per month, the rule allows no more than 5 percent positive samples per month. If a system has greater than 5 percent total coliform-positive (TC-positive) samples in a month, then this is considered a monthly MCL violation, which needs to be reported to the KDHE and to the public in a specific timeframe. All TC-positive samples must be analyzed for the presence of Escherichia coli (E. coli) or fecal coliforms. If two consecutive samples are TC-positive and one is also fecal coliform- or E. coli-positive, then this is defined as an acute violation of the MCL; the system must collect repeat samples and notify the KDHE and the public using mandatory language developed by the USEPA.

Secondary disinfection is required under the TCR in accordance with the following:

- A minimum disinfectant residual of 0.2 mg/L free chlorine or 0.5 mg/L chloramines measured as total chlorine must be present throughout the distribution system continually.
- A sample with HPCs less than 500 cfu/100 mL is assumed to carry the required minimum residual.

Compliance Status

Microbial data collected in 2007 and 2008 were absent of E.coli and total coliforms for all samples collected. The chlorine residual ranged between 3.1 and 4.0 mg/L. As a result, the City of Lawrence is currently in compliance with each of the requirements listed in this section.

B.6 Microbial/Disinfection Byproducts Rule

Disinfection of drinking water is one of the major public health advances of the 20th century. However, the disinfectants themselves can react with naturally occurring materials in the water to form unintended byproducts that may pose health risks. A major challenge for water suppliers is balancing the risks from microbial pathogens and disinfection byproducts. The following set of five SDWA amendments together address these risks.

B.6.a Interim Enhanced Surface Water Treatment Rule

Following promulgation of the SWTR in 1989, several waterborne outbreaks of Cryptosporidiosis occurred in the U.S. In response, the SDWA required the USEPA to promulgate an enhanced SWTR by November 1998 to address the risk of chlorine resistant pathogens such as Cryptosporidium. However, the rule was to have been based upon information obtained from the Information Collection Rule (ICR) that would not be available until mid-1999.

In order to address these concerns and comply with the 1998 congressional mandate, the USEPA expedited the development and promulgation of the IESWTR for large systems. The primary purposes of the IESWTR are:

- To improve control of microbial pathogens in drinking water, in particular, Cryptosporidium.
- To guard against significant increases in microbial risk that might otherwise occur when systems implement Stage 1 of the Disinfectants/Disinfection Byproducts Rule (Stage 1 D/DBPR).

The IESWTR was final on December 16, 1998 and became effective in December 2001. The Rule built upon the treatment technique requirements of the SWTR with the following provisions:

- A MCLG of zero for the protozoan genus Cryptosporidium.
- Filtered surface water and GWUDI systems, which serve 10,000 or more people, must achieve at least 99 percent (2-log) removal of Cryptosporidium.
- The IESWTR strengthened turbidity performance requirements as measured every 4 hours in the combined filter effluent which, including:
- Average turbidity of < 0.3 NTU in 95 percent of the samples.
- Maximum allowable turbidity of 1.0 NTU.
- Monitoring of individual filter effluents for process control is required every 15 minutes, with the exception that reporting to the State may be required based on the following criteria:
- Any individual filter with an effluent turbidity >1.0 NTU based upon two consecutive measurements taken 15 minutes apart.
- Any individual filter with an effluent turbidity > 0.5 NTU after 4 hours of ripening based on two measurements taken 15 minutes apart.
- Self assessment in conformance with the USEPA published guidelines is required for any filter with an effluent turbidity > 1.0 NTU, based upon two measurements taken 15 minutes apart at any time in each of three consecutive months.

- Comprehensive Performance Evaluation (CPE) in conformance with the USEPA published guidelines is required for any filter with an effluent turbidity > 2.0 NTU, based upon two measurements taken 15 minutes apart at any time in each of two consecutive months.
- Surface water and GWUDI systems are required to cover all new treated water reservoirs, holding tanks, and other storage facilities.

Compliance Status

The Kaw and Clinton WTPs are currently in compliance with this rule.

B.6.b Long Term 1 Enhanced Surface Water Treatment Rule

The Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) was proposed on April 10, 2000, and promulgated on January 14, 2002. The purpose of the LT1ESWTR was to improve control of microbial pathogens in drinking water and address risk trade-offs with disinfection byproducts. This rule also extended the requirements of the IESWTR to systems serving less than 10,000 people.

Quick Reference Guides to LT1ESWTR Rule can be found on the EPA website:
http://water.epa.gov/lawsregs/rulesregs/sdwa/mdbp/lt1/lt1eswtr.cfm

B.6.c Long Term 2 Enhanced Surface Water Treatment Rule

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) was promulgated in December 2005, and published in the Federal Register on January 4, 2006. This rule applies to systems that use surface water or groundwater under the direct influence of surface water. The purpose of the LT2ESWTR is to reduce illnesses linked with Cryptosporidium and other disease-causing microorganisms in drinking water. The rule supplements existing regulations by targeting additional Cryptosporidium treatment requirements to higher risk systems. Other pathogens may also be included in this rule, if information on occurrence, health effect, and treatment demonstrate the need for these regulations.

Quick Reference Guides to LT2ESWTR Rule can be found on the EPA website:
http://water.epa.gov/lawsregs/rulesregs/sdwa/lt2/compliance.cfm

Requirement 1 - Source Water Monitoring

Both filtered and unfiltered surface water/GWUDI systems must conduct a 24-month monitoring survey of their source water for Cryptosporidium. The action bin assignment is based upon sampling the source water for Cryptosporidium, E. coli, and turbidity on a predetermined schedule for 24 months. The Rule specifies testing with USEPA methods 1622 and 1623. Either of the following protocols may be used to determine action bin assignment:

- Based upon the highest 12-month running annual average of monthly Cryptosporidium samples.
- Based on two-year mean for monitoring conducted twice per month for 24 months.

Systems having at least 24 measurement results, but fewer than 48, would compute the average result for each set of 12 consecutive results. Systems having 48 or more measurements would compute the mean.

Systems may use previously collected data (i.e., grandfathered data) to determine their bin classification instead of monitoring if specified criteria are met. Filtered systems must also record source water E. coli and turbidity levels.

Table TM6.7: Cryptosporidium Inactivation Requirements

Bin No.	Average Source Water Cryptosporidium Concentration (oocysts/L)	Additional Treatment Requirements	
		Conventional Filtration, Diatomaceous Earth Filtration, or Slow Sand Filtration	Direct Filtration
1	< 0.075	No Action	No Action
2	0.075 to < 1.0	1 - log	1.5 - log
		using any or all of the microbial toolbox technologies	
3	1.0 to < 3.0	2 - log	2.5 - log
		with at least 1-log of treatment accomplished using: Ozone Chlorine Dioxide UV Membranes Bag/cartridge filters Bank filtration	
4	≥ 3.0	2.5 - log	3.0 - log
		with at least 1-log of treatment accomplished using: Ozone Chlorine Dioxide UV Membranes Bag/cartridge filters Bank filtration	

Requirement 2 - Risk-Based Treatment Requirements

The source water monitoring results will then be used to determine the system's risk "bin" and the level of additional treatment needed, if any, as summarized in Table TM6.7. It should be noted that under this rule, USEPA recognizes that UV disinfection is available and feasible. The LT2ESWTR includes tables specifying UV doses needed to achieve up to 3-log inactivation of Giardia, up to 3-log inactivation of Cryptosporidium, and up to 4-log inactivation of viruses.

Data collected in 2007 and 2008 shows that the Kaw and Clinton WTPs are both category Bin 1. As a result, the City does not need to achieve any additional Cryptosporidium removal credits. See Table TM6.9 for the next round of testing.

If higher levels of Cryptosporidium are detected in the future, additional treatment will be required. The City can choose from an array of options listed in the "microbial toolbox", as summarized in Table TM6.8. The microbial toolbox provides systems with flexibility in selecting cost-effective LT2ESWTR compliance strategies for Cryptosporidium. The draft Toolbox Guidance Manual provides general information on the LT2ESWTR regulation and treatment requirements and can be found at: http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_toolboxguidancemanual.pdf
The manual also provides guidance on the selection, design, and operation of treatment and management strategies for each of the 15 treatment options in the LT2ESWTR "microbial toolbox" that can be used to comply with treatment requirements under the rule.

Additional treatment requirements are based on the assumption that conventional treatment plants with filtration performance in compliance with the IESWTR achieve an average of 2-log removal of Cryptosporidium. Given this, the total Cryptosporidium removal requirements for conventional treatment action bins 2 - 4 in Table TM6.7 correspond to total Cryptosporidium removals of 3, 4, and 4.5-log, respectively.

Other Requirements

In addition to the Cryptosporidium source water monitoring and removal requirements, the requirements of the LT2ESWTR are intended to ensure that systems maintain adequate protection against microbial pathogens as they take steps to reduce formation of disinfection by-products. Key provisions of the

Table TM6.8: Microbial Toolbox Options

Toolbox Option	Maximum Cryptosporidium Treatment Credit Possible
Source Protection and Management Toolbox Options	
Watershed control program	0.5-log
Alternative source/intake management	No prescribed credit
Prefiltration Toolbox Options	
Presedimentation basin with coagulation	0.5-log
Two-stage lime softening	
Bank filtration	
Treatment Performance Toolbox Options	
Combined filter performance	0.5-log
Individual filter performance	0.5-log credit (in addition to 0.5-log combined performance filter credit)
Demonstration of performance	Credit at discretion of the State
Additional Filtration Toolbox Options	
Bag and cartridge filters	Up to 2- to 2.5-log
Membrane filtration (MF, UF, NF, RO)	Credit at discretion of the State
Second stage filtration	0.5-log
Slow sand filters	2.5-log
Inactivation Toolbox Options	
Chlorine dioxide	Log credit based on measured CT
Ozone	Log credit based on measured CT
UV	Log credit based on validated UV dose (reactor validation testing to establish UV dose and operating conditions)

proposed LT2ESWTR relating to this effort includes:

- Covering, treating, or implementing a risk management plan for uncovered finished water reservoirs. PWSs must notify the State if they use uncovered finished water storage facilities no later than April 1, 2008. PWSs must meet this requirement or be in compliance with a State-approved schedule for meeting these requirements no later than April 1, 2009.
- Disinfection profiling and benchmarking to assure continued levels of microbial protection while PWSs take the necessary steps to comply with new disinfection by-product standards.

Compliance Timeline

The standard compliance timeline for "Schedule 1" systems (those serving a population of ≥100,000) is detailed in Table TM6.9.

Table TM6.9: LT2ESWTR Schedule 1 Compliance Dates

July 1, 2006	Systems must submit their: Sampling schedule that specifies the dates of sample collection and location of sampling for initial source water monitoring to USEPA electronically; or Notify USEPA or the state of the system's intent to submit results for grandfathering data; or Notify USEPA or the state of the system's intent to provide at least 5.5-log of treatment for Cryptosporidium.
October 1, 2006	No later than this month systems must begin 24 months of source water monitoring.
December 1, 2006	No later than this date; systems must submit monitoring results for the data they want to have grandfathered.
December 10, 2006	System submits results for the first month of source water monitoring.
April 1, 2006	No later than this month, systems must notify the USEPA or the state of all uncovered treated water storage facilities.
September 2008	No later than this month, systems must complete their initial round of source water monitoring.
March 2009	No later than this month, filtered systems must report their initial bin classification to the USEPA or the state for approval.
April 1, 2009	No later than this date, uncovered finished water storage facilities must be covered, or the water must be treated before entry into the distribution system, or the system must be in compliance with a state-approved schedule.
March 31, 2012	Systems must install and operate additional treatment in accordance with their bin classification.
January 1, 2015	Systems must submit their sampling schedule that specifies the dates of sample collection and location of sampling for the second round of source water monitoring to the state.
April 1, 2015	Systems must begin their second round of source water monitoring. Based on the results, systems must re-determine bin classification and provide additional Cryptosporidium treatment, if necessary.

B.6.d Stage 1 Disinfectants/Disinfection Byproducts Rule

Stage 1 of the Disinfectants/Disinfection By-Products Rule (Stage 1 D/DBP Rule) was finalized on December 16, 1998, and became effective for public water systems serving more than 10,000 people on January 1, 2002. The Stage 1 D/DBP Rule is part of the Microbial Disinfectant Byproducts (M-DBP) cluster of rules. The intent of the M-DBP cluster is to balance the risk of microbial disease outbreaks against the risks associated with disinfection and their by-products.

The requirements of the Stage 1 D/DBP Rule are summarized in Table TM6.10. Under the Stage 1 D/DBP Rule, large surface water plants are required to take four samples per plant per quarter. At least 25 percent of these samples are to be taken from the locations representative of the maximum residence time with the remainder representing the average residence times. Compliance with the maximum residual disinfectant level (MRDL) is based upon a running annual average, computed quarterly.

Table TM6.10: Stage 1 D/DBP Rule MCL and MRDL

Constituent	Concentration (mg/L)	
	MCL	MRDL
Total Trihalomethanes (TTHM)	0.080	--
Haloacetic Acids (HAA5)	0.060	--
Bromate Ion (BrO3-)	0.010	--
Chlorite Ion (ClO2-)	1.0	--
Free Chlorine [1]	--	4.0
Chloramines [1,2]	--	4.0
Chlorine Dioxide	--	0.8

(1) As total chlorine.

(2) Sum of mono-, di-, tri-chloroacetic acids, and mono- and di-bromoacetic acids.

TTHM and HAA5 data for 2008 and 2010 are shown in Figures B.30 to B.33 in Appendix B. HAA5 values range between 20 and 40 µg/L leaving both plants and get as high as 50 µg/L in the distribution system. TTHM values range between 40 and 70 µg/L leaving both plants, and get just below the regulatory limit in the distribution system. At 1030 N 3rd St, TTHM was recorded to be 79 µg/L on 5/11/2010. These values are just below the regulatory limits outlined in Table TM6.10.

Disinfection By-Product Precursor Removal

In addition to establishing the MCLs and MRDLs, the Stage 1 D/DBPR requires the reduction of DBP precursors. The treatment technique specified is termed enhanced coagulation or enhanced softening and uses total organic carbon (TOC) as a surrogate for natural organic matter (a DBP precursor material). Source water TOC concentration of >2.0 mg/L triggers implementation of this treatment technique. The Rule specifies the percentage of influent TOC that must be removed based on the raw water TOC and alkalinity levels, as shown in Table TM6.11.

Table TM6.11: Stage 1 D/DBP Required Removal of TOC by Enhanced Coagulation

Raw Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0 to 60	>60 to 120	>120
>2.0 – 4.0	35.0%	25.0%	15.0%
>4.0 to 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Conventional treatment plants are required to monitor TOC concentrations by taking one "paired" sample per month. A paired sample consists of simultaneously measuring the TOC in a treated water sample (prior to the point of combined filter effluent turbidity monitoring) and the TOC in a source water sample (prior to any treatment). One source water alkalinity sample per month is also taken at the same time and location as the source water TOC sample. Reduced monitoring (per quarter) is permitted if the average annual treated water TOC is <2.0 mg/L for two consecutive years or <1.0 mg/L for one year. Compliance with the TOC requirement is calculated with a running annual average, computed quarterly.

Raw water TOC data for the Kaw WTP is shown in Figure B.7 and ranges between 4.0 and 9.5 mg/L. The raw water alkalinity, as shown in Figure B.5, ranges between 125 and 260 mg/L. As a result, 25 percent TOC reduction is required for most sampling periods. Raw water TOC for the Clinton WTP is shown in Figure B.16 and ranges between 3.2 and 6.0 mg/L. The raw water alkalinity, as shown in Figure B.14, ranges between 110 and 160 mg/L. The TOC and alkalinity conditions range over four requirements in Table TM6.11. The TOC reduction requirement for the Clinton WTP ranges between 15 and 35 percent, based on TOC and alkalinity.

The percentage reduction of TOC for the Kaw and Clinton WTPs is shown in Figure B.26. The daily TOC reduction ranges between 5 and 55 percent. The average TOC reduction for each month for the Kaw WTP ranges between 25 to 45 percent. The average TOC monthly TOC reduction for the Clinton WTP ranges between 25 and 35 percent. As a result, the Kaw and Clinton WTPs are in compliance with regards to TOC reduction.

Alternative Compliance

The IESWTR also provides alternative compliance criteria (to TOC removal) that are separate and independent of the Step 2 enhanced coagulation procedure and the enhanced softening alternative performance criteria, from the treatment technique requirements provided certain conditions are met:

- Source water TOC <2.0 mg/L based on monthly monitoring calculated quarterly as a running annual average of all measurements.
- Finished water TOC <2.0 mg/L based on monthly monitoring calculated quarterly as a running annual average of all measurements.
- Source water specific ultraviolet absorption (SUVA) is less than or equal to 2.0 L/mg-m based on monthly monitoring calculated quarterly as a running annual average of all measurements. SUVA is equal to UV absorption at 254 nm (UV254) divided by the dissolved organic carbon (DOC) concentration.
- Finished Water SUVA is less than or equal to 2.0 L/mg-m based on monthly monitoring calculated quarterly as a running annual average of all measurements.
- Source water TOC <4.0 mg/L; Source water alkalinity >60 mg/L as CaCO3; TTHM <0.040 mg/L; HAA5 <0.030 mg/L based on monthly monitoring for TOC and alkalinity or quarterly monitoring for TTHMs and HAA5, calculated quarterly as a running annual average of all measurements.
- TTHM <0.040 mg/L; HAA5 <0.030 mg/L based on monitoring for TTHMs and HAA5, calculated quarterly as a running annual average of all measurements.

Following a one-year monitoring period, systems that do not satisfy the TOC removal requirements or the alternative compliance criteria must conduct jar testing (Step 2) to determine alternative compliance criteria for TOC removal, if they are not practicing enhanced softening. Under the Step 2 enhanced coagulation protocol, the alternative enhanced coagulation compliance criteria for TOC removal are defined either as:

- The dose of coagulant that achieves the percent removal dictated by the TOC removal matrix.

- OR –

- The percent TOC removal occurring at the point of diminishing return (PODR) for the coagulant. The PODR is defined as the point on the TOC removal-vs-coagulant addition plot where the slope changes from greater than 0.3/10 (mg/L TOC removal / mg/L coagulant dose) to less than 0.3/10 and stays at less than 0.3/10 until the target pH is reached.

If softening systems cannot meet the Step 1 TOC removal requirements, they must meet one of the following three alternative enhanced softening compliance criteria based on monthly monitoring calculated quarterly as a running annual average of all measurements.

- Produce a finished water with a SUVA <2.0 L/mg-m;
- Remove a minimum of 10 mg/L magnesium hardness (as $CaCO_3$); or
- Lower alkalinity to less than 60 mg/L as $CaCO_3$.

B.6.e Stage 2 Disinfection/Disinfection By-Products Rule

The Stage 2 Disinfectants/Disinfection By-Products Rule (Stage 2 DBPR) was finalized in December 2005 and published in the Federal Register on January 4, 2006. The Stage 1 D/DBPR will remain in effect until compliance monitoring for the Stage 2 DBPR begins in 2012 (first for systems serving populations greater than 100,000).

All PWS serving populations greater than 500 people and using a primary disinfectant other than UV light are subject to the Stage 2 DBPR. The purpose of this Rule is to strengthen the Stage 1 D/DBPR requirements and reduce occurrences of disinfection by-products concentration spikes in distribution systems. The MCLs for TTHMs and HAAs remain the same as those in the Stage 1 D/DBP Rule (80 and 60 µg/L respectively), but the manner in which compliance is calculated has changed.

For Stage 2, the MCLs for TTHMs and HAAs must be met as a locational running annual average (LRAA) – the average concentration at each monitoring location, rather than as the running annual average (RAA) of the system as a whole. Furthermore, samples must be taken during peak months of TTHM and HAA occurrence. The new compliance requirements are meant to enforce a reduction of average DBP concentrations at peak locations and peak times. For the compliance calculation, samples are taken at each monitoring location. The LRAA is calculated as the average of the most recent sample and the three preceding samples.

Compliance monitoring under the Stage 2 DBP Rule is preceded by an Initial Distribution System Evaluation (IDSE) study to select site-specific optimal sampling points for capturing peak disinfection by-product concentrations. Current sampling locations are acceptable.

The IDSE requirements can be met by one of three different criteria as required by the Stage II Rule.

- Standard Monitoring Plan (SMP) – A distribution system sampling plan that has been developed by the USEPA and includes one year of sampling. The sampling requirements vary based on population served.
- System Specific Study (SSS) – The use of historical data that exceeds the SMP data requirements or the use of a calibrated hydraulic model and one round of sampling to determine compliance monitoring locations.
- 40/30 Certification – Two years of data that show that THM and HAA samples have never exceeded 40 µg/L and 30 µg/L respectively in the distribution system. If 40/30 certification is met, systems are not required to perform the IDSE.

After compliance monitoring begins, the Stage 2 DBPR requires the PWS to calculate operational evaluation levels (OEL) after every quarterly sample. The OEL is meant to prevent MCL violations by providing an early warning of possible future violations. If the OEL exceeds the MCL, the PWS must provide a report to the administering agency detailing the changes it is going to make in order to avoid an MCL violation.

Compliance Timeline

The standard compliance timeline for “Schedule 1” systems (those serving a population of ≥100,000 is detailed in Table TM6.12.

B.7 Unregulated Contaminant Monitoring (UCM)

EPA uses the Unregulated Contaminant Monitoring (UCM) program to collect data for contaminants suspected to be present in drinking water, but that do not have health-based standards set under the Safe Drinking Water Act (SDWA). The data assists in determining whether or not to regulate those contaminants.

Every five years EPA reviews the list of contaminants, largely based on the Contaminant Candidate List. The SDWA Amendments of 1996 provide for:

- Monitoring no more than 30 contaminants per 5-year cycle
- Monitoring only a representative sample of public water systems serving less than 10,000 people
- Storing analytical results in a National Contaminant Occurrence Database (NCOD)

Table TM6.12: DBPR2 Schedule 1 Compliance Dates

Compliance Date	Requirement
January 4, 2006	Systems must submit to the USEPA or state primacy agency either a: Standard monitoring plan (SMP), System-specific study (SSS) plan, or 40/30 certification (1)
October 1, 2007	Systems conducting SMP or SSS begin collecting samples in accordance with their approved plan.
September 30, 2008	No later than this date, systems conducting SMP or SSS complete their monitoring or study.
January 1, 2009	No later than this date, systems conducting SMP or SSS must submit their IDSE report.
April 1, 2009	Consecutive systems must begin monitoring for chlorine or chloramines as specified under the Stage 1 DBPR.
April 1, 2012	No later than this date, systems must: Complete their Stage 2 DBPR Compliance Monitoring Plan Begin complying with monitoring requirements
January 2013	Systems must begin complying with rule requirements to determine compliance with the operational evaluation levels for TTHMs and HAA5s.
(1) A system that during a specific time period has all individual Stage 1 DBPR1 compliance samples ≤0.040 mg/L for TTHM and 0.030 mg/L HAA5 and has no monitoring violations during that same time period.	

The UCM program progressed in several stages. The history of the UCM program includes:

- UCM Rounds 1 & 2 (1988-1997): State drinking water programs managed the original program and required public water systems (PWSs) serving more than 500 people to monitor contaminants.
- UCMR 1 (2001-2005): the SDWA Amendments of 1996 redesigned the UCM program to incorporate a tiered monitoring approach. The rule required all large PWS and a nationally representative sample of small PWSs serving less than 10,000 people to monitor the contaminants.
- UCMR 2 (2007-2010): EPA manages the second monitoring cycle. This monitoring cycle establishes a new set of unregulated contaminants.

EPA is requiring select public water systems (PWSs) to monitor for 25 chemicals using five different analytical methods. The UCMR2 contaminants are summarized below in Table TM6.13. All PWSs serving more than 10,000 people, and a representative sample of 800 PWSs serving 10,000 or fewer people, are required to conduct Assessment Monitoring (List 1) for 10 chemicals during a 12-month period during January 2008-December 2010. All PWSs serving more than 100,000 people, 320 selected PWSs serving 10,001 to 100,000 people, and 480 selected PWSs serving 10,000 or fewer people are required to conduct the Screening Survey (List 2) for 15 contaminants during a 12-month period during January 2008-December 2010.

Table TM6.13: UCMR 2 Contaminants

Assessment Monitoring List 1	**Screening Survey List 2**
Contaminant	Contaminant
Dimethoate Terbufos sulfone	Acetochlor Alachlor Metolachlor
Five Flame Retardants	Six Acetanilide Degradates
2,2’,4,4’-tetrabromodiphenyl ether (BDE-47) 2,2’,4,4’,5-pentabromodiphenyl ether (BDE-99) 2,2’,4,4’,5,5’-hexabromobiphenyl (HBB) 2,2’,4,4’,5,5’-hexabromodiphenyl ether (BDE-153) 2,2’,4,4’,6-pentabromodiphenyl ether (BDE-100)	Acetochlor ethane sulfonic acid (ESA) Acetochlor oxanilic acid (OA) Alachlor ethane sulfonic acid(ESA) Alachlor oxanilic acid (OA) Metolachlor ethane sulfonic acid(ESA) Metolachlor oxanilic acid (OA)
Three Explosives	Six Nitrosamines
1,3-dinitrobenzene 2,4,6-trinitrotoluene (TNT) Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	N-nitroso-diethylamine (NDEA) N-nitroso-dimethylamine (NDMA) N-nitroso-di-n-butylamine (NDBA) N-nitroso-di-n-propylamine (NDPA) N-nitroso-methylethylamine (NMEA) N-nitroso-pyrrolidine (NPYR)

UCMR2 contaminant data collected on May 13, 2009; August 4, 2009; November 11, 2009; and February 13, 2009 on the Clinton WTP finished water was below the detection limit for all samples collected. With the exception of NDMA, samples were also below the detection limit for the Kaw WTP. NDMA was detected between 0.0033 and 0.0041 µg/L in the Kaw WTP finished water on three of the four days sampled.

C. Potential Future Regulations

C.1 Contaminant Candidate List (CCL)

The EPA uses the Contaminant Candidate List (CCL) to prioritize research and data collection efforts in order to determine whether a specific contaminant should be regulated. The contaminants on the list are known or anticipated to occur in public water systems, but are currently unregulated. The EPA periodically publishes the CCL and decides whether to regulate at least five or more contaminants on the list (called Regulatory Determinations). These new rules will further strengthen existing drinking water standards and thus enhance public health protection for many water systems.

The first CCL of 60 contaminants was published in March 1998. In February 2005, the EPA published the second CCL of 51 (of the original 60) unregulated contaminants from the first CCL, including nine microbiological contaminants and 42 chemical contaminants or contaminant groups. The microbiological contaminants included cyanobacteria, other freshwater algae, and their toxins.

The EPA announced the third draft of the Drinking Water Contaminant Candidate List (CCL 3) in February 2008. It includes 116 contaminants, including 104 chemicals or chemical groups and 12 microbiological contaminants. Several new chemical contaminants were added to the list, including three cyanotoxins (Anatoxin-a, Microcystin-LR, and Cylindrospermopsin).

CCL3 is the first CCL to use a process for screening contaminants for the list based on a formal National Drinking Water Advisory Council (NDWAC) recommendation. The USEPA also stated that the CCL3 incorporated recommendations from different groups, including the American Metropolitan Water Agencies (AMWA), American Waterworks Association (AWWA), National Research Council, and the National Drinking Water Advisory Council. AMWA recommended that three nitrosamines, N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA) and N-nitrosodi-n-propylamine (NDPA) be added to the list. Their letter stated that as systems turn to chloramination as a result of the Stage 2 MDBP rules, understanding more about these and other nitrosamine DBPs are critical, since their occurrence in drinking water may increase.

NDMA

NDMA is part of the Nitrosamine family of N-DBPs, where the characteristic functional group is nitrogen based. The family includes N-nitrosodiethylamine (NDEA), N-nitrosodimethylamine (NDMA), N-nitroso-di-n-butylamine (NDBA), N-nitroso-di-n-propylamine (NDPA), N-nitrosomethylethylamine (NMEA), and N-nitrosopyrrolidine (NPYR). NDMA is the most frequently found compound, and as a result, the most studied. Research studies show that NDMA is formed during the chloramination of natural waters with organic matter. Toxicity studies indicate that the cancer potencies are several orders of magnitude higher than TTHM and HAA5, resulting in a lifetime cancer risk at low ng/L levels.

NDMA was detected in the Kaw WTP finished water on three of four sampling days. The sample results are shown in Figure B.36 in Appendix B and ranged between 0.0033 and 0.0041 µg/L. The fourth sample was below the detection limit of 0.002 µg/L (2 ng/L). The suggested regulatory MCL for NDMA is between 2 and 10 ng/L.

The organic nitrogen-containing compounds that might act as precursors for nitrosamine formation during chloramination are numerous. Removal of these precursors prior to chloramination is required to reduce NDMA formation. DBP reduction strategies typically include improved coagulation, PAC, GAC, and preoxidation.

The percent of DOC reduction for the Kaw and Clinton Plant for 2010 is shown in Figure B.29 in Appendix B. The treatment process is able to remove between 20 and 30 percent of the DOC at both plants. While improving DOC reduction has been shown to reduce chlorinated disinfection byproducts, it is still unclear how DOC reduction will impact NDMA formation, with some studies showing minimal improvement.

Like other raw water constituents, adsorption of NDMA precursors onto activated carbon strongly depends on the chemical structure of the compound, hydrophobicity, and Kow (octanol water partitioning coefficient). Overall, NDMA precursors adsorb very well onto activated carbon. Some studies have shown that NDMA formation potential was reduced with PAC addition. Pre-oxidation of NDMA precursors with ozone and chlorine dioxide can also significantly reduce NDMA formation potential, while free chlorine will have minimal impact.

C.2 Perchlorate Regulations

Perchlorate was absent from the CCL2 list, but included in the draft CCL3 to determine if it would require future regulations. In 2008, USEPA staff indicated that federal regulation under the current administration was unlikely. USEPA, however, continued to collect data on total perchlorate exposure, including the release of the FDA’s Total Diet Study. Legislation that would provide USEPA with two-and-a-half years to promulgate a final national drinking water regulation for perchlorate was approved by a House subcommittee in early November 2007 (H.R. 1747) would require USEPA to propose a perchlorate MCL one year after the bill's enactment and promulgate a final national regulation 18 months thereafter.

On January 7, 2011, the Office of Environmental Health Hazard Assessment (OEHHA) released a draft public health goal (PHG) of 1 part per billion (ppb) for perchlorate in drinking water. The proposed goal would revise the existing PHG for perchlorate, which was set at 6 ppb in 2004. Release of the proposed revision begins a 45-day public comment period.

On February 2, 2011, EPA Administrator Lisa Jackson announced in a press release and in her testimony to the Senate Committee on Environment and Public Works that the agency will move forward to develop a regulation for perchlorate in drinking water. The decision to undertake a first-ever national standard for perchlorate reverses a decision made by the previous administration and comes after Administrator Jackson ordered EPA scientists to undertake a thorough review of the emerging science of perchlorate. EPA will propose the perchlorate standard within 24 months.

Perchlorate is both a naturally occurring and man-made chemical, and scientific research indicates that it may impact the normal function of the thyroid, which produces important developmental hormones. Thyroid hormones are critical to the normal development and growth of fetuses, infants and children. Based on this potential concern, EPA will move forward with proposing a formal rule. This process will include receiving input from key stakeholders as well as submitting any formal rule to a public comment process.

This regulation will likely have minimal impact on the Kaw and Clinton WTPs.

C.3 Volatile Organic Compounds

On February 2, 2011, EPA Administrator Lisa Jackson announced that the agency will move toward establishing one drinking water standard that will address a group of up to 16 carcinogenic VOCs, including trichloroethylene (TCE), tetrachloroethylene (PCE) and other regulated and unregulated contaminants that are discharged from industrial operations. The VOC standard will be developed as part of EPA's new strategy for drinking water, announced by the administrator in March 2010. A key principle of the strategy is to address contaminants as groups rather than individually in order to provide public health protections more quickly and also allow utilities to more effectively and efficiently plan for improvements.

Data collected in 2009 and 2010 for the Kaw and Clinton WTPs showed non-detect for each VOC sample. As a result, this regulation will likely have minimal impact on the Kaw and Clinton WTPs.

* * * * *

Technical Memorandum No. 7
Process Evaluation

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
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City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 7

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A. General

The purpose of this chapter is to provide a summary of the current treatment process of the Kaw WTP. This performance assessment examines each unit process and its ability to meet current and future water quality goals, comply with applicable drinking water regulations, and consider expansion. The process evaluation identifies treatment limitations, additional testing that may be required, and potential modifications to the existing treatment process and/or addition of new unit processes required to achieve additional plant capacity.

Regulatory requirements from KDHE's minimum design standards entitled "Policies, General Considerations, and Design Requirements for Public Water Supply Systems in Kansas, 2008 edition are used for the evaluation. The KDHE recommendations were also compared with the engineering recommendations from the Standards for Water Works 2007 Edition (aka 10 State Standards) and drinking water industry recommendations.

A.1 Background

The Kaw WTP was constructed in 1917 and included a lime mixing basin, two alum coagulation basins, aeration, primary settling, and the four original filters. The plant has been through numerous expansion and improvement projects through the years (1926, 1954, 1958, 1967, 1971, 1988, and 2001), with some areas being modified through several improvement projects. For example, the 1926 expansion included a new primary settling basin and converted the existing primary settling into a secondary settling basin. In 1954, the primary settling basin was converted into a pre-settling basin, and the secondary settling basin was converted into a clearwell. The 1954 improvements project also added the first primary and secondary settling basins, two new filters, and a new chemical building. Two new secondary settling basins and two additional filters were built during the 1958 plant expansion. A presedimentation basin and CO_2 equipment were added in 1967, with flume repairs, basin rehabilitation, and new equipment added during the 1971 and 1989 improvement projects. A carbon contact basin was added in 2001 by retrofitting the existing pre-settling basin.

A.2 Water Quality

The Kaw WTP raw water supply includes surface water from the Kansas River with the potential to provide a small volume of groundwater from the Kansas River alluvium. The maximum annual water rights from both sources total 22.4 MGD.

Kaw WTP raw water data between January 2008 and December 2010 is summarized in Table TM7.1. The daily data are shown in Figures B.1 through B.7 of Appendix B. The surface water can be characterized as high turbidity with high variability (between 6 and 2,427 ntu), high hardness and alkalinity, moderate to high iron, and moderate manganese.

Figure B.24 in Appendix B shows the Kaw raw water TOC (total organic carbon) varies between 3.3 and 10.2 mg/L, which is significantly higher than TOC for the Clinton WTP, which typically ranges between 4 and 5 mg/L. Figure B.27 shows the DOC (dissolved organic carbon) is also variable, ranging between 2.9 and 7.4 mg/L, with an average value of 5.0 mg/L. As shown in Figure B.28, approximately 80 to 95 percent of the Kaw raw water TOC is DOC. The wide range in turbidity, TOC, and DOC in the Kansas River can make this source difficult to treat.

Table TM7.1: Kaw WTP Raw Water Quality (January 2008 – December 2010)

Parameter	Units	Range	Average
Flow	MGD	3 – 11.5	5.13
Turbidity	Ntu	6 – 2,427	145
Temperature	degrees C	1.5 – 28.8	15.0
pH	s.u.	7.2 – 8.8	8.1
Total Alkalinity	mg/L as $CaCO_3$	119 – 262	191
Total Hardness	mg/L as $CaCO_3$	148 – 442	252
Iron*	mg/L	3 – 11	5.2
Manganese*	mg/L	0.13 – 0.55	0.33
TOC *	mg/L	3.3 – 10.2	5.8
DOC *	mg/L	2.9 – 7.4	5.0

* 2010 data only

A.3 Finished Water Goals

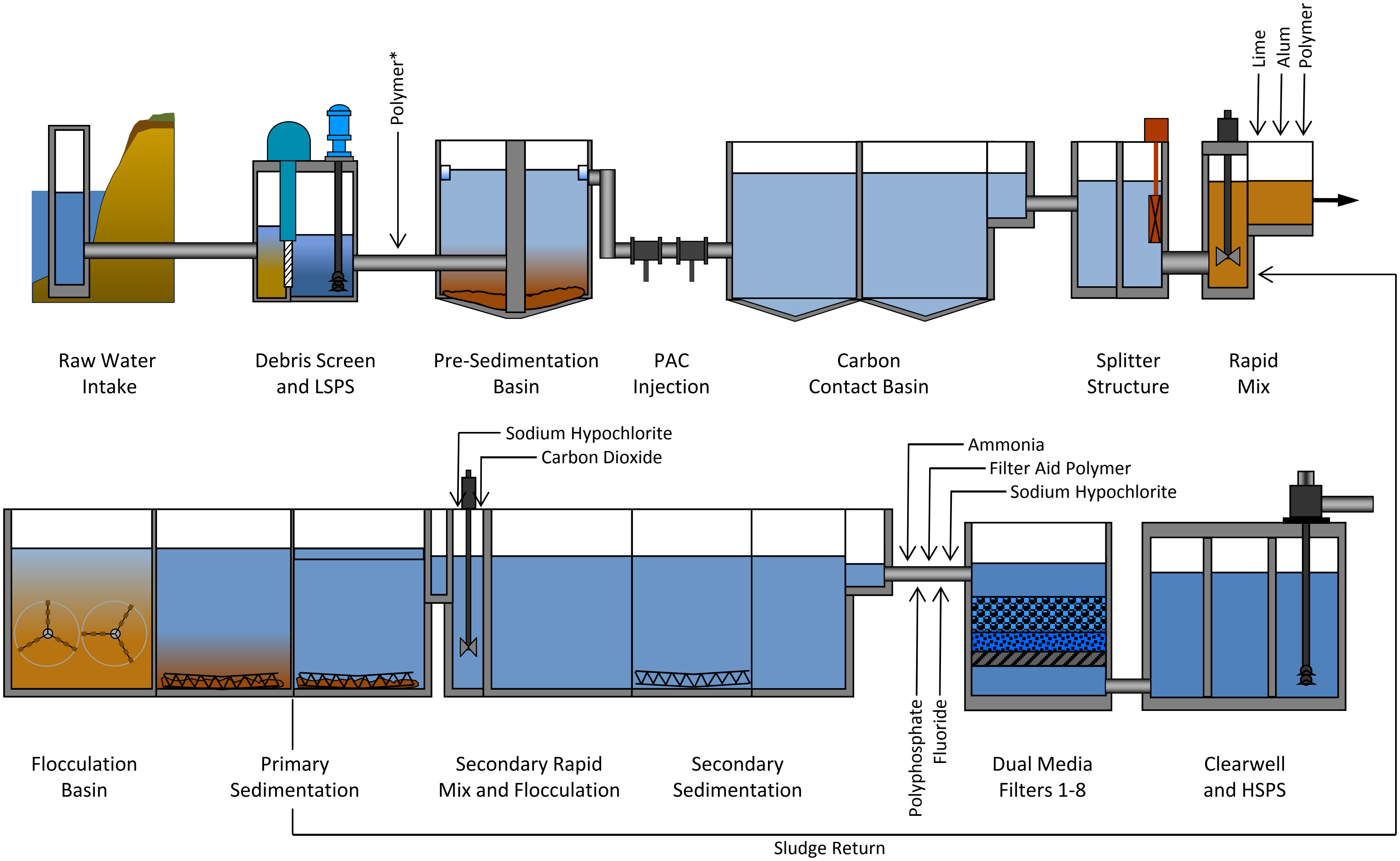
Water treatment plants must satisfy existing water quality regulatory standards and anticipate future water quality standards that may be more stringent than the existing standards. Table TM7.2 lists the key finished water quality goals for the Kaw WTP. Some of the parameters listed, such as pH and alkalinity, are not primary drinking water standards but are included because they affect finished water stability and are of a concern with respect to the aesthetic quality of the distribution system water.

Table TM7.2: Finished Water Quality Goals

Parameter	Goal	Regulatory Limit
Filter Effluent Turbidity (combined filter effluent)	$\leq$ 0.1 NTU for 95% of readings (Not to exceed 0.3 NTU)	$\leq$ 0.3 NTU for 95% of readings (Not to exceed 1 NTU)
Filter Effluent Particle Counts (individual filter)	$\leq$ 10 particles/mL for particles from 2 to 15 µm in diameter	N/A
TOC removal through process	Equivalent or better than the existing standard for conventional treatment.	25% depending upon TOC monthly average.
Pathogen Inactivation:		
Giardia	$\geq$ 3-log removal/inactivation	3-log removal/inactivation
Cryptosporidium	$\geq$ 3-log removal/inactivation	2-log removal/inactivation
Viruses	$\geq$ 4-log removal/inactivation	4-log removal/inactivation
pH	8.0- 8.5 s.u.	6.5 -8.5 s.u.
Alkalinity	$\geq$ 60 mg/L as $CaCO_3$	Lead and Copper Stability
TTHM	$\leq$ 60 µg/L	80 µg/L
HAA5	$\leq$ 40 µg/L	60 µg/L
Taste and Odor	No objectionable taste and odor based upon Flavor Profile Analysis	N/A

A.4 System Overview

The Kaw WTP is a lime softening and conventional plant that includes presedimentation, carbon contact basin, primary treatment (rapid mix, flocculation, and sedimentation), secondary treatment (rapid mix and sedimentation), dual media filtration, primary disinfection with free chlorine, and secondary disinfection with monochloramine. A process schematic is shown in Figure TM7.1. Kaw WTP performance data is shown in Appendix C.



Note:

*Can feed polymer before pressed, but only in very high turbidity (over 400 ntu).

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Figure TM7.1

Lawrence, Kansas

Kaw WTP Process Schematic

B. Process Evaluation

B.1 Presedimentation Basin

The presedimentation basin is being utilized to provide contact time for settling of grit, sand, and larger fraction of suspended solids. Approximately 0.5 mg/L of Nalco 8102 plus cationic polymer (low-med molecular weight, 20 percent active) is added at the entrance to the basin and varies with the solids loading from the river. The basin does not have a mechanical mixer and relies on the hydraulic action of the basin to provide the mixing energy.

The basin is a circular, open top, cast in place concrete basin with a 120 foot diameter with V-notch weirs around the perimeter at WSE of 866.33 foot. The floor slab starts at 853.67 foot (12.67 foot depth) and slopes downward at 1:12 for the outside 32 foot to 851.00 foot (15.33 foot depth). The slope then increases to 2:12 between 28 foot and 10 foot radial distance to an elevation of 847.67 foot (18.67 foot depth). The volume can be calculated by adding the base cylinder with the two conical frustums created by the sloping floor slab. The total volume was calculated to be 1.2 million gallons.

B.1.a State Requirements

Chapter V, Section E of KDHE’s minimum design standards (2008 edition) state that waters containing high turbidity, gravel, sand, or silt should have pretreatment. High turbidity is typically defined as raw water in excess of 1,000 NTU. If any of these criteria are met, presedimentation, with or without the addition of coagulation chemicals, should be used and requires the following:

- Detention time – Two hours for Kansas River
- Overflow Rate – 3,500 gpd/sqft (2.4 gpm/sqft)
- Weir Rate – 20,000 gpd/ft (13.9 gpm/ft)
- Basin design – Hopper bottoms or be equipped with continuous mechanical sludge removal apparatus, and provide arrangements for dewatering
- Inlet – Incoming water shall be dispersed across the full width of the line of travel as quickly as possible; short-circuiting must be prevented
- Bypass – Provisions for bypassing presedimentation basins shall be included

B.1.b Process Limitations

Figure TM7.2 provides a summary of the hydraulic retention time (HRT) for the presedimentation basin at various plant flows. Based on the KDHE requirement of two hour detention time, the presedimentation basin is limited at 14 MGD. One could argue that contact time is required to disperse the polymer into

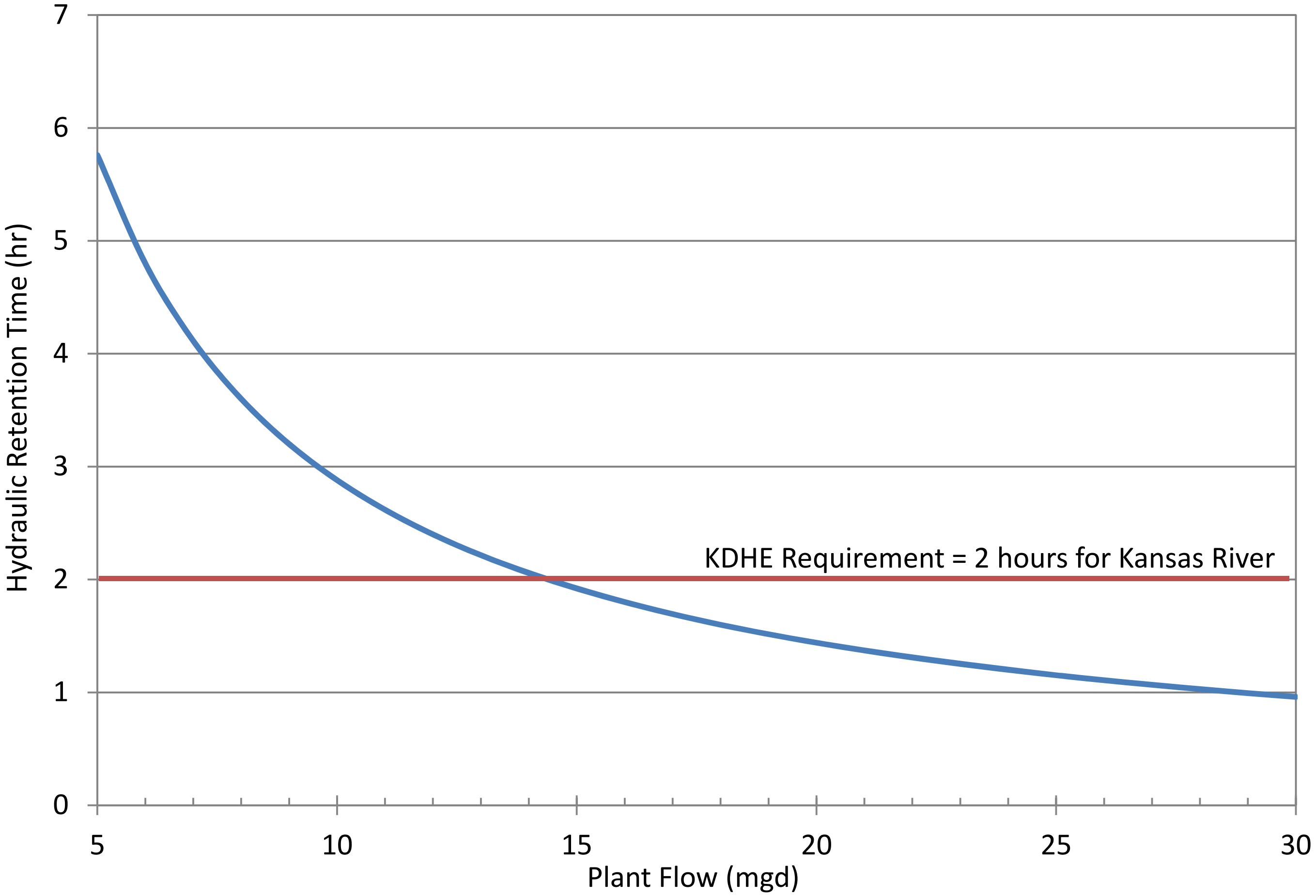

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Figure TM7.2

Lawrence, Kansas

Presedimentation Basin
Hydraulic Retention Time

solution and coagulate the suspended solids and organics into settleable flocs. However, HRT is not the primary process parameter that drives settling. Once the flocs are formed, which typically takes between 5 and 20 minutes, a more useful parameter for particle setting is the basin overflow rate, measured in gpm/sqft.

Overflow rate can be used to determine the size of particles that will be removed through settling. Small particles and flocs that form from the polymer addition with a settling velocity less than the overflow rate will not be removed during this process. These particles may be removed during primary treatment and/or filtration. The presedimentation basin overflow rate for various plant flows is shown in Figure TM7.3. Based on the KDHE recommended overflow rate of 2.4 gpm/sqft, the presedimentation basin is limited at 38 MGD. Based on the general engineering recommendation of 1.5 gpm/sqft, the presedimentation basin is limited at 25 MGD.

The polymer addition will bridge a portion of the smaller particles to form larger particles and help that fraction settle-out. However, it will not account for much TOC reduction or offer significant process improvements at such low dose.

This is especially important considering the impact it may have on rapid mix. Once polymer is added and flocs begin to form, additional mixing through process piping will sheer flocs. Once the flocs are sheered, it is very difficult to get them to form in the downstream flocculation process. It is possible that some particles are formed, sheered into colloidal particles, and pass through flocculation, sedimentation, and even filtration.

Bench scale testing is recommended to optimize polymer addition and mixing requirements. Jar testing will determine if polymer addition is even required at this location, or if increasing the dose and mixing energy might offer increased turbidity reduction or improvements to primary treatment.

B.1.c Zebra Mussels

The Kaw WTP is very susceptible to zebra mussel infestation and typically requires cleaning on an annual basis. While zebra mussels have been a problem in recent years, a crib inspection did not find zebra mussels during the summer of 2011.

Presently, the Kaw WTP does not have facilities in place for controlling zebra mussels at the intake or within the raw water pipeline. Zebra mussel infestation can reduce intake capacity and cause taste and

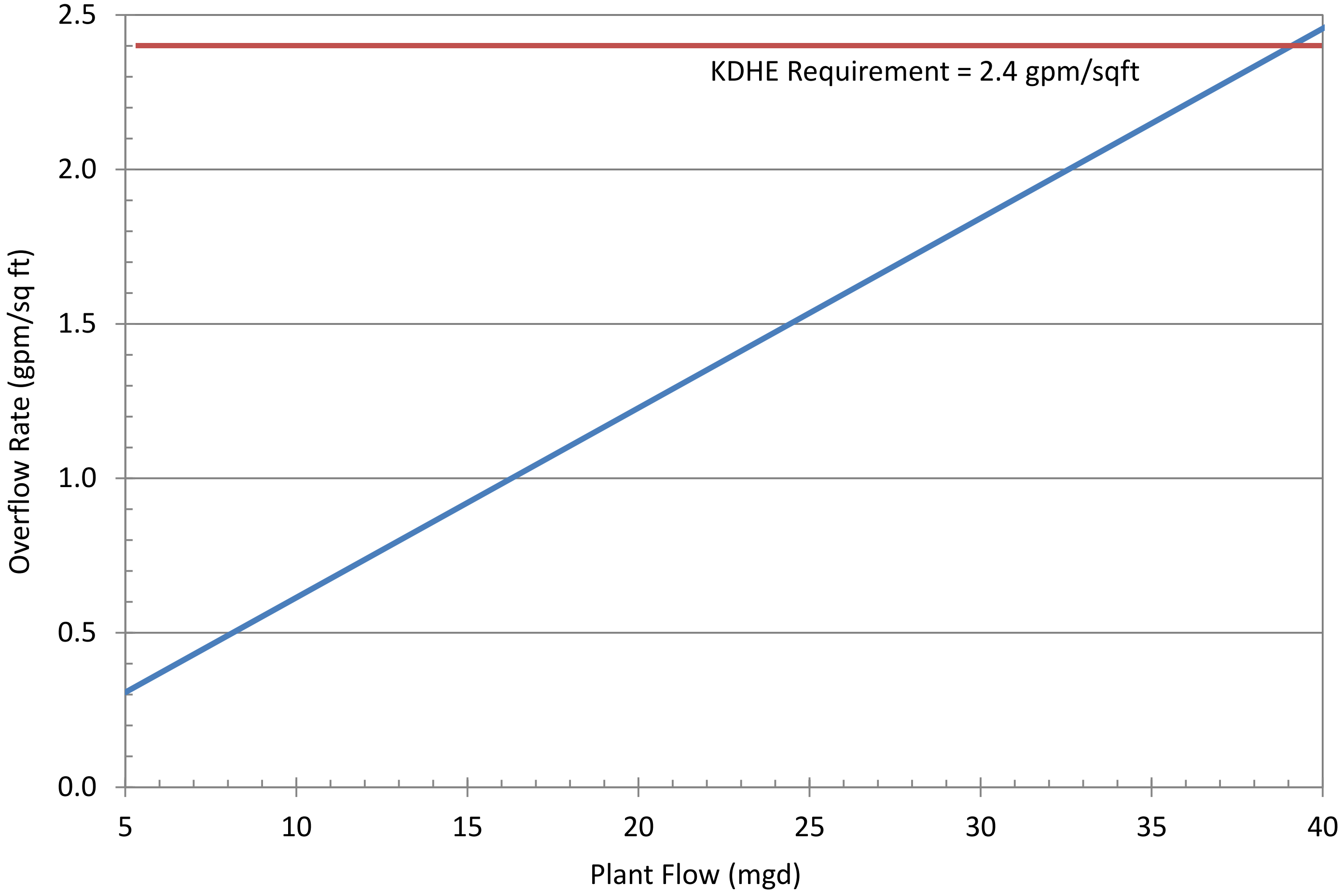

Figure TM7.3

Lawrence, Kansas

Presedimentation Basin Overflow Rate

odor problems in the finished water. Similarly, algae can also cause taste and odor problems and increased turbidity levels in the finished water. A commonly used and successful method to control the growth of zebra mussels is the addition of a disinfectant (i.e. chlorine, potassium permanganate, hydrogen peroxide, etc.) at the raw water inlet. At many water treatment facilities with similar zebra mussel infestation, the addition of chemical feed lines mounted at the intake structure and inside the intake pipelines provides the plant staff with the ability to feed chemicals for zebra mussel and algae control.

Potential Control Measures

A commonly used and successful method to control the growth of zebra mussels is the continuous addition of an oxidant (i.e. chlorine, potassium permanganate, chlorine dioxide, etc.) or copper solution at the inlet. The City of Oklahoma City, for example, uses hydrogen peroxide for algae and zebra mussel control at the intake to the Overholser WTP. When released into water, hydrogen peroxide can react to form hydroxyl radicals, an extremely powerful oxidant that has been proven to control the formation of zebra mussels and provide some ability to control algae. The residual will likely be carried through the plant until it quenches with chlorine residual.

The City of Wichita recently selected a copper ion solution to control zebra mussel growth around the intake. While this has been proven to be very effective for zebra mussels, it does nothing for algae or taste and odor, which requires a disinfectant such as ozone, chlorine dioxide, or free chlorine.

To control the growth of algae within the treatment process, a small liquid sodium hypochlorite feed system to provide a free chlorine residual of 0.2 to 0.5 mg/L throughout problem areas could be used, but will likely increase disinfection byproduct formation. Another option could be to use a chlorine dioxide system. Chlorine dioxide has also been proven effective at controlling algae in water treatment processes[1]. Chlorine dioxide is believed to attack the pyrole ring of the chlorophyll, which cleaves the ring and leaves the chlorophyll inactive. Since algae cannot function without chlorophyll metabolism, they are destroyed. The reaction of chlorine dioxide with algae and its essential oils forms tasteless, odorless substances. In addition, chlorine dioxide does not form the regulated carcinogenic compounds known as TTHMs and HAA. It has been reported that even small amounts of chlorine dioxide (1.0 mg/L), are sufficient to inhibit the formation of THMs by as much as 20 percent. This is achieved by reacting with certain THM precursor compounds and rendering them unreactive or unavailable for THM production[2]. A drawback to

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[1] Demers, L.D. and R. Renne, 1992 Alternative Disinfectant Technologies for Small Drinking Water Systems.

[2] Miltner, R. The effect of Chlorine Dioxide on THM in Drinking Water. Masters thesis, University of Cincinnati.

utilizing chlorine dioxide would be the dose limitations due to formation of the regulated constituent chlorite ion.

Another possible means to control mussel deposition on the intake screens would be to apply a specialized coating to the intake screens, or replace the copper-nickel alloy screens. Specialized coatings can be effective in controlling zebra mussels in raw water systems. Traditional antifouling coatings leach an aquatic toxin, typically cuprous oxide, into the water to repel fouling organisms, such as the zebra mussel. These products are effective for approximately two to five years. Foul-release coatings create a smooth surface that minimizes the adhesion of the zebra mussel. These products are considered more environmentally sound because they do not leach aquatic toxins. However, they are subject to abrasion and therefore their use should be limited to areas that are not susceptible to damage caused by ice and debris.

Thermal-spray coatings are metallic coatings such as zinc, copper, and brass can also be used for preventing zebra mussel attachment in influent screens. Thermal-sprayed coatings are applied by melting a wire feedstock and propelling the molten droplets in a stream of compressed air on the surface to be treated. These coatings repel zebra mussels through the slow dissolution of metal ions into the water. Zinc thermal spray also provides excellent corrosion resistance on steel surfaces. Copper and brass should never be applied directly to steel because the steel will sacrificially corrode. Thermal spray coatings should not be used on nonferrous metal substrates. With proper surface preparation, they may be used on concrete. Thermal spray coatings are potentially the most durable and longest lasting zebra-mussel repellent coating.

B.2 Carbon Contact Basin

The carbon contact building was added in 2001 by retrofitting the existing pre-settling basin. The 30-inch line from the presedimentation basin was increased to 36-inch where powdered activated carbon (PAC) can be injected in two locations.

The plant historically fed 12 to 13 mg/L of PAC from Cal-Pacific Carbon. In November 2010, the plant switched to Calgon PAC at a feed rate between 8 to 9 mg/L.

The primary characteristic of PAC that differentiates it from granular activated carbon (GAC) is its small particle size, which offers a higher surface to volume ratio. PAC is porous, like a solid sponge, with a very large internal surface area that allows it to adsorb organic compounds more rapidly than large particles. The primary advantages to using PAC are the low capital costs, ability to alter the PAC dose as the water quality changes, and able to discontinue its use in the absence of target contaminant.

PAC offers several process benefits and can be used for the following:

- Taste and odor abatement
- DOC adsorption
- Reduce chlorinated disinfection byproduct formation
- Removal of many organic emerging contaminants, including pesticides, pharmaceutically active compounds, and endocrine disrupting compounds
- Removal of algal toxins (i.e. microcystins)

The removal efficiency for each process goal is dependent on the type of carbon used, carbon dose, contact time, and competitive adsorption (by molecules with higher affinity). The optimal process performance, where most of the benefit of using PAC is realized, requires between one to two hours of contact time. Decreasing the contact time will translate to either adding more PAC to achieve the same result or a decrease in process performance.

A summary of the hydraulic retention time (HRT) for the carbon contact basin at various plant flows is shown in Figure TM7.4. A plant flow of 12 and 24 MGD corresponds to an HRT of 1.0 and 0.5 hours, respectively. While at least one hour is optimal, 50 to 80 percent of the process benefits can be achieved within 30 minutes of contact time, as discussed in the following subsections. Bench scale testing is required to determine the minimum PAC dose and contact time required to achieve the target process goals.

Where to add PAC is also important. Inadequate taste and odor control removal typically occur when the raw water application (i.e. either pretreatment basin or carbon contact basin) is bypassed or when PAC is added directly in the rapid mix basins. These observations are reinforced by the results of an American Water Works Association Research Foundation (AWWARF) project conducted in 2000. This project (AWWARF Project #909) examined several utilities to evaluate differences in PAC performance for taste and odor removal. The results indicate that the optimal conditions for taste and odor removal occur when PAC was added with sufficient contact time prior to coagulation, with greater removals occurring with longer PAC pre-coagulation contact times.

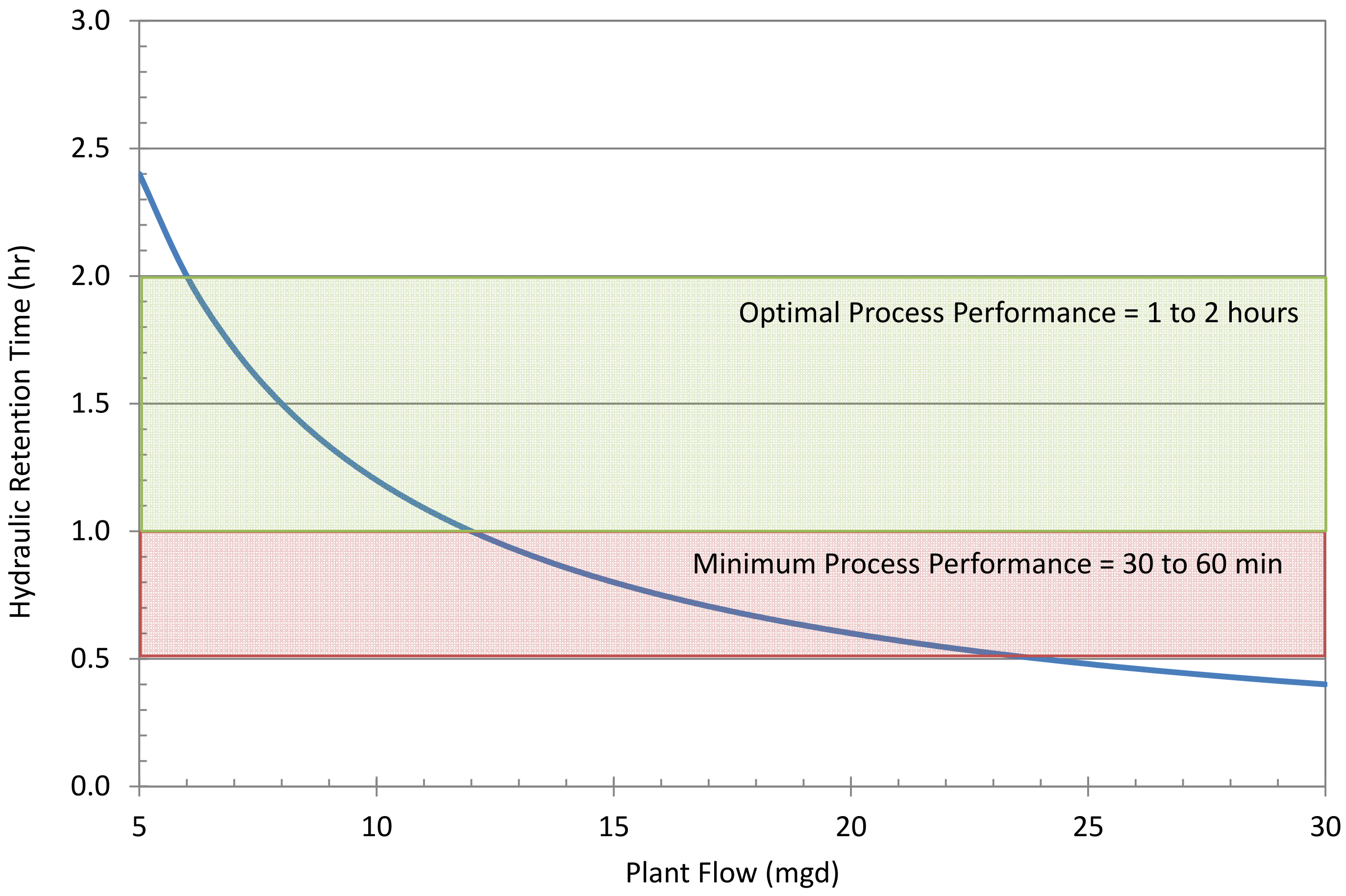

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Figure TM7.4

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Carbon Contact Basin
Hydraulic Retention Time

B.2.a Taste & Odor Abatement

PAC can be added to the carbon contact basin for control of taste and odor. The carbon contact basin provides an ideal mixing environment and contact time for the PAC to adsorb the taste and odor compounds present in the raw water. While many compounds can tribute to taste and odor, MIB and geosmin are among the more difficult to remove, and coincidently, the most easily to detect. Concentrations between 7 and 12 ng/L have been reported to be the minimal threshold that will typically trigger earthly and musty customer complaints. A typical PAC dose of 10 mg/L can be effective for many common and more easily removed taste and odor compounds. More resistant compounds, such as MIB and geosmin, require higher doses, usually between 15 and 30 mg/L.

Contact Time

Significant research conducted during the last twenty years have shown that a single isotherm may be sufficient to yield the necessary information to determine a particular carbon's feasibility for each target taste and odor compound[3] as shown in Figure TM7.5. Recent studies with other drinking water utilities have shown that the percent removal of taste and odor compounds, in a particular natural water at equilibrium for a given carbon dose, is independent of its initial concentration. In addition, a minimum contact time is required to achieve the point of diminishing returns where additional contact time will asymptote to a maximum percent removal. Thus, for a given carbon dose, the amount of trace compound adsorbed is directly proportional to its initial concentration after a minimum contact time is achieved. While the required contact time varies for each water source and target compound, between 30 and 60 minutes is typically required to get 80 percent of the maximum removal of most taste and odor compounds. In other words, if a maximum 70 percent removal is achieved after four hours, 50 and 60 percent removal can be expected at 40 and 60 minutes, respectively.

Carbon Dose

Recent bench scale testing conducted on raw and settled water spiked with MIB and Geosmin for another drinking water utility is shown in Figure TM7.6. The data shows that PAC dose up to 50 mg/L can be required to achieve significant removals of MIB and Geosmin. The removal is also dependent on competitive adsorption by natural organic matter that may be present. Research[4] has found an increased affinity for certain types of organic matter (i.e. lower MW organic acids) as the pH of the water is

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[3] Gillogly, T. E. T et al. (1998) Kinetic and Equilibrium Studies of ^{14}C-MIB Adsorption on PAC in Natural Water. *Journal of the American Water Works Association*, 90:1:116

[4] Weber W. J. Jr. et al. (1983) Adsorption of Humic Substances: the Effects of Heterogeneity and System Characteristics. *Journal of the American Water Works Association*, 75:12:612-619

lowered due to a reduction of the negative charges on both the organic matter (protonation) and the PAC[5]. In this case, the neutral MIB molecule would be substituted with the organic matter on the surface of the PAC particle.

Manatee County Public Works in Bradenton, Florida is a leading utility for taste and odor research in the United States. Manatee County utilizes PAC to control MIB and Geosmin through addition to the raw water prior to coagulation with alum. Manatee Co. raw water is characterized by high TOC (12 to 24 mg/L), high color (100 to 400 PCU), and low alkalinity and hardness (11 to 45 mg/L as $CaCO_3$). The removal curves for five different carbons tested by Manatee, Co for Geosmin (solid curves) are shown in Figure TM7.7. These data are also compared to the results from three other utilities (hollow symbols). As shown in Figure TM7.7, the removal efficiencies vary significantly based on raw water, natural organic matter, and carbon type. As a result, bench scale testing will be required to determine the required dose to achieve adequate taste and odor reduction for each target compound.

B.2.b Adsorption of Dissolved Organic Carbon

RO and nanofiltration membranes provide the ultimate barrier for most organic contaminants.
For maximum removal of organic pollutants, a multi-barrier treatment train containing membranes, activated carbon, and a strong oxidant (i.e., ozone) would be ideal. However, RO and nanofiltration membranes are expensive and require significant capital investment.

If moderate levels of removal are acceptable, studies have shown PAC and GAC to be effective for removing DOC and the majority of organic contaminants found in raw water supplies. Hydrophobic compounds are more readily absorbed by activated carbon than hydrophilic compounds. In general, compound removal efficiencies by PAC and GAC are closely related to the compound’s octanol-water partition coefficient (Kow), a physical parameter that is readily available in the literature. Kow is the ratio of the concentration in octanol and water at equilibrium. This relationship can be used to correlate a compounds fate in the environment and tendency to partition to organic material, GAC and PAC.

Figure B.24 in Appendix B shows high variations of raw water TOC. The suspended fraction of TOC that is not dissolved can be removed through coagulation, flocculation, sedimentation, and filtration. Figure B.28 shows that between 80 and 95 percent of the raw water TOC is in the form of DOC. DOC requires

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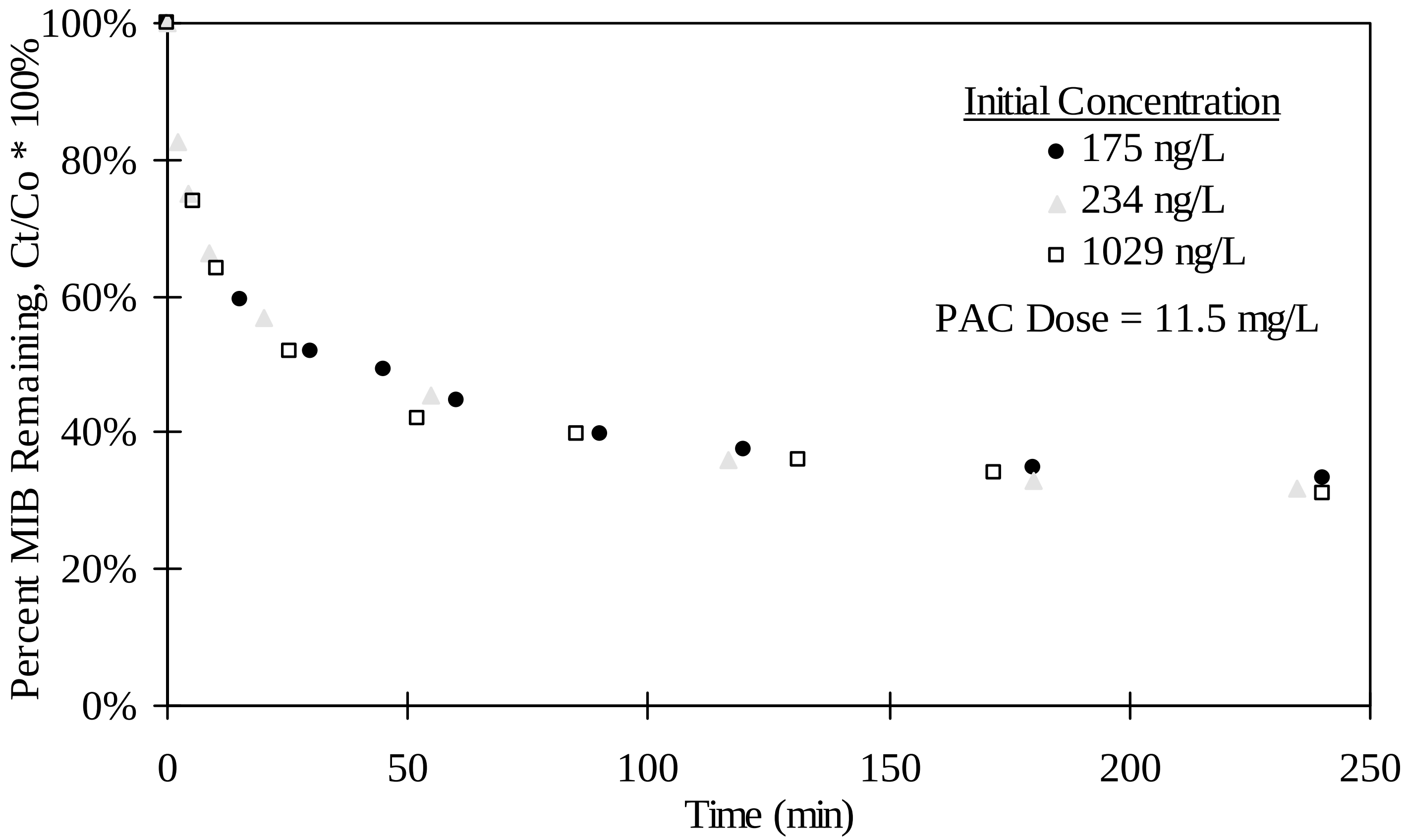
[5] Newcombe, G.C. et al. (1994) Adsorption onto Activated Carbon: Electrostatic and Non-Electrostatic Interactions. *Water Supply*, 14:129.



Note: Figure courtesy of Gillogly et. al (1998)

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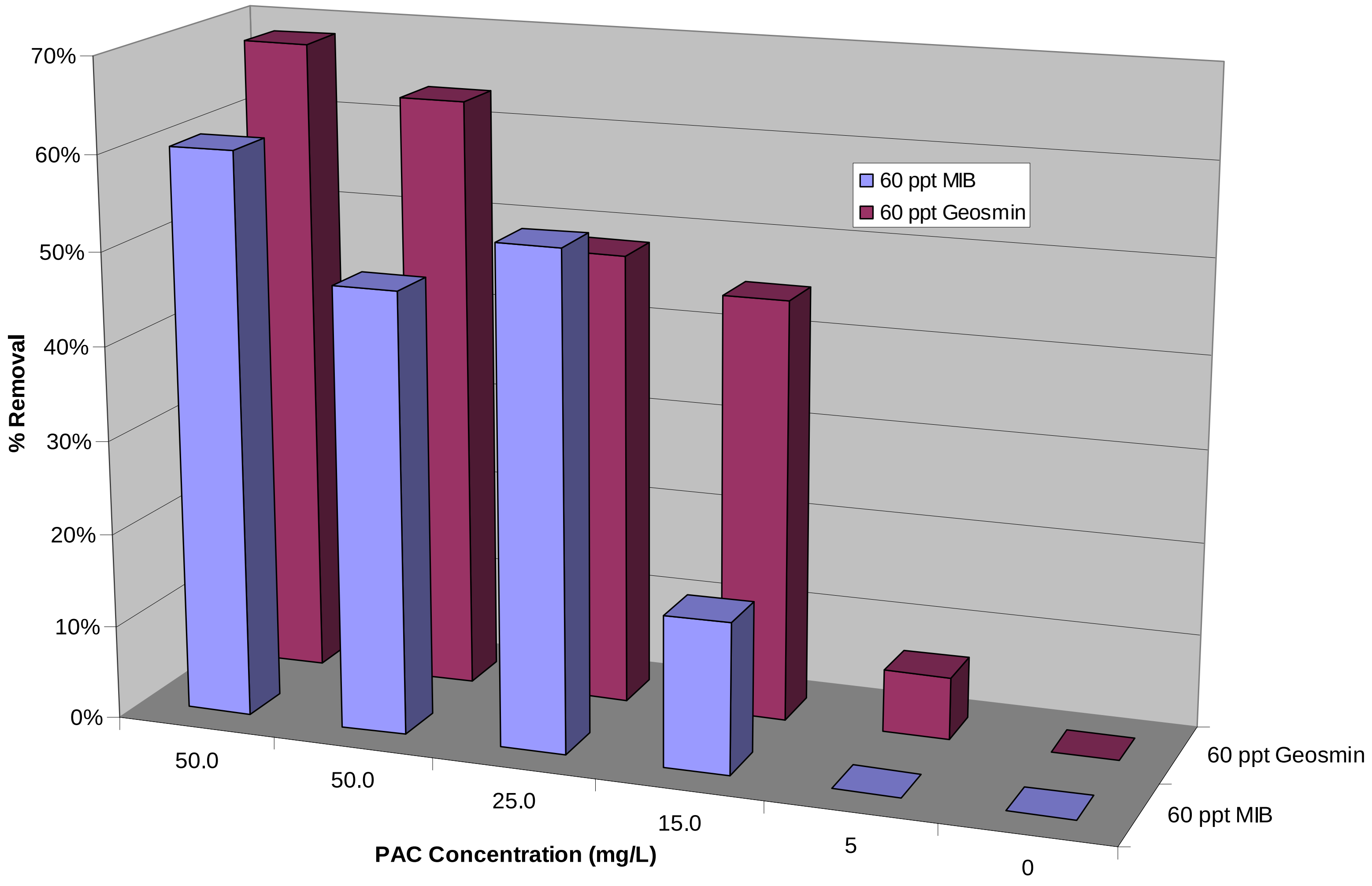
Figure TM7.5

Lawrence, Kansas

MIB Adsorption for Various
Influent Concentrations

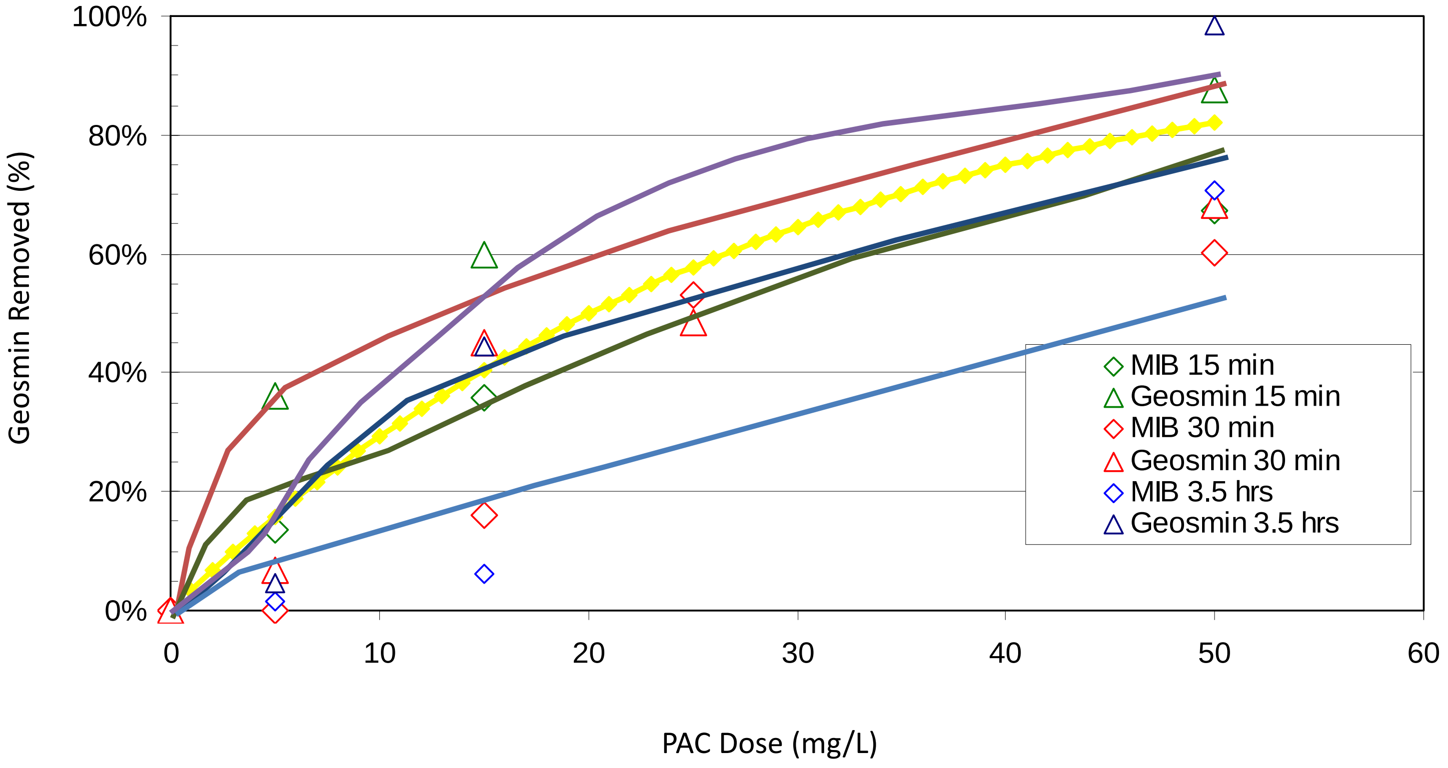


Note: Data taken from another evaluation.

Figure TM7.6

Lawrence, Kansas

PAC Dose on MIB and Geosmin Removal



Note: Data taken from another evaluation.

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Figure TM7.7

Lawrence, Kansas

PAC Dose and Removal Efficiency for Geosmin adsorption of the dissolved compounds onto the surface of PAC or metal-hydroxide floc (formed during rapid mix and coagulation), followed by physical separation by either sedimentation or filtration. In general, lime softening is able to remove around 5 to 10 percent of DOC. Conventional treatment with alum or ferric is able to remove between 10 and 20 percent DOC. Figure B.29 shows that between 20 and 30 percent of DOC is removed through treatment, which makes up about half of the TOC removed (see Figure B.26). Adding the PAC and providing adequate contact time, coupled with adequate coagulation and flocculation, allows the Kaw WTP to achieve up to 30 percent DOC reduction.

B.2.c Reduce Disinfection Byproduct Formation

Free chlorine reacts with natural organic matter (NOM) and certain inorganics (such as bromide) to form trihalomethanes (THMs), haloacetic acids (HAAs), and other chlorinated disinfection byproducts (DBPs) that are not regulated by the US Environmental Protection Agency (EPA). THMs and HAAs are a problem for surface water and groundwater treatment facilities with moderate to high levels of dissolved organic compounds (DOC). The approach recommended 10 years ago was “don’t make any.” However, utilities must balance the risk of disinfection requirements and microbial disease outbreaks against the risks associated with their by-products.

In recent years, the Stage 1 and 2 Disinfection/Disinfection Byproduct Rules have increased the emphasis to remove NOM from raw water supplies. In addition to DBPs, the removal of NOM from drinking water will also reduce color, ultraviolet absorbance (UVA-254), and chlorine demand. There are two current practices to reduce DBPs:

- Remove DBP precursors before disinfection through coagulation, softening, PAC, GAC, MIEX, or other methods
- Remove them after they form using aeration or GAC

When coagulation alone cannot achieve sufficient removal of NOM, additional treatment technologies are required to meet finished water goals. Adsorption with GAC or PAC is widely used when dissolved organics must be removed. Many of the EPA’s current and proposed regulations for THM and HAA reduction reference GAC as a best available technology due to its ability to remove DBP precursors. When GAC is considered too expensive, PAC is often regarded as a suitable alternative.

TTHM and HAA5 data collected in 2008 and 2010 for the Kaw WTP tap and in the distribution system are shown in Figures B.30 through B.33 in Appendix B. The figures show that TTHM leaving the Kaw WTP is between 60 and 70 µg/L and between 70 and 80 µg/L in the distribution system during the summer months. Data collected from plant staff shows that chloroform makes up between 60 and 80 percent of TTHM. Chloroform, unlike the other brominated species, is more closely linked to chlorine decay than chlorine residual. Being able to reduce the DBP precursors and lower chlorine demand will reduce TTHM formation potential. Determining how the PAC dose impacts DOC reduction and lowering DBP formation can be achieved through bench scale testing.

B.2.d Reduction of Emerging Contaminants

Each source water is unique with regards to water quality, target compounds, and competitive adsorption. The doses and contact times determined from bench scale and full-scale testing for other water utilities show that PAC contact times of 1 to 4 hours and PAC dosages of 5 to 50 mg/L are required to achieve between 25 and 90 percent reduction for various pharmaceutically active compounds. As a result, bench scale testing would be required to determine the PAC dose to achieve adequate reduction for each target compound. Additionally, water quality frequently changes on the Kaw River; therefore, periodic bench scale testing is recommended to determine if changes are required to handle specific flow events.

B.2.e Reduction of Algal Toxins

Increased awareness to health risks have lead many water treatment plants to provide higher levels of enhanced public health protection compared to existing regulatory requirements and historic operational practices. One emerging area is related to cyanobacteria, or blue-green algae, and the toxins they produce. Cyanobacteria are photosynthetic bacteria found in surface waters. Certain species of cyanobacteria are able to produce a wide range of taste and odor compounds and potent toxins, including a group known as microcystins. While cyanotoxins (aka algal toxins) are not currently regulated, future regulations may limit the microcystin family to 1 µg/L.

Microcystins are water-soluble hepatopeptides that can be removed by various treatment processes, depending on whether they exist as intracellular or extracellular. Most of the algal toxins exist as intracellular, until a harsh physical or chemical process causes the cell to lysis, or break open, which results in the release of extracellular compounds. There is some disagreement in the literature regarding how well conventional treatment is in removing intracellular and extracellular algal toxins. Most studies have shown that coagulation, sedimentation, and filtration are able to remove intact cells. One study showed that an alum dose of 5.8 mg/L in conventional treatment was able to remove the algal cells and intracellular toxins (Chow et al, 1999). Other studies have shown that conventional treatment was not effective at removing extracellular toxins and that additional processes are required to achieve adequate removal (Hart et al, 1998).

GAC and PAC have been shown to be effective at removing extracellular toxins. Several studies have shown that PAC is able to achieve 10 to 50 percent removal at low to moderate doses of 10 to 20 mg/L, with higher removals of 80 to 90 percent observed at doses between 20 to 30 mg/L. Ozone and chlorine dioxide are able to effectively oxidize both the intracellular and extracellular algal toxins. Chlorine, however, does very little for algal toxin oxidation, and requires a dose that is not practical for most treatment plants. UV with hydrogen peroxide also requires a very high dose that is not practical or cost effective.

In 2011, the Kaw plant measured microcystins above 1 µg/L in the raw water. The plant also noticed that higher levels were observed in the plant effluent when the PAC dose was reduced. This is not surprising considering how well PAC is at removing the microcystin family. A PAC dose of 20 mg/L may be required to achieve adequate removals through the plant, which would require higher operating cost to both feed PAC and dispose of the solids that are removed. A pre-oxidant may be required, such as ozone or chlorine dioxide, to achieve a long-term, cost effective strategy. A strong pre-oxidant would also provide additional benefits with regards to process improvements, oxidation, and disinfection.

Bench scale testing is recommended to determine the PAC dose required to achieve adequate reduction of DOC, TTHM formation potential, and microcystins.

B.3 Rapid Mix

The goal of rapid mix is to disperse and completely mix the coagulation chemicals throughout the water as quickly as possible using high mixing. Each treatment train is equipped with a rapid mix basin for primary and secondary treatment. The primary rapid mix basins are where primary treatment coagulants are added and will be the focus of this evaluation. The secondary treatment rapid mix is used for adding other process chemicals, primarily for disinfection and associated CT credits.

Rapid mix was added as part of the 1954 expansion and improvements project. Two additional rapid mix basins were added in 1958 to feed a second treatment train. Rapid Mix No.3 was added for future expansion. Each basin is single stage and equipped with a 3-phase 10 Hp turbine mixer. Lime (100 to 170 mg/L), alum (6 to 10 mg/L), and polymer (3 to 4 mg/L) are added to the primary rapid mix. Solids from primary sedimentation basins are continuously recycled to improve coagulation. Rapid Mix No.1 has a 5 foot square base with approximately 8 feet of mixing height. Rapid Mix No. 2 and 3 are slightly smaller with 5 feet x 4.25 feet base and 8 feet of mixing height.

B.3.a State Requirements

Chapter V, Section F of KDHE's minimum design standards (2008 edition) requires that the hydraulic retention time of the rapid mix basin not exceed 30 seconds at the maximum flow rate. The optimal mixing depends on the mechanism involved, but should achieve complete mixing and dispersion of the process chemicals. After that, flocs start forming that requires a tapered gradient. Continual mixing past this point can shear the bridging that forms between flocs that is difficult to reattach in downstream processes.

B.3.b Process Limitations

A summary of the hydraulic retention time (HRT) for the primary rapid mix at various plant flows is shown in Figure TM7.8. Both rapid mix basins have less than 30 seconds of detention time at plant flows greater than 8 MGD.

One of the main concerns with traditional rapid mix using constant speed hp motor in a square basin is the lack of variable speed mixing and flexibility. Based upon the horsepower of the rapid mixer, a value for the mixing intensity (G) may be calculated using the following equation for a completely mixed chamber:

$G = [P_w/\mu V]^{1/2}$

Where:

$P_w = HP * Eff_{Gear} * Eff_{motor}$

It is desirable to provide conditions for ideal mixing energy such that instantaneous and uniform dispersion of coagulant can be achieve. Recommend G-values are listed below:

- 800 to 1000 sec-1 for alum or ferric
- 300 to 400 sec-1 for polymer

The calculated mixing intensity (G) value for the rapid mixing is between 750 and 810 sec-1, which is an acceptable range for adequate mixing. The calculated GT (Mixing Intensity multiplied by detention time) values for Rapid Mix No.1 and 2 are shown in Figure TM7.9 and are between 16,000 and 6,500 between 10 and 25 MGD, respectively, depending on plant flow and water temperature. These values are an acceptable range for adequate mixing at 25 MGD.

The design of the existing rapid mix system uses alum for charge neutralization in an effort to enhance the removal of TOC by adsorption of dissolved natural organic matter on the aluminum hydroxide

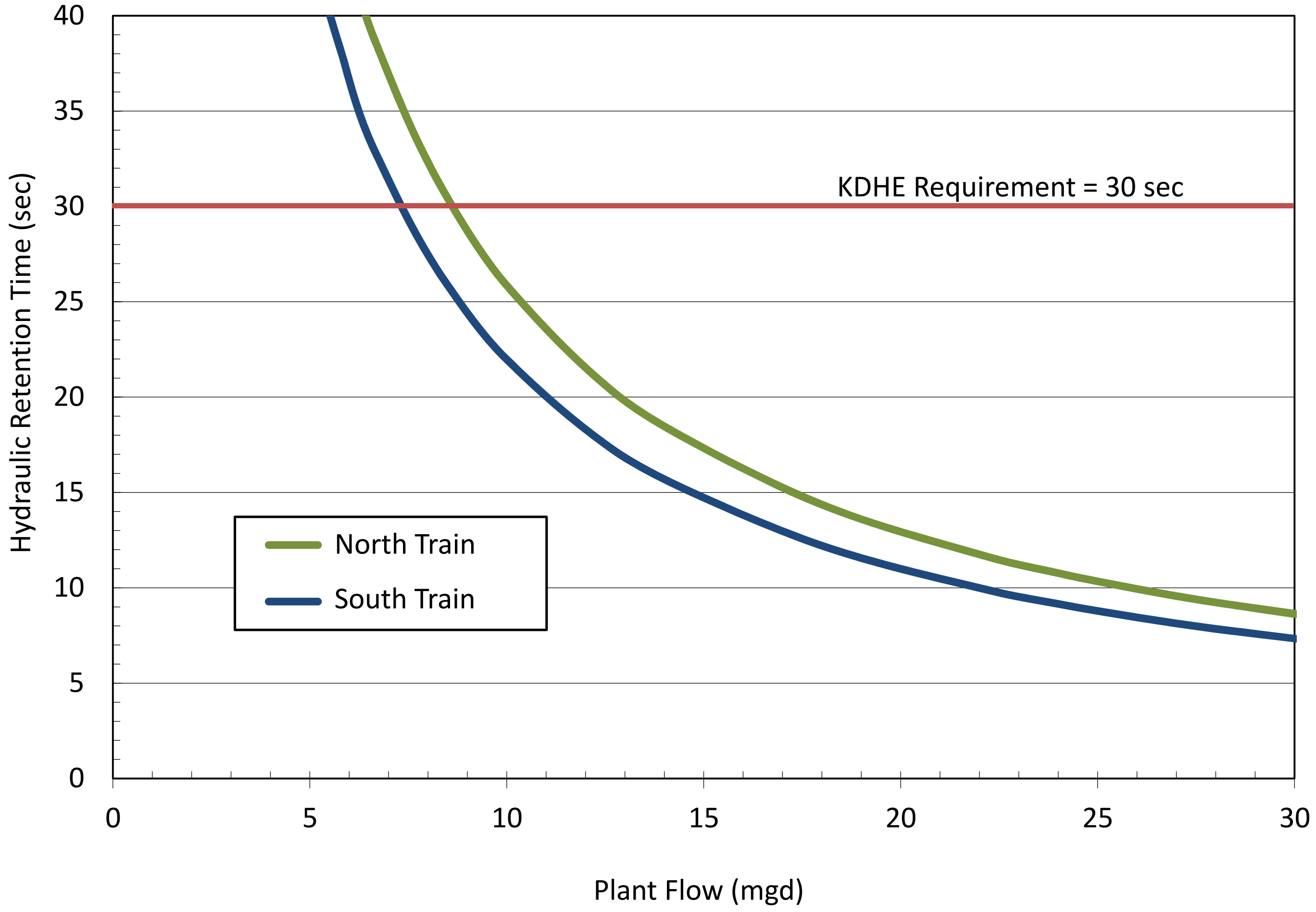

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Figure TM7.8

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Rapid Mix Basin Hydraulic
Retention Time

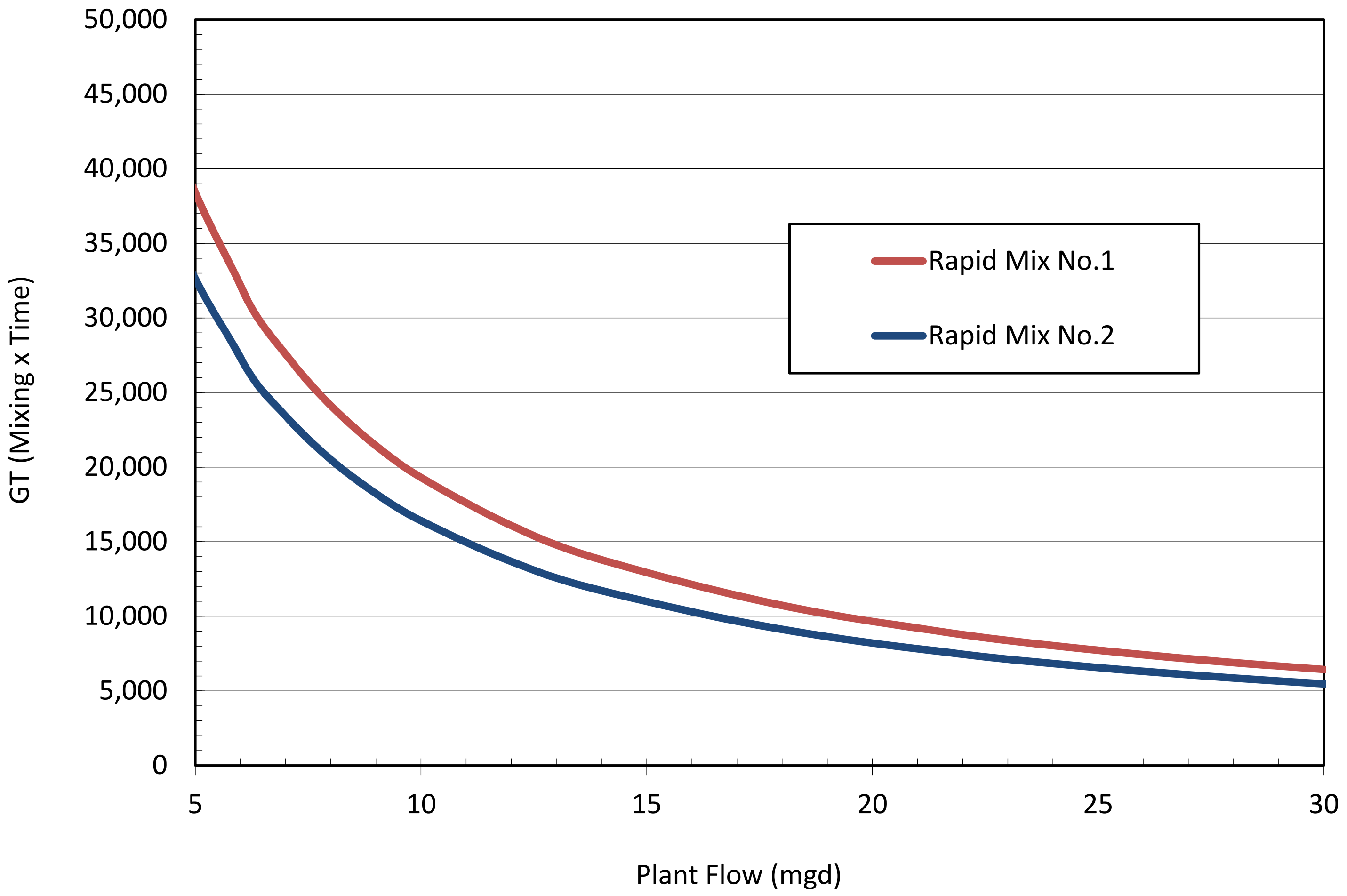

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Figure TM7.9

Lawrence, Kansas

Rapid Mix GT Values

precipitate. Total plant removal of the TTHM precursors starts with effective rapid mix using an adequate dose of alum. EPA recommends conducting bench and jar testing with alum without acidification to determine the "point-of-diminishing returns" for TOC removal. This will allow the plant to add alum for optimal turbidity and TOC removal through charge neutralization mechanisms without requiring sweep coagulation that occurs at high alum dose. The reactions that precede charge neutralization with alum are extremely fast, on the order of microseconds (O'Melia, 1972[6]).

Studies found in the literature indicate that the primary removal mechanism for DOC and the Natural Organic Matter (NOM) type of TTHM precursors is via complexation with soluble aluminum hydroxide in the rapid mix via the following equation:

$$Al(OH)_2^{+} + NOM^{-X} \quad \rightarrow \quad AlOH\text{-}NOM(complex)$$

The AIOH-NOM complex is removed either by co-precipitation or adsorption of this soluble complex with the aluminum hydroxide precipitates [$Al(OH)_3$] generated in the flocculation and sedimentation portions of the process.

Conventional treatment with alum is able to remove approximately 10 percent of raw water DOC. In fact, how well rapid mix and flocculation are performing is directly linked to DOC reduction through primary treatment. By improving rapid mix (high mixing energy, short contact time, alum dose, and pH) and flocculation (tapered mixing gradient, between 20 to 40 min contact time, and minimizing shear stresses from horizontal velocity and paddle wheel tip speed), additional DOC removal can be achieved. Figure B.29 shows that between 20 and 30 percent of DOC is removed through treatment, which makes up about half of the TOC that is being removed (see Figure B.26). The high level of DOC removal is from the addition of PAC (~20 percent DOC removal), coupled with the performance of rapid mix and coagulation (another 10 percent DOC removal).

B.4 Jar Testing

Jar testing is useful to compare process performance under varying conditions. The jar testing can be conducted to optimize chemical feed addition and determine the best combination of process modifications and chemical feed requirements to meet regulatory requirements and finished water goals.

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[6] O'Melia, C.R. *Coagulation and Flocculation,* Chap 2 in Physicochemical Processes for Water Quality Control, 1972

Jar testing can be conducted in a series of steps to reduce time and costs. The first jar testing regime could vary lime addition to meet hardness, pH, and alkalinity goals. The second regime would use the optimal lime dose and determine how varying the alum dose impacts settleability, turbidity, and TOC reduction. The third jar testing regiment could then examine process modifications to the rapid mix and flocculation. Recent optimization studies and jar testing have shown that minor physical improvements, such as increasing the rapid mix energy or providing tapered flocculation mixing gradient, can have a significant impact improving process goals.

Additional jar testing could be conducted to determine how varying the current polymer increases process goals, how it compares to other polymers used in the water industry, and if polymer addition can possibly decrease coagulant dose.

B.4.a Lime Softening

Chemical precipitation is one of the more common methods used to soften water. Lime is often used to reduce the hardness of water and adjust finished water stability by increasing pH and adding alkalinity. As shown in the caption below, calcium hardness is precipitated as calcium carbonate ($CaCO_3$), while magnesium hardness is precipitated as magnesium hydroxide ($Mg(OH)_2$). Both reactions consume alkalinity in the process. These precipitates are then removed by conventional processes of coagulation/flocculation, sedimentation, and filtration.

Hardness		Lime		Precipitate
CO_2	+	$Ca(OH)_2$	→	$CaCO_3 + H_2O$
$Ca(HCO_3)_2$	+	$Ca(OH)_2$	→	$2CaCO_3 + H_2O$
$Mg(HCO_3)_2$	+	$Ca(OH)_2$	→	$CaCO_3 + MgCO_3 + H_2O$
$MgCO_3$	+	$Ca(OH)_2$	→	$CaCO_3 + Mg(OH)_2$

Noncarbonate hardness is the portion of total hardness that is not produced by carbonate species. When total hardness is greater than total alkalinity, non-carbonate hardness equals the difference between total hardness and total alkalinity (and carbonate hardness equals total alkalinity). The Kaw WTP raw water alkalinity and hardness is shown in Figure C.5 of Appendix C. The alkalinity ranges between 120 and 260 mg/L, with an average value of 200 mg/L. The hardness ranges between150 and 400 mg/L, with an average value of 260 mg/L.

Figure C.5 shows that the hardness is split between carbonate hardness and noncarbonated hardness. The noncarbonated hardness varies between 40 and 150 mg/L. Lime can be used to remove the fraction of carbonate hardness to the point of carbonate exhaustion. Lime addition after the point of carbonate exhaustion will only add hardness. At this point, soda ash must be used to add carbonate into solution to remove noncarbonate hardness.

Alum is required for TOC reduction and lower settled water turbidity. However, it lowers the pH, consumes alkalinity, and negatively impacts the softening that occurs for a given lime dose. As a result, additional lime is required, which consumes additional alkalinity in the process.

Figure C.6 shows the finished water hardness and alkalinity for the Kaw WTP. The finished water hardness varies due to the noncarbonated hardness, as shown by the large variations between raw water hardness and alkalinity in Figure C.5. The figure also shows the finished water alkalinity is below the recommended limit of 60 mg/L for corrosion control in the distribution system. Low alkalinity waters lack the buffering capacity to deal with acids, so they can easily become acidic and corrosive.

Hardness Goal

Figure C.7 shows the relationship between the pH during softening and finished water hardness. In general, a hardness goal is achieved at a specific softening pH. Higher raw water alkalinity translates to additional lime being required to achieve the pH in which calcium carbonate is no longer soluble and precipitates out of solution. Similarly, a decrease in raw water pH translates to lower lime requirements.

Figure C.6 shows that either the Kaw WTP does not have a target finished water hardness goal or that the goal is ignored for most of the year. For example, from April to October of 2008, the alkalinity dropped from 240 to 130 mg/L. As a result, the finished water hardness dropped from 150 to 80 mg/L. When the alkalinity climbed from 130 back to 200 mg/L, the hardness increased from 80 back to 150 mg/L. In February of 2009, the noncarbonated hardness spiked, which then caused the finished water hardness to spike. The noncarbonate hardness was not able to be removed through the process due to the lack of treatment optimization.

Lime should be added to reach a target pH and hardness goal. Based on the data shown in Figure C.6, 140 mg/L would be a good starting point and could be adjusted based on chemical usage and finished water quality. In addition, soda ash should be used to add carbonate, increase alkalinity, and improve the buffering capacity in the distribution system.

B.4.b Alum Addition

Alum is added to increase TOC reduction and reduce settled water turbidity. Lower solids loading going to filtration translates to longer filter runs, improved finished water turbidity, and reduced backwash water used for cleaning the filters.

Based on the raw water alkalinity and TOC, the Kaw WTP needs 25 percent TOC reduction to meet regulatory requirements. Figure B.26 shows the percent TOC reduction through the Kaw WTP ranges between 25 and 50 percent. The high level of TOC reduction is due to the following:

- Sedimentation that settles out 90 to 95 percent of turbidity and suspended fraction of TOC;
- Filtration that removes an additional 1 to 5 ntu of turbidity ;
- PAC addition that removes approximately 20 percent of DOC via adsorption; and
- Flocculation and coagulation that approximately 10 percent of DOC via adsorption to aluminum hydroxide floc particles.

Additional alum is added to compensate for the high settled water turbidities, which ranges between 1 and 10 ntu (see Figure C.1). Polymer is added, but it is unclear how much benefit it is providing with regards to settled water turbidity.

B.4.c Polymer Addition

Polymers behave as a micro floc-bridging agent that combine with the existing aluminum hydroxide floc particles to create larger, denser particles with increased strength. Low molecular weight cationic polymers are frequently used in water treatment because they have a cost-effective amount of cationic charge that can significantly reduce coagulant doses under charge neutralization conditions. However, unless the raw water contains a significant amount of particulate TOC or humic content, a low molecular weight ($<10^5$) polymer will contribute little to turbidity or TOC removal.

Figure C.1 in Appendix C shows how turbidity is removed through the treatment processes. Figure C.2 shows the percent rank of turbidity for the raw, primary, secondary, and finished water. The raw water turbidity ranges between 6 and 2,450 ntu with finished water turbidity less than 0.14 ntu 95 percent of the time.

As shown in the right side of Figure C.1, the primary and secondary settled water turbidity is very similar and ranges between 1 and 10 ntu. In general, the goal of sedimentation is to get the settled water turbidity lower than 3 ntu to reduce the solids loading onto the filters. Alum can only go so far in reducing the turbidity before a polymer is required. These data indicate that the polymer may not be working as well as it should and using a different polymer may provide increased turbidity reduction.

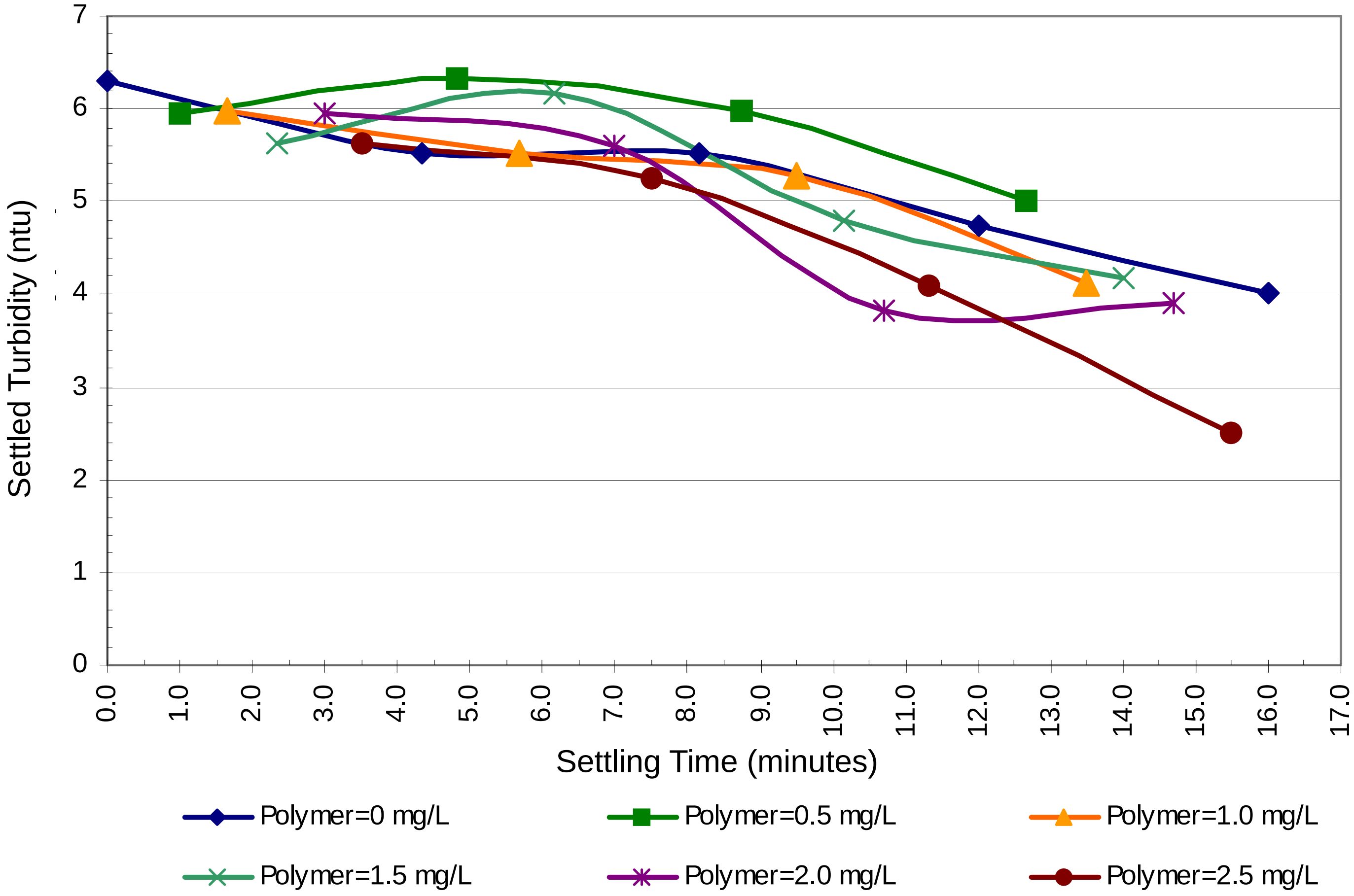
Bench testing results conducted at another water treatment facility with polymer is shown in Figure TM7.10. The testing showed the impact of varying the amount of polymer addition at rapid mix. As shown in the figure, the plant polymer was not effective over the range of value tested, between 0 and 2.5 mg/L. Bench scale testing showed that several other polymers were far more effective compared to the existing plant polymer that were capable of reducing the settled water turbidity from 5 to 1 ntu.

B.5 Flocculation Basin

A good flocculation process is critical to creating large, dense, well-settling particles by inducing velocity gradients (G) in the fluid. The aggregation of optimum size floc requires mixing intensity between 25 and 100 sec-1 for approximately 30 minutes in the summer months and 45 minutes in the winter months. Flocculation can be improved by providing adequate time and mixing gradient for the desired floc size and density to form. Typically, the first stage of flocculation is operated at mixing intensity between 70 and 80 sec-1 with additional stages operating at two thirds and one third of this value. The mixing intensity can be varied by either installing flocculation equipment with variable speed drives or by adding or removing sections of paddles from a constant speed flocculators. If the velocity gradient is too great, the shear forces will prevent the formation of a large floc. If the velocity gradient is insufficient, adequate inter-particle collisions will not occur and a proper floc will not develop or settle out too quickly.

The existing flocculation basins for both treatment trains are equipped with horizontal paddle wheel type flocculators. Two sets of three horizontal paddles run opposite to flow for each basin without baffle walls. The second stage operates three percent faster than first stage. The paddle wheels are 11 feet in diameter centered at 850.50 feet. The basins are 60 feet wide, 30 feet long, with an average depth of approximately 15.5 feet.

Given that the primary removal mechanism for turbidity is the settling process and filtration, it is critical that the flocculation process produce a larger, denser floc. Typically, the paddlewheel flocculation units provide sufficient mixing, but depend on the number of blades, blade surface area and distance from center, and blade rotational velocity. Optimizing these three variables enables the flocculation equipment



Note: Data taken from another evaluation.

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Figure TM7.10

Lawrence, Kansas

Polymer Addition at
Rapid Mix

to provide the necessary localized velocity gradients without high shear forces at the tips of the paddlewheels.

In addition, the inlets and outlets should be designed to minimize short circuiting and sheer stress. Blade tip speeds should be designed to operate between 0.5 and 3 feet/sec to reduce sheer stress and promote floc growth. The flow velocity through the basin, pipes, and flumes should be greater than 0.5 feet/sec to prevent settling but not exceed 1.5 feet/sec to avoid floc sheer stress.

B.5.a State Requirements

Chapter V, Section G of KDHE's minimum design standards (2008 edition) states that the minimum detention time of 20 and 30 minutes should be used for flocculation and softening, respectively. These values increase by 1.15 during the winter, but typically not an issue due to lower flows in cold months.

B.5.b Process Limitations

Hydraulic Retention Time

A summary of the hydraulic retention time (HRT) for the flocculation basins at various plant flows are summarized in Figure TM7.11. Based upon the hydraulic detention time of 30 minutes, the design capacity for the flocculation process is approximately 20 MGD. Increasing the plant flow to 25 MGD would decrease the detention time to 24 minutes.

Table TM7.3: Recommended Minimum Flocculation Basin Detention Times

Reference	Winter Detention Time (min)	Summer Detention Time (min)
Karamura[7]	45	20-30
ASCE/AWWA[8]	- -	20
AWWARF Study[9]	- -	15-20
10 State Standards[10]	- -	30
KS Standards	35	30

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[7] Kawamura, Water Treatment Facilities, Ch 3, 2000

[8] ASCE, Water Treatment Plant Design, 1990

[9] AWWRF, Mixing in Coagulation and Flocculation, 1991, Chapter 11

[10] Recommended Standards for Water Works, 1997, Great Lakes Upper Mississippi Board of State and Provincial Public Health and Environmental Managers

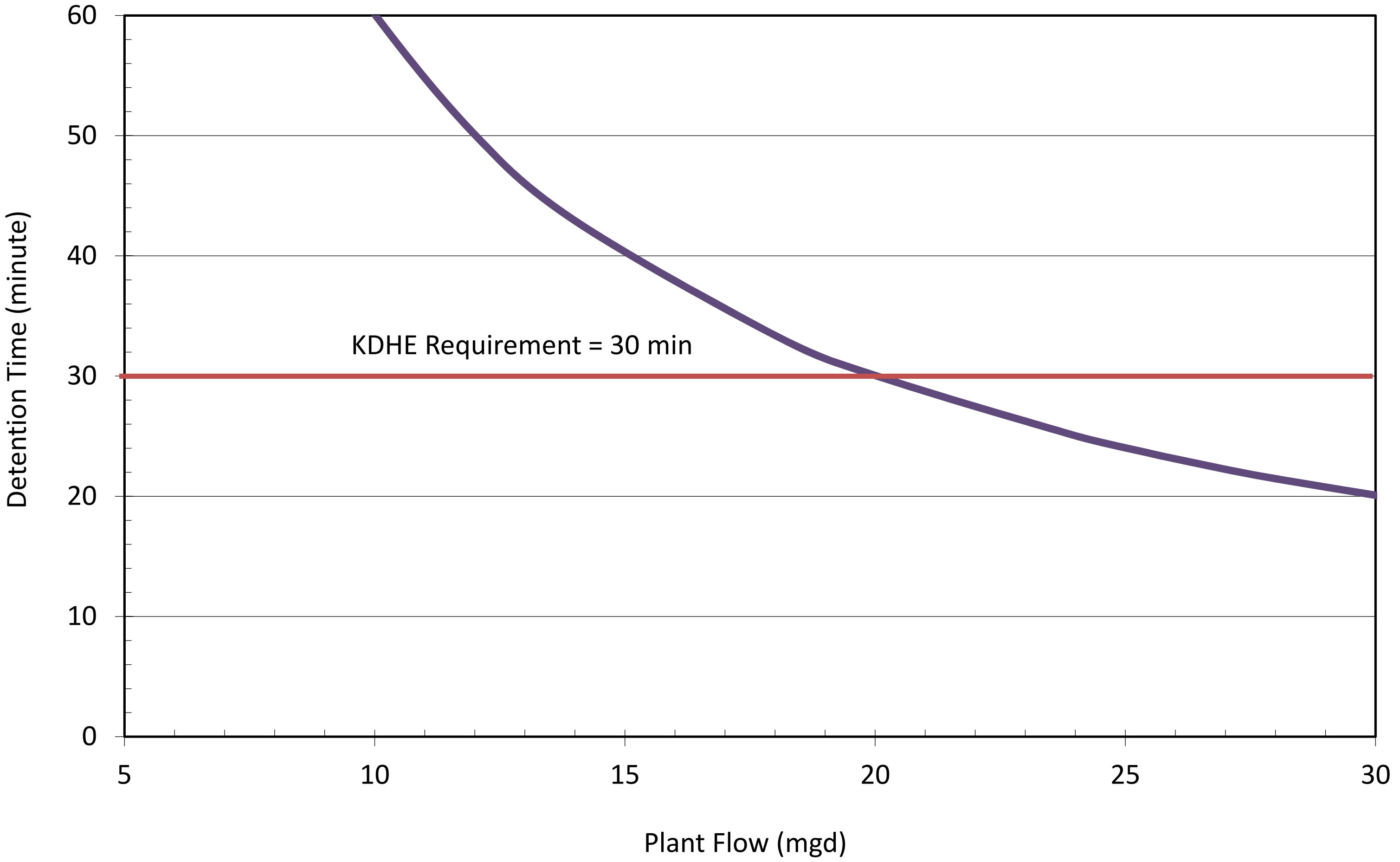

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Figure TM7.11

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Flocculation Basin
Hydraulic Retention Time

Of the common design parameters for flocculation, none is more critical to developing a well settling floc particle than providing a well baffled, multi-stage flocculation regime with adequate hydraulic detention times. A summary of recommended flocculation detention times from various key engineering references is listed below in Table TM7.3.

Review of Table TM7.3 indicates a high degree of variability in the recommended minimum flocculation basin detention times during warm water temperatures. Much of this variability in recommended hydraulic detention time has to do with the raw water turbidity, coagulation regime (i.e. chemicals added), flocculation basin configuration and velocity gradients. In general, waters with high raw water turbidities (>60 NTU), with well baffled flocculation stages, and serpentine arrangement will not require as much flocculation time as waters with lower raw water turbidities (5 to15 NTU) and non-baffled flocculation.

The Kaw WTP has raw water with moderate to high turbidities, non-baffled flocculation, alum coagulation, and polymer addition. The high turbidity will help compensate for the lack of baffle walls or serpentine arrangement. As a result, the minimum flocculation detention times should be 20 minutes to develop a well settling floc. Bench scale testing and field investigations will be required to determine if the flocculation process can be optimized to promote greater floc settleability (0.1 to 2.0 mm effective size) such that flocculation basin hydraulic detentions of less than 30 minutes can be utilized.

Horizontal Velocity

The flocculation basins should be designed to operate between 0.5 and 1.5 ft/min. Horizontal velocity for the flocculation basins at various plant flows is illustrated in Figure TM7.12. The horizontal velocity is in compliance between plant flows of 10 and 30 MGD.

B.6 Sedimentation Basin

Sedimentation is an important step in conventional treatment in the delivery of water of high clarity and turbidity in the finished water. The ideal design of a settling basin provides a sufficient path length for a particle to settle by gravity before the inertial forces carry it from the basin to the next process. Low settled water turbidities translate to long filter runs, low volumes of backwash wastewater, and improved finished water turbidities.

Each treatment train at the Kaw WTP has two 60-foot square, horizontal flow basins in series for primary sedimentation. The inlet and outlet of the first stage (i.e. the first 60-foot square) of primary sedimentation is equipped with wood baffles to improve flow distribution across the basin. The second stage of primary sedimentation is utilized for polishing. The sedimentation basin discharge is controlled by 90 degree

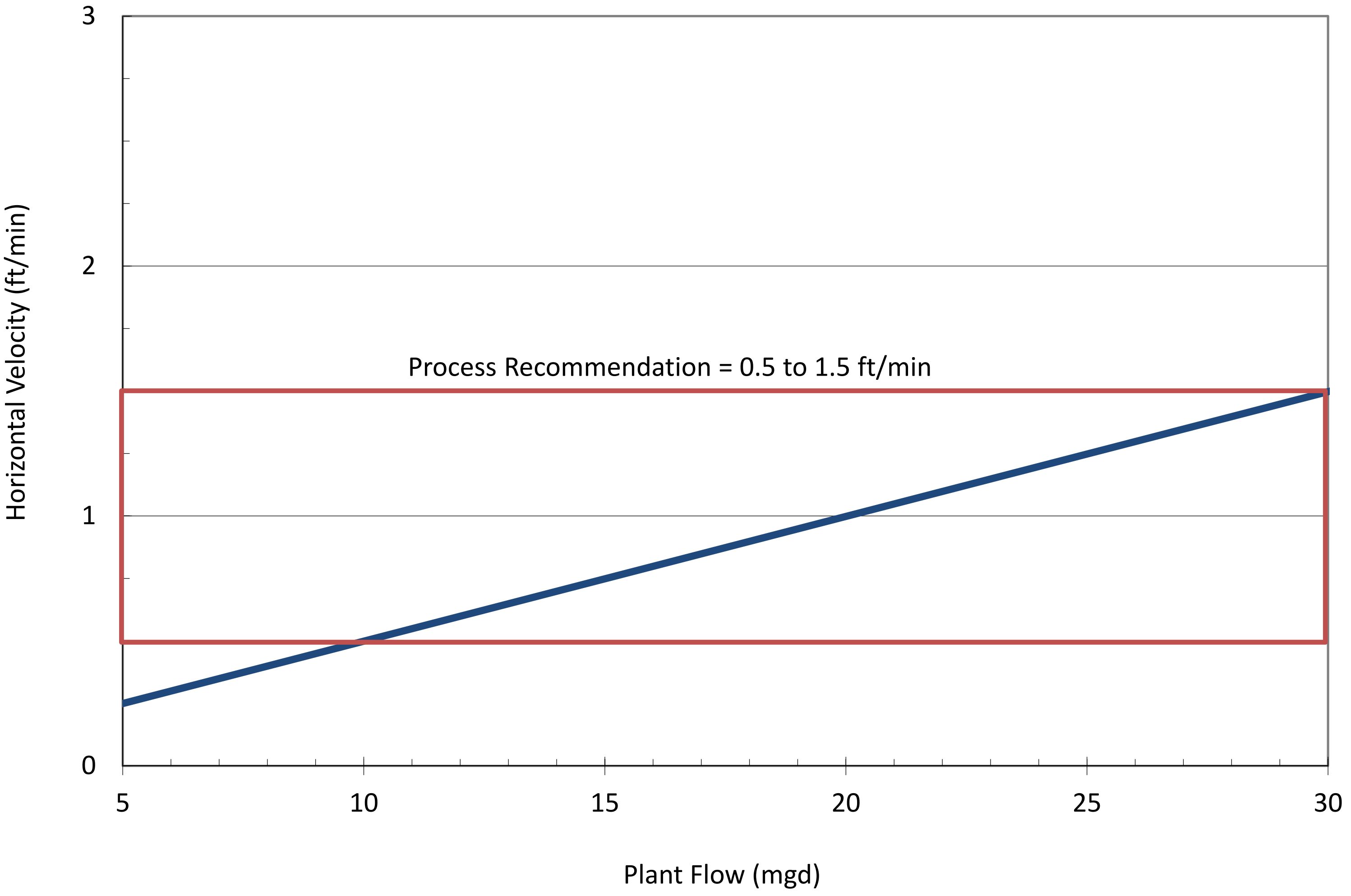

Figure TM7.12

Lawrence, Kansas

Flocculation Basin
Horizontal Velocity

V-notch weirs mounted on square effluent launders stretching the length of the second stage portion of the basin. Both stages of primary sedimentation are equipped with circular, mechanical sludge rakes for sludge removal.

B.6.a State Requirements

Chapter V, Section H of KDHE's minimum design standards (2008 edition) recommends the following:

- A minimum hydraulic detention of three hours with presedimentation, without inclined plate settlers.
- Maximum surface overflow rate of 600 gpd/sqft (0.417 gpm/sqft).
- Minimum length to width ratio for rectangular basins of 2.5:1.

B.6.b Process Limitations

Hydraulic Retention Time

Hydraulic detention time is a measurement of the mean retention time of the fluid in the sedimentation basins. Prior to the design of sedimentation basins based on the dimensionless flow characteristics, basins were designed to maintain a certain hydraulic detention time, usually between three and four hours.

The effluent weir crest is at an elevation of 859.50 feet. With an average depth of 17 foot, 60 foot width, and 120 foot length, each basin as a total volume of 915,600 gallons. A summary of the hydraulic retention time (HRT) for the sedimentation basins for total plant flow is shown in Figure TM7.13. Using the state recommended value of three hours for hydraulic detention, each basin is sized for 7.5 MGD, or total plant flow of 15 MGD.

Length to Width Ratio (L: W)

In general, the higher the length to width ratio, the better a sedimentation basin will perform. The primary sedimentation basins have an L:W ratio of 2:1, which is very limiting to process performance. KDHE recommends the L:W ratio is greater than 2.5:1. Values greater than 4:1 are recommended.

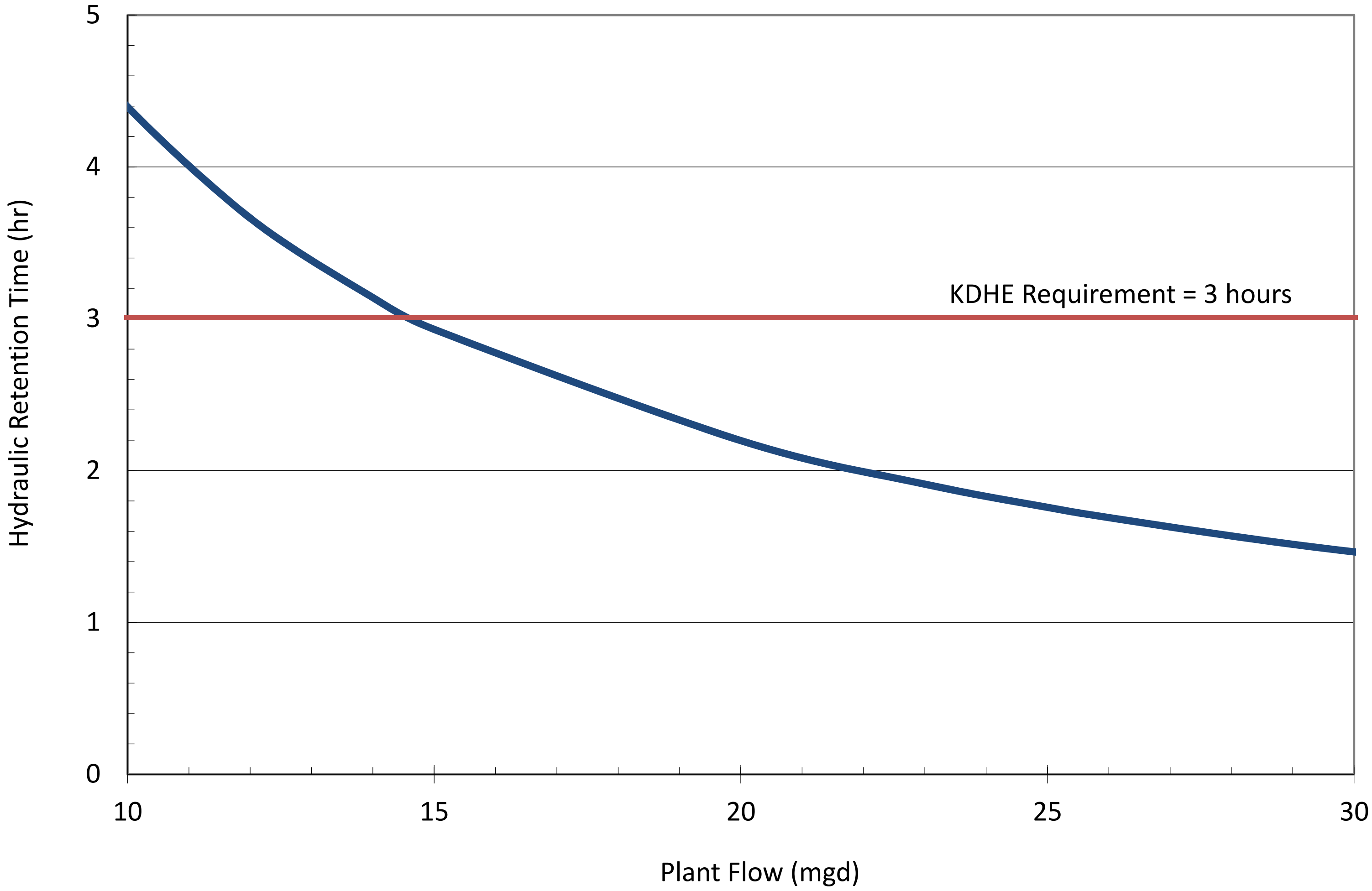

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Figure TM7.13

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Sedimentation Basin
Hydraulic Retention Time

Reynolds Number (Re)

The Reynolds Number is a dimensionless number which expresses a relationship between fluid viscosity (ʋ) and inertia (VR):

Equation 1 Re = VR/ʋ

Where:
(ces/tfqs) ytisocsiV citameniK= ʋ
R = Hydraulic Radius (A/P)
A = Surface Area of Basin (L*W) (sqft)
P = Wetted Perimeter of Basin (ft)
V = Displacement Flow Velocity (ft/sec)

In general, the lower the Reynolds Number the better the performance of the sedimentation basin. Recommended value for Reynolds Number is less than 14,000. At 15, 20, 23, and 25 MGD, the Reynolds number was calculated to be 10.4k, 13.9k, 16.0k, and 17.3k. These values indicate that the sedimentation capacity is limited to around 20 MGD.

Surface Overflow Rate

The efficiency of sedimentation is a function of the settling velocity of the particle to be removed. The lower the surface overflow rate, the better the degree of sedimentation since it will capture a higher proportion of the slower settling particles. The surface overflow rate is used as a general criterion for designing sedimentation basins utilizing actual data regarding the settling rate of the suspended matter with the application of an appropriate safety factor. This implies that the efficiency of the removal of suspended matter is independent of its depth and detention time. However, since the basin does not behave as a perfect plug flow reactor, the detention time is a factor in particle removal efficiency since the flocculated particles usually become larger and heavier with time due to the mixing effect in the tank. In addition, the overflow rate does not factor into account the degree of plug flow in the basin, where increasing plug flow and decreasing preferential flow paths will improve settling characteristics. These factors can increase or decrease the capture efficiency beyond that predicted by the overflow rate.

As a rule of thumb, sedimentation basins can operate at surface loading rates between 0.35 and 1.0 gpm/sqft. KDHE recommends a maximum surface overflow rate for horizontal basins to be 600 gpd/sqft, or 0.417 gpm/sqft. For a rectangular sedimentation basin with moderate to good hydraulics (i.e. plug flow confirmed through a tracer test) and treatment conditions (moderate turbidity, metal salt coagulation, and adequately designed flocculation), a maximum surface loading of 0.60 to 0.75 gpm/sqft is appropriate. Figure TM7.14 indicates that, based upon the overflow rate recommended by KDHE, the plant flow is limited to 8.7 MGD. Using a general rule of thumb of 0.75 gpm/sqft, the plant flow is limited to 15 MGD.

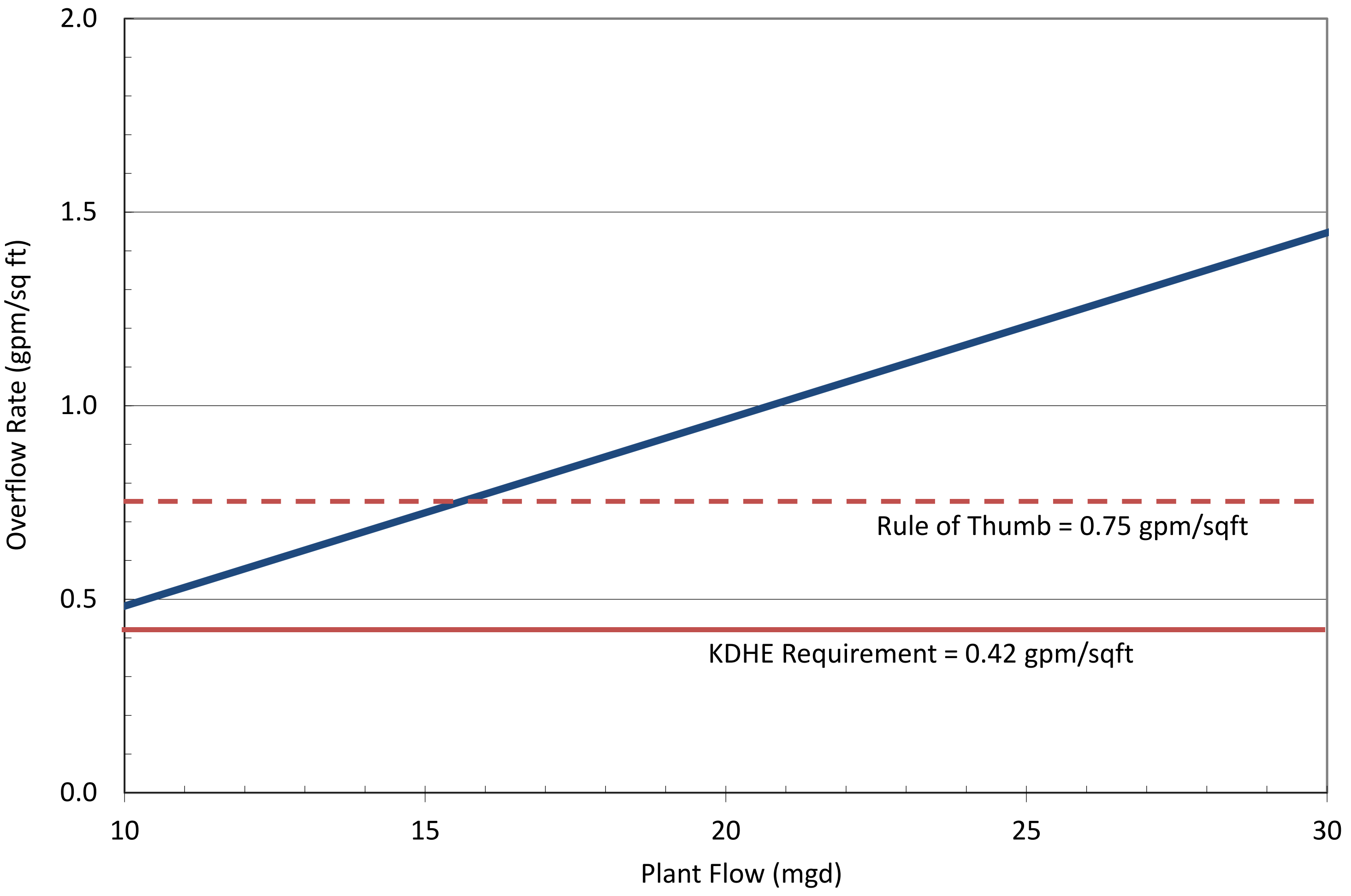

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Figure TM7.14

Lawrence, Kansas

Sedimentation Basin
Overflow Rate

Horizontal Velocity

Horizontal velocity is a measurement of the cross flow velocity through the sedimentation basin. Basins are generally designed to minimize the cross flow velocity through the basin in order to reduce the scour from the bottom of the basins. Basins designed according to horizontal velocity and hydraulic detention time were usually wide and deep which tends to exhibit flow instability and a distinct density flow pattern that has a negative effect on turbidity removal performance. The horizontal velocity through the sedimentation basins is shown in Figure TM7.15. The recommended process standard for sedimentation is between 0.5 and 1.0 ft/sec. Based on this condition, the plant is limited to 22 MGD.

A summary of the sedimentation process design parameters are shown in Table TM7.4. These values indicate that the sedimentation basins are limited by process variables to around 16 MGD without improvements. Process and physical improvements could increase sedimentation capacity to 22 MGD.

Table TM7.4: Sedimentation Basin Design Parameters

Parameter	Units	Recommended[11]	Sedimentation Basin			
			16 MGD	20 MGD	22 MGD	25 MGD
Length:Width	---	>4:1	2.0:1	2.0:1	2.0:1	2.0:1
Hydraulic Detention Time	Hours	1.5 - 4 3[12]	2.75	2.2	2.0	1.7
Surface Overflow Rate	Gpm/ sqft	0.5 - 0.75 < 0.42[13]	0.77	0.96	1.06	1.21
Horizontal Velocity	Ft/min	0.5 - 1.0 < 1.0[14]	0.73	0.91	1.00	1.14

B.7 Filtration

With the possible exception of disinfection, filtration is the most important phase in the series of unit processes. It is the final process in the removal of suspended material from the water. Filtration is also effective removing microorganisms, thus reducing the disinfectant demand imposed upon chlorination

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[11] Kawamura, S. Integrated Design and Operation of Water Treatment Facilities

[12] KDHE:Chapter V, Section H-2a, Minimum Design Standards (2008 edition)

[13] KDHE:Chapter V, Section H-2b, Minimum Design Standards (2008 edition)

[14] James M. Montgomery, Water Treatment Principles and Design

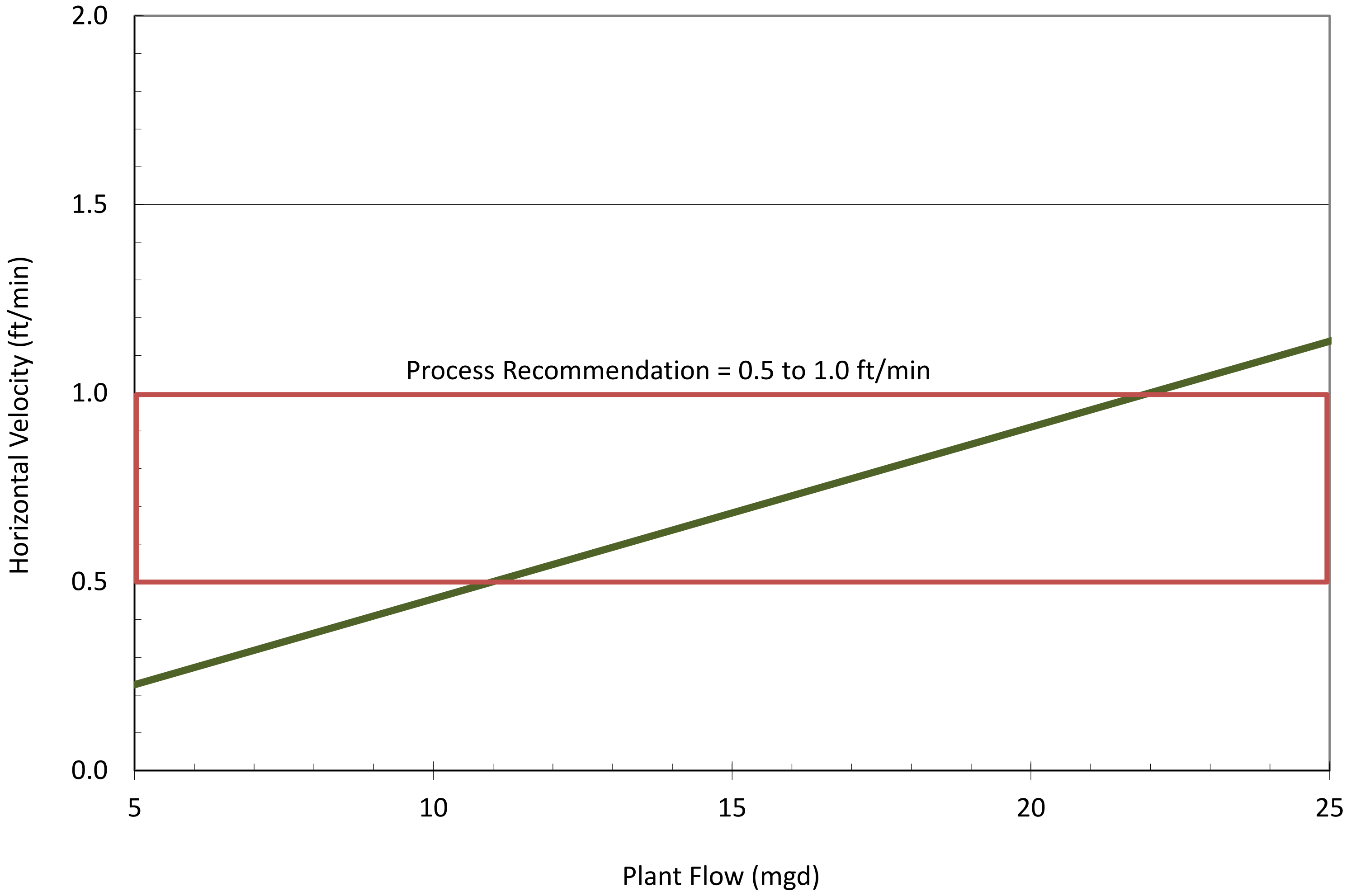

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Figure TM7.15

Lawrence, Kansas

Sedimentation Basin
Horizontal Velocity

and protecting the consumer against viral and bacterial contamination in the finished water. Many operators want to know what to look for when filters are acting poorly, but it is just as important to know what to look for when things are going well.

The Kaw WTP currently utilizes eight dual media (anthracite/sand) gravity filters following the secondary sedimentation basins. The filter design includes single-cell filters with fiberglass wash water collection troughs spanning the width of each cell and connecting to a centralized, concrete waste gullet, spanning the length of the filter.

Filters 1 through 4 were built as part of the original 1917 construction. Each original filter is 14 feet by 18 feet (252 sqft). Filters No. 5 and 6 were added as part of the 1954 expansion and are much larger at 24.5 feet by 28 feet (686 sq ft). Filters No. 7 and 8 were added in 1958 to match Filters No. 5 and 6.

The filters operate in a constant rate mode. Effluent rate-of-flow controllers maintain an equal flow split to all filters in service. Manual filter backwash is initiated based on filter run time, with some exceptions due to headloss and turbidity. A typical backwash consists of 10 to15 minutes of water (with no air).

B.7.a State Requirements

Chapter V, Section J of KDHE’s minimum design standards (2008 edition) recommends the following for dual media filters:

- Maximum filtration rates of 4 gpm/sqft of surface area
- Minimum depth of the filter box of 8.5 feet
- Minimum water depth of 3 feet above the surface of the filter media
- Maximum water velocity of 2 feet/sec in pipes and conduits to filters
- Wash water troughs must be designed to provide a maximum horizontal travel of suspended particles not exceeding three feet in reaching the trough
- Dual media must have:
  - Sand with an effective size of 0.4 to 0.55 mm and UC of no greater than 1.65
  - Anthracite with an effective size of 0.8 to 1.1 mm and UC of no greater than 1.7
  - At least 30 inches of media with at least 12 inches of sand
- Facilities must provide for the washing of filters as follows:
  - At least 15 gpm/sqft, 20 gpm/sqft is recommended
  - At least 15 minutes wash of one filter at the design rate of wash

B.7.b Process Limitations

Surface loading rate for filters at the Kaw WTP is shown in Figure TM7.16. This figure shows that the existing filter capacity of the four newer filters is 15.8 MGD at the KDHE recommended surface loading rate of 4 gpm/sqft when all filters are in service. The firm capacity with one filter out of service is 11.9 MGD. The four old filters, which have much smaller surface area, have a combined rated capacity of 5.8 MGD with all filters in service, and total firm capacity of 4.4 MGD.

The total filtration and firm capacity for all eight filters is shown Figure TM7.17. With all filters in service, the total capacity is 21.6 mgd. When one large filter is out of service, the firm capacity is 17.7 MGD.

According to Kawamura (2000)[15], most dual media filters operating with alum coagulation can perform well up to a loading rate of 6 gpm/sqft. According to Figure TM7.17, if the existing filters were loaded at a capacity of 5 gpm/sqft, the plant flow capacity for this unit process would be 27.0 MGD with all filters in service and 22.1 with one filter out of service.

B.7.c Filter Backwash

The four indicators used to trigger a filter backwash cycle include: 1) filtered water turbidity, 2) length of the filter run, 3) headloss through the filter, and 4) operator convenience. Ultimately what is most critical to proper treatment is the turbidity removal of the filtration process since this is what most regulatory and performance standards are based. It is recommended that data be collected by plant operators at the end of each filter run to document the average filter flow while in operation, filter run time, turbidity at backwash, headloss at backwash, and the reason backwash was initiated.

B.7.d Filter Evaluation

A filter evaluation is recommended to assess the filtration performance by examining a series of performance indicators and quantitative evaluations. The performance indicators typically used in evaluating filter performance include turbidity removal, the length of the filter run, unit filter run volume, and the ratio of backwash water used to the volume of filtered water produced. The quantitative evaluations performed consist of a series of tests that include measuring the bed depth, media and gravel

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[15] Kawamura, S. Integrated Design and Operation of Water Treatment Facilities

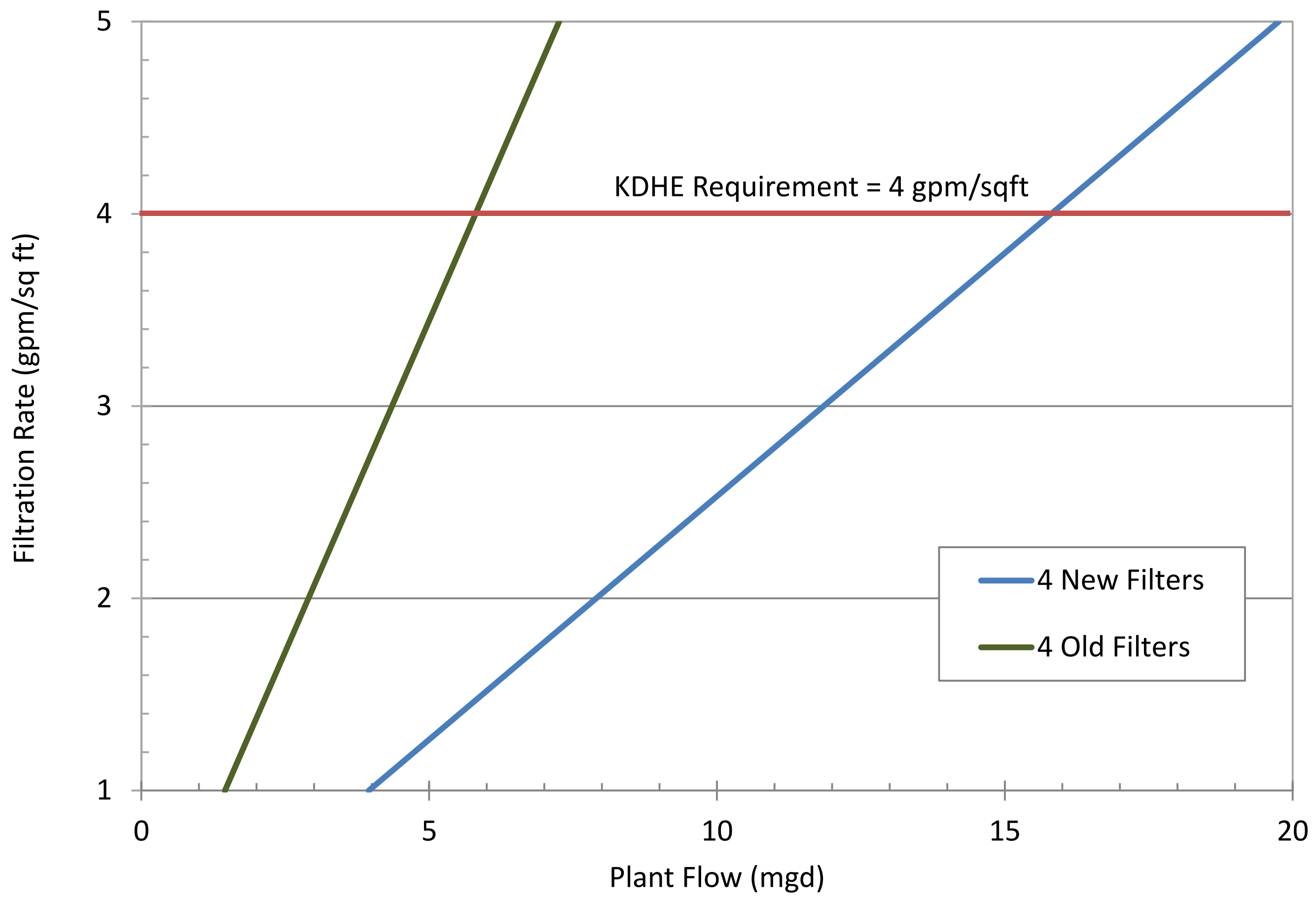

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Figure TM7.16

Lawrence, Kansas

Filter Capacity

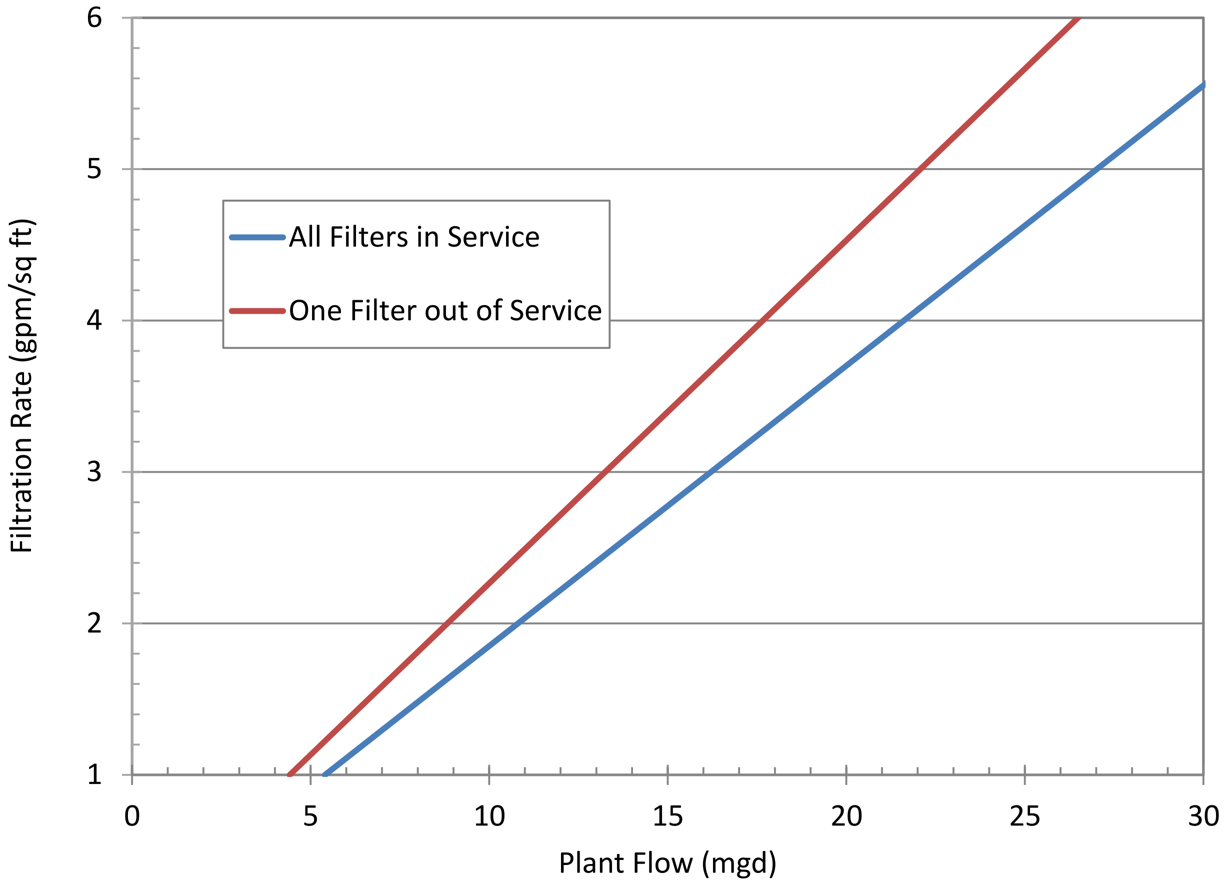

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Figure TM7.17

Lawrence, Kansas

Total and Firm
Filter Capacity

migration, physical media analysis, general appearance, solids retention before and after backwash, and backwash analysis. The results from the quantitative evaluation will supplement the performance indicators to develop recommendations that will increase filter run time and lower filtered water turbidity.

For some utilities, filter improvements have doubled filter run time through more effective backwash and better utilization of the anthracite layer's solids storage capacity. If the filter evaluation and subsequent stress testing do not provide additional process capacity, additional filters or low pressure membranes may be required to increase plant capacity.

B.8 Process Evaluation Summary

The following summarizes the treatment processes at the Kaw WTP and the ability to produce water beyond the existing capacity of 16 mgd. This performance assessment focused on the treatment capacity based on regulatory compliance and process performance. Each process is depicted graphically in Figure TM7.18 and summarized below to highlight the limiting factor for each process.

B.8.a Presedimentation

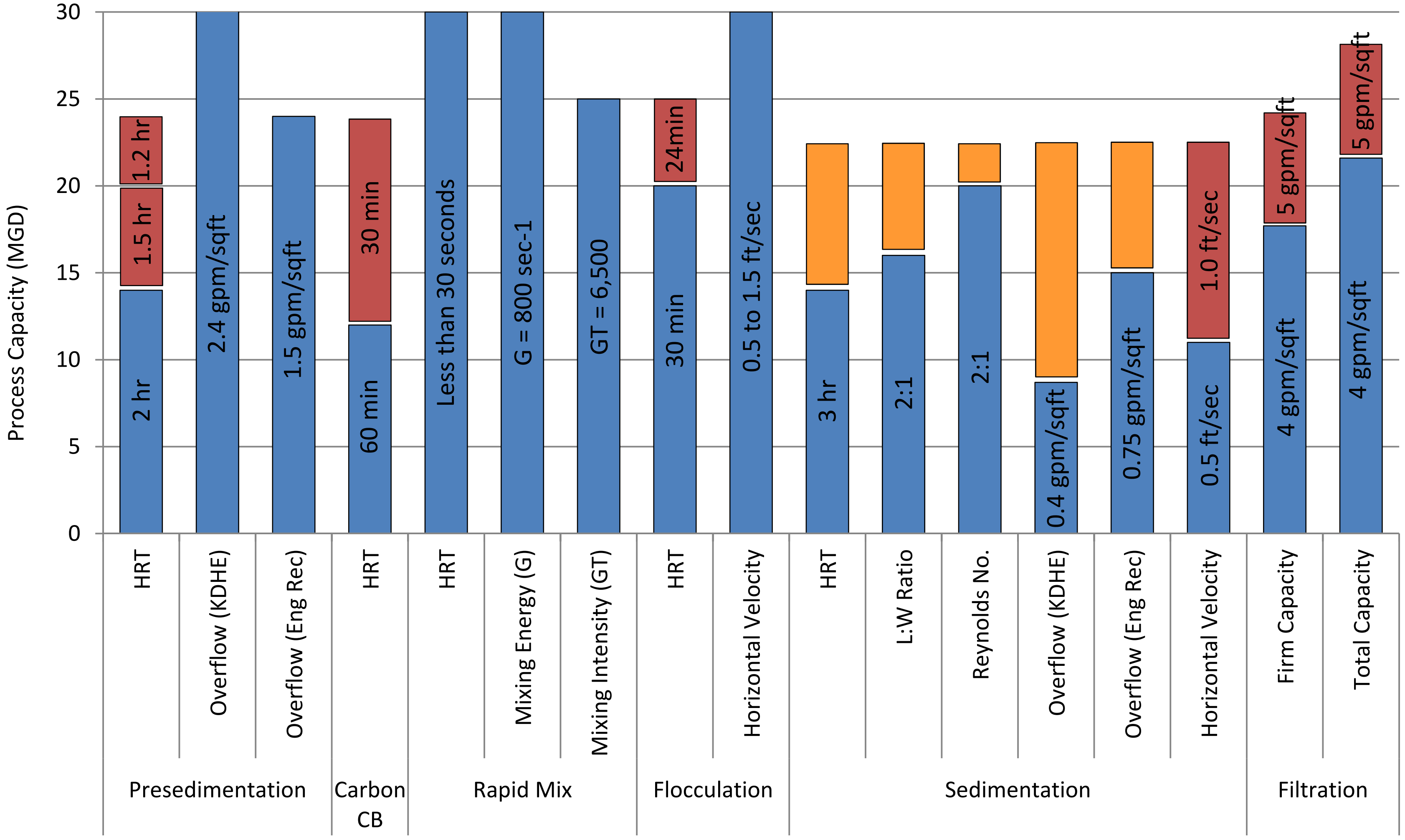
Based on the KDHE requirement of two hour detention time, the presedimentation basin is limited at 14 MGD. However, HRT is not the primary process parameter that drives settling. Once the flocs are formed, which typically takes between 5 and 20 minutes, a more useful parameter for particle setting is the basin overflow rate, measured in gpm/sqft.

Based on the KDHE recommended overflow rate of 2.4 gpm/sqft, the presedimentation basin is limited at 38 MGD. Based on the general engineering recommendation of 1.5 gpm/sqft, the presedimentation basin is limited at 24 MGD.

Polymer addition at this location will bridge a portion of the smaller particles to form larger particles and help that fraction settle-out. The flocs that do not settle out will be exposed to sheer stress through process piping between the presedimentation basin and rapid mix. Once the flocs are sheered, it is very difficult to get them to form in the primary flocculation process. It is possible that some particles are formed, sheered into colloidal particles, and pass through flocculation, sedimentation, and even filtration.

Recommendation

Bench scale testing is recommended to optimize polymer addition and mixing requirements. Jar testing will determine if polymer addition is even required at this location, or if changing the dose and mixing



🟦 Rated Capacity
🟥 Additional Testing Is Required - Additional Capacity May Be Possible
🟧 Plant Improvements Are Required

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Figure TM7.18

Lawrence, Kansas

Kaw WTP Process Limitations

energy might offer increased turbidity reduction and improvements to carbon adsorption, flocculation, and sedimentation.

B.8.b Carbon Contact Basin

PAC offers several process benefits and can be used for the following:

- Taste and odor abatement
- DOC adsorption
- Reduce chlorinated disinfection byproduct formation
- Removal of many organic emerging contaminants, including pesticides, pharmaceutically active compounds, and endocrine disrupting compounds
- Removal of algal toxins (i.e. microcystins)

Plant flows of 12 and 24 MGD corresponds to an HRT of 1.0 and 0.5 hours, respectively. While at least one hour is optimal, 50 to 80 percent of the process benefits can be achieved within 30 minutes of contact time. However, additional PAC will be required to achieve the same benefit at higher flows. Bench scale testing is required to determine the minimum PAC dose and contact time required to achieve the target process goals. Preliminary data at the plant and work done for other utilities indicate that 20 mg/L PAC would be required for microcystin reduction below 1 µg/L. Additional PAC may also be required to help reduce chlorinated DBP that form in the plant and in the distribution system.

PAC addition is a low-capital cost option when a utility only requires a 10 to 20 percent reduction to achieve the target process goals with a dose of 5 to 10 mg/L. After 10 mg/L, the cost of PAC becomes a significant operating cost. A better alternative to PAC addition would be to use a strong pre-oxidant, such as ozone or chlorine dioxide.

While ozone has higher capital cost, it has very low operating cost. Many utilities find that using ozone has lower 20-year life cycle costs compared to using PAC between 20 and 30 mg/L. In addition, ozone would provide additional benefits with regards to process improvements, oxidation, and disinfection. For example, ozone addition will provide taste and odor reduction, reduce chlorinated DBP formation, improve plant performance (flocculation, coagulation, and filtration), improve color, clarity, and TOC reduction, and oxidize algal toxins and many emerging contaminants.

Recommendation

Bench scale testing is recommended to determine the PAC dose required to achieve various process goals, including the reduction of DOC, TTHM formation potential, and microcystins. Different PAC types should be evaluated and ranked according to performance for each process goal.

Ozone bench scale testing is recommended to determine the ozone demand, decay, and sizing requirements to achieve disinfection, oxidation, process goals, and water treatment improvements.

B.8.c Rapid Mix

The calculated mixing intensity (G) value for the rapid mixing is between 750 and 810 sec^{-1}, which is an acceptable range for adequate energy mixing. The calculated GT (Mixing Intensity multiplied by detention time) values for Rapid Mix No.1 and 2 are between 16,000 and 6,500 between 10 and 25 MGD. These values are an acceptable range for adequate mixing intensity at 25 MGD.

Jar testing can be conducted to optimize chemical feed addition and determine the best combination of process modifications and chemical feed requirements to meet regulatory requirements and finished water goals. The following process improvements can be optimized through jar testing:

- Lime dose to meet hardness, pH, and alkalinity goals
- Impact of alum dose on settleability, turbidity, and TOC reduction
- Examine how process modifications can improve rapid mix and flocculation
- Impact of polymer type and dose on process goals and coagulant addition
- Compare anionic, cationic, and nonionic polymers

Recommendation

Bench scale testing is recommended to evaluate how to improve treatment and lower operating costs.

B.8.d Flocculation

The design capacity for the flocculation process is approximately 20 MGD based upon the hydraulic detention time of 30 minutes. Increasing the plant flow to 25 MGD would decrease the detention time to 24 minutes.

The flocculation basins should be designed to operate between 0.5 and 1.5 ft/min. Horizontal velocity for the flocculation basins at various plant flows is illustrated in Figure TM7.12 and shows the horizontal velocity is in compliance between plant flows of 10 and 30 MGD.

Recommendation

Bench scale testing and field investigations will be required to determine if the flocculation process can be optimized to promote greater floc settleability (0.1 to 2.0 mm effective size) such that flocculation basin hydraulic detention time less than 30 minutes can be utilized.

B.8.e Sedimentation

Using the state recommended value of three hours for hydraulic detention, each basin is sized for 7.5 MGD, or total plant flow of 15 MGD.

Recommended value for Reynolds Number is less than 14,000. At 15, 20, 23, and 25 MGD, the Reynolds number was calculated to be 10.4k, 13.9k, 16.0k, and 17.3k. These values indicate that the sedimentation capacity is limited to around 20 MGD.

Based upon surface overflow rate recommended by KDHE, the plant flow is limited to 8.7 MGD. Using a general rule of thumb of 0.75 gpm/sqft, the plant flow is limited to 15 MGD.

The recommended process standard for sedimentation horizontal velocity is between 0.5 and 1.0 ft/sec. Based on this condition, the plant is limited to 11 MGD at 0.5 ft/sec, and 22 MGD at 1.0 ft/sec.

These values indicate that the sedimentation basins are limited by process variables to around 16 MGD without improvements. Process improvements through bench testing and optimization could increase sedimentation capacity to between 16 and 18 MGD. Physical improvements could be made to increase sedimentation capacity to 22 MGD or higher, but would require capital investment.

Recommendation

Further investigation would be required before final design recommendations can be made, but likely improvements would include tapered mixing energy in the flocculation basin, longitudinal baffling in the sedimentation basin (to increase the length-to-width ratio and decrease short circuiting), and replacement of the sludge removal mechanism.

B.8.f Filtration

With all filters in service, the total capacity is 21.6 mgd at 4 gpm/sqft. When one large filter is out of service, the firm capacity is 17.7 MGD.

Most dual media filters operating with alum coagulation can perform well up to a loading rate of 6 gpm/sqft. If the existing filters were loaded at a capacity of 5 gpm/sqft, the plant flow capacity for this unit process would be 27.0 MGD with all filters in service and 22.1 with one filter out of service.

Recommendation

A filter evaluation is recommended to assess the filtration performance to see if additional capacity can be achieved by examining a series of performance indicators and quantitative evaluations. The results from the quantitative evaluation will supplement the performance indicators to develop recommendations that will increase filter run time and lower filtered water turbidity.

For some utilities, filter improvements have doubled filter run time through more effective backwash and better utilization of the anthracite layer’s solids storage capacity. If the filter evaluation and subsequent stress testing do not provide additional process capacity, additional filters or low pressure membranes may be required to increase plant capacity.

Technical Memorandum No. 8
Hydraulic Model Development

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 8

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TECHNICAL MEMORANDUM NO. 8
Lawrence, Kansas Water Master Plan
December 20, 2012

A. General

Technical Memo (TM) No. 8 discusses the field testing program, model development for static analysis, model calibration, and the criteria for hydraulic analysis. The model is used to determine water distribution system improvements for years 2010, 2020, 2030, and buildout. SCADA information for the high service pumps, booster pumps and tanks are used to develop diurnal curves for the system and each pressure zone as well as data for the extended period simulations. The results of the diurnal evaluation provide peak hour and minimum hour demand ratios and are incorporated into model scenarios for each year. The diurnal evaluation also provides the system equalization volume and is used in the storage analysis. Fire demands for each year are also evaluated in the model.

B. Field Testing and Data Collection

Field testing for model development and calibration was conducted by City staff from July 19 through August 2, 2010 and consisted of installing pressure recording devices across the distribution system and conducting fire hydrant flow tests. Field testing was performed in two phases: one phase for the CS pressure zone and one phase for the WH pressure zone.

Continuous water system operating data was collected from the City's SCADA system. The only data not recorded by SCADA is the volumetric flow delivered by gravity from the Oread and Kasold Reservoirs to the CS pressure zone when either of the BPSs is in operation. For example, when the Oread BPS is pumping to the WH pressure zone, the Oread Reservoirs can still supply water to the CS pressure zone by gravity. Mass balance derivation between BPS flowrate and variations in tank level, in theory, will determine the gravity portion of the volumetric flowrate. However, the size of the reservoirs is too large to impart noticeable differences in tank level (drafting/filling rates). Attempts were made to extract the water supply contribution from each reservoir and determined that the gravity portion of the volumetric flowrate had little to no impact on the system as a whole. Listed below is a brief description of data collected from the SCADA system used in the diurnal analysis and for model calibration:

- Central Service PZ:
    - Kaw WTP HSPS flowrate and discharge pressure
    - Clinton WTP HSPS flowrate and discharge pressure
    - Harper Tank level
    - Kasold Reservoir level
    - Oread Reservoir level

- West Hills PZ:
    - Kaw WTP HSPS flowrate and discharge pressure
    - Clinton WTP HSPS flowrate and discharge pressure
    - Kasold BPS flowrate
    - Stoneridge Tank level
    - 6th Street Tank level
    - Stratford Tank level

Data loggers were strategically placed to record pressure in each field testing phase (CS pressure zone and WH pressure zone). The data logger locations for the CS pressure zone are shown in Figure TM8.1 and the locations for the WH pressure zone are shown in Figure TM8.2. Pressure plots for each data logger are included in Appendix D.

Fire hydrant testing was conducted at 28 locations in the CS pressure zone and at 25 locations in the WH pressure zone as shown in Figures TM8.3 and TM8.4. Fire hydrant testing stimulates hydraulic stress to the distribution system and the test results are used to calibrate the hydraulic model. A summary of each fire hydrant test with the static pressure reading, residual pressure reading, calculated flow, and location sketch of the gauged and flowing hydrants is included in Appendix E.

C. Model Construction

An ESRI ArcGIS 9.3 geodatabase containing water system feature classes was provided by the City and used to construct the hydraulic model. The geodatabase included a dataset that encompassed all relevant water system information including nodes, pipes, valves, tanks, booster pumps, and reservoirs feature classes.

The water system data was imported into the hydraulic model using tools available in the modeling software. The City's topologically correct geometric network of the water system was imported to construct the base model and a series of processes were executed to condense the water system by removing features not critical for hydraulic analysis. The process of condensing the system is known as skeletonization, and allows the system to be modeled accurately while reducing the number of features modeled. The model does not include dedicated fire hydrant lines, dedicated building and/or customer service lines, fire lines, private lines, abandoned lines, or dead end mains of short length with no customer consumption data.

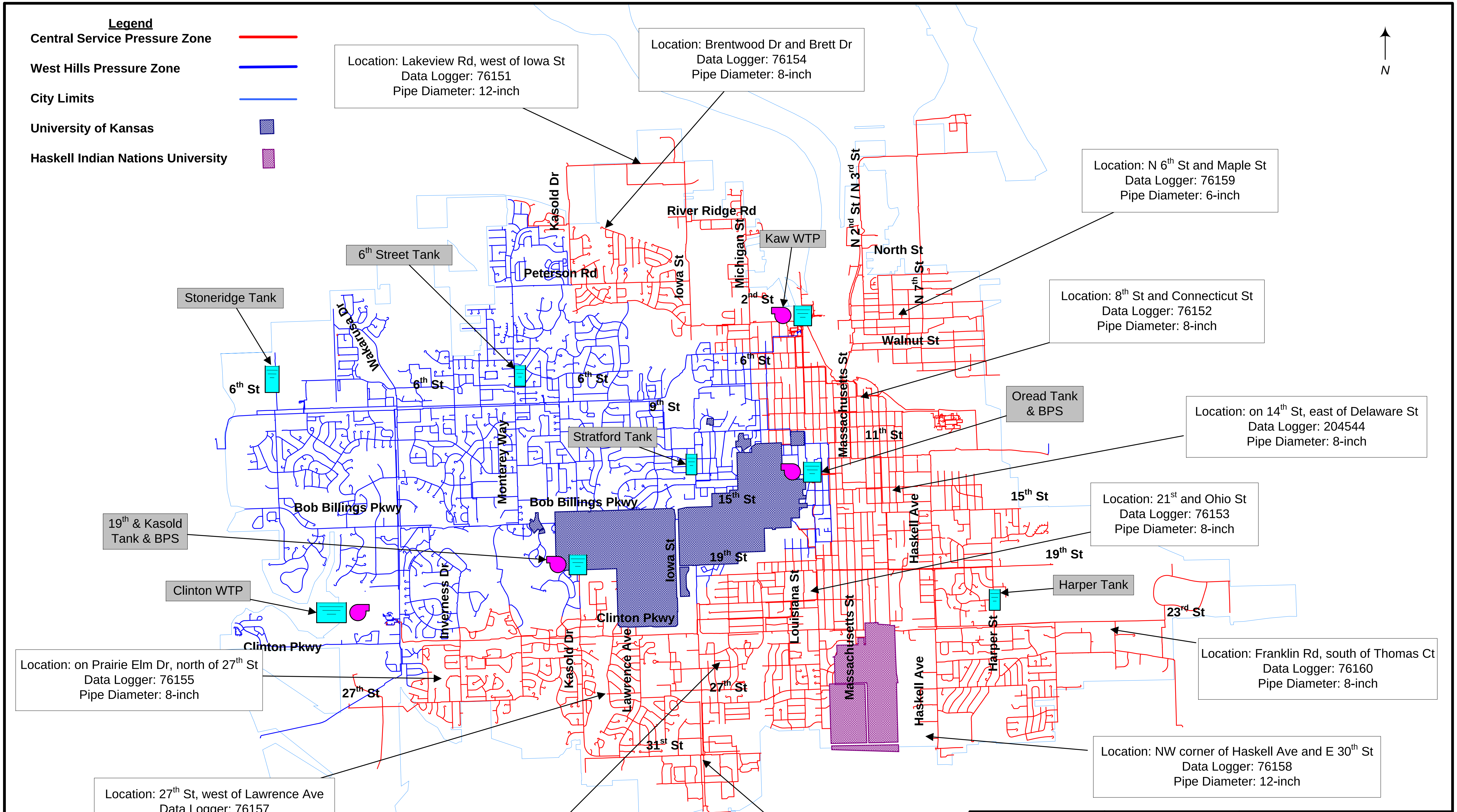

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Figure TM8.1

Lawrence, Kansas

Data Logger Locations:
Central Service Pressure Zone

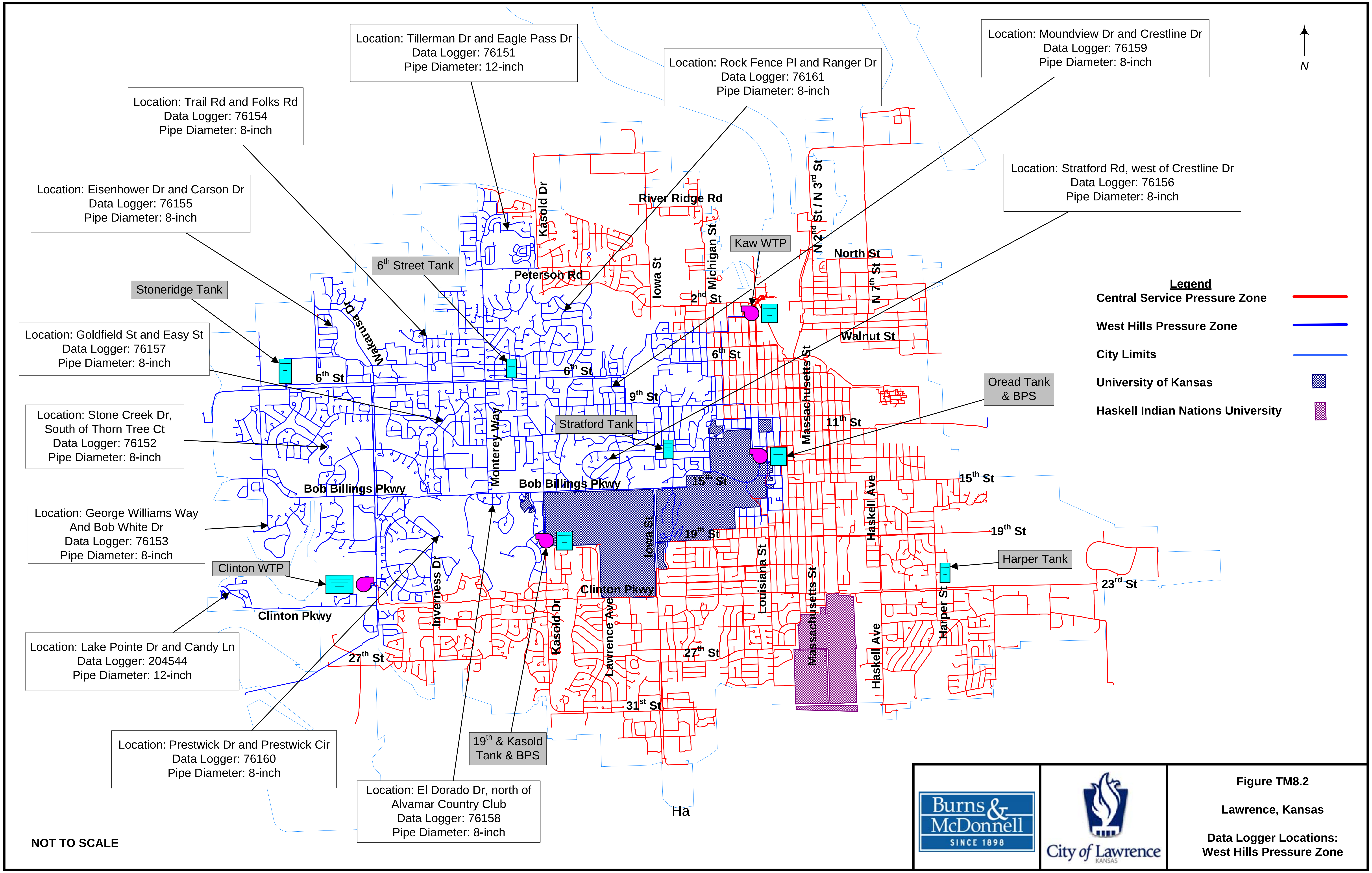

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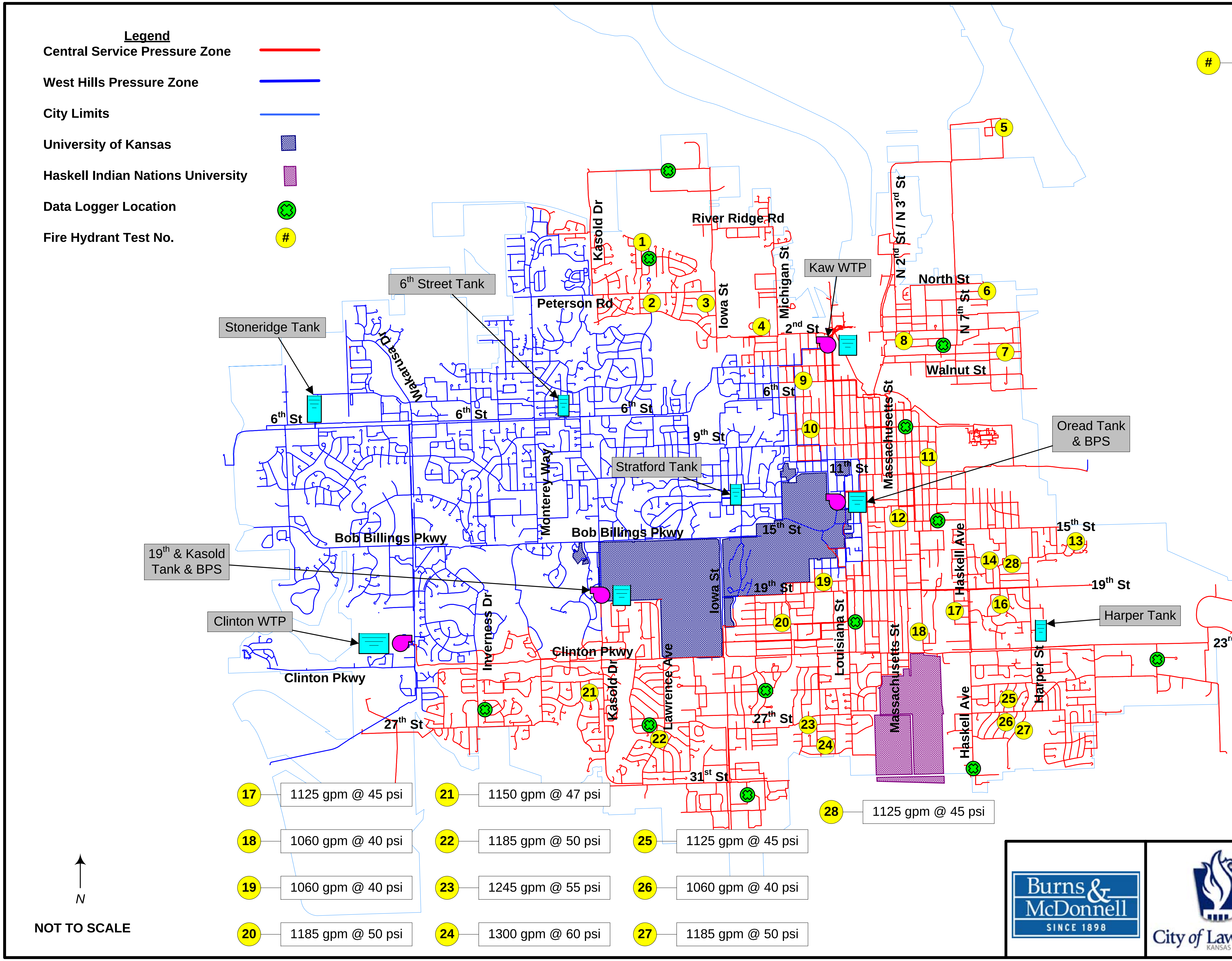
Figure TM8.2

Lawrence, Kansas

Data Logger Locations:
West Hills Pressure Zone



Fire Hydrant Test Results

#	Hydrant Flow Rate @ Residual Pressure
1	1090 gpm @ 42 psi
2	990 gpm @ 35 psi
3	1060 gpm @ 40 psi
4	990 gpm @ 35 psi
5	1440 gpm @ 74 psi
6	1190 gpm @ 50 psi
7	1245 gpm @ 55 psi
8	1300 gpm @ 60 psi
9	1245 gpm @ 55 psi
10	890 gpm @ 28 psi
11	1150 gpm @ 47 psi
12	750 gpm @ 20
13	1020 gpm @ 37
14	1280 gpm @ 58
15	1300 gpm @ 60 psi
16	1185 gpm @ 50 psi
17	1125 gpm @ 45 psi
18	1060 gpm @ 40 psi
19	1060 gpm @ 40 psi
20	1185 gpm @ 50 psi
21	1150 gpm @ 47 psi
22	1185 gpm @ 50 psi
23	1245 gpm @ 55 psi
24	1300 gpm @ 60 psi
25	1125 gpm @ 45 psi
26	1060 gpm @ 40 psi
27	1185 gpm @ 50 psi
28	1125 gpm @ 45 psi

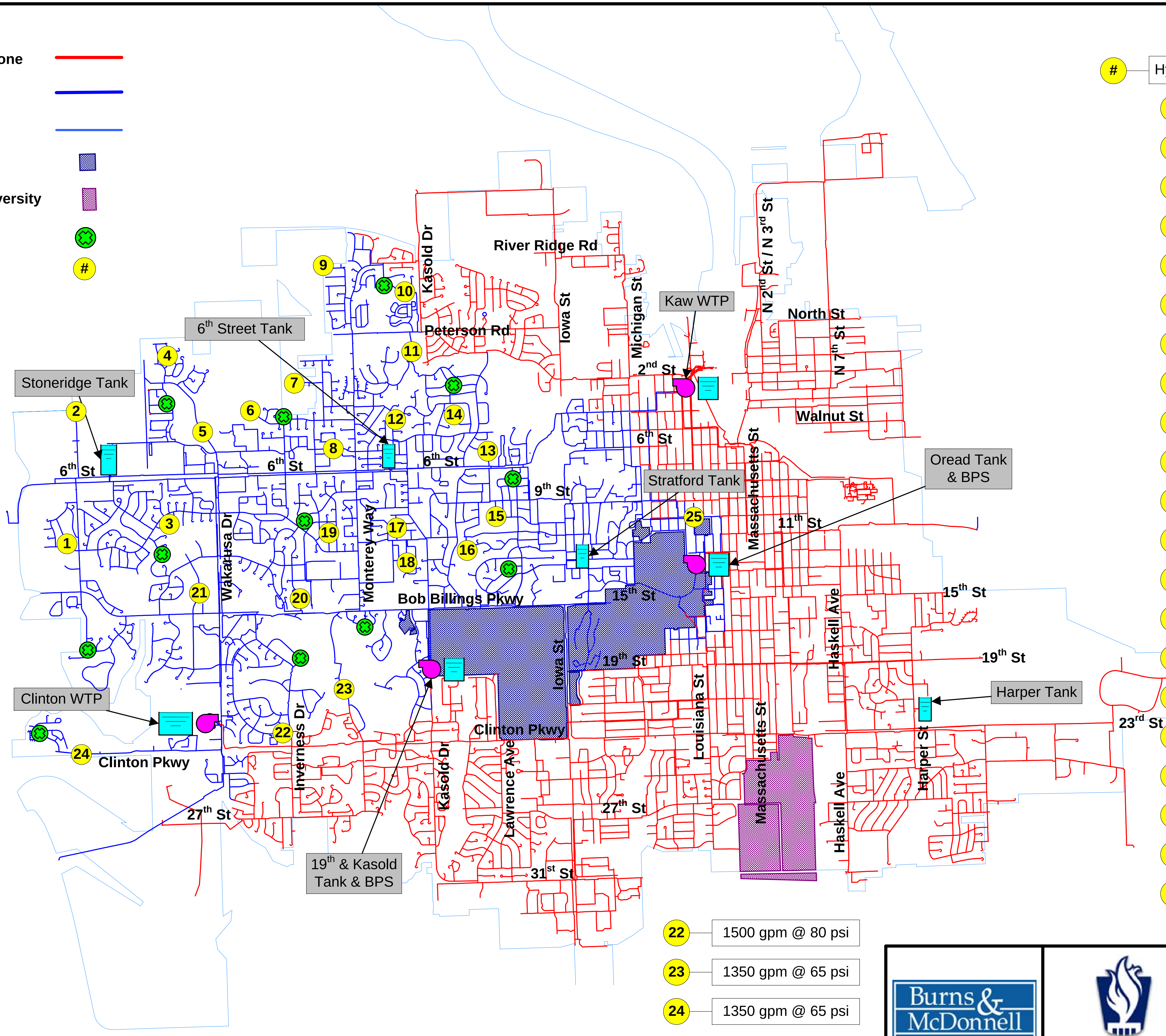
Figure TM8.3

Lawrence, Kansas

Fire Hydrant Test Locations:
Central Service Pressure Zone

Legend

Central Service Pressure Zone	—
West Hills Pressure Zone	—
City Limits	—
University of Kansas	▨
Haskell Indian Nations University	▨
Data Logger Location	⊗
Fire Hydrant Test No.	#



Fire Hydrant Test Results

#	Hydrant Flow Rate @ Residual Pressure
1	1190 gpm @ 50 psi
2	1275 gpm @ 58 psi
3	1250 gpm @ 55 psi
4	1250 gpm @ 55 psi
5	1250 gpm @ 55 psi
6	1070 gpm @ 40 psi
7	1060 gpm @ 40 psi
8	1190 gpm @ 50 psi
9	1190 gpm @ 50 psi
10	1550 gpm @ 85 psi
11	1405 gpm @ 70 psi
12	1300 gpm @ 60 psi
13	1000 gpm @ 35 psi
14	1250 gpm @ 55 psi
15	1190 gpm @ 50 psi
16	1350 gpm @ 65 psi
17	1190 gpm @ 50 psi
18	1350 gpm @ 65 psi
19	1300 gpm @ 60 psi
20	1405 gpm @ 70 psi
21	1350 gpm @ 60 psi
22	1500 gpm @ 80 psi
23	1350 gpm @ 65 psi
24	1350 gpm @ 65 psi
25	1725 gpm @ 105 psi

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Figure TM8.4

Lawrence, Kansas

Fire Hydrant Test Locations:
West Hills Pressure Zone

The node feature class houses water demand information in the model. The demand data includes metered water usage from 2010 provided by the City, and projected water demands for 2020, 2030 and buildout. The metered water usage data was distributed in the model by a process called geocoding. Geocoding connects customer water usage data to the City's GIS parcel data through address or meter identification information. Once all metered sales data was connected to the parcels, GIS and hydraulic modeling tools place the metered sales data to the closest node in the model. Only 3 meters with a total of 0.16 gpm of demand had metered sales data that could not be physically located. This minor demand was distributed evenly across all model nodes to account for the total water usage.

D. Model Calibration

Model calibration is performed by adjusting the Hazen-Williams C-value that is assigned to each pipe to match the field testing data collected for each fire hydrant test and the data logger pressure information. C-values are adjusted in the model to achieve the actual field test conditions within 5 psi up to a pressure of 80 psi. Above 80 psi, the C-values are adjusted to achieve field conditions within 10 percent. The initial C-value assignment from the previous model is incorporated to initiate calibration. The model calibration results are listed in Tables TM8.1 and TM8.2. Field tests were conducted on both CS and WH pressure zones and 18 tests were used to calibrate each zone. Model input data from the field testing includes the hydrant flows for each test and the model results are compared to the residual pressures measured during field testing. This information is also summarized in Tables TM8.1 and TM8.2 and indicates the model is calibrated.

During the initial stages of calibration, model results for the Weir pumps at Kaw WTP serving the CS pressure zone delivered between 200 gpm and 300 gpm more flow in comparison to the data collected by the SCADA system. The pump curves supplied by the City also indicated that the flow rate from the SCADA system was too low based on the observed discharge pressure. This discrepancy is attributed to declining accuracy in the flow meter readings at low flows, which is not uncommon. To correct this in the model, the pumps are set to match the discharge pressure from the SCADA system at the corresponding flow rate based on the pump curves.

The C-values assigned in the model represent the relative internal roughness and provide an indication of the degree of friction within a pipe. Pipes with high C-values convey water with little frictional headloss, but C-values generally decrease with age. Pipes with low C-values can be indicative of partially closed

Table TM8.1

Model Calibration Summary: Central Service Pressure Zone
Lawrence, Kansas

			Water Supply						System Storage			Data Logger (DL) Locations											Fire Hydrant Test Data & Model Results			
			Clinton WTP High Service Pumps			Kaw WTP High Service Pumps																				
Hydrant Test Location	Date	Time	Res. Level (ft)	Discharge (psi)	Flowrate (gpm)	Clearwell Level (ft)	Discharge (psi)	Flowrate (gpm)	Harper Tank Level (ft)	Kasold Reservoir Level (ft)	Oread Reservoirs[1] Level (ft)	Brentwood & Brett 76154 (psi)	8th & Connecticut 76152 (psi)	31st St 76161 (psi)	6th & Maple 76159 (psi)	Ohio & 21st 76153 (psi)	Franklin Rd & Thomas Ct 76160 (psi)	Prairie Elm 76155 (psi)	Lakeview 76151 (psi)	27th St 76157 (psi)	Ousdahl & 25th St 76156 (psi)	30th & Haskell 76158 (psi)	Model Junction ID	Hydrant Flow (gpm)	Gage Hyd Static (psi)	Gage Hyd Flowing (psi)
17th St & Gennessee St - 13	7/22/2010	8:28																								
Field			989.0	28	4233	849.0	71	2221	1011.9	1007.8	1012.5	51	76	73	83	58	43	65	53	70	68	75	FT-11329	1021	64	45
Model			989.0	30	4233	849.0	72	2473	1011.9	1007.8	1012.5	53	78	74	84	61	47	67	55	68	65	79	FT-11324	1021	64	49
Noria Rd & 23rd St - 15	7/22/2010	8:56																								
Field			989.1	29	4164	848.1	72	2221	1011.9	1008.9	1012.7	51	76	73	83	59	43	66	52	71	69	75	SV-8043	1300	82	74
Model			989.1	29	4164	848.1	72	2464	1011.9	1008.9	1012.7	53	78	74	84	61	44	67	56	68	65	79	FT-1448	1300	85	71
Westchester & Kingston - 3	7/22/2010	10:00																								
Field			987.7	29	4164	849.0	71	2290	1011.8	1011.2	1013.0	51	76	74	83	59	44	66	53	71	69	76	J-14	1061	60	55
Model			987.7	30	4164	849.0	72	2477	1011.8	1011.2	1013.0	49	78	75	84	61	47	68	52	69	65	80	FT-130	1061	59	54
2nd St & Minnesota- 4	7/22/2010	10:22																								
Field			988.2	29	4095	849.8	71	2290	1011.9	1011.9	1013.2	51	76	73	83	59	44	66	53	71	68	76	FT-2360	993	63	60
Model			988.2	30	4095	849.8	72	2481	1011.9	1011.9	1013.2	51	78	75	84	61	47	68	54	69	66	80	FT-2580	993	68	64
Maverick Ln - 25	7/22/2010	10:35																								
Field			988.3	30	4095	850.0	72	2290	1011.7	1012.0	1013.3	51	76	74	83	59	42	67	53	71	69	73	FT-9324	1126	59	57
Model			988.3	30	4095	850.0	72	2475	1011.7	1012.0	1013.3	53	78	75	84	61	46	68	56	69	66	77	FT-2174	1126	64	62
Fair Ln & 21st St - 16	7/22/2010	12:47																								
Field			987.4	27	3539	849.8	73	2290	1011.6	1012.0	1013.3	51	76	73	83	59	44	65	53	70	68	76	FT-1458	1186	54	53
Model			987.4	27	3539	849.8	72	2477	1011.6	1012.0	1013.3	53	78	74	84	61	46	66	55	68	65	79	FT-1473	1186	58	57
Maple Ln & Miller Dr -14	7/22/2010	1:01																								
Field			987.5	27	3262	849.6	73	2290	1011.6	1012.0	1013.4	51	76	73	83	59	44	65	52	71	68	76	FT-11391	1278	64	62
Model			987.5	26	3262	849.6	72	2474	1011.6	1012.0	1013.4	53	78	74	84	61	46	66	56	68	65	79	FT-11393	1278	69	67
Glenn Dr & Maple Ln - 28	7/22/2010	1:15																								
Field			987.9	24	3123	849.4	72	2290	1011.5	1012.0	1013.3	49	76	72	82	58	43	64	50	69	68	75	FT-11346	1126	64	64
Model			987.9	25	3123	849.4	72	2474	1011.5	1012.0	1013.3	53	78	73	84	60	46	65	55	67	65	79	FT-11393	1126	69	68
Bowstring Dr - 2	7/22/2010	1:42																								
Field			988.6	25	3054	849.2	71	2290	1011.4	1012.1	1013.3	51	76	72	83	58	43	64	53	69	67	75	J-17	993	50	45
Model			988.6	24	3054	849.2	70	2229	1011.4	1012.1	1013.3	48	78	73	84	60	46	65	51	67	64	79	J-16	993	56	46
27th Ter & Lawrence Ave - 22	7/22/2010	2:07																								
Field			989.3	24	3123	848.9	72	2221	1011.5	1012.0	1012.9	51	76	71	83	58	42	63	53	69	68	75	FT-7198	1186	56	54
Model			989.3	24	3123	848.9	72	2475	1011.5	1012.0	1012.9	53	78	71	84	60	46	64	55	65	63	79	FT-2334	1186	59	56
14th St & Rhode Island - 12	7/22/2010	2:26																								
Field			989.8	25	3123	848.7	72	2290	1011.4	1012.0	1013.0	51	76	72	83	58	43	64	52	70	68	76	J-15	750	71	70
Model			989.8	25	3123	848.7	72	2471	1011.4	1012.0	1013.0	53	78	73	84	60	46	65	55	67	65	79	FT-13544	750	73	73
10th & Delaware - 11	7/22/2010	2:30																								
Field			989.9	25	3054	848.7	72	2290	1011.5	1012.0	1013.0	51	76	73	83	58	43	64	53	70	68	75	FT-4668	1150	69	67
Model			989.9	24	3054	848.7	70	2224	1011.5	1012.0	1013.0	53	78	73	84	60	46	65	55	67	64	79	FT-820	1150	68	68
3rd & Perry - 8	7/22/2010	2:45																								
Field (North Lawrence)			990.2	24	3192	848.6	72	2290	1011.4	1012.0	1012.8	50	75	72	82	58	43	64	52	69	67	75	FT-4566	1300	80	75
Model			990.2	24	3192	848.6	70	2226	1011.4	1012.0	1012.8	53	78	73	81	60	46	65	55	67	64	79	FT-7075	1300	82	79
18th St & Illinois - 19	7/22/2010	2:48																								
Field			990.3	25	3054	848.5	71	2290	1011.4	1012.0	1012.9	50	76	73	83	58	44	65	52	70	68	76	FT-4779	1061	54	52
Model			990.3	23	3054	848.5	70	2222	1011.4	1012.0	1012.9	53	78	73	84	60	46	65	55	67	64	79	FT-4778	1061	57	56
8th St & Locust - 7	7/22/2010	2:58																								
Field (North Lawrence)			990.6	25	3123	848.3	72	2221	1011.4	1012.0	1012.8	51	76	73	83	58	44	64	52	70	68	76	FT-4571	1244	80	79
Model			990.6	25	3123	848.3	72	2473	1011.4	1012.0	1012.8	53	78	73	81	60	46	65	55	67	64	79	FT-365	1244	82	78
21st St & Hillview - 20	7/22/2010	3:10																								
Field			990.9	25	3054	848.2	72	2221	1011.3	1012.0	1012.8	51	76	73	83	59	44	65	53	70	68	76	FT-12617	1186	60	57
Model			990.9	23	3054	848.2	70	2221	1011.3	1012.0	1012.8	53	78	73	84	60	46	65	55	67	64	79	FT-12504	1186	62	60
8th & Hickory - 6	7/22/2010	3:15																								
Field (North Lawrence)			991.0	25	3123	848.1	71	2290	1011.4	1012.0	1012.8	51	76	72	83	58	43	64	53	70	68	75	FT-5295	1186	80	66
Model			991.0	25	3123	848.1	72	2472	1011.4	1012.0	1012.8	53	78	73	82	60	46	65	55	67	64	79	FT-5075	1186	83	68
29th Ter & Alabama - 24	7/22/2010	3:40																								
Field			991.5	25	3123	847.9	72	2290	1011.3	1012.0	1012.8	53	77	73	84	59	44	64	55	70	68	76	FT-7197	1300	78	73
Model			991.5	25	3123	847.9	72	2468	1011.3	1012.0	1012.8	53	78	73	84	60	46	65	55	67	64	79	FT-10712	1300	81	75

Notes:
1. Variations in the Oread Ground Storage Tank levels assume drafting/filling is dedicated to the Central Service Pressure Zone; there is no available SCADA information that indicates if the Oread BPS is in operation and pumping to the West Hills Pressure Zone

Table TM8.2

Model Calibration Summary: West Hills Pressure Zone
Lawrence, Kansas

			Water Supply						System Storage			Data Logger Locations												Fire Hydrant Test Data & Model Results			
			Clinton WTP High Service Pumps			Kaw WTP High Service Pumps																					
Hydrant Test Location	Date	Time	Reservoir Level (ft)	Discharge (psi)	Flowrate (gpm)	Clearwell Level (ft)	Discharge (psi)	Flowrate (gpm)	6th & Kasold Tank Level (ft)	Stoneridge Tank Level (ft)	Stratford Tank Level (ft)	El Dorado 76158 (psi)	Tillerman & Eagle Pass 76151 (psi)	Rockfence & Ranger 76161 (psi)	Easy St & Goldfield 76157 (psi)	Stratford 76156 (psi)	Prestwick 76160 (psi)	Lake Pointe 204544 (psi)	Eisenhower & Carson 76155 (psi)	Stonecreek 76152 (psi)	George Williams & Bob White 76153 (psi)	Folks & Trail 76154 (psi)	Moundview & Crestline 76159 (psi)	Model Junction ID	Hydrant Flow (gpm)	Gage Hyd Static (psi)	Gage Hyd Flowing (psi)
304 N Eaton Dr -- 4	7/29/2010	8:27																									
Field			990.2	84	2845	850.1	142	2151	1164.9	1161.0	1164.7	82	83	107	67	84	94	77	74	76	87	67	63	FT-11458	1250	80	70
Model			**990.2**	**85**	**2845**	**850.1**	**143**	**2138**	**1164.9**	**1161.0**	**1164.7**	**82**	**85**	**108**	**68**	**85**	**95**	**78**	**76**	**78**	**86**	**69**	**64**	**FT-11463**	**1250**	**78**	**68**
Yale & Schwartz -- 15	7/29/2010	8:32																									
Field			990.5	84	2845	850.1	141	2151	1164.7	1161.0	1164.7	82	84	107	67	84	94	76	74	76	87	67	63	J-22	1190	71	68
Model			**990.5**	**85**	**2845**	**850.1**	**142**	**2145**	**1164.7**	**1161.0**	**1164.7**	**82**	**85**	**108**	**68**	**85**	**95**	**78**	**78**	**78**	**86**	**69**	**63**	**FT-13573**	**1190**	**68**	**66**
Randall Rd -- 18	7/29/2010	9:05																									
Field			989.7	84	2429	850.1	141	2221	1164.6	1161.1	1164.1	82	83	107	67	83	94	77	74	76	87	67	63	FT-1346	1350	87	80
Model			**989.7**	**85**	**2429**	**850.1**	**142**	**2141**	**1164.6**	**1161.1**	**1164.1**	**81**	**85**	**108**	**68**	**85**	**95**	**78**	**78**	**78**	**86**	**69**	**64**	**FT-4397**	**1350**	**86**	**76**
Roundabout Cir & Trail Rd -- 6	7/29/2010	9:10																									
Field			989.6	84	2498	850.1	141	2151	1164.3	1161.0	1164.0	81	83	106	66	83	93	76	73	76	86	67	62	J-87	1070	80	74
Model			**989.6**	**85**	**2498**	**850.1**	**143**	**2136**	**1164.3**	**1161.0**	**1164.0**	**82**	**85**	**108**	**68**	**85**	**95**	**78**	**78**	**78**	**86**	**68**	**64**	**FT-420**	**1070**	**77**	**70**
Andover -- 19	7/29/2010	9:56																									
Field			990.5	85	4164	850.1	141	2151	1163.6	1160.6	1163.0	83	84	108	68	84	95	78	74	77	88	68	63		1300	74	71
Model			**990.5**	**87**	**4164**	**850.1**	**142**	**2142**	**1163.6**	**1160.6**	**1163.0**	**82**	**85**	**108**	**68**	**85**	**96**	**79**	**78**	**78**	**86**	**70**	**64**	**FT-1175**	**1300**	**71**	**69**
4117 Saddlehorn Dr -- 7	7/29/2010	10:14																									
Field			990.5	86	2984	850.1	143	2151	1163.6	1160.8	1164.1	85	86	110	70	85	97	80	77	80	90	70	65	SV-2504	1060	64	54
Model			**990.5**	**86**	**2984**	**850.1**	**143**	**2134**	**1163.6**	**1160.8**	**1164.1**	**82**	**85**	**108**	**68**	**85**	**96**	**78**	**78**	**78**	**86**	**69**	**64**	**FT-331**	**1060**	**63**	**53**
4043 Overland Dr -- 8	7/29/2010	10:31																									
Field			990.0	86	2845	850.1	145	2151	1163.6	1160.7	1165.1	87	88	112	72	87	99	81	79	82	92	72	66	FT-693	1190	64	60
Model			**990.0**	**85**	**2845**	**850.1**	**143**	**2128**	**1163.6**	**1160.7**	**1165.1**	**82**	**85**	**108**	**68**	**86**	**96**	**78**	**78**	**78**	**86**	**69**	**64**	**FT-7098**	**1190**	**62**	**61**
Riverview Rd & Boulder Ct -- 12	7/29/2010	10:50																									
Field			989.5	86	2776	850.1	145	2151	1163.7	1160.7	1166.3	86	87	110	72	87	99	82	78	81	91	72	67	FT-501	1300	76	70
Model			**989.5**	**86**	**2776**	**850.1**	**143**	**2123**	**1163.7**	**1160.7**	**1166.3**	**82**	**85**	**107**	**68**	**86**	**96**	**78**	**78**	**78**	**86**	**70**	**65**	**FT-423**	**1300**	**73**	**70**
3100 Campfire Dr -- 14	7/29/2010	12:34																									
Field			989.1	86	4025	846.9	139	1110	1163.7	1163.2	1164.8	83	85	108	69	84	97	80	75	78	89	69	63	FT-411	1250	78	72
Model			**989.1**	**88**	**4025**	**846.9**	**139**	**1074**	**1163.7**	**1163.2**	**1164.8**	**83**	**85**	**107**	**69**	**85**	**97**	**80**	**79**	**79**	**87**	**70**	**64**	**FT-429**	**1250**	**78**	**75**
2803 Schwarz Rd -- 13	7/29/2010	12:54																									
Field			989.0	86	4025	846.1	137	0	1163.7	1164.1	1164.6	83	84	108	69	83	96	80	75	78	89	69	63		1000	70	66
Model			**989.0**	**88**	**4025**	**846.1**	**137**	**0**	**1163.7**	**1164.1**	**1164.6**	**83**	**86**	**109**	**69**	**85**	**98**	**81**	**80**	**80**	**87**	**71**	**64**	**FT-615**	**1000**	**69**	**68**
Diamondhead -- 1	7/29/2010	1:10																									
Field			988.7	87	3956	845.9	136	0	1163.7	1164.1	1164.5	86	87	109	72	84	99	83	79	81	92	71	64		1190	80	68
Model			**988.7**	**88**	**3956**	**845.9**	**137**	**0**	**1163.7**	**1164.1**	**1164.5**	**83**	**86**	**109**	**69**	**85**	**98**	**80**	**80**	**79**	**87**	**71**	**64**	**FT-7820**	**1190**	**73**	**71**
3908 Day Flowers -- 9	7/29/2010	1:13																									
Field			988.7	87	3886	845.9	139	0	1163.7	1164.1	1164.5	87	89	112	74	84	101	83	81	83	93	73	64	SV-8941	1190	78	62
Model			**988.7**	**88**	**3886**	**845.9**	**137**	**0**	**1163.7**	**1164.1**	**1164.5**	**83**	**82**	**108**	**69**	**85**	**97**	**80**	**79**	**80**	**87**	**70**	**64**	**FT-7995**	**1190**	**76**	**62**
Research Park -- 21	7/29/2010	1:21																									
Field			988.5	86	4025	845.8	138	0	1163.8	1164.0	1164.8	84	85	108	70	84	96	80	77	78	88	69	63	FT-13673	1350	84	79
Model			**988.5**	**88**	**4025**	**845.8**	**137**	**0**	**1163.8**	**1164.0**	**1165.0**	**83**	**86**	**109**	**69**	**85**	**97**	**80**	**79**	**79**	**87**	**70**	**64**	**FT-13879**	**1350**	**79**	**78**
3520 Tillerman -- 10	7/29/2010	1:26																									
Field			988.4	87	3817	845.7	139	0	1163.8	1164.0	1165.0	85	81	108	72	83	99	79	79	81	91	71	63		1550	104	90
Model			**988.4**	**88**	**3817**	**845.7**	**137**	**0**	**1163.8**	**1164.0**	**1165.0**	**83**	**79**	**108**	**69**	**85**	**97**	**80**	**79**	**79**	**87**	**70**	**64**	**FT-48**	**1550**	**95**	**88**
Clinton Parkway -- 24	7/29/2010	1:36																									
Field			988.4	87	3817	845.7	138	0	1163.7	1164.1	1165.1	84	85	108	69	84	96	64	75	79	90	69	63	FT-2483	1350	94	82
Model			**988.4**	**86**	**3817**	**845.7**	**137**	**0**	**1163.7**	**1164.1**	**1165.1**	**83**	**86**	**109**	**69**	**85**	**96**	**64**	**79**	**79**	**87**	**70**	**64**	**FT-7845**	**1350**	**85**	**76**
Crossgate -- 23	7/29/2010	2:27																									
Field			987.1	85	3470	845.9	137	0	1164.3	1163.9	1165.7	84	85	108	70	84	97	80	77	80	90	70	63	FT-1823	1350	113	86
Model			**987.1**	**87**	**3470**	**845.9**	**137**	**0**	**1164.3**	**1163.9**	**1165.7**	**82**	**86**	**109**	**69**	**85**	**97**	**80**	**79**	**79**	**87**	**70**	**64**	**FT-1452**	**1350**	**113**	**64**
Stone Meadows & Brighton -- 20	7/29/2010	2:45																									
Field			987.0	86	3956	845.9	135	0	1165.3	1163.8	1165.3	84	86	109	70	84	99	82	77	81	91	70	63	FT-1575	1405	90	87
Model			**987.0**	**88**	**3956**	**845.9**	**137**	**0**	**1165.3**	**1163.8**	**1165.3**	**83**	**86**	**109**	**69**	**85**	**97**	**80**	**79**	**79**	**87**	**71**	**64**	**FT-1153**	**1405**	**88**	**87**
Inverness & Wimbledon -- 22	7/29/2010	2:58																									
Field			986.8	86	3886	845.9	137	0	1165.9	1163.8	1165.0	85	86	109	71	84	99	82	78	81	91	71	63	FT-11454	1500	106	102
Model			**986.8**	**87**	**3886**	**845.9**	**137**	**0**	**1165.9**	**1163.8**	**1165.0**	**83**	**86**	**109**	**69**	**85**	**96**	**79**	**79**	**79**	**87**	**71**	**64**	**FT-1225**	**1500**	**104**	**101**

valves in the distribution system, scaling, or other water quality issues. Pipes related to future growth are assigned a C-value of 140 for consistency with the City's desire to install new PVC pipe.

E. Hydraulic Analysis Criteria

Analyses of system storage, WTP high service pumping, and inter-system booster pumping are conducted to determine their ability to meet equalization storage, projected water demands, and identify deficiencies with respect to water supply, storage, pipeline capacity, pumping, pressure, and fire flow. Guidelines used to determine the performance of distribution system components are listed below

- Distribution system pressures are greater than 40 psi;
- Distribution system pressures are greater than 20 psi during fire flow analyses;
- High service pump stations have firm capacity capable of pumping the average demand of the maximum day, which is equivalent to the WTP capacity, at adequate pressure with the largest pump out of service;
- Equalization storage can be replenished over an 8-hour period at night;
- Transmission pipeline velocity is less than 5 feet per second (ft/s), and head loss is less than 6 feet per 1,000 feet. Additional deficiencies to inadequate pipeline velocities and head losses, such as insufficient fire flow or low pressure or additional growth, are typically required to justify pipe replacement;
- Evaluation of total head loss compared to the length of pipe.

The hydraulic model used in this study is the Bentley WaterGEMS V8i. This program analyzes steady state flows and pressures for pipe distribution system. The pipe network modeled is based on a numbering system for each pipe segment and node. Information for each pipe includes length, start node, end node, Hazen Williams C-value, and pipe diameter. Information for each node includes ground elevation, water demand, demand factors, and x and y coordinates. Other feature classes for pumps, valves, tanks, and water supply sources are also included in the model.

Model scenarios for the years 2010, 2020, 2030 and buildout are evaluated for the following steady-state demand conditions to determine the distribution system's capabilities, need, and location for additional supply, piping, storage, and pump stations:

- Maximum day;
- Peak hour;
- Minimum hour plus storage replenishment;

- Maximum day plus fire flow requirements (for comparison to the City's ISO report);

Extended period simulations (EPS) for years 2010, 2020, and 2030 are also evaluated in the model to validate system operation and water age.

The maximum day scenario tests whether the water supply has sufficient capacity and if the demands can be met throughout the system while maintaining adequate pressures. The peak hour scenario tests the adequacy of the storage facilities and distribution system to supply high rates of flow. The minimum hour scenario simulates the ability of the water distribution system to replenish tank storage overnight. The maximum day plus fire flow scenarios represent the performance of the water distribution system with a fire flow demand at a specific location on the maximum day. The EPS is used to determine water age in the distribution system and evaluate pump and storage tank performance and sizing.

Distribution system improvement projects are developed, evaluated and verified with model scenarios of the water system hydraulics and evaluations of resulting flows, hydraulic grade lines, and pressures. Various combinations of improvements are analyzed, where required, to determine a means of meeting projected system growth and operating goals.

F. Diurnal Evaluation

Diurnal curves represent changes in water demand over the course of a day, reflecting times when the City's customers are using more or less water than the average for that day. The average demand over the 24-hour period represents 100 percent. The diurnal curve determines the equalization storage factor, peak hour factor, minimum hour factor, as well as the diurnal pattern used for the EPS. Equalization storage refers to the amount of water stored in the City's elevated tanks for use during peak periods or periods where the system demand exceeds the system supply.

Diurnal curves are developed from information collected by the City's SCADA system during the field testing period from July 19, 2010, through August 2, 2010 as listed in Appendix F. A summary of the diurnal evaluation is listed in Table TM8.3 and includes equalization storage, minimum hour, and peak hour factors for each day during field testing in each pressure zone. The demand factors applied in the model for each pressure zone are listed below and the diurnal curves from which they were selected are shown in Figures TM8.5 and TM8.6:

Table TM8.3

Diurnal Evaluation Summary
Lawrence, Kansas

Pressure Zone	Date	Day	Equlization Storage (%)	Minimum Hour Factor	Peak Hour Factor	Pressure Zone Demand[1] (MGD)
Central Service	7/19/2010	weekday	5.0	0.56	1.31	7.3
	7/20/2010	weekday	11.3	0.54	1.45	7.8
	7/21/2010	weekday	5.3	0.69	1.49	5.5
	7/22/2010[3]	weekday	--	--	--	--
	7/23/2010	weekday	9.2	0.44	1.50	6.6
	7/24/2010	weekend	7.7	0.63	1.38	7.2
	7/25/2010	weekend	8.5	0.73	1.48	6.7
	7/26/2010	weekday	7.2	0.54	1.47	7.1
	7/27/2010	weekday	12.2	0.36	**1.54**	7.1
	7/28/2010	weekday	7.9	0.53	1.47	7.9
	7/29/2010	weekday	7.4	**0.30**	1.37	7.1
	7/30/2010	weekday	6.7	0.71	1.45	7.5
	7/31/2010	weekend	6.8	0.56	1.42	6.9
	8/1/2010	weekend	4.9	0.76	1.31	7.4
	8/2/2010	weekday	5.1	0.69	1.40	8.2
	Average		7.5	0.57	1.43	7.2
West Hills	7/19/2010	weekday	16.0	0.50	2.39	7.4
	7/20/2010	weekday	17.5	0.42	2.21	6.2
	7/21/2010	weekday	12.2	0.33	2.09	4.3
	7/22/2010[3]	weekday	--	--	--	--
	7/23/2010	weekday	15.0	0.42	2.43	5.8
	7/24/2010	weekend	14.2	0.53	1.67	6.1
	7/25/2010	weekend	9.5	0.38	1.81	4.5
	7/26/2010	weekday	14.8	0.57	2.00	5.2
	7/27/2010	weekday	11.9	**0.23**	2.08	6.1
	7/28/2010	weekday	13.3	0.39	1.92	6.7
	7/29/2010	weekday	12.6	0.58	1.97	6.6
	7/30/2010	weekday	10.9	0.30	2.03	6.4
	7/31/2010	weekend	11.0	0.53	1.60	6.6
	8/1/2010	weekend	9.3	0.33	1.54	7.0
	8/2/2010	weekday	15.4	0.41	**2.45**	7.7
	Average		13.1	0.42	2.01	6.2

Notes:
1. Demand is a calculated daily demand developed from the City's SCADA system information.
2. Calculations for the diurnal data and demand are included Appendix F.
3. System wide pressure drop resulted in abnormal peaking factors; data not used in diurnal evaluation.
4. Bold cells highlight maximum peak hour factors and minimum min hour factors.

Figure TM8.5
Peak Hour and Minimum Hour Factors: Central Service Pressure Zone
Lawrence, Kansas

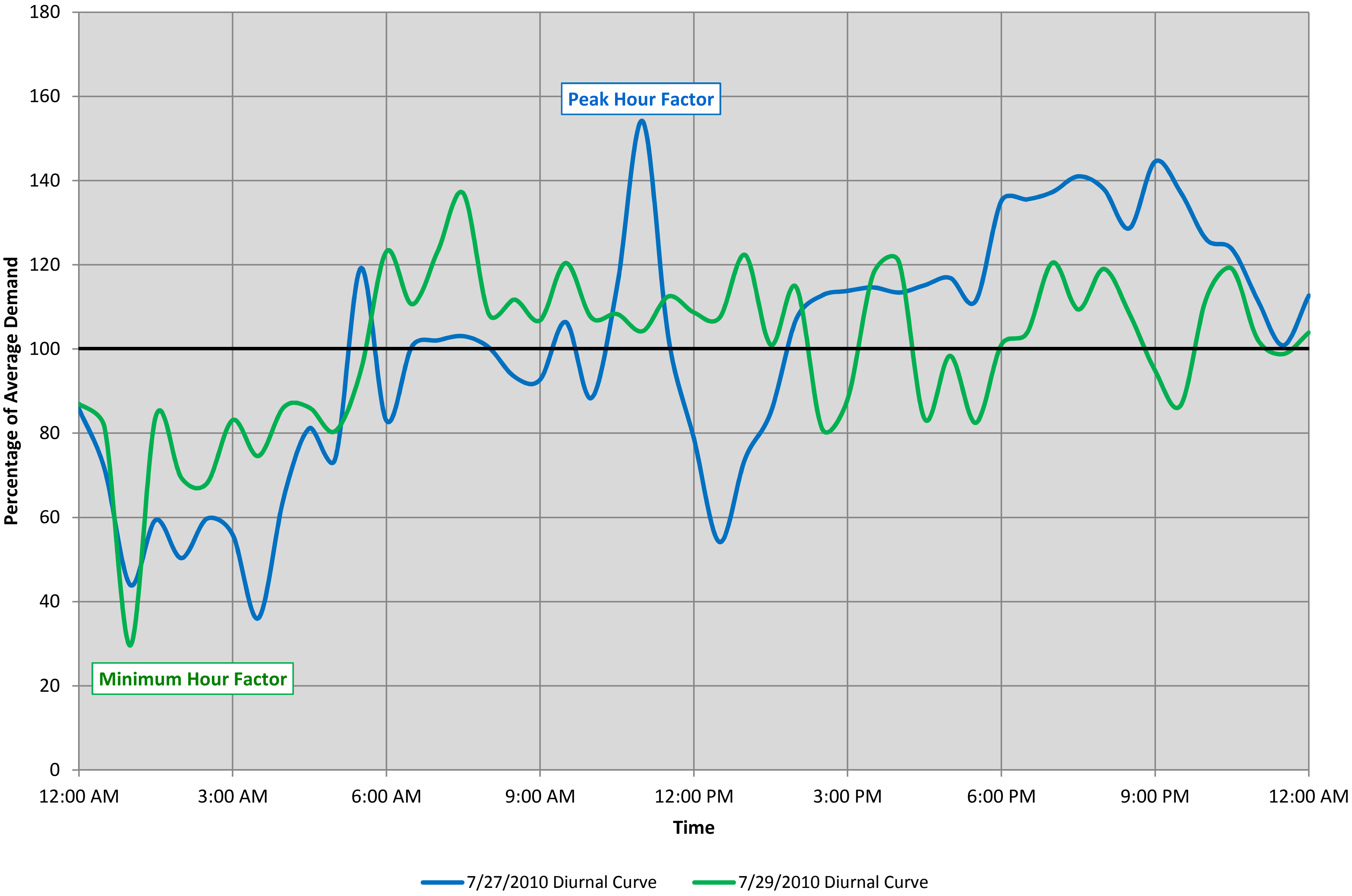
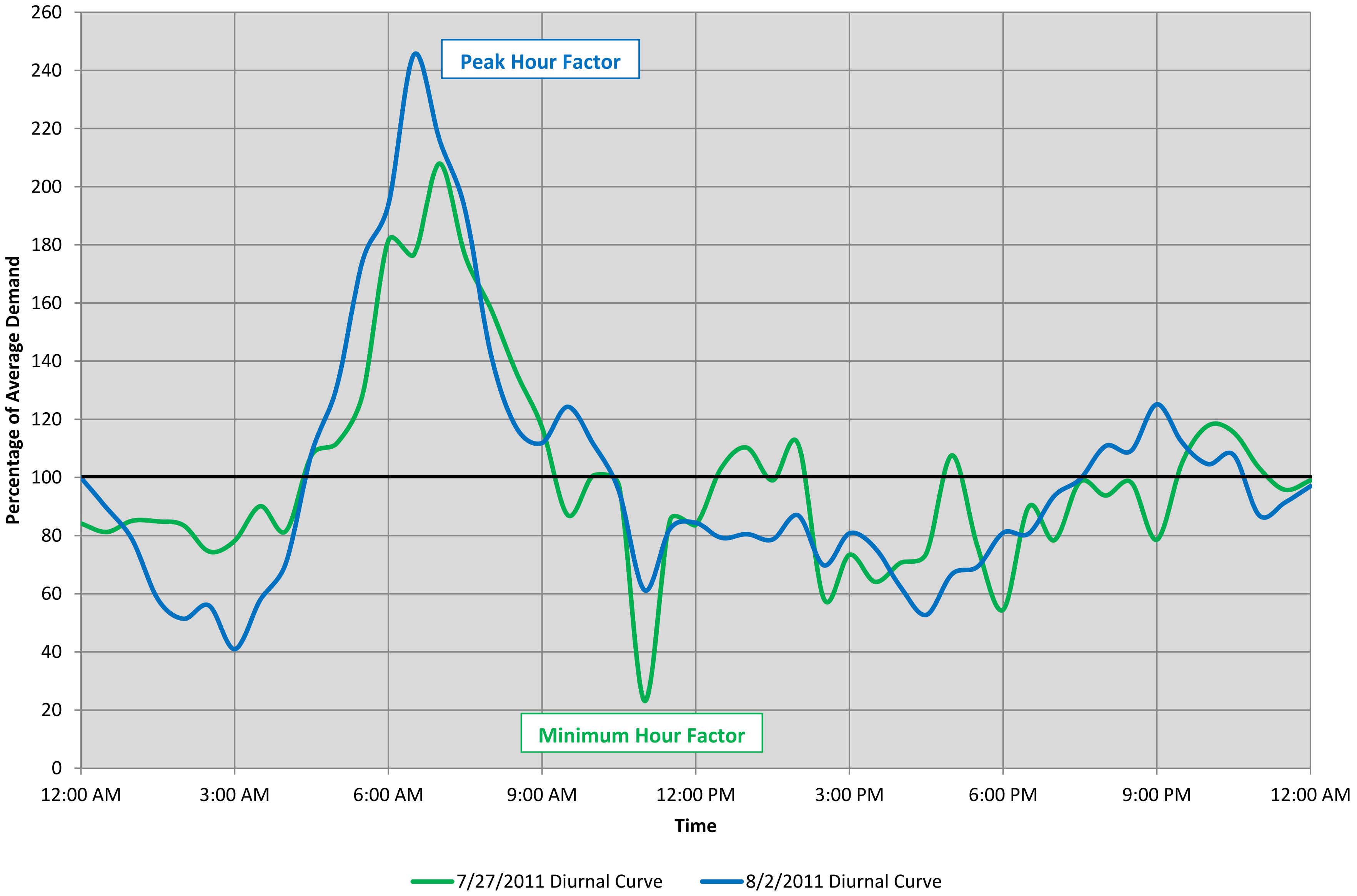


Figure TM8.6
Peak Hour and Minimum Hour Factors: West Hills Pressure Zone
Lawrence, Kansas



- Central Service:
  - Minimum Hour Demand Factor = 0.30
  - Peak Hour Demand Factor = 1.54
- West Hills Pressure Zone:
  - Minimum Hour Demand Factor = 0.23
  - Peak Hour Demand Factor = 2.45

G. Fire Demand

Fire or emergency storage includes water that must be available at all times to fight the most severe fires as determined by the Insurance Services Office (ISO), which defines fire demand and duration. Insurance companies use these studies to set insurance rates for city residents. A copy of the City's most recent ISO report can be found in Appendix G. The ISO report requirement for needed fire flow is 2,500 gpm for two hours and 3,500 gpm for three hours depending on the location. For the purposes of this report and hydraulic model, distribution system improvements related to improving the available fire flow are based on 3,500 gpm for three hours.

H. Storage Analysis

Equalization and emergency storage are required for the operation of a distribution system. Equalizing demand is water use greater than the 24-hour average daily use that results in the depletion of system storage. Equalization storage is typically considered the upper halves of elevated storage and the volume of ground storage that can be replenished over a 24-hour period. The distribution system must be capable of replenishing equalization storage within the same 24-hour period of the maximum day demand. Emergency storage refers to water needed for fire flow and system failures. The ISO requirement for emergency storage is a maximum of 3,500 gpm for three hours. Available emergency storage is typically considered as the bottom portion of elevated storage.

The area above or below the 100 percent line on the diurnal curve is equivalent to the equalization storage volume. A storage factor is calculated to represent this volume and is determined as the ratio of equalizing volume to the 24-hour demand. The storage factor in the CS pressure zone ranges from 4.9 percent to 12.2 percent. The storage factor in the WH pressure zone ranges from 9.3 percent to 17.5 percent. The storage evaluation also considered the ability to transfer water between the two pressure zones via the Oread and Kasold pump stations. Multiplying the storage factor by the year 2030 maximum day demand for each pressure zone is the required equalization storage volume and emergency storage needed for the City. The storage factors and maximum day demands used in the storage analysis for each pressure zone are listed below:

- CS pressure zone storage factor of 13 percent for a year 2030 demand of 17.6 MGD.
- WH pressure zone storage factor of 18 percent for a year 2030 demand of 19.3 MGD.

Based on the maximum day demand of 36.9 MGD, the City currently has a slight storage deficit of 0.1 MG for equalization and emergency volumes through the year 2030 as listed in Table TM8.4. Based on the extended period simulation runs, the storage appears to be adequate for year 2030 demands and additional storage will be placed in the growth areas or new pressure zones when sufficient demand occurs in those areas. As part of the final tank design process, the tank capacity should be maximized at Oread based on available constructible space to meet height restrictions. Additionally, more costly cast-in-place alternatives can be developed and evaluated at that time.

Table TM8.4: Storage Analysis for Year 2030

Item	Amount
Fire or Emergency Demand (gpm)	3,500
Duration (hours)	3.0
Fire or Emergency Volume (MG)	0.63
WH Equalizing Factor (MG/MGD of Demand)	0.18
WH 2030 Maximum Day Demand (MGD)	19.3
WH Equalizing Volume (MG)	3.47
CS Equalizing Factor (MG/MGD of Demand)	0.13
CS 2030 Maximum Day Demand (MGD)	17.6
CS Equalizing Volume (MG)	2.29
Total Storage Volume Required (MG)	6.4
Total Available (full) Storage (MG)	6.3
Year 2030 Maximum Day Storage Deficit (MG)	**-0.1**

Notes:
1. Total available storage includes the full capacity of Kasold and new Oread reservoir at about 1.7 MG.
2. Improvements to Kasold BPS/reservoir will include emergency power hook-up capability and the proposed Oread BPS/reservoir site will include emergency power hook-up capability.

Technical Memorandum No. 9
Hydraulic Analysis and System Improvements

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 9

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A. General

Technical Memo (TM) No. 9 discusses the hydraulic analysis of years 2010, 2020, 2030 and buildout systems. The model is used to evaluate the strengths and weaknesses of the 2010 water system. It is also used to determine water distribution system improvements required to meet future growth areas and the associated projected demands for year 2020, year 2030, and buildout. Additionally, preliminary concepts are developed for improvements at Oread and Kasold tanks and booster stations for inclusion in the CIP based on the results of the modeling.

B. Hydraulic Model Analysis

Hydraulic analyses include the use of the computer model of the distribution system and engineering judgment to evaluate improvements and meet the criteria discussed above. The following demand conditions are evaluated for years 2010, 2020, 2030 and buildout:

- Average day;
- Maximum day;
- Peak hour;
- Minimum hour plus storage tank replenishment; and
- Maximum day plus fire flows.

The maximum day demand condition tests whether the water supply has sufficient capacity and if the water can be distributed throughout the system while maintaining adequate pressures above 40 psi. Based on the review of historical data, the maximum day demand is 2.2 times the average day demand. The peak hour demand condition tests the adequacy of the storage facilities and distribution system to supply high rates of flow. The minimum hour demand condition simulates the ability of the water distribution system to replenish distribution system storage overnight. The maximum day plus fire flow demand condition simulates the ability of the water distribution system to deliver fire flow requirements at a specific location under the maximum day demand. Extended period simulation, EPS, is conducted to evaluate the tank turnover and water age.

Projected demands are listed below in Table TM9.1 for the years 2020, 2030 and buildout and are discussed in the following sections. An extrapolated year 2010 "dry year" maximum day demand is also listed for comparison purposes.

Table TM9.1: Modeled Projected Demands

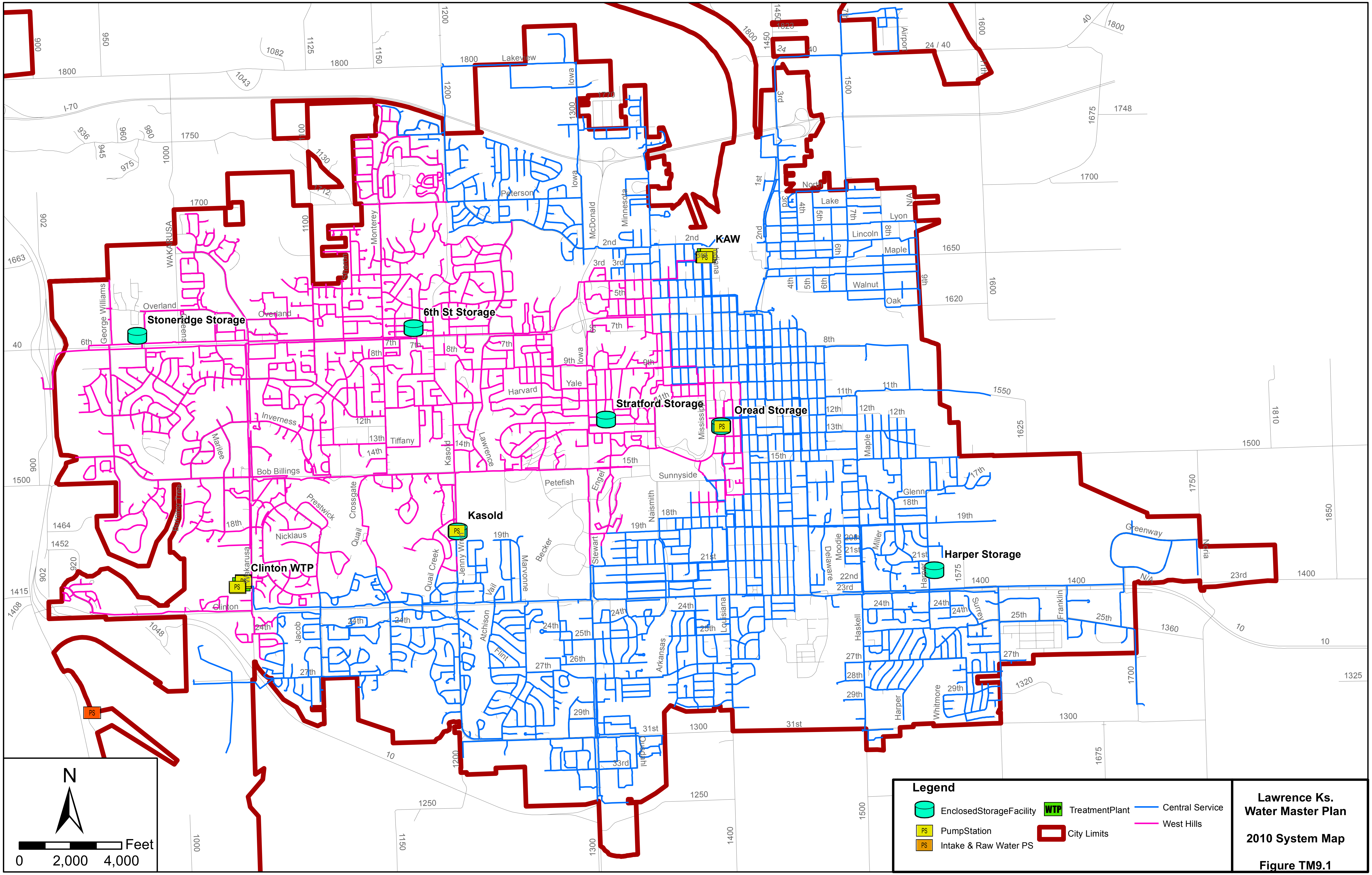
Year	Maximum Day Demand (MGD)
2010	19.5 (extrapolated dry year)
2020	32.7
2030	36.9
Buildout	71.7

The year 2010 system currently has two pressure zones, two WTPs that can serve either zone, six tanks and two booster stations. Kaw WTP has a potential capacity of 17.5 MGD and Clinton WTP has a potential capacity of 25 MGD for year 2020 and 2030 scenarios. This provides up to 42.5 MGD of capacity, which exceeds the year 2030 projected maximum day demand. For the buildout scenario, hydraulic modeling was completed based on a 17.5 MGD supply from Kaw WTP with the remaining 54.2 MGD supplied by an expanded Clinton WTP, as this is the worst case for the distribution system. The addition of the 36-inch Kaw transmission main provides excess capacity beyond 17.5 MGD from the Kaw WTP and will allow the plant to convey 25 MGD into the distribution system if expanded in the future. This scenario with 25.0 MGD from the Kaw WTP and the remaining 46.7 MGD from the Clinton WTP plant was not modeled as part of this effort.

B.1 2010 System Model

The distribution system as shown in Figure TM9.1 is modeled with year 2010 demand data and is analyzed to determine the strengths and weaknesses under the current operation of the system. The 2010 hydraulic model of the system has 5140 nodes. During maximum day demand conditions, system pressures in the CS zone range from 40 to 85 psi. However, model results indicate 32 nodes in the CS zone have pressures less than 40 psi. Fourteen of these low pressure nodes are localized and located in the WTP yard piping or near the base of the 19th & Kasold, Harper, and Oread storage tanks in the CS zone and range from 16.3 psi to 20.8 psi depending on the static water level in the tanks.

A low pressure area is located near the intersection of Sunflower and Sunnyside. There are five low pressure nodes associated with a 16-inch CS zone water main that passes through an area of high elevation within the WH pressure zone, resulting in nodes with pressures in the 17 to 21 psi range. The water demands in the model near these nodes, representative of the City's customers, are supplied by the



Lawrence Ks.
Water Master Plan

2010 System Map

Figure TM9.1

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WH pressure zone. This area of low pressure could be corrected by using the model to design a connection between the WH and CS mains at this location to increase pressures in this area.

One other area of low pressure is located near the intersection of Glenview and Creekwood, near the boundary where CS and WH meet. This area is in the CS zone but is at a higher elevation, and consequently has lower pressures at five nodes ranging from 36 to 39 psi. Pressures in the WH zone range from 40 psi up to 133 psi.

There is a single node with a pressure of 39.2 psi located along Lakeview east of Kasold caused by high elevation. The remaining six nodes with low pressures are located at the end of long dead end runs and high elevations, usually near the boundary between the WH and CS zones.

There are 6355 pipes in the 2010 hydraulic model. Of these pipes, only 161 have C-values less than 70. These low C-value pipes are older ductile and cast iron pipes, located in some residential neighborhoods southeast of 23rd and Haskell, along Perry in North Lawrence, and in downtown Lawrence. Although these pipes have lower C-values the model indicates fire flows and pressures are adequate, and the pipes do not need replacement in the near-term. Appendix H contains a list of these pipes for reference.

Under maximum day demand conditions all pipe velocities in the system are below 5 feet per second (fps). Three pipes with diameters 8 inches or less have head loss gradients higher than six feet per 1000 feet. These pipes were previously included in the City's existing pipe replacement program listed in Appendix H.

During peak hour conditions, 46 nodes have pressures less than 40 psi, in locations consistent with the maximum day results throughout the system therefore no pipeline replacement is proposed. During peak hour, nine pipes have velocities greater than 5 fps, and 30 pipes have head loss gradients above six feet per 1000 feet. As the nodes along these pipes have system pressures greater than 40 psi, and the head loss and velocities are only high during peak hour, replacement is not recommended at this time.

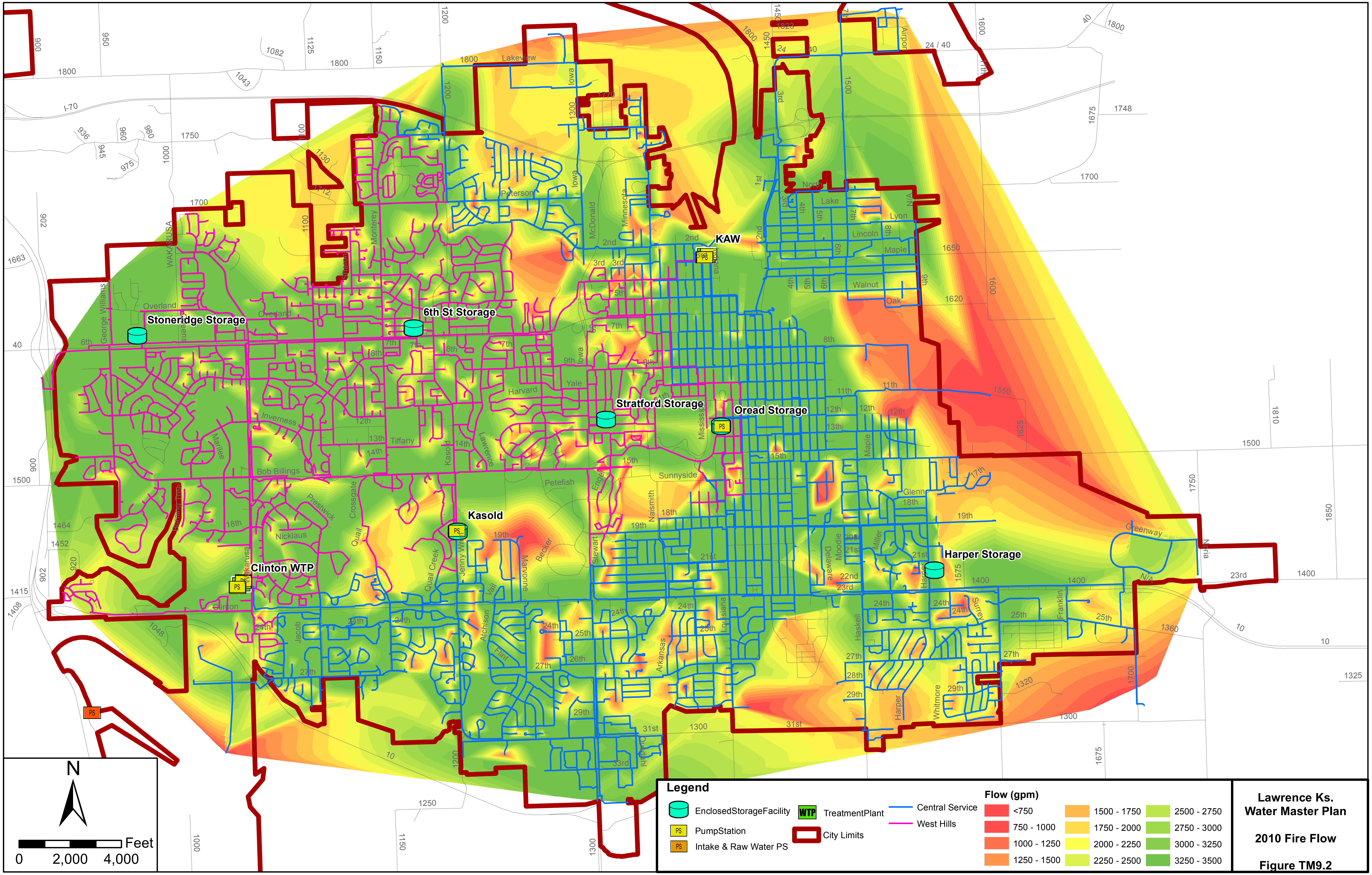
The hydraulic criteria of velocity greater than 5 fps and headloss greater than 6 feet per 1000 feet are general guidelines to identify pipes for potential replacement. These decisions are based on total headloss, length of pipe, and the acceptability of available fire flow and system pressure.

Based on our analysis, no pipe replacement in addition to those currently listed in the City's pipe replacement program and small main replacement program is recommended based on these criteria.

A fire flow analysis for the 2010 system was evaluated with the model. The 2010 system was modeled using the maximum day demand with a fire flow added to each node. The fire flow analysis is based on one fire flow event at a time. The existing system scenario has 34 nodes with available fire flows less than 750 gpm and 74 nodes with fire flows less than 1,000 gpm. Most of these are small diameter dead end pipes which are 4-inch diameter or smaller, and are being addressed through the City's small main replacement program. The 2010 fire flow contours are shown in Figure TM9.2.

EPS analysis computes water age in the distribution system to evaluate residence time in tanks and assist in predicting areas in the distribution system with the greatest potential for water quality deteriorations. The EPS includes a time period extensive enough to capture the longest travel time within the distribution system to reach equilibrium. A 14-day EPS was evaluated under the average day demand condition. The average water age in the distribution system is determined as a weighted average of the water age for each model node based on the percent of demand for that node.

Water age contours based on the 2010 average day demand condition are shown in Figure TM9.3. The distribution system locations resulting in the highest water age under average day demand conditions are generally nodes located at the outskirts and dead ends of the system where there is little or no demand. The average water age in the CS zone is 29 hours and 32 hours in the WH zone. The localized, or concentrated, contours with water age greater than 250 hours (red contours) shown in Figure TM9.3 represent dead end mains with little or no demand. If the customer consumption/demand increases similar to the surrounding area, then the water age would decrease and be representative of those contours in the surrounding area. The area around KU indicates several areas of high water age, all at dead ends. KU wholesale meter demands were distributed in the model via geocoding. and if the location of the meter is different, at the dead end instead of the main line where geocoding placed the demand, the water age will be improved. Therefore, high water age locations within KU could be improved based on actual meter location and the presented information is a worst case situation.



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2010 Fire Flow

Figure TM9.2

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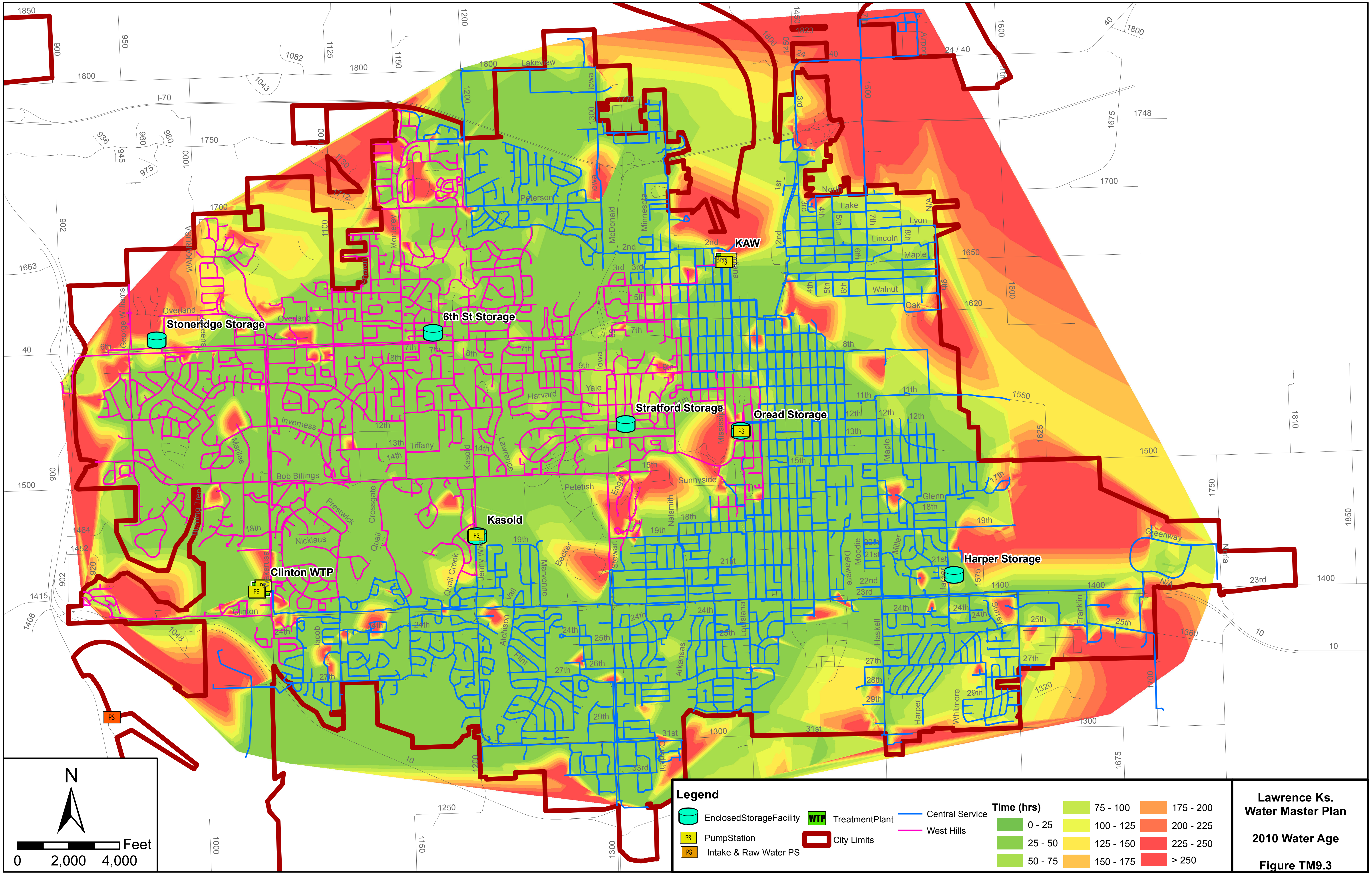

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2010 Water Age

Figure TM9.3

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B.2. Year 2020 Model

Year 2020 demand data was analyzed to determine system improvements to meet the projected demands. For these runs a number of system improvements were made as well as additional growth related improvements. System improvements include the City's current small-main replacement program, where older, 4-inch diameter pipes are replaced with new 8-inch diameter PVC pipe. Other improvements include the addition of Phase I of the Kaw Transmission Main, addition of a pressure reducing valve between the WH and CS pressure zones, a BPS and associated piping at Harper Tank, and a number of other pipe replacement projects identified by the City and as a result of the 2010 model runs. These improvements are shown on Figure TM9.4 and listed in Table TM10.1.

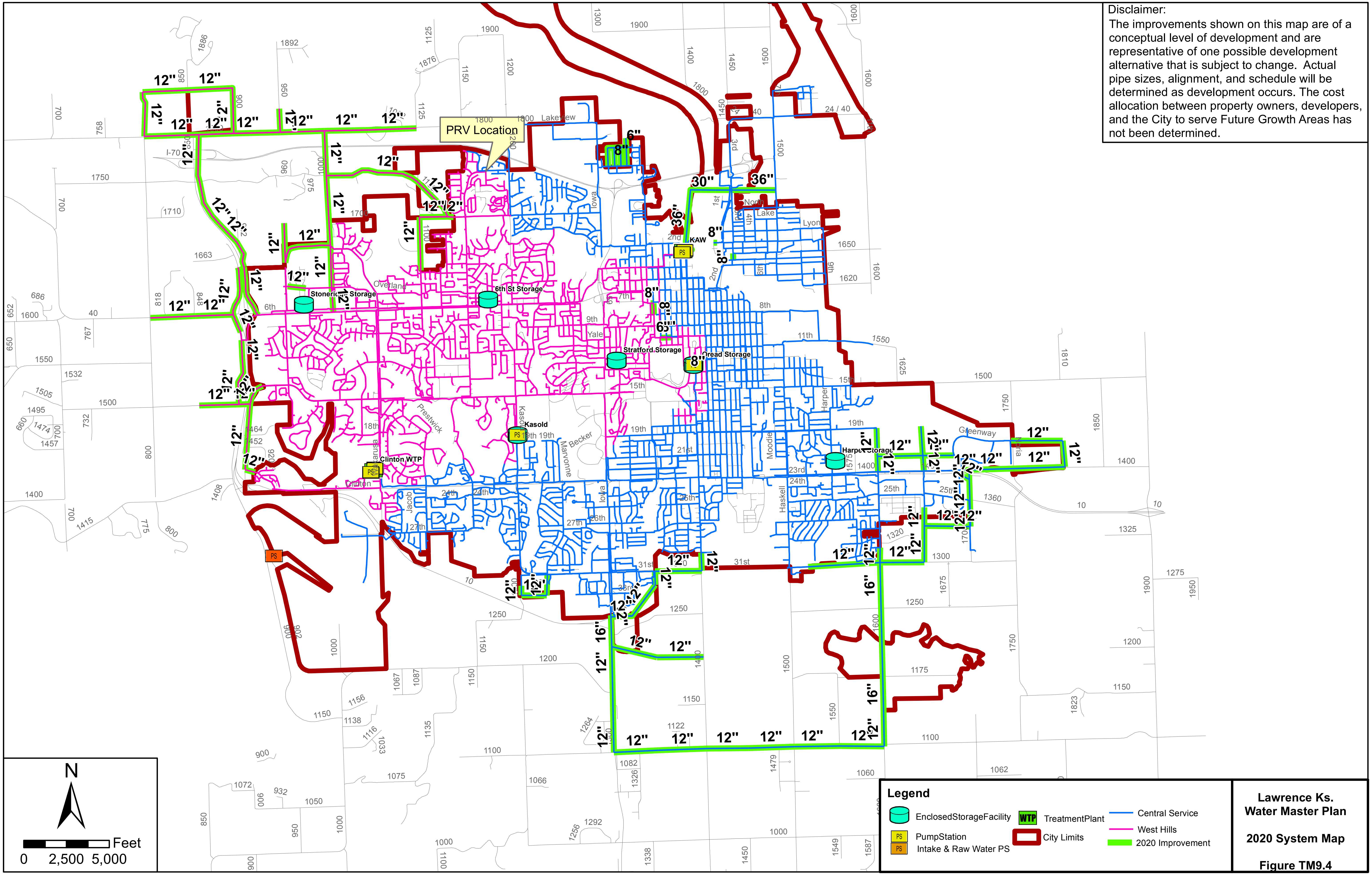
The 2020 system was modeled using the projected maximum day demand of 32.7 MGD. Model results of the 2020 system indicate the pressure in the CS zone ranging from 40 psi to 85 psi. However, there are 39 nodes in the distribution portion of the CS zone that the model indicates have pressures less than 40 psi. Of these nodes, 20 are located in the yard piping around Oread and 19th & Kasold tanks or at locations of high elevation near the intersection of Sunflower and Sunnyside where CS lines are transmitting through the WH zone, and have pressures ranging from 16 psi to 30 psi. The water demands near this intersection, representative of the City's customers, are supplied by the WH pressure zone.

There is a low pressure area caused by elevation north of I-70 along Lakeview Road near the Kmart distribution center. Pressure at the node in this area falls to 37 psi under maximum day demand and 35 psi under peak hour demands. A pressure reducing valve was added in the model between the WH and CS pressure zones to help maintain pressures in this area.

One node with low pressure caused by elevation is located in the new growth area to the southeast, along 1100 Road where the pressure is 32 psi. There are substantial changes in ground surface elevation in the south area that will require careful planning for low pressure associated with development at these high elevations. These should be handled on a case by case basis based on the proposed development. They may require development of a small sub-pressure zone with a small booster station and hydro-pneumatic tank or requirements for booster pumps in the houses.

The 17 remaining low pressure nodes are located at areas of high elevation where CS and WH pressure zones meet, and have pressures ranging from 34 to 39 psi.

Disclaimer:
The improvements shown on this map are of a conceptual level of development and are representative of one possible development alternative that is subject to change. Actual pipe sizes, alignment, and schedule will be determined as development occurs. The cost allocation between property owners, developers, and the City to serve Future Growth Areas has not been determined.



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Legend

●	EnclosedStorageFacility	WTP	TreatmentPlant	—	Central Service
PS	PumpStation	▭	City Limits	—	West Hills
PS	Intake & Raw Water PS			🟩	2020 Improvement

Lawrence Ks.
Water Master Plan

2020 System Map

Figure TM9.4

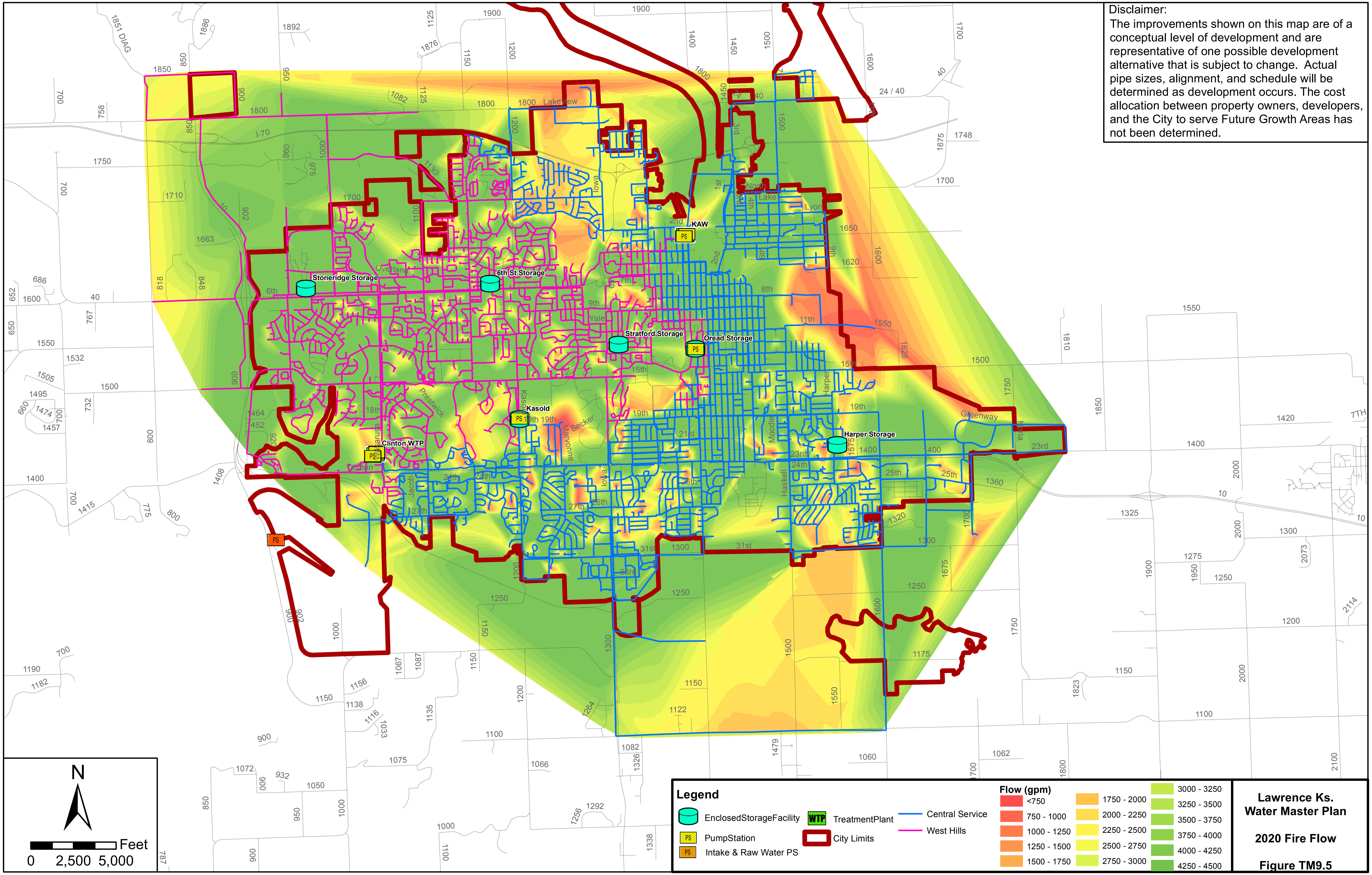
Pressures in the WH zone generally range from 40 psi to 136 psi; however, there is one node in the WH zone with a pressure of 20 psi near the boundary between the CS and WH pressure zones at the base of the 19th & Kasold tank.

Under 2020 maximum day demand conditions all distribution pipe velocities are below five feet per second except for the 24-inch transmission mains at the Clinton plant that supply the WH zone. These pipes have a velocity as high as 6.04 fps, but as their head loss gradients are less than 6 feet per 1000 feet, they are not recommended for replacement. Throughout the distribution system most pipes have head loss gradients less than six feet per 1000 feet, with the exception of five pipes that are between 6 to 11 feet per 1000 feet. While the head loss gradient is slightly high in these pipes, the velocities are below 5 fps, so they are not recommended for replacement.

Peak hour conditions are consistent with the maximum day results throughout the system, with 93 nodes having pressures less than 40 psi. These nodes are located in the same areas that had low pressure under maximum day conditions, around tanks and at areas of high elevation. While more nodes have low pressure due to the higher flows at peak hour, 38 of the nodes still have pressures greater than 35 psi. These are isolated instances of pressures slightly below 40 psi under the harshest demand conditions caused primarily by higher elevations. Therefore, no improvements are recommended but could be evaluated on a case by case basis when development plans are provided to the City based on the proposal.

Under peak hour demands there are 24 pipes having velocities greater than 5 fps, generally associated with the 24-inch concrete transmission mains leading out of the water treatment plants and branch pipes near the plants, and 62 pipes have head loss gradients above six feet per 1000 feet. The relatively low number of pipes with high velocities and head loss gradients are indicative of a robust distribution system. Therefore, these pipes are not recommended for replacement based on velocity or headloss gradient.

A fire flow analysis for the 2020 system was completed using the model. The system was modeled using the projected 2020 maximum day demand with a fire flow added to each node. The improvements to the 2020 system, especially the replacement of the small mains, improves the available fire flow as the 2020 scenario has only 7 nodes with available fire flows less than 750 gpm and 30 nodes with fire flows less than 1,000 gpm. These low flow nodes are located on small diameter dead end pipes at the perimeter of the system. The 2020 fire flow contours are shown in Figure TM9.5.



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Legend

EnclosedStorageFacility	WTP TreatmentPlant	Central Service	
PS PumpStation	City Limits	West Hills	
PS Intake & Raw Water PS			

Flow (gpm)

- <750
- 750 - 1000
- 1000 - 1250
- 1250 - 1500
- 1500 - 1750
- 1750 - 2000
- 2000 - 2250
- 2250 - 2500
- 2500 - 2750
- 2750 - 3000
- 3000 - 3250
- 3250 - 3500
- 3500 - 3750
- 3750 - 4000
- 4000 - 4250
- 4250 - 4500

Lawrence Ks.
Water Master Plan

2020 Fire Flow

Figure TM9.5

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A 14-day EPS was completed at the projected 2020 average day demand conditions. Water age contours based on the 2020 average day demand condition are shown in Figure TM9.6. The distribution system locations resulting in the highest water age under average day demand conditions are generally nodes located at the outskirts of the system where there is little or no demand. The average water age in the CS zone is 29 hours and 31 hours in the WH zone. The localized, or concentrated, contours with water age greater than 250 hours (red contours) as shown in Figure TM9.6 represent dead end mains with little or no demand. If the customer consumption/demand increases similar to the surrounding area, then the water age would decrease and be representative of those contours in the surrounding area. The high water age anomalies near KU are again representative of the demand distribution rather than actual water age.

B.3. Year 2030 Model

The projected maximum day demand for 2030 is 36.9 MGD, a small increase of 4.2 MGD, compared to the year 2020 demand. Year 2030 demand data was analyzed to determine the improvements required to meet the projected demands. System improvements for these runs were limited to completion of Phases 2 and 3 of the Southeast Lawrence transmission main and pipelines to serve additional growth areas. The expanded 2030 system is shown in Figure TM9.7.

During year 2030 maximum day demand conditions of 36.9 MGD, system pressures in the CS zone generally range from 41 psi to 90 psi. However, there are 28 nodes in the CS zone with pressures less than 40 psi. Fourteen of these nodes are located in the same areas that were identified in the 2010 and 2020 runs, around Oread and 19th & Kasold tanks and in areas of high elevation where the CS lines pass through portions of the WH pressure Zone. The remaining low pressure nodes are located at areas of high elevation where CS and WH pressure zones meet.

In 2030, lower than normal pressure occurs in the area of high elevation north of I-70 along Lakeview Road near the Kmart distribution center. The minimum pressure in this area under maximum day demand is 35 psi, and 27 psi under peak hour demands. Adjusting the pressure reducing valve installed in the system between the WH and CS pressure zones has a significant effect on this area, and helps to maintain higher pressures. For the model analysis the PRV was set to open at 35 psi, resulting in the pressures listed above. Reducing the set pressure of the PRV will cause the PRV to open sooner and maintain higher pressures in these areas.

Two nodes with low pressure caused by elevation changes are also located in the new growth area to the southeast, along 1100 Road. Pressures at these nodes at maximum day demands are 32 psi to 34 psi

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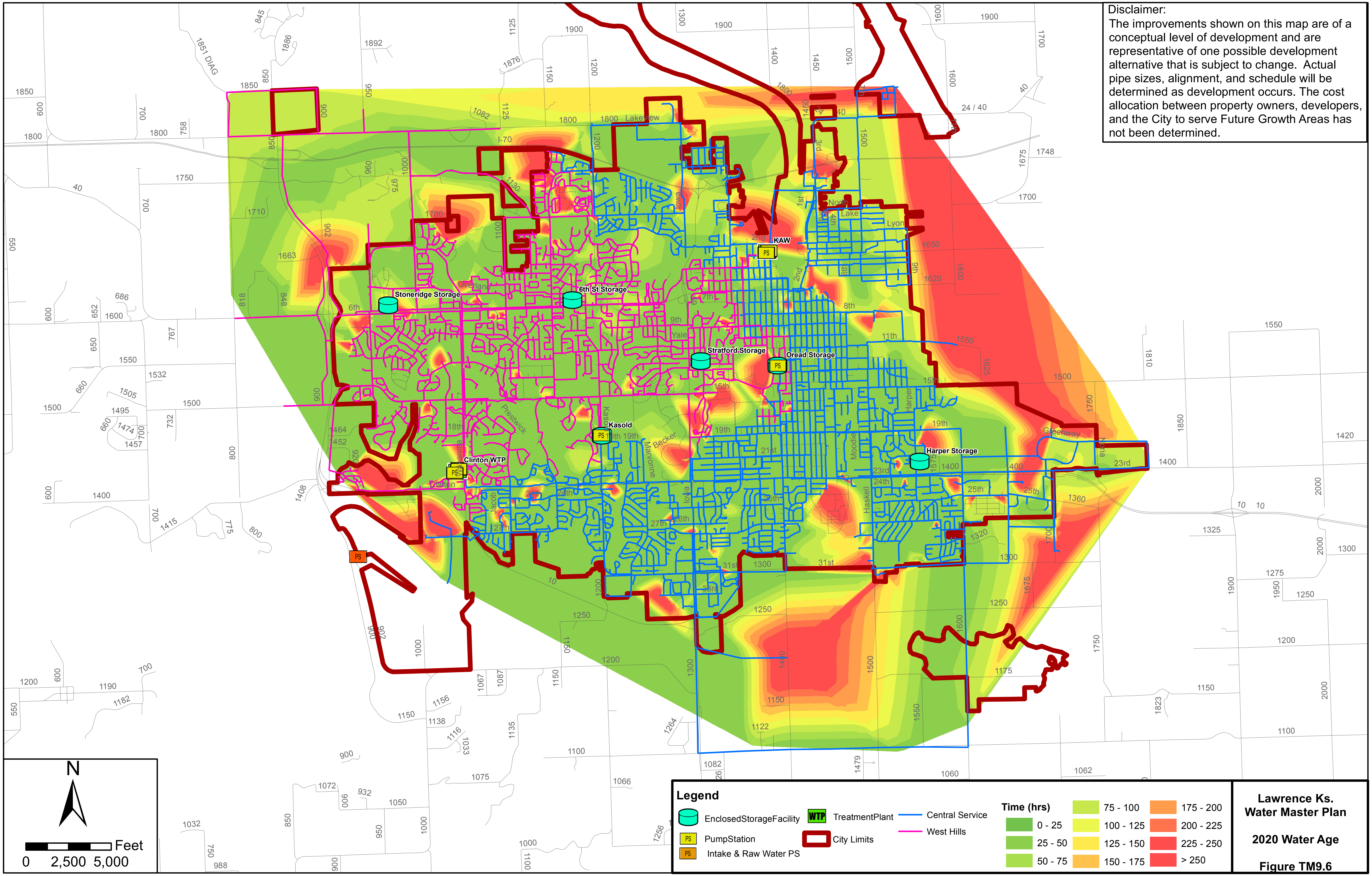

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Water Master Plan

2020 Water Age

Figure TM9.6

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Lawrence Ks. Water Master Plan

2030 System Map

Figure TM9.7

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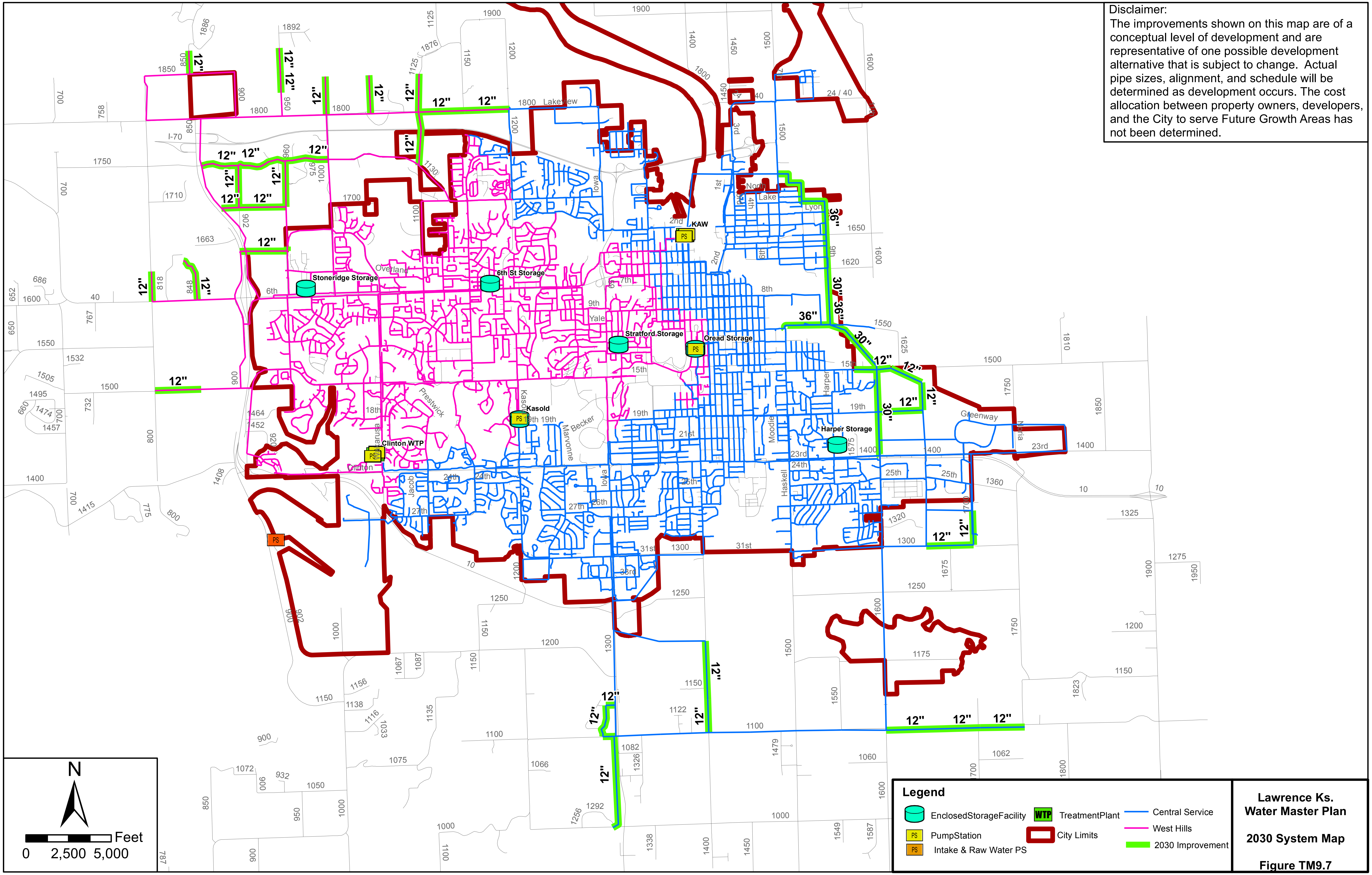

Legend

●	EnclosedStorageFacility	WTP	TreatmentPlant	—	Central Service
PS	PumpStation	▭	City Limits	—	West Hills
PS	Intake & Raw Water PS			🟩	2030 Improvement

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due to the elevation in those areas. Customers at these higher elevations will most likely need a booster pump in their house/facility to supply adequate pressure.

Pressures in the WH zone generally range from 44 psi to 139 psi. One node in the distribution portion of the WH zone near the 19th & Kasold tank has a pressure of 23 psi. This node is located in the yard at the base of the 19th & Kasold tank and is a dead end line that represents the isolation valve between the WH and CS pressure zones.

Under 2030 maximum day demand conditions all distribution pipe velocities are below 5 fps except for the 24-inch transmission mains at the Clinton WTP HSPS that supply both pressure zones. These pipes have velocities as high as 5.9 fps. However, the head loss gradients in these pipes are acceptable at less than 6 feet per 1000 feet, so improvements to replace these pipes not recommended under these conditions. Under the maximum day demand condition, the head loss gradient of 25 pipes are between 6 to 15 feet per 1000 feet with the rest of the pipes having head loss gradients less than six feet per 1000 feet. Since the velocities in these pipes are acceptable at less than 5 fps, the pipes are not recommended for replacement at this time.

During peak hour conditions, low pressure areas are consistent with the 2030 maximum day results throughout the system. The number of nodes with pressures less than 40 psi in these areas increases to a total of 61, due to the higher flows. Twenty-three of these low pressure nodes are in yard piping areas, around Oread, Kasold and Harper tanks, and at high elevations and have pressures from 16 psi to 30 psi. The remaining 38 nodes are at areas of high elevation or dead end junctions and have pressures ranging from 30 psi to 40 psi. Flow increases at peak hour resulted in 32 pipes with velocities greater than 5 fps, and 100 pipes have head loss gradients above 6 feet per 1000 feet. Replacement of these pipes is not recommended at this time as they are adequate for meeting all demands. .

A fire flow analysis for the existing system was completed using the model. The system was modeled using the projected 2030 maximum day demand with a fire flow added to each node. The 2030 system scenario has 6 nodes with available fire flows less than 750 gpm and 19 nodes with fire flows less than 1,000 gpm. These nodes are located at the end of small diameter dead end pipes at the perimeter of the system, or at low pressure junctions at the base of tanks. The 2030 fire flow contours are shown in Figure TM9.8.

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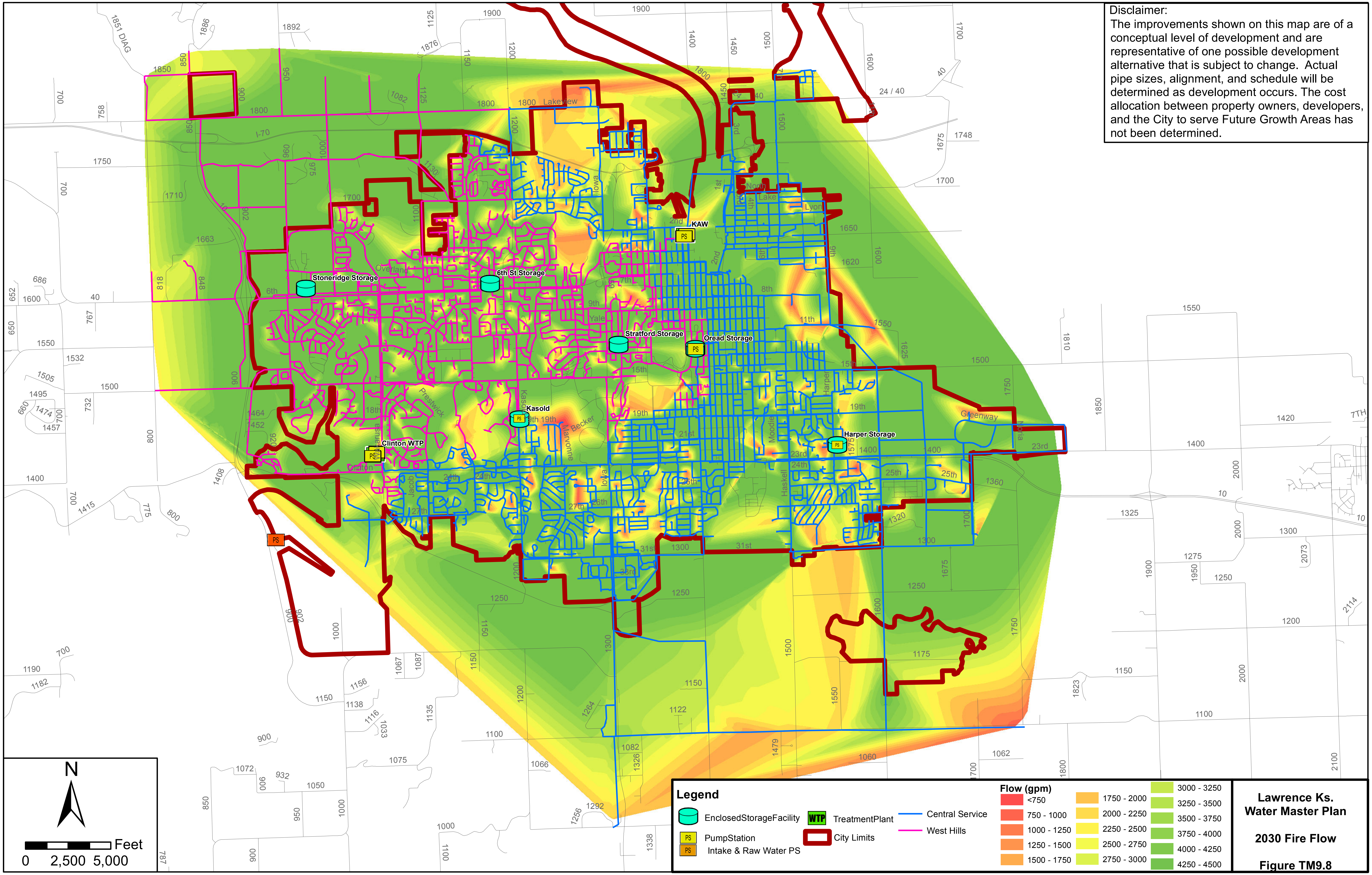

Lawrence Ks.
Water Master Plan

2030 Fire Flow

Figure TM9.8

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A 14 day EPS was completed under average day demand conditions. Water age contours based on the 2030 average day demand condition are shown in Figure TM9.9. The distribution system locations resulting in the highest water age under average day demand conditions are nodes generally located at the outskirts of the system where there is little or no demand. The average water age in the CS zone was calculated to be 34 hours, and 27 hours in the WH zone. The localized, or concentrated, contours with water age greater than 250 hours (red contours) as shown in Figure TM9.9 represent dead end mains with little or no demand. These dead end mains can represent water supply lines for future customers or no customers currently present; if the customer consumption/demand increases similar to the surrounding area, then the water age would decrease and be representative of those contours in the surrounding area.

B.4. Buildout Model.

The buildout scenario uses the projected maximum day demand of 71.7 MGD. The buildout scenario data was analyzed to determine major improvements that would be necessary in the existing system to meet projected demands and growth. The buildout growth areas are evaluated at a high level to determine transmission and distribution main size.

System improvements for the buildout scenario were limited to major transmission lines to new growth areas. Demands in the 2030 system were not significantly larger in the buildout scenario, so distribution improvements were not required within the 2030 service area. Additional improvements will be incorporated into the system prior to the buildout scenario coming to pass. Buildout improvements are of a conceptual level of development and are representative of one possible development alternative that is subject to change. Actual pipe sizes, alignment, and schedule will be determined as development occurs. For the purposes of the model, improvements were limited to replacement of the 24-inch concrete transmission mains leading out of the Kaw and Clinton WTPs with a 36-inch ductile iron transmission main.

Additional transmission and distribution mains to accommodate the new growth areas were added to the system. These were modeled as 24, 20, and 16-inch PVC transmission mains and 12-inch PVC distribution mains along existing roads in the buildout service area. The demands in the growth areas were distributed to the various nodes based on projected growth per acre. Variations of ground elevation in the south required that this area be divided into three additional pressure zones. Three booster stations were added to supply the pressures zones, and four elevated storage tanks were added in the south and two in the northwest to meet additional storage needs. Additional raw water supply and pumping

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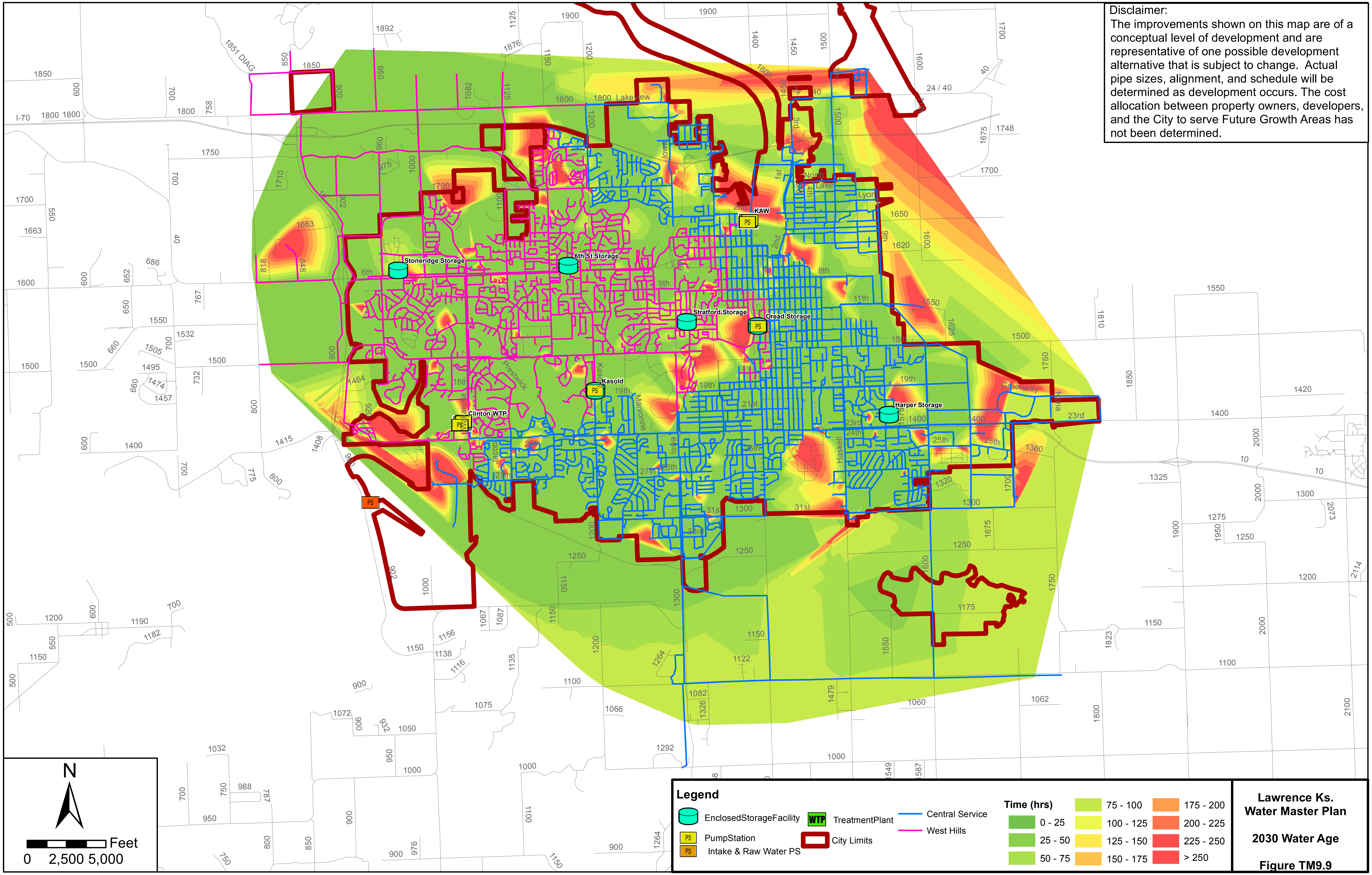

Lawrence Ks.
Water Master Plan

2030 Water Age

Figure TM9.9

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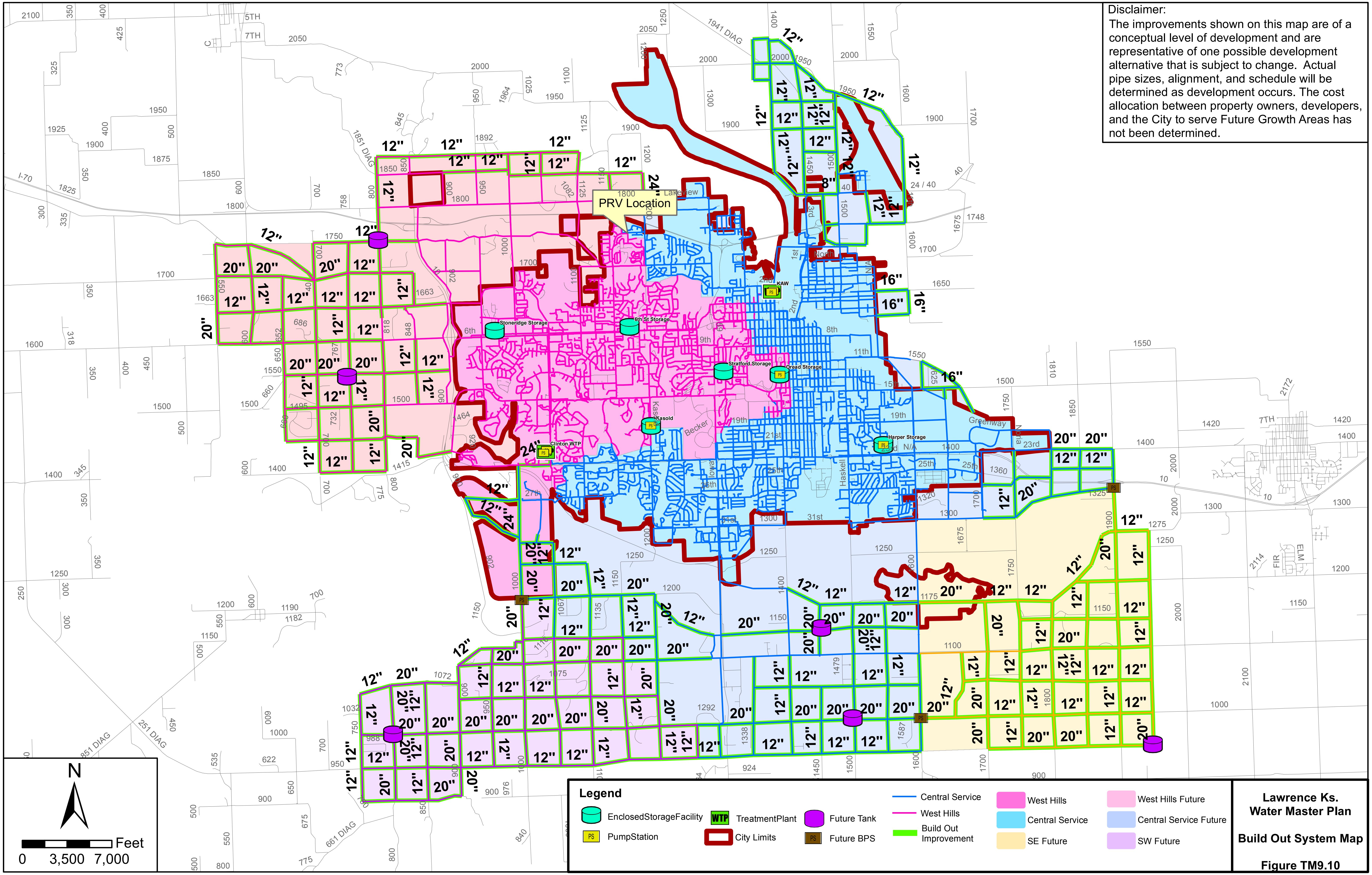
capacity were modeled at Clinton WTP by adding additional flow into the system. The buildout system is shown in Figure TM9.10.

The buildout system was modeled using the projected maximum day demand of 71.7 MGD. During maximum day demand conditions, system pressures in the CS zone generally range from 40 to 97 psi; however, there are 20 nodes in the distribution portion of the CS zone that the model indicates have pressures less than 40 psi. Fifteen of these nodes have pressures ranging from 16 to 25 psi and are located near Oread and Kasold tanks, or near the intersection of Sunflower and Sunnyside where a CS transmission line passes through an area of high elevation. Two of the remaining 5 nodes have pressures ranging from 35 psi to 39 psi and are located at dead end nodes in areas of high elevation. The new growth area to the south has one node with a pressure of 36 psi caused by elevation located at the boundary between a high (SWPZ) and low (CS) pressure zone. Pressures in this area can be managed either by booster pumps at the demand location or through alternative pressure zone concepts. Two nodes in the northwest growth area near one of the new tanks have pressures of 35 to 36 psi due to the elevation in those areas. Pressures in these areas can be controlled by increasing the tank height.

Pressures in the WH zone generally range from 41 psi to 147 psi. However, there are three nodes in the distribution portion of the WH zone that the model indicates have pressures less than 40 psi. One of these low pressure nodes is located next to the Kasold tank where the WH zone ties into the CS zone. The remaining two nodes with low pressure are located in the new growth area to the northwest. Pressures at these nodes range from 38 to 39 psi due to the elevation of the nodes.

Under maximum day demand conditions there are 49 distribution pipes with velocities greater than five fps. These pipes general have velocities between 5.0 and 10.1 fps. There are 126 pipes that have head loss gradients greater than six feet per 1000 feet. These pipes are generally between 6 to 24 feet per 1000 feet and are generally older, 12-inch diameter or less pipes connecting larger diameter pipes. Eleven pipes with a combined length of 149 feet have head loss gradients ranging from 25 to 56 feet per 1000 feet. Peak hour conditions have pressures that are consistent with the maximum day results throughout the system, 27 pipes have velocities greater than 5 fps, and 122 pipes have head loss gradients above 6 feet per 1000 feet. Given the extended time required to reach build-out demands and changes in development that will occur, these higher than typical velocities and head losses can be adjusted in the future.



Disclaimer:
The improvements shown on this map are of a conceptual level of development and are representative of one possible development alternative that is subject to change. Actual pipe sizes, alignment, and schedule will be determined as development occurs. The cost allocation between property owners, developers, and the City to serve Future Growth Areas has not been determined.

Lawrence Ks.
Water Master Plan

Build Out System Map

Figure TM9.10

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Technical Memorandum No. 10
Capital Improvement Plan

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

City of Lawrence, Kansas

Water Master Plan Technical Memorandum No. 10

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TECHNICAL MEMORANDUM NO. 10
Lawrence, Kansas Water Master Plan
December 20, 2012

A. General

Technical Memo (TM) No. 10 discusses capital improvements for the water distribution system for years 2013 through 2020; 2021 through 2025; and 2026 through 2030. These improvements are based on modeling the 2010, 2020, 2030, and build-out water systems, existing City programs, and condition and regulatory assessments of water supply, water treatment, and distribution system components. Improvements are separated in the following three justification categories: 1) Growth; 2) Regulatory; and 3) Reliability. Improvements include a minimum of one category but can include all three.

B. Opinion of Probable Costs

Opinions of project cost are based on construction and other cost allowances including contingency, engineering, surveying, legal, and other related costs. System improvement related costs are summarized in Table TM10.1 and growth related costs are summarized in Table TM10.2. Unit cost data and component cost information for the proposed improvements are based on historical projects and vendor's cost information. Unit costs are based on an Engineering News Record Construction Cost Index (ENR-CCI) of 10497.62 Kansas City, Missouri for February 2012.

Project costs include construction costs, contingencies, and other costs. The total includes a contingency, which varies based on the project from 20 to 25 percent, and engineering and other costs, which vary by project. Contingency covers items that are not anticipated, changes in conditions, or other factors that may increase the cost.

Other costs accounts for technical, professional and special services that are required to execute the project. These include environmental, technical, and geotechnical studies, land and right-of-way appraisals and negotiations, design and resident engineering fees, construction material testing, legal fees, project insurance, land surveying and legal descriptions, project design surveying, operation and maintenance manuals, and personnel training. Land and right-of-way costs for each improvement are not included in the cost opinions.

These order-of-magnitude cost opinions are based on experience and judgment as a professional consultant combined with information from past experience, vendors, and published sources, such as Means. Burns & McDonnell does not guarantee the actual rates, costs, etc. will not vary from the opinions and projections developed herein.

Table 10.1
WATER FACILITIES MASTER PLAN
CITY OF LAWRENCE, KANSAS
Preliminary Opinions of Improvement Costs

												5 Year Period Ending	
	Item	Reason for Improvement	2012 Cost Opinion	2013 (1)	2014 (1)	2015 (1)	2016 (1)	2017 (1)	2018 (1)	2019 (1)	2020 (1)	2025 (1)	2030 (1)
1	**Storage & Pumps**												
a	Oread Storage & BPS	3	$ 3,604,400	1,248,000	2,704,600								
b	19th & Kasold Pump Station - Pump underground with Building	3	$ 380,000		411,000								
c	Harper Booster Station	3	$ 600,000	624,000									
d	Tower Coatings (Stratford @ 0.5 MG, 6th @ 0.5 MG, Harper @ 0.5 MG, and Ground Storage at Clinton @ 1.5 MG)	3	$ 4,080,000	1,040,000			1,684,600	876,000			985,400		
e	PRV from WH to CS for Fire Flow and Peak Day in CS at I-70, West of Iowa and North	3	$ 70,000							92,100			
f	Automated Meter Reading for Distribution System - (2)	3	$ 8,500,000						8,500,000				
	Subtotal		$ 17,234,400										
2	**Transmission ****												
a	31st St. - extend 12" to O'Connell	1	$ 659,000	685,400									
b	31st St. & O'Connell - Extend 16" to WWTP (includes River crossing) - New Connection Point for Baldwin & RDW #4	1	$ 1,781,400	1,852,700									
c	Kaw 36" WM to North Lawrence (One 30" river crossings) - Phase 1	1,3	$ 7,535,000	7,836,400									
d	Kaw 36" WM to North Lawrence (One 30" river crossings) - Phase 2 and Phase 3	3	$ 13,325,000								18,236,200		
e	Concrete Main Assessment	3	$ 600,000		648,960								
	Subtotal		$ 23,900,400										
3	**Distribution 8" & Larger**												
a	Pipeline Replacement Program - 2013 to 2030	3	$ 40,475,200	2,338,600	2,432,100	2,529,400	2,630,600	2,735,800	2,845,200	2,959,000	3,077,400	17,334,900	21,090,500
b	Water Main Relocation Program for Road Projects	1	$ 9,927,885	1,985,000	500,000	520,000	540,800	562,400	584,900	608,300	632,700	3,563,800	4,335,900
	Subtotal		$ 50,403,085										
4	**Distribution 8" & Smaller (Potential In-House)**												
a	Small Water Main Replacement Program - Conventional Construction	3	$ 10,450,000	1,358,500	1,412,800	1,469,400	1,528,100	1,589,300	1,652,800	1,718,900	1,787,700		
b	Small Water Main Replacement Program - In-House Design / Construct	3	$ 7,450,000	968,500	1,007,200	1,047,500	1,089,400	1,133,000	1,178,300	1,225,500	1,274,500		
5	**Kaw WTP**												
a	Structural	3	$ 596,000	619,800									
b	Electrical	3	$ 750,000		811,200								
c	Process	2, 3	$ 317,500				166,700					291,400	
d	Microcystin and Taste & Odor, Viral Reduction Treatment Measures - Advanced Oxidation	2	$ 9,150,000	104,000								15,062,300	
e	Annual Plant Improvement Program - $75,000 for Two Years then $300,000	3	$ 4,950,000	75,000	78,000	300,000	312,000	324,500	337,500	351,000	365,000	2,055,900	2,501,500
	Subtotal		$ 15,763,500										
6	**Clinton WTP**												
a	Intake	1, 3	$ 1,660,000		1,297,900	517,400							
b	Electrical	1, 3	$ 755,000			849,300							
c	Process	2, 3	$ 560,000		108,200		187,200				410,600	166,500	
d	Filter Expansion/Process	1, 3	$ 7,500,000								10,264,300		
e	Microcystin and Taste & Odor, Viral Reduction Treatment Measures - Advanced Oxidation	2	$ 9,000,000									14,985,700	
f	Basin Coatings	3	$ 1,130,000					1,374,800					
g	Annual Plant Improvement Program - $75,000 for Two Years then $300,000	3	$ 4,950,000	75,000	78,000	300,000	312,000	324,500	337,500	351,000	365,000	2,055,900	2,501,500
	Subtotal		$ 25,555,000										
7	**Raw Water Supply**												
a	Bowersock Dam Improvements (3)	3	$ 425,000	425,000									
b	HCWs (three at 25 MGD total)	1, 2, 3	$ 17,100,000										34,641,500
c	42 Pipeline to Clinton WTP	1, 2, 3	$ 22,680,000										45,945,500
d	36" Pipeline to Kaw WTP	1, 2, 3	$ 7,300,000										14,788,500
	Subtotal		$ 47,505,000										
	2020 and 2030 Total - Conventional Construction		**$ 190,811,385**	**20,267,400**	**10,482,760**	**6,485,500**	**7,362,000**	**7,787,300**	**14,257,900**	**6,080,300**	**36,124,300**	**55,516,400**	**125,804,900**
	2020 and 2030 Total - In-House Design / Construct		**$ 187,811,385**	**19,877,400**	**10,077,160**	**6,063,600**	**6,923,300**	**7,331,000**	**13,783,400**	**5,586,900**	**35,611,100**	**55,516,400**	**125,804,900**

(1) - 4% Inflation Used to Calculate 2013 to 2030 Costs
(2) - Not Inflated Due to Expected Technology Advances
(3) - Not Inflated Due to Contract
** Development Related Growth Projects Are Not Included in CIP

2013 - 2020 Total - Conventional Construction	**108,847,460**
2013 - 2020 Total - In-House Design / Construct	**105,253,860**

Reason for Improvement
1- Growth
2 - Regulatory
3 - Reliability

Table 10.2
WATER FACILITIES MASTER PLAN
CITY OF LAWRENCE, KANSAS
Preliminary Opinions of Growth Related Improvement Costs

											5 Year Period Ending	
	Item	Reason for Improvement	2012 Cost Opinion	2013 (1)	2014 (1)	2015 (1)	2016 (1)	2017 (1)	2018 (1)	2019 (1)	2020 (1)	2025 (1)	2030 (1)
1	**Transmission**												
a	2020 - Future Growth Areas - 12" and Larger Mains - (2), (3)	1	$ 23,624,000	3,071,100	3,194,000	3,321,700	3,454,600	3,592,800	3,736,500	3,885,900	4,041,400		
b	2030 - Future Growth Areas - 12" and Larger Mains - (2), (3)	1	$ 11,660,000									8,988,900	10,936,300
	Subtotal		$ 35,284,000										
	Total		**$ 35,284,000**	**$ 3,071,100**	**$ 3,194,000**	**$ 3,321,700**	**$ 3,454,600**	**$ 3,592,800**	**$ 3,736,500**	**$ 3,885,900**	**$ 4,041,400**	**$ 8,988,900**	**$ 10,936,300**

(1) - 4% Inflation Used to Calculate 2013 to 2030 Costs

(2) - Future Growth Areas are Split Equally from 2013 to 2020 and 2021 to 2030 - Triggered by Development Activity

(3) - Cost allocation between property owners, developers and the City for Transmission Mains to serve Future Growth Areas has not been determined.

Reason for Improvement

1- Growth

2 - Regulatory

3 - Reliability

C. Capital Improvements Plan

Capital improvements are summarized in Table TM10.1 through the year 2030. The CIP distinguishes the improvements into the following categories:

1. Storage & Pumps
2. Transmission
3. Distribution 8-inch and larger
4. Distribution 8-inch and smaller
5. Kaw WTP
6. Clinton WTP
7. Raw Water Supply

The improvements included in each of these categories are described in the following sections and detailed cost breakdown is listed in Appendix H.

C.1 Storage & Pumps:

C.1.1 Oread Tank Replacement:

Oread includes two steel ground storage tanks, one built in 1931 and one built in 1954, with a combined capacity of 2.4 MG and a small BPS. The site is very limited on space based on the available property size, building height restrictions, and topography. As the tanks are in poor structural condition, demolition of both tanks and the BPS (Figure TM10.1) and replacement with a single pre-stressed concrete tank and new BPS is recommended to improve system reliability. Based on modeling through year 2030, the Oread site can be demolished and replaced with the following preliminary concept as shown in Figures TM10.2:

- Minimum 1.7 MG ground storage tank (maximize in final design) (Figure TM10.3);
- 2.9 MGD booster pump station including two 125 Hp pumps rated for 1000 gpm at 185 feet of head each – pumps will be located below grade and the controls and access will be above grade (Figure TM10.4);
- Primary water supply into the tank will continue to be provided by the existing 16-inch main. This can also be routed around the tank to the BPS for in-line boosting. The existing 12-inch supply line can also be used for redundancy. Tank, BPS, and yard piping will be configured to be filled by either pressure zone;
- Pump discharge piping will be routed to the existing 12-inch water main to the WH pressure zone;

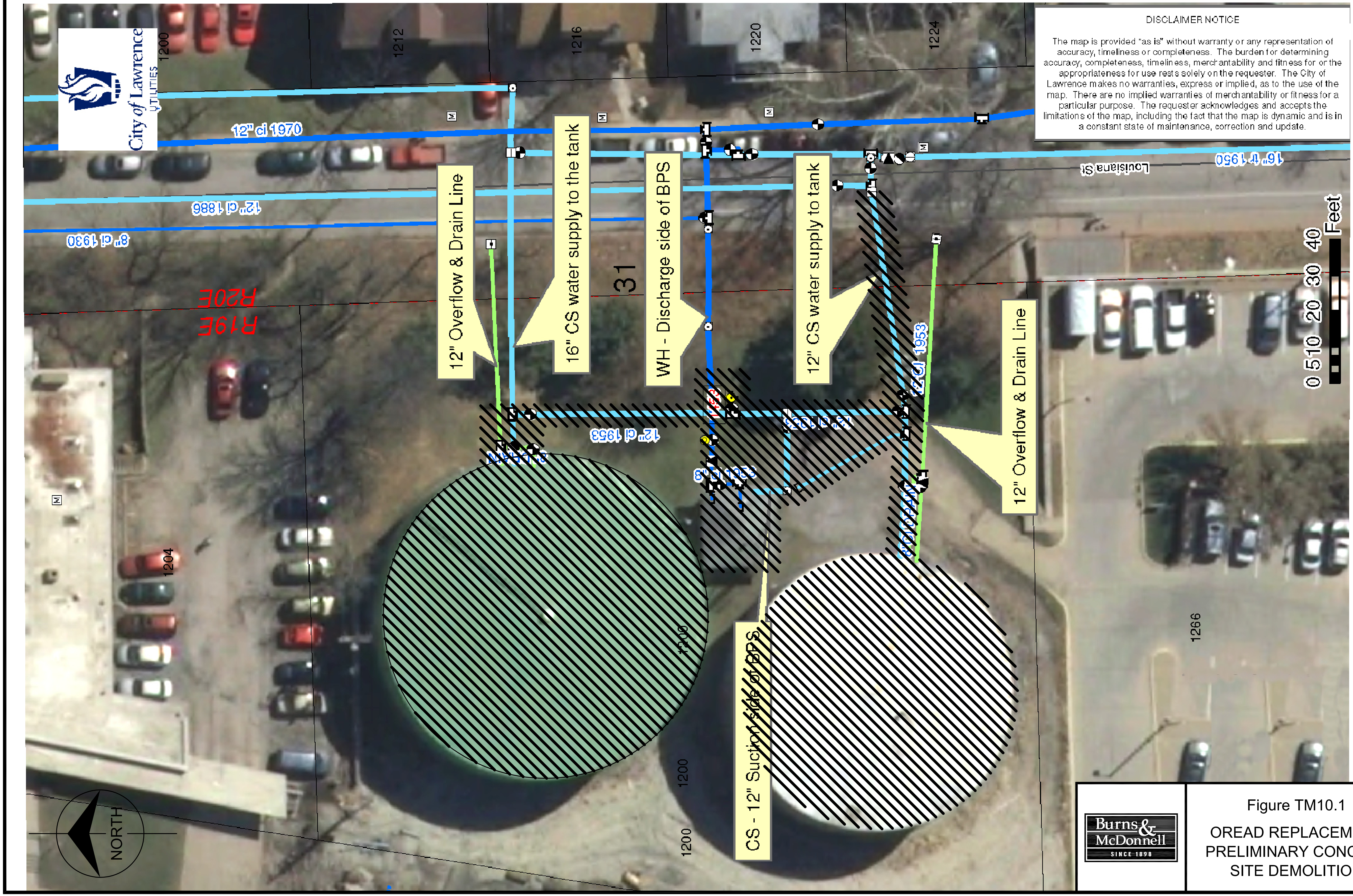

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Figure TM10.1

OREAD REPLACEMENT
PRELIMINARY CONCEPT
SITE DEMOLITION

J:\LAWRENCEOREADFIGURE_1.DWG 6/25/2012 3:41 PM JOLIPHANT

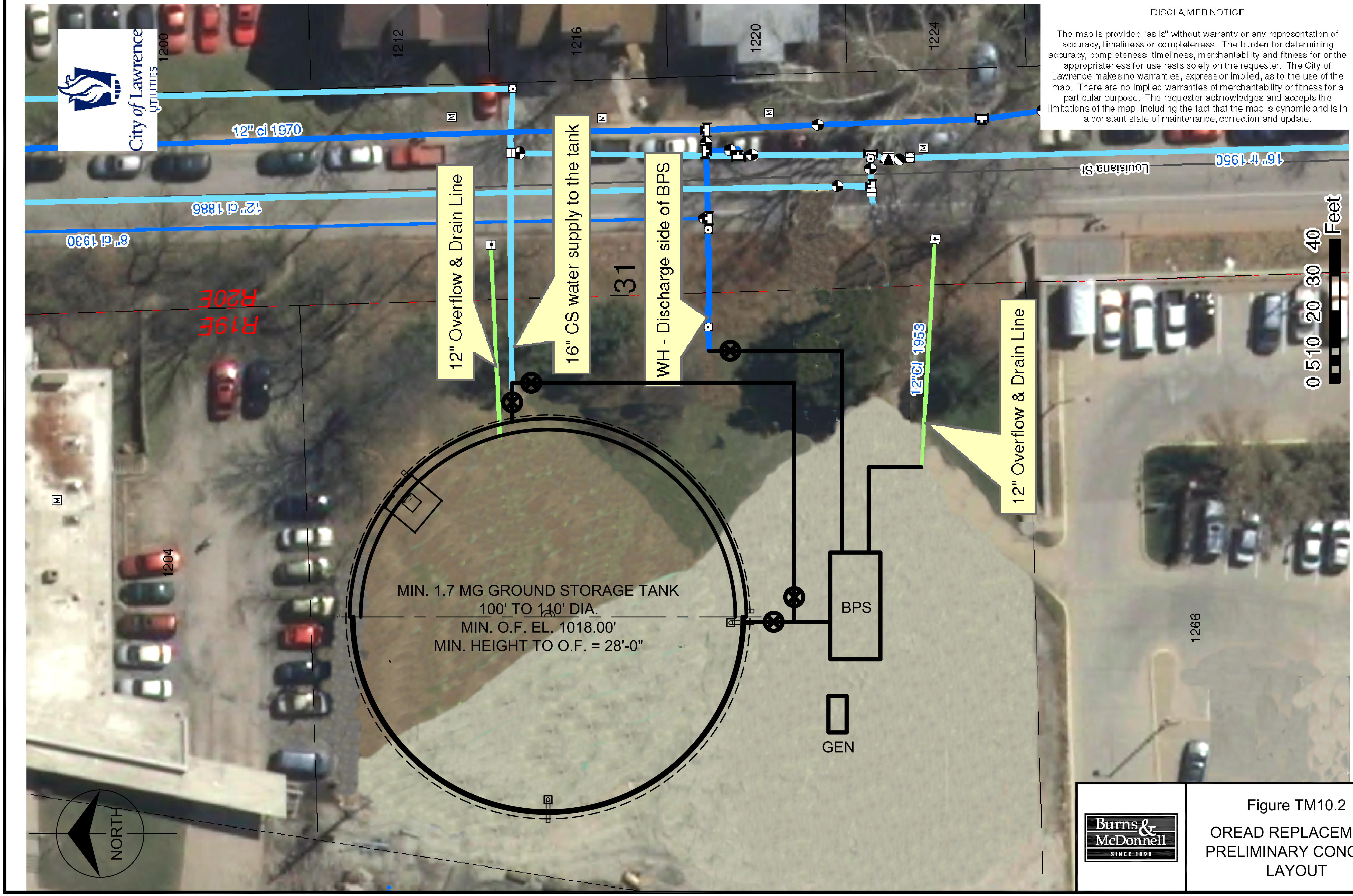

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Figure TM10.2

OREAD REPLACEMENT
PRELIMINARY CONCEPT
LAYOUT

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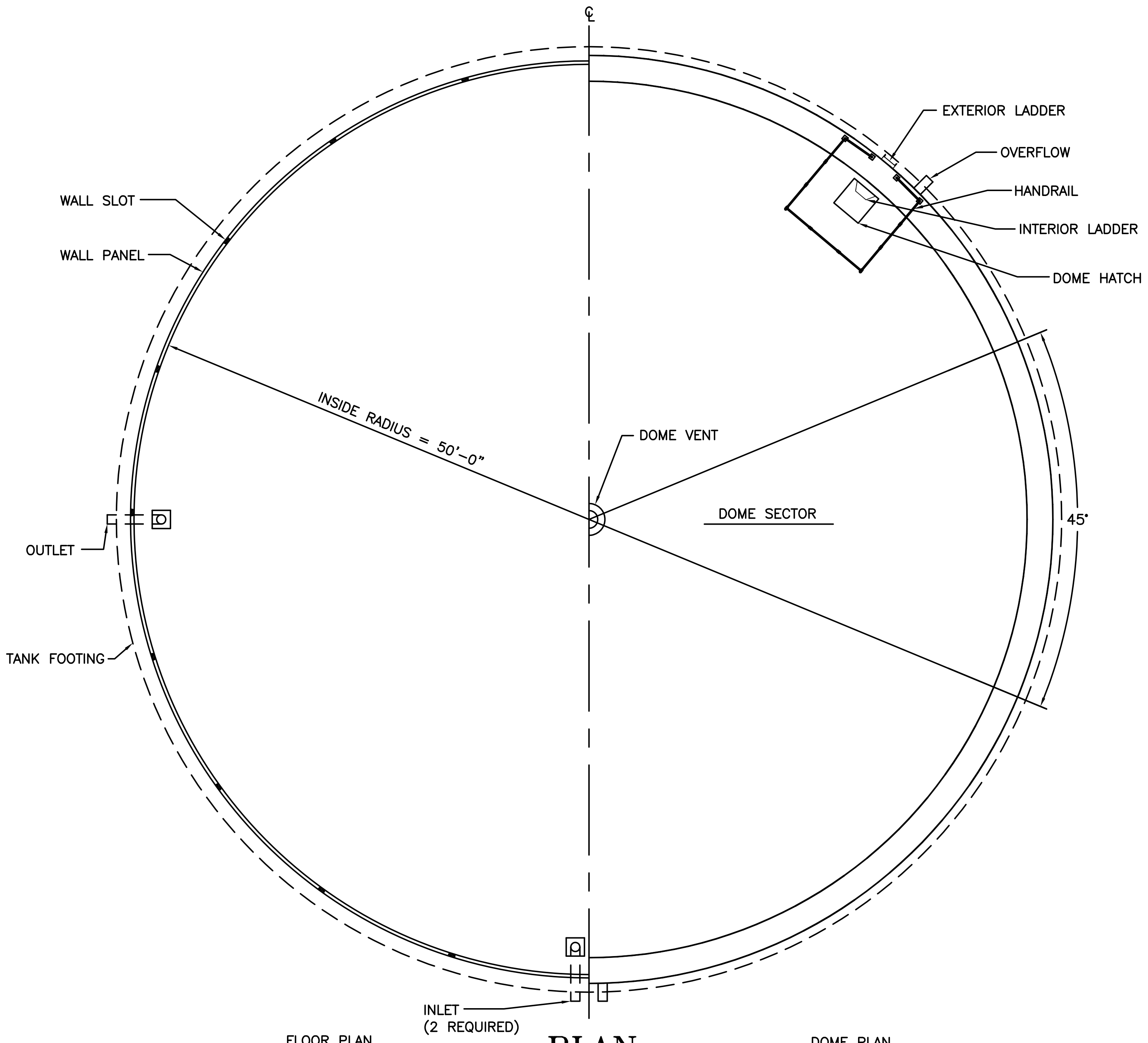
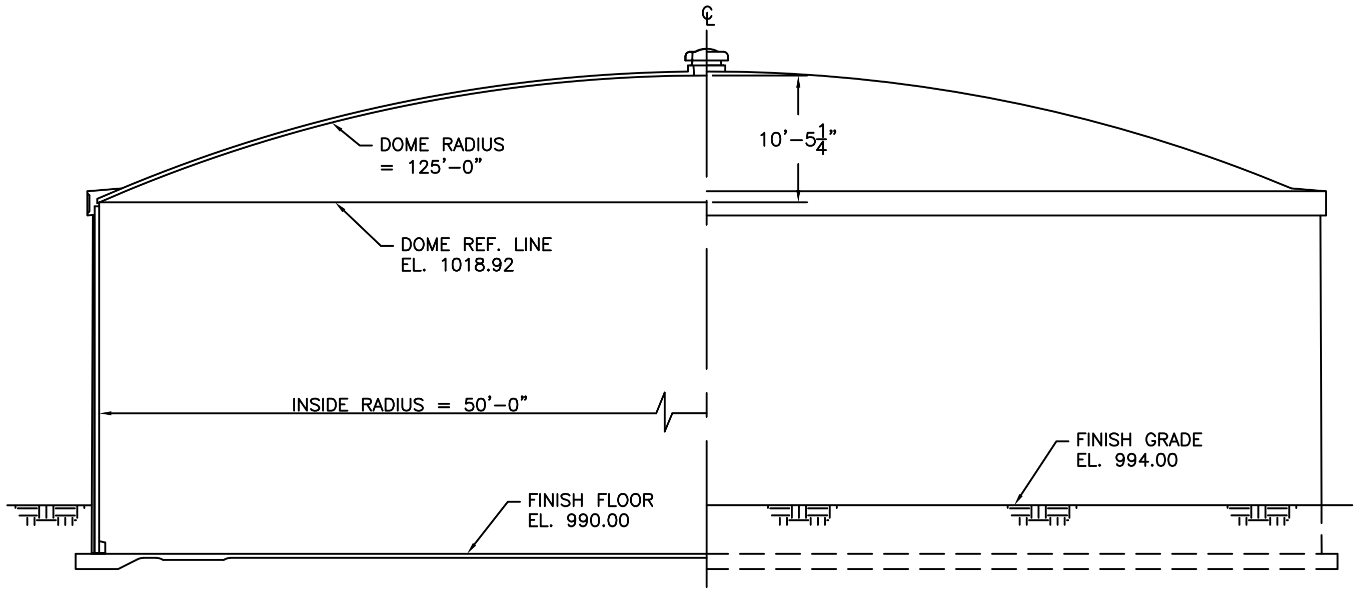


PLAN

SCALE: 1/8" = 1'–0"



TANK SECTION & ELEVATION

SCALE: 1/8" = 1'–0"

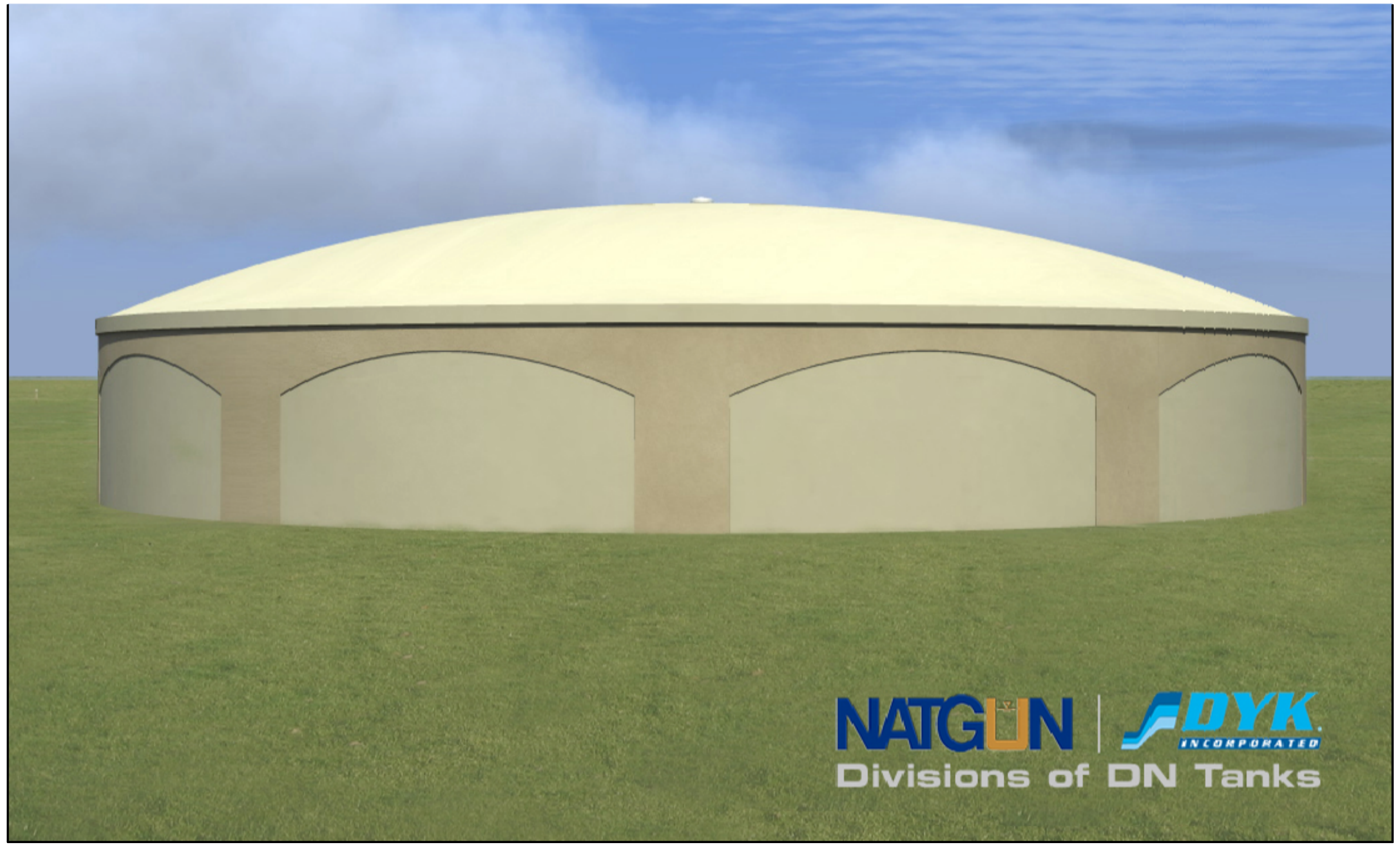


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Figure TM10.3

OREAD REPLACEMENT
PRELIMINARY CONCEPT
DIMENSIONS & ELEVATION

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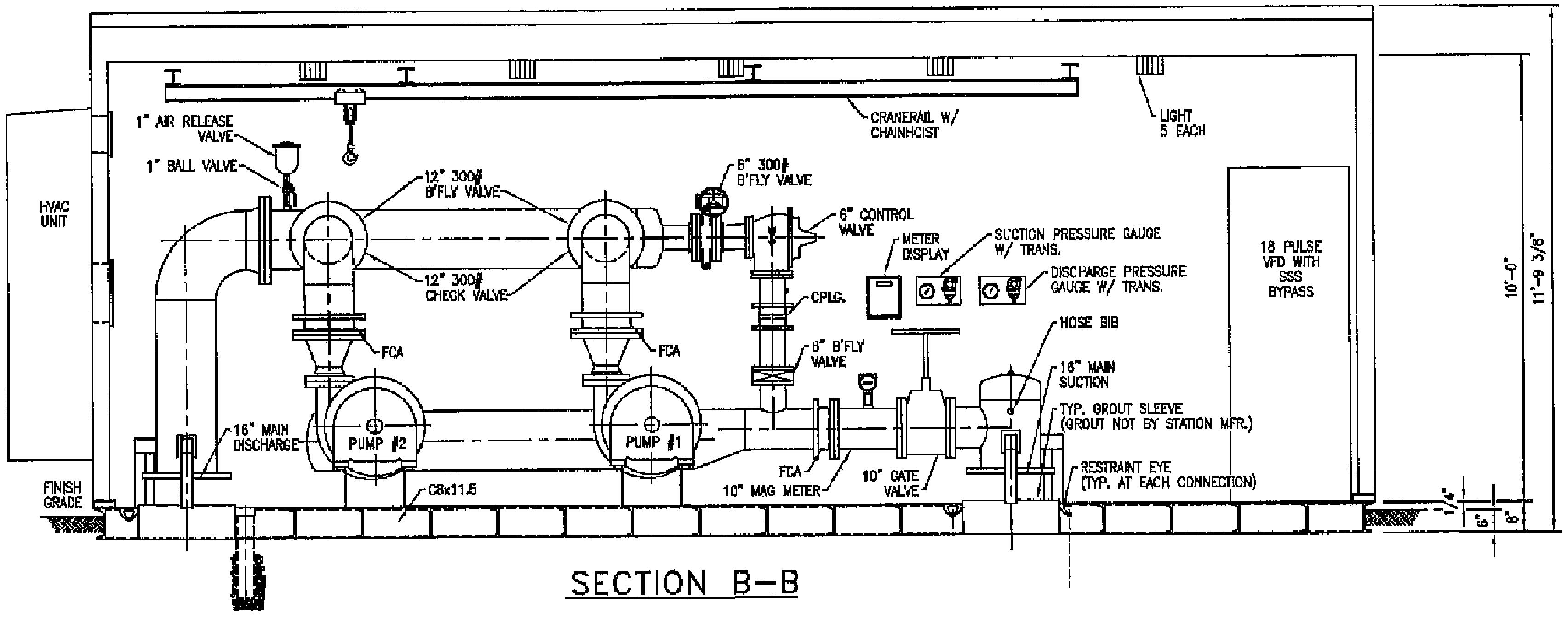
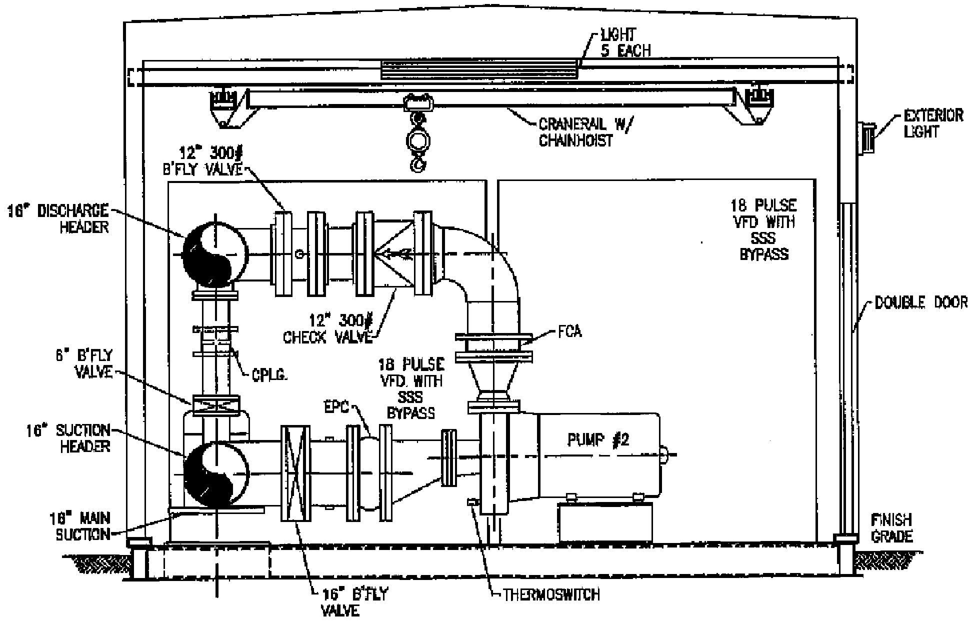
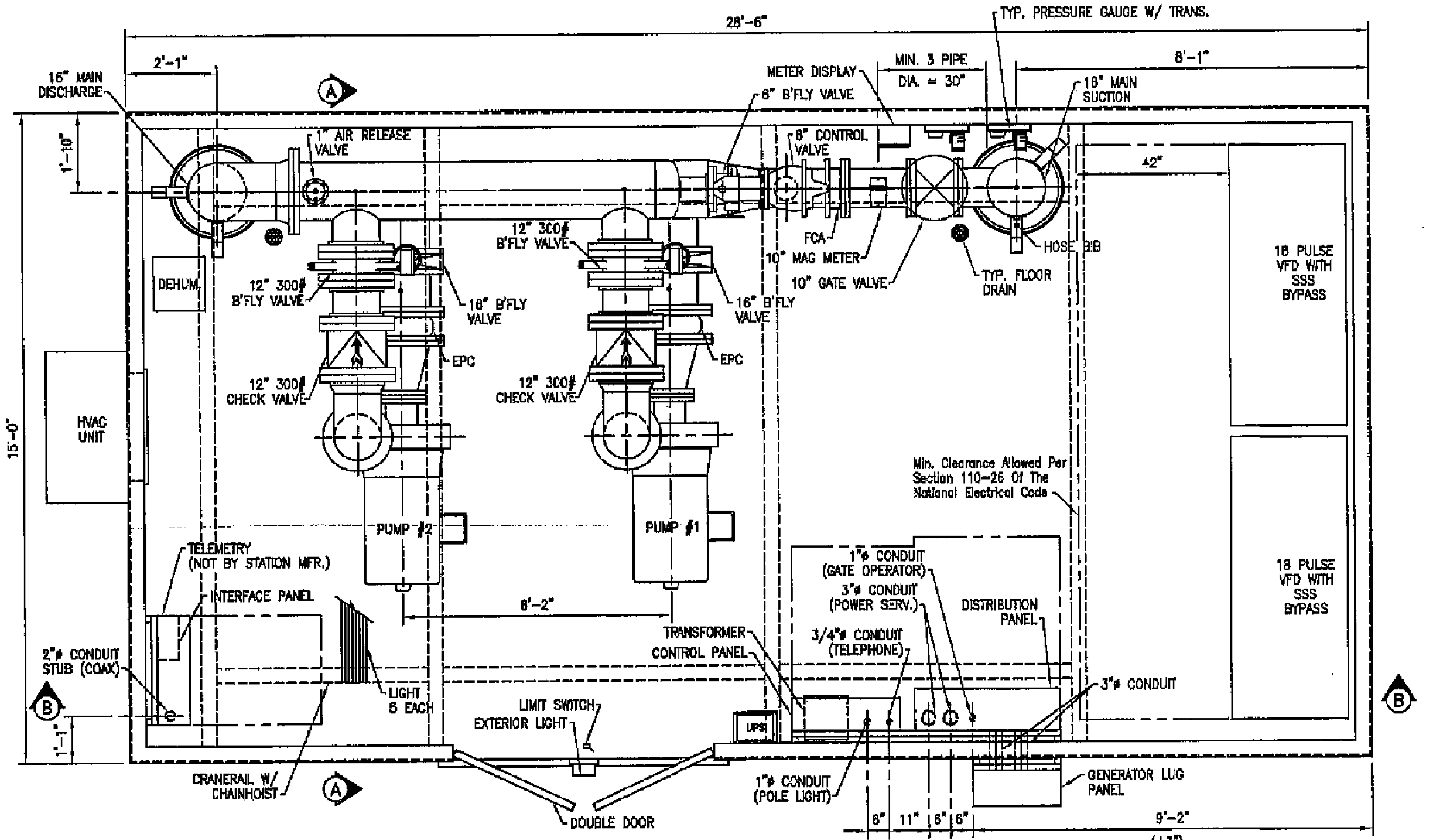


SECTION B-B



SECTION A-A



PLAN

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Figure TM10.4

OREAD REPLACEMENT
PRELIMINARY CONCEPT
BOOSTER PUMP STATION

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- Piping will allow feed from WH to CS through the proposed booster pump station;
- Electrical including a location of a portable generator and a manual transfer switch in the pump station;
- SCADA for control and monitoring of the tank and pump station.

The lot across the street adjacent to the KU parking garage was evaluated and determined unfeasible. This was due to limited lot sizes, the number of homes on the historical register in the area, building height, and proximity restrictions to the existing parking garage.

Replacement of the tank is planned for 2013. Evaluation of the system demands indicates that the system can operate temporarily without Oread during the construction process. However, to minimize the impact on the system, the tank construction should take place during periods of low water demand. To assist with system operation, the new tank could be built in three phases. First the existing tank and pump station will need to be demolished. Next, the new BPS could be constructed first to allow transfer of water between the two pressure zones to accommodate demands. The new tank would then be built and tied into the system through the BPS. One possible configuration for a new tank and piping is shown in Figures TM10.1 and TM10.2. Alternate and final designs of the actual layout for the new tank, piping, and BPS will be part of the design process. These can maximize volume based on a site survey and consider alternate more expensive cast-in-place alternatives.

C.1.2. 19th & Kasold Booster Station Improvements:

The Kasold tank and BPS are in good working condition. However, the BPS is small making it difficult to remove pumps and maintain the station. The station will remain, but will be modified and a building will be added above grade for access and controls over the pumps. The building will include roof hatches to allow City crews to easily pull the pumps with their existing boom trucks. This improvement is reliability driven and is planned for 2014.

C.1.3. New Harper Tank Booster Station:

A 2.9 MGD BPS is recommended at Harper Tank to improve reliability and allow City operators to assure turnover in the Harper tank. The BPS will also increase system pressures in the areas around the tank. As Harper is an elevated tank, a BPS built at grade is recommended to ease access and maintenance.

C.1.4. Tower Coatings:

Coatings on Stratford, 6th Street, Harper and the ground storage tanks at Clinton WTP need restored to maintain system reliability. The external and internal coatings deteriorate over time, and must be recoated to maintain the tanks in a satisfactory operating condition. The coatings on the tanks are not just for aesthetics. They also protect the structure of the tank and prevent deterioration, such as corrosion, of the structures. Additionally, some of the tanks have lead paint which requires special abatement procedures. One tank will be recoated per year to minimize distribution system impacts. Therefore, recoating occurs over several years up to year 2020.

C.1.5. Pressure Reducing Valve

A pressure reducing valve should be installed between the WH and CS pressure zones at the intersection of Grand Vista Drive and Eagle Pass Drive, as shown in Figure TM9.4. This PRV is required to maintain adequate system pressures in the Central Service pressure zone north and west of MacDonald. When pressures in the CS zone drop due to high demands or emergencies, the PRV will open and supply water from the WH zone at a higher pressure. This will improve pressures and available fire flows in the area. This valve is reliability driven and is anticipated to be required by 2020.

C.1.6 Automated Meter Reading:

The City has been evaluating conversion of their current meter reading system to a fixed network automated reading system. The current system requires a City vehicle to drive all the City streets and collect data; manual collection is still required to complete collection and validate questionable readings. A fixed network system allows virtually instantaneous collection of the system data on any frequency – monthly, weekly, daily, hourly, etc. Some manual collection will still be required, but this system minimizes labor and provides greater availability of data for operations staff. The system can also be used to identify water leaks. This system is reliability driven and is required by 2020.

C.2. Transmission:

C.2.1. Future Growth Areas

Future growth, especially through build-out, is extensive. The improvements used in the model are of a conceptual level of development and are representative of one possible development alternative that is subject to change depending on where and when development occurs. Actual pipe sizes, alignment, and schedule will be determined as development occurs. Implementation of improvements should be geared to actual increases in demand in combination with physical expansion.

C.3. Distribution 8-inch and Larger:

The existing water transmission and distribution system network is robust by virtue of its interconnectivity. This is illustrated by the lack of need for additional transmission mains to meet demands through the year 2030. All the transmission and distribution mains scheduled for replacement by year 2020 are based on condition, age and frequency of breaks as listed in Appendix H. The City has a long-standing program to replace older pipes before they become an operations and maintenance issue and cause the City’s low water loss of less than 5 percent to increase. To date, funding for these replacements has been inadequate to maintain the program at the recommended level. Deferring the replacements only extends the program and / or increases the annual program cost to “catch-up.” Replacement of these older mains is a major reliability issue. Continued deferment of older main replacement will likely increase water main breaks, increase water loss, and could accelerate the timing of future treatment capacity projects.

C.4. Distribution 8-inch and Smaller:

The City’s has an ongoing small main replacement program to replace mains 4-inch diameter and smaller with a minimum of 8-inch pipes. This program is about one-third complete and annual replacement is scheduled through the year 2020. The improved system fire flows, service pressures, and system reliability are predicated upon completion of the small main replacement program by 2020.

C.5. Kaw WTP:

Kaw WTP is an old plant with typical structural, electrical and process issues for a plant of its age and number of expansions. Numerous structural steel and concrete repairs are required to the basins and steel paddle wheels, rakes, cages and walkways to keep the plant operational. Photos illustrating the condition of the plant are included in Appendix I. If these are not addressed, structural failures of walls, equipment supports, and walkways could eventually occur. The electrical system components, such as MCCs 1 through 3, need to be updated to meet current code. The other issue is availability of parts. The City currently has to use salvaged parts to keep the existing MCCs running as parts are no longer made. These are all reliability improvements.

Process evaluations and improvements are also recommended for regulatory and reliability reasons. Process evaluations are scheduled in 2013 to improve operations, chemical costs, and regulatory issues.

Other process improvements are scheduled through 2025. The City also has an ongoing annual plant improvement fund to maintain and improve the plant. Raw water quality and taste and odor issues due to algal toxins may drive the need additional process improvements such as ozone.

C.6. Clinton WTP:

Clinton WTP has a number of issues at the intake and the WTP. The intake requires expansion to pumping and electrical improvements and back-up power generation to increase firm pumping capacity to 25 MGD. The WTP treatment trains are capable of 25 MGD or more. The filters are in the process of being rated to 25 MGD, but may not be able to sustain that flow rate. Recent discussions with Burns & McDonnell staff on treatment process improvements and optimization have made progress towards improving filter run times. Process evaluations are required to determine an optimal approach to improving operations while increasing production capacity. Raw water quality and taste and odor issues due to algal toxins may drive the need for additional process improvements such as ozone. The WTP also requires basin coatings. Addition of a generator to operate the WTP at 15 MGD is also recommended. These improvements are reliability, regulatory and growth related and are phased through 2030.

C.7. Raw Water Supply

Additional diversion capacity is projected to be required by 2028 to meet future demands. As the current water sources do not have redundancy, this new diversion capacity also improves system reliability and allows the City to meet future regulations.

Clinton reservoir is fully allocated for maximum diversion. Any additional diversion capacity will need to come from the Kansas River or its alluvium. Options for additional diversion include a new or expanded surface water intake and/or HCWs. An expanded surface water intake could be adequate for additional treatment capacity at the Kaw WTP up to a total treatment capacity of 25 MGD. Additional expansion of treatment capacity beyond that would need to take place at the Clinton WTP which has more space for expansion. Water supply to serve future Clinton WTP expansions or a redundant raw water source for Kaw WTP would likely come from HCWs in the Kansas River alluvium. The addition of HCWs not only improves reliability but could allow the City to meet future regulatory requirements with a more consistent quality source of raw water.

Appendix A
Population and TAZ Data

Water Master Plan

for

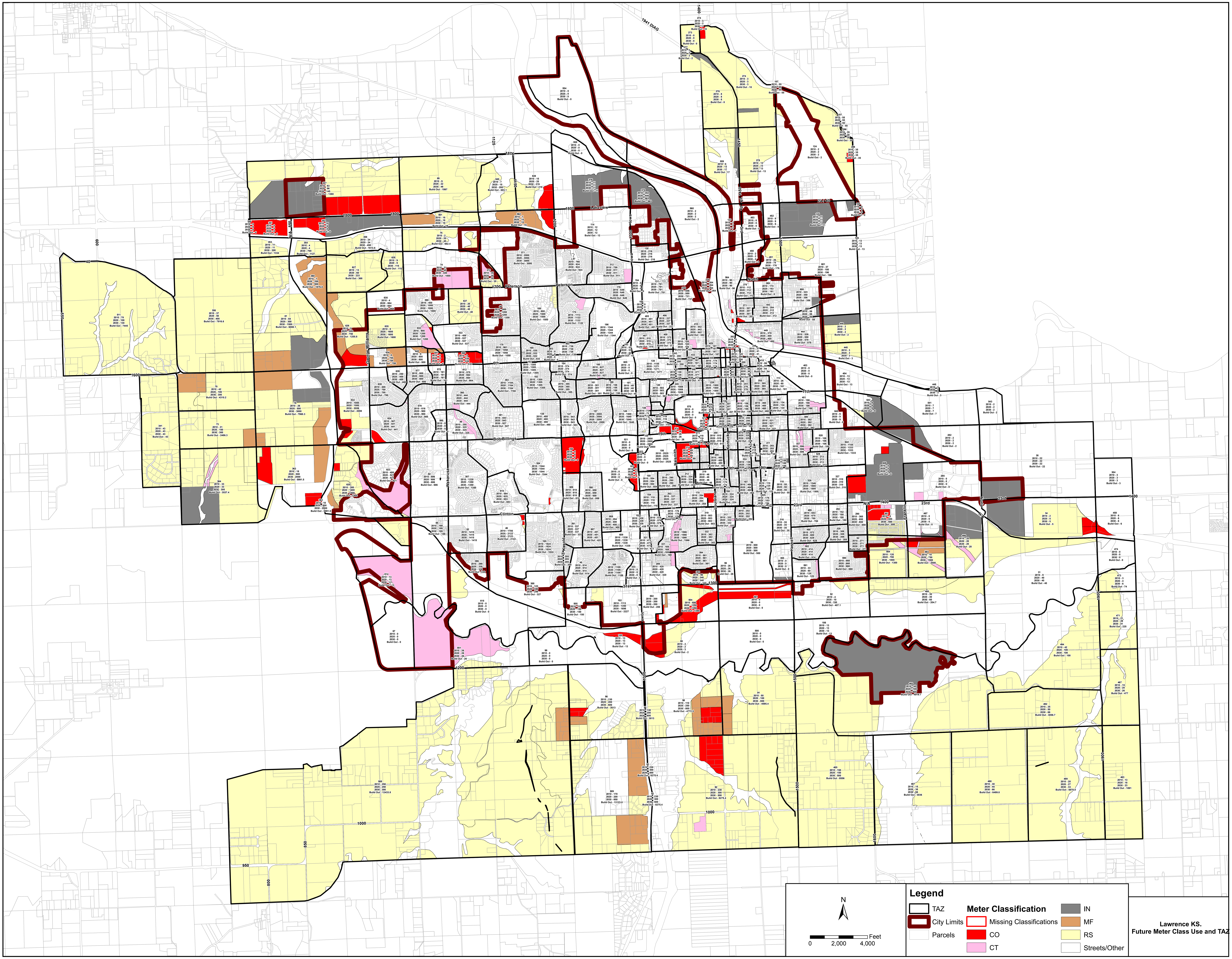
Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114



Lawrence KS.
Future Meter Class Use and TAZ

Appendix B
Regulatory Evaluation

Water Master Plan

for

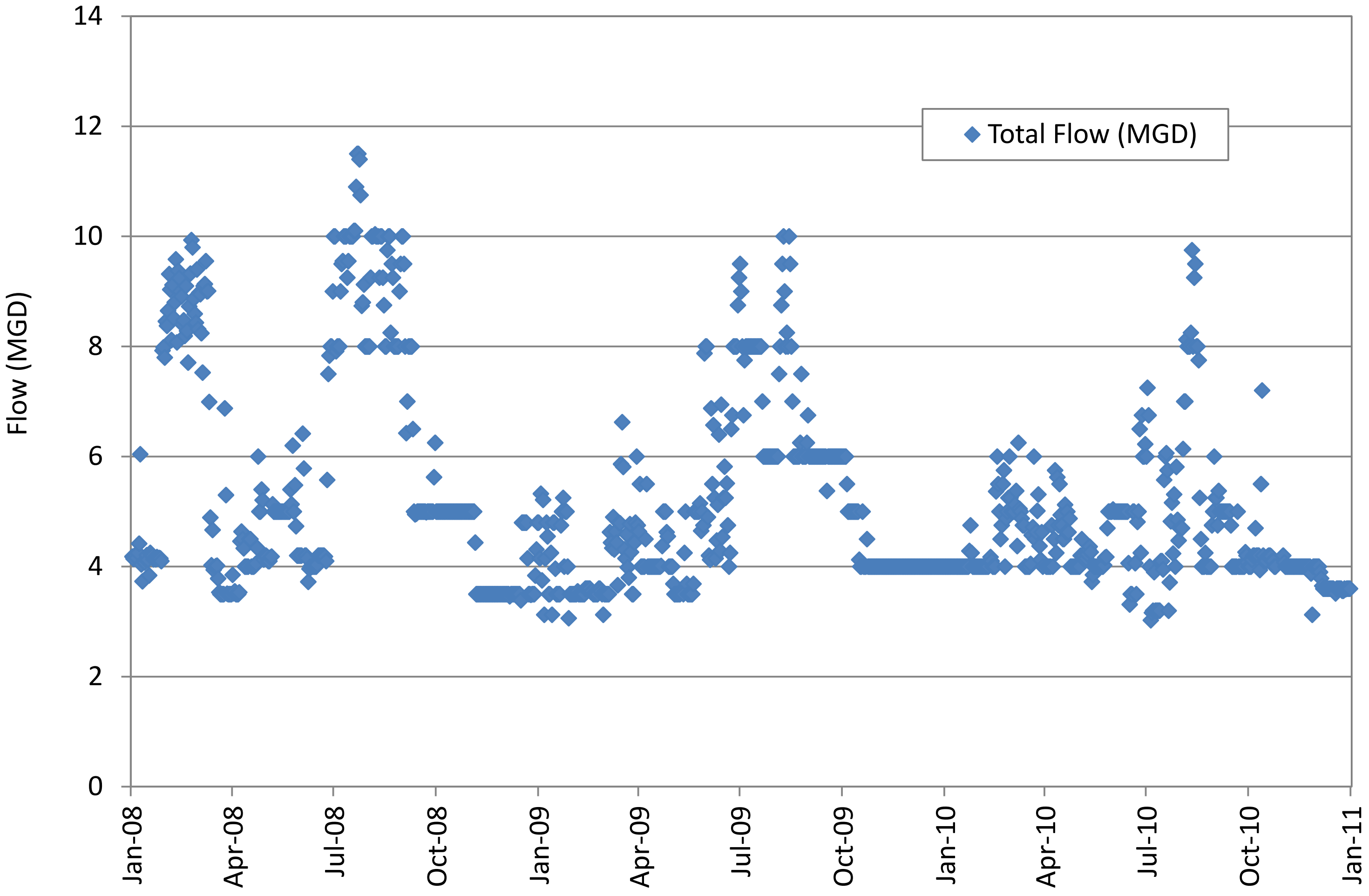
Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114



	Min	Ave	Max
2008	3.4	5.9	11.5
2009	3.1	5.0	10.0
2010	3.0	4.5	9.8

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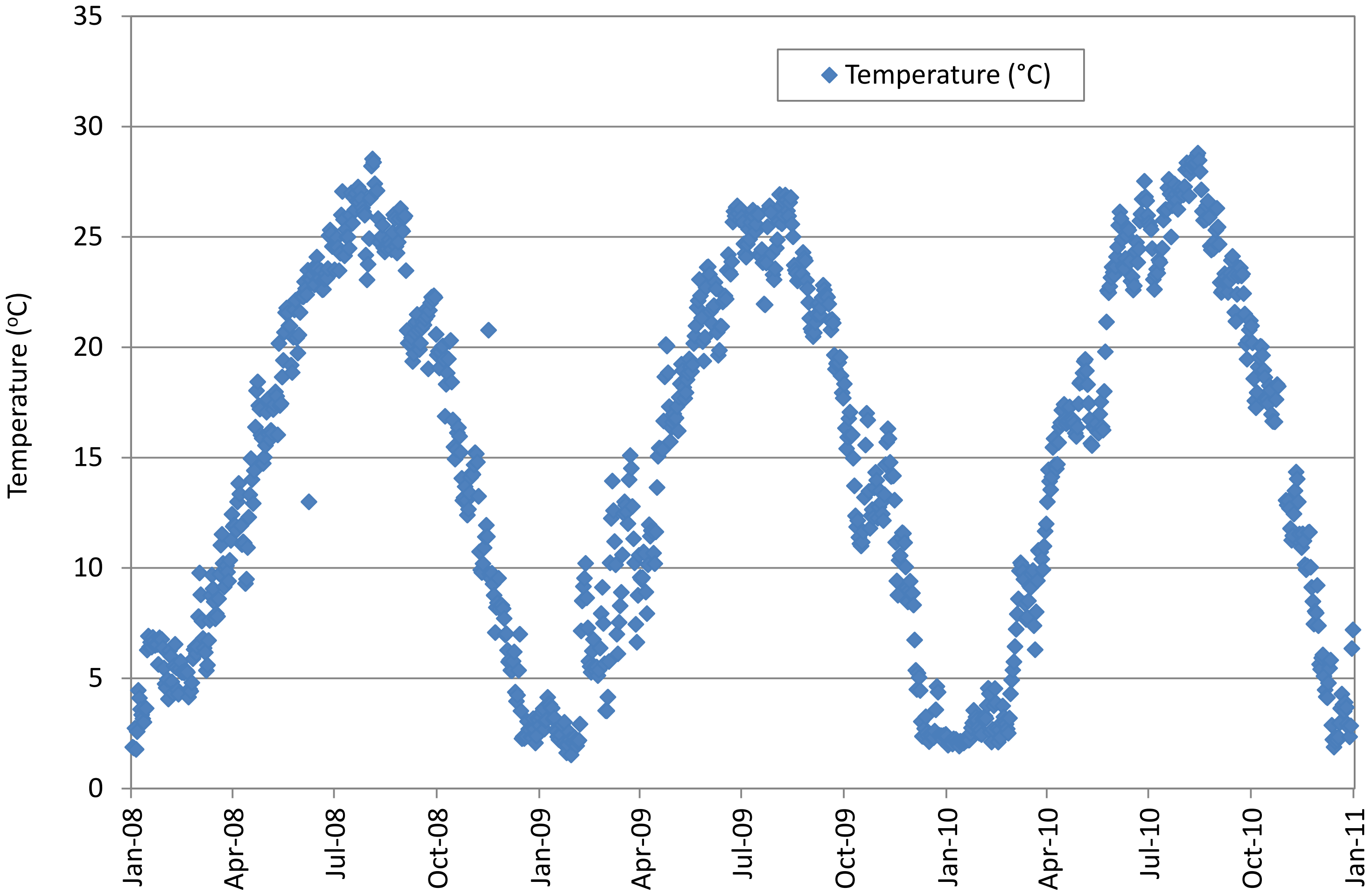
City of Lawrence
KANSAS

Figure B.1

Lawrence, Kansas

Kaw Plant – Total Flow



	Min	Ave	Max
2008	1.8	15.0	28.5
2009	1.5	14.6	26.9
2010	1.9	15.2	28.8

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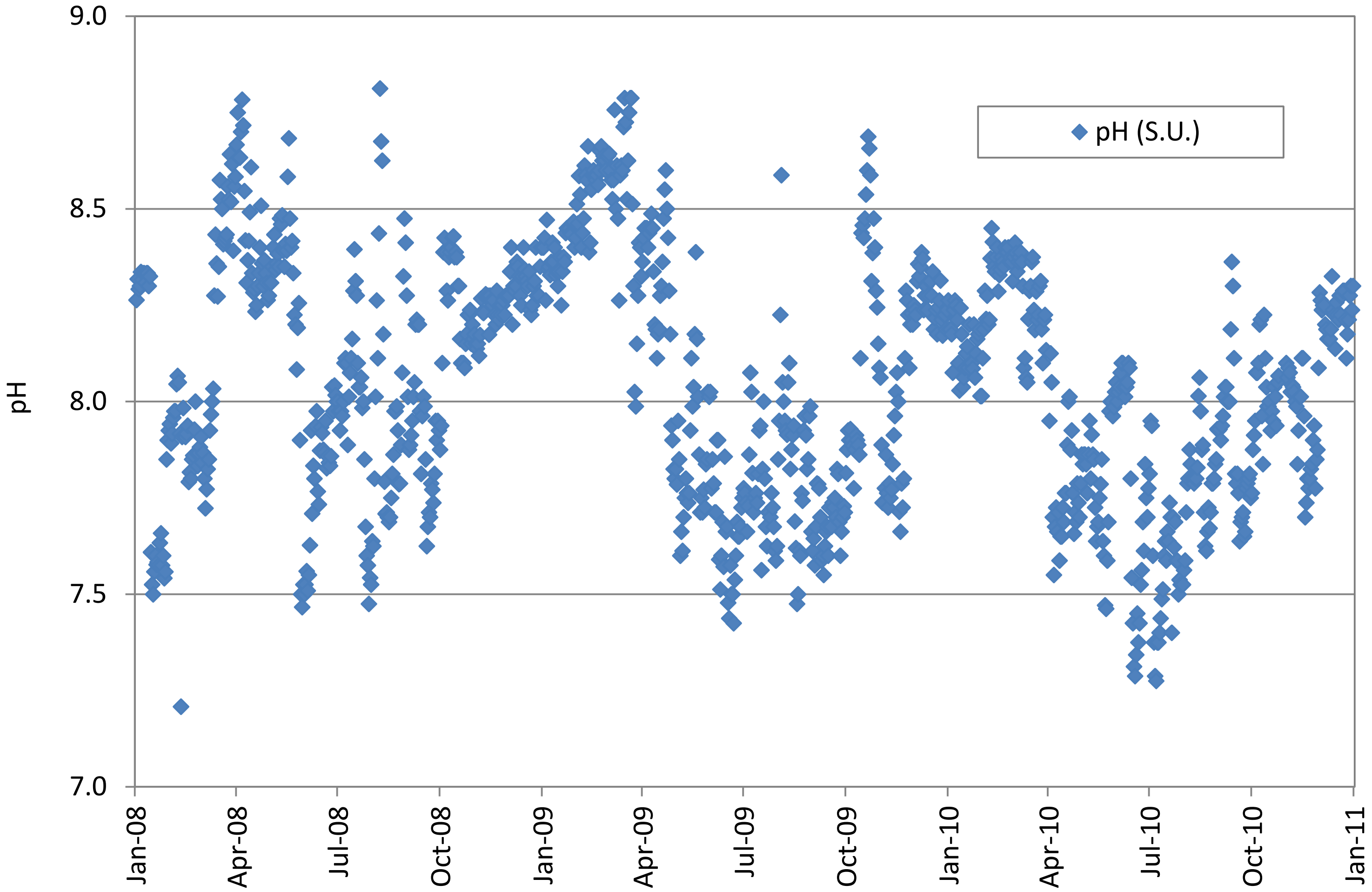
Figure B.2

Lawrence, Kansas

Kaw Plant – Raw Water Temperature



	Min	Ave	Max
2008	7.2	8.1	8.8
2009	7.4	8.1	8.8
2010	7.3	8.0	8.4

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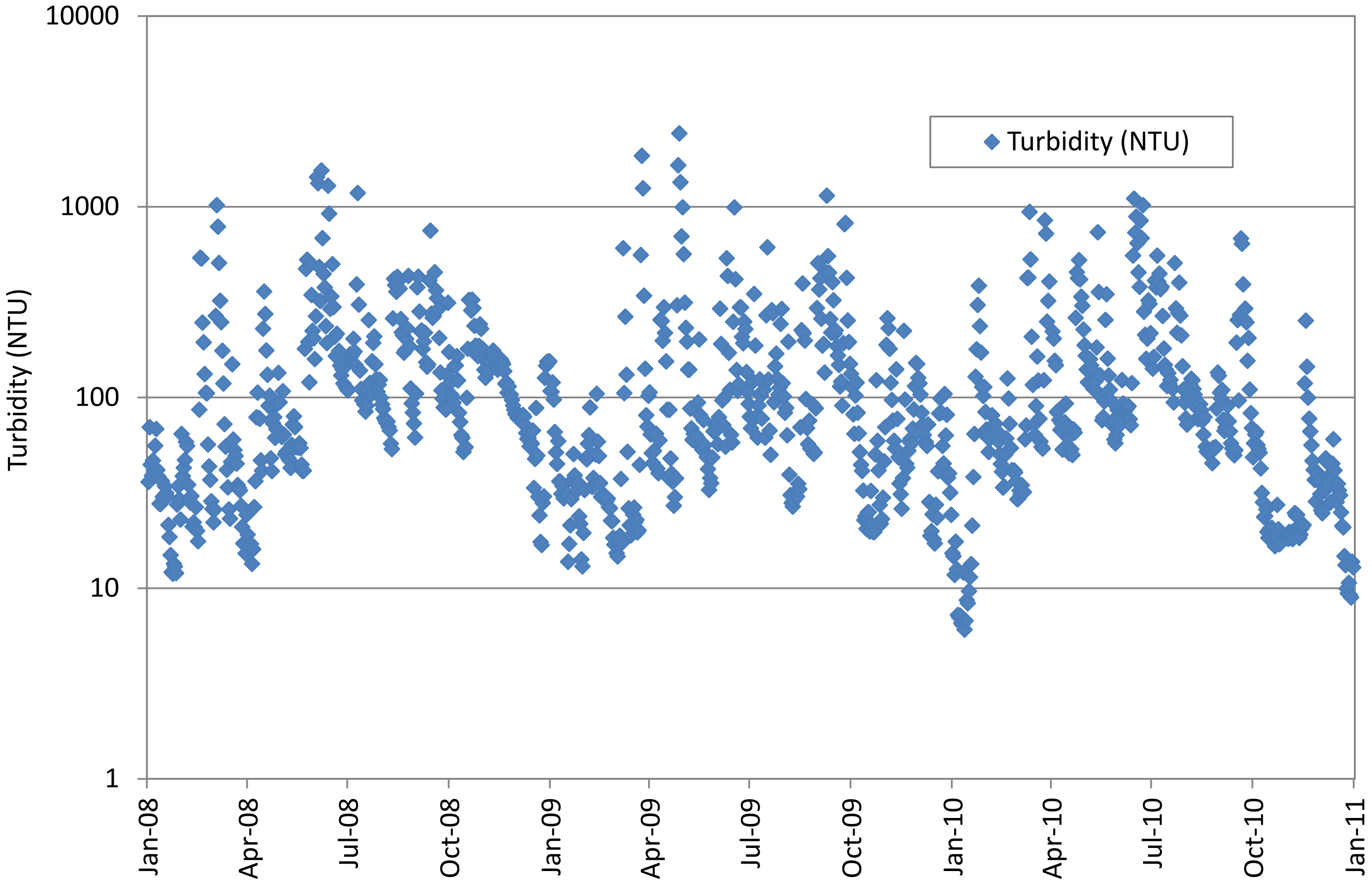
Figure B.3

Lawrence, Kansas

Kaw Plant – Raw Water
pH



	Min	Ave	Max
2008	11.9	159.0	1552
2009	13.0	141.6	2427
2010	6.1	135.0	1105

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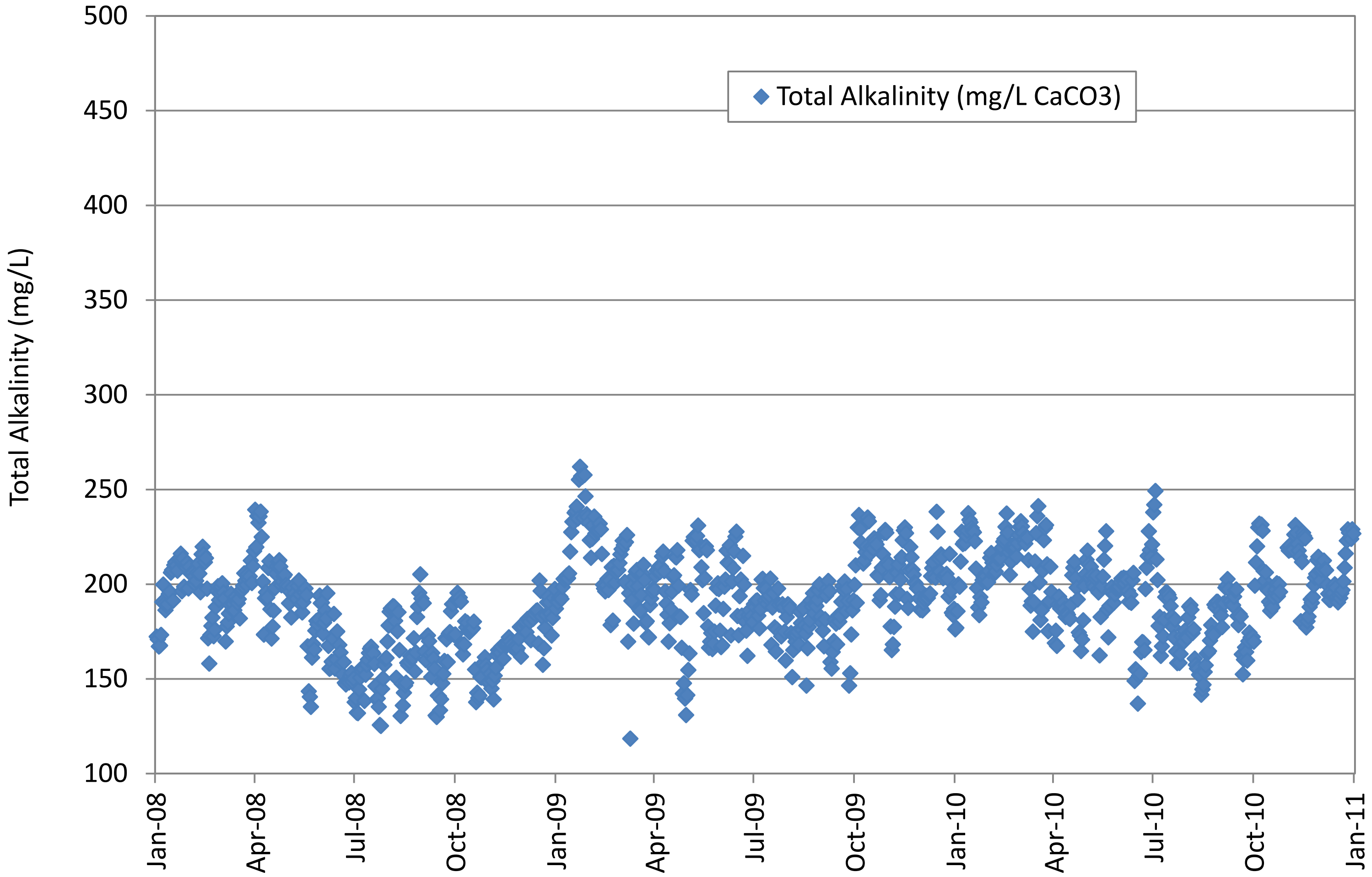
Figure B.4

Lawrence, Kansas

Kaw Plant – Raw Water Turbidity



	Min	Ave	Max
2008	125	178	239
2009	119	198	262
2010	137	197	249

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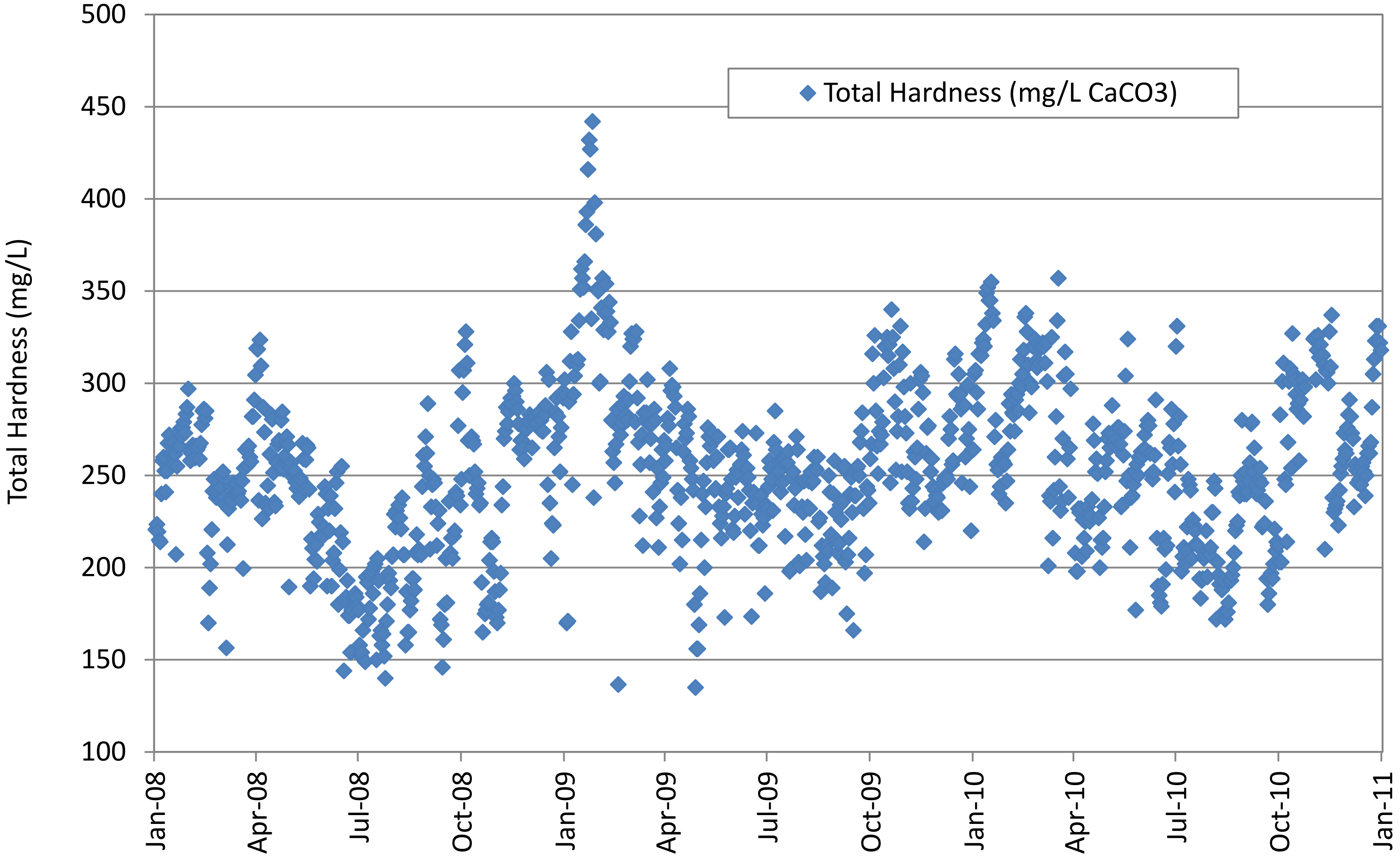
Figure B.5

Lawrence, Kansas

Kaw Plant – Raw Water
Total Alkalinity



	Min	Ave	Max
2008	84	236	328
2009	135	263	442
2010	172	259	357

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Figure B.6

Lawrence, Kansas

Kaw Plant – Raw Water
Total Hardness

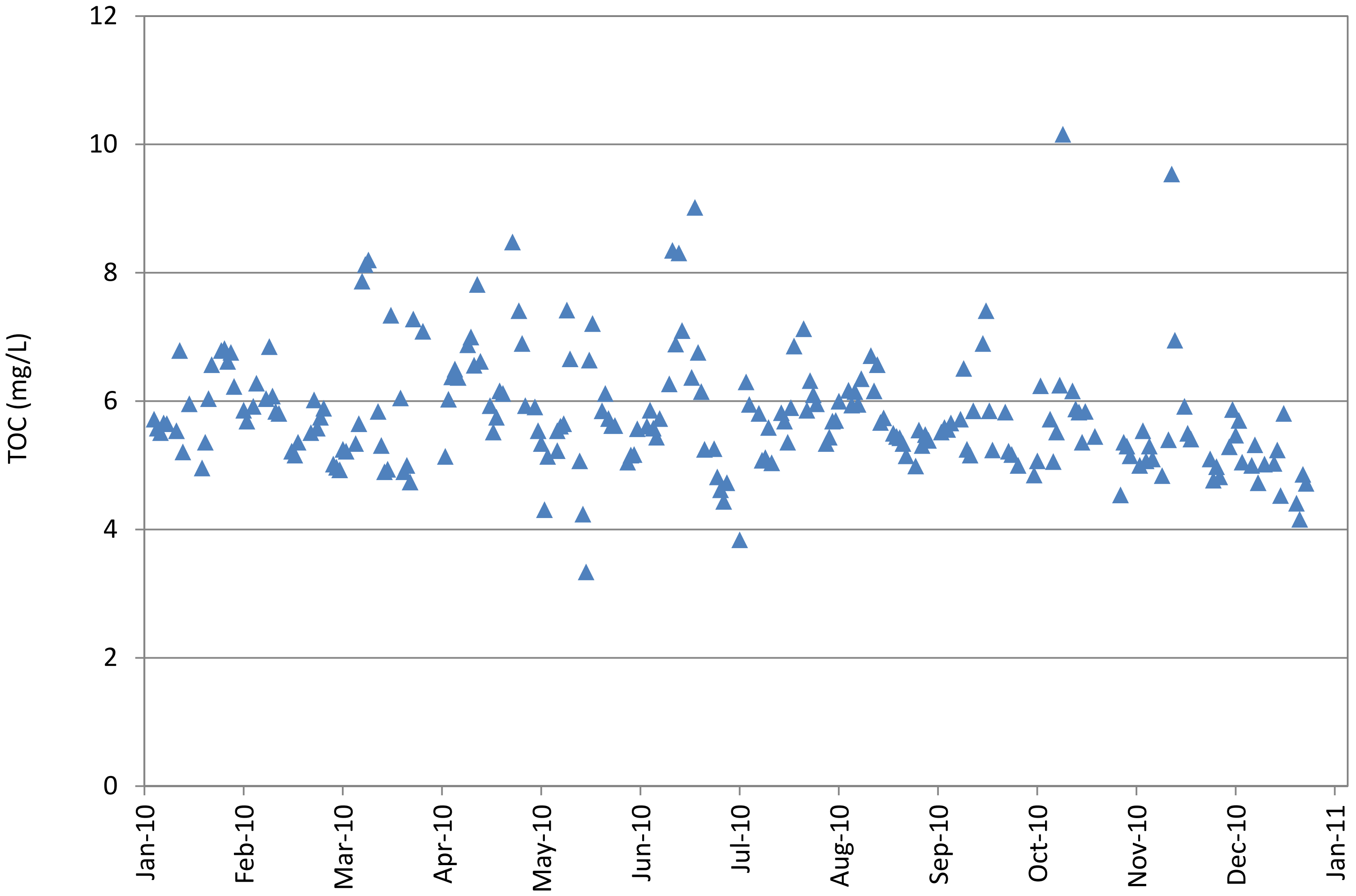

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Figure B.7

Lawrence, Kansas

Kaw Plant – Raw Water TOC

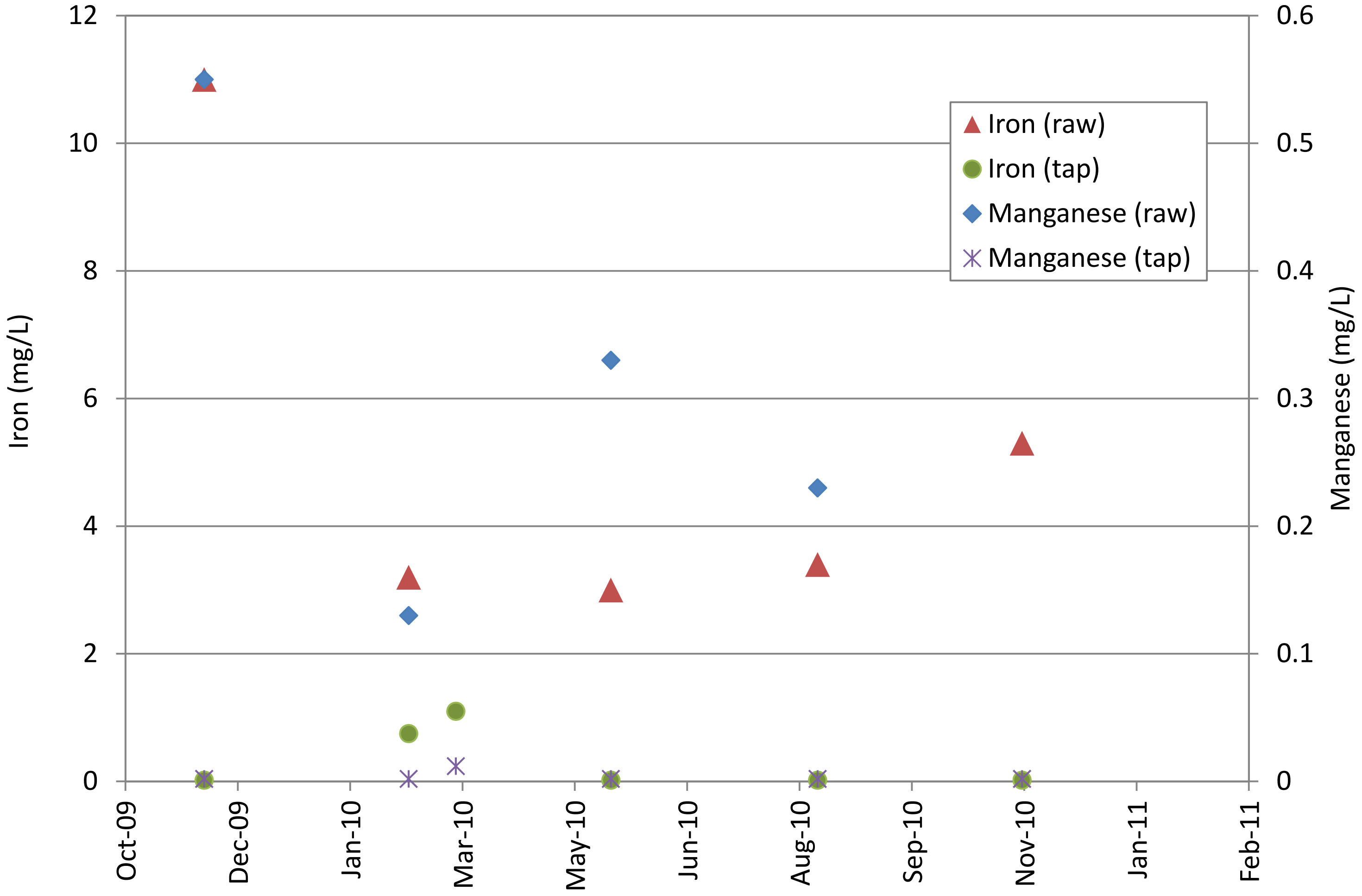

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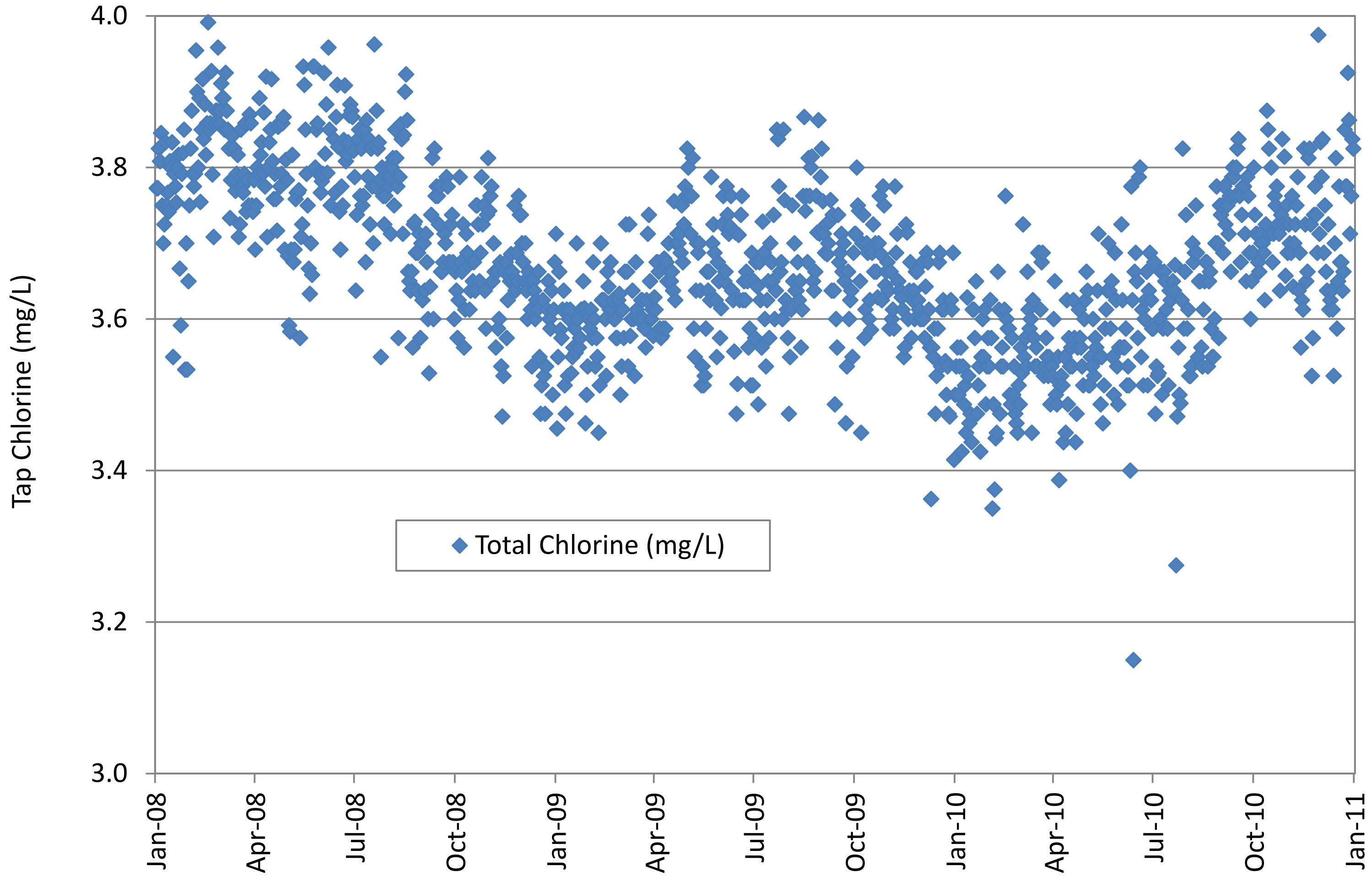
Figure B.8

Lawrence, Kansas

Kaw Plant – Iron and Manganese



	Min	Ave	Max
2008	3.5	3.7	4.0
2009	3.4	3.6	3.9
2010	3.2	3.6	4.0

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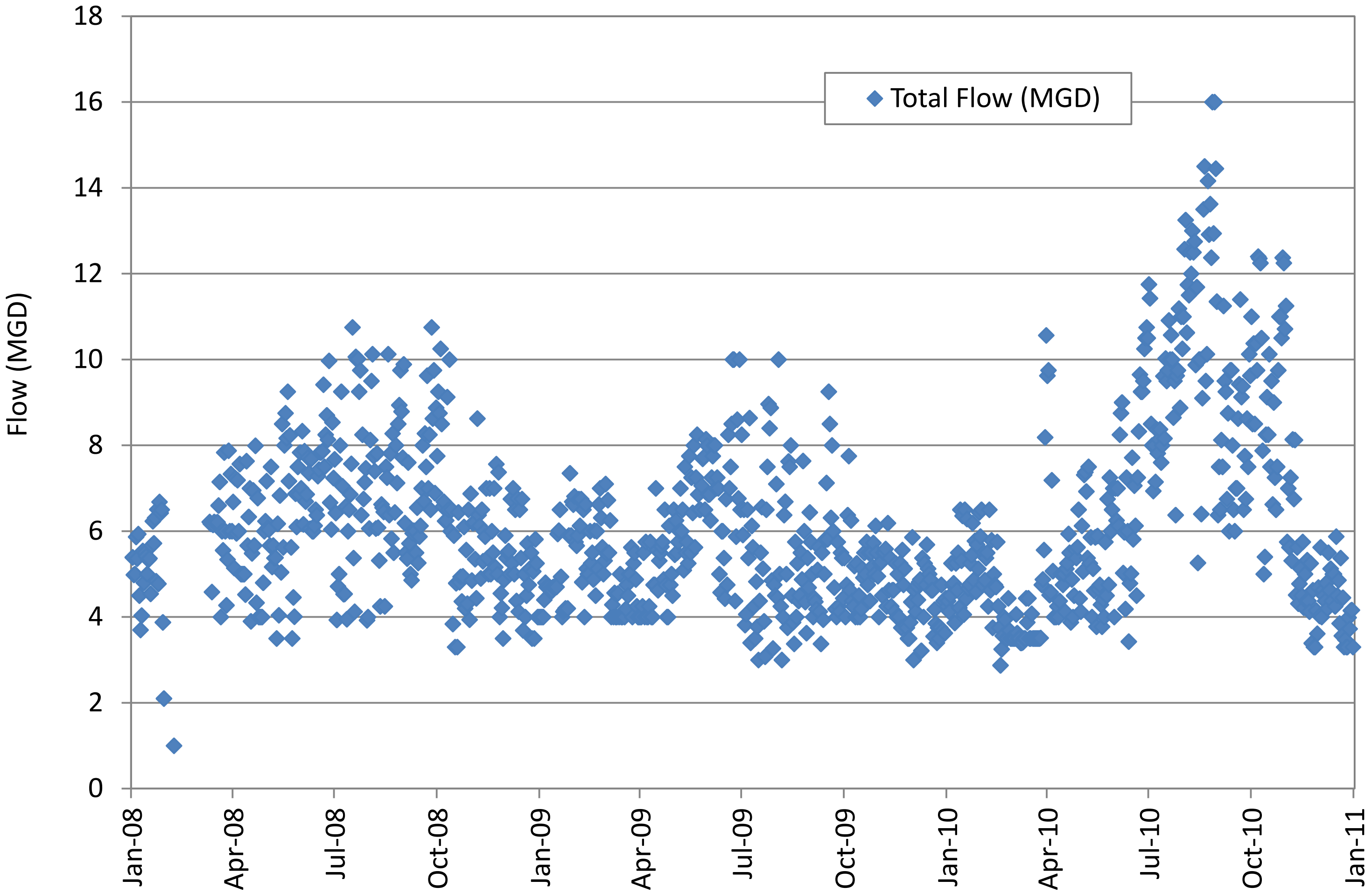
Figure B.9

Lawrence, Kansas

Kaw Plant –Total Chlorine
in Finished Water



	Min	Ave	Max
2008	1.0	6.3	10.8
2009	3.0	5.3	10.0
2010	2.9	6.7	16.0

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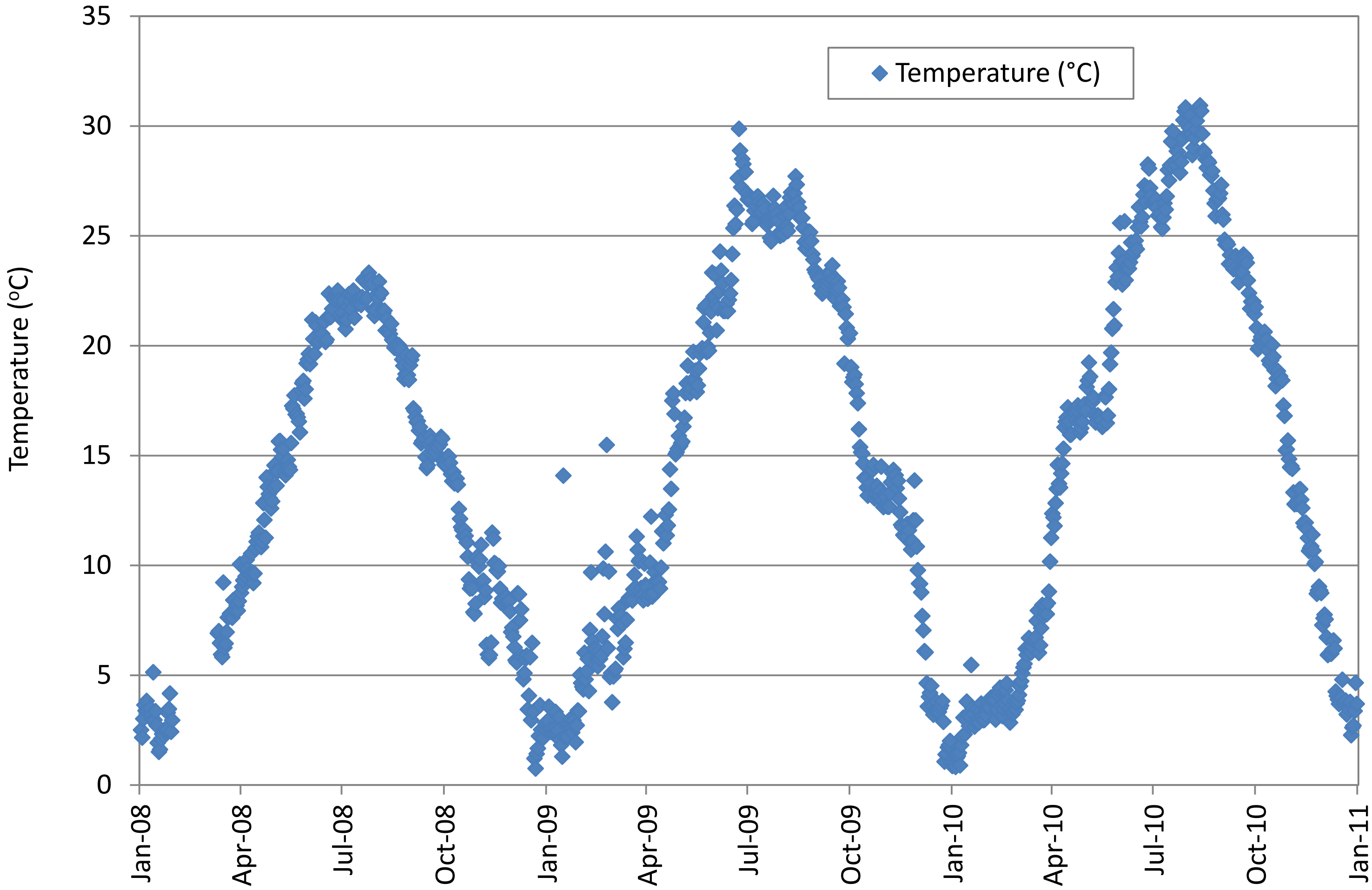
Figure B.10

Lawrence, Kansas

Clinton Plant – Total Flow



	Min	Ave	Max
2008	0.8	13.1	23.3
2009	1.0	15.0	29.9
2010	0.8	15.7	30.9

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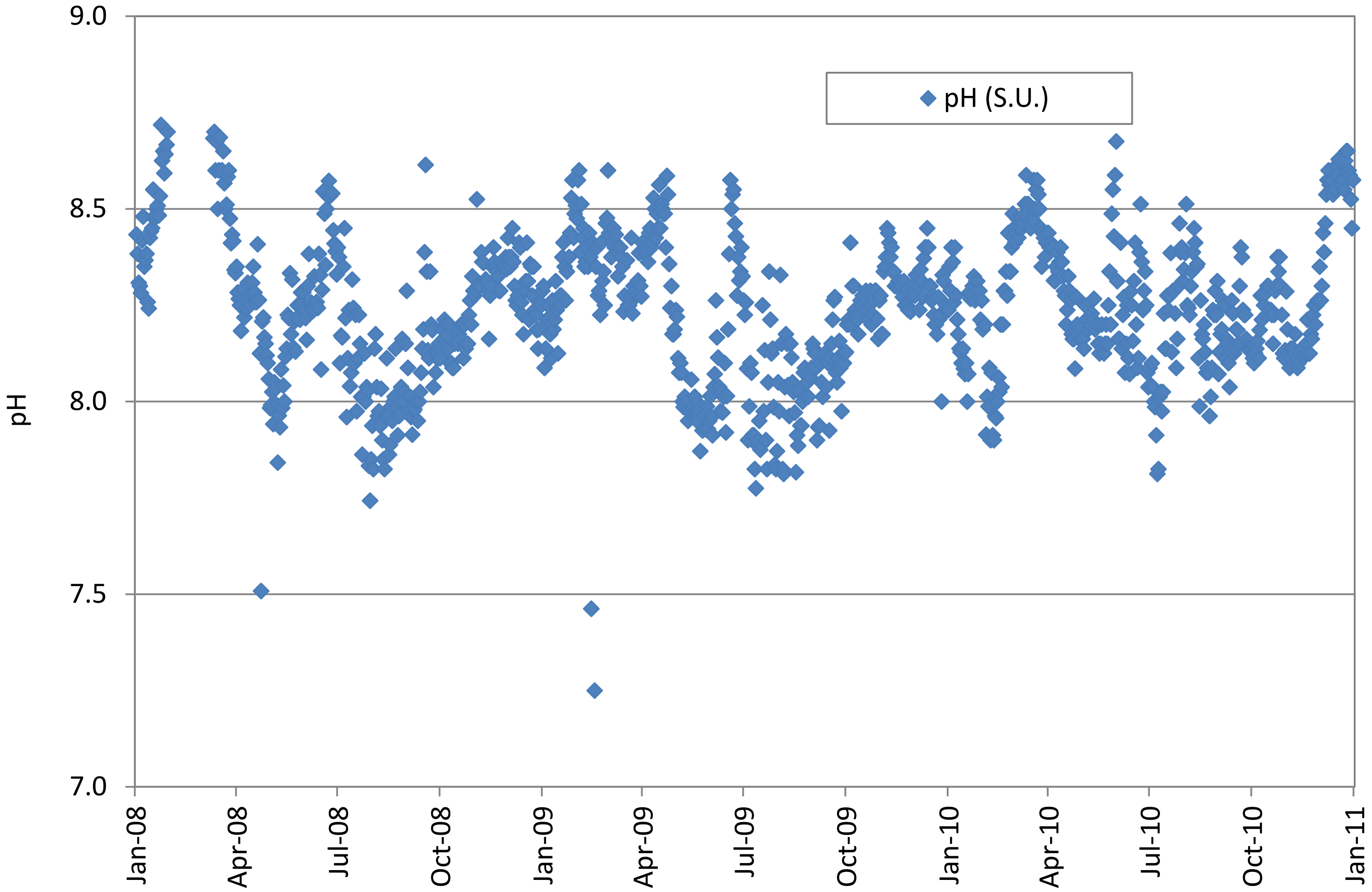
Figure B.11

Lawrence, Kansas

Clinton Plant – Raw Water Temperature



	Min	Ave	Max
2008	7.5	8.2	8.7
2009	7.3	8.2	8.6
2010	7.8	8.3	8.7

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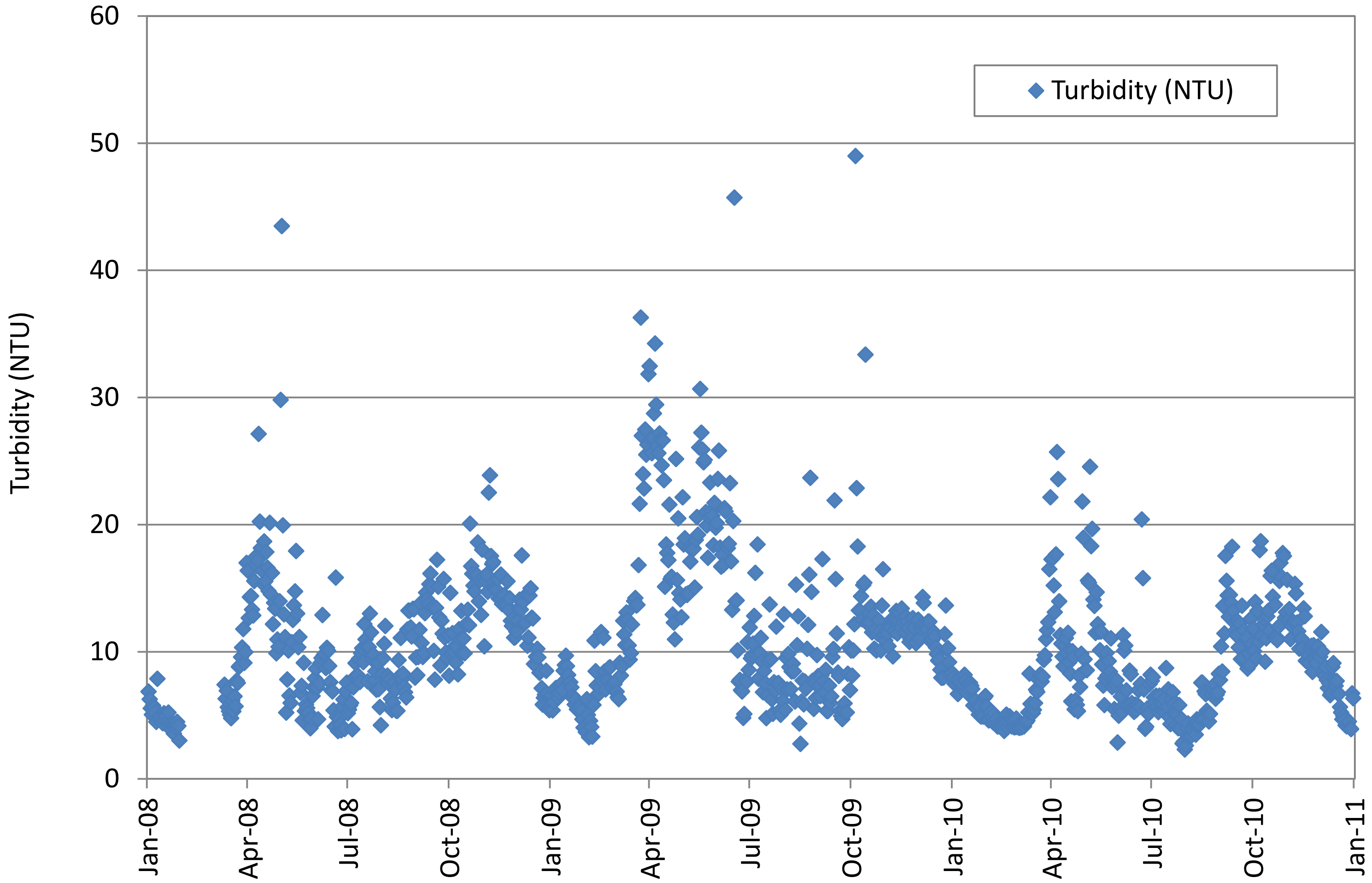
Figure B.12

Lawrence, Kansas

Clinton Plant – Raw Water
pH



	Min	Ave	Max
2008	3.0	10.5	43.5
2009	2.8	12.6	49.0
2010	2.3	8.6	25.7

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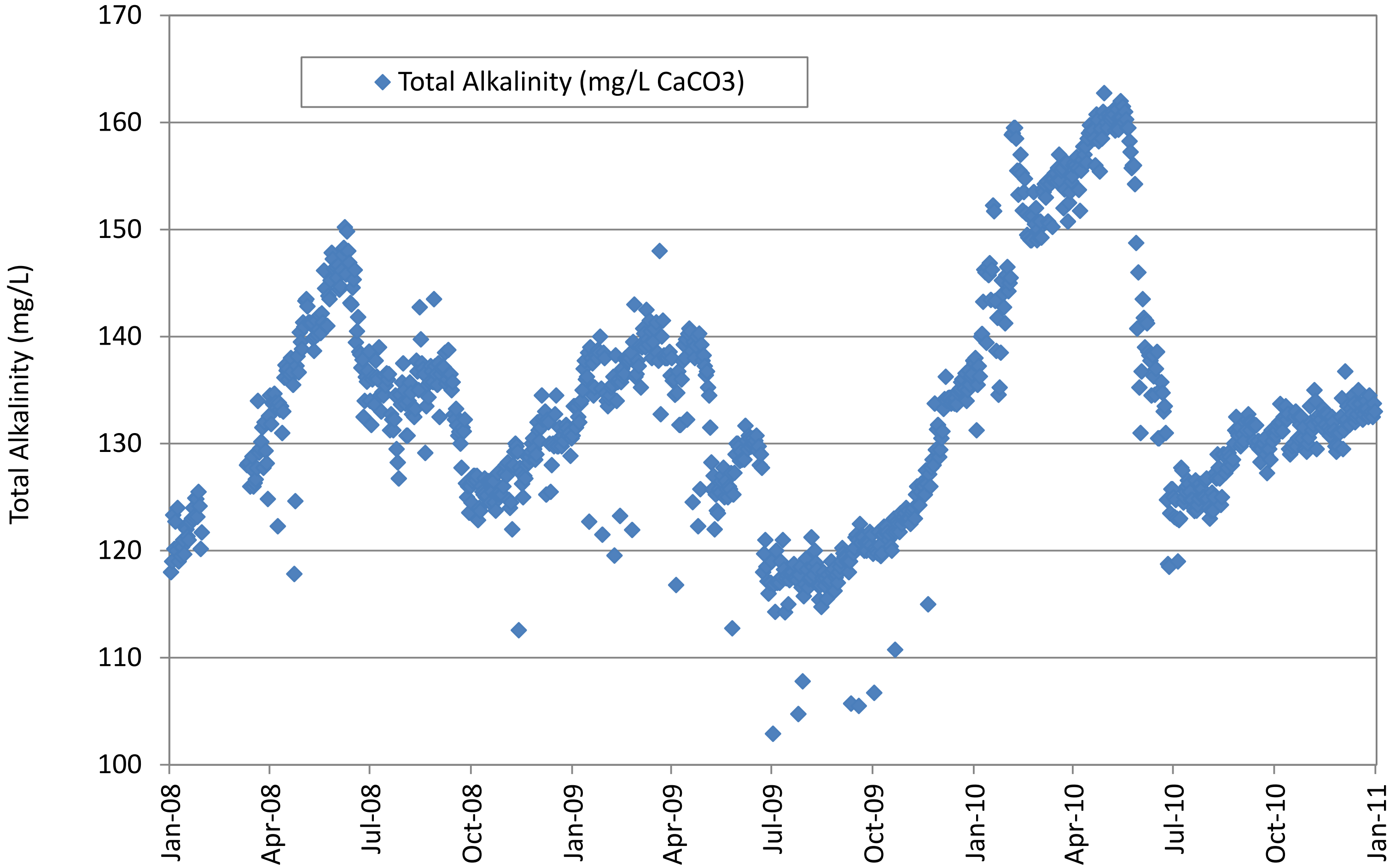
Figure B.13

Lawrence, Kansas

Clinton Plant – Raw Water Turbidity

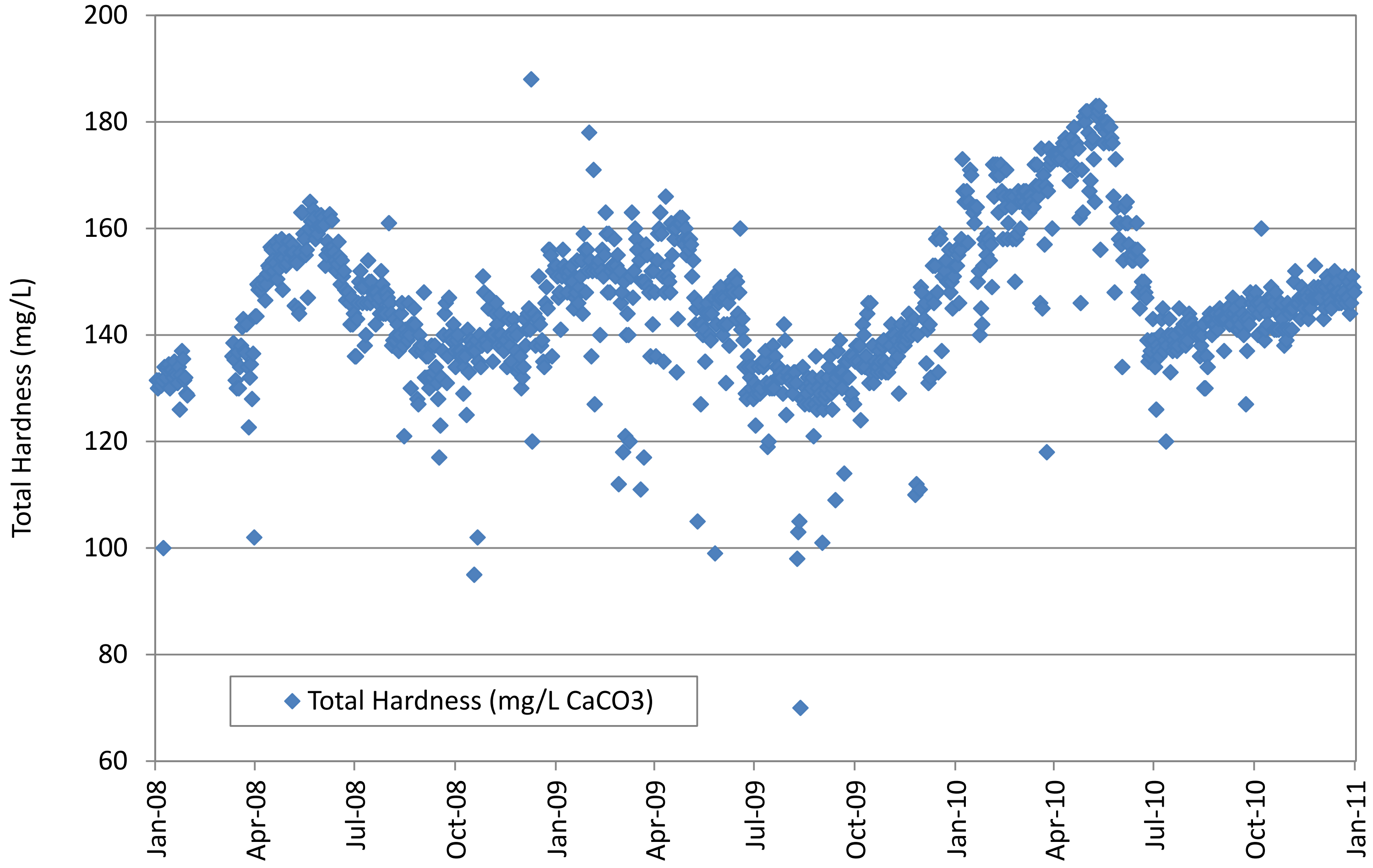


	Min	Ave	Max
2008	113	132	150
2009	103	128	148
2010	119	140	163

Figure B.14

Lawrence, Kansas

Clinton Plant – Raw Water
Total Alkalinity



	Min	Ave	Max
2008	95	143	188
2009	70	141	178
2010	118	153	183

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Figure B.15

Lawrence, Kansas

Clinton Plant – Raw Water
Total Hardness

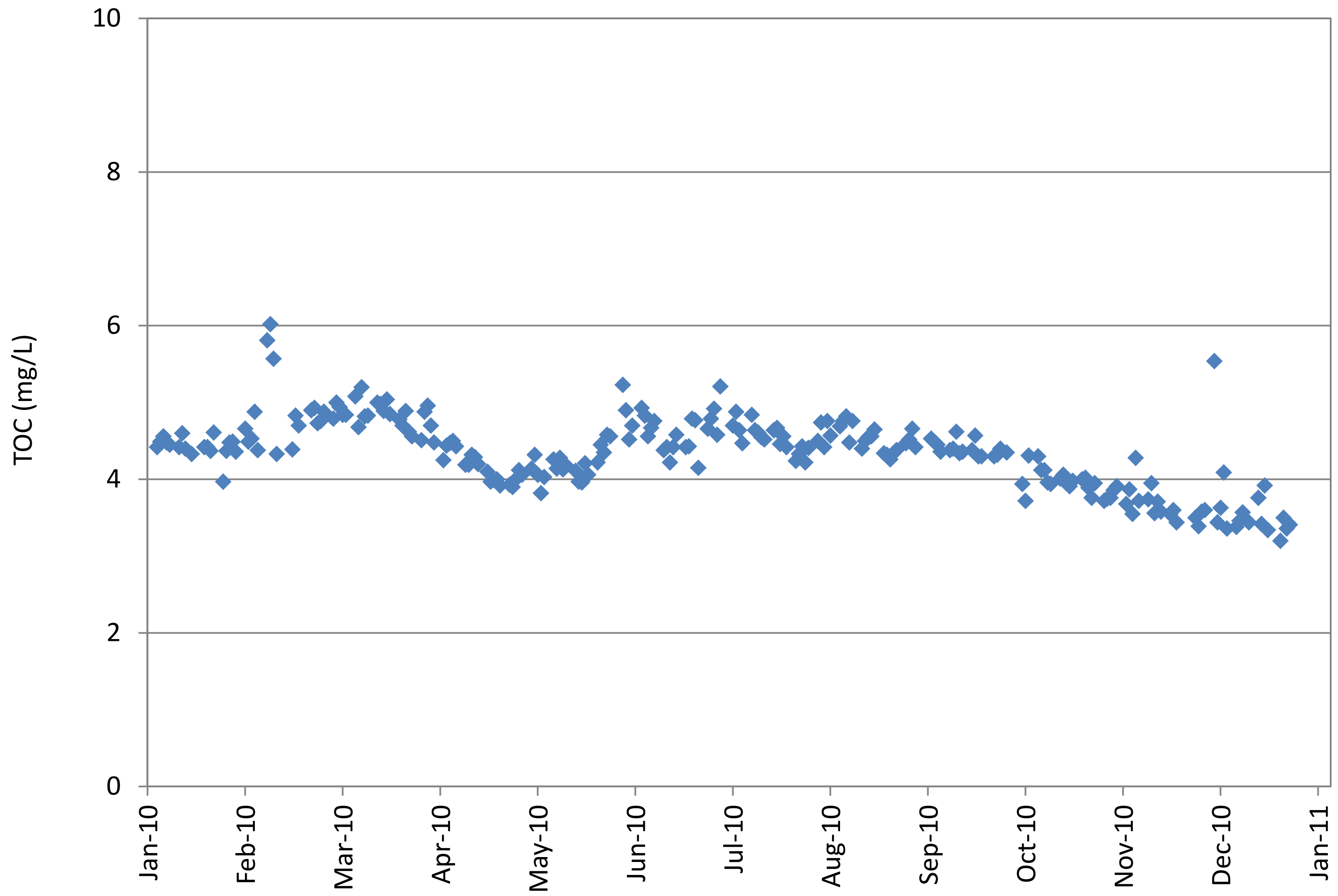

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Figure B.16

Lawrence, Kansas

Clinton Plant – Raw Water TOC

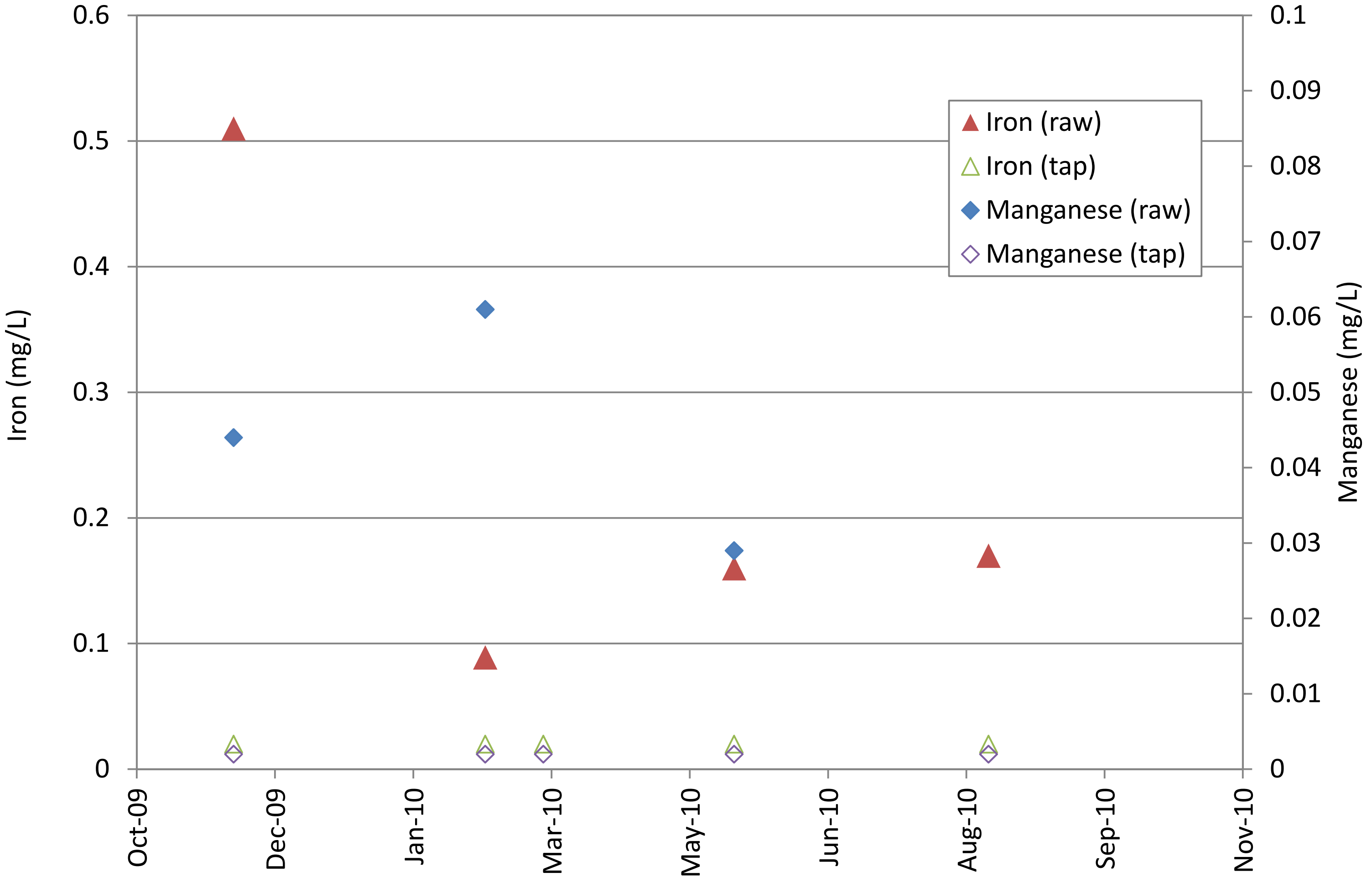

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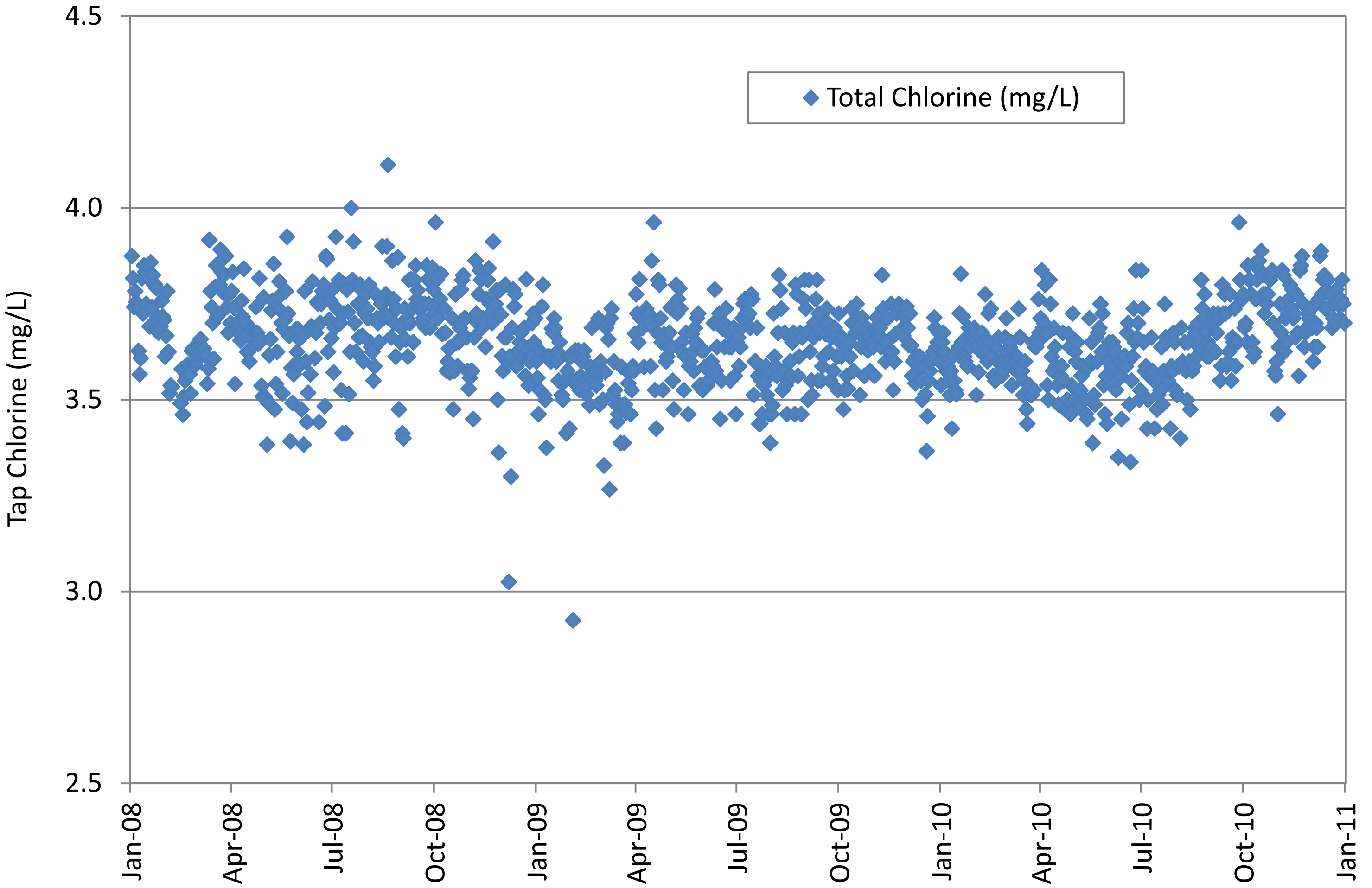
Figure B.17

Lawrence, Kansas

Clinton Plant – Iron and Manganese



	Min	Ave	Max
2008	3.0	3.7	4.1
2009	2.9	3.6	4.0
2010	3.3	3.6	4.0

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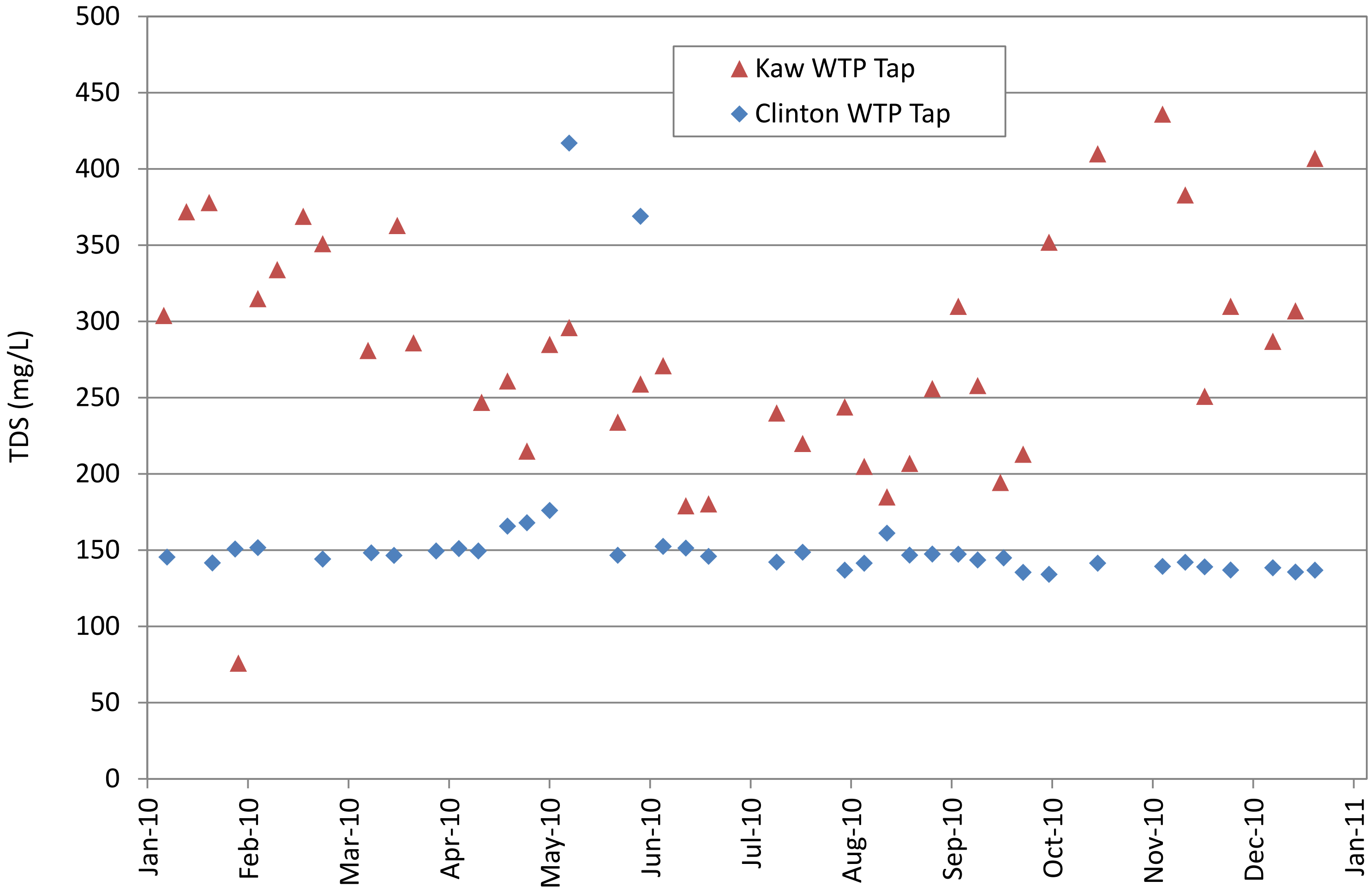
Figure B.18

Lawrence, Kansas

Clinton Plant – Total Chlorine in Finished Water



2010	Min	Ave	Max
Kaw	76	281	436
Clinton	134	159	417

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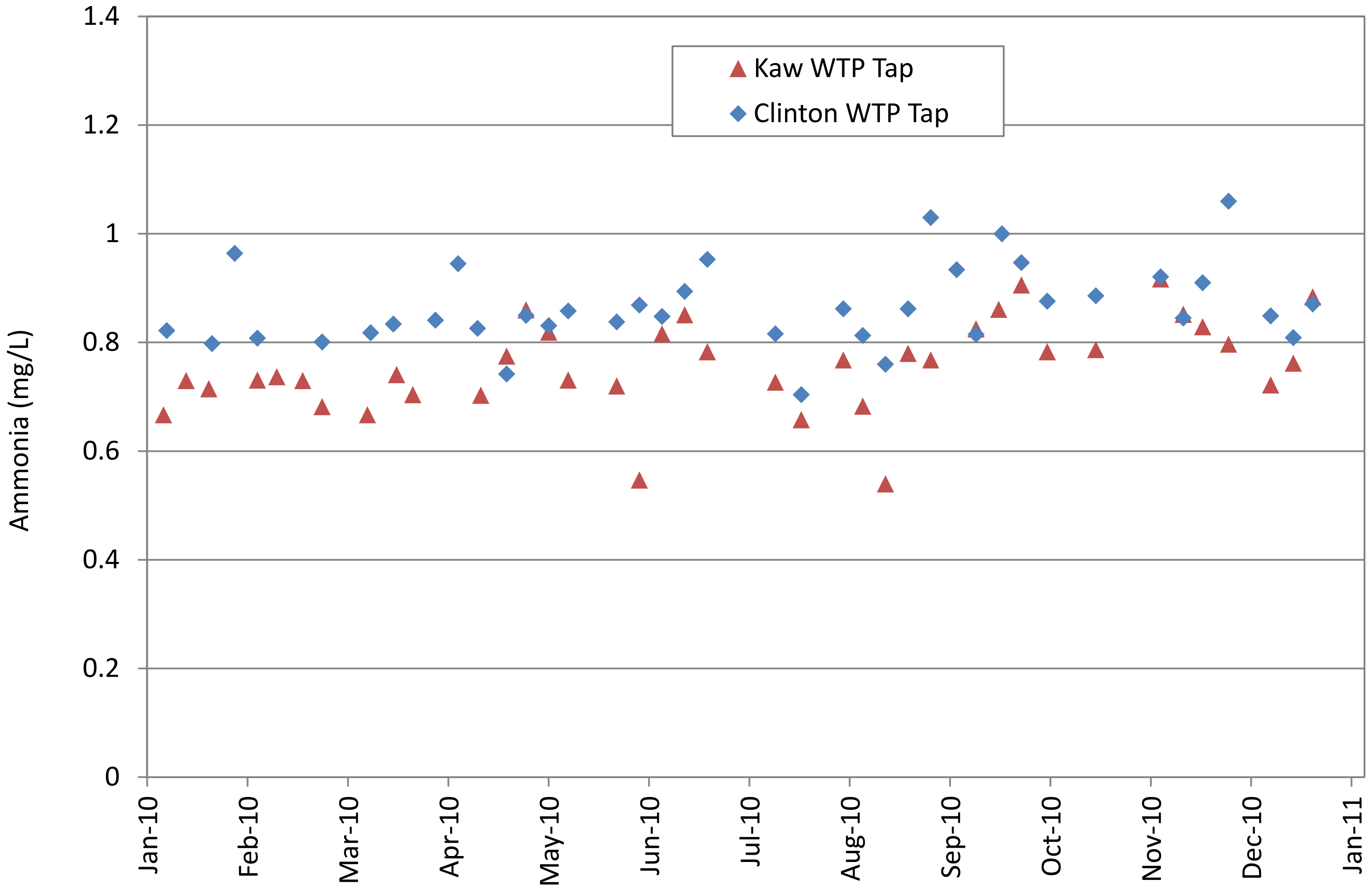
Figure B.19

Lawrence, Kansas

Finished Water Quality – TDS



2010	Min	Ave	Max
Kaw	0.54	0.77	1.22
Clinton	0.70	0.86	1.06

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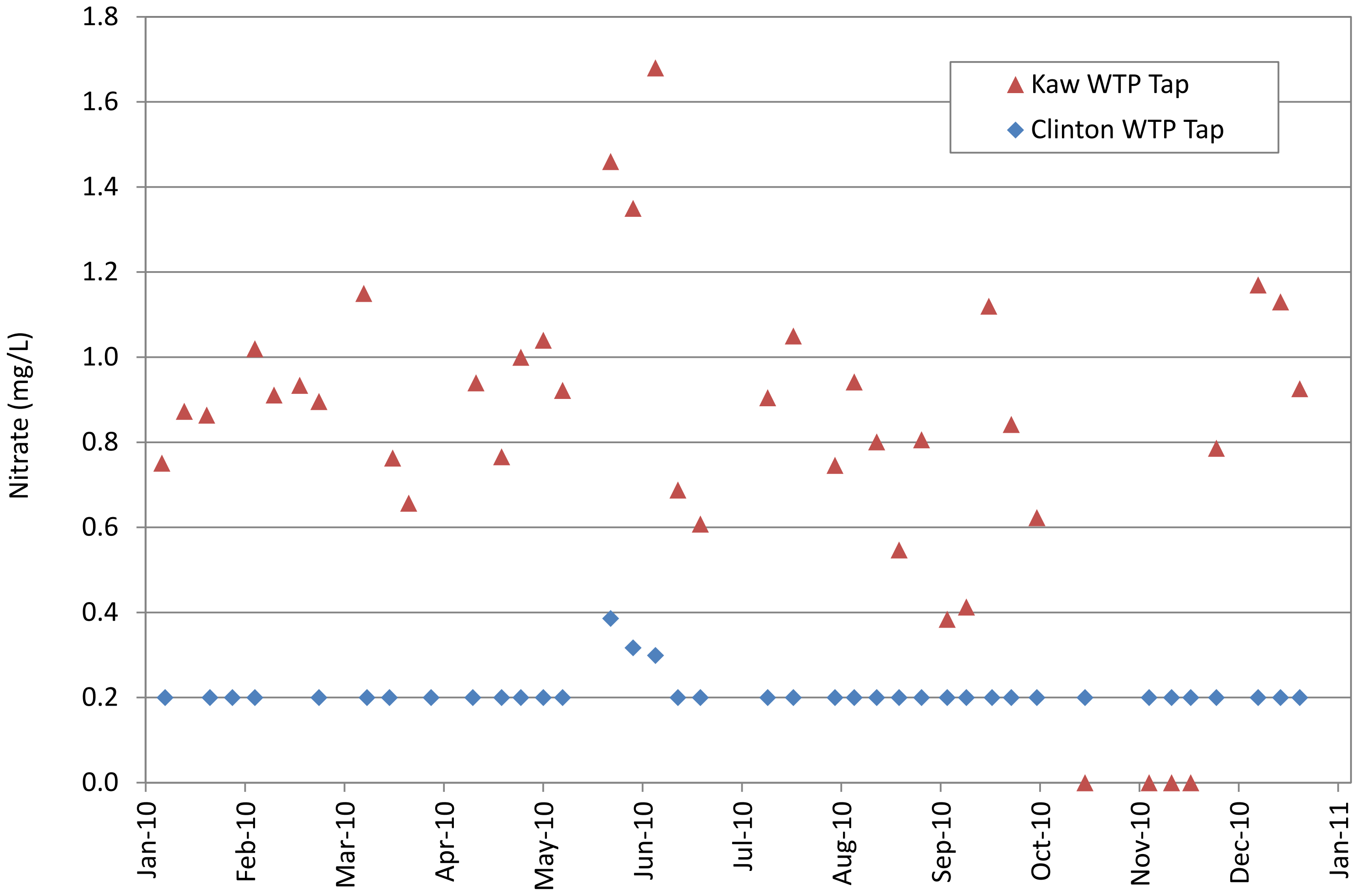
Figure B.20

Lawrence, Kansas

Finished Water Quality – Ammonia



2010	Min	Ave	Max
Kaw	0.38	0.90	1.68
Clinton	<0.23	<0.23	0.39

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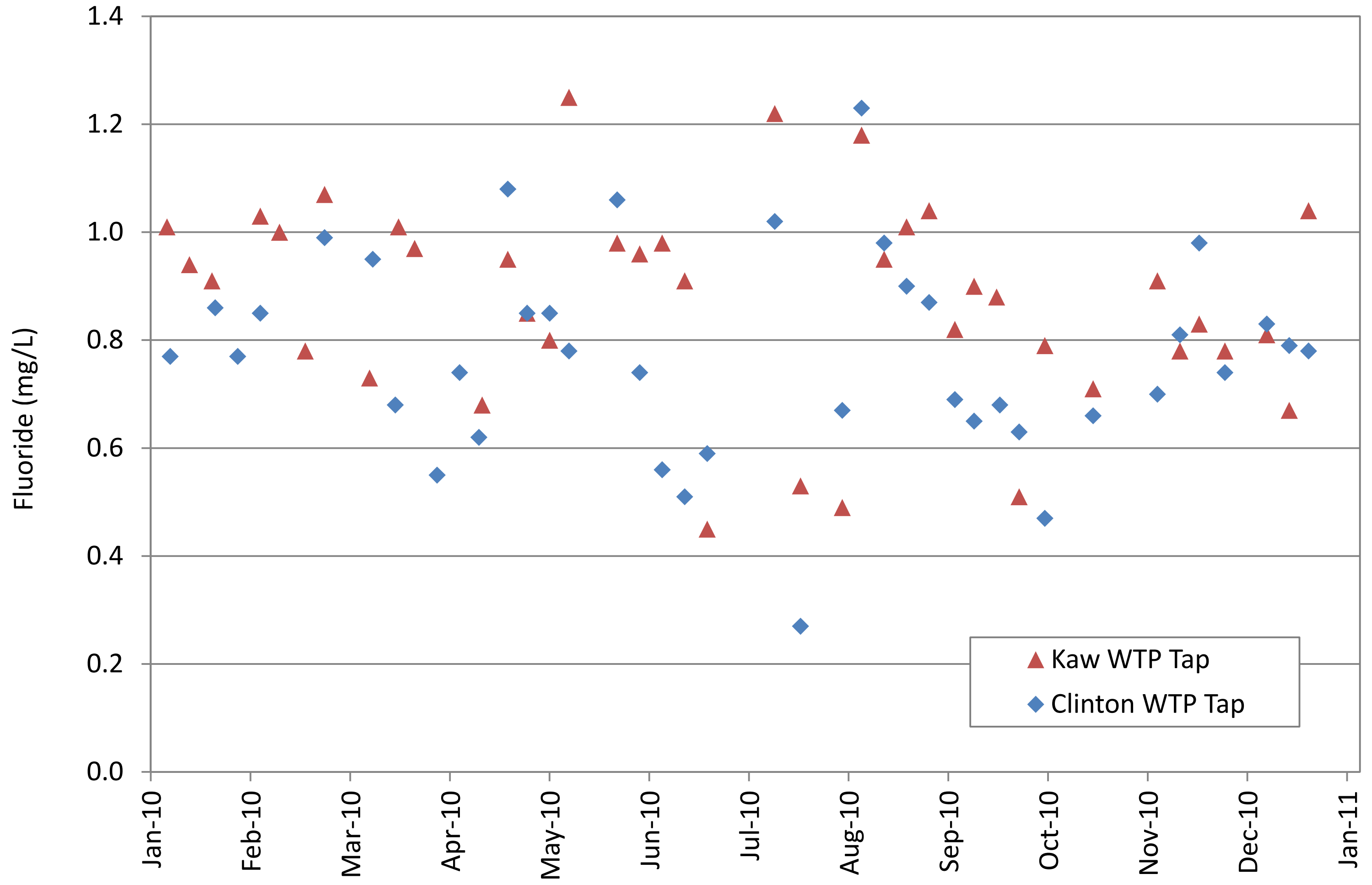
Figure B.21

Lawrence, Kansas

Finished Water Quality – Nitrate



2010	Min	Ave	Max
Kaw	0.45	0.88	1.25
Clinton	0.27	0.77	1.23

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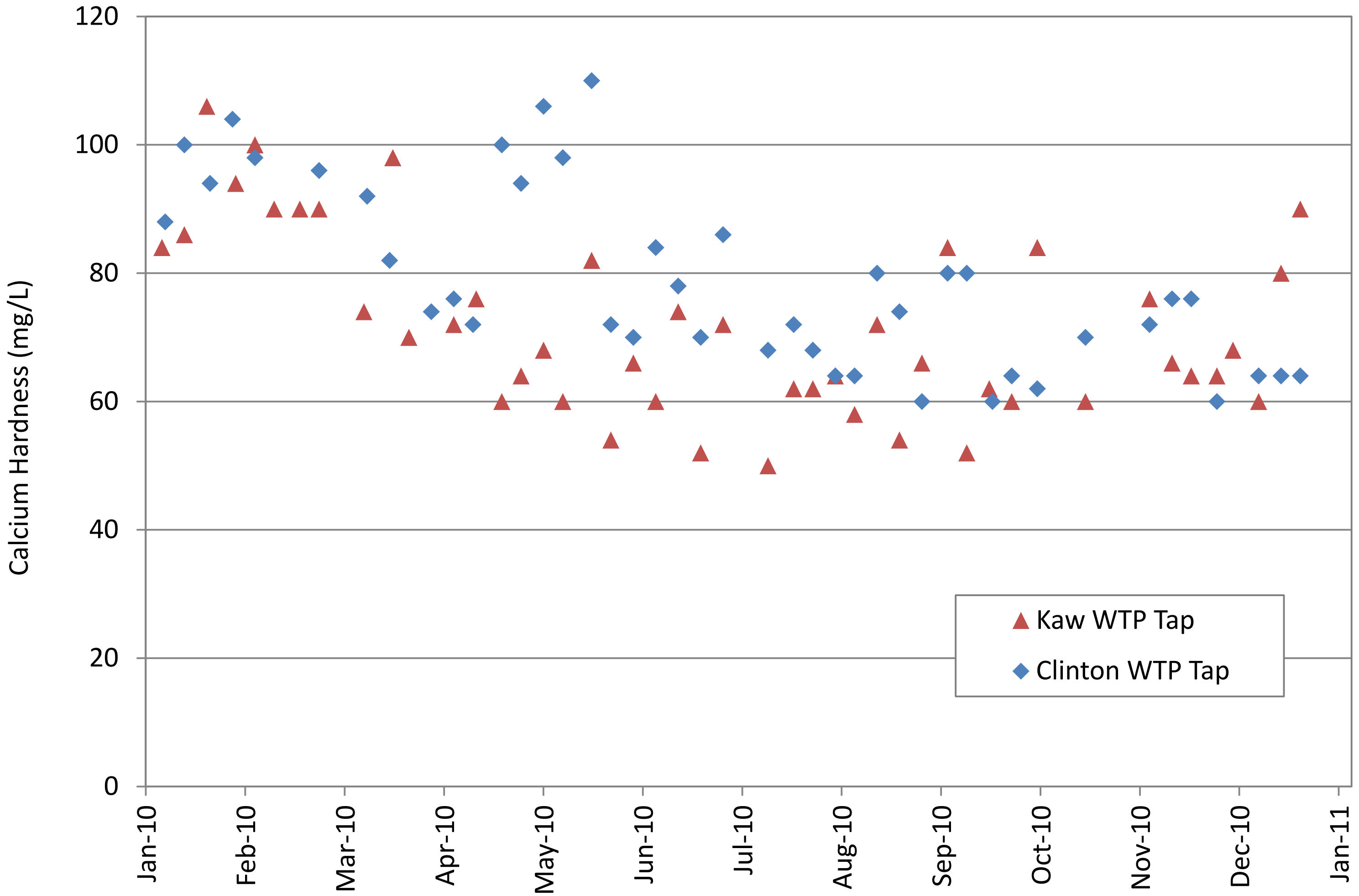
Figure B.22

Lawrence, Kansas

Finished Water Quality – Fluoride



2010	Min	Ave	Max
Kaw	50	72	106
Clinton	60	79	110

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Figure B.23

Lawrence, Kansas

Finished Water Quality –
Calcium Hardness

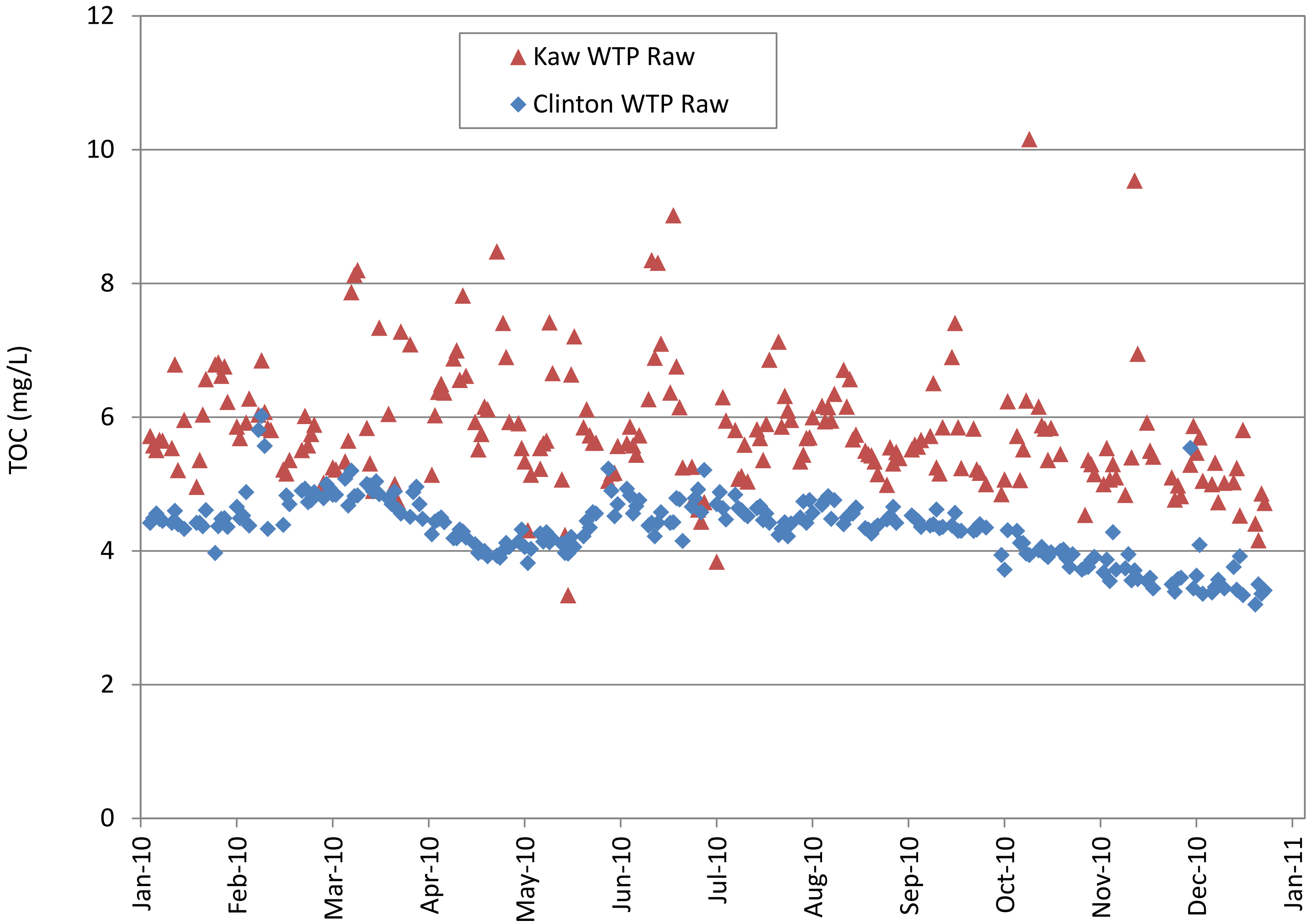

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Figure B.24

Lawrence, Kansas

Raw Water Quality – TOC

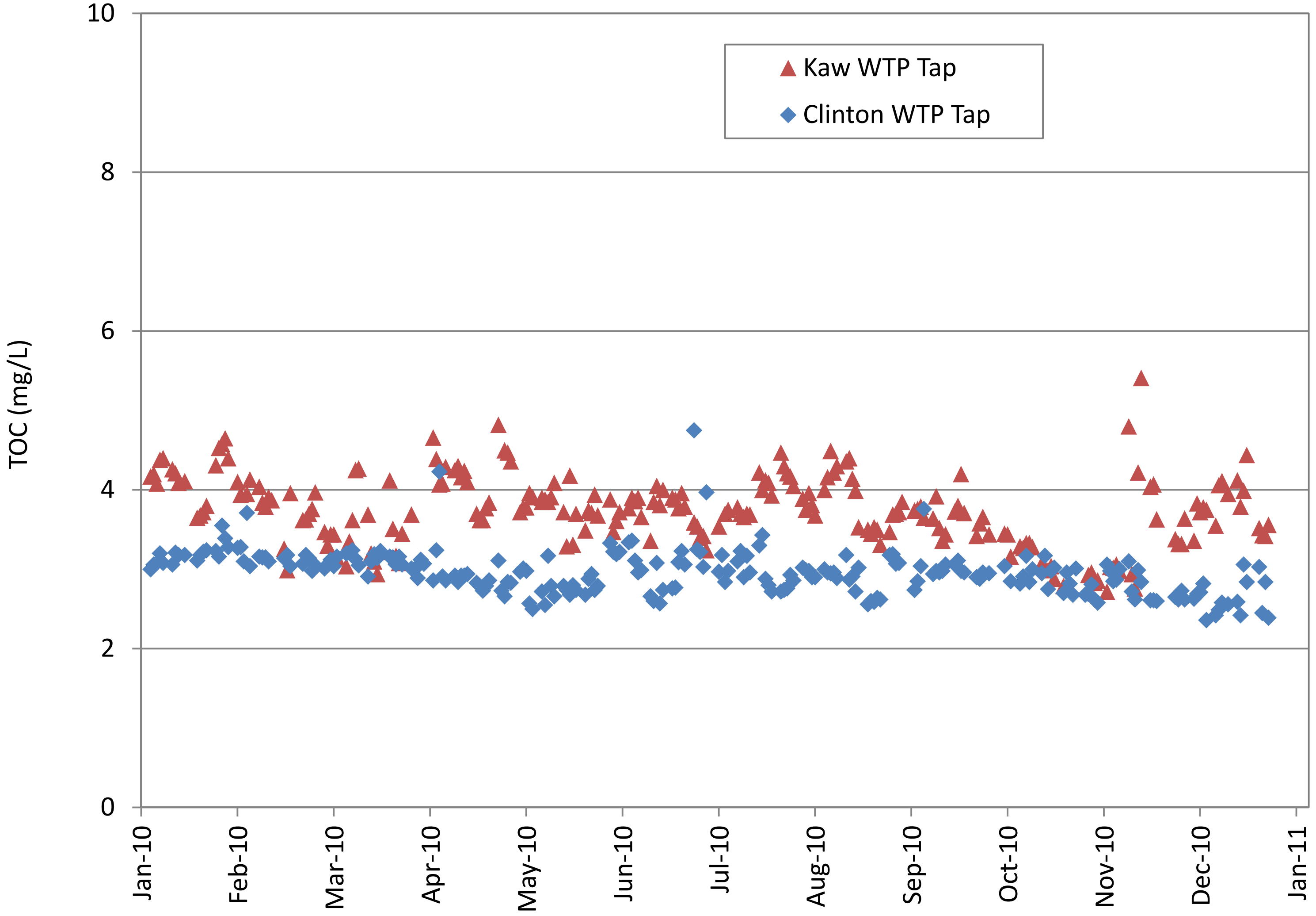

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Figure B.25

Lawrence, Kansas

Finished Water Quality – TOC

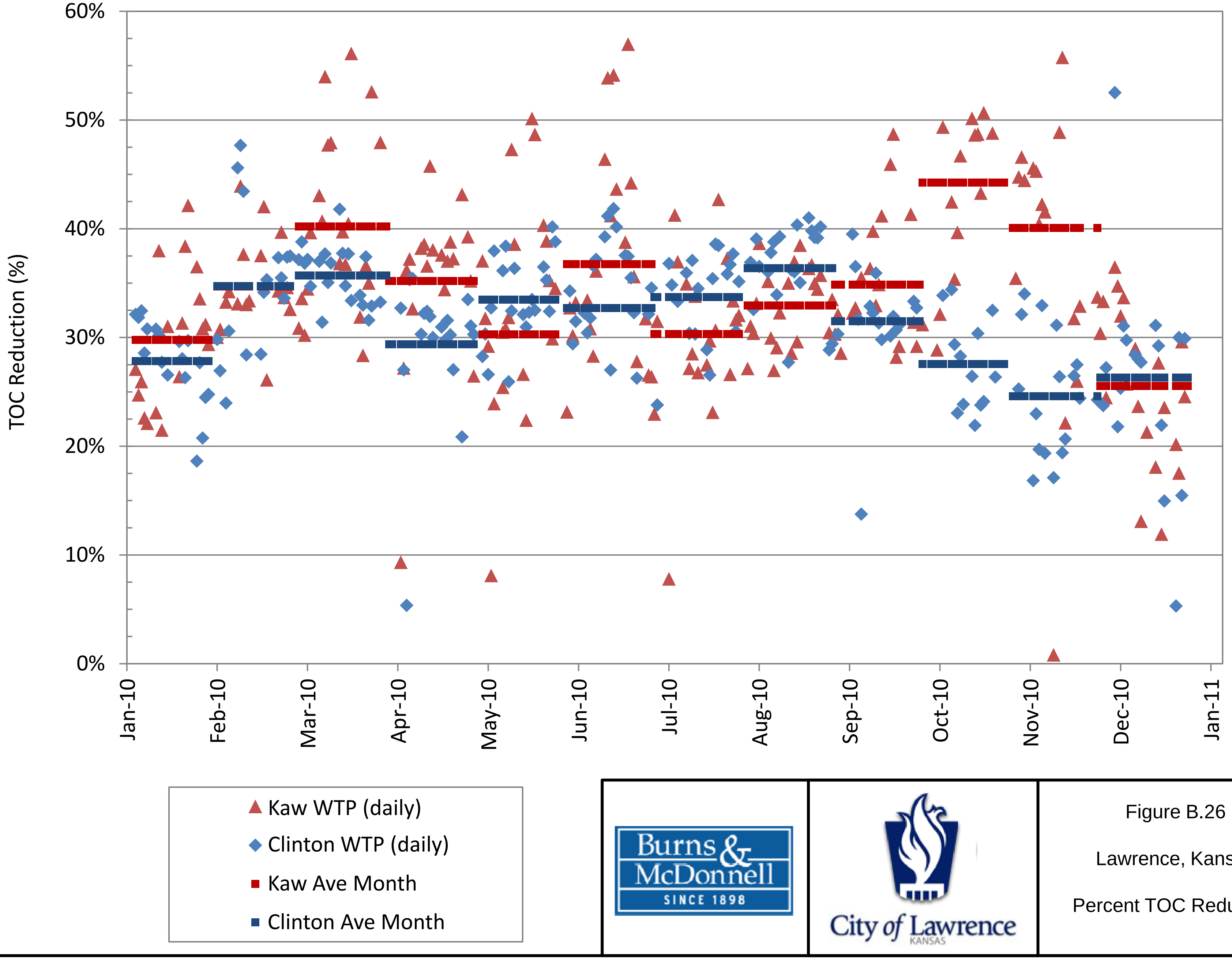

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Figure B.26

Lawrence, Kansas

Percent TOC Reduction

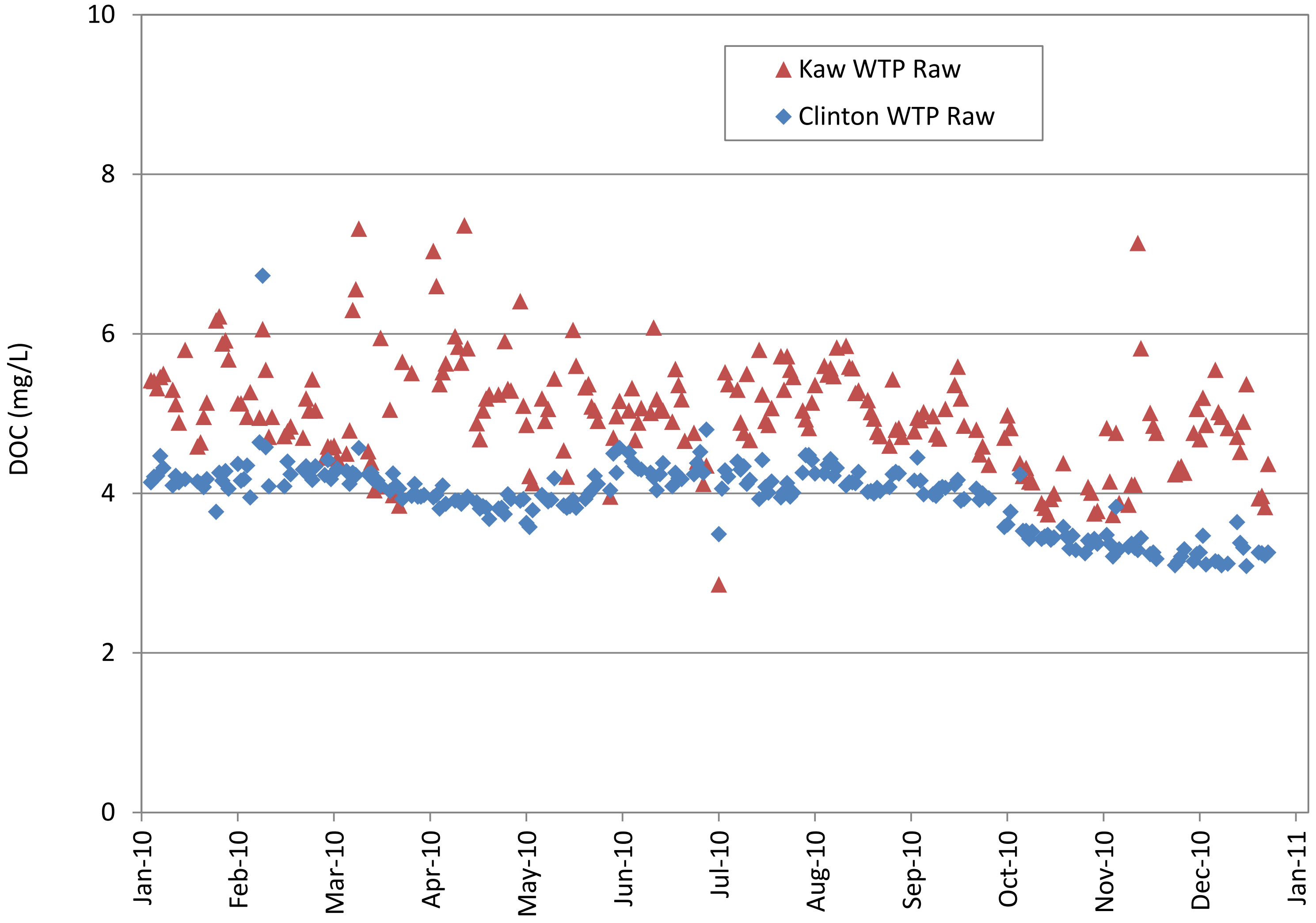

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Figure B.27

Lawrence, Kansas

Raw Water Quality – DOC

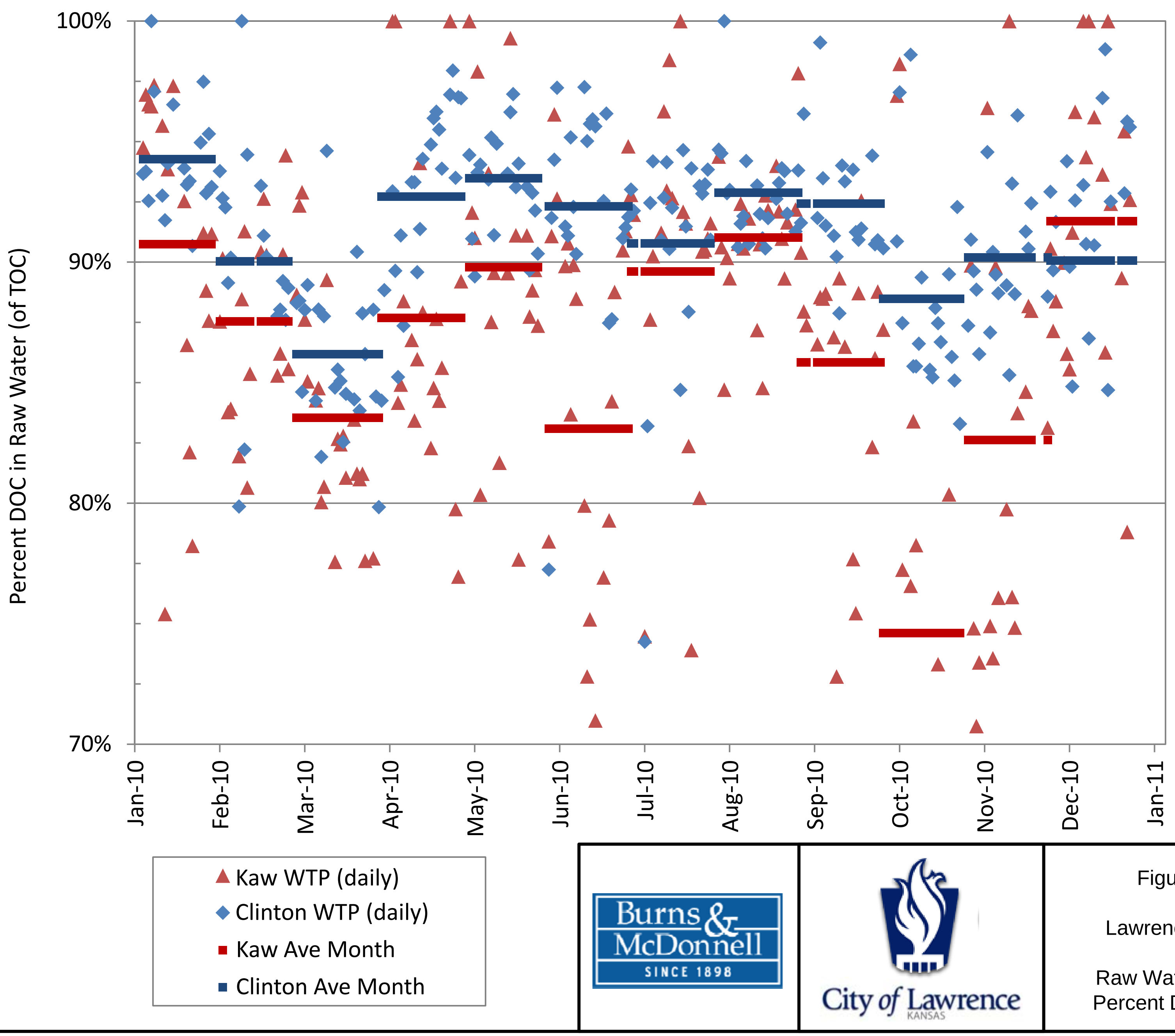

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Figure B.28

Lawrence, Kansas

Raw Water Quality –
Percent DOC of TOC

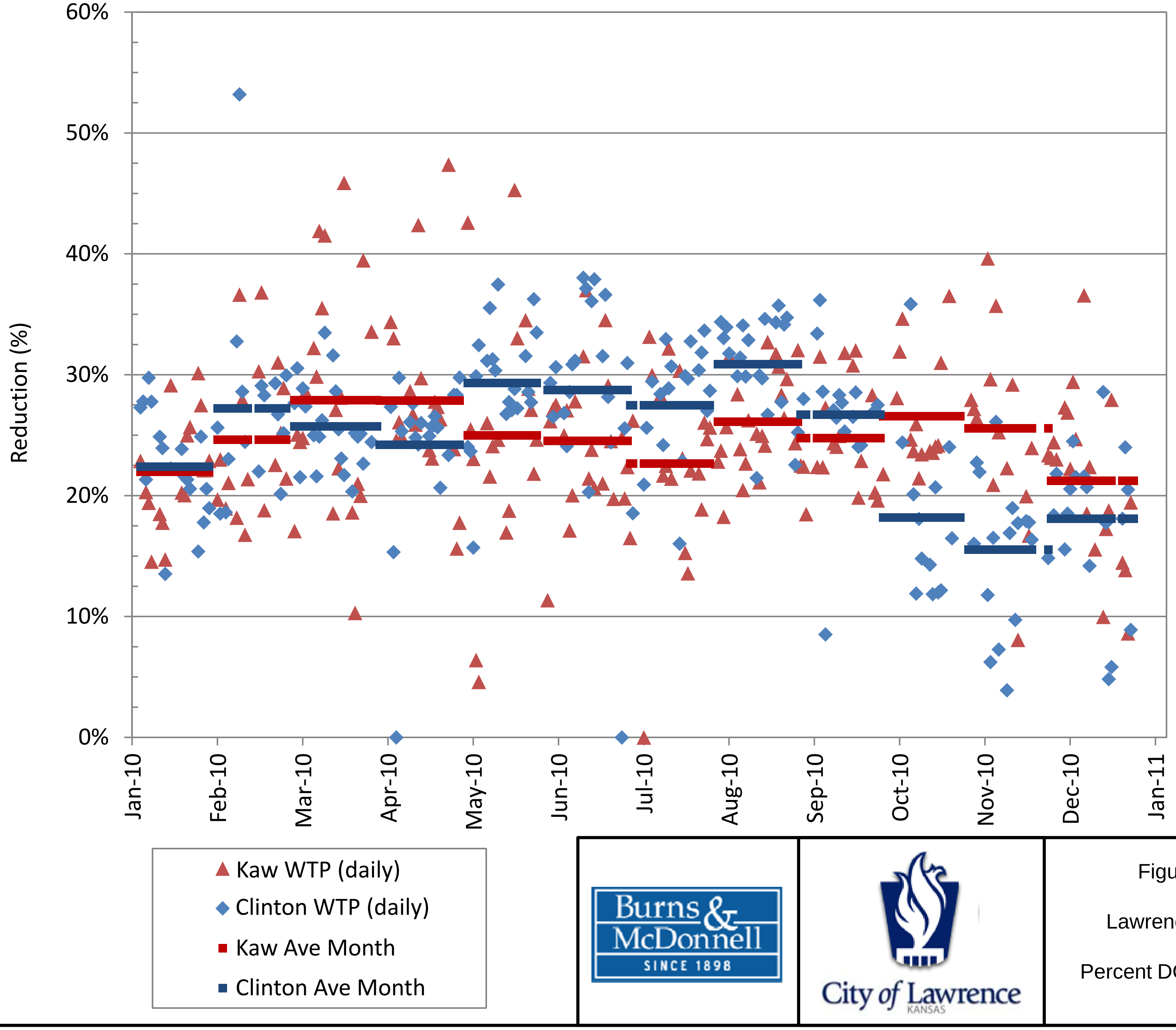

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Figure B.29

Lawrence, Kansas

Percent DOC Reduction

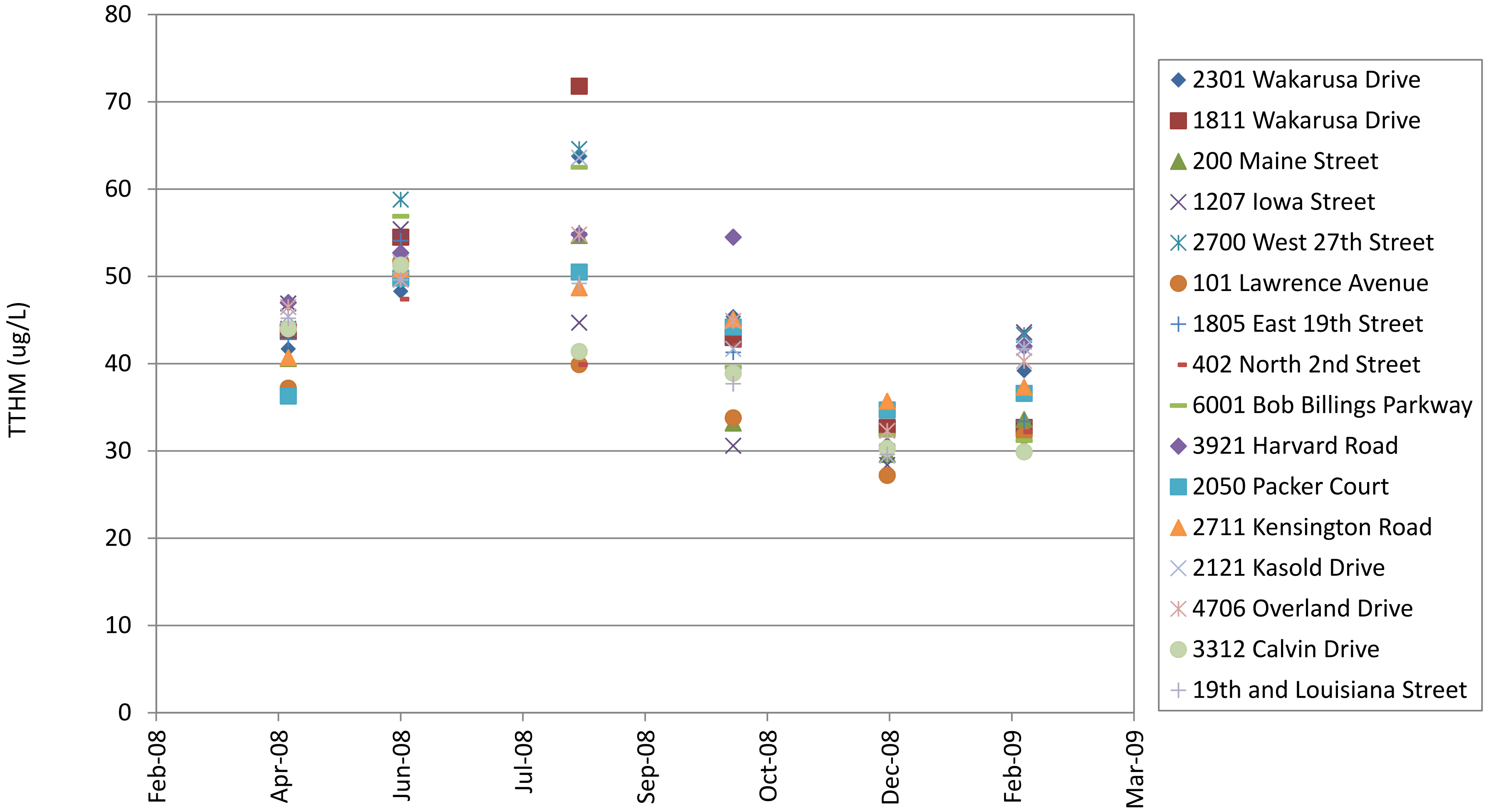

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Figure B.30

Lawrence, Kansas

Finished Water Quality – TTHM (2008)

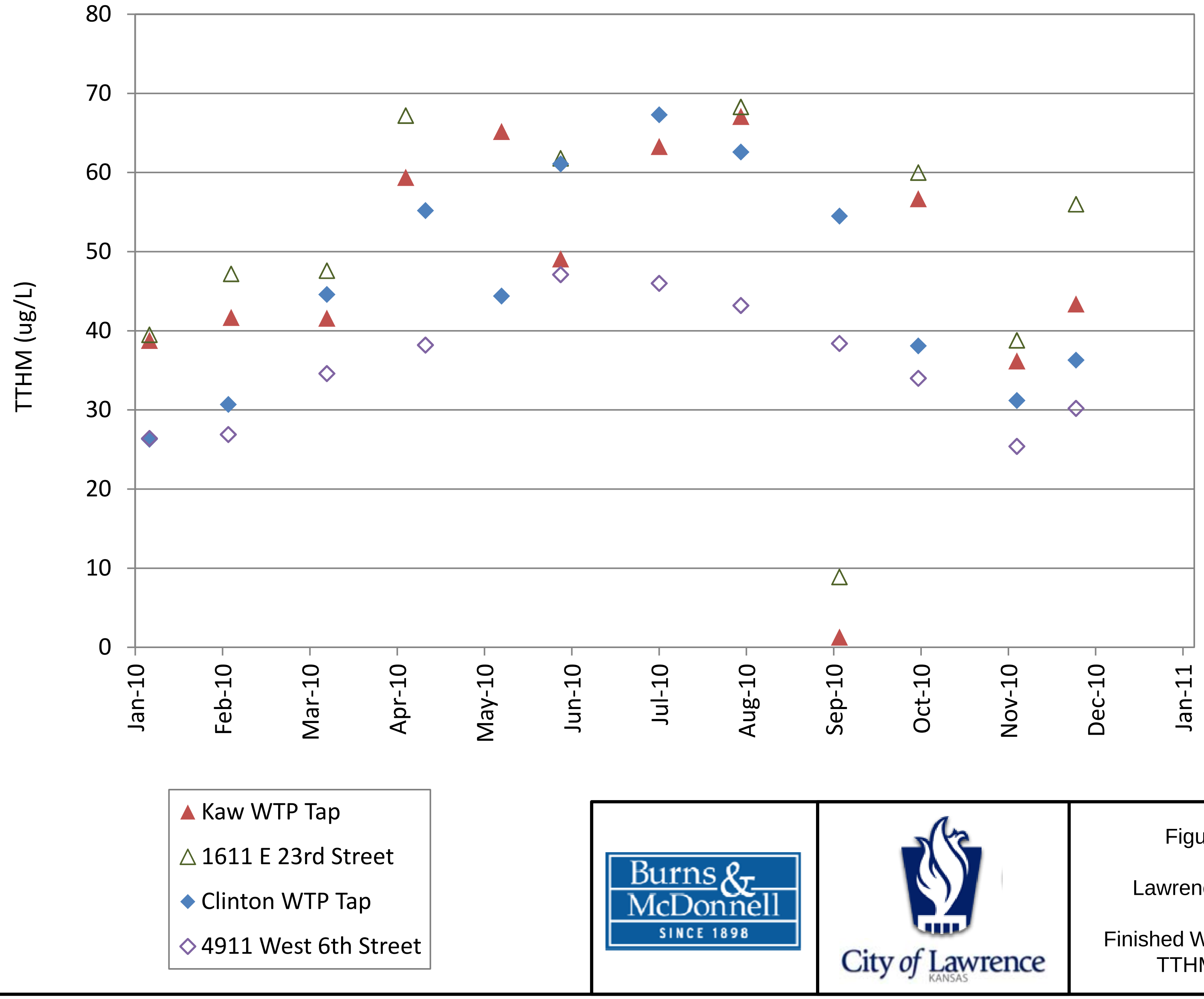

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Figure B.31

Lawrence, Kansas

Finished Water Quality –
TTHM (2010)

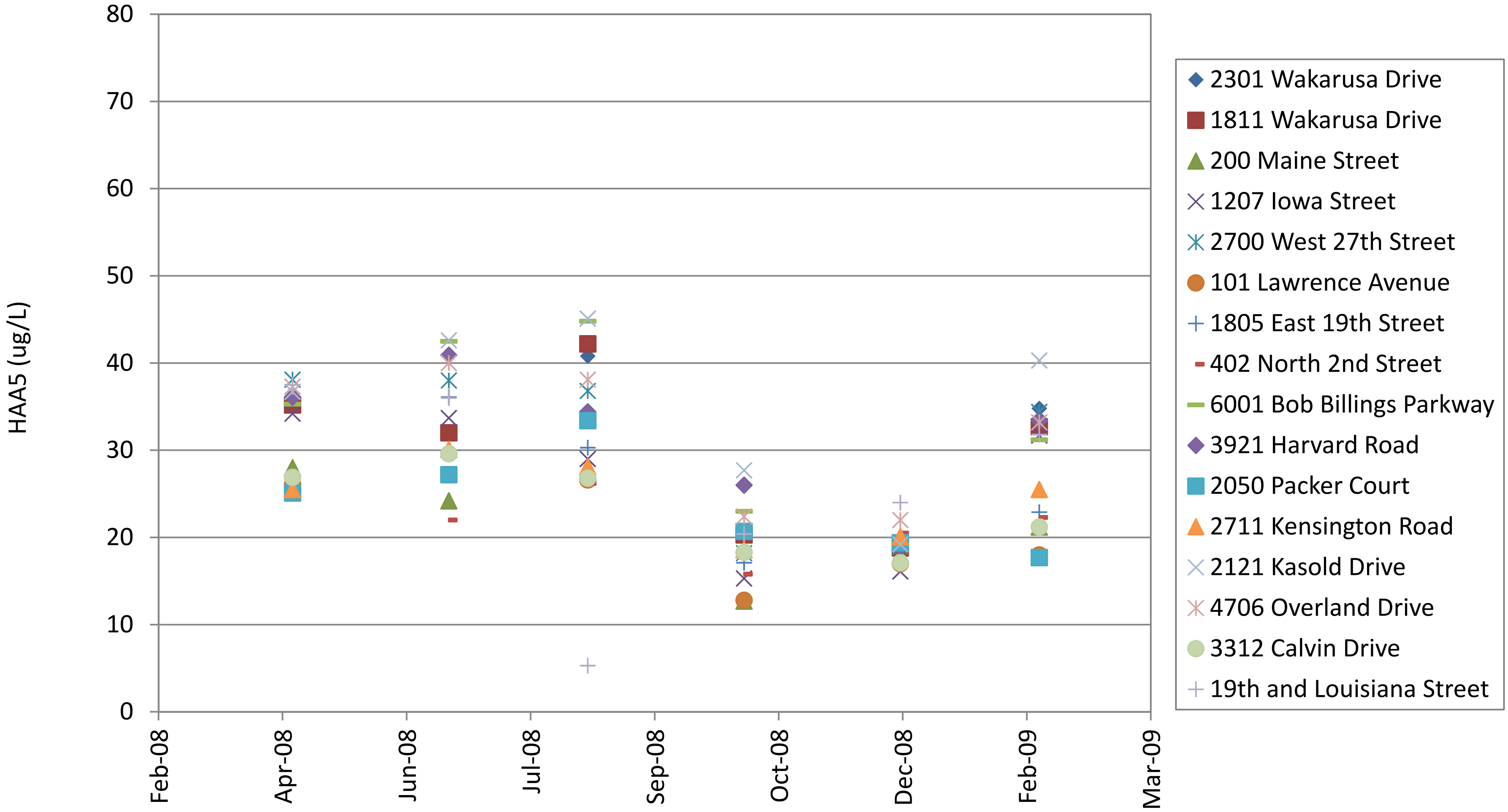

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Figure B.32

Lawrence, Kansas

Finished Water Quality – HAA5 (2008)

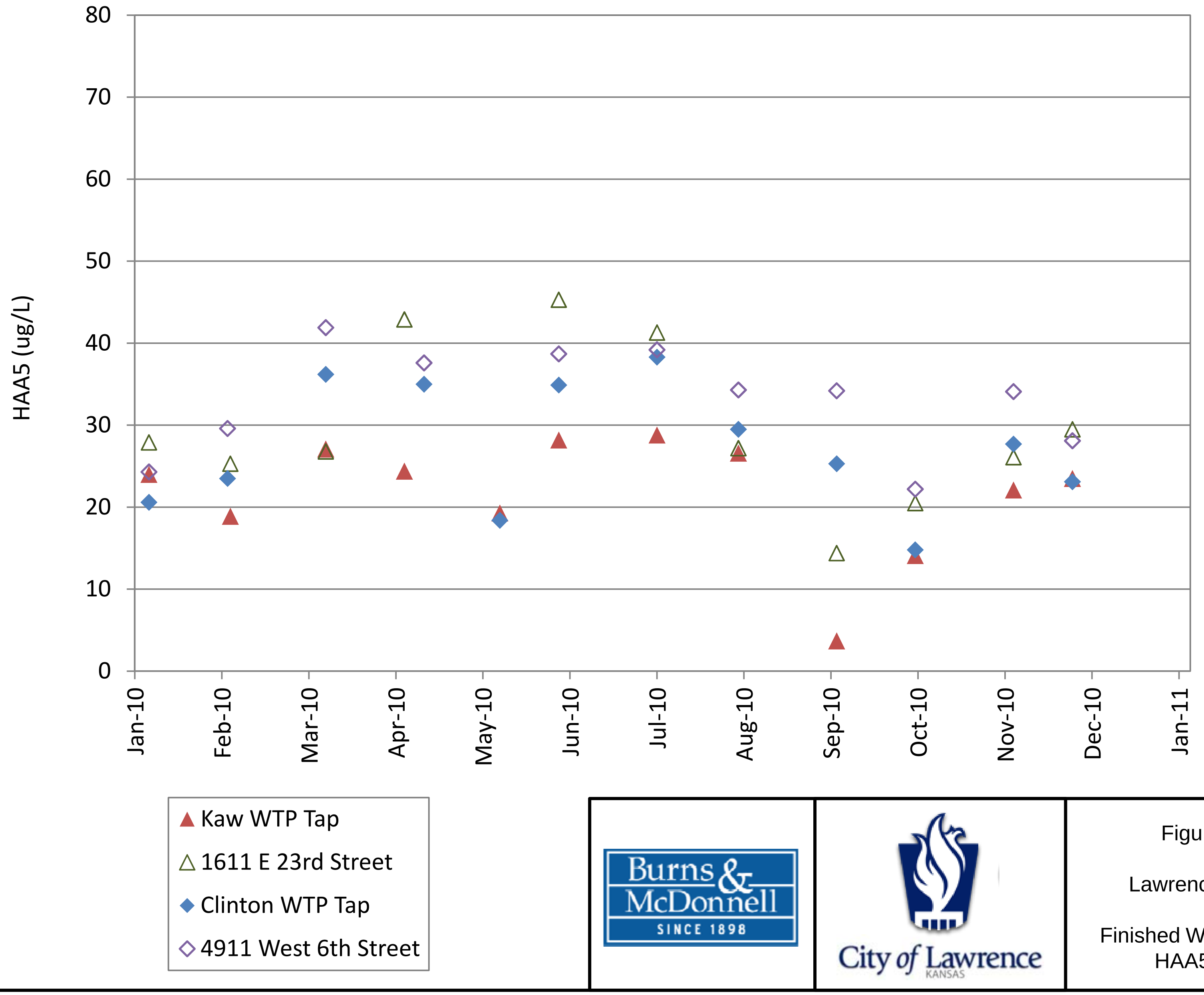

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Figure B.33

Lawrence, Kansas

Finished Water Quality – HAA5 (2010)

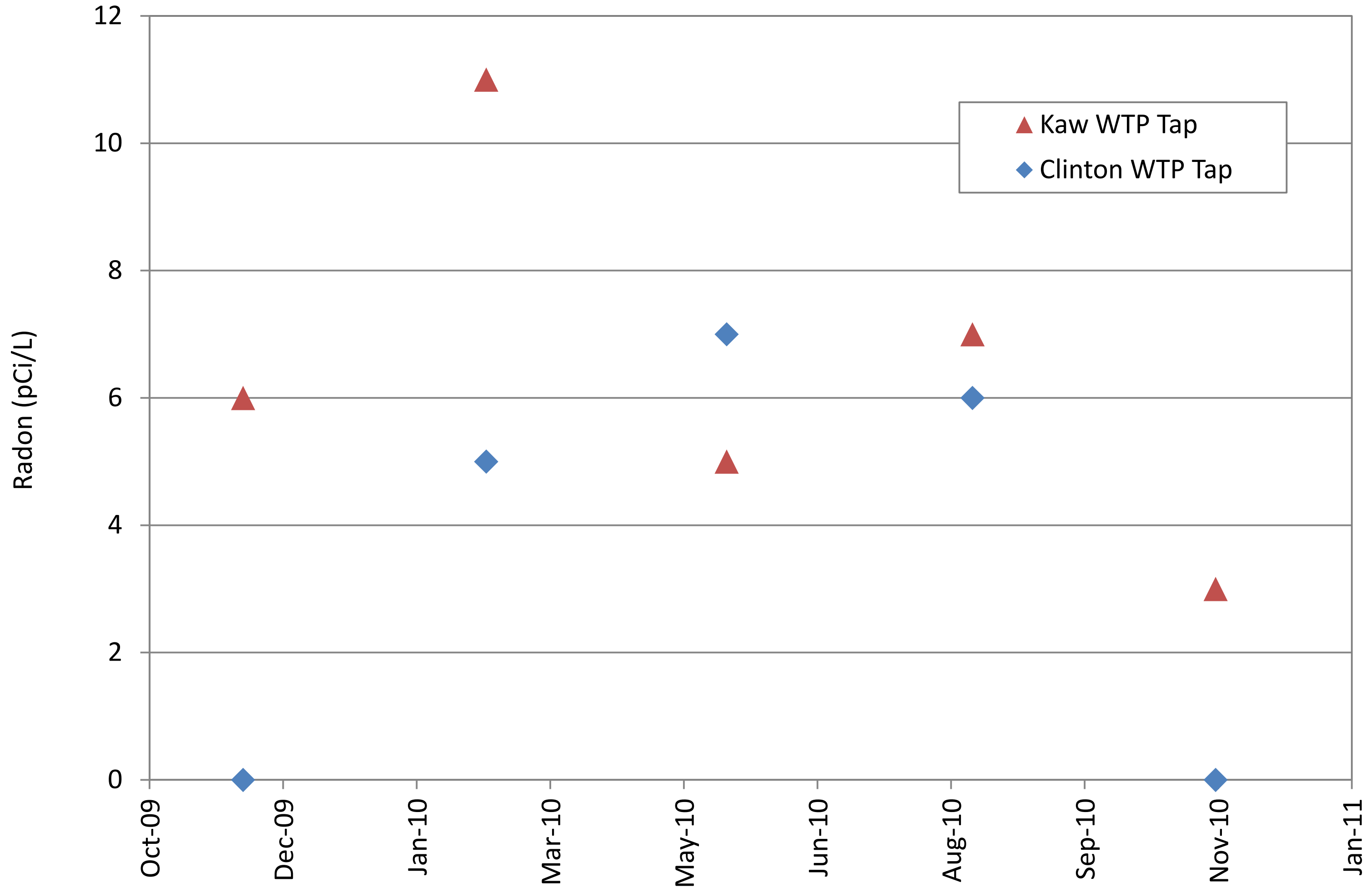

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Figure B.34

Lawrence, Kansas

Finished Water Quality – Radon

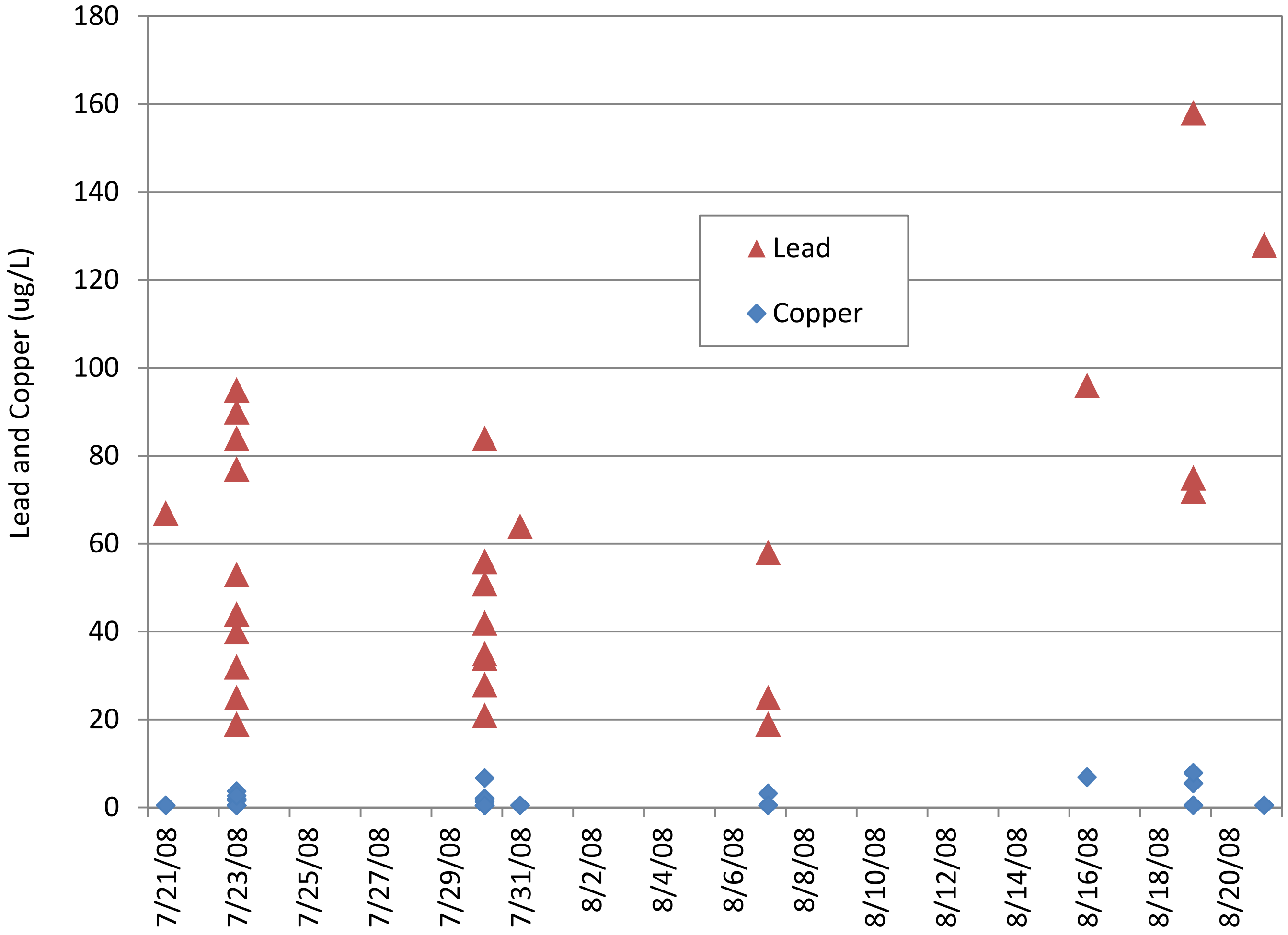

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Figure B.35

Lawrence, Kansas

Finished Water Quality –
Lead and Copper

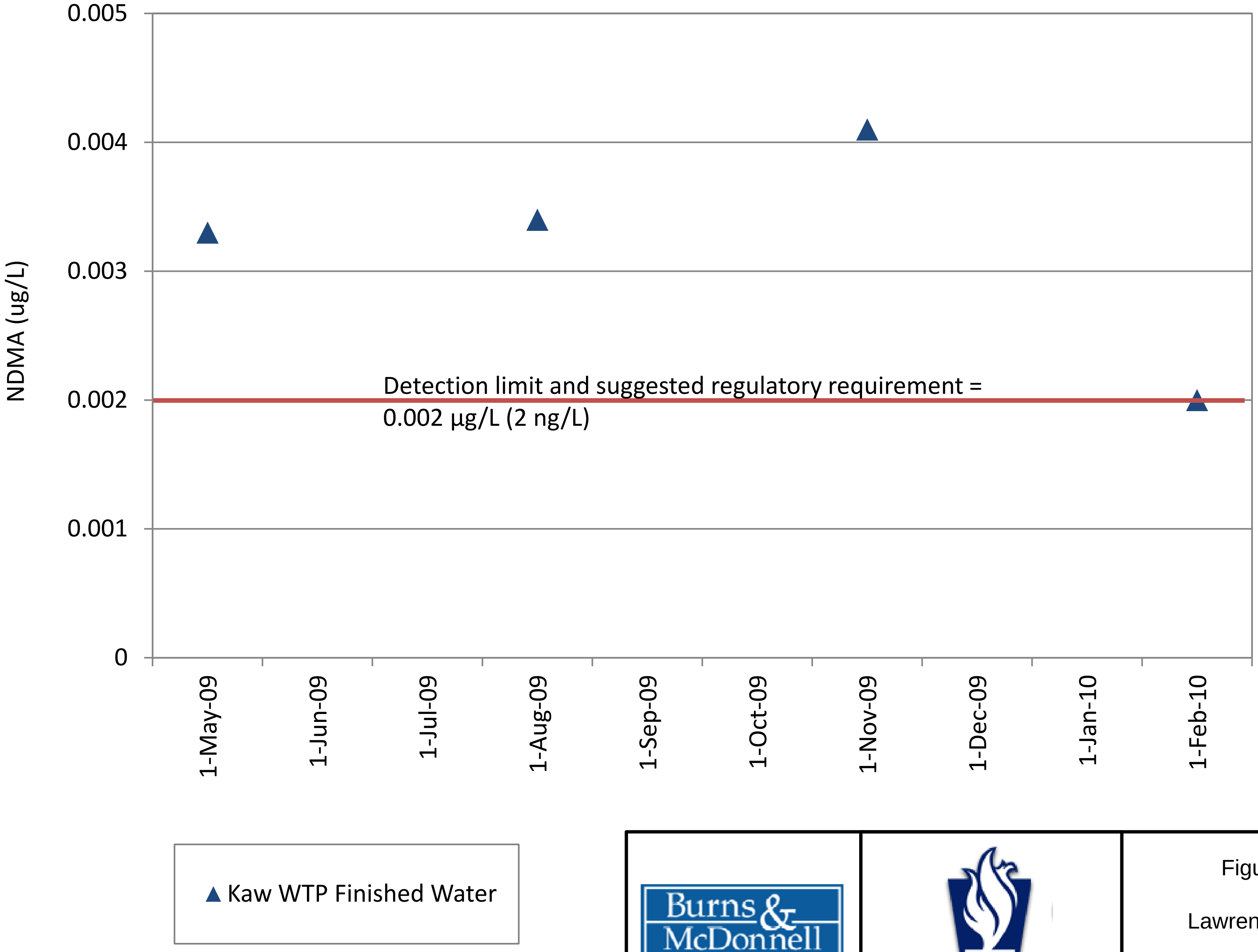

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Figure B.36

Lawrence, Kansas

Finished Water Quality – NDMA

Table B.1 Maximum Contaminant Levels for Drinking Water Contaminants

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
Microorganisms		
Cryptosporidium	0	TT[1]
Giardia lamblia	0	TT[1]
Heterotrophic plate count	---	TT[1]
Legionella	0	TT[1]
Total Coliforms	0	5.0%[2]
Turbidity	---	TT[1]
Viruses (enteric)	0	TT[1]
Disinfection Byproducts		
Bromate	0	0.01
Chlorite	0.8	1.0
Haloacetic acids (HAA5)	---	0.060
Total Trihalomethanes (TTHMs)	---	0.080
Disinfectants		
Chloramines (as Cl_2)	4	4
Chlorine (as Cl_2)	4	4
Chlorine dioxide (as ClO_2)	0.8	0.8
Inorganic Chemicals		
Antimony	0.006	0.006
Arsenic	0	0.01
Asbestos	7 MFL[3]	7 MFL[3]
Barium	2	2
Beryllium	0.004	0.004
Cadmium	0.005	0.005
Chromium (total)	0.1	0.1

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
Copper	1.3	TT[4] Action Level=1.3
Cyanide	0.2	0.2
Fluoride	4	4
Lead	0	TT[4] Action Level=0.015
Mercury (inorganic)	0.002	0.002
Nitrate (measured as N)	10	10
Nitrite (measured as N)	1	1
Selenium	0.05	0.05
Thallium	0.0005	0.002
Organic Chemicals		
Acrylamide	0	TT[5]
Alachlor	0	0.002
Atrazine	0.003	0.003
Benzene	0	0.005
Benzo(a)pyrene (PAHs)	0	0.0002
Carbofuran	0.04	0.04
Carbon tetrachloride	0	0.005
Chlordane	0	0.002
Chlorobenzene	0.1	0.1
2,4-D	0.07	0.07
Dalapon	0.2	0.2
1,2-Dibromo-3-chloropropane (DBCP)	0	0.0002
o-Dichlorobenzene	0.6	0.6
p-Dichlorobenzene	0.075	0.075
1,2-Dichloroethane	0	0.005
1,1-Dichloroethylene	0.007	0.007
cis-1,2-Dichloroethylene	0.07	0.07

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
trans-1,2-Dichloroethylene	0.1	0.1
Dichloromethane	0	0.005
1,2-Dichloropropane	0	0.005
Di(2-ethylhexyl) adipate	0.4	0.4
Di(2-ethylhexyl) phthalate	0	0.006
Dinoseb	0.007	0.007
Dioxin (2,3,7,8-TCDD)	0	0.00000003
Diquat	0.02	0.02
Endothall	0.1	0.1
Endrin	0.002	0.002
Epichlorohydrin	0	TT[5]
Ethylbenzene	0.7	0.7
Ethylene dibromide	0	0.00005
Glyphosate	0.7	0.7
Heptachlor	0	0.0004
Heptachlor epoxide	0	0.0002
Hexachlorobenzene	0	0.001
Hexachlorocyclopentadiene	0.05	0.05
Lindane	0.0002	0.0002
Methoxychlor	0.04	0.04
Oxamyl (Vydate)	0.2	0.2
Polychlorinated biphenyls (PCBs)	0	0.0005
Pentachlorophenol	0	0.001
Picloram	0.5	0.5
Simazine	0.004	0.004
Styrene	0.1	0.1
Tetrachloroethylene	0	0.005
Toluene	1	1

Contaminant	**MCLG (mg/L)**	**MCL or TT (mg/L)**
Toxaphene	0	0.003
2,4,5-TP (Silvex)	0.05	0.05
1,2,4-Trichlorobenzene	0.07	0.07
1,1,1-Trichloroethane	0.2	0.2
1,1,2-Trichloroethane	0.003	0.005
Trichloroethylene	0	0.005
Vinyl chloride	0	0.002
Xylenes (total)	10	10
Radionuclides		
Alpha particles	0	15 pCi/L
Beta particles and photon emitters	0	4 mrem/yr
Ra-226 and Ra-228	0	5 pCi/L
Strontium-90	---	8 pCi/L
Tritium	---	20,000 pCi/L
Uranium	0	30 ug/L
Disinfectants	**MRDLG (mg/L)**	**MRDL (mg/L)**
Chloramines (as Cl_2)	4	4
Chlorine (as Cl_2)	4	4
Chlorine dioxide (as ClO_2)	0.8	0.8

Notes:

(1) USEPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium: 99% removal
- Giardia lamblia: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- Legionella: No limit, but USEPA believes that if Giardia and viruses are removed/ inactivated, Legionella will also be controlled
- Turbidity: At no time can turbidity exceed 1 NTU and must not exceed 0.3 NTU in 95% of daily samples in any month
- HPC: No more than 500 bacterial colonies/mL

(2) More than 5.0% samples total coliform-positive in a month. For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month. Every sample that has total coliform must be analyzed for either fecal coliforms or Escherichia coli if two consecutive TC-positive samples, and one is also positive for E.coli fecal coliforms, system has an acute MCL violation.
(3) MFL = million fibers per liter, with fiber length >10 μm.
(4) Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.
(5) Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

Definitions:

- Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.
- Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

Table B.2 Contaminants and Secondary Drinking Water Standards

Constituent	**Effect (s)**	**Secondary Standard (mg/L)**
Aluminum	Colored water	0.05 - 0.2
Chloride	Salty taste	250
Color (color units)	Visible tint	15 color units
Copper	Metallic taste; blue-green stain	1.0
Corrosivity	Metallic taste; corrosion; fixture staining	Non-corrosive
Fluoride [1]	Tooth discoloration	2
Foaming Agents (MBAs)	Frothy, cloudy; bitter taste; odor	0.5
Iron	Rusty color; sediment; metallic taste; reddish or orange staining	0.3
Manganese	Black-to-brown color; black staining; bitter, metallic taste	0.05
Odor, threshold (odor units)	“Rotten egg,” musty, or chemical smell	3 threshold odor number (TON)
pH	Low pH: bitter metallic taste, corrosion; high pH: slippery feel, soda taste, deposits	6.5-8.5
Silver	Skin discoloration; greying of the white part of the eye	0.1
Sulfate	Salty taste	250
Total Dissolved Solids (TDS)	Hardness; deposits; colored water; staining; salty taste	500
Zinc	Metallic taste	5

Notes:

(1) Failure to meet the fluoride secondary standard requires public notification pursuant to KDHE 28-15a-208.

Appendix C
Process Evaluation

Water Master Plan

for

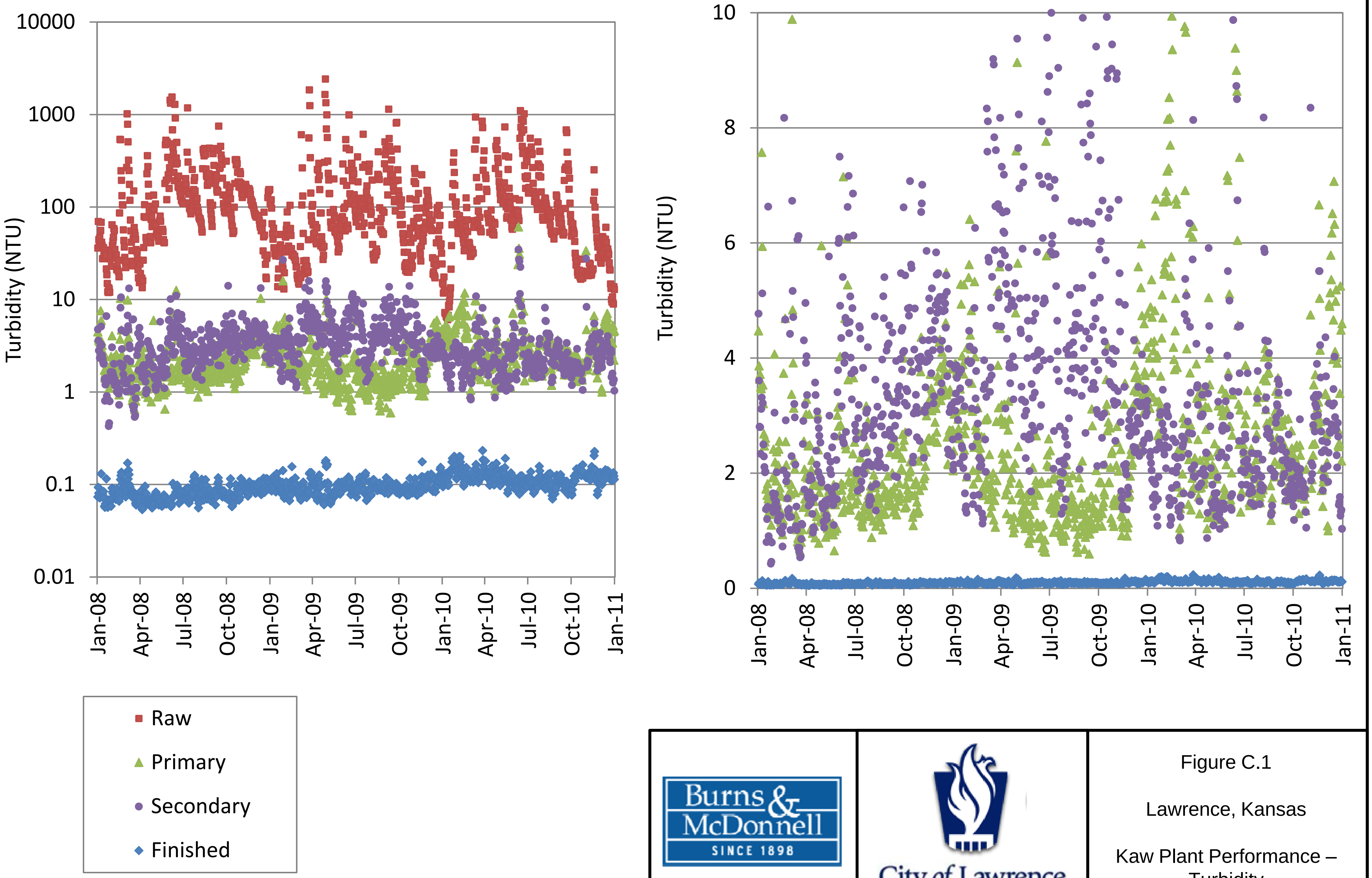
Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114



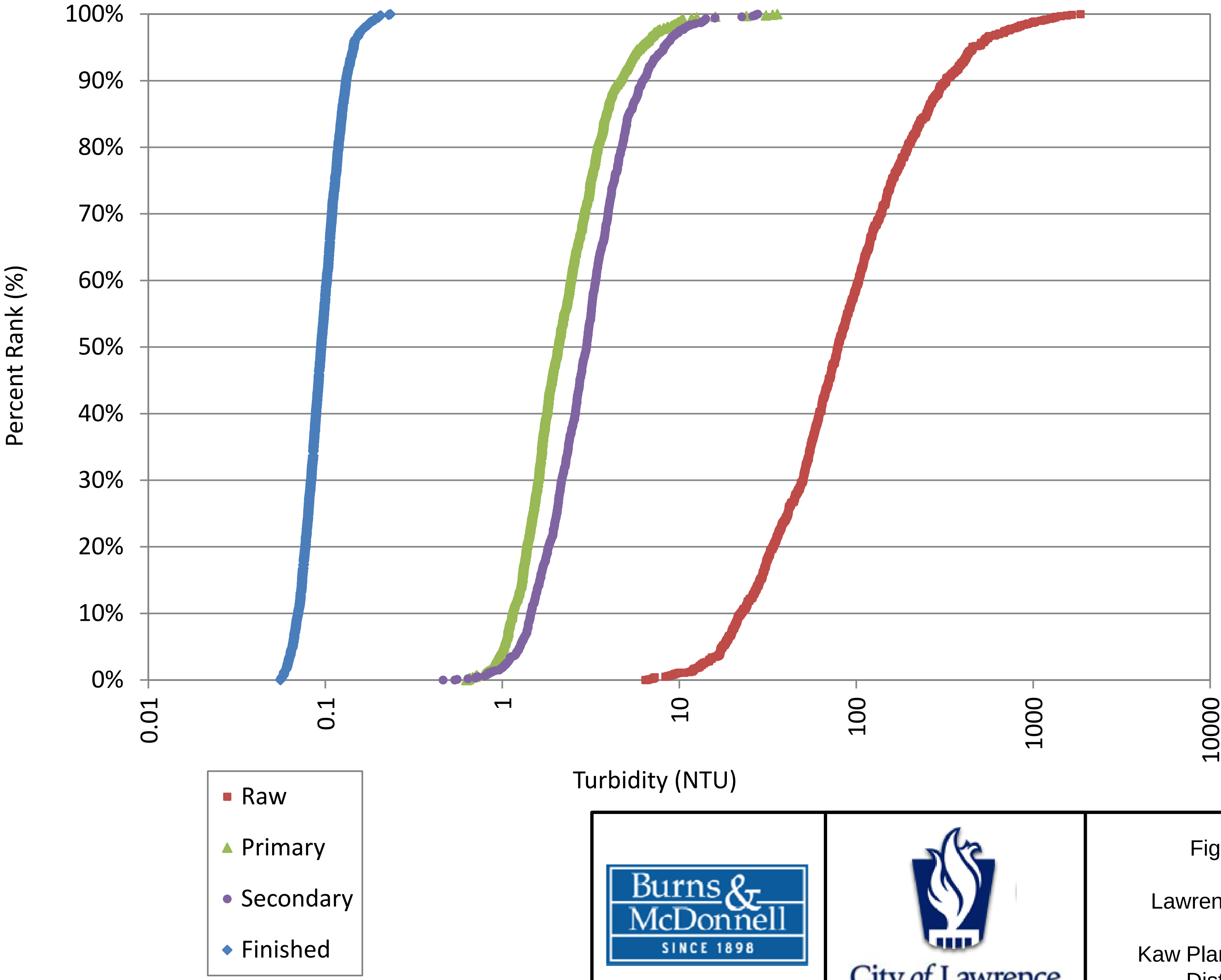
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.1

Lawrence, Kansas

Kaw Plant Performance – Turbidity



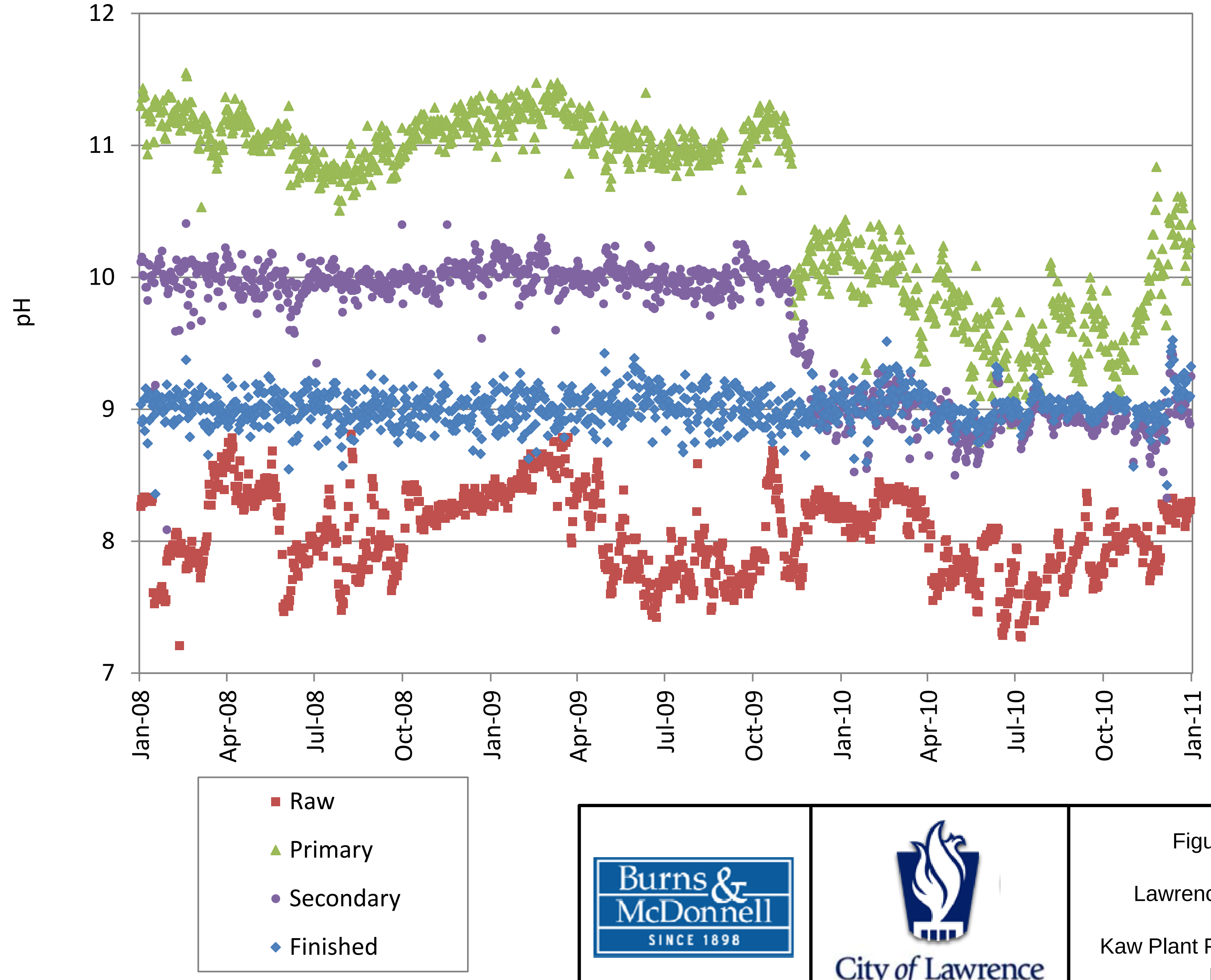
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.2

Lawrence, Kansas

Kaw Plant – Turbidity Distribution



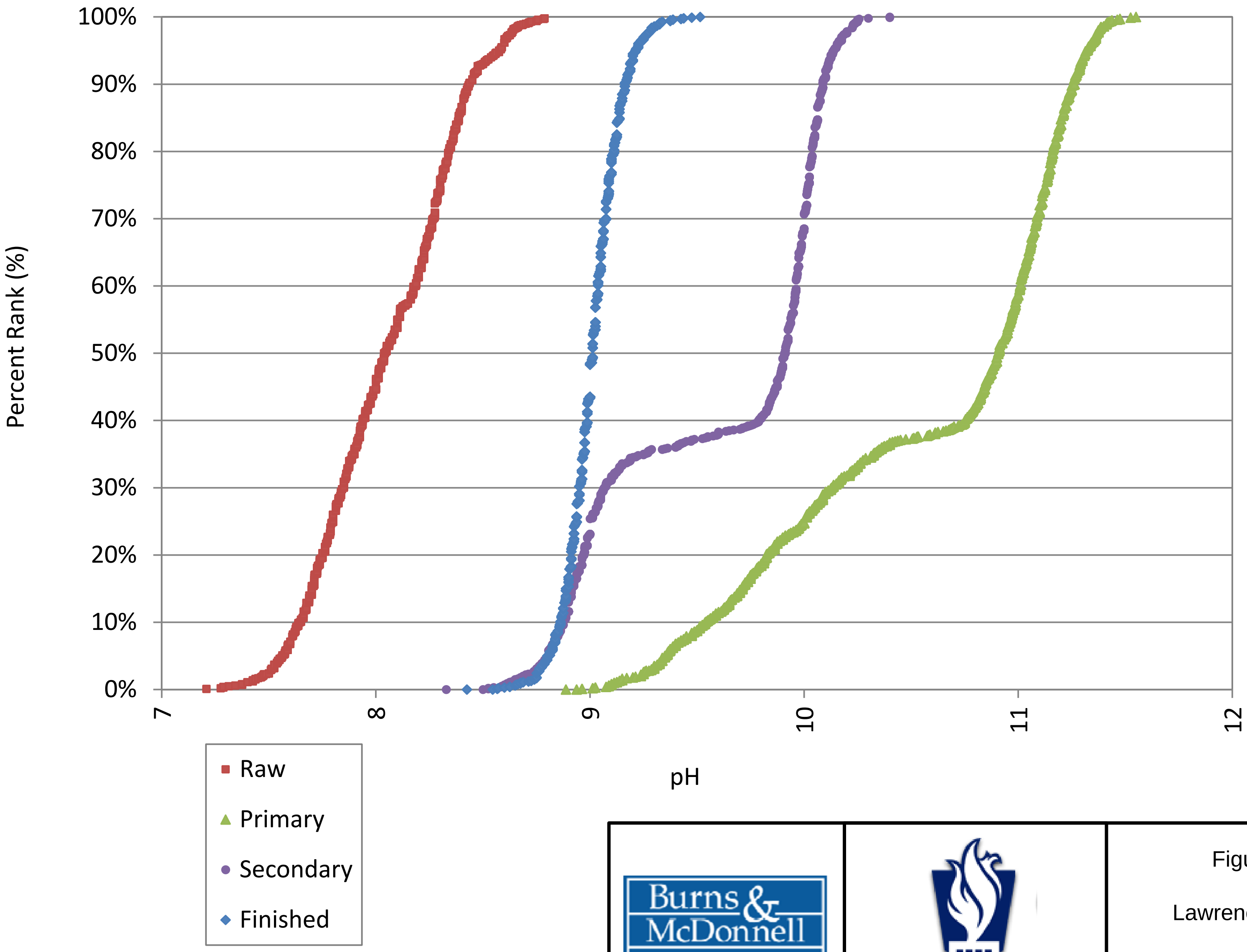
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.3

Lawrence, Kansas

Kaw Plant Performance – pH



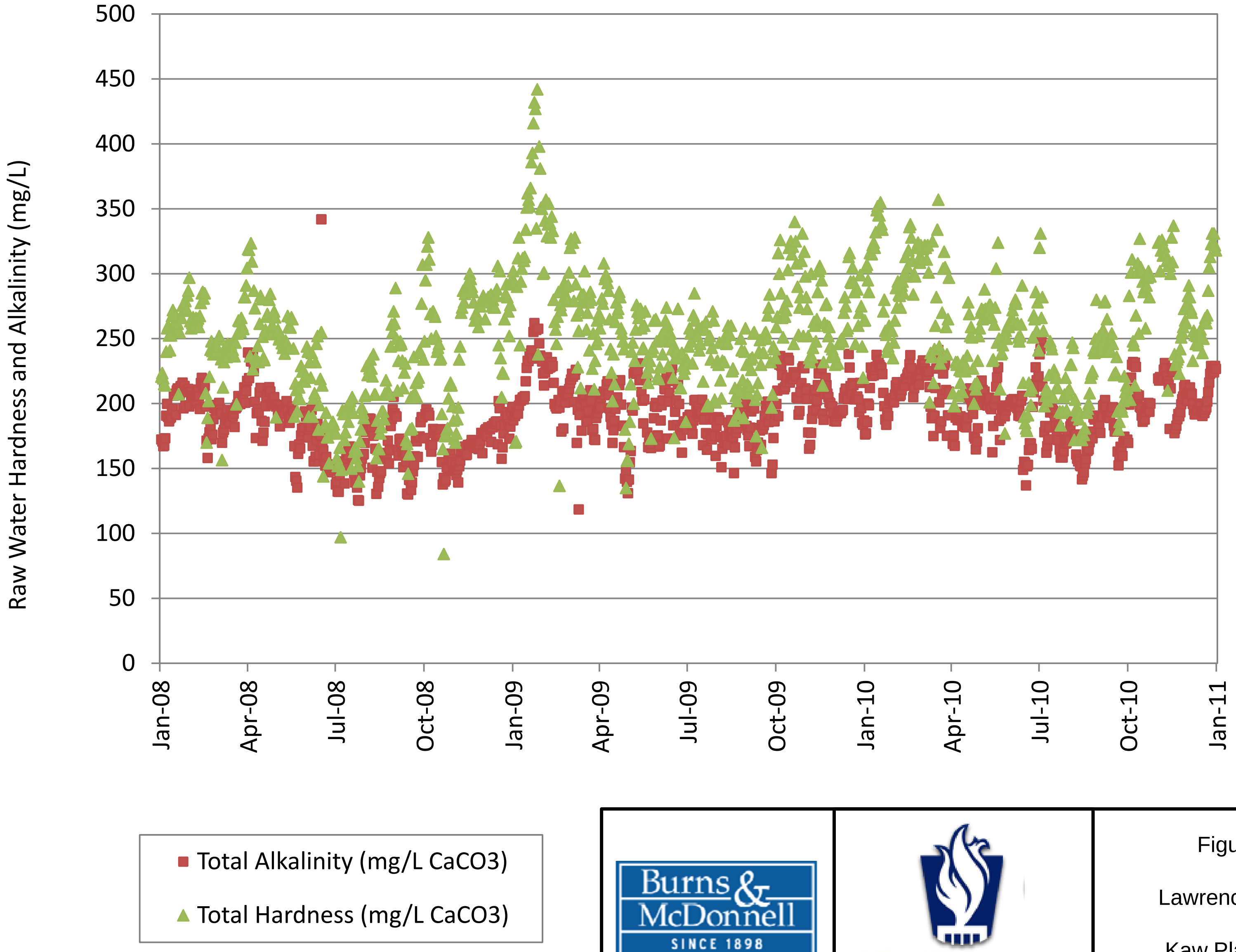
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.4

Lawrence, Kansas

Kaw Plant – pH Distribution



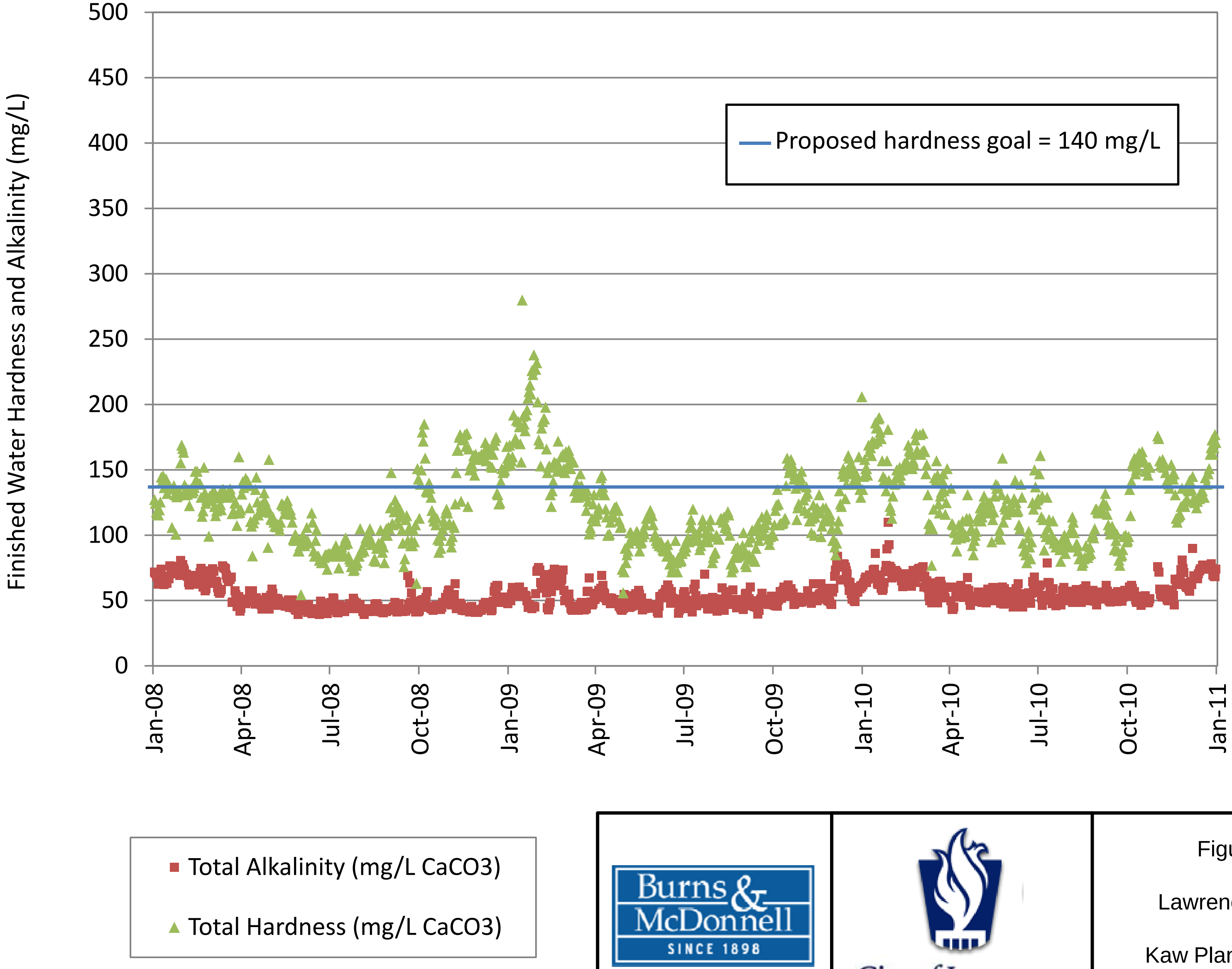
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.5

Lawrence, Kansas

Kaw Plant – Raw Hardness and Alkalinity



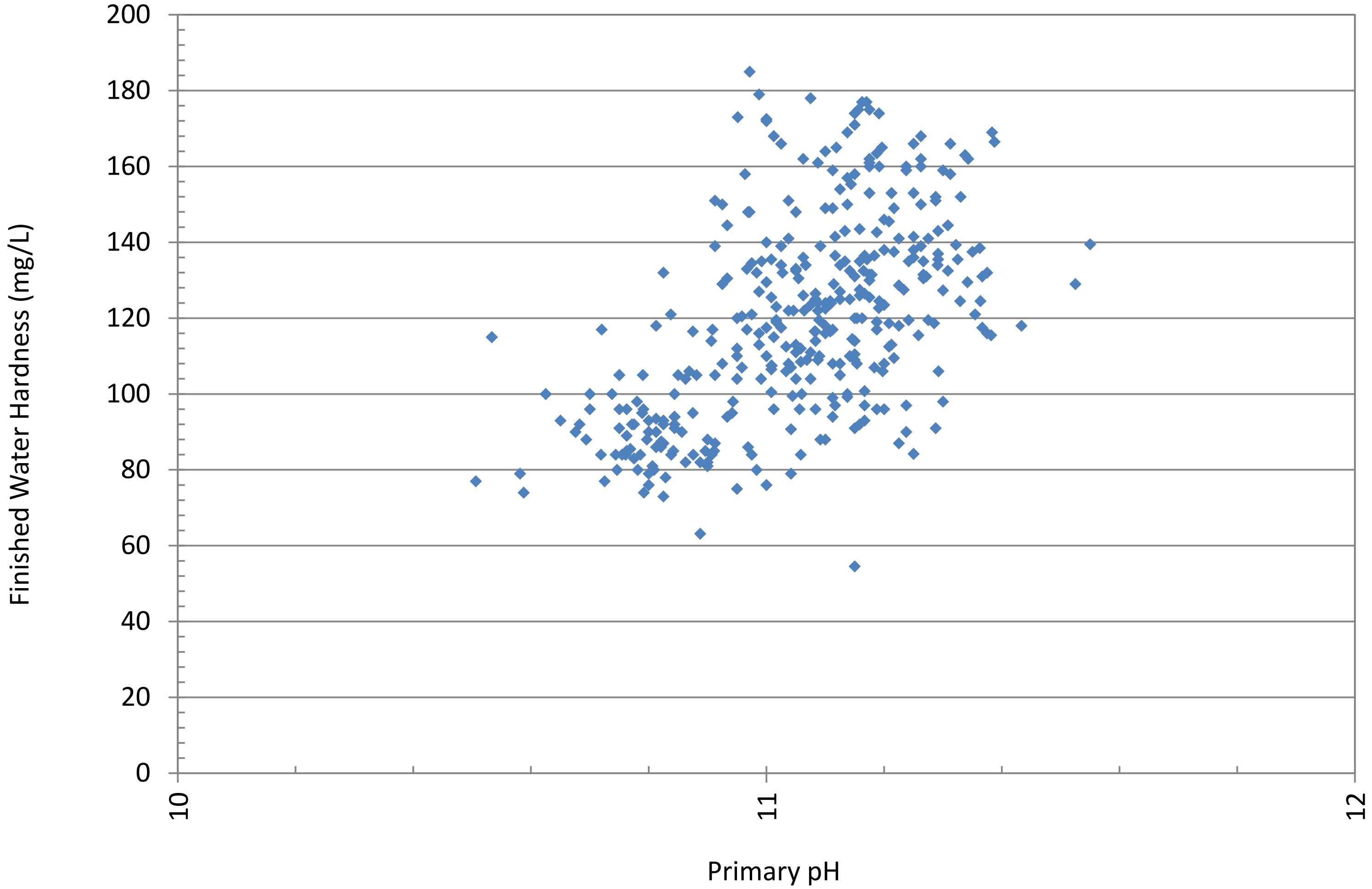
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.6

Lawrence, Kansas

Kaw Plant – Finished Hardness and Alkalinity



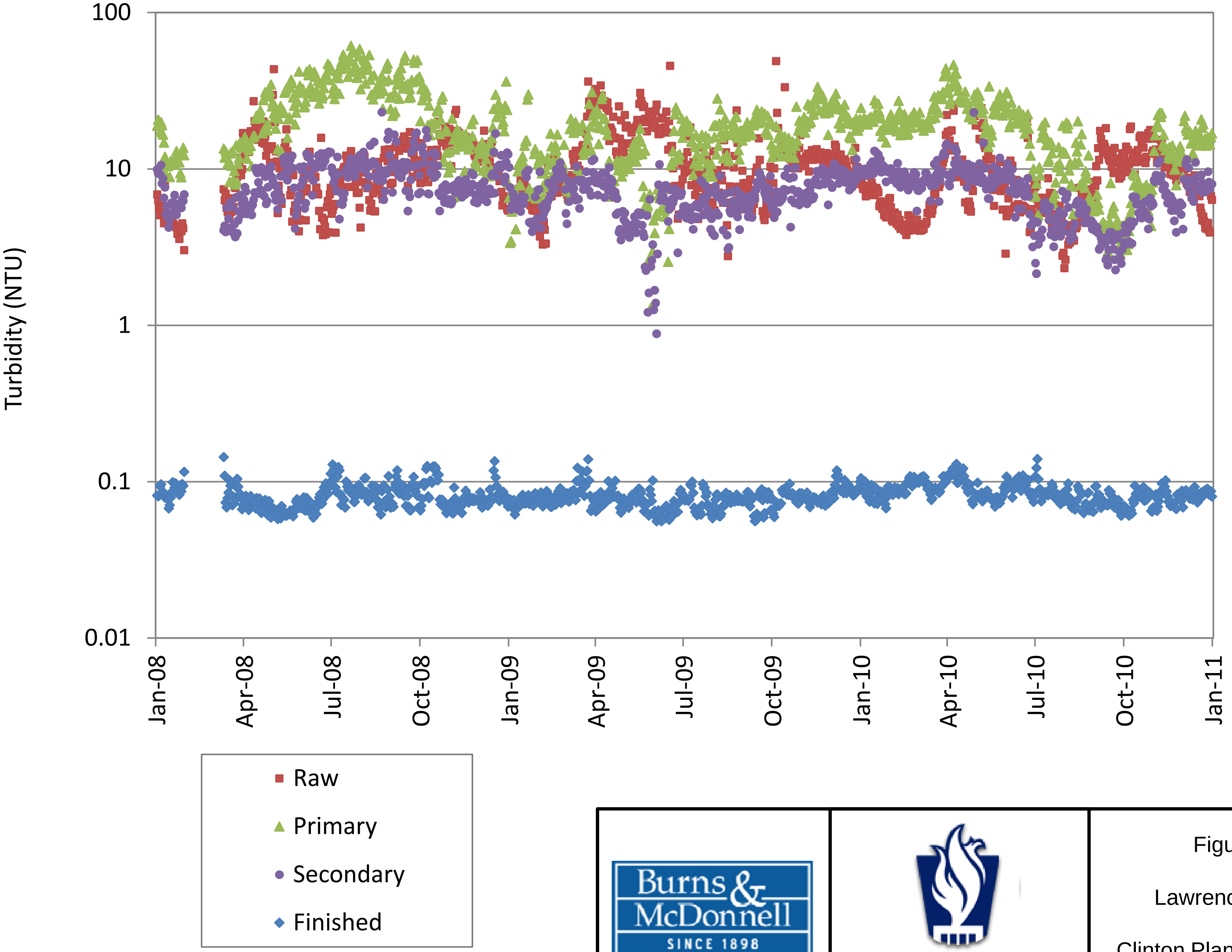
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.7

Lawrence, Kansas

Kaw Plant – Primary pH vs Finished Hardness



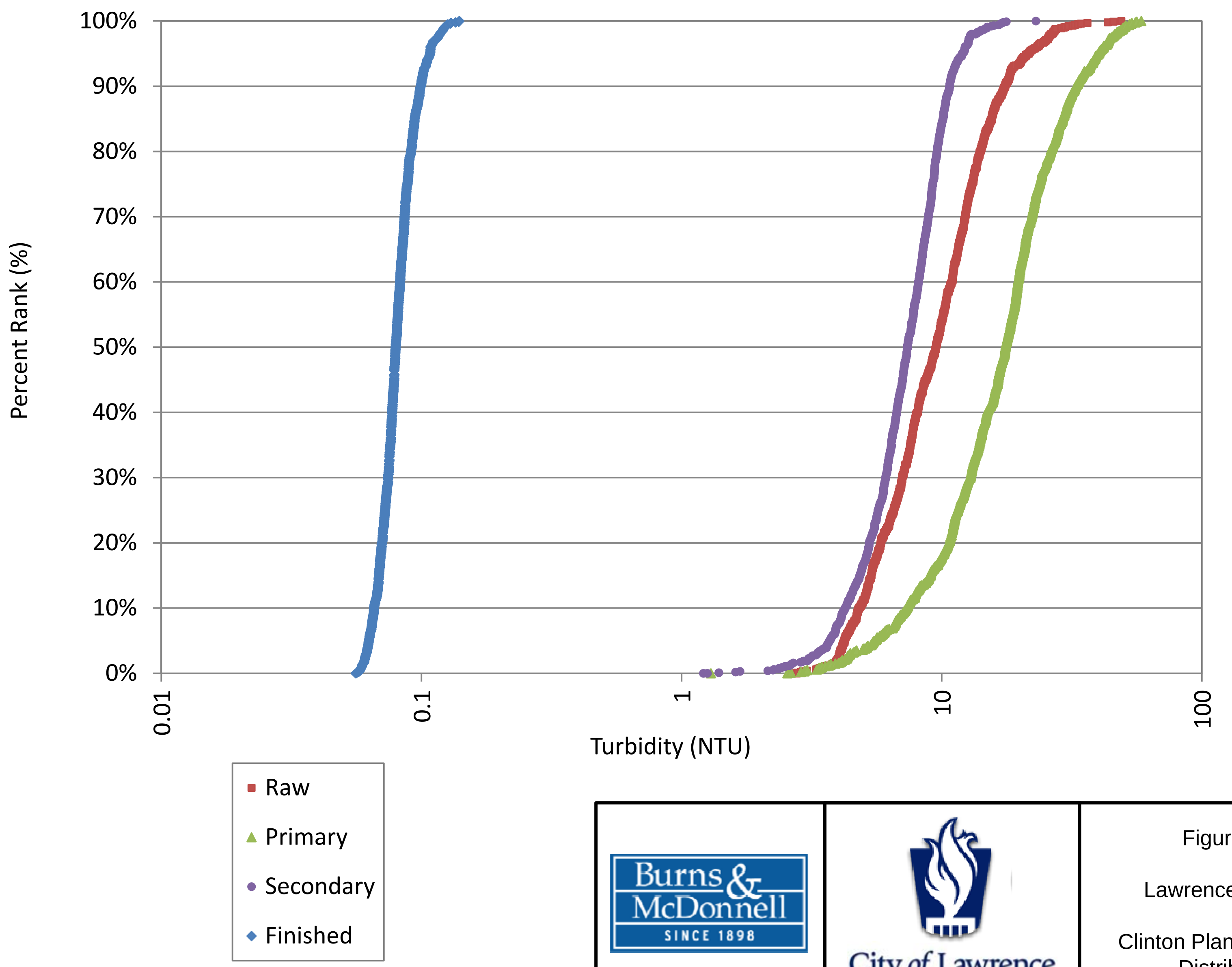
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.8

Lawrence, Kansas

Clinton Plant Performance – Turbidity



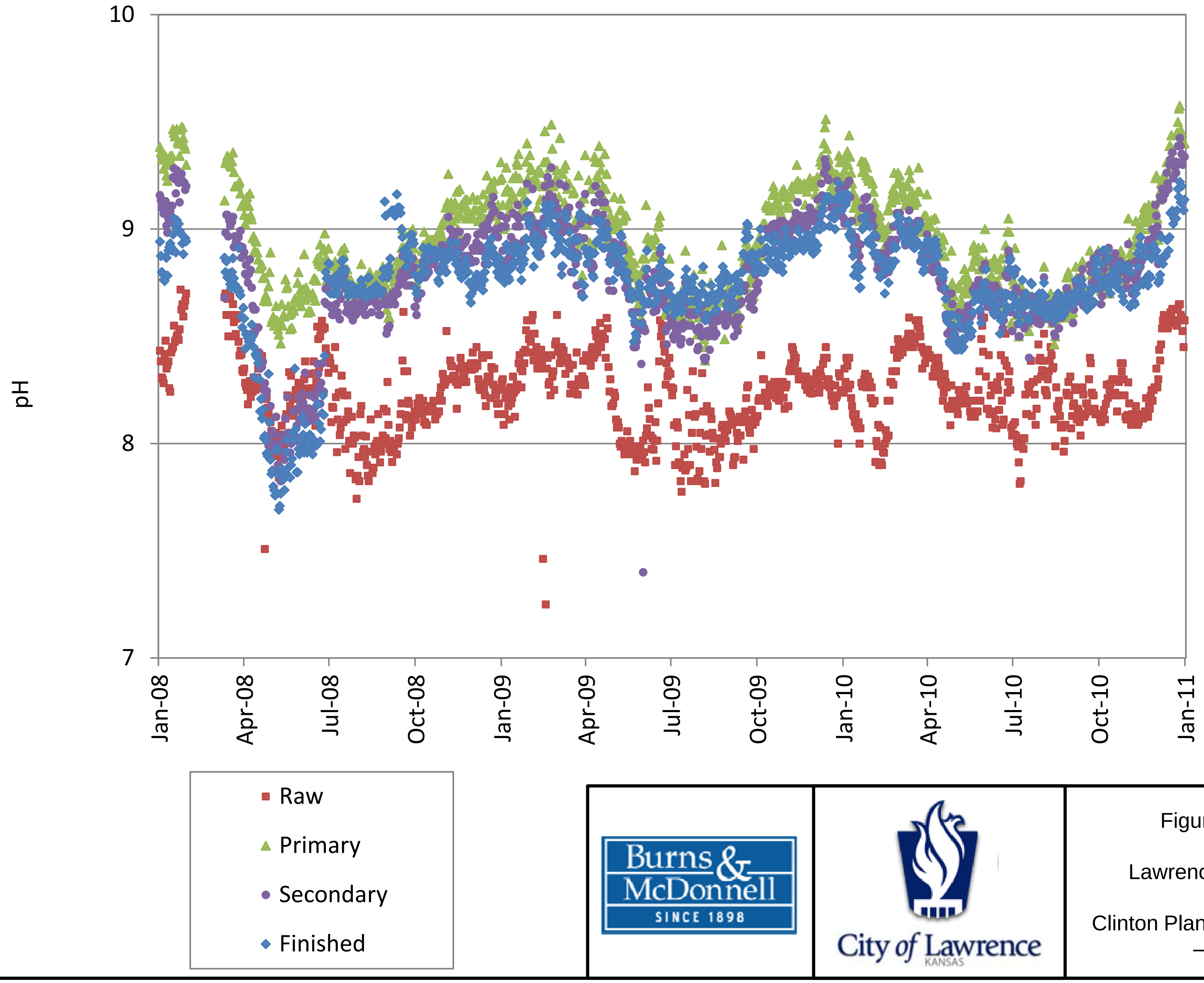
Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.9

Lawrence, Kansas

Clinton Plant – Turbidity Distribution



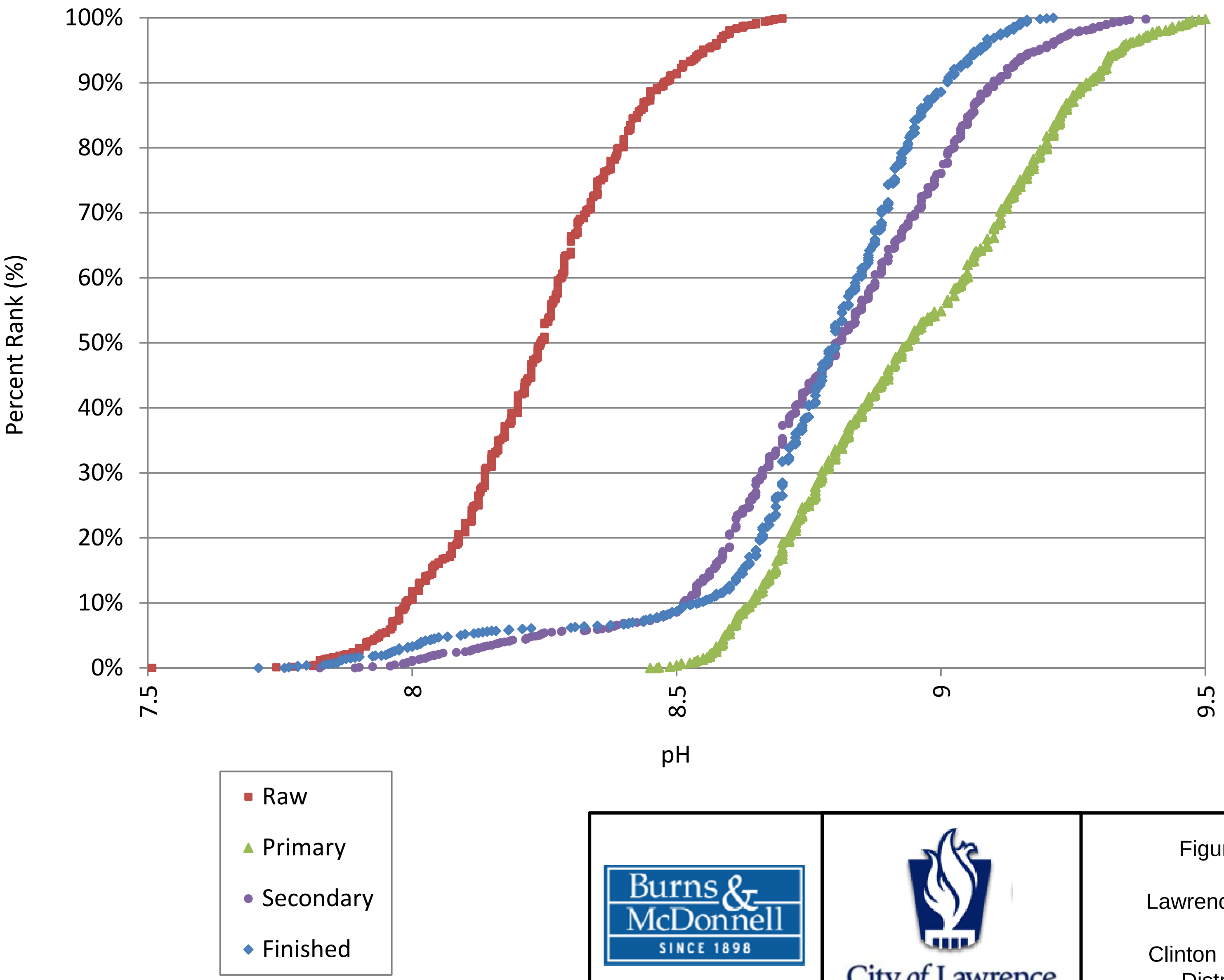
Burns & McDonnell SINCE 1898

City of Lawrence KANSAS

Figure C.10

Lawrence, Kansas

Clinton Plant Performance – pH



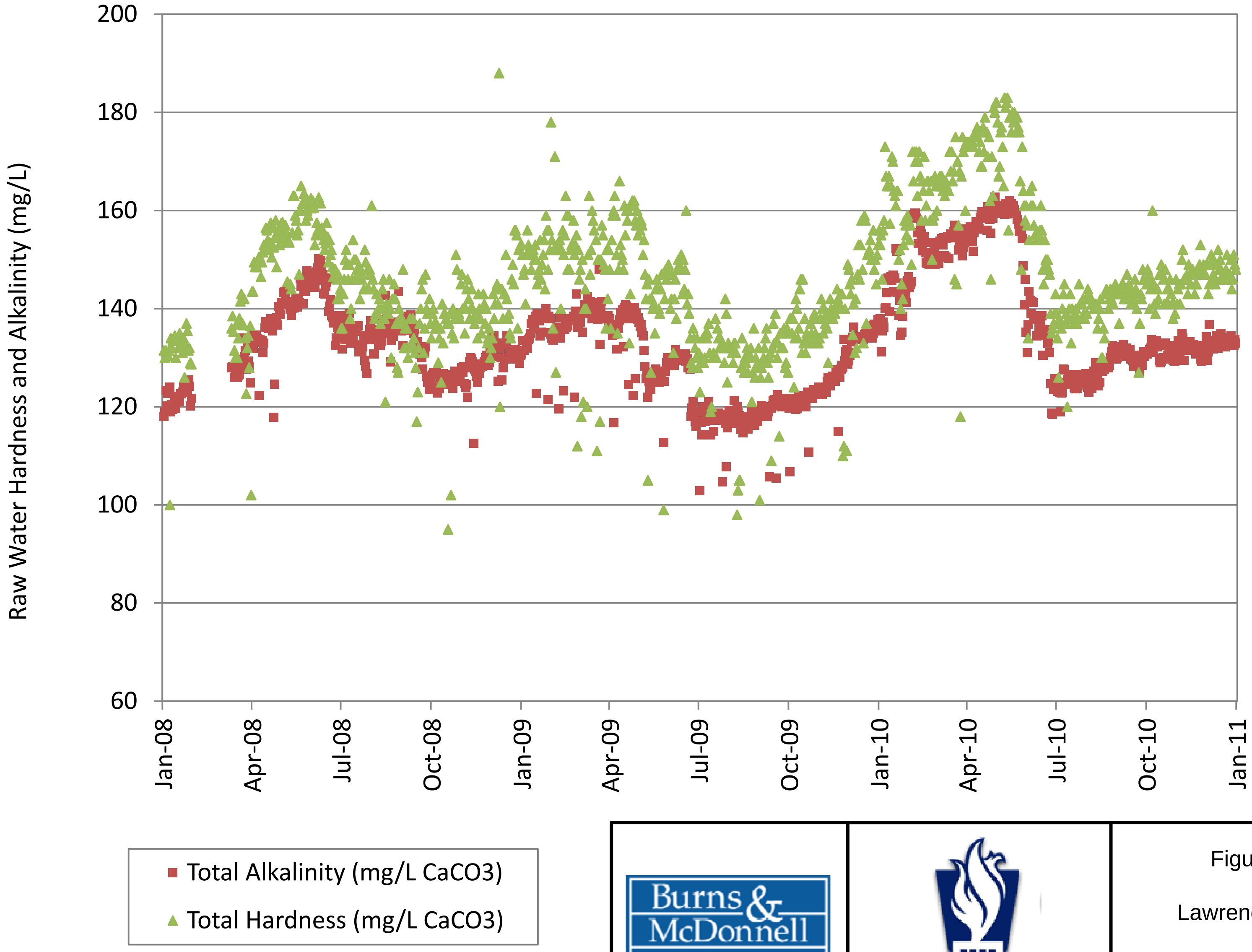
Burns & McDonnell SINCE 1898

City of Lawrence KANSAS

Figure C.11

Lawrence, Kansas

Clinton Plant – pH Distribution



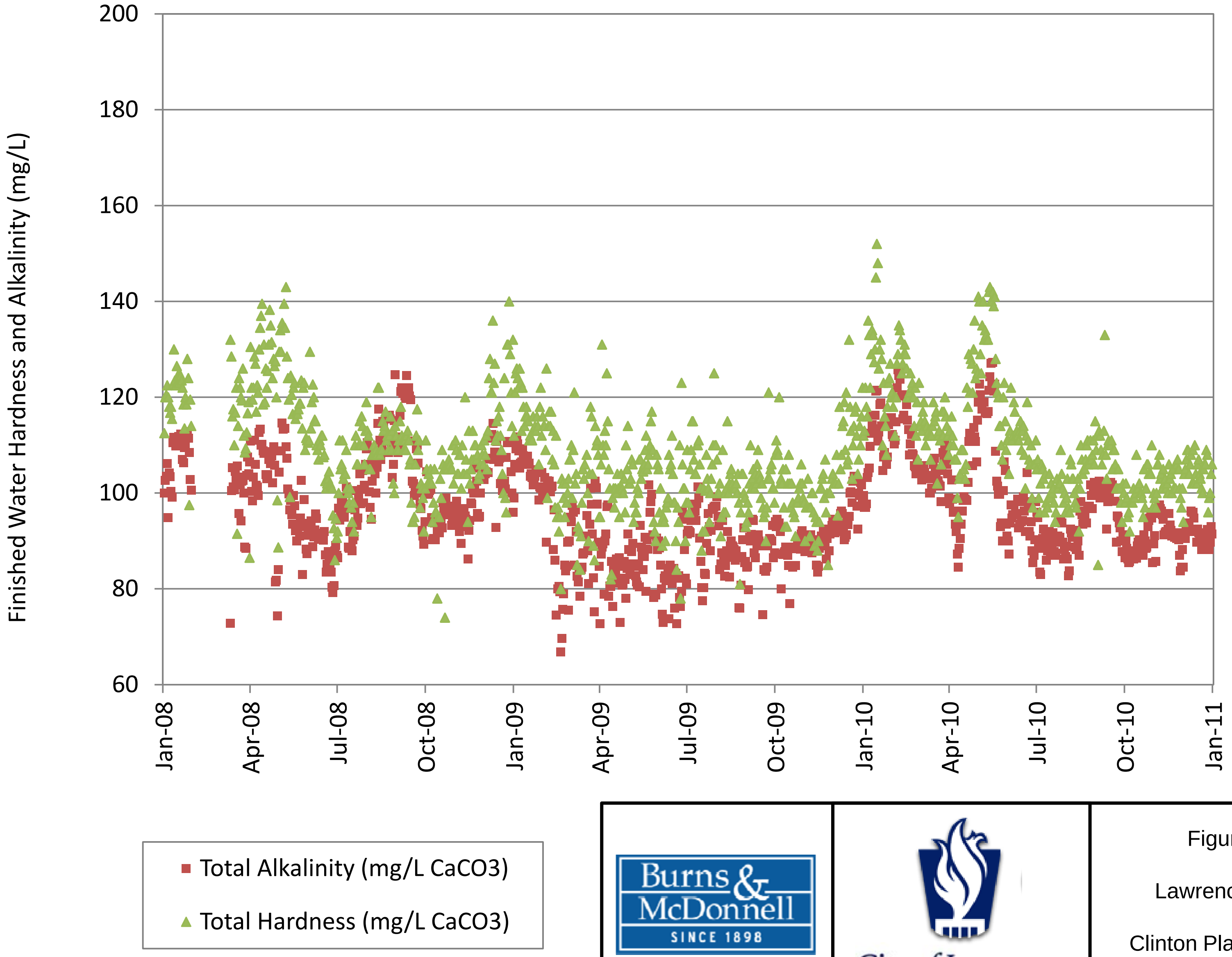
Burns & McDonnell SINCE 1898

City of Lawrence KANSAS

Figure C.12

Lawrence, Kansas

Clinton Plant – Raw Hardness and Alkalinity



Burns & McDonnell
SINCE 1898

City of Lawrence
KANSAS

Figure C.13

Lawrence, Kansas

Clinton Plant – Finished Hardness and Alkalinity

Appendix D
Distribution System Data

Water Master Plan

for

Lawrence, Kansas

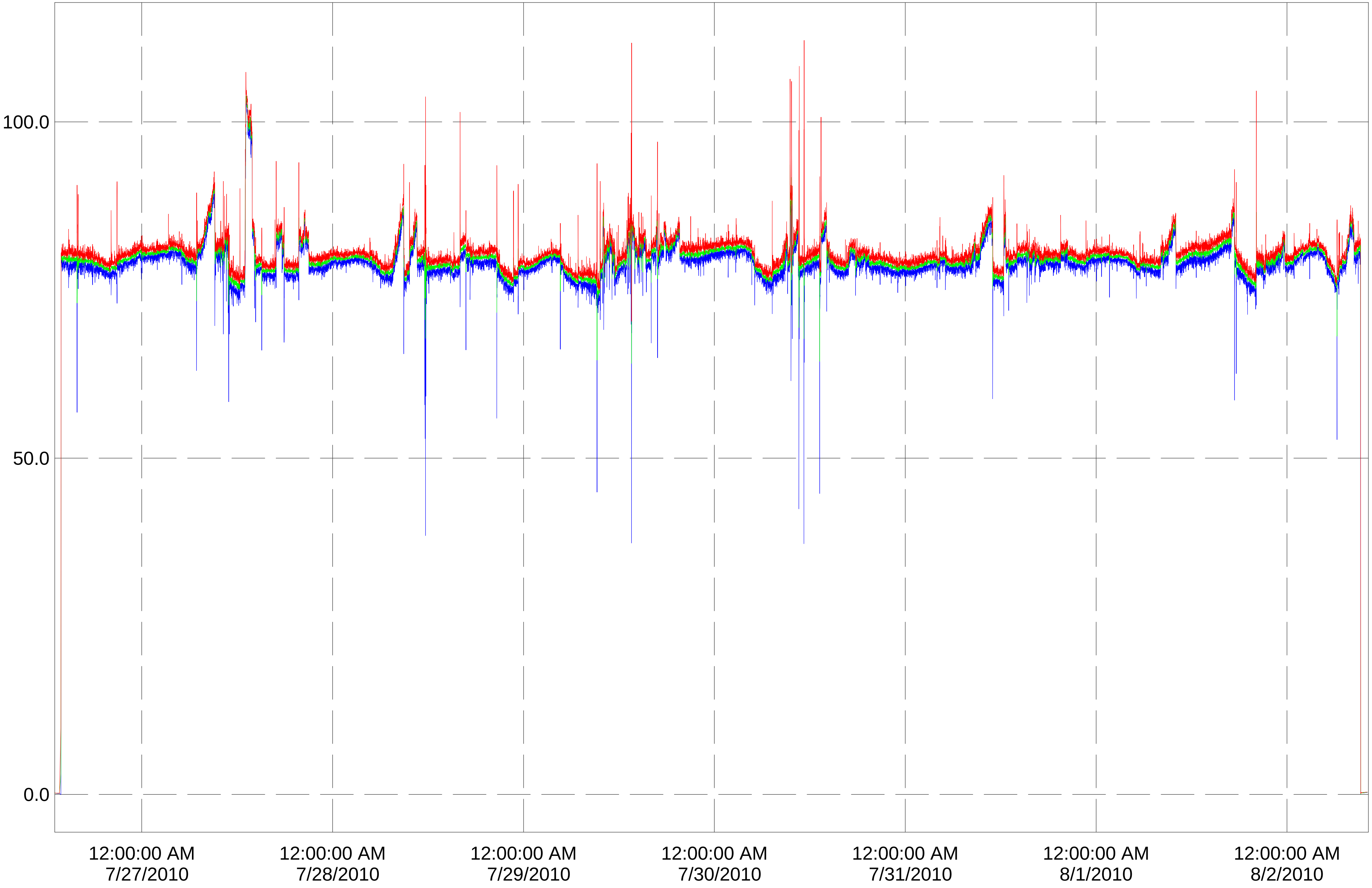
City of Lawrence, Kansas

BMcD Project No. 59410

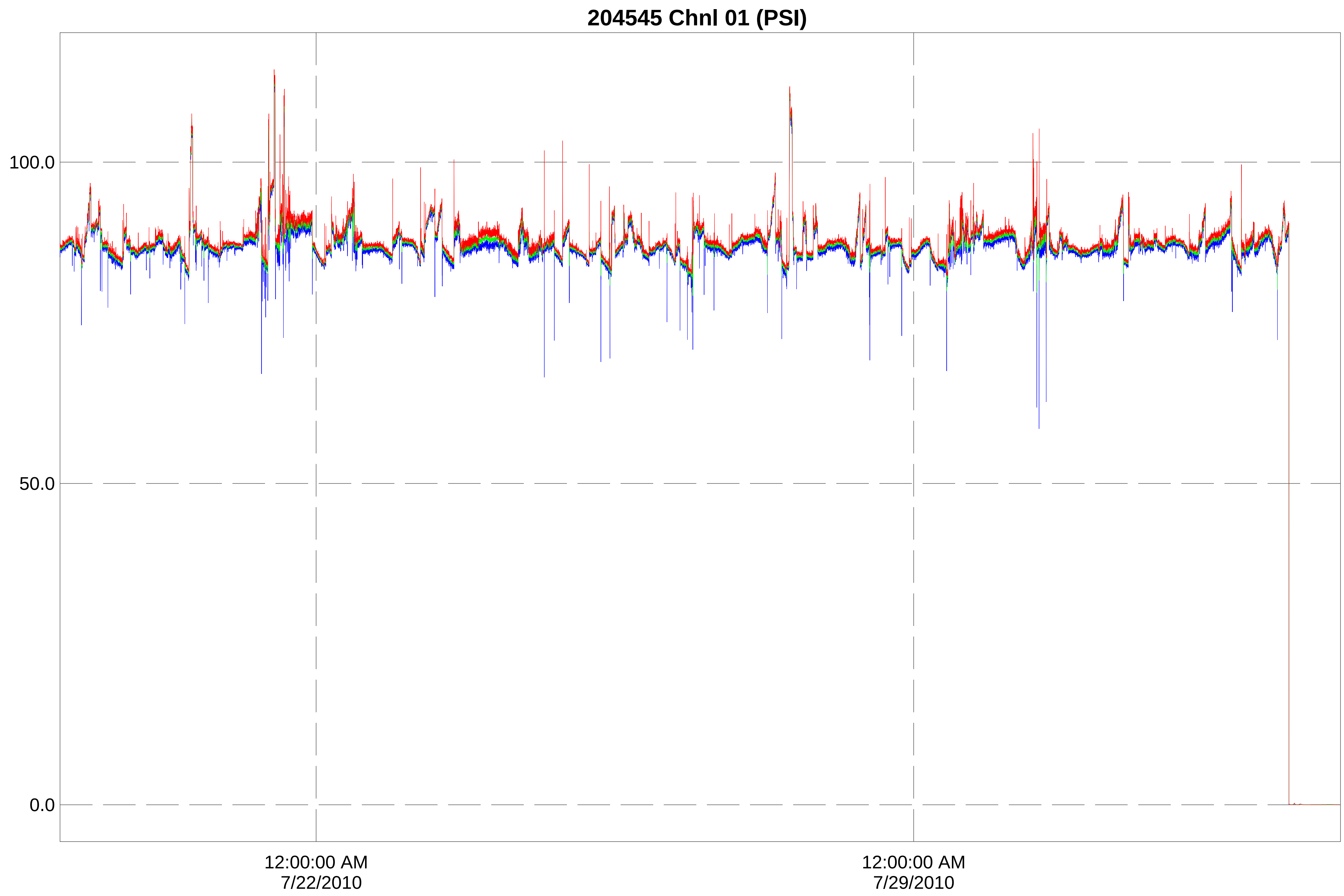
City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

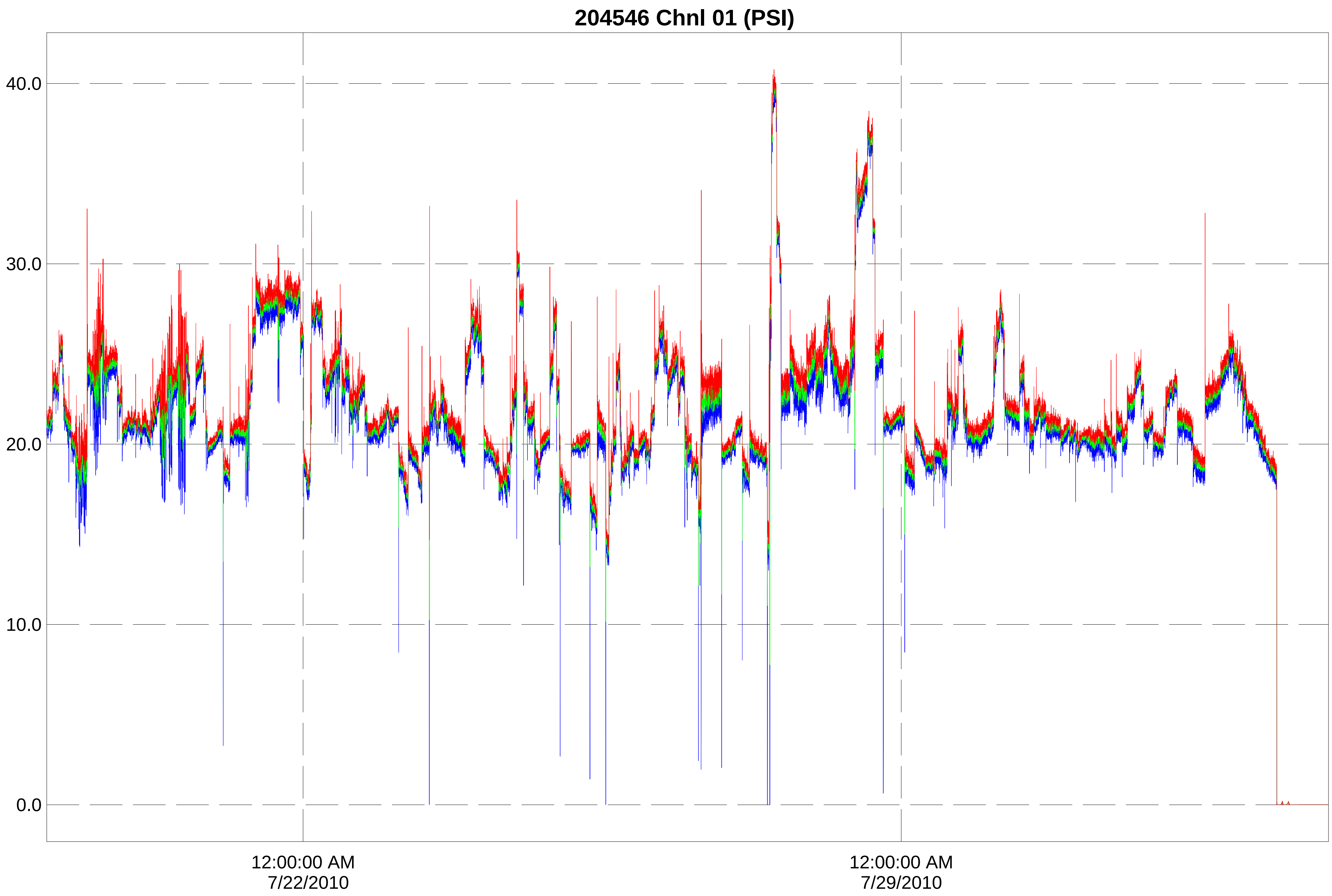
14th & Delaware
Hydrant No. 1238
204544 Chnl 01 (PSI)



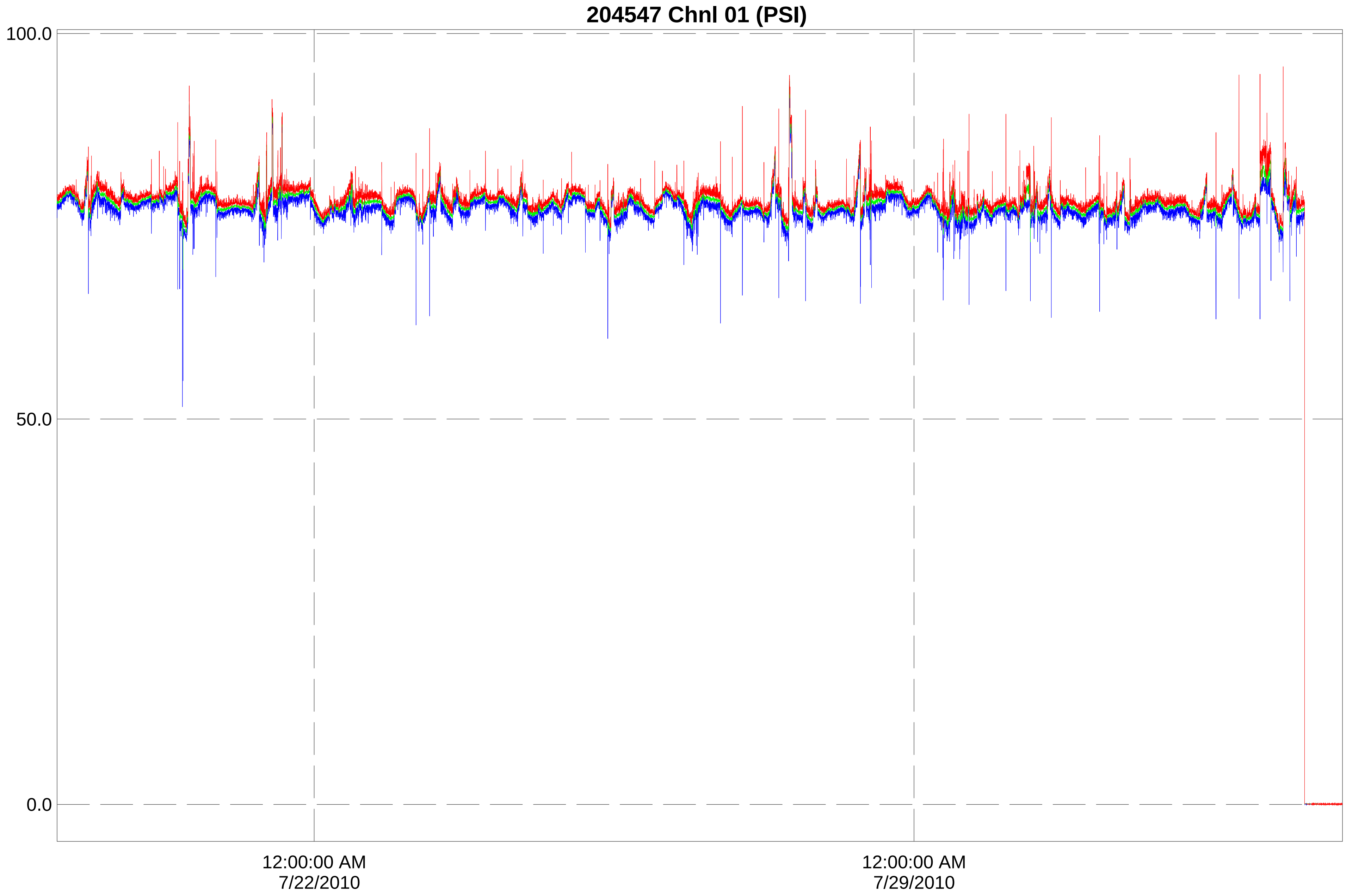
Clinton WTP 2



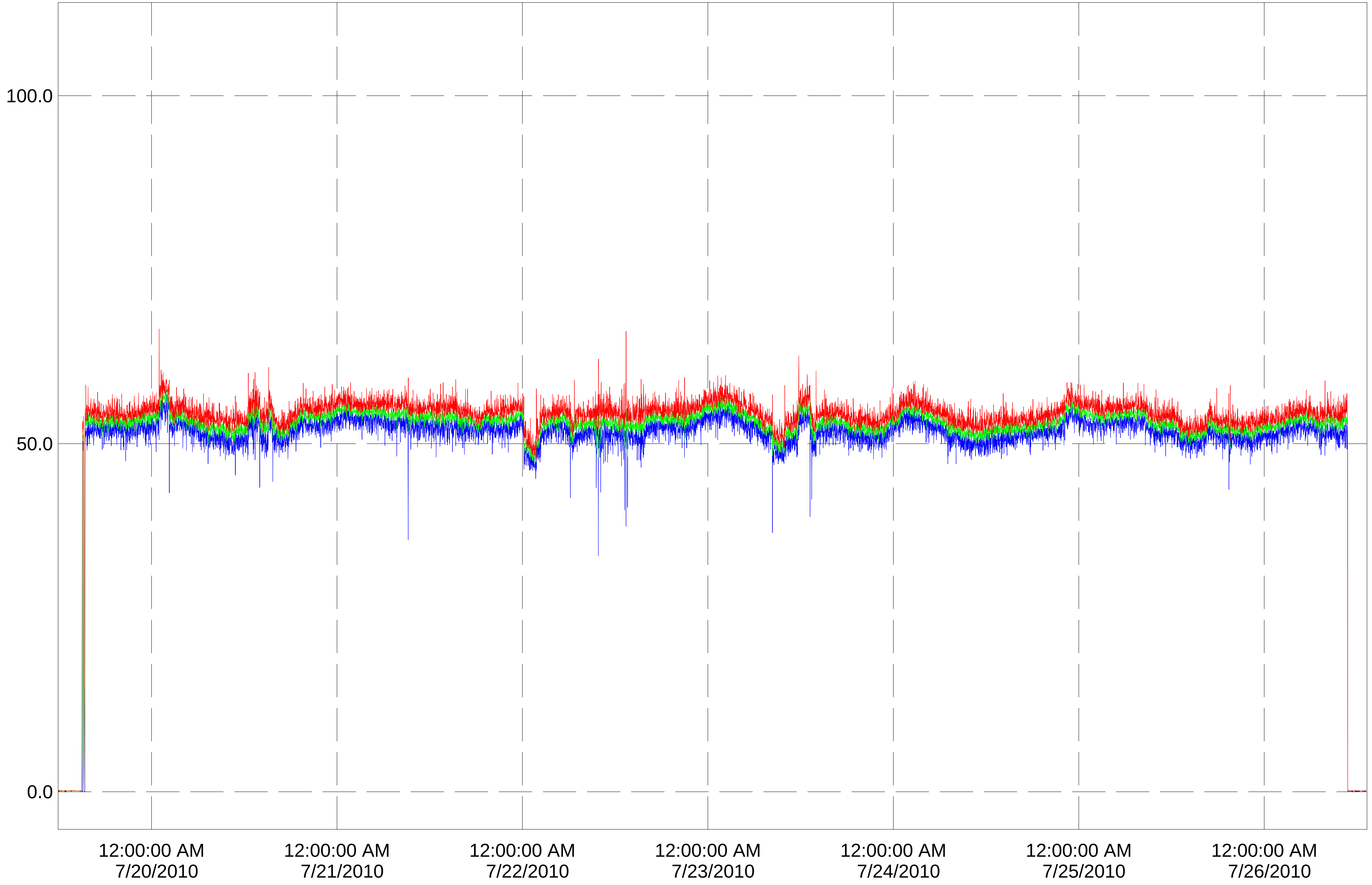
Clinton WTP 1



Oread Booster Pumps

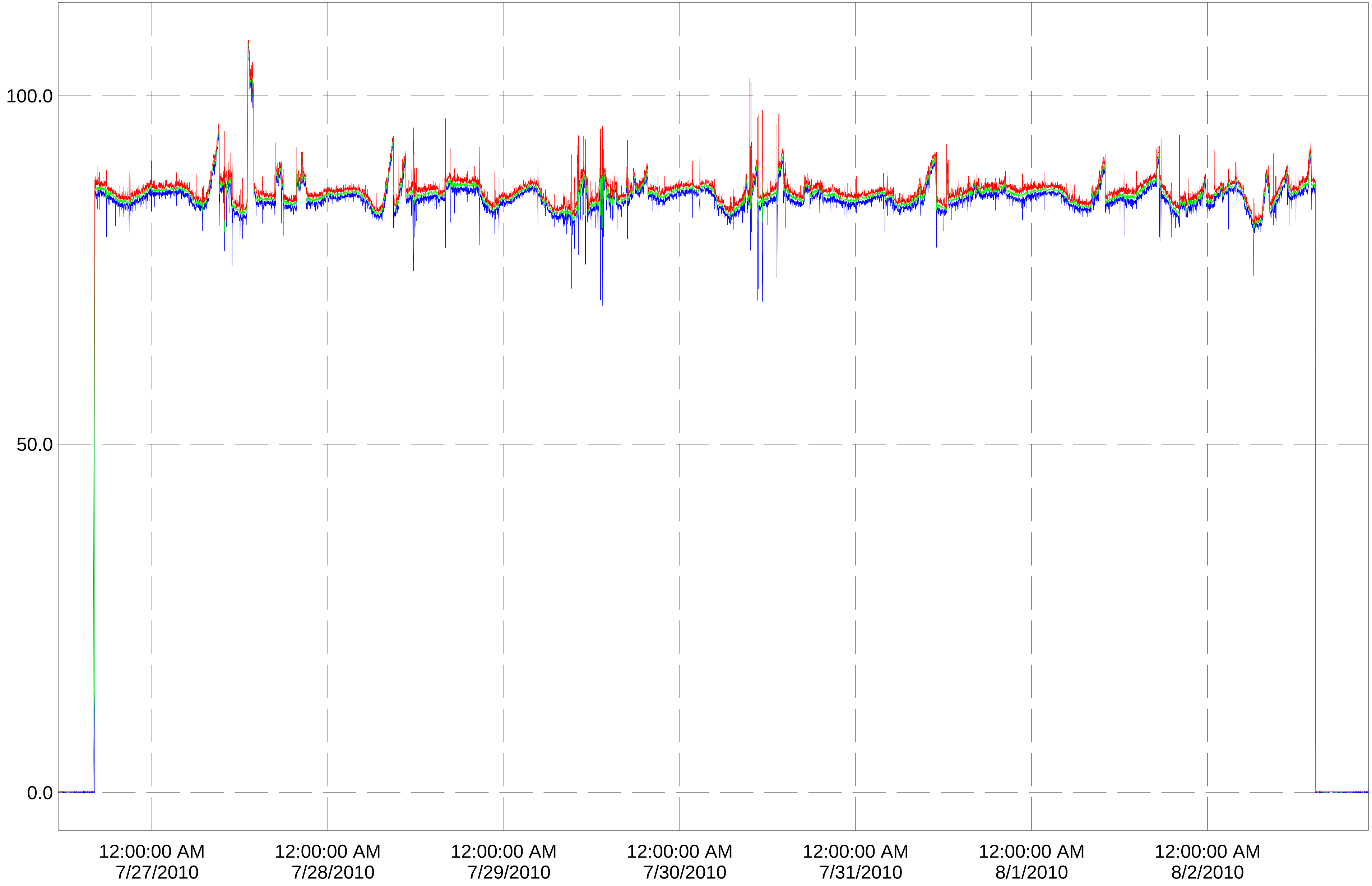


Lakeview West of Iowa
Hydrant No. 7079



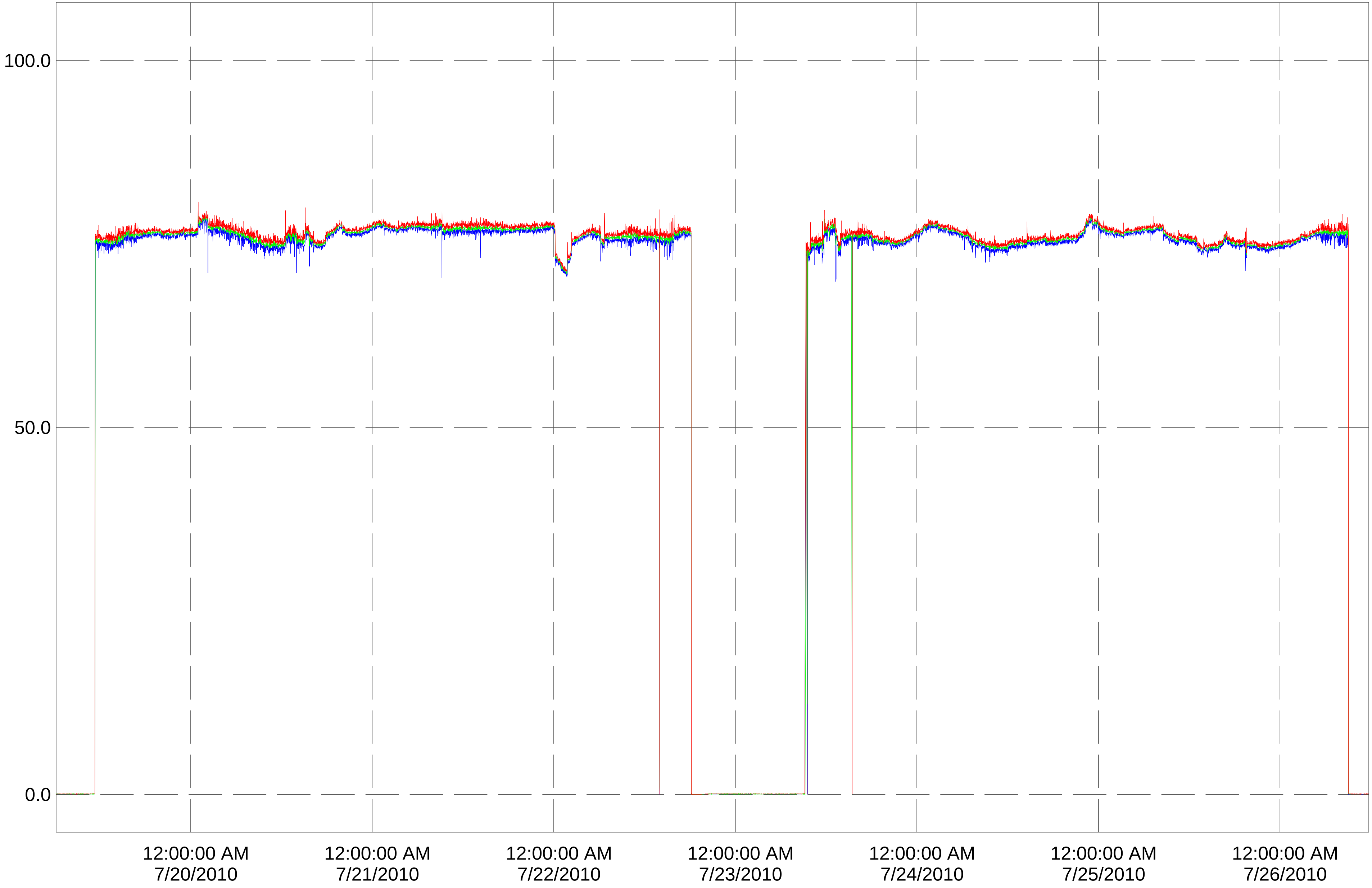
Tillerman & Eagle Pass
Hydrant No. 5701

76151 Chnl 01 (PSI)



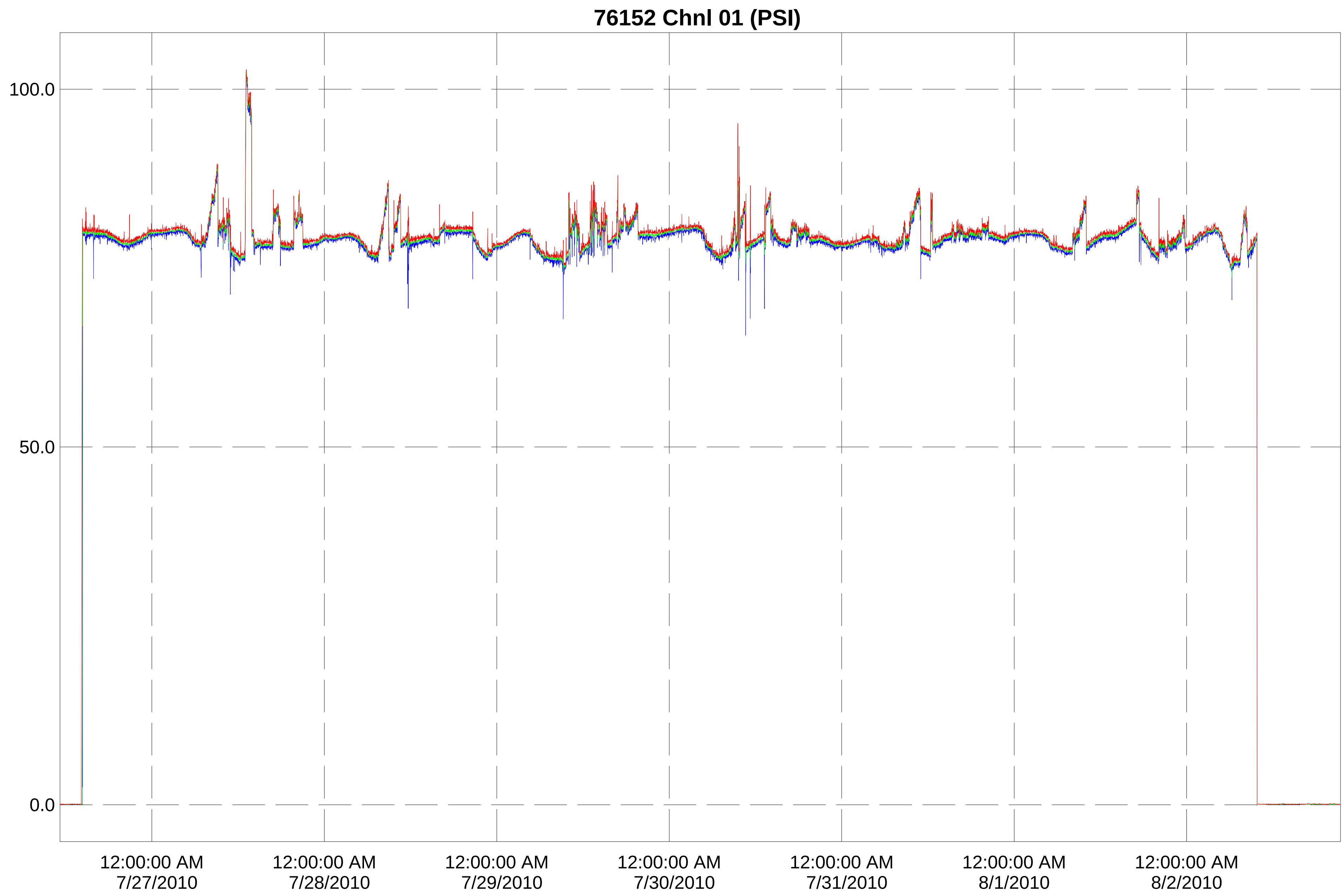
8th & Connecticut
Hydrant No. 1129

76152 Chnl 01 (PSI)



Stonecreek Drive North of Legends

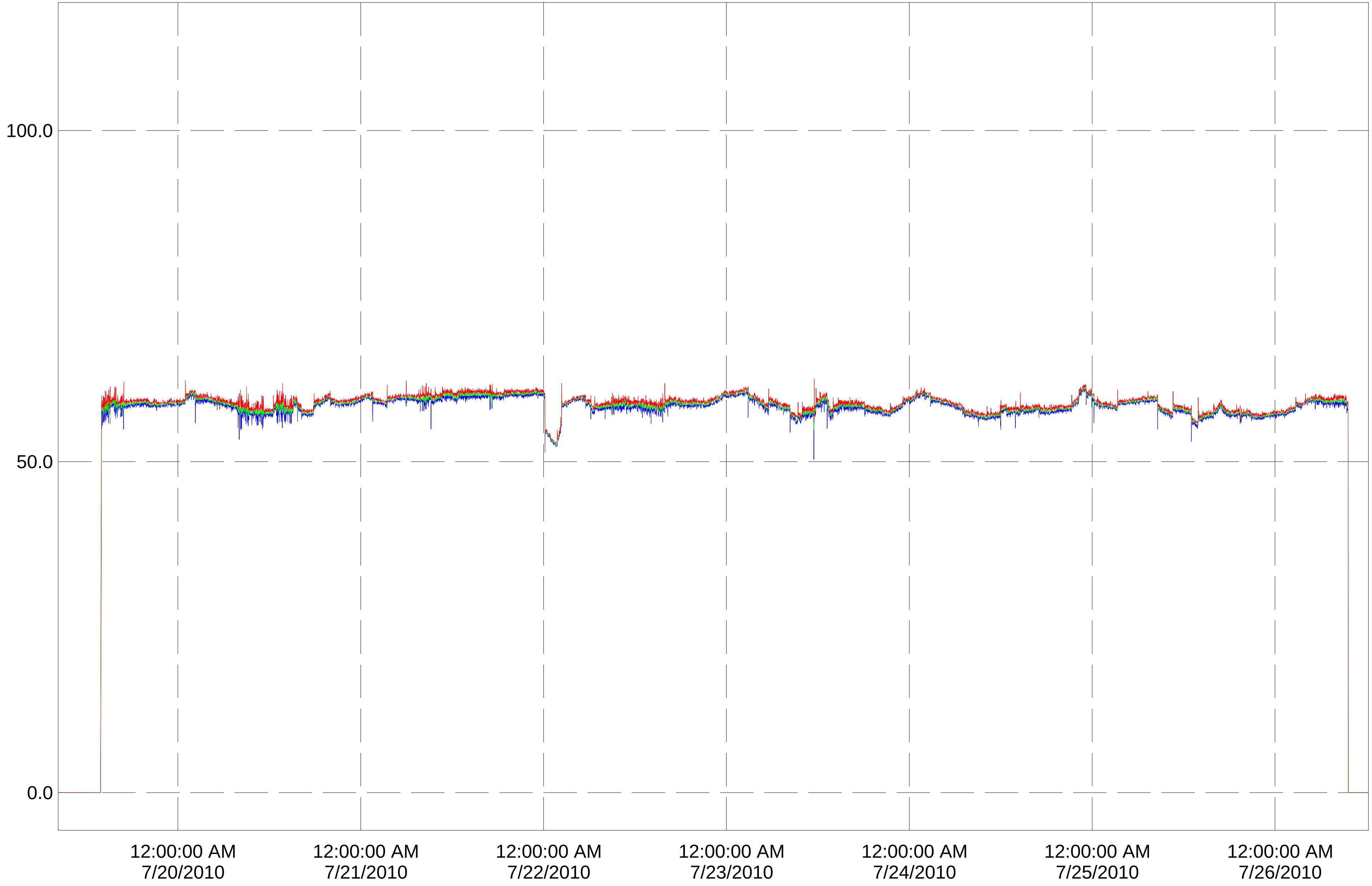
Hydrant No. 5790



Ohio & 21st

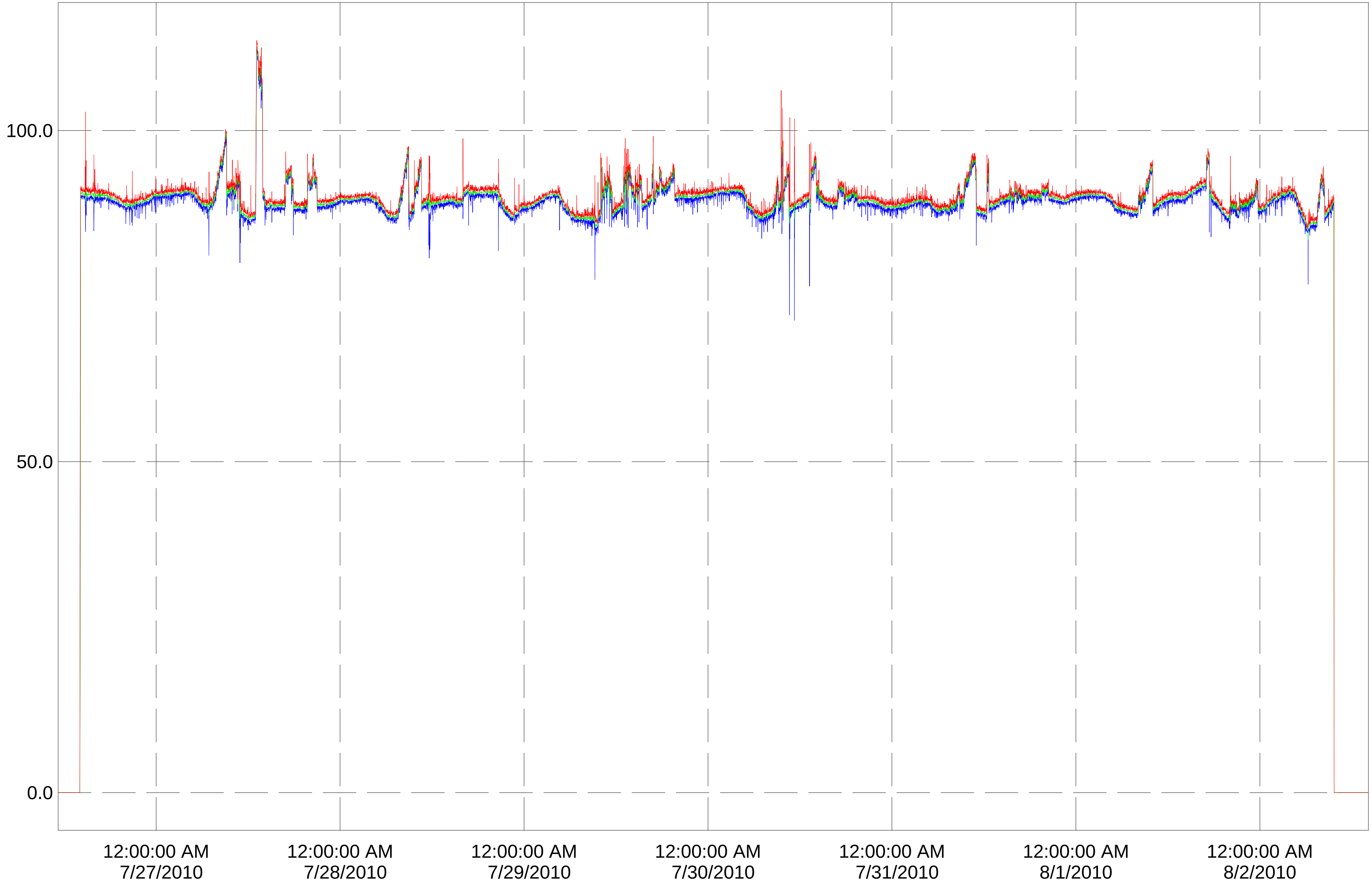
Hydrant No. 2440

76153 Chnl 01 (PSI)



George Williams & Bob White
Hydrant No. 6221

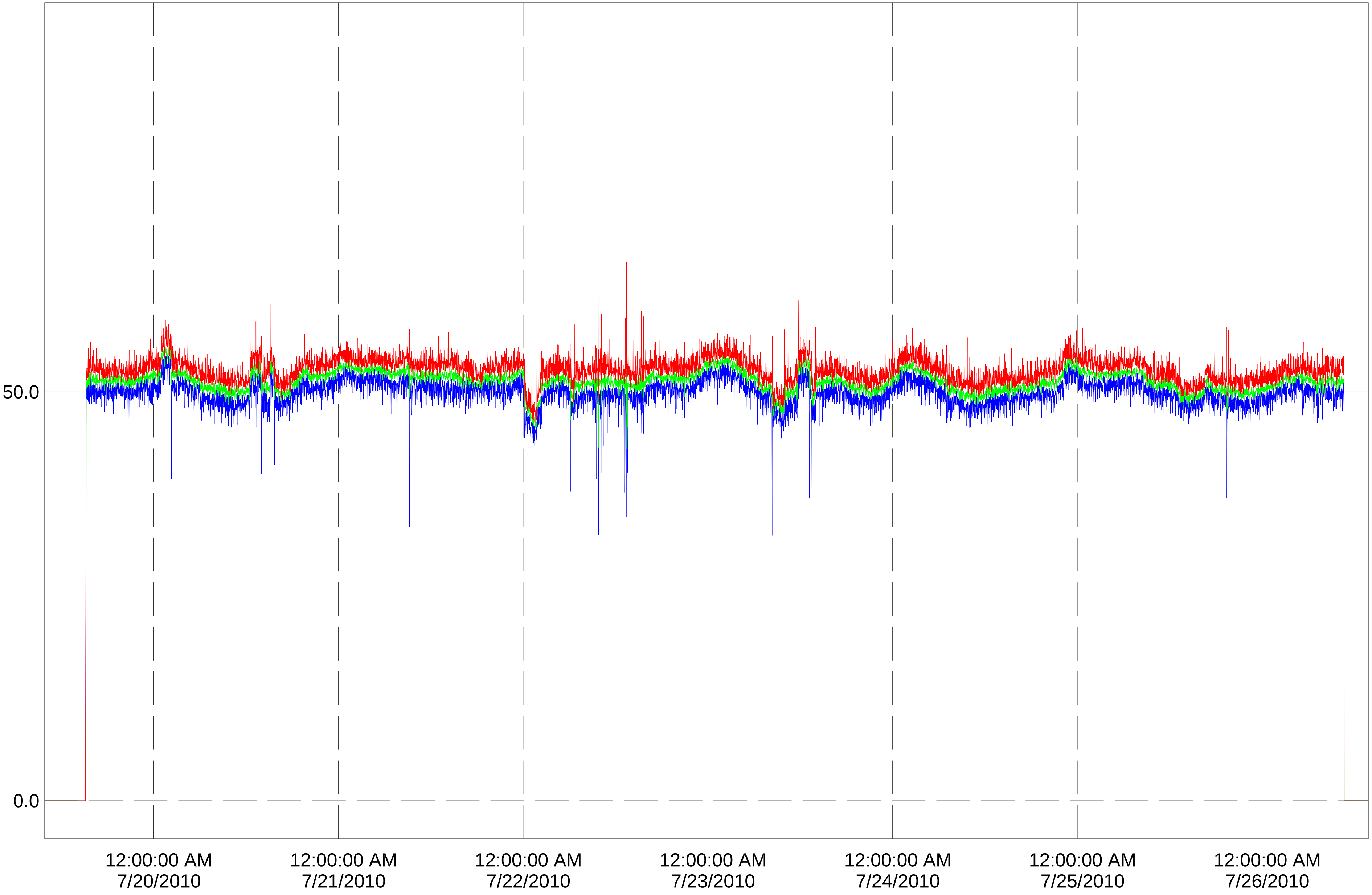
76153 Chnl 01 (PSI)



Brentwood & Brett

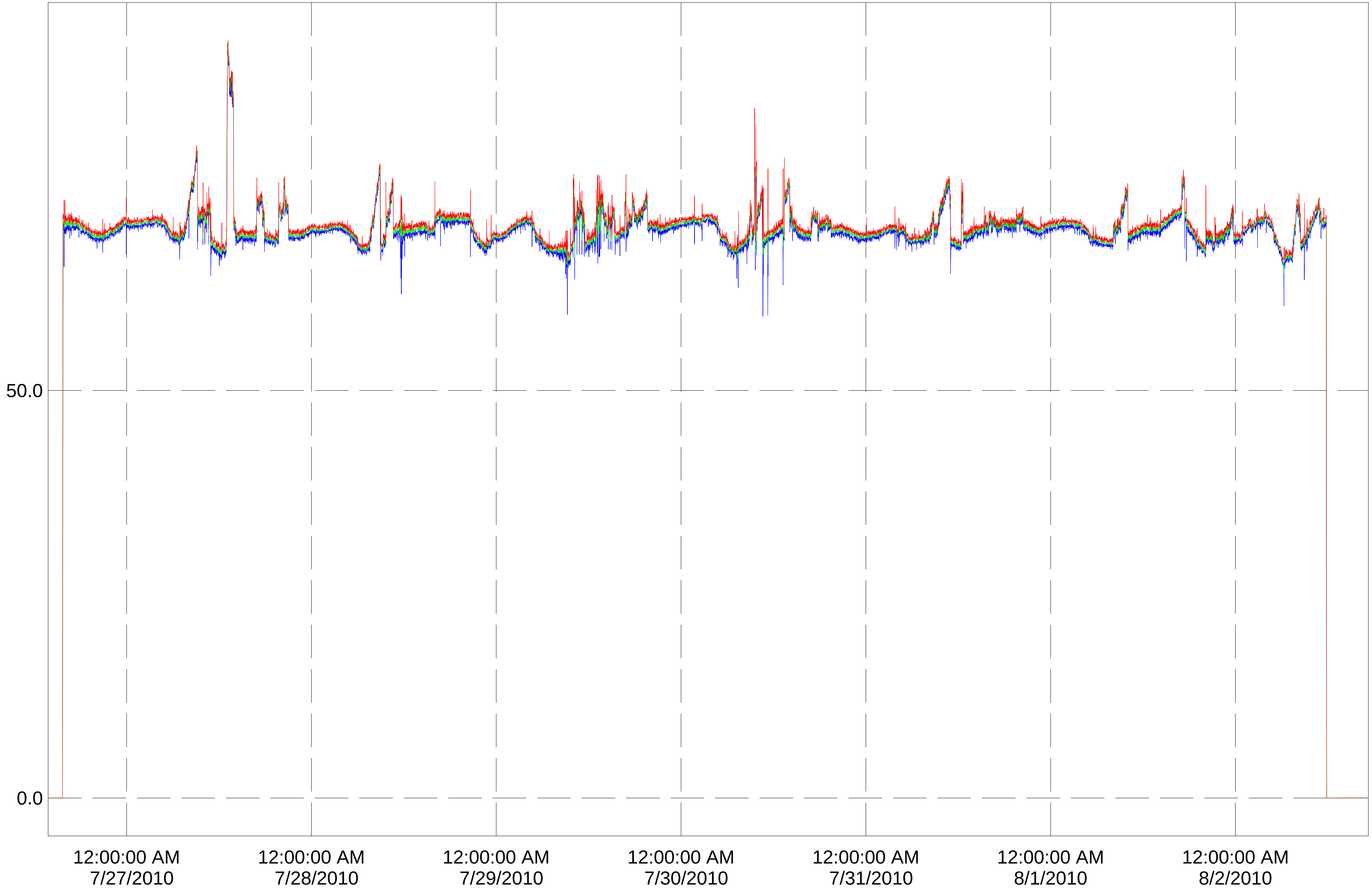
Hydrant No. 3271

76154 Chnl 01 (PSI)



Folks & Trail

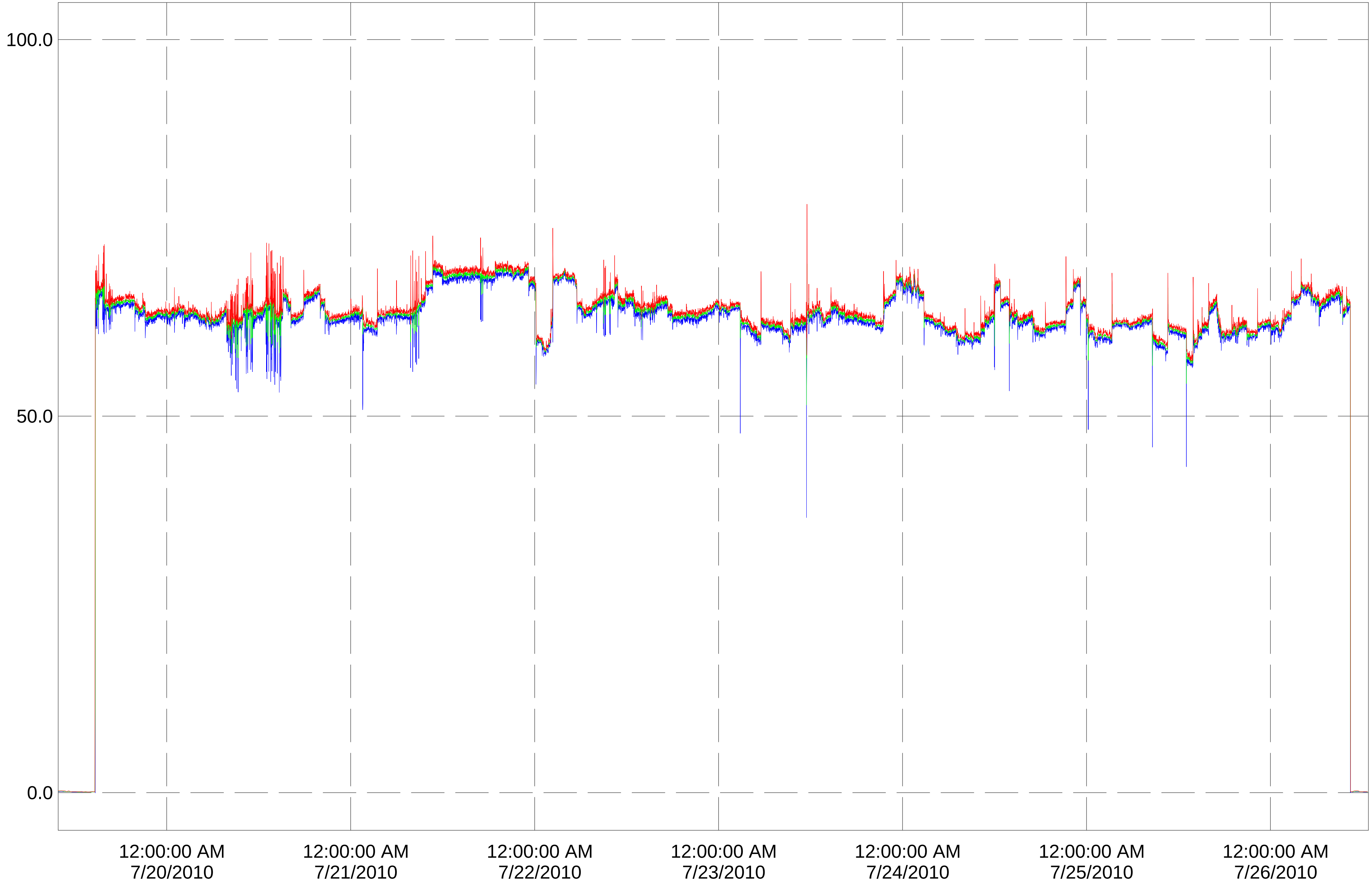
Hydrant No. 3932



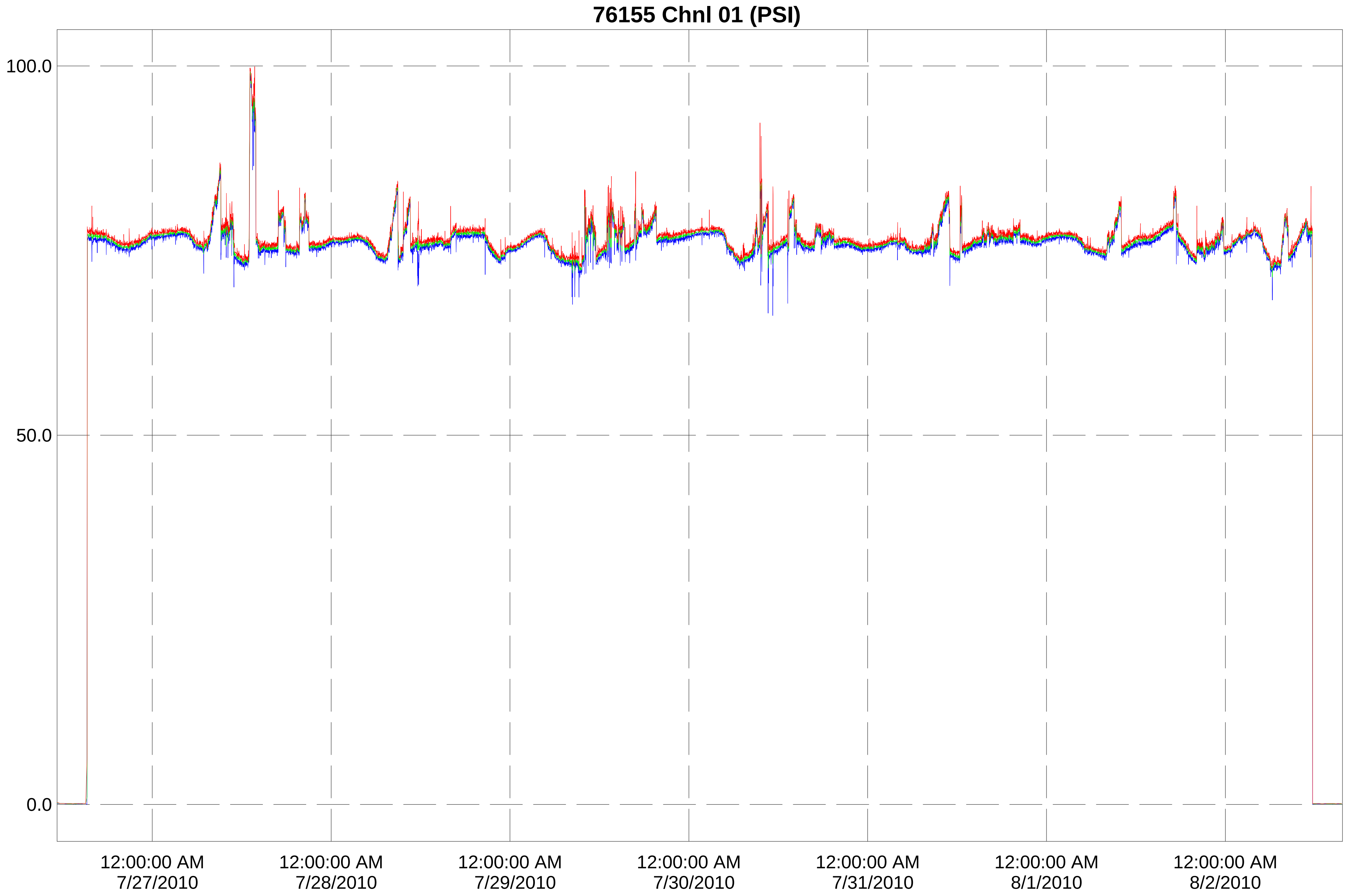
Prairie Elm North of 27th

Hydrant No. 5636

76155 Chnl 01 (PSI)

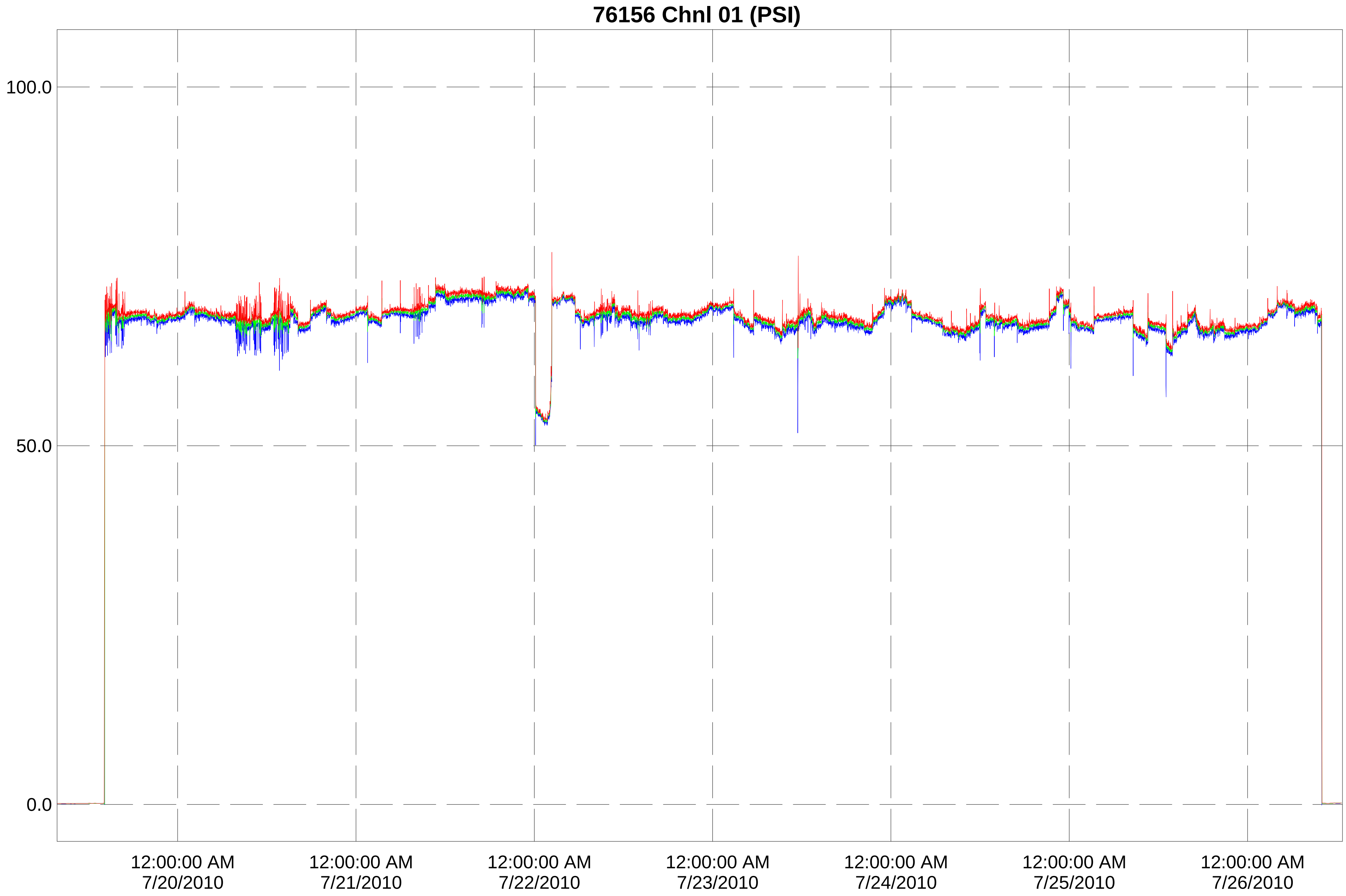


Eisenhower Drive & Carson Place
Hydrant No. 6295



Ousdahl & 25th

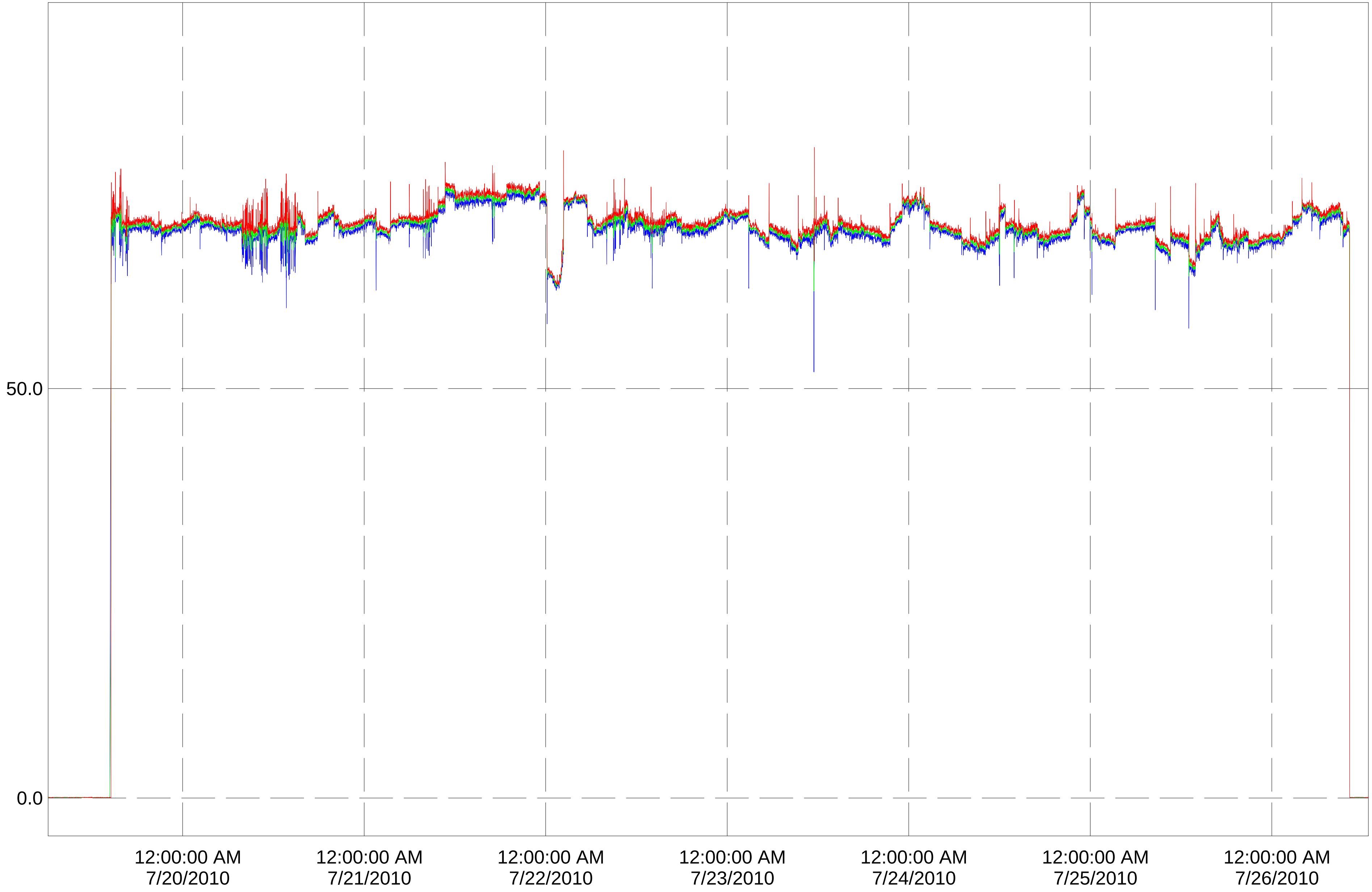
Hydrant No. 4531



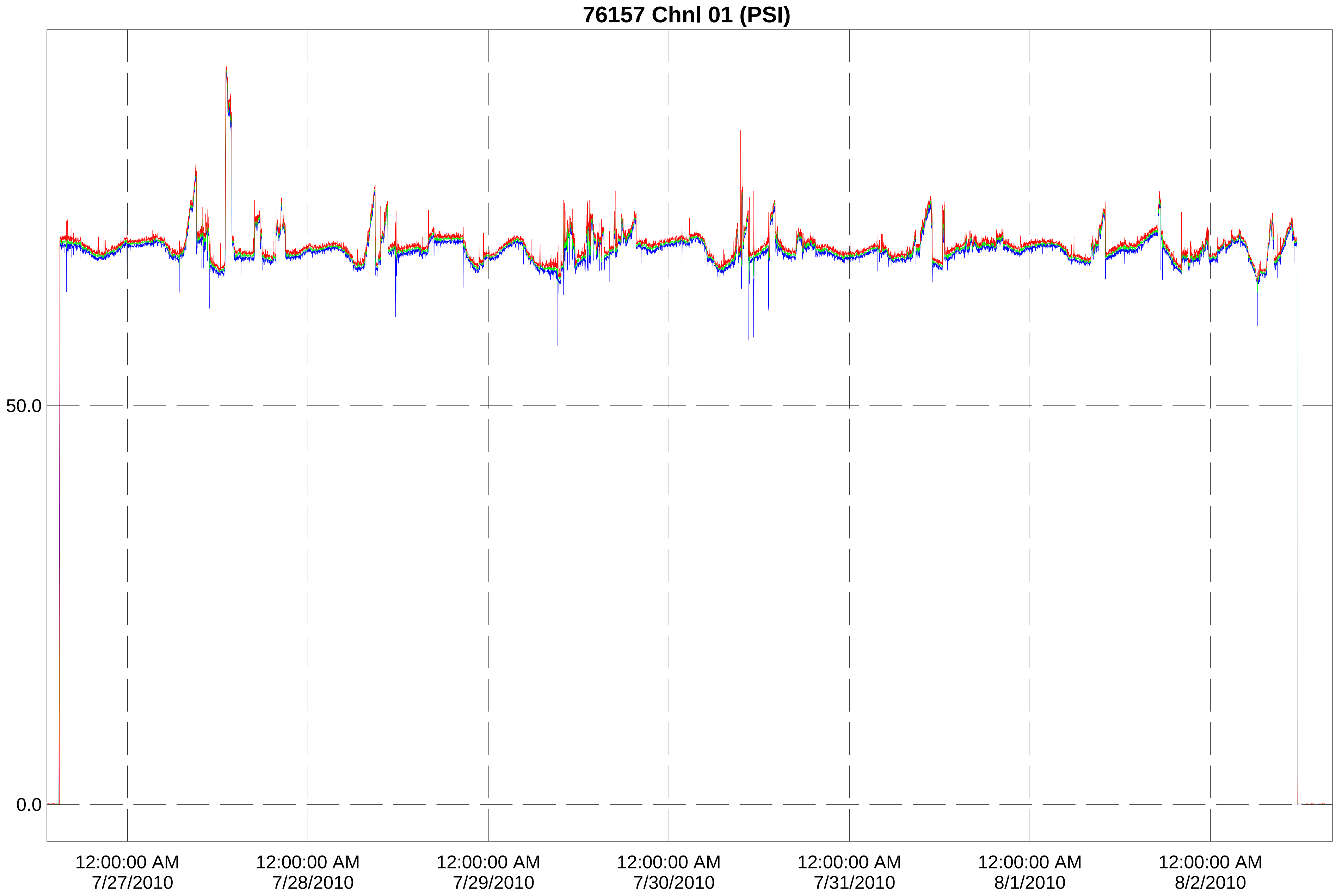
Stratford Road
Hydrant No. 3528
76156 Chnl 01 (PSI)

27th Street West of Lawrence
Hydrant No. 4725

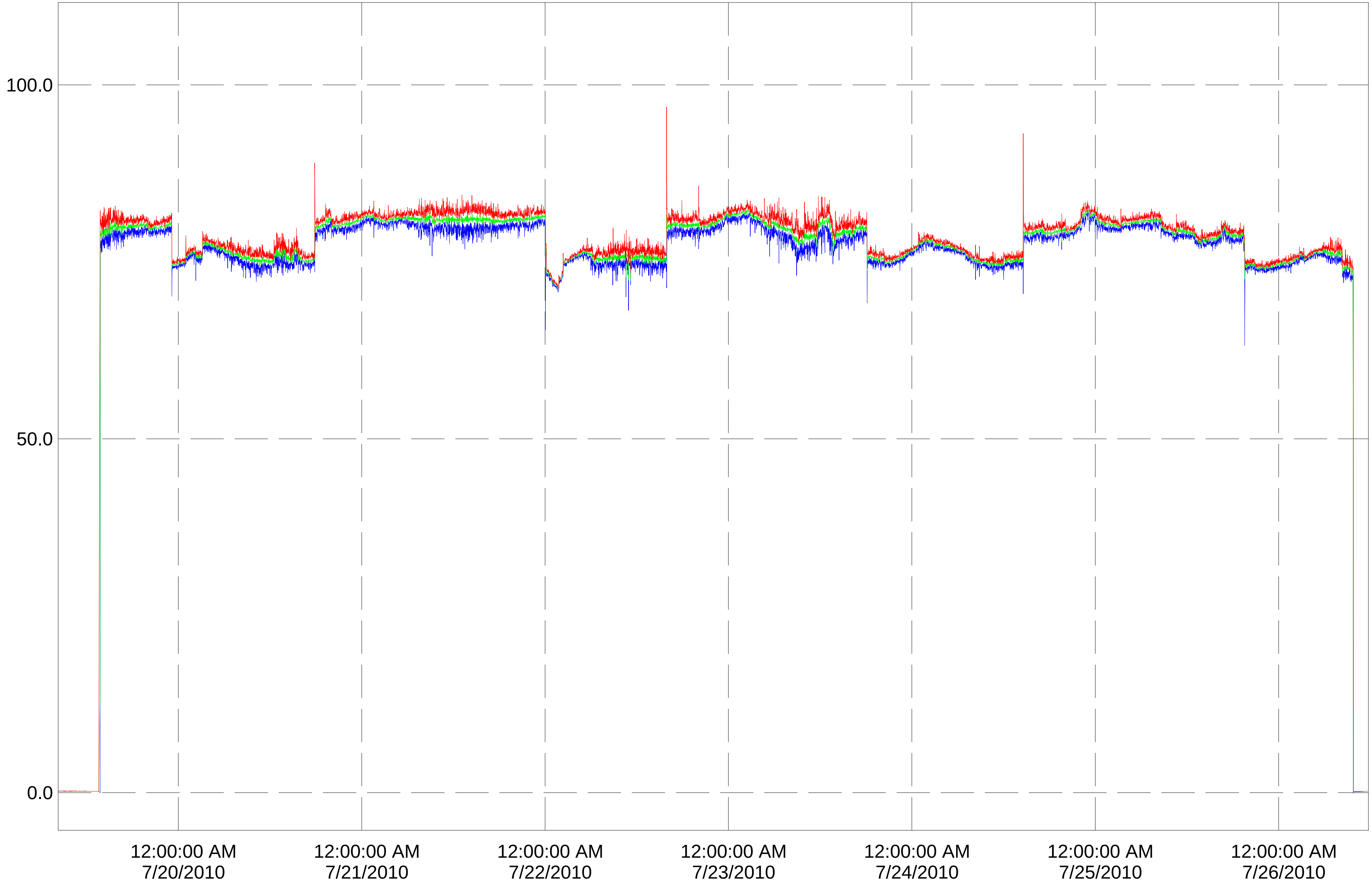
76157 Chnl 01 (PSI)



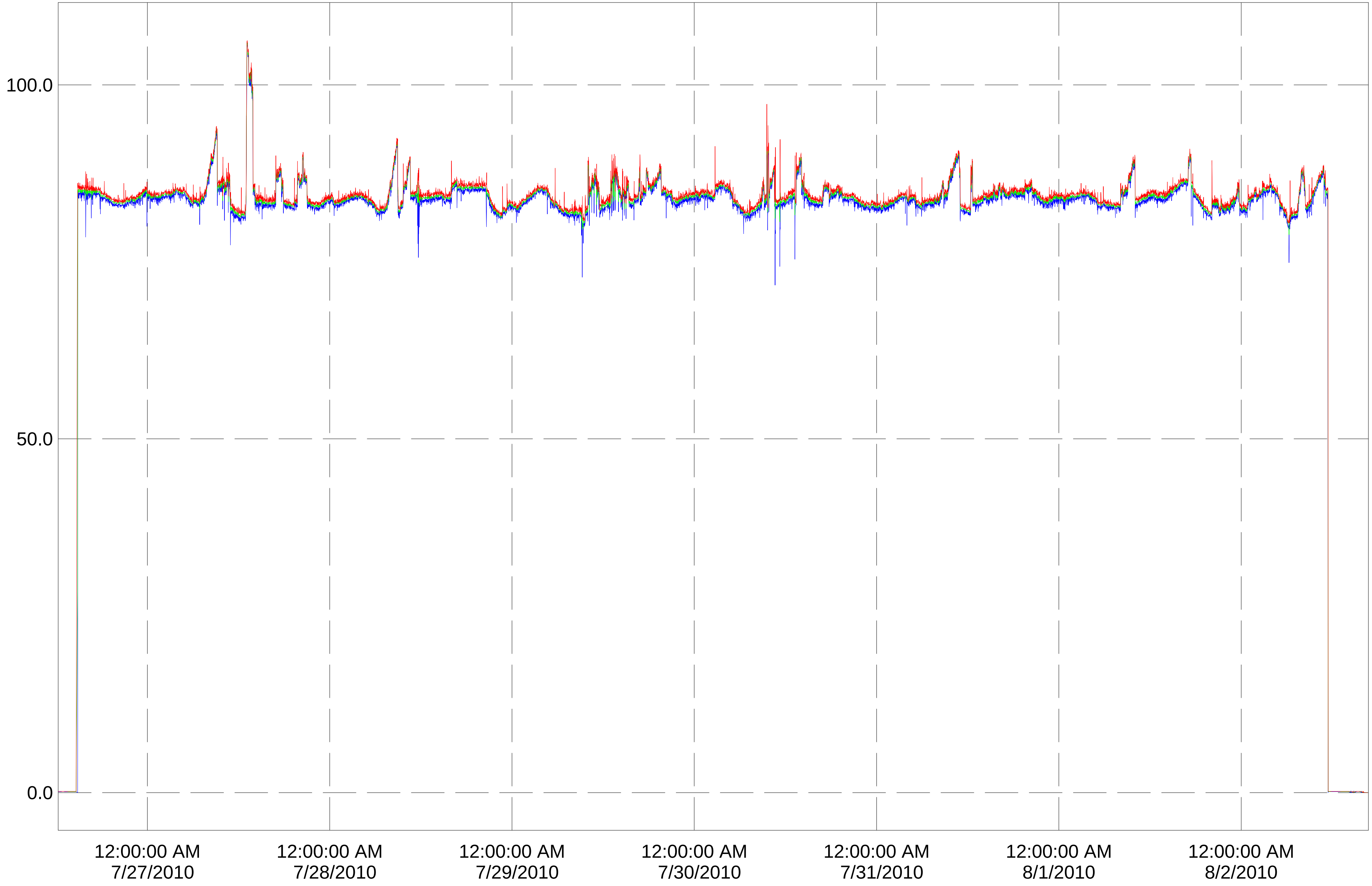
Easy Street & Goldfield
Hydrant No. 3993



30th & Haskell
Hydrant No. 2150

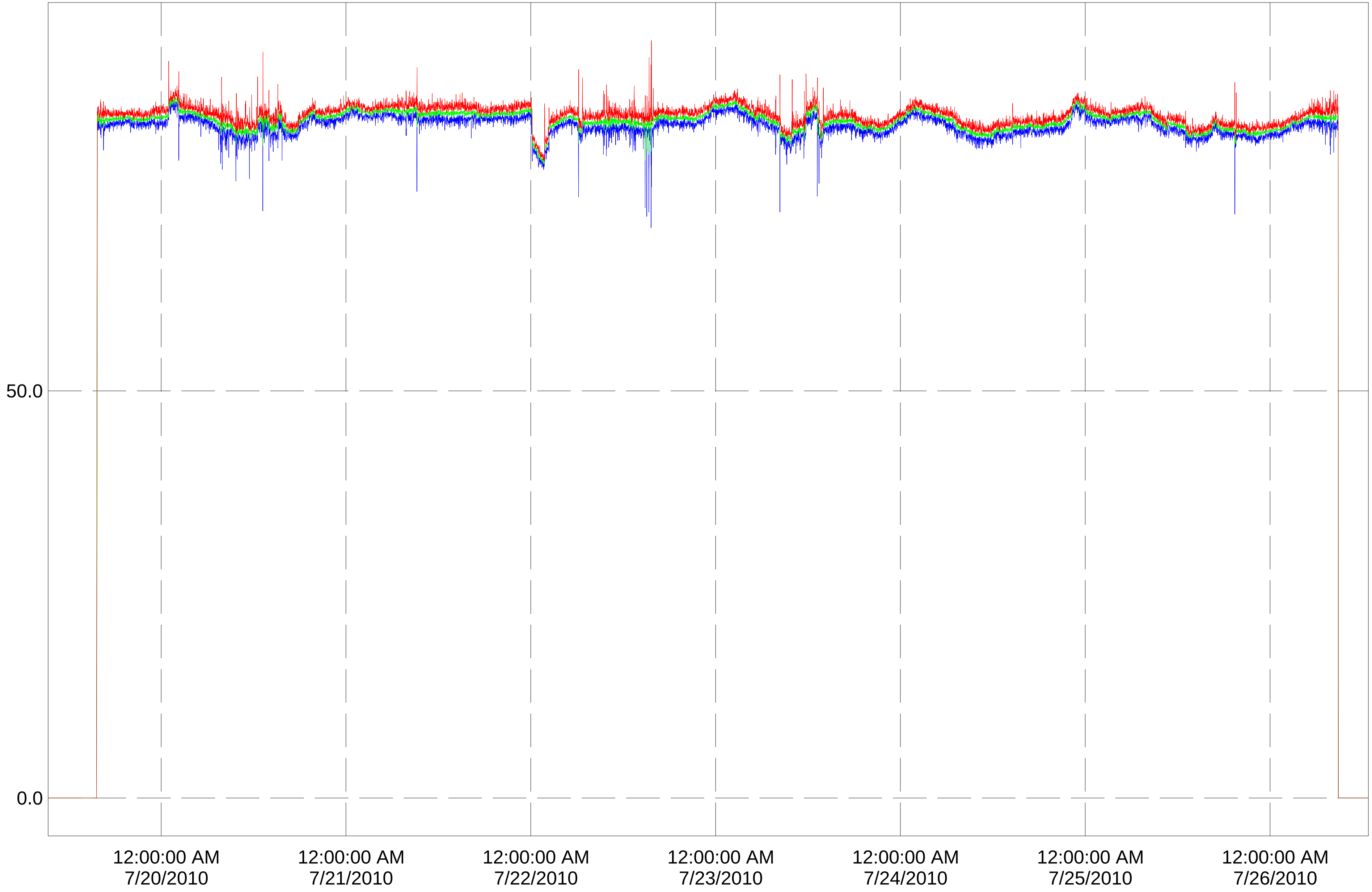


El Dorado North of Country Club
Hydrant No. 3626

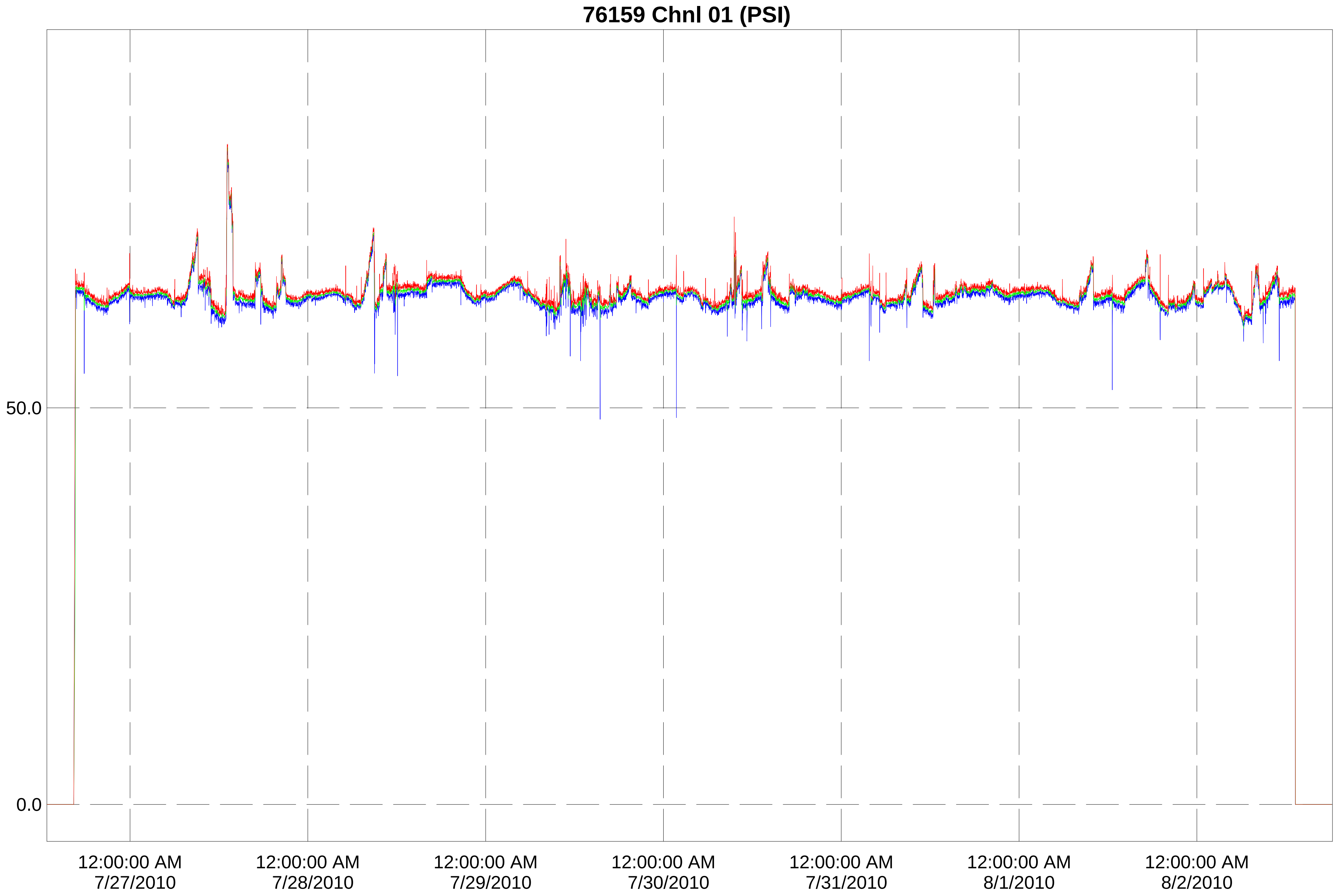


N. 6th & Maple
Hydrant No. 1844

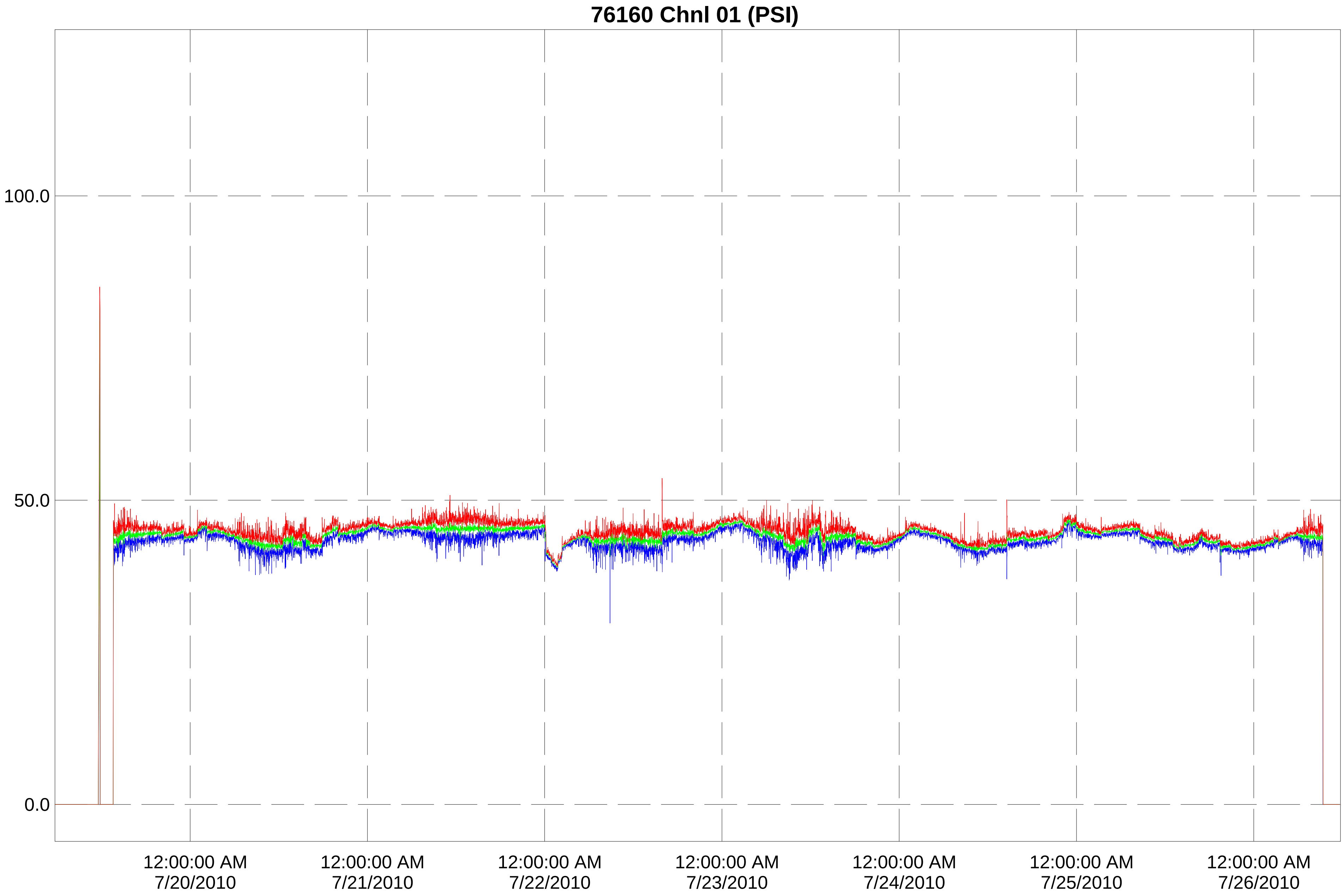
76159 Chnl 01 (PSI)



Mountview & Crestline
Hydrant No. 3440

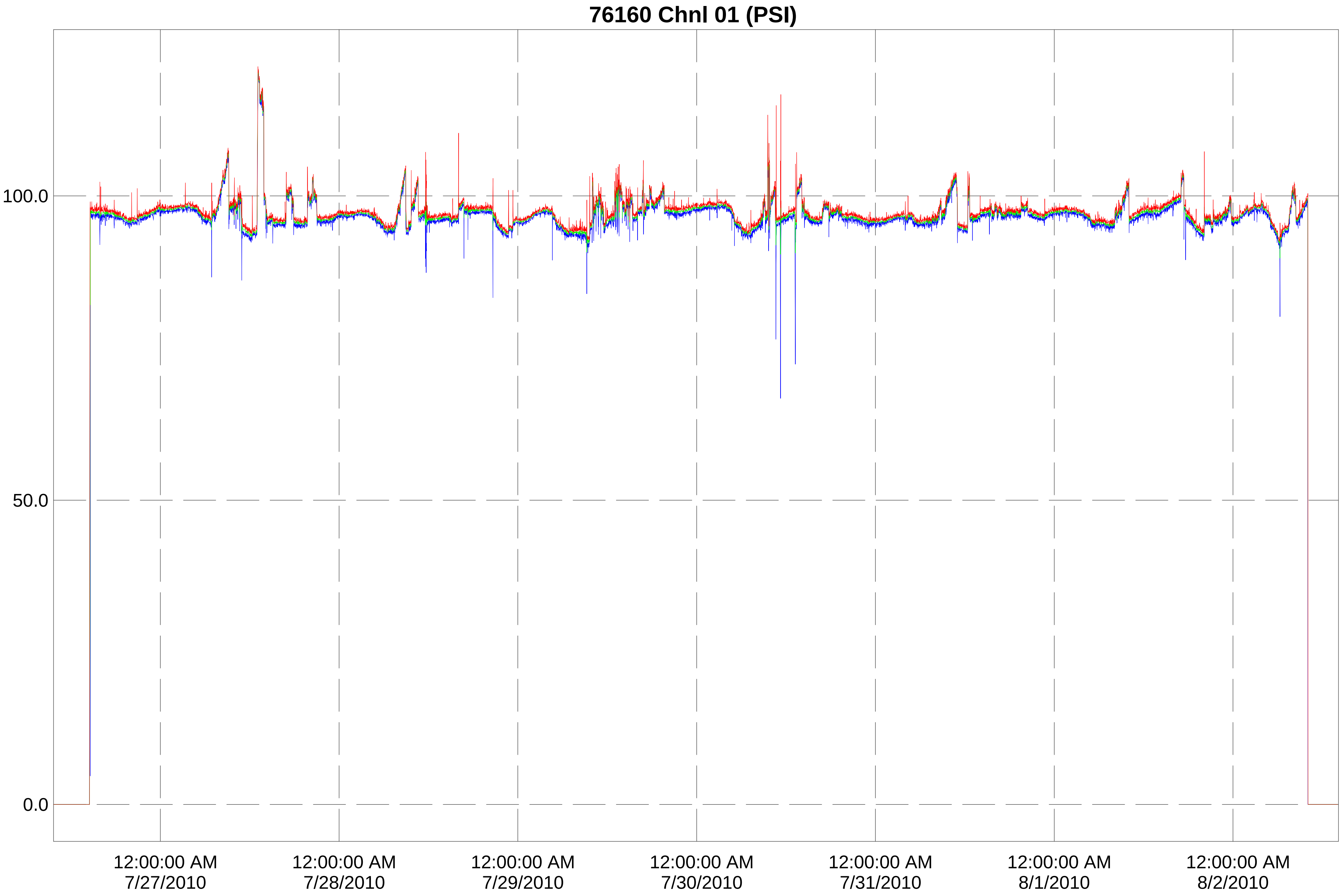


Franklin Road & Thomas Court
Hydrant No. 26122

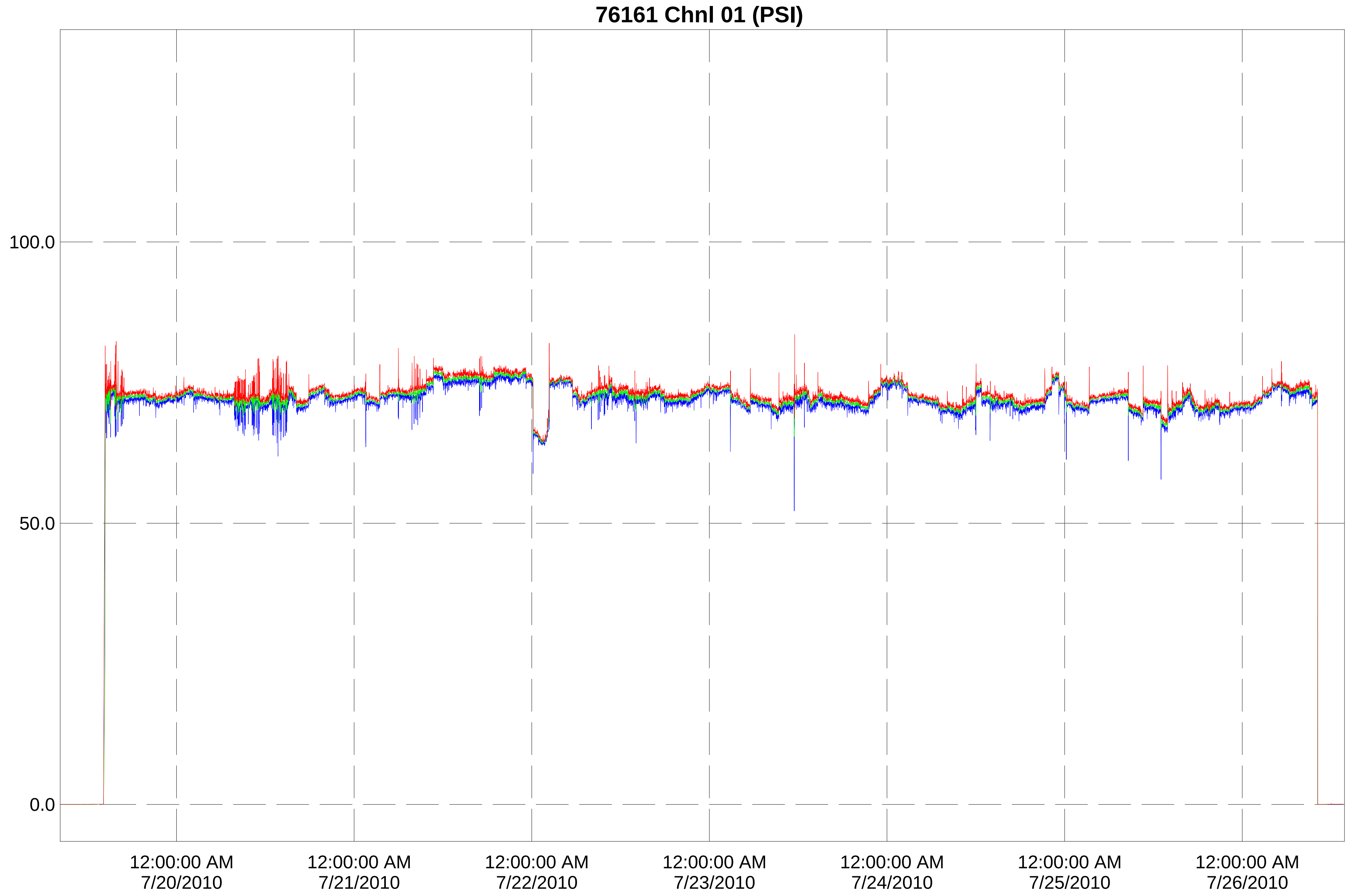


Prestwick Circle

Hydrant No. 4160

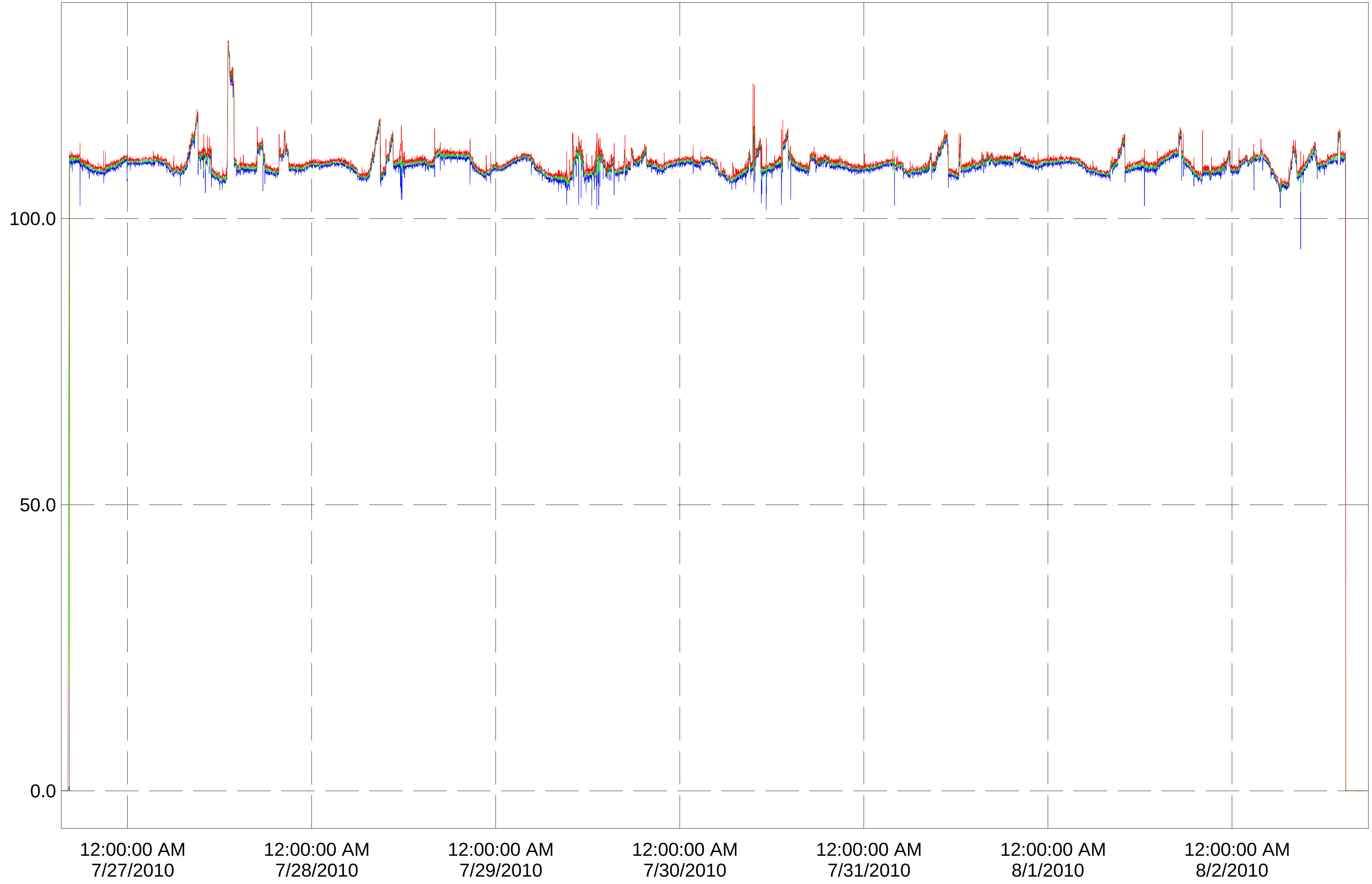


31st Street Behind Walmart
Hydrant No. 4627



Rockfence and Ranger
Hydrant No. 3213

76161 Chnl 01 (PSI)



Appendix E
Distribution System Testing Field Notes

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

System: Lawrence Wh

Date: 7-29-10 **Time:** ____

C-Value or [✓ Hydrant] Test

Main Size: ____ FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge	Hydrant A: #7023	52 PSI	50-52 PSI	NA
	Hydrant B:			NA
Flow	Flowing Hydrant: #7016		58 PSI	1275
	Differential Static Pressure:			
	Differential Flowing Pressure:			
	Headloss (feet):			
	C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 303-305 George Williams way & 6th st

Sketch:

Time 8:04 Am 8:06 Am

System: WH

Date: 7/29 **Time:** 805

C-Value or [✓ Hydrant] Test

Main Size: 8"? FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	125	[illegible] 121	NA
Hydrant B:			NA
Flowing Hydrant:		105	[illegible] 1725
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 10th + Illinois FH #1436

Sketch:

System: Lawrence W h

Date: 7-29-10 **Time:** ____________

C-Value or [✓ Hydrant] Test

Main Size: ____________ FH Opening Size: 2 1/2

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge Hydrant A: 6409	80 PSI	70 PSI	NA
Hydrant B:			NA
Flow Flowing Hydrant: #6410		55 PSI	1250
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 304 N Eaton Dr & 332 N Eaton Dr

Sketch:

Time 8:26 Am 8:28 Am

System: WH

Date: 7/29 **Time:** 8:32

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	~~70~~ 71	68	NA
Hydrant B:			NA
Flowing Hydrant:		50	1190
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Yale + Schwartz #3428

Sketch:

System: WH

Date: 7/29 **Time:** 8:44

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	94	90	NA
Hydrant B:			NA
Flowing Hydrant:		65	1350
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Westdale & Wellington #3551

Sketch:

System: Lawrence WH

Date: 7-29-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2 1/2

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge Hydrant A: # 6278	72 PSI	70 PSI	NA
Hydrant B:			NA
Flow Flowing Hydrant: # 6281		55 PSI	1250
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 450 WaKarusa Dr & 400 Wakarusa Dr

Sketch:

Time 8:45 AM 8:47 AM

System: WA

Date: 7/29 **Time:** 9:05

C-Value or [✓ Hydrant] Test

Main Size: ________ FH Opening Size: ________

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	87	80	NA
Hydrant B:			NA
Flowing Hydrant:		65	1350

Differential Static Pressure: ________

Differential Flowing Pressure: ________

Headloss (feet): ________

C-Value: ________

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Randall Rd #3604

Sketch:

System: Lawrence wH

Date: 7-29-2010 **Time:** ____

C-Value or [✓ Hydrant] Test

Main Size: ____ FH Opening Size: 2 1/2

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge Hydrant A: # 5565	80 PSI	74	NA
Hydrant B: 5564			NA
Flow Flowing Hydrant: #		40 PSI	1070

Differential Static Pressure: ____

Differential Flowing Pressure: ____

Headloss (feet): ____

C-Value: ____

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 4612 roundabout Cir & 4612 Trail Rd

Sketch:

Time 9:09 Am 9:11 Am

System: WH

Date: 7/29 **Time:** 9:17

C-Value or [✓ Hydrant] Test

Main Size: ________ FH Opening Size: ________

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	71	68	NA
Hydrant B:			NA
Flowing Hydrant:		50	1190

Differential Static Pressure: ________

Differential Flowing Pressure: ________

Headloss (feet): ________

C-Value: ________

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: College + Harvard #3363

Sketch:

System: WH

Date: 7/29 **Time:** 9:56

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	74	71	NA
Hydrant B:			NA
Flowing Hydrant:		60	1300

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Andover 6 # 3919 F3910

Sketch:

System: Lawrence WH

Date: 7-29-2010 **Time:** ________

C-Value or [✓ Hydrant] Test

Main Size: ________ FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge	Hydrant A: # 3999	64 PSI	54 PSI	NA
	Hydrant B:			NA
Flow	Flowing Hydrant: # 3910		40 PSI	1060 ~~1100~~

Differential Static Pressure: ________

Differential Flowing Pressure: ________

Headloss (feet): ________

C-Value: ________

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 4117 Saddlehorn Dr & 4213 Saddlehorn Dr ~~129 Sh[illegible]on Dr~~

Sketch:

Time 10:13 Am 10:15 Am

cvalueform.xls 7/13/2010

System: Lawrence WH

Date: 7-29-2010 **Time:** ______

C-Value or [✓ Hydrant] Test

Main Size: ______ FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge Hydrant A: # 3738	64 PSI	60 PSI	NA
Hydrant B:			NA
Flow Flowing Hydrant: # 3745		50	1190
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 4043 overland dr & 4001 overland dr

Sketch:

Time 10:31 Am 10:37 Am

System: Lawrence W H

Date: 7-29-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge Hydrant A: # 3314	76	70 PSI	NA
Hydrant B:			NA
Flow Flowing Hydrant: # 3304		60 PSI	1300
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 3617 Riverview Rd & 3615 Boulder ct

Sketch:

Time 10:50 Am 10:52 Am

Hydrant said 3316 but
should be 3314
3615 Boulder ct

System: Lawrence wH

Date: 7-29-2010 **Time:** ____

C-Value or [✓ Hydrant] Test

Main Size: ____ FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge	Hydrant A: # 3382	~~108~~ 106 PSI	98 PSI	NA
	Hydrant B:			NA
Flow	Flowing Hydrant: # 3383		70	1405

Differential Static Pressure: ____

Differential Flowing Pressure: ____

Headloss (feet): ____

C-Value: ____

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 300 Fallcreek — ~~300~~ 309 Fallcreek

Sketch:

Time 11:10 AM — Am

System: Lawrence WA

Date: 7-29-2010 **Time:** ____________

C-Value or [✓ Hydrant] Test

Main Size: ____________ FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge Hydrant A: # 3229	78 PSI	72 PSI	NA
Hydrant B:			NA
—Flow Flowing Hydrant: # 3228		55 PSI	1250

Differential Static Pressure: ____________

Differential Flowing Pressure: ____________

Headloss (feet): ____________

C-Value: ____________

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 3100 Campfire Dr & 3018 Campfire Dr

Sketch:

Time 12:34 pm ____________ pm

System: WH

Date: 7/09 **Time:** 12:44

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	73	71	NA
Hydrant B:			NA
Flowing Hydrant:		55	1250

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Summerfield F 5547 63977

Sketch:

System: Lawrence W H

Date: 7-29-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge Hydrant A: # 3247	70 [illegible] PSI	66 PSI	NA
Hydrant B:			NA
Flow Flowing Hydrant: # 3248		35	1000

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2803 Schwarz rd & 2911 Schwarz rd

Sketch:

Time 12:54 pm 12:56 pm

System: WH

Date: 7/29 **Time:** 1:10

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	80	73	NA
Hydrant B:			NA
Flowing Hydrant:		50	1250

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Diamondhead ? G 6516 F 6517

Diamondhead Dr

Sketch:

System: Lawrence

Date: 7-29-2010 **Time:** ______

C-Value or [✓ Hydrant] Test

Main Size: ______ FH Opening Size: 2 1/2

		Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge	Hydrant A: # 6584	78 PSI	62 PSI	NA
	Hydrant B:			NA
Flow	Flowing Hydrant: # 6585		50	1190

Differential Static Pressure: ______

Differential Flowing Pressure: ______

Headloss (feet): ______

C-Value: ______

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 3908 - day Flowers & 3932 day Flowers

Sketch:

Time 1:13 PM ______ PM

System: WH

Date: 7/29 **Time:** 1:21

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	84	79	NA
Hydrant B:			NA
Flowing Hydrant:		60	1350
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Research Park Dr G 3754 F 5458

Sketch:

System: Lawrence WH

Date: 7-29-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge Hydrant A: #	104 PSI	90 PSI	NA
Hydrant B:			NA
Flow Flowing Hydrant: #		85	1550

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 3520 Tillerman 3428 Tillerman

Sketch:

Time 1:28 PM 1:30 PM

System: WH

Date: 7/29 **Time:** 1:30

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	94	82	NA
Hydrant B:			NA
Flowing Hydrant:		65	1350
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Clinton Pkwy G 6406 F 6407

Sketch:

System: WH

Date: 7/29 **Time:** 2:27

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	113	86	NA
Hydrant B:			NA
Flowing Hydrant:		65	1350

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Crossgate G 4153 F 4152

Sketch:

System: WH

Date: 7/29 **Time:** 2:45

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	90	87	NA
Hydrant B:			NA
Flowing Hydrant:		70	1465
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Stone Meadows + Brighton G3643 F3644

Sketch:

System: WH

Date: 7/29 **Time:** 2:58

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	106	102	NA
Hydrant B:			NA
Flowing Hydrant:		80	1500

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Inverness + Wimbledon 6# 4193 F

Sketch:

System: WH

Date: 7/29 **Time:** 3:29

C-Value or Hydrant [✓ Test]

Main Size: FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:			NA
Hydrant B:			NA
Flowing Hydrant:			

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: G 5478 F 4204

Sketch:

System: Lawrence CS

Date: 7-22-10 **Time:** ____

C-Value or Hydrant Test

Main Size: ____ FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Gauge Hydrant A: 6385	64	45	NA
Hydrant B:			NA
[✓ Flowing Hydrant:] 6387		37	1000 1021

Differential Static Pressure: ____

Differential Flowing Pressure: ____

Headloss (feet): ____

C-Value: ____

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2027 E 17th & 2121 E. 17th

Sketch:

Time 8:25 Am 8:28 Am

System: Lawrence CS

Date: 7-22-2010 **Time:**

C-Value or Hydrant Test

Main Size: FH Opening Size: 2 1/2

		Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**	
gauge	Hydrant A: 5721	82	74	NA	
	Hydrant B:			NA	
	[✓ Flowing Hydrant:] 5723	~~[illegible]~~	60-62	1300 ~~[illegible]~~	1300

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2201

Sketch:

Time 8:54 Am 8:56 AM

gauge Hydrant #5721 North driveway

Flow Hydrant #5723 South driveway

off Noria Rd

System: CS

Date: **Time:** 10:00

C-Value or Hydrant Test

Main Size: 8" FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**	
Hydrant A:	60	55	NA	
Hydrant B:			NA	
Flowing Hydrant:		~~20~~ 40	700	1061

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Westchester + Kingston #3134

Sketch:

System: CS

Date: **Time:** 10:22

C-Value or Hydrant Test

Main Size: 6" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	63	60	NA
Hydrant B:			NA
Flowing Hydrant:		~~16~~ 35	993
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2nd St + Minnesota #1626

Sketch:

System: Lawrence, CS

Date: 7-22-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size:

		Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**	
gauge [redacted]	Hydrant A: # 2126	[redacted] 59	57	NA	
	Hydrant B: [redacted]			NA	
Flow	Flowing Hydrant: # 2133		45	~~1085~~ 1080	1126

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2501 Maverick Ln & 2641 Maverick Ln

Sketch:

Time [redacted] AM 10:35 AM
10:33

System: Lawrence, CS

Date: ______ **Time:** ______

C-Value or [✓ Hydrant] Test

Main Size: ______ FH Opening Size: 2 1/2

		Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**	
gauge	Hydrant A: # 2129	51	48	NA	
	Hydrant B: [redacted]			NA	
Flow	Flowing Hydrant: # 6390		40	1000	1061

Differential Static Pressure: ______

Differential Flowing Pressure: ______

Headloss (feet): ______

C-Value: ______

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2701 Rawhide Ln & 2721 Rawhide LN

Sketch:

Time 10:50 AM 10:55 AM

System: CS

Date: **Time:** 10:52

C-Value or [✓ Hydrant] Test

Main Size: 8" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	74	72	NA
Hydrant B:			NA
Flowing Hydrant:		~~35~~ 55	~~960~~ 1244
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 5th and Illinois #1721

Sketch:

System: Lawrence

Date: 7-22-2010 **Time:** ______

C-Value or [✓ Hydrant] Test

Main Size: ______ FH Opening Size: ______

		Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**	
gauge	Hydrant A: # 2165	53	49	NA	
	Hydrant B:			NA	
Flow	Flowing Hydrant: # 2166		50	1115	1186

Differential Static Pressure: ______

Differential Flowing Pressure: ______

Headloss (feet): ______

C-Value: ______

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2741 Harper st - 2717 Harper St.

Sketch:

Time 11:13 AM 11:15 AM

System: CS

Date: **Time:** 11:13

C-Value or [✓ Hydrant] Test

Main Size: 12" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	60	58	NA
Hydrant B:			NA
Flowing Hydrant:		~~13~~ 28	888
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 8th + Alabama #1718

Sketch:

System: Lawrence CS

Date: 7-22-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2 1/2

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge Hydrant A: #- 2647	54	53	NA
Hydrant B:			NA
Flow Flowing Hydrant: #2639		50	1115 1184

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 1320 Fair Ln & 1331 E 21st St

Sketch:

Time 12:45 PM 12:47 PM

System: Lawrence CS

Date: 7-22-2010 **Time:** ____

C-Value or [✓ Hydrant] Test

Main Size: ____ FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)	
gauge	Hydrant A: #2619	64	62	NA	
	Hydrant B:			NA	
Flow	Flowing Hydrant: #2618		58 ~~57.5~~	1280	1278
	Differential Static Pressure:				
	Differential Flowing Pressure:				
	Headloss (feet):				
	C-Value:				

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 17th Maple NEC & 1734 Maple

Sketch:

Time 1:01 PM 1:03 PM

System: Lawrence CS

Date: 7-22-2010 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)	
gauge	Hydrant A: # 2619	64	64	NA	
	Hydrant B:			NA	
Flow	Flowing Hydrant: # 2620		45	1080	1124

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 1734 Maple & 1632 E Glenn Dr

Sketch:

Time 1:12 pm 1:15 pm

System: Lawrence CS

Date: 7-22-2010 **Time:** ______

C-Value or [✓ Hydrant] Test

Main Size: ______ FH Opening Size: 2 1/2

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge Hydrant A: # 2430	56	54	NA
Hydrant B:			NA
Flow Flowing Hydrant: # 2447		45	1080 1126
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 20th Moodie NEC & 911 E. 21st.

Sketch:

Time 1:34 pm 1:37 pm

System: CS

Date: **Time:** ~~9:44~~ 1:33

C-Value or [✓ Hydrant] Test

Main Size: 8" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	50	~~46~~ 44	NA
Hydrant B:			NA
Flowing Hydrant:		~~27~~ 42	1087

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Winston + Arrowhead #5586

Sketch:

System: CS

Date: **Time:** 9~~3~~5 1:42

C-Value or [✓ Hydrant] Test

Main Size: 6" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	50	45	NA
Hydrant B:			NA
Flowing Hydrant:		~~18~~ 35	655 993
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Bowstring Dr. #3120

Sketch:

System: Lawrence CS

Date: 7-22-2010 **Time:**

C-Value or Hydrant Test

Main Size: FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)	
gauge	Hydrant A: # 2435	54	54	NA	
	Hydrant B:			NA	
Flow	Flowing Hydrant: #2463		40-42.5	1000	1061

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2205 Learnard Ave - 2111 Learnard Ave.

Sketch:

Time 2:00 PM 2:03 PM

System: CS

Date: **Time:** ~~8:55~~ 2:00

C-Value or [✓ Hydrant] Test

Main Size: 6" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	74	[illegible] [illegible] [illegible] 69	NA
Hydrant B:			NA
Flowing Hydrant:		[illegible] 47	865 1150
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Lazybrook Ln. + Brushcreek [illegible]. #4810

Sketch:

System: CS

Date: ______ **Time:** ~~8:10~~ 2:07

C-Value or [✓ Hydrant] Test

Main Size: 12" FH Opening Size: ______

	Static Pressure (psi)		Flowing Pressure (psi)		Flow (gpm)	
Hydrant A:	~~54~~ 56	56	~~50~~ 54		NA	
Hydrant B:					NA	
Flowing Hydrant:			~~30~~ 58	50	865	1186
Differential Static Pressure:						
Differential Flowing Pressure:						
Headloss (feet):						
C-Value:						

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 27th Terr. & Lawrence Ave. # 4735

Sketch:

System: Lawrence CS

Date: ________ **Time:** ________

C-Value or [✓ Hydrant] Test

Main Size: ________ FH Opening Size: 2 1/2

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
gauge Hydrant A: # 1225	71	70	NA
Hydrant B:			NA
Flow Flowing Hydrant: # 1221		20 - 22.5	700 750
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 14th Rhode Island - 1400 Connecticutt

Sketch: 14th St & Rhode Island

Time 2:26 pm 2:27 pm

System: CS

Date: **Time:** 2:30

C-Value or [✓ Hydrant] Test

Main Size: 8" FH Opening Size:

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	69	67	NA
Hydrant B:			NA
Flowing Hydrant:		47	1150

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 10th + Delaware #1149

Sketch:

System: C S

Date: **Time:** 2:45

C-Value or [✓ Hydrant] Test

Main Size: 8" FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	80	75	NA
Hydrant B:			NA
Flowing Hydrant:		60	1300
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 3rd and Perry (North Lawrence) #1819

Sketch:

System: Lawrence CS

Date: ______ **Time:** ______

C-Value or [✓ Hydrant] Test

Main Size: ______ FH Opening Size: 2 1/2

		Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
gauge	Hydrant A: #2542	54	52	NA
	Hydrant B:			NA
Flow	Flowing Hydrant: #2504		40 – 42.5	1000 1061

Differential Static Pressure: ______

Differential Flowing Pressure: ______

Headloss (feet): ______

C-Value: ______

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 1801 mississippi – 1745 Illnois

18th & Illinois

Sketch:

Time 2:47 pm 2:50 pm

System: CS

Date: **Time:** 2:58

C-Value or [✓ Hydrant] Test

Main Size: 6" FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	80	[illegible] 79	NA
Hydrant B:			NA
Flowing Hydrant:		55	1244

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 8th St. + Locust #1867

Sketch:

System: Lawrence CS

Date: 7-22-2010 **Time:** ____

C-Value or [✓ Hydrant] Test

Main Size: ____ FH Opening Size: 2 1/2 "

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Gauge Hydrant A: #7007	#60	57	NA
Hydrant B: #			NA
Flow Flowing Hydrant: 4436		50-52.5	1115 1186

Differential Static Pressure: ____

Differential Flowing Pressure: ____

Headloss (feet): ____

C-Value: ____

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 1410 W. 21st 2043 Hillview

Sketch:

Time 3:09 pm 3:11 pm

System: CS

Date: **Time:** 3:15

C-Value or [✓ Hydrant] Test

Main Size: 8 FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	80	66	NA
Hydrant B:			NA
Flowing Hydrant:		50	1186

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 9th & Hillcrest (North Lawrence) # 6300
Hickory

Sketch:

System:

Date: 07-22 **Time:**

C-Value or [✓ Hydrant] Test

Main Size: FH Opening Size: 2½

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)	
Gauge Hydrant A: # 2343	57	54	NA	
Hydrant B:			NA	
Flow Flowing Hydrant: # 4612		55	1170	1244

Differential Static Pressure:

Differential Flowing Pressure:

Headloss (feet):

C-Value:

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 1002 W. 27th Terrace # 2722 Missouri

Sketch:

Time 3:27 pm. 3:30 pm.

System: CS

Date: **Time:** 3:27

C-Value or [✓ Hydrant] Test

Main Size: 8" FH Opening Size:

	Static Pressure (psi)	**Flowing Pressure (psi)**	**Flow (gpm)**
Hydrant A:	80	74	NA
Hydrant B:			NA
Flowing Hydrant:		?	
Differential Static Pressure:			
Differential Flowing Pressure:			
Headloss (feet):			
C-Value:			

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: Airport Waterline #7074

Sketch:

System: CS?

Date: 07-22-10 **Time:** ________

C-Value or [✓ Hydrant] Test

Main Size: ________ FH Opening Size: 2 1/2

	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Gauge Hydrant A: #2356	78	73	NA
Hydrant B:			NA
Flow Flowing Hydrant #2355		60	1280 1300

Differential Static Pressure: ________

Differential Flowing Pressure: ________

Headloss (feet): ________

C-Value: ________

HL = 0.002083L(100/C)^1.85*(GPM^1.85/D^4.8655)

Location: 2912 Alabama 2913 Belle Haven Dr.

29th Ter & Alabama

Sketch:

Time 3:40pm 3:42pm

Appendix F
Distribution System Diurnal Curves

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

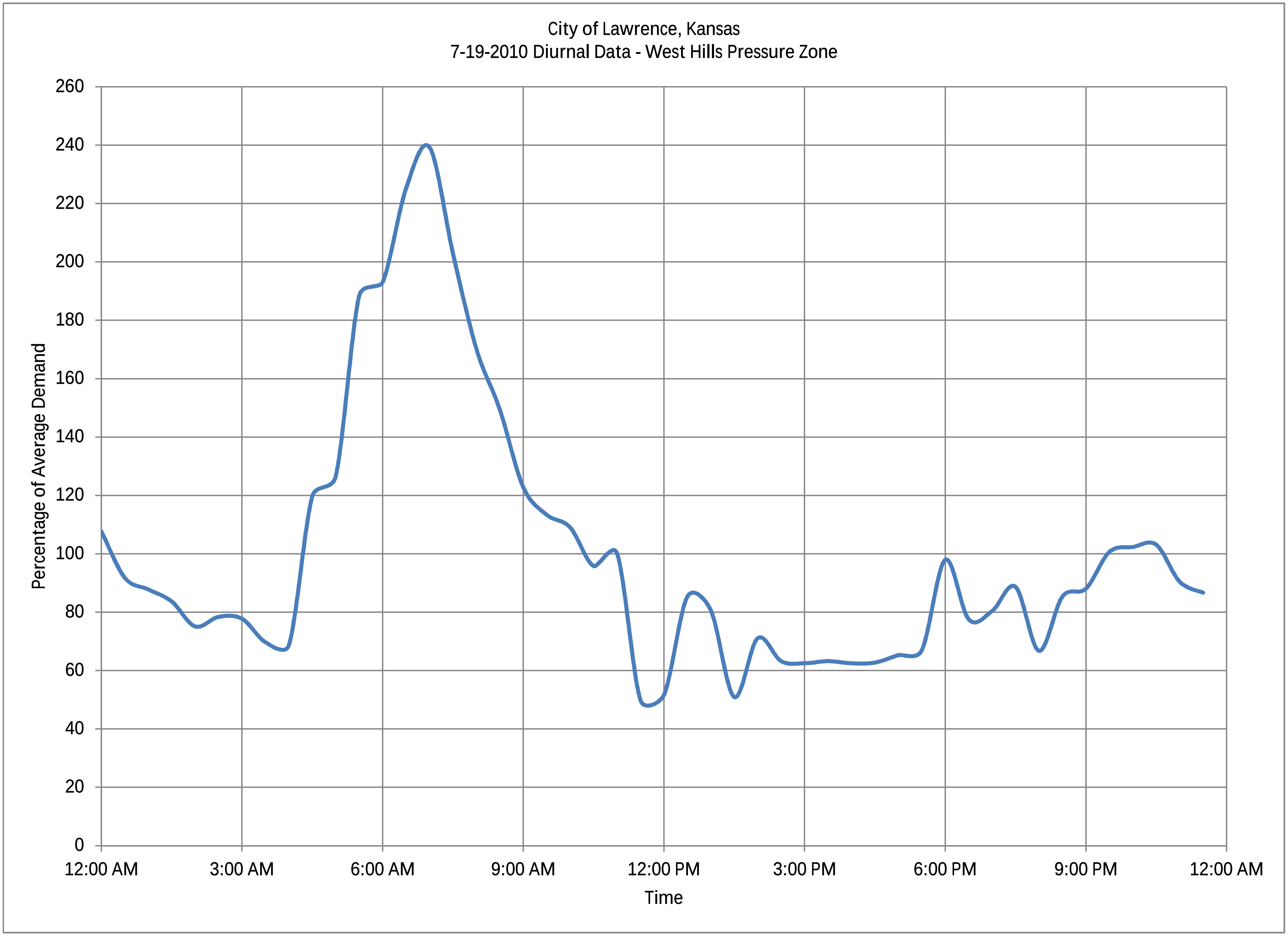
BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

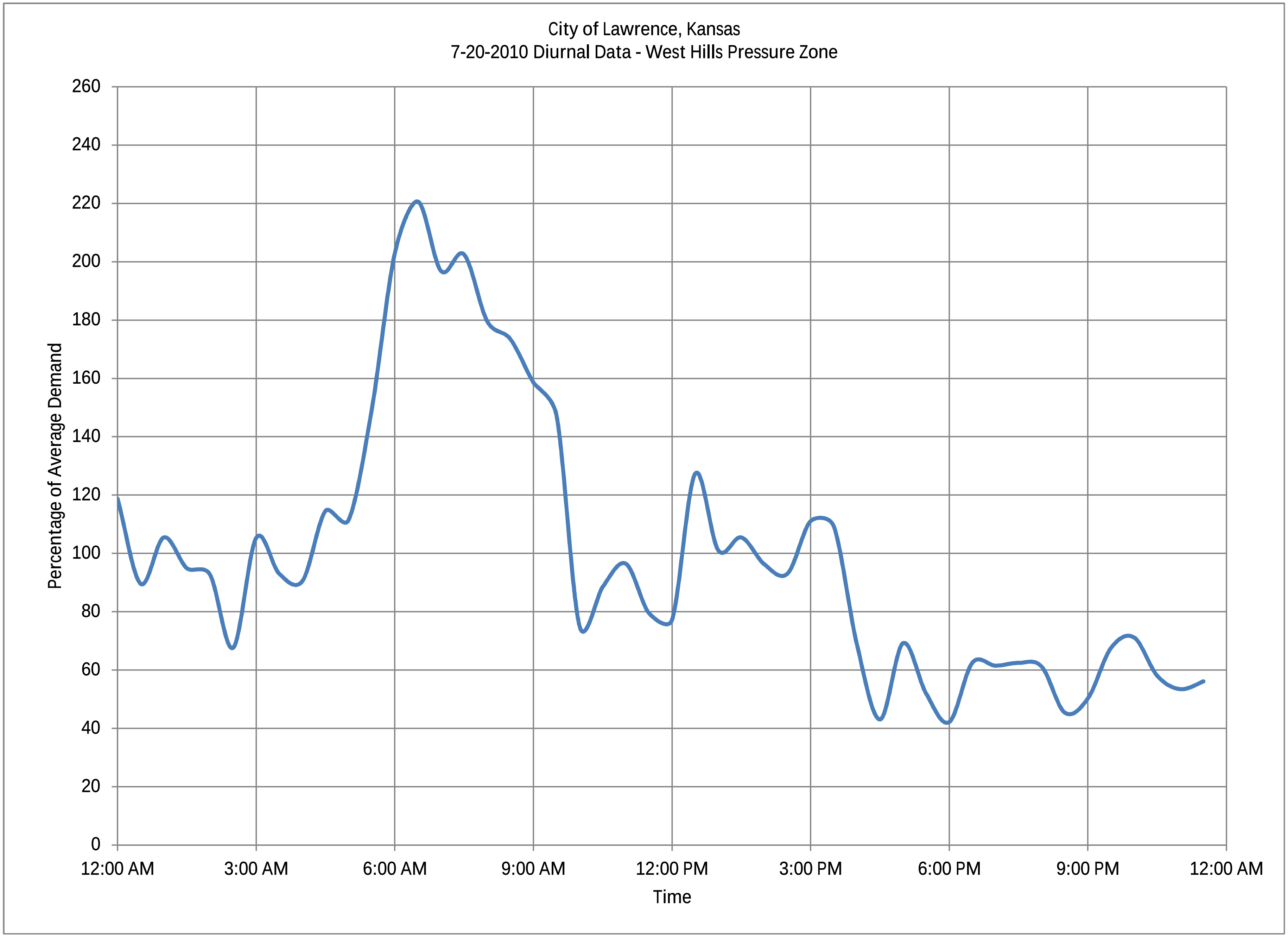
City of Lawrence, Kansas - 2011 Water Master Plan
July 19, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/19/2010	0:00	4.8	0.1000	0.0	0.0	0.0	0.0	3.2	0.0667	1166.3	0.0000	1166.0	0.0000	1168.1	0.0000	0.0	0.0000	0.17		-0.01		108	
7/19/2010	0:30	4.3	0.0896	0.0	0.0	0.0	0.0	3.2	0.0667	1166.5	0.0075	1166.0	0.0000	1168.5	0.0067	0.0	0.0000	0.14	0.01			92	
7/19/2010	1:00	4.2	0.0875	0.0	0.0	0.0	0.0	3.2	0.0667	1166.8	0.0112	1165.9	-0.0013	1169.0	0.0083	0.0	0.0000	0.14	0.02			88	
7/19/2010	1:30	4.2	0.0875	0.0	0.0	0.0	0.0	3.2	0.0667	1167.2	0.0150	1166.0	0.0013	1169.5	0.0083	0.0	0.0000	0.13	0.03			84	
7/19/2010	2:00	4.2	0.0875	0.0	0.0	0.0	0.0	3.2	0.0667	1167.9	0.0262	1166.0	0.0000	1170.2	0.0117	0.0	0.0000	0.12	0.04			75	
7/19/2010	2:30	4.2	0.0875	0.0	0.0	0.0	0.0	3.2	0.0667	1168.5	0.0225	1165.9	-0.0013	1170.9	0.0117	0.0	0.0000	0.12	0.03			78	
7/19/2010	3:00	4.2	0.0875	0.0	0.0	0.0	0.0	3.1	0.0646	1169.0	0.0187	1166.0	0.0013	1171.6	0.0117	0.0	0.0000	0.12	0.03			78	
7/19/2010	3:30	3.2	0.0667	0.0	0.0	0.0	0.0	3.1	0.0646	1169.4	0.0150	1166.0	0.0000	1172.1	0.0083	0.0	0.0000	0.11	0.05			70	
7/19/2010	4:00	2.0	0.0417	0.0	0.0	0.0	0.0	3.1	0.0646	1169.3	-0.0037	1165.9	-0.0013	1172.4	0.0050	0.0	0.0000	0.11	0.05			69	
7/19/2010	4:30	3.4	0.0708	0.0	0.0	0.0	0.0	3.1	0.0646	1168.2	-0.0412	1166.0	0.0013	1171.8	-0.0100	0.0	0.0000	0.19		-0.03		120	
7/19/2010	5:00	5.2	0.1083	0.0	0.0	0.0	0.0	3.1	0.0646	1167.8	-0.0150	1165.9	-0.0013	1171.4	-0.0067	0.0	0.0000	0.20		-0.04		127	
7/19/2010	5:30	5.8	0.1208	0.0	0.0	0.0	0.0	3.2	0.0667	1166.5	-0.0487	1166.0	0.0013	1170.5	-0.0150	2.0	0.0417	0.29		-0.14		188	
7/19/2010	6:00	5.9	0.1229	0.0	0.0	0.0	0.0	3.2	0.0667	1165.0	-0.0562	1165.9	-0.0013	1169.9	-0.0100	2.0	0.0417	0.30		-0.14		193	
7/19/2010	6:30	6.7	0.1396	0.0	0.0	0.0	0.0	3.2	0.0667	1163.0	-0.0750	1165.6	-0.0039	1168.6	-0.0217	2.0	0.0417	0.35		-0.19		225	
7/19/2010	7:00	8.8	0.1833	0.0	0.0	0.0	0.0	3.2	0.0667	1161.7	-0.0487	1165.1	-0.0066	1167.2	-0.0233	2.0	0.0417	0.37		-0.22		239	
7/19/2010	7:30	9.3	0.1938	0.0	0.0	0.0	0.0	3.2	0.0667	1161.6	-0.0037	1165.2	0.0013	1166.5	-0.0117	1.9	0.0396	0.31		-0.16		203	
7/19/2010	8:00	8.7	0.1813	0.0	0.0	0.0	0.0	3.1	0.0646	1161.6	0.0000	1165.1	-0.0013	1167.9	0.0233	1.9	0.0396	0.26		-0.11		170	
7/19/2010	8:30	8.2	0.1708	0.0	0.0	0.0	0.0	3.0	0.0625	1161.6	0.0000	1165.2	0.0013	1170.2	0.0383	1.8	0.0375	0.23		-0.08		149	
7/19/2010	9:00	9.1	0.1896	0.0	0.0	0.0	0.0	0.0	0.0000	1162.6	0.0375	1165.2	0.0000	1170.3	0.0017	1.9	0.0396	0.19		-0.04		123	
7/19/2010	9:30	9.1	0.1896	0.0	0.0	0.0	0.0	0.0	0.0000	1164.0	0.0525	1165.2	0.0000	1168.0	-0.0383	0.0	0.0000	0.18		-0.02		113	
7/19/2010	10:00	8.1	0.1688	0.0	0.0	0.0	0.0	3.1	0.0646	1165.5	0.0562	1165.2	0.0000	1168.5	0.0083	0.0	0.0000	0.17		-0.01		109	
7/19/2010	10:30	8.2	0.1708	0.0	0.0	0.0	0.0	3.1	0.0646	1167.3	0.0675	1165.3	0.0013	1169.6	0.0183	0.0	0.0000	0.15	0.01			96	
7/19/2010	11:00	8.1	0.1688	0.0	0.0	0.0	0.0	3.0	0.0625	1168.8	0.0562	1165.3	0.0000	1170.8	0.0200	0.0	0.0000	0.16	0.00			100	
7/19/2010	11:30	4.7	0.0979	0.0	0.0	0.0	0.0	3.1	0.0646	1170.4	0.0600	1165.2	-0.0013	1172.4	0.0267	0.0	0.0000	0.08	0.08			50	
7/19/2010	12:00	1.8	0.0375	0.0	0.0	0.0	0.0	3.1	0.0646	1170.4	0.0000	1166.5	0.0171	1172.7	0.0050	0.0	0.0000	0.08	0.07			52	
7/19/2010	12:30	2.0	0.0417	0.0	0.0	0.0	0.0	3.1	0.0646	1169.4	-0.0375	1168.4	0.0250	1171.9	-0.0133	0.0	0.0000	0.13	0.02			85	
7/19/2010	13:00	2.0	0.0417	0.0	0.0	0.0	0.0	3.1	0.0646	1169.1	-0.0112	1168.1	-0.0039	1171.7	-0.0033	0.0	0.0000	0.12	0.03			81	
7/19/2010	13:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1168.8	-0.0112	1168.0	-0.0013	1171.6	-0.0017	0.0	0.0000	0.08	0.08			51	
7/19/2010	14:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1167.9	-0.0337	1168.0	0.0000	1170.9	-0.0117	0.0	0.0000	0.11	0.04			71	
7/19/2010	14:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1167.2	-0.0262	1168.1	0.0013	1170.4	-0.0083	0.0	0.0000	0.10	0.06			63	
7/19/2010	15:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1166.6	-0.0225	1168.0	-0.0013	1169.9	-0.0083	0.0	0.0000	0.10	0.06			62	
7/19/2010	15:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1165.9	-0.0262	1168.1	0.0013	1169.4	-0.0083	0.0	0.0000	0.10	0.06			63	
7/19/2010	16:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1165.3	-0.0225	1168.0	-0.0013	1168.9	-0.0083	0.0	0.0000	0.10	0.06			62	
7/19/2010	16:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1164.7	-0.0225	1168.0	0.0000	1168.3	-0.0100	0.0	0.0000	0.10	0.06			63	
7/19/2010	17:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1164.1	-0.0225	1167.7	-0.0039	1167.7	-0.0100	0.0	0.0000	0.10	0.05			65	
7/19/2010	17:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1163.5	-0.0225	1167.2	-0.0066	1167.1	-0.0100	0.0	0.0000	0.10	0.05			67	
7/19/2010	18:00	4.1	0.0854	0.0	0.0	0.0	0.0	3.1	0.0646	1163.2	-0.0112	1167.3	0.0013	1167.6	0.0083	0.0	0.0000	0.15	0.00			98	
7/19/2010	18:30	4.1	0.0854	0.0	0.0	0.0	0.0	3.1	0.0646	1163.2	0.0000	1167.3	0.0000	1169.4	0.0300	0.0	0.0000	0.12	0.03			78	
7/19/2010	19:00	5.1	0.1063	0.0	0.0	0.0	0.0	3.1	0.0646	1164.1	0.0337	1167.5	0.0026	1170.0	0.0100	0.0	0.0000	0.12	0.03			80	
7/19/2010	19:30	5.1	0.1063	0.0	0.0	0.0	0.0	3.1	0.0646	1165.2	0.0412	1167.3	-0.0026	1169.7	-0.0050	0.0	0.0000	0.14	0.02			89	
7/19/2010	20:00	3.3	0.0688	0.0	0.0	0.0	0.0	3.1	0.0646	1166.0	0.0300	1167.3	0.0000	1169.7	0.0000	0.0	0.0000	0.10	0.05			67	
7/19/2010	20:30	3.3	0.0688	0.0	0.0	0.0	0.0	3.1	0.0646	1166.2	0.0075	1167.2	-0.0013	1169.4	-0.0050	0.0	0.0000	0.13	0.02			85	
7/19/2010	21:00	3.3	0.0688	0.0	0.0	0.0	0.0	3.1	0.0646	1166.2	0.0000	1167.1	-0.0013	1169.3	-0.0017	0.0	0.0000	0.14	0.02			88	
7/19/2010	21:30	3.4	0.0708	0.0	0.0	0.0	0.0	3.1	0.0646	1165.8	-0.0150	1167.2	0.0013	1168.9	-0.0067	0.0	0.0000	0.16	0.00			101	
7/19/2010	22:00	3.4	0.0708	0.0	0.0	0.0	0.0	3.1	0.0646	1165.4	-0.0150	1167.1	-0.0013	1168.5	-0.0067	0.0	0.0000	0.16	0.00			102	
7/19/2010	22:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1165.4	0.0000	1167.1	0.0000	1168.3	-0.0033	0.0	0.0000	0.16	0.00			103	
7/19/2010	23:00	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1165.7	0.0112	1167.1	0.0000	1168.6	0.0050	0.0	0.0000	0.14	0.01			90	
7/19/2010	23:30	4.3	0.0896	0.0	0.0	0.0	0.0	3.1	0.0646	1166.1	0.0150	1167.1	0.0000	1168.9	0.0050	0.0	0.0000	0.13	0.02			87	
																		0.15	1.19	-1.19	16.0	119	7.43


City of Lawrence, Kansas
7-19-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

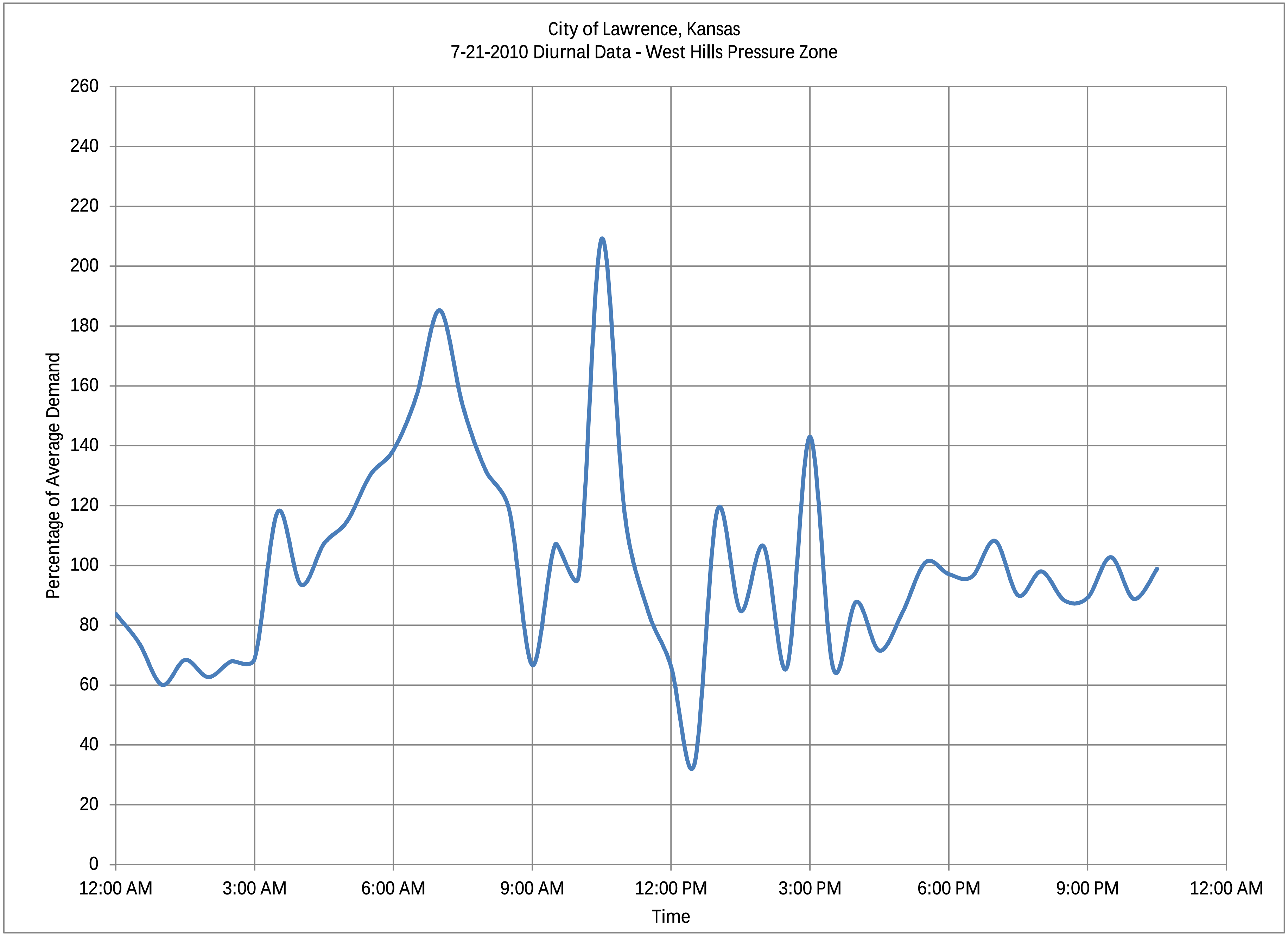
City of Lawrence, Kansas - 2011 Water Master Plan
July 20, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
		Flow	Volume	Flow	Volume	Flow	Volume	Flow	Volume		Volume		Volume		Volume	Flow	Volume						
Date	Time	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	(MGD)	(MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/20/2010	0:00	4.3	0.0890	0.0	0.0	0.0	0.0	3.1	0.0646	1166.7	0.0000	1167.1	0.0000	1169.4	0.0000	0.0	0.0000	0.15		-0.02		119	
7/20/2010	0:30	3.3	0.0693	0.0	0.0	0.0	0.0	3.1	0.0646	1167.0	0.0112	1167.1	0.0000	1169.8	0.0067	0.0	0.0000	0.12	0.01			90	
7/20/2010	1:00	3.4	0.0698	0.0	0.0	0.0	0.0	3.1	0.0646	1166.9	-0.0037	1167.1	0.0000	1169.9	0.0017	0.0	0.0000	0.14		-0.01		105	
7/20/2010	1:30	3.4	0.0707	0.0	0.0	0.0	0.0	3.1	0.0646	1167.1	0.0075	1167.1	0.0000	1170.2	0.0050	0.0	0.0000	0.12	0.01			95	
7/20/2010	2:00	3.4	0.0703	0.0	0.0	0.0	0.0	3.1	0.0646	1167.4	0.0112	1167.0	-0.0013	1170.5	0.0050	0.0	0.0000	0.12	0.01			93	
7/20/2010	2:30	3.4	0.0705	0.0	0.0	0.0	0.0	1.5	0.0313	1167.7	0.0112	1167.1	0.0013	1170.6	0.0017	0.0	0.0000	0.09	0.04			68	
7/20/2010	3:00	4.9	0.1012	0.0	0.0	0.0	0.0	1.6	0.0333	1168.0	0.0112	1167.0	-0.0013	1169.9	-0.0117	0.0	0.0000	0.14		-0.01		105	
7/20/2010	3:30	4.8	0.1000	0.0	0.0	0.0	0.0	1.6	0.0333	1168.4	0.0150	1167.1	0.0013	1169.7	-0.0033	0.0	0.0000	0.12	0.01			93	
7/20/2010	4:00	5.4	0.1126	0.0	0.0	0.0	0.0	1.5	0.0313	1168.9	0.0187	1167.2	0.0013	1170.1	0.0067	0.0	0.0000	0.12	0.01			91	
7/20/2010	4:30	5.4	0.1133	0.0	0.0	0.0	0.0	1.6	0.0333	1168.9	0.0000	1167.2	0.0000	1170.0	-0.0017	0.0	0.0000	0.15		-0.02		115	
7/20/2010	5:00	4.3	0.0900	0.0	0.0	0.0	0.0	3.1	0.0646	1168.9	0.0000	1167.1	-0.0013	1170.7	0.0117	0.0	0.0000	0.14		-0.01		111	
7/20/2010	5:30	4.4	0.0915	0.0	0.0	0.0	0.0	3.1	0.0646	1168.0	-0.0337	1167.1	0.0000	1170.5	-0.0033	0.0	0.0000	0.19		-0.06		149	
7/20/2010	6:00	5.2	0.1084	0.0	0.0	0.0	0.0	4.5	0.0938	1166.6	-0.0525	1167.0	-0.0013	1170.1	-0.0067	0.0	0.0000	0.26		-0.13		203	
7/20/2010	6:30	5.9	0.1231	0.0	0.0	0.0	0.0	4.5	0.0938	1165.8	-0.0300	1167.1	0.0013	1170.2	0.0017	2.0	0.0417	0.29		-0.16		221	
7/20/2010	7:00	5.2	0.1085	0.0	0.0	0.0	0.0	4.5	0.0938	1165.2	-0.0225	1167.1	0.0000	1170.9	0.0117	2.0	0.0417	0.25		-0.13		197	
7/20/2010	7:30	5.2	0.1075	0.0	0.0	0.0	0.0	4.5	0.0938	1164.6	-0.0225	1167.1	0.0000	1171.1	0.0033	2.0	0.0417	0.26		-0.13		202	
7/20/2010	8:00	5.1	0.1062	0.0	0.0	0.0	0.0	4.5	0.0938	1164.7	0.0037	1167.1	0.0000	1171.3	0.0033	1.9	0.0396	0.23		-0.10		180	
7/20/2010	8:30	5.1	0.1058	0.0	0.0	0.0	0.0	4.5	0.0938	1165.0	0.0112	1167.1	0.0000	1171.5	0.0033	1.9	0.0396	0.22		-0.10		173	
7/20/2010	9:00	5.1	0.1065	0.0	0.0	0.0	0.0	4.5	0.0938	1165.7	0.0262	1167.1	0.0000	1172.0	0.0083	1.9	0.0396	0.21		-0.08		159	
7/20/2010	9:30	5.0	0.1044	0.0	0.0	0.0	0.0	4.4	0.0917	1166.5	0.0300	1167.1	0.0000	1172.9	0.0150	1.9	0.0396	0.19		-0.06		147	
7/20/2010	10:00	3.3	0.0678	0.0	0.0	0.0	0.0	1.6	0.0333	1167.1	0.0225	1167.1	0.0000	1171.8	-0.0183	0.0	0.0000	0.10	0.03			75	
7/20/2010	10:30	2.2	0.0459	0.0	0.0	0.0	0.0	0.0	0.0000	1166.3	-0.0300	1167.2	0.0013	1169.4	-0.0400	0.0	0.0000	0.11	0.01			89	
7/20/2010	11:00	2.3	0.0473	0.0	0.0	0.0	0.0	0.0	0.0000	1165.3	-0.0375	1167.2	0.0000	1167.0	-0.0400	0.0	0.0000	0.12	0.00			96	
7/20/2010	11:30	0.0	0.0000	0.0	0.0	0.0	0.0	0.0	0.0000	1163.9	-0.0525	1165.9	-0.0171	1165.0	-0.0333	0.0	0.0000	0.10	0.03			80	
7/20/2010	12:00	0.0	0.0000	0.0	0.0	0.0	0.0	0.0	0.0000	1162.5	-0.0525	1164.7	-0.0158	1163.1	-0.0317	0.0	0.0000	0.10	0.03			77	
7/20/2010	12:30	5.6	0.1169	0.0	0.0	0.0	0.0	0.0	0.0000	1161.8	-0.0262	1164.2	-0.0066	1162.2	-0.0150	0.0	0.0000	0.16		-0.04		127	
7/20/2010	13:00	7.0	0.1454	0.0	0.0	0.0	0.0	1.5	0.0313	1161.7	-0.0037	1164.3	0.0013	1165.1	0.0483	0.0	0.0000	0.13	0.00			101	
7/20/2010	13:30	7.5	0.1556	0.0	0.0	0.0	0.0	3.1	0.0646	1162.5	0.0300	1164.2	-0.0013	1168.4	0.0550	0.0	0.0000	0.14		-0.01		105	
7/20/2010	14:00	7.3	0.1525	0.0	0.0	0.0	0.0	3.1	0.0646	1164.8	0.0862	1164.3	0.0013	1168.7	0.0050	0.0	0.0000	0.12	0.00			96	
7/20/2010	14:30	5.8	0.1216	0.0	0.0	0.0	0.0	3.1	0.0646	1166.2	0.0525	1165.3	0.0132	1168.7	0.0000	0.0	0.0000	0.12	0.01			93	
7/20/2010	15:00	5.8	0.1208	0.0	0.0	0.0	0.0	3.1	0.0646	1166.9	0.0262	1167.1	0.0237	1168.2	-0.0083	0.0	0.0000	0.14		-0.01		111	
7/20/2010	15:30	5.7	0.1184	0.0	0.0	0.0	0.0	3.1	0.0646	1167.7	0.0300	1168.1	0.0132	1168.1	-0.0017	0.0	0.0000	0.14		-0.01		109	
7/20/2010	16:00	3.3	0.0688	0.0	0.0	0.0	0.0	3.1	0.0646	1168.4	0.0262	1168.2	0.0013	1169.1	0.0167	0.0	0.0000	0.09	0.04			69	
7/20/2010	16:30	1.8	0.0370	0.0	0.0	0.0	0.0	3.0	0.0625	1169.0	0.0225	1168.3	0.0013	1170.3	0.0200	0.0	0.0000	0.06	0.07			43	
7/20/2010	17:00	1.9	0.0387	0.0	0.0	0.0	0.0	3.0	0.0625	1169.0	0.0000	1168.3	0.0000	1171.0	0.0117	0.0	0.0000	0.09	0.04			69	
7/20/2010	17:30	1.9	0.0396	0.0	0.0	0.0	0.0	3.0	0.0625	1169.7	0.0262	1168.2	-0.0013	1171.6	0.0100	0.0	0.0000	0.07	0.06			52	
7/20/2010	18:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1169.7	0.0000	1168.2	0.0000	1172.2	0.0100	0.0	0.0000	0.05	0.07			42	
7/20/2010	18:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1169.3	-0.0150	1168.1	-0.0013	1172.2	0.0000	0.0	0.0000	0.08	0.05			63	
7/20/2010	19:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1168.9	-0.0150	1168.1	0.0000	1172.2	0.0000	0.0	0.0000	0.08	0.05			61	
7/20/2010	19:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1168.6	-0.0112	1168.1	0.0000	1171.9	-0.0050	0.0	0.0000	0.08	0.05			62	
7/20/2010	20:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.1	0.0646	1168.3	-0.0112	1168.1	0.0000	1171.7	-0.0033	0.0	0.0000	0.08	0.05			61	
7/20/2010	20:30	0.0	0.0000	0.0	0.0	0.0	0.0	1.6	0.0333	1167.8	-0.0187	1168.1	0.0000	1171.3	-0.0067	0.0	0.0000	0.06	0.07			45	
7/20/2010	21:00	0.0	0.0000	0.0	0.0	0.0	0.0	0.0	0.0000	1166.9	-0.0337	1168.0	-0.0013	1169.5	-0.0300	0.0	0.0000	0.07	0.06			50	
7/20/2010	21:30	3.5	0.0729	0.0	0.0	0.0	0.0	0.0	0.0000	1167.1	0.0075	1168.1	0.0013	1168.1	-0.0233	0.0	0.0000	0.09	0.04			68	
7/20/2010	22:00	4.4	0.0917	0.0	0.0	0.0	0.0	0.0	0.0000	1167.4	0.0112	1168.1	0.0000	1167.4	-0.0117	0.0	0.0000	0.09	0.04			71	
7/20/2010	22:30	4.4	0.0910	0.0	0.0	0.0	0.0	0.0	0.0000	1168.0	0.0225	1168.1	0.0000	1167.0	-0.0067	0.0	0.0000	0.08	0.05			58	
7/20/2010	23:00	3.8	0.0791	0.0	0.0	0.0	0.0	0.0	0.0000	1168.3	0.0112	1168.0	-0.0013	1167.0	0.0000	0.0	0.0000	0.07	0.06			53	
7/20/2010	23:30	3.7	0.0781	0.0	0.0	0.0	0.0	0.0	0.0000	1168.4	0.0037	1168.0	0.0000	1167.1	0.0017	0.0	0.0000	0.07	0.06			56	
																		0.13	1.09	-1.09	17.5	84	6.21


City of Lawrence, Kansas
7-20-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

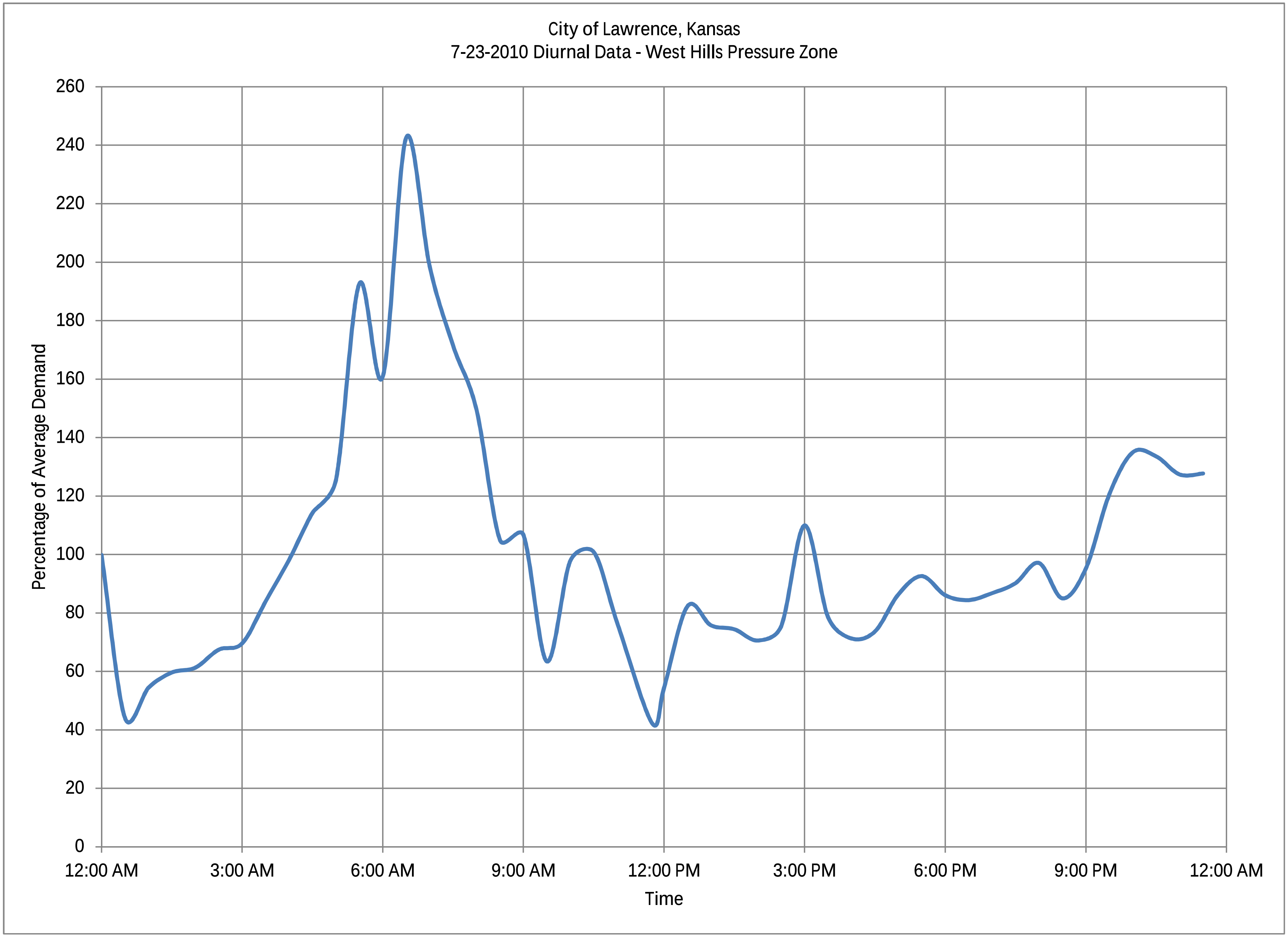
City of Lawrence, Kansas - 2011 Water Master Plan
July 21, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG Elevated Tank		6th & Kasold 0.5 MG Elevated Tank		Stratford 0.5 MG Elevated Tank		19th and Kasold BPS Booster Pump Station		Total Demand	Equalization Storage		Equalization Factor	Diurnal	Total Daily Demand
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS											Fill	Draft			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/21/2010	0:00	3.8	0.0792	0.0	0.0000	0.0	0.0000	0.0	0.0	1168.6	0.0000	1168.1	0.0000	1167.4	0.0000	0.0	0.0000	0.08	0.02			84	
7/21/2010	0:30	3.8	0.0792	0.0	0.0000	0.0	0.0000	0.0	0.0	1168.8	0.0075	1168.1	0.0000	1167.5	0.0017	0.0	0.0000	0.07	0.02			74	
7/21/2010	1:00	3.7	0.0771	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.2	0.0150	1168.0	-0.0013	1167.9	0.0067	0.0	0.0000	0.06	0.04			60	
7/21/2010	1:30	3.0	0.0625	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.1	-0.0037	1168.0	0.0000	1168.0	0.0017	0.0	0.0000	0.06	0.03			68	
7/21/2010	2:00	3.0	0.0625	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.1	0.0000	1168.0	0.0000	1168.2	0.0033	0.0	0.0000	0.06	0.04			63	
7/21/2010	2:30	3.0	0.0625	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.1	0.0000	1168.0	0.0000	1168.1	-0.0017	0.0	0.0000	0.06	0.03			68	
7/21/2010	3:00	3.1	0.0646	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.1	0.0000	1168.1	0.0013	1168.0	-0.0017	0.0	0.0000	0.06	0.03			69	
7/21/2010	3:30	4.5	0.0938	0.0	0.0000	0.0	0.0000	0.0	0.0	1168.8	-0.0112	1168.0	-0.0013	1167.7	-0.0050	0.0	0.0000	0.11		-0.02		118	
7/21/2010	4:00	5.3	0.1104	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.3	0.0187	1168.0	0.0000	1167.9	0.0033	0.0	0.0000	0.09	0.01			94	
7/21/2010	4:30	5.3	0.1104	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.5	0.0075	1168.0	0.0000	1168.0	0.0017	0.0	0.0000	0.10		-0.01		107	
7/21/2010	5:00	5.3	0.1104	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.6	0.0037	1168.0	0.0000	1167.9	-0.0017	0.0	0.0000	0.11		-0.01		115	
7/21/2010	5:30	6.0	0.1250	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.7	0.0037	1168.0	0.0000	1167.8	-0.0017	0.0	0.0000	0.12		-0.03		130	
7/21/2010	6:00	6.0	0.1250	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.6	-0.0037	1168.1	0.0013	1167.6	-0.0033	0.0	0.0000	0.13		-0.04		139	
7/21/2010	6:30	6.0	0.1250	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.2	-0.0150	1168.0	-0.0013	1167.2	-0.0067	0.0	0.0000	0.15		-0.05		157	
7/21/2010	7:00	5.8	0.1208	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.0	-0.0075	1168.1	0.0013	1166.7	-0.0083	1.9	0.0396	0.17		-0.08		185	
7/21/2010	7:30	5.7	0.1188	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.0	0.0000	1168.0	-0.0013	1167.6	0.0150	1.9	0.0396	0.14		-0.05		153	
7/21/2010	8:00	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.0	0.0000	1168.0	0.0000	1169.4	0.0300	1.8	0.0375	0.12		-0.03		132	
7/21/2010	8:30	5.5	0.1146	0.0	0.0000	0.0	0.0000	0.0	0.0	1169.0	0.0000	1168.0	0.0000	1171.8	0.0400	1.8	0.0375	0.11		-0.02		119	
7/21/2010	9:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	0.0	0.0	1167.8	-0.0450	1167.9	-0.0013	1170.8	-0.0167	0.0	0.0000	0.06	0.03			67	
7/21/2010	9:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	0.0	0.0	1166.4	-0.0525	1167.5	-0.0053	1168.2	-0.0433	0.0	0.0000	0.10		-0.01		107	
7/21/2010	10:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	0.0	0.0	1165.3	-0.0412	1166.4	-0.0145	1166.1	-0.0350	0.0	0.0000	0.09	0.00			96	
7/21/2010	10:30	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0	1164.2	-0.0412	1165.8	-0.0079	1164.2	-0.0317	0.0	0.0000	0.20		-0.10		209	
7/21/2010	11:00	9.1	0.1896	0.0	0.0000	0.0	0.0000	0.0	0.0	1165.6	0.0525	1165.8	0.0000	1165.8	0.0267	0.0	0.0000	0.11		-0.02		117	
7/21/2010	11:30	10.1	0.2104	0.0	0.0000	0.0	0.0000	0.0	0.0	1168.4	0.1050	1165.7	-0.0013	1167.4	0.0267	0.0	0.0000	0.08	0.01			85	
7/21/2010	12:00	9.9	0.2063	0.0	0.0000	0.0	0.0000	0.0	0.0	1171.4	0.1125	1165.8	0.0013	1169.2	0.0300	0.0	0.0000	0.06	0.03			66	
7/21/2010	12:30	7.5	0.1563	0.0	0.0000	0.0	0.0000	0.0	0.0	1172.3	0.0337	1167.9	0.0276	1173.0	0.0633	0.0	0.0000	0.03	0.06			33	
7/21/2010	13:00	2.3	0.0479	0.0	0.0000	0.0	0.0000	0.0	0.0	1171.3	-0.0375	1168.3	0.0053	1171.1	-0.0317	0.0	0.0000	0.11		-0.02		118	
7/21/2010	13:30	2.0	0.0417	0.0	0.0000	0.0	0.0000	0.0	0.0	1170.8	-0.0187	1168.2	-0.0013	1170.0	-0.0183	0.0	0.0000	0.08	0.01			85	
7/21/2010	14:00	4.1	0.0854	0.0	0.0000	0.0	0.0000	0.0	0.0	1170.4	-0.0150	1168.2	0.0000	1170.0	0.0000	0.0	0.0000	0.10		-0.01		106	
7/21/2010	14:30	4.1	0.0854	0.0	0.0000	0.0	0.0000	0.0	0.0	1170.4	0.0000	1168.2	0.0000	1171.4	0.0233	0.0	0.0000	0.06	0.03			66	
7/21/2010	15:00	0.0	0.0000	3.1	0.0646	3.8	0.0792	0.0	0.0	1170.1	-0.0112	1168.2	0.0000	1172.6	0.0200	0.0	0.0000	0.14		-0.04		143	
7/21/2010	15:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	0.0	0.0	1170.6	0.0187	1168.2	0.0000	1172.5	-0.0017	0.0	0.0000	0.06	0.03			66	
7/21/2010	16:00	0.0	0.0000	3.0	0.0625	2.3	0.0479	0.0	0.0	1171.6	0.0375	1168.2	0.0000	1171.9	-0.0100	0.0	0.0000	0.08	0.01			88	
7/21/2010	16:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	0.0	0.0	1172.0	0.0150	1168.2	0.0000	1171.7	-0.0033	0.0	0.0000	0.07	0.03			71	
7/21/2010	17:00	0.0	0.0000	2.5	0.0521	1.8	0.0375	0.0	0.0	1172.0	0.0000	1168.2	0.0000	1172.3	0.0100	0.0	0.0000	0.08	0.01			84	
7/21/2010	17:30	0.0	0.0000	2.6	0.0542	1.8	0.0375	0.0	0.0	1171.9	-0.0037	1168.2	0.0000	1172.3	0.0000	0.0	0.0000	0.10	0.00			101	
7/21/2010	18:00	0.0	0.0000	2.5	0.0521	1.8	0.0375	0.0	0.0	1171.8	-0.0037	1168.2	0.0000	1172.4	0.0017	0.0	0.0000	0.09	0.00			97	
7/21/2010	18:30	0.0	0.0000	2.5	0.0521	1.8	0.0375	0.0	0.0	1171.9	0.0037	1168.2	0.0000	1172.1	-0.0050	0.0	0.0000	0.09	0.00			96	
7/21/2010	19:00	0.0	0.0000	2.6	0.0542	1.8	0.0375	0.0	0.0	1171.7	-0.0075	1168.1	-0.0013	1172.0	-0.0017	0.0	0.0000	0.10		-0.01		108	
7/21/2010	19:30	0.0	0.0000	2.6	0.0542	1.8	0.0375	0.0	0.0	1171.8	0.0037	1168.2	0.0013	1172.1	0.0017	0.0	0.0000	0.08	0.01			90	
7/21/2010	20:00	0.0	0.0000	2.6	0.0542	1.9	0.0396	0.0	0.0	1171.7	-0.0037	1168.2	0.0000	1172.4	0.0050	0.0	0.0000	0.09	0.00			98	
7/21/2010	20:30	0.0	0.0000	2.6	0.0542	1.8	0.0375	0.0	0.0	1171.7	0.0000	1168.2	0.0000	1172.9	0.0083	0.0	0.0000	0.08	0.01			88	
7/21/2010	21:00	0.0	0.0000	2.6	0.0542	1.8	0.0375	0.0	0.0	1171.8	0.0037	1168.1	-0.0013	1173.2	0.0050	0.0	0.0000	0.08	0.01			89	
7/21/2010	21:30	0.0	0.0000	2.6	0.0542	1.8	0.0375	0.0	0.0	1171.8	0.0000	1168.2	0.0013	1172.8	-0.0067	0.0	0.0000	0.10	0.00			103	
7/21/2010	22:00	0.0	0.0000	2.5	0.0521	1.8	0.0375	0.0	0.0	1171.9	0.0037	1168.1	-0.0013	1173.0	0.0033	0.0	0.0000	0.08	0.01			89	
7/21/2010	22:30	0.0	0.0000	2.5	0.0521	1.8	0.0375	0.0	0.0	1171.8	-0.0037	1168.1	0.0000	1173.0	0.0000	0.0	0.0000	0.09	0.00			99	
7/21/2010	23:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	0.0	0.0	1171.7	-0.0037	1168.1	0.0000	1173.4	0.0067	0.0	0.0000	0.00				-3	
7/21/2010	23:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	0.0	0.0	1170.5	-0.0450	1168.1	0.0000	1171.6	-0.0300	0.0	0.0000	0.07				79	
																		0.09	0.53	-0.53	12.2	84	4.34


City of Lawrence, Kansas
7-21-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

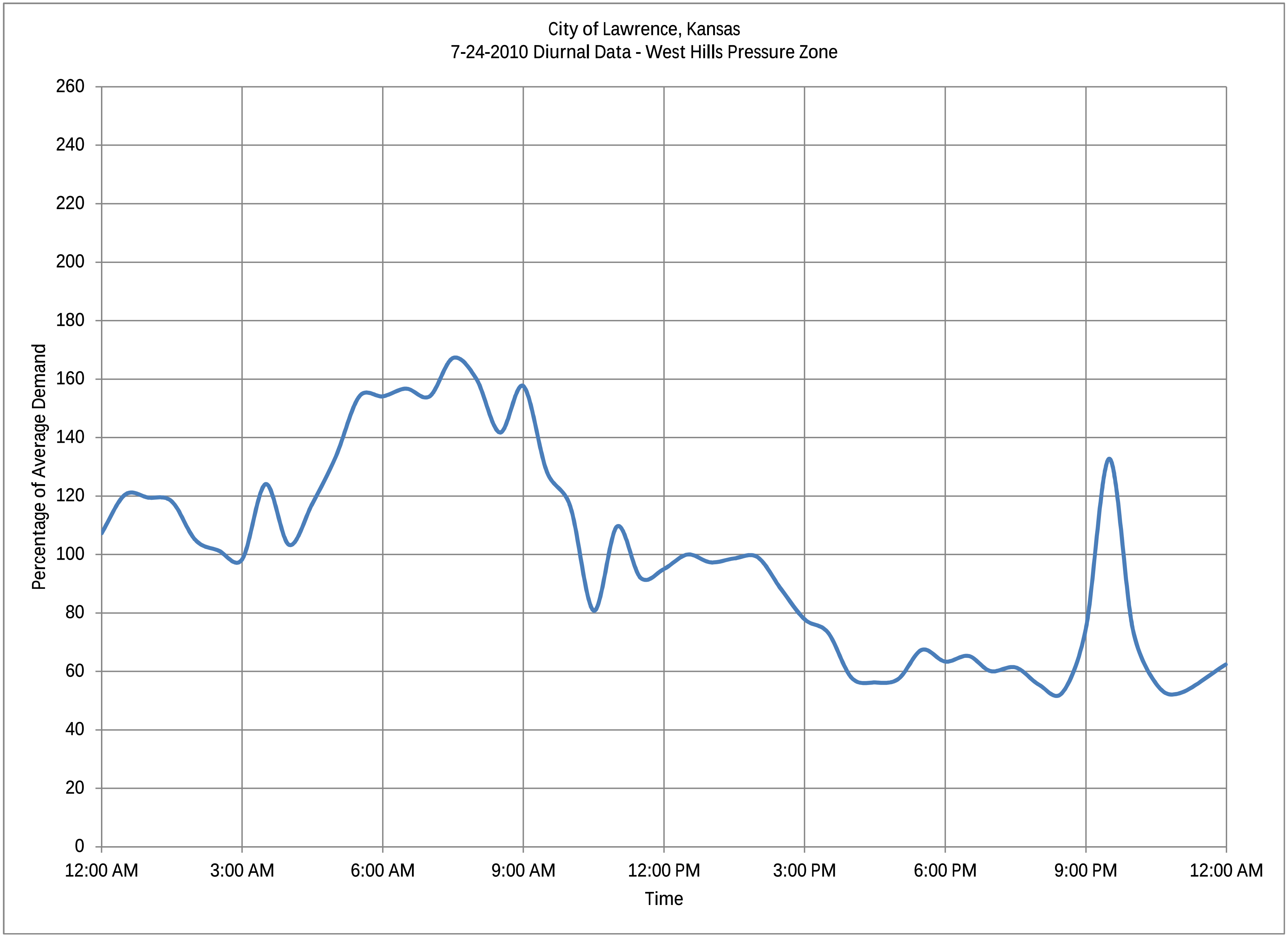
City of Lawrence, Kansas - 2011 Water Master Plan
July 23, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
		Flow	Volume	Flow	Volume	Flow	Volume	Flow	Volume		Volume		Volume		Volume	Flow	Volume						
Date	Time	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	(MGD)	(MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/23/2010	0:00	4.2	0.0875	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.3	0.0000	1168.1	0.0000	1169.2	0.0000	0.0	0.0000	0.12	0.00			100	
7/23/2010	0:30	2.2	0.0458	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.5	0.0075	1168.1	0.0000	1170.3	0.0183	0.0	0.0000	0.05	0.07			44	
7/23/2010	1:00	2.1	0.0438	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.4	-0.0037	1168.1	0.0000	1171.2	0.0150	0.0	0.0000	0.07	0.06			54	
7/23/2010	1:30	2.2	0.0458	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.4	0.0000	1168.0	-0.0013	1171.7	0.0083	0.0	0.0000	0.07	0.05			60	
7/23/2010	2:00	2.2	0.0458	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.4	0.0000	1168.0	0.0000	1172.0	0.0050	0.0	0.0000	0.07	0.05			61	
7/23/2010	2:30	2.2	0.0458	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.3	-0.0037	1168.1	0.0013	1172.0	0.0000	0.0	0.0000	0.08	0.04			67	
7/23/2010	3:00	2.2	0.0458	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.2	-0.0037	1168.0	-0.0013	1172.0	0.0000	0.0	0.0000	0.08	0.04			70	
7/23/2010	3:30	2.3	0.0479	0.0	0.0000	0.0	0.0000	1.6	0.0333	1169.8	-0.0150	1168.1	0.0013	1171.6	-0.0067	0.0	0.0000	0.10	0.02			84	
7/23/2010	4:00	2.3	0.0479	0.0	0.0000	0.0	0.0000	1.6	0.0333	1169.1	-0.0262	1168.0	-0.0013	1171.0	-0.0100	0.0	0.0000	0.12	0.00			98	
7/23/2010	4:30	2.5	0.0521	0.0	0.0000	0.0	0.0000	1.7	0.0354	1168.2	-0.0337	1168.1	0.0013	1169.9	-0.0183	0.0	0.0000	0.14		-0.02		114	
7/23/2010	5:00	2.6	0.0542	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.6	-0.0600	1167.9	-0.0026	1167.8	-0.0350	0.0	0.0000	0.15		-0.03		125	
7/23/2010	5:30	6.1	0.1271	0.0	0.0000	0.0	0.0000	0.0	0.0000	1165.1	-0.0562	1166.9	-0.0132	1165.6	-0.0367	0.0	0.0000	0.23		-0.11		193	
7/23/2010	6:00	6.0	0.1250	0.0	0.0000	0.0	0.0000	0.0	0.0000	1164.7	-0.0150	1166.8	-0.0013	1164.9	-0.0117	2.0	0.0417	0.19		-0.07		161	
7/23/2010	6:30	8.1	0.1688	0.0	0.0000	0.0	0.0000	1.7	0.0354	1164.0	-0.0262	1166.3	-0.0066	1164.0	-0.0150	2.0	0.0417	0.29		-0.17		243	
7/23/2010	7:00	9.5	0.1979	0.0	0.0000	0.0	0.0000	1.7	0.0354	1164.6	0.0225	1166.3	0.0000	1164.6	0.0100	1.9	0.0396	0.24		-0.12		199	
7/23/2010	7:30	9.4	0.1958	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.8	0.0450	1166.3	0.0000	1165.7	0.0183	1.9	0.0396	0.21		-0.09		171	
7/23/2010	8:00	9.1	0.1896	0.0	0.0000	0.0	0.0000	1.7	0.0354	1167.4	0.0600	1166.2	-0.0013	1167.2	0.0250	1.9	0.0396	0.18		-0.06		149	
7/23/2010	8:30	8.9	0.1854	0.0	0.0000	0.0	0.0000	0.0	0.0000	1169.3	0.0712	1166.3	0.0013	1168.6	0.0233	1.8	0.0375	0.13		-0.01		105	
7/23/2010	9:00	9.0	0.1875	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.4	0.0412	1167.6	0.0171	1168.6	0.0000	0.0	0.0000	0.13		-0.01		107	
7/23/2010	9:30	5.0	0.1042	0.0	0.0000	0.0	0.0000	0.0	0.0000	1171.0	0.0225	1168.1	0.0066	1168.5	-0.0017	0.0	0.0000	0.08	0.04			63	
7/23/2010	10:00	5.0	0.1042	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.8	-0.0075	1168.1	0.0000	1168.1	-0.0067	0.0	0.0000	0.12	0.00			98	
7/23/2010	10:30	4.8	0.1000	0.0	0.0000	0.0	0.0000	1.5	0.0313	1170.6	-0.0075	1168.1	0.0000	1169.1	0.0167	0.0	0.0000	0.12	0.00			101	
7/23/2010	11:00	4.7	0.0979	0.0	0.0000	0.0	0.0000	1.5	0.0313	1170.6	0.0000	1168.2	0.0013	1171.2	0.0350	0.0	0.0000	0.09	0.03			77	
7/23/2010	11:45	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.5	0.0469	1170.0	-0.0225	1168.2	0.0000	1172.3	0.0183	0.0	0.0000	0.05	0.07			42	
7/23/2010	12:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.5	0.0313	1169.4	-0.0225	1168.3	0.0013	1171.5	-0.0133	0.0	0.0000	0.07	0.06			54	
7/23/2010	12:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.6	0.0333	1168.3	-0.0412	1168.3	0.0000	1170.0	-0.0250	0.0	0.0000	0.10	0.02			82	
7/23/2010	13:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.5	0.0313	1167.3	-0.0375	1168.2	-0.0013	1168.7	-0.0217	0.0	0.0000	0.09	0.03			76	
7/23/2010	13:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.5	0.0313	1166.3	-0.0375	1168.1	-0.0013	1167.5	-0.0200	0.0	0.0000	0.09	0.03			74	
7/23/2010	14:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.5	0.0313	1165.3	-0.0375	1168.1	0.0000	1166.5	-0.0167	0.0	0.0000	0.09	0.04			71	
7/23/2010	14:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.6	0.0333	1164.4	-0.0337	1167.4	-0.0092	1165.6	-0.0150	0.0	0.0000	0.09	0.03			75	
7/23/2010	15:00	0.0	0.0000	2.2	0.0458	1.9	0.0396	1.5	0.0313	1163.9	-0.0187	1167.2	-0.0026	1165.9	0.0050	0.0	0.0000	0.13		-0.01		110	
7/23/2010	15:30	0.0	0.0000	2.2	0.0458	1.9	0.0396	1.5	0.0313	1163.8	-0.0037	1167.1	-0.0013	1167.5	0.0267	0.0	0.0000	0.10	0.03			79	
7/23/2010	16:00	0.0	0.0000	2.1	0.0438	1.9	0.0396	1.5	0.0313	1163.8	0.0000	1167.1	0.0000	1169.2	0.0283	0.0	0.0000	0.09	0.03			71	
7/23/2010	16:30	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.5	0.0313	1163.8	0.0000	1167.1	0.0000	1170.6	0.0233	0.0	0.0000	0.09	0.03			74	
7/23/2010	17:00	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.6	0.0333	1164.7	0.0337	1167.2	0.0013	1169.1	-0.0250	0.0	0.0000	0.10	0.02			86	
7/23/2010	17:30	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.5	0.0313	1165.2	0.0187	1167.2	0.0000	1168.0	-0.0183	0.0	0.0000	0.11	0.01			93	
7/23/2010	18:00	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.6	0.0333	1165.7	0.0187	1167.2	0.0000	1167.5	-0.0083	0.0	0.0000	0.10	0.02			86	
7/23/2010	18:30	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.5	0.0313	1166.1	0.0150	1167.1	-0.0013	1167.3	-0.0033	0.0	0.0000	0.10	0.02			84	
7/23/2010	19:00	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.6	0.0333	1166.4	0.0112	1167.1	0.0000	1167.2	-0.0017	0.0	0.0000	0.11	0.02			87	
7/23/2010	19:30	0.0	0.0000	2.1	0.0438	1.8	0.0375	1.6	0.0333	1166.5	0.0037	1167.1	0.0000	1167.3	0.0017	0.0	0.0000	0.11	0.01			90	
7/23/2010	20:00	0.0	0.0000	2.1	0.0438	1.8	0.0375	3.1	0.0646	1166.9	0.0150	1167.1	0.0000	1168.1	0.0133	0.0	0.0000	0.12	0.00			97	
7/23/2010	20:30	0.0	0.0000	2.1	0.0438	1.8	0.0375	3.1	0.0646	1167.4	0.0187	1167.8	0.0092	1169.0	0.0150	0.0	0.0000	0.10	0.02			85	
7/23/2010	21:00	0.0	0.0000	2.1	0.0438	1.8	0.0375	3.1	0.0646	1167.8	0.0150	1168.1	0.0039	1169.7	0.0117	0.0	0.0000	0.12	0.01			95	
7/23/2010	21:30	0.0	0.0000	2.1	0.0438	1.8	0.0375	3.1	0.0646	1167.7	-0.0037	1168.0	-0.0013	1170.0	0.0050	0.0	0.0000	0.15		-0.02		121	
7/23/2010	22:00	0.0	0.0000	2.7	0.0563	2.2	0.0458	3.1	0.0646	1167.7	0.0000	1168.0	0.0000	1170.2	0.0033	0.0	0.0000	0.16		-0.04		135	
7/23/2010	22:30	0.0	0.0000	2.8	0.0583	2.2	0.0458	3.1	0.0646	1167.8	0.0037	1168.0	0.0000	1170.4	0.0033	0.0	0.0000	0.16		-0.04		134	
7/23/2010	23:00	0.0	0.0000	2.8	0.0583	2.1	0.0438	3.1	0.0646	1168.0	0.0075	1168.0	0.0000	1170.7	0.0050	0.0	0.0000	0.15		-0.03		127	
7/23/2010	23:30	0.0	0.0000	2.8	0.0583	2.2	0.0458	3.1	0.0646	1168.2	0.0075	1168.0	0.0000	1171.1	0.0067	0.0	0.0000	0.15		-0.03		128	
																		0.12	0.87	-0.87	15.0	107	5.81


City of Lawrence, Kansas
7-23-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

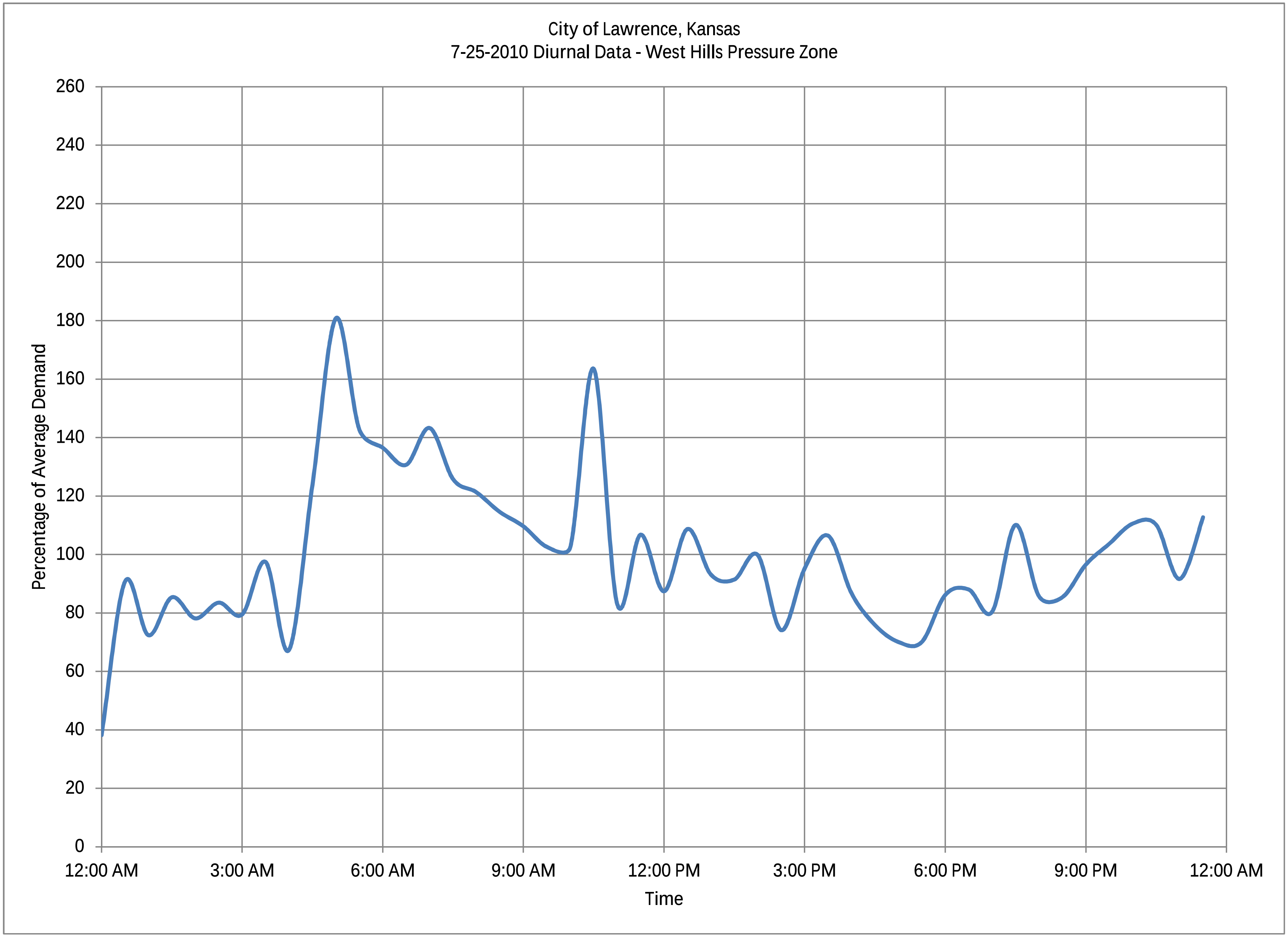
City of Lawrence, Kansas - 2011 Water Master Plan
July 24, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG Elevated Tank		6th & Kasold 0.5 MG Elevated Tank		Stratford 0.5 MG Elevated Tank		19th and Kasold BPS Booster Pump Station		Total Demand	Equalization Storage		Equalization Factor	Diurnal	Total Daily Demand
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS											Fill	Draft			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/24/2010	0:00	0.0	0.0000	2.7	0.0563	2.2	0.0458	1.6	0.0333	1168.7	0.0000	1168.0	0.0000	1171.5	0.0000	0.0	0.0000	0.14		-0.01		107	
7/24/2010	0:30	0.0	0.0000	2.7	0.0563	2.1	0.0438	1.6	0.0333	1168.6	-0.0037	1168.0	0.0000	1170.6	-0.0150	0.0	0.0000	0.15		-0.03		120	
7/24/2010	1:00	0.0	0.0000	2.8	0.0583	2.1	0.0438	1.6	0.0333	1168.5	-0.0037	1168.0	0.0000	1169.9	-0.0117	0.0	0.0000	0.15		-0.02		119	
7/24/2010	1:30	0.0	0.0000	2.7	0.0563	2.1	0.0438	1.6	0.0333	1168.3	-0.0075	1168.0	0.0000	1169.4	-0.0083	0.0	0.0000	0.15		-0.02		118	
7/24/2010	2:00	0.0	0.0000	2.7	0.0563	2.1	0.0438	1.6	0.0333	1168.4	0.0037	1167.9	-0.0013	1169.3	-0.0017	0.0	0.0000	0.13		-0.01		105	
7/24/2010	2:30	0.0	0.0000	2.7	0.0563	2.1	0.0438	1.6	0.0333	1168.5	0.0037	1167.9	0.0000	1169.4	0.0017	0.0	0.0000	0.13	0.00			101	
7/24/2010	3:00	0.0	0.0000	2.7	0.0563	2.2	0.0458	1.6	0.0333	1168.8	0.0112	1167.9	0.0000	1169.4	0.0000	0.0	0.0000	0.12	0.00			98	
7/24/2010	3:30	0.0	0.0000	2.1	0.0438	1.6	0.0333	1.6	0.0333	1168.7	-0.0037	1167.9	0.0000	1169.6	0.0033	2.2	0.0458	0.16		-0.03		124	
7/24/2010	4:00	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.6	0.0333	1169.0	0.0112	1167.9	0.0000	1170.6	0.0167	2.2	0.0458	0.13		0.00		103	
7/24/2010	4:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.6	0.0333	1169.0	0.0000	1167.9	0.0000	1171.2	0.0100	2.2	0.0458	0.15		-0.02		117	
7/24/2010	5:00	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.6	0.0333	1168.6	-0.0150	1168.0	0.0013	1171.4	0.0033	2.2	0.0458	0.17		-0.04		134	
7/24/2010	5:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.6	0.0333	1167.8	-0.0300	1168.0	0.0000	1170.9	-0.0083	2.1	0.0438	0.19		-0.07		154	
7/24/2010	6:00	0.0	0.0000	2.3	0.0479	1.6	0.0333	1.6	0.0333	1167.1	-0.0262	1168.0	0.0000	1170.3	-0.0100	2.1	0.0438	0.19		-0.07		154	
7/24/2010	6:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.6	0.0333	1166.3	-0.0300	1168.0	0.0000	1169.6	-0.0117	2.1	0.0438	0.20		-0.07		157	
7/24/2010	7:00	0.0	0.0000	2.2	0.0458	1.7	0.0354	1.6	0.0333	1165.6	-0.0262	1168.0	0.0000	1169.0	-0.0100	2.1	0.0438	0.19		-0.07		154	
7/24/2010	7:30	0.0	0.0000	2.3	0.0479	1.7	0.0354	3.2	0.0667	1164.5	-0.0412	1167.5	-0.0066	1168.2	-0.0133	0.0	0.0000	0.21		-0.08		167	
7/24/2010	8:00	0.0	0.0000	2.3	0.0479	1.7	0.0354	3.2	0.0667	1163.6	-0.0337	1167.0	-0.0066	1167.5	-0.0117	0.0	0.0000	0.20		-0.08		160	
7/24/2010	8:30	0.0	0.0000	2.3	0.0479	1.7	0.0354	3.2	0.0667	1163.2	-0.0150	1166.7	-0.0039	1166.9	-0.0100	0.0	0.0000	0.18		-0.05		142	
7/24/2010	9:00	0.0	0.0000	3.0	0.0625	2.4	0.0500	3.2	0.0667	1162.9	-0.0112	1166.3	-0.0053	1166.7	-0.0033	0.0	0.0000	0.20		-0.07		158	
7/24/2010	9:30	0.0	0.0000	3.0	0.0625	2.4	0.0500	3.1	0.0646	1162.9	0.0000	1166.3	0.0000	1167.6	0.0150	0.0	0.0000	0.16		-0.04		128	
7/24/2010	10:00	0.0	0.0000	3.0	0.0625	2.3	0.0479	3.1	0.0646	1162.8	-0.0037	1166.3	0.0000	1169.5	0.0317	0.0	0.0000	0.15		-0.02		116	
7/24/2010	10:30	0.0	0.0000	2.5	0.0521	1.9	0.0396	1.6	0.0333	1162.8	0.0000	1166.4	0.0013	1170.8	0.0217	0.0	0.0000	0.10	0.02			81	
7/24/2010	11:00	0.0	0.0000	2.5	0.0521	1.9	0.0396	1.6	0.0333	1162.7	-0.0037	1166.3	-0.0013	1170.3	-0.0083	0.0	0.0000	0.14		-0.01		110	
7/24/2010	11:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.6	0.0333	1162.7	0.0000	1166.4	0.0013	1170.0	-0.0050	0.0	0.0000	0.12	0.01			92	
7/24/2010	12:00	0.0	0.0000	2.2	0.0458	1.7	0.0354	1.7	0.0354	1163.1	0.0150	1166.4	0.0000	1168.9	-0.0183	0.0	0.0000	0.12	0.01			95	
7/24/2010	12:30	0.0	0.0000	2.3	0.0479	1.7	0.0354	1.7	0.0354	1163.7	0.0225	1166.4	0.0000	1167.1	-0.0300	0.0	0.0000	0.13	0.00			100	
7/24/2010	13:00	0.0	0.0000	2.3	0.0479	1.6	0.0333	1.7	0.0354	1163.9	0.0075	1166.5	0.0013	1166.2	-0.0150	0.0	0.0000	0.12	0.00			97	
7/24/2010	13:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1163.9	0.0000	1166.5	0.0000	1165.6	-0.0100	0.0	0.0000	0.12	0.00			99	
7/24/2010	14:00	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1163.7	-0.0075	1166.4	-0.0013	1165.5	-0.0017	0.0	0.0000	0.13	0.00			99	
7/24/2010	14:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1163.7	0.0000	1166.4	0.0000	1165.7	0.0033	0.0	0.0000	0.11	0.02			88	
7/24/2010	15:00	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1163.7	0.0000	1166.5	0.0013	1166.6	0.0150	0.0	0.0000	0.10	0.03			78	
7/24/2010	15:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1163.7	0.0000	1167.8	0.0171	1166.9	0.0050	0.0	0.0000	0.09	0.03			73	
7/24/2010	16:00	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1164.8	0.0412	1168.2	0.0053	1166.6	-0.0050	0.0	0.0000	0.07	0.05			58	
7/24/2010	16:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1165.9	0.0412	1168.0	-0.0026	1166.9	0.0050	0.0	0.0000	0.07	0.06			56	
7/24/2010	17:00	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1166.8	0.0337	1168.0	0.0000	1167.4	0.0083	0.0	0.0000	0.07	0.05			57	
7/24/2010	17:30	0.0	0.0000	2.2	0.0458	1.6	0.0333	1.7	0.0354	1167.4	0.0225	1167.9	-0.0013	1167.9	0.0083	0.0	0.0000	0.09	0.04			67	
7/24/2010	18:00	0.0	0.0000	2.1	0.0438	1.6	0.0333	1.7	0.0354	1168.0	0.0225	1167.9	0.0000	1168.5	0.0100	0.0	0.0000	0.08	0.05			63	
7/24/2010	18:30	0.0	0.0000	2.1	0.0438	1.6	0.0333	1.7	0.0354	1168.5	0.0187	1168.0	0.0013	1169.1	0.0100	0.0	0.0000	0.08	0.04			65	
7/24/2010	18:58	0.0	0.0000	2.1	0.0408	1.6	0.0311	1.7	0.0331	1169.0	0.0187	1167.9	-0.0013	1169.8	0.0117	0.0	0.0000	0.08	0.05			60	
7/24/2010	19:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1168.1	-0.0337	1167.9	0.0000	1169.3	-0.0083	0.0	0.0000	0.08	0.05			61	
7/24/2010	20:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1167.4	-0.0262	1167.9	0.0000	1168.8	-0.0083	0.0	0.0000	0.07	0.06			55	
7/24/2010	20:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.8	-0.0225	1168.0	0.0013	1168.2	-0.0100	0.0	0.0000	0.07	0.06			53	
7/24/2010	21:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.7	-0.0412	1167.8	-0.0026	1167.3	-0.0150	0.0	0.0000	0.09	0.03			75	
7/24/2010	21:30	5.8	0.1208	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.6	-0.0037	1167.6	-0.0026	1167.0	-0.0050	0.0	0.0000	0.17		-0.04		133	
7/24/2010	22:00	5.8	0.1208	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.9	0.0487	1167.6	0.0000	1167.8	0.0133	0.0	0.0000	0.09	0.03			75	
7/24/2010	22:30	5.7	0.1188	0.0	0.0000	0.0	0.0000	1.7	0.0354	1168.6	0.0637	1167.6	0.0000	1169.0	0.0200	0.0	0.0000	0.07	0.06			56	
7/24/2010	23:00	5.6	0.1167	0.0	0.0000	0.0	0.0000	1.6	0.0333	1170.2	0.0600	1167.5	-0.0013	1170.5	0.0250	0.0	0.0000	0.07	0.06			53	
7/24/2010	23:59	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0697	1169.7	-0.0187	1167.6	0.0013	1171.0	0.0083	0.0	0.0000	0.08	0.05			62	
																		0.13	0.86	-0.86	14.2	38	6.06


City of Lawrence, Kansas
7-24-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
July 25, 2010 Diurnal Data
West Hills Pressure Zone

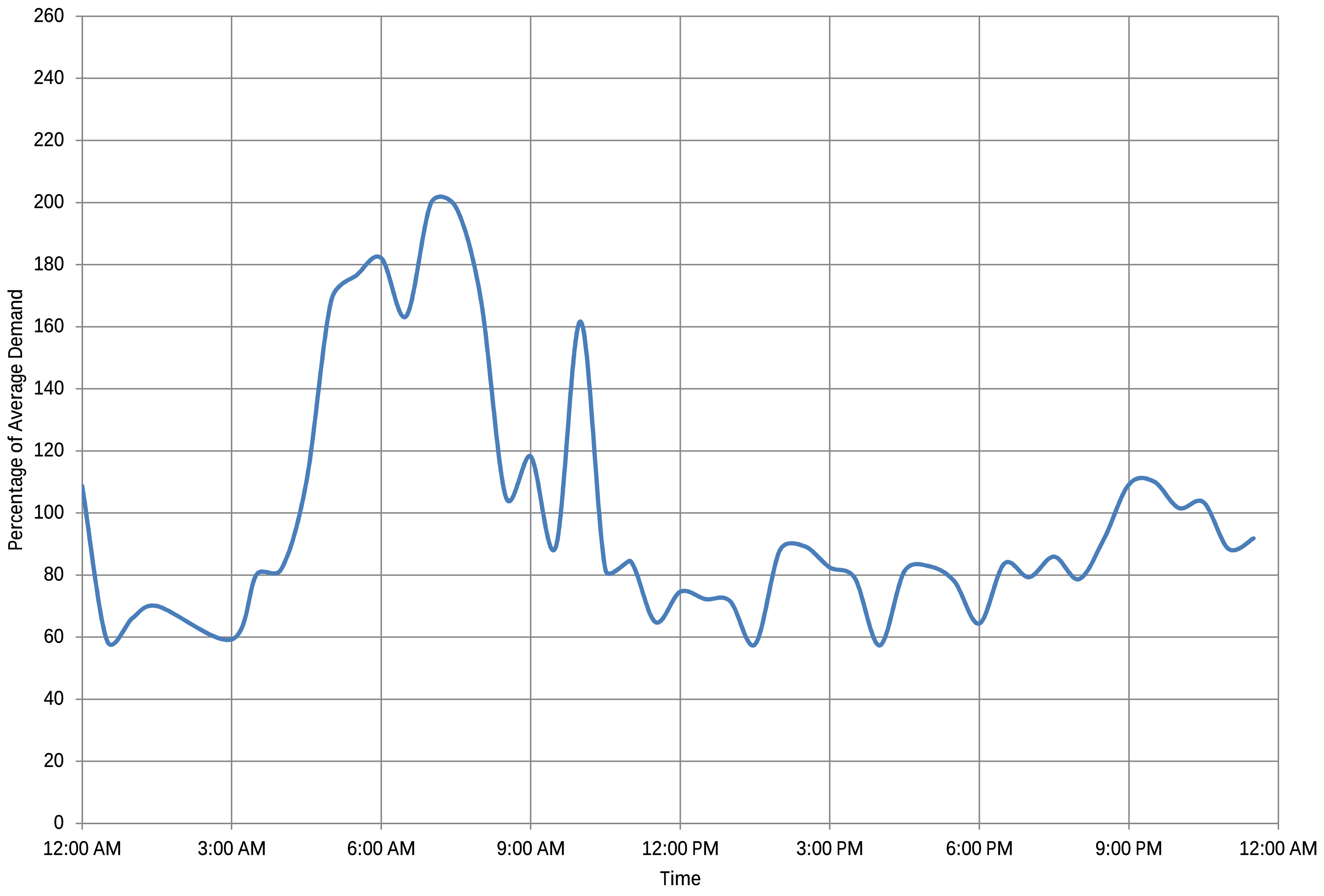
		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/25/2010	0:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1169.7	0.0000	1167.6	0.0000	1171.0	0.0000	0.0	0.0000	0.04	0.06			38	
7/25/2010	0:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1169.1	-0.0225	1167.6	0.0000	1171.3	0.0050	0.0	0.0000	0.08	0.01			91	
7/25/2010	1:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1168.9	-0.0075	1167.5	-0.0013	1171.8	0.0083	0.0	0.0000	0.07	0.03			72	
7/25/2010	1:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1168.4	-0.0187	1168.1	0.0079	1171.7	-0.0017	0.0	0.0000	0.08	0.01			85	
7/25/2010	2:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1168.2	-0.0075	1168.1	0.0000	1171.8	0.0017	0.0	0.0000	0.07	0.02			78	
7/25/2010	2:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1168.0	-0.0075	1168.1	0.0000	1171.6	-0.0033	0.0	0.0000	0.08	0.02			84	
7/25/2010	3:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1167.9	-0.0037	1168.1	0.0000	1171.4	-0.0033	0.0	0.0000	0.07	0.02			79	
7/25/2010	3:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	3.2	0.0667	1167.4	-0.0187	1168.1	0.0000	1171.1	-0.0050	0.0	0.0000	0.09	0.00			97	
7/25/2010	4:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.9	-0.0187	1168.1	0.0000	1170.6	-0.0083	0.0	0.0000	0.06	0.03			67	
7/25/2010	4:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.8	-0.0412	1167.6	-0.0066	1168.7	-0.0317	0.0	0.0000	0.11		-0.02		124	
7/25/2010	5:00	4.6	0.0958	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.5	-0.0112	1167.2	-0.0053	1167.5	-0.0200	0.0	0.0000	0.17		-0.07		181	
7/25/2010	5:30	4.6	0.0958	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.7	0.0075	1167.3	0.0013	1166.9	-0.0100	0.0	0.0000	0.13		-0.04		143	
7/25/2010	6:00	4.5	0.0938	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.9	0.0075	1167.3	0.0000	1166.6	-0.0050	0.0	0.0000	0.13		-0.03		137	
7/25/2010	6:30	4.4	0.0917	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.1	0.0075	1167.3	0.0000	1166.5	-0.0017	0.0	0.0000	0.12		-0.03		131	
7/25/2010	7:00	4.3	0.0896	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.8	0.0262	1167.3	0.0000	1167.2	0.0117	2.2	0.0458	0.13		-0.04		143	
7/25/2010	7:30	4.3	0.0896	0.0	0.0000	0.0	0.0000	1.6	0.0333	1167.7	0.0337	1167.3	0.0000	1168.3	0.0183	2.2	0.0458	0.12		-0.02		126	
7/25/2010	8:00	4.2	0.0875	0.0	0.0000	0.0	0.0000	1.6	0.0333	1168.6	0.0337	1167.3	0.0000	1169.4	0.0183	2.1	0.0438	0.11		-0.02		121	
7/25/2010	8:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1167.2	-0.0525	1167.3	0.0000	1168.3	-0.0183	0.0	0.0000	0.11		-0.01		115	
7/25/2010	9:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.0	-0.0450	1167.2	-0.0013	1167.1	-0.0200	0.0	0.0000	0.10		-0.01		110	
7/25/2010	9:30	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.0	-0.0375	1166.9	-0.0039	1166.0	-0.0183	0.0	0.0000	0.10	0.00			103	
7/25/2010	10:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	1.7	0.0354	1164.1	-0.0337	1166.2	-0.0092	1165.0	-0.0167	0.0	0.0000	0.10	0.00			102	
7/25/2010	10:30	0.0	0.0000	2.4	0.0500	1.7	0.0354	0.0	0.0000	1163.2	-0.0337	1165.5	-0.0092	1163.6	-0.0233	0.0	0.0000	0.15		-0.06		164	
7/25/2010	11:00	0.0	0.0000	0.0	0.0000	0.0	0.0000	0.0	0.0000	1162.3	-0.0337	1164.1	-0.0184	1162.1	-0.0250	0.0	0.0000	0.08	0.02			83	
7/25/2010	11:30	4.1	0.0854	0.0	0.0000	0.0	0.0000	0.0	0.0000	1162.3	0.0000	1164.3	0.0026	1163.5	0.0233	1.9	0.0396	0.10		-0.01		107	
7/25/2010	12:00	4.3	0.0896	0.0	0.0000	0.0	0.0000	0.0	0.0000	1162.2	-0.0037	1165.2	0.0118	1165.9	0.0400	1.9	0.0396	0.08	0.01			87	
7/25/2010	12:30	4.5	0.0938	0.0	0.0000	0.0	0.0000	0.0	0.0000	1163.3	0.0412	1165.8	0.0079	1165.4	-0.0083	2.3	0.0479	0.10		-0.01		109	
7/25/2010	13:00	4.4	0.0917	0.0	0.0000	0.0	0.0000	0.0	0.0000	1164.5	0.0450	1166.8	0.0132	1165.1	-0.0050	2.3	0.0479	0.09	0.01			93	
7/25/2010	13:30	4.4	0.0917	0.0	0.0000	0.0	0.0000	0.0	0.0000	1165.6	0.0412	1167.7	0.0118	1165.2	0.0017	2.3	0.0479	0.08	0.01			91	
7/25/2010	14:00	4.3	0.0896	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.4	0.0300	1168.2	0.0066	1165.7	0.0083	2.3	0.0479	0.09	0.00			100	
7/25/2010	14:30	4.7	0.0979	0.0	0.0000	0.0	0.0000	0.0	0.0000	1167.0	0.0225	1168.2	0.0000	1166.1	0.0067	0.0	0.0000	0.07	0.02			74	
7/25/2010	15:00	4.8	0.1000	0.0	0.0000	0.0	0.0000	0.0	0.0000	1167.0	0.0000	1168.2	0.0000	1166.8	0.0117	0.0	0.0000	0.09	0.00			95	
7/25/2010	15:30	4.8	0.1000	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.9	-0.0037	1168.2	0.0000	1167.1	0.0050	0.0	0.0000	0.10		-0.01		106	
7/25/2010	16:00	4.6	0.0958	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.9	0.0000	1168.1	-0.0013	1168.1	0.0167	0.0	0.0000	0.08	0.01			87	
7/25/2010	16:30	4.5	0.0938	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.9	0.0000	1168.1	0.0000	1169.5	0.0233	0.0	0.0000	0.07	0.02			76	
7/25/2010	17:00	3.9	0.0813	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.8	-0.0037	1168.1	0.0000	1170.7	0.0200	0.0	0.0000	0.07	0.03			70	
7/25/2010	17:30	3.2	0.0667	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.8	0.0000	1168.1	0.0000	1170.8	0.0017	0.0	0.0000	0.07	0.03			70	
7/25/2010	18:00	3.0	0.0625	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.7	-0.0037	1168.2	0.0013	1169.9	-0.0150	0.0	0.0000	0.08	0.01			86	
7/25/2010	18:30	3.6	0.0750	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.7	0.0000	1168.2	0.0000	1169.5	-0.0067	0.0	0.0000	0.08	0.01			88	
7/25/2010	19:00	3.6	0.0750	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.8	0.0037	1168.2	0.0000	1169.3	-0.0033	0.0	0.0000	0.07	0.02			80	
7/25/2010	19:30	3.0	0.0625	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.8	0.0000	1168.1	-0.0013	1169.0	-0.0050	1.6	0.0333	0.10		-0.01		110	
7/25/2010	20:00	2.0	0.0417	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.7	-0.0037	1168.2	0.0013	1168.5	-0.0083	1.3	0.0271	0.08	0.01			86	
7/25/2010	20:30	1.9	0.0396	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.8	0.0037	1168.1	-0.0013	1167.6	-0.0150	1.3	0.0271	0.08	0.01			85	
7/25/2010	21:00	2.0	0.0417	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.6	-0.0075	1168.1	0.0000	1166.8	-0.0133	1.3	0.0271	0.09	0.00			97	
7/25/2010	21:30	2.1	0.0438	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.2	-0.0150	1168.2	0.0013	1166.1	-0.0117	1.3	0.0271	0.10	0.00			104	
7/25/2010	22:00	4.2	0.0875	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.1	-0.0037	1168.1	-0.0013	1165.5	-0.0100	0.0	0.0000	0.10		-0.01		111	
7/25/2010	22:30	4.2	0.0875	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.0	-0.0037	1167.9	-0.0026	1165.0	-0.0083	0.0	0.0000	0.10		-0.01		110	
7/25/2010	23:00	4.2	0.0875	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.2	0.0075	1167.9	0.0000	1164.7	-0.0050	0.0	0.0000	0.09	0.01			92	
7/25/2010	23:30	4.1	0.0854	0.0	0.0000	0.0	0.0000	1.7	0.0354	1166.5	0.0112	1167.9	0.0000	1165.0	0.0050	0.0	0.0000	0.10		-0.01		113	
																		0.09	0.42	-0.42	9.5	109	4.45


City of Lawrence, Kansas
7-25-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
July 26, 2010 Diurnal Data
West Hills Pressure Zone

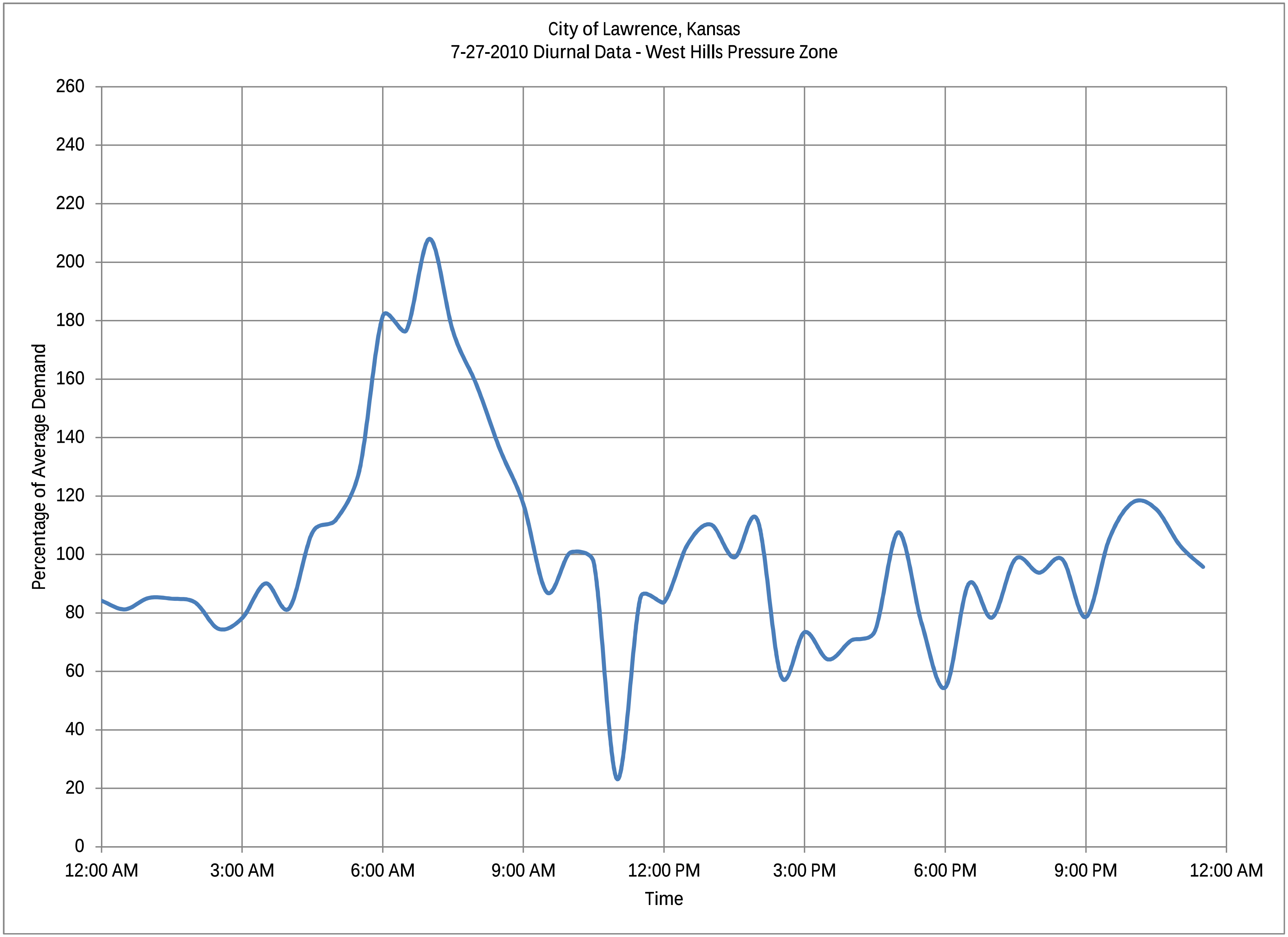
		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/26/2010	0:00	4.1	0.0854	0.0	0.0	0.0	0.0	1.7	0.0354	1167.4	0.0000	1167.9	0.0000	1166.2	0.0000	0.0	0.0000	0.12		-0.01		109	
7/26/2010	0:30	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1168.0	0.0225	1167.9	0.0000	1167.3	0.0183	0.0	0.0000	0.07	0.05			59	
7/26/2010	1:00	3.2	0.0667	0.0	0.0	0.0	0.0	1.7	0.0354	1168.4	0.0150	1167.8	-0.0013	1168.2	0.0150	0.0	0.0000	0.07	0.04			66	
7/26/2010	1:30	3.2	0.0667	0.0	0.0	0.0	0.0	1.7	0.0354	1168.7	0.0112	1167.9	0.0013	1168.9	0.0117	0.0	0.0000	0.08	0.03			70	
7/26/2010	2:00	2.7	0.0563	0.0	0.0	0.0	0.0	3.2	0.0667	Bad		Bad		Bad		Bad	Bad	Bad					
7/26/2010	2:30	2.2	0.0458	0.0	0.0	0.0	0.0	3.2	0.0667	1170.1		1167.9		1171.5		0.0	0.0000	0.11				101	
7/26/2010	3:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.2	0.0667	1169.8	-0.0112	1167.8	-0.0013	1172.3	0.0133	0.0	0.0000	0.07	0.05			59	
7/26/2010	3:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.2	0.0667	1169.2	-0.0225	1167.8	0.0000	1172.3	0.0000	0.0	0.0000	0.09	0.02			80	
7/26/2010	4:00	0.0	0.0000	0.0	0.0	0.0	0.0	3.2	0.0667	1168.6	-0.0225	1167.9	0.0013	1172.1	-0.0033	0.0	0.0000	0.09	0.02			82	
7/26/2010	4:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.2	0.0667	1167.5	-0.0412	1167.8	-0.0013	1171.3	-0.0133	0.0	0.0000	0.12		-0.01		110	
7/26/2010	5:00	2.4	0.0500	0.0	0.0	0.0	0.0	3.2	0.0667	1166.1	-0.0525	1167.8	0.0000	1170.2	-0.0183	0.0	0.0000	0.19		-0.08		169	
7/26/2010	5:30	5.1	0.1063	0.0	0.0	0.0	0.0	3.2	0.0667	1165.7	-0.0150	1167.8	0.0000	1169.7	-0.0083	0.0	0.0000	0.20		-0.09		176	
7/26/2010	6:00	5.8	0.1208	0.0	0.0	0.0	0.0	3.1	0.0646	1166.2	0.0187	1167.8	0.0000	1170.3	0.0100	2.2	0.0458	0.20		-0.09		182	
7/26/2010	6:30	2.4	0.0500	0.0	0.0	0.0	0.0	3.2	0.0667	1165.6	-0.0225	1167.8	0.0000	1170.5	0.0033	2.2	0.0458	0.18		-0.07		163	
7/26/2010	7:00	2.4	0.0500	0.0	0.0	0.0	0.0	3.2	0.0667	1164.3	-0.0487	1167.6	-0.0026	1170.0	-0.0083	2.2	0.0458	0.22		-0.11		200	
7/26/2010	7:30	2.4	0.0500	0.0	0.0	0.0	0.0	3.2	0.0667	1163.2	-0.0412	1167.2	-0.0053	1169.3	-0.0117	2.2	0.0458	0.22		-0.11		198	
7/26/2010	8:00	2.5	0.0521	0.0	0.0	0.0	0.0	1.7	0.0354	1162.7	-0.0187	1166.4	-0.0105	1167.8	-0.0250	2.2	0.0458	0.19		-0.08		169	
7/26/2010	8:30	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1162.1	-0.0225	1165.9	-0.0066	1166.4	-0.0233	1.4	0.0292	0.12		-0.01		105	
7/26/2010	9:00	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1161.3	-0.0300	1165.0	-0.0118	1164.9	-0.0250	1.4	0.0292	0.13		-0.02		118	
7/26/2010	9:30	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1160.5	-0.0300	1164.1	-0.0118	1163.6	-0.0217	0.0	0.0000	0.10	0.01			89	
7/26/2010	10:00	4.0	0.0833	0.0	0.0	0.0	0.0	1.7	0.0354	1160.3	-0.0075	1163.9	-0.0026	1162.3	-0.0217	1.4	0.0292	0.18		-0.07		162	
7/26/2010	10:30	7.8	0.1625	0.0	0.0	0.0	0.0	1.7	0.0354	1162.6	0.0862	1165.9	0.0263	1163.6	0.0217	1.3	0.0271	0.09	0.02			82	
7/26/2010	11:00	7.6	0.1583	0.0	0.0	0.0	0.0	1.7	0.0354	1164.8	0.0825	1167.5	0.0211	1165.0	0.0233	1.3	0.0271	0.09	0.02			84	
7/26/2010	11:30	6.7	0.1396	0.0	0.0	0.0	0.0	1.6	0.0333	1166.7	0.0712	1168.1	0.0079	1166.3	0.0217	0.0	0.0000	0.07	0.04			65	
7/26/2010	12:00	5.8	0.1208	0.0	0.0	0.0	0.0	1.6	0.0333	1168.1	0.0525	1168.0	-0.0013	1167.5	0.0200	0.0	0.0000	0.08	0.03			75	
7/26/2010	12:30	5.7	0.1188	0.0	0.0	0.0	0.0	1.6	0.0333	1169.4	0.0487	1168.1	0.0013	1168.8	0.0217	0.0	0.0000	0.08	0.03			72	
7/26/2010	13:00	5.6	0.1167	0.0	0.0	0.0	0.0	1.6	0.0333	1170.7	0.0487	1168.1	0.0000	1170.1	0.0217	0.0	0.0000	0.08	0.03			72	
7/26/2010	13:30	2.1	0.0438	0.0	0.0	0.0	0.0	1.6	0.0333	1170.7	0.0000	1168.2	0.0013	1170.8	0.0117	0.0	0.0000	0.06	0.05			58	
7/26/2010	14:00	2.1	0.0438	0.0	0.0	0.0	0.0	1.6	0.0333	1170.1	-0.0225	1168.2	0.0000	1170.9	0.0017	0.0	0.0000	0.10	0.01			88	
7/26/2010	14:30	2.2	0.0458	0.0	0.0	0.0	0.0	1.6	0.0333	1169.6	-0.0187	1168.1	-0.0013	1170.9	0.0000	0.0	0.0000	0.10	0.01			89	
7/26/2010	15:00	2.1	0.0438	0.0	0.0	0.0	0.0	1.6	0.0333	1169.3	-0.0112	1168.1	0.0000	1170.7	-0.0033	0.0	0.0000	0.09	0.02			82	
7/26/2010	15:30	2.2	0.0458	0.0	0.0	0.0	0.0	1.6	0.0333	1169.2	-0.0037	1168.1	0.0000	1170.4	-0.0050	0.0	0.0000	0.09	0.02			79	
7/26/2010	16:00	1.0	0.0208	0.0	0.0	0.0	0.0	1.7	0.0354	1169.0	-0.0075	1168.1	0.0000	1170.4	0.0000	0.0	0.0000	0.06	0.05			57	
7/26/2010	16:30	2.3	0.0479	0.0	0.0	0.0	0.0	1.7	0.0354	1168.9	-0.0037	1168.1	0.0000	1170.2	-0.0033	0.0	0.0000	0.09	0.02			81	
7/26/2010	17:00	2.2	0.0458	0.0	0.0	0.0	0.0	1.7	0.0354	1168.7	-0.0075	1168.1	0.0000	1170.0	-0.0033	0.0	0.0000	0.09	0.02			83	
7/26/2010	17:30	2.3	0.0479	0.0	0.0	0.0	0.0	1.6	0.0333	1168.6	-0.0037	1168.1	0.0000	1169.9	-0.0017	0.0	0.0000	0.09	0.02			78	
7/26/2010	18:00	2.3	0.0479	0.0	0.0	0.0	0.0	0.0	0.0000	1168.2	-0.0150	1168.2	0.0013	1169.3	-0.0100	0.0	0.0000	0.07	0.04			64	
7/26/2010	18:30	2.3	0.0479	0.0	0.0	0.0	0.0	0.0	0.0000	1167.6	-0.0225	1168.0	-0.0026	1168.1	-0.0200	0.0	0.0000	0.09	0.02			84	
7/26/2010	19:00	2.4	0.0500	0.0	0.0	0.0	0.0	0.0	0.0000	1167.0	-0.0225	1168.2	0.0026	1167.0	-0.0183	0.0	0.0000	0.09	0.02			79	
7/26/2010	19:30	2.4	0.0500	0.0	0.0	0.0	0.0	0.0	0.0000	1166.3	-0.0262	1168.0	-0.0026	1166.0	-0.0167	0.0	0.0000	0.10	0.02			86	
7/26/2010	20:00	2.5	0.0521	0.0	0.0	0.0	0.0	0.0	0.0000	1165.8	-0.0187	1168.0	0.0000	1165.0	-0.0167	0.0	0.0000	0.09	0.02			79	
7/26/2010	20:30	3.5	0.0729	0.0	0.0	0.0	0.0	0.0	0.0000	1165.4	-0.0150	1167.7	-0.0039	1164.4	-0.0100	0.0	0.0000	0.10	0.01			92	
7/26/2010	21:00	5.2	0.1083	0.0	0.0	0.0	0.0	0.0	0.0000	1165.3	-0.0037	1167.5	-0.0026	1164.0	-0.0067	0.0	0.0000	0.12		-0.01		109	
7/26/2010	21:30	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1165.6	0.0112	1167.5	0.0000	1164.6	0.0100	0.0	0.0000	0.12		-0.01		110	
7/26/2010	22:00	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1166.1	0.0187	1167.4	-0.0013	1165.4	0.0133	0.0	0.0000	0.11	0.00			102	
7/26/2010	22:30	5.1	0.1063	0.0	0.0	0.0	0.0	1.7	0.0354	1166.5	0.0150	1167.4	0.0000	1166.1	0.0117	0.0	0.0000	0.12	0.00			103	
7/26/2010	23:00	5.1	0.1063	0.0	0.0	0.0	0.0	1.7	0.0354	1167.3	0.0300	1167.4	0.0000	1166.9	0.0133	0.0	0.0000	0.10	0.01			88	
7/26/2010	23:30	5.1	0.1063	0.0	0.0	0.0	0.0	1.7	0.0354	1168.0	0.0262	1167.4	0.0000	1167.7	0.0133	0.0	0.0000	0.10	0.01			92	
																		0.11	0.76	-0.76	14.8	84	5.23

City of Lawrence, Kansas
7-26-2010 Diurnal Data - West Hills Pressure Zone



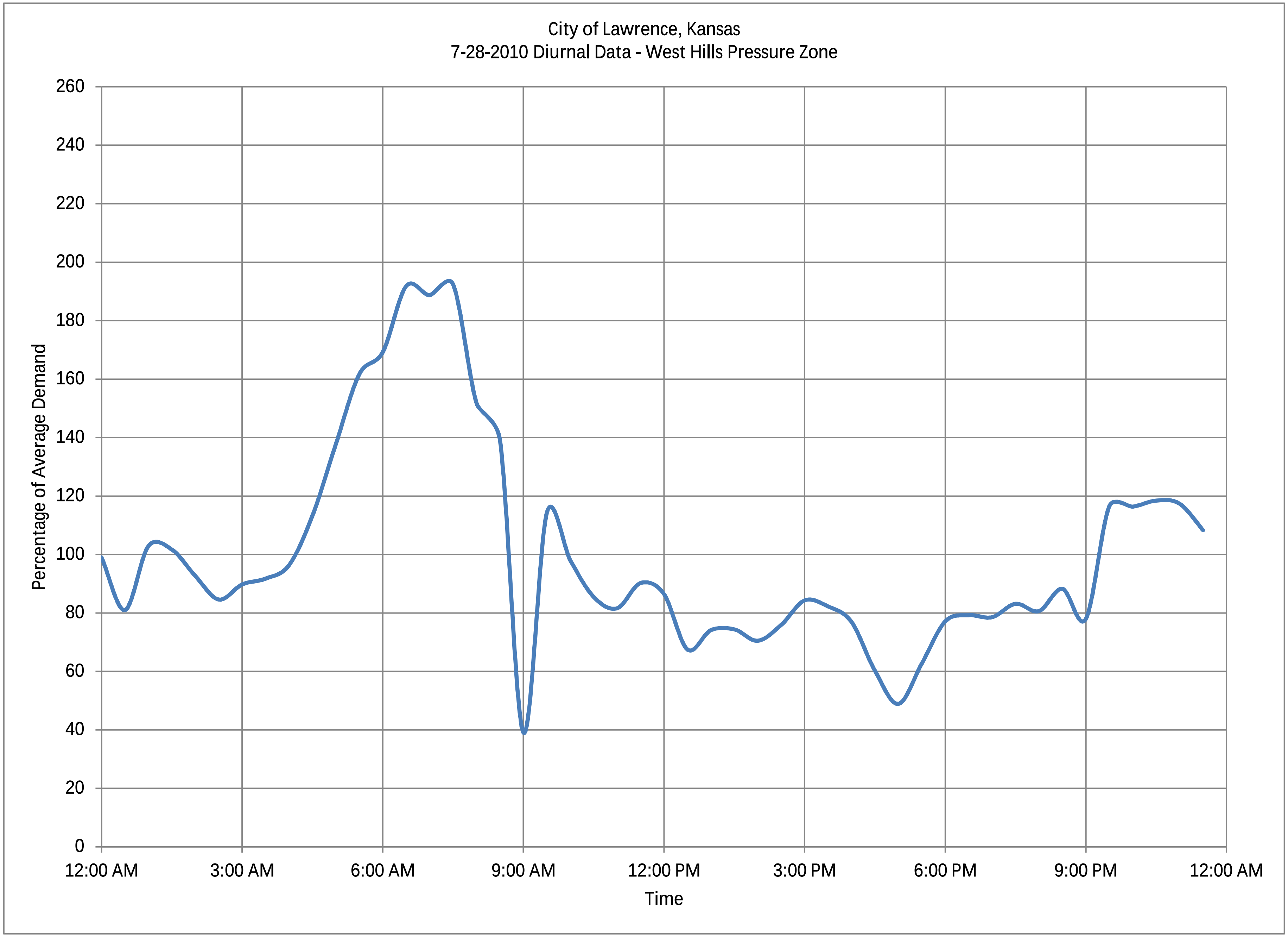
City of Lawrence, Kansas - 2011 Water Master Plan
July 27, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG Elevated Tank		6th & Kasold 0.5 MG Elevated Tank		Stratford 0.5 MG Elevated Tank		19th and Kasold BPS Booster Pump Station		Total Demand	Equalization Storage		Equalization Factor	Diurnal	Total Daily Demand
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS											Fill	Draft			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/27/2010	0:00	5.1	0.1063	0.0	0.0	0.0	0.0	0	0.0000	1168.8	0.0000	1167.5	0.0000	1168.6	0.0000	0.0	0.0000	0.11	0.02			84	
7/27/2010	0:30	5.0	0.1042	0.0	0.0	0.0	0.0	0	0.0000	1169.1	0.0112	1167.4	-0.0013	1168.1	-0.0083	0.0	0.0000	0.10	0.02			81	
7/27/2010	1:00	5.0	0.1042	0.0	0.0	0.0	0.0	0	0.0000	1169.2	0.0037	1167.5	0.0013	1167.6	-0.0083	0.0	0.0000	0.11	0.02			85	
7/27/2010	1:30	5.1	0.1063	0.0	0.0	0.0	0.0	0	0.0000	1169.3	0.0037	1167.4	-0.0013	1167.4	-0.0033	0.0	0.0000	0.11	0.02			85	
7/27/2010	2:00	5.1	0.1063	0.0	0.0	0.0	0.0	0	0.0000	1169.4	0.0037	1167.3	-0.0013	1167.3	-0.0017	0.0	0.0000	0.11	0.02			84	
7/27/2010	2:30	5.1	0.1063	0.0	0.0	0.0	0.0	0	0.0000	1169.6	0.0075	1167.4	0.0013	1167.5	0.0033	0.0	0.0000	0.09	0.03			75	
7/27/2010	3:00	5.1	0.1063	0.0	0.0	0.0	0.0	0	0.0000	1169.8	0.0075	1167.4	0.0000	1167.5	0.0000	0.0	0.0000	0.10	0.03			78	
7/27/2010	3:30	5.8	0.1208	0.0	0.0	0.0	0.0	0	0.0000	1169.9	0.0037	1167.4	0.0000	1167.7	0.0033	0.0	0.0000	0.11	0.01			90	
7/27/2010	4:00	5.9	0.1229	0.0	0.0	0.0	0.0	0	0.0000	1170.3	0.0150	1167.4	0.0000	1168.0	0.0050	0.0	0.0000	0.10	0.02			82	
7/27/2010	4:30	5.9	0.1229	0.0	0.0	0.0	0.0	0	0.0000	1170.0	-0.0112	1167.4	0.0000	1167.9	-0.0017	0.0	0.0000	0.14		-0.01		108	
7/27/2010	5:00	5.9	0.1229	0.0	0.0	0.0	0.0	0	0.0000	1169.6	-0.0150	1167.4	0.0000	1167.7	-0.0033	0.0	0.0000	0.14		-0.01		112	
7/27/2010	5:30	5.9	0.1229	0.0	0.0	0.0	0.0	0	0.0000	1168.9	-0.0262	1167.4	0.0000	1166.9	-0.0133	0.0	0.0000	0.16		-0.04		129	
7/27/2010	6:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1167.6	-0.0487	1167.4	0.0000	1165.7	-0.0200	0.0	0.0000	0.23		-0.10		182	
7/27/2010	6:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1166.8	-0.0300	1167.3	-0.0013	1165.7	0.0000	1.5	0.0313	0.22		-0.10		177	
7/27/2010	7:00	7.4	0.1542	0.0	0.0	0.0	0.0	1.7	0.0354	1165.9	-0.0337	1167.2	-0.0013	1165.3	-0.0067	1.5	0.0313	0.26		-0.14		208	
7/27/2010	7:30	8.0	0.1667	0.0	0.0	0.0	0.0	1.7	0.0354	1166.0	0.0037	1167.2	0.0000	1165.6	0.0050	1.4	0.0292	0.22		-0.10		176	
7/27/2010	8:00	7.6	0.1583	0.0	0.0	0.0	0.0	1.7	0.0354	1166.0	0.0000	1167.3	0.0013	1166.8	0.0200	1.3	0.0271	0.20		-0.07		158	
7/27/2010	8:30	7.2	0.1500	0.0	0.0	0.0	0.0	1.6	0.0333	1166.0	0.0000	1167.3	0.0000	1169.0	0.0367	1.2	0.0250	0.17		-0.05		136	
7/27/2010	9:00	6.7	0.1396	0.0	0.0	0.0	0.0	1.5	0.0313	1166.0	0.0000	1167.2	-0.0013	1171.7	0.0450	1.0	0.0208	0.15		-0.02		117	
7/27/2010	9:30	4.2	0.0875	0.0	0.0	0.0	0.0	1.6	0.0333	1165.9	-0.0037	1167.3	0.0013	1172.5	0.0133	0.0	0.0000	0.11	0.02			87	
7/27/2010	10:00	4.1	0.0854	0.0	0.0	0.0	0.0	1.6	0.0333	1165.9	0.0000	1167.3	0.0000	1172.0	-0.0083	0.0	0.0000	0.13	0.00			101	
7/27/2010	10:30	5.0	0.1042	0.0	0.0	0.0	0.0	0.0	0.0000	1165.8	-0.0037	1167.3	0.0000	1171.1	-0.0150	0.0	0.0000	0.12	0.00			97	
7/27/2010	11:00	0.0	0.0000	0.0	0.0	0.0	0.0	0.0	0.0000	1165.5	-0.0112	1167.2	-0.0013	1170.1	-0.0167	0.0	0.0000	0.03	0.10			23	
7/27/2010	11:30	0.0	0.0000	0.0	0.0	0.0	0.0	0.0	0.0000	1164.3	-0.0450	1166.1	-0.0145	1167.2	-0.0483	0.0	0.0000	0.11	0.02			85	
7/27/2010	12:00	0.0	0.0000	0.0	0.0	0.0	0.0	0.0	0.0000	1162.9	-0.0525	1165.1	-0.0132	1164.8	-0.0400	0.0	0.0000	0.11	0.02			84	
7/27/2010	12:30	2.6	0.0542	0.0	0.0	0.0	0.0	0.0	0.0000	1162.0	-0.0337	1164.4	-0.0092	1162.8	-0.0333	0.0	0.0000	0.13	0.00			103	
7/27/2010	13:00	2.4	0.0500	0.0	0.0	0.0	0.0	3.2	0.0667	1161.8	-0.0075	1164.4	0.0000	1161.9	-0.0150	0.0	0.0000	0.14		-0.01		110	
7/27/2010	13:30	7.2	0.1500	0.0	0.0	0.0	0.0	2.9	0.0604	1161.9	0.0037	1164.4	0.0000	1166.8	0.0817	0.0	0.0000	0.13	0.00			99	
7/27/2010	14:00	9.2	0.1917	0.0	0.0	0.0	0.0	1.7	0.0354	1162.4	0.0187	1165.1	0.0092	1170.3	0.0583	0.0	0.0000	0.14		-0.01		112	
7/27/2010	14:30	4.3	0.0896	0.0	0.0	0.0	0.0	1.7	0.0354	1164.0	0.0600	1166.6	0.0197	1168.6	-0.0283	0.0	0.0000	0.07	0.05			58	
7/27/2010	15:00	4.3	0.0896	0.0	0.0	0.0	0.0	1.7	0.0354	1165.0	0.0375	1167.6	0.0132	1167.5	-0.0183	0.0	0.0000	0.09	0.03			73	
7/27/2010	15:30	2.3	0.0479	0.0	0.0	0.0	0.0	1.7	0.0354	1165.2	0.0075	1168.1	0.0066	1166.8	-0.0117	0.0	0.0000	0.08	0.05			64	
7/27/2010	16:00	2.3	0.0479	0.0	0.0	0.0	0.0	1.7	0.0354	1165.1	-0.0037	1168.7	0.0079	1166.2	-0.0100	0.0	0.0000	0.09	0.04			71	
7/27/2010	16:30	2.3	0.0479	0.0	0.0	0.0	0.0	1.7	0.0354	1165.1	0.0000	1168.2	-0.0066	1166.0	-0.0033	0.0	0.0000	0.09	0.03			74	
7/27/2010	17:00	4.8	0.1000	0.0	0.0	0.0	0.0	1.6	0.0333	1164.9	-0.0075	1168.2	0.0000	1166.3	0.0050	0.0	0.0000	0.14		-0.01		108	
7/27/2010	17:30	4.8	0.1000	0.0	0.0	0.0	0.0	1.6	0.0333	1165.0	0.0037	1168.2	0.0000	1168.3	0.0333	0.0	0.0000	0.10	0.03			76	
7/27/2010	18:00	3.3	0.0688	0.0	0.0	0.0	0.0	0.0	0.0000	1164.9	-0.0037	1168.1	-0.0013	1168.6	0.0050	0.0	0.0000	0.07	0.06			55	
7/27/2010	18:30	3.3	0.0688	0.0	0.0	0.0	0.0	0.0	0.0000	1164.7	-0.0075	1167.8	-0.0039	1166.6	-0.0333	0.0	0.0000	0.11	0.01			90	
7/27/2010	19:00	3.3	0.0688	0.0	0.0	0.0	0.0	0.0	0.0000	1164.7	0.0000	1167.4	-0.0053	1165.1	-0.0250	0.0	0.0000	0.10	0.03			78	
7/27/2010	19:30	3.3	0.0688	0.0	0.0	0.0	0.0	0.0	0.0000	1164.6	-0.0037	1167.1	-0.0039	1164.1	-0.0167	1.5	0.0313	0.12	0.00			98	
7/27/2010	20:00	4.8	0.1000	0.0	0.0	0.0	0.0	0.0	0.0000	1164.6	0.0000	1167.0	-0.0013	1164.7	0.0100	1.3	0.0271	0.12	0.01			94	
7/27/2010	20:30	4.6	0.0958	0.0	0.0	0.0	0.0	1.5	0.0313	1164.6	0.0000	1167.1	0.0013	1166.3	0.0267	1.2	0.0250	0.12	0.00			98	
7/27/2010	21:00	4.8	0.1000	0.0	0.0	0.0	0.0	1.5	0.0313	1164.6	0.0000	1167.0	-0.0013	1168.3	0.0333	0.0	0.0000	0.10	0.03			79	
7/27/2010	21:30	5.0	0.1042	0.0	0.0	0.0	0.0	1.6	0.0333	1165.2	0.0225	1166.9	-0.0013	1167.3	-0.0167	0.0	0.0000	0.13		-0.01		105	
7/27/2010	22:00	5.1	0.1063	0.0	0.0	0.0	0.0	1.6	0.0333	1165.4	0.0075	1166.9	0.0000	1166.3	-0.0167	0.0	0.0000	0.15		-0.02		118	
7/27/2010	22:30	5.1	0.1063	0.0	0.0	0.0	0.0	1.6	0.0333	1165.5	0.0037	1166.9	0.0000	1165.7	-0.0100	0.0	0.0000	0.15		-0.02		116	
7/27/2010	23:00	5.1	0.1063	0.0	0.0	0.0	0.0	1.6	0.0333	1165.8	0.0112	1167.0	0.0013	1165.5	-0.0033	0.0	0.0000	0.13	0.00			103	
7/27/2010	23:30	5.1	0.1063	0.0	0.0	0.0	0.0	1.6	0.0333	1166.2	0.0150	1166.9	-0.0013	1165.8	0.0050	0.0	0.0000	0.12	0.01			96	
																		0.13	0.72	-0.72	11.9	99	6.06


City of Lawrence, Kansas
7-27-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
July 28, 2010 Diurnal Data
West Hills Pressure Zone

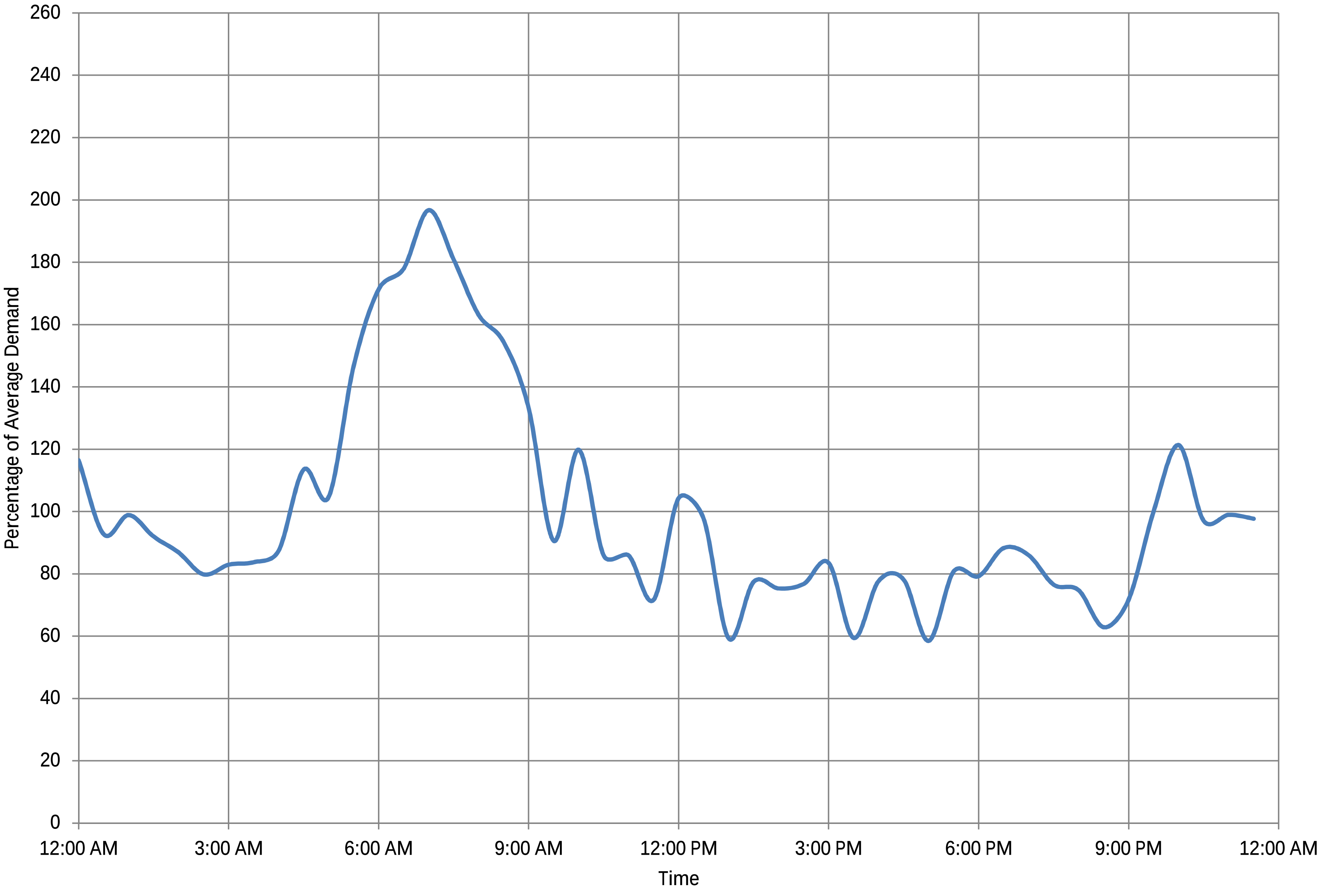
		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG Elevated Tank		6th & Kasold 0.5 MG Elevated Tank		Stratford 0.5 MG Elevated Tank		19th and Kasold BPS Booster Pump Station		Total Demand	Equalization Storage		Equalization Factor	Diurnal	Total Daily Demand
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS											Fill	Draft			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/28/2010	0:00	5.0	0.1042	0.0	0.0	0.0	0.0000	1.6	0.0333	1166.9	0.0000	1166.9	0.0000	1166.3	0.0000	0.0	0.0000	0.14	0.00			99	
7/28/2010	0:30	5.0	0.1042	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.3	0.0150	1166.9	0.0000	1166.9	0.0100	0.0	0.0000	0.11	0.03			81	
7/28/2010	1:00	5.0	0.1042	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.2	-0.0037	1166.9	0.0000	1166.8	-0.0017	0.0	0.0000	0.14	0.00			103	
7/28/2010	1:30	5.0	0.1042	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.1	-0.0037	1166.9	0.0000	1166.8	0.0000	0.0	0.0000	0.14	0.00			102	
7/28/2010	2:00	5.1	0.1063	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.3	0.0075	1166.9	0.0000	1167.0	0.0033	0.0	0.0000	0.13	0.01			93	
7/28/2010	2:30	5.0	0.1042	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.7	0.0150	1166.9	0.0000	1167.3	0.0050	0.0	0.0000	0.12	0.02			85	
7/28/2010	3:00	5.1	0.1063	0.0	0.0	0.0	0.0000	1.6	0.0333	1168.0	0.0112	1166.8	-0.0013	1167.6	0.0050	0.0	0.0000	0.12	0.01			90	
7/28/2010	3:30	5.0	0.1042	0.0	0.0	0.0	0.0000	1.6	0.0333	1168.1	0.0037	1166.9	0.0013	1167.9	0.0050	0.0	0.0000	0.13	0.01			92	
7/28/2010	4:00	5.1	0.1063	0.0	0.0	0.0	0.0000	1.6	0.0333	1168.2	0.0037	1166.8	-0.0013	1168.1	0.0033	0.0	0.0000	0.13	0.01			96	
7/28/2010	4:30	5.1	0.1063	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.7	-0.0187	1167.0	0.0026	1168.0	-0.0017	0.0	0.0000	0.16		-0.02		113	
7/28/2010	5:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1.6	0.0333	1167.1	-0.0225	1166.8	-0.0026	1167.4	-0.0100	0.0	0.0000	0.19		-0.05		138	
7/28/2010	5:30	5.9	0.1229	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.2	-0.0337	1166.8	0.0000	1167.2	-0.0033	0.0	0.0000	0.22		-0.09		162	
7/28/2010	6:00	5.9	0.1229	0.0	0.0	0.0	0.0000	3.1	0.0646	1165.1	-0.0412	1166.7	-0.0013	1166.9	-0.0050	0.0	0.0000	0.24		-0.10		169	
7/28/2010	6:30	5.9	0.1229	0.0	0.0	0.0	0.0000	3.1	0.0646	1163.8	-0.0487	1165.8	-0.0118	1165.8	-0.0183	0.0	0.0000	0.27		-0.13		192	
7/28/2010	7:00	5.9	0.1229	0.0	0.0	0.0	0.0000	3.1	0.0646	1162.9	-0.0337	1165.7	-0.0013	1165.3	-0.0083	1.5	0.0313	0.26		-0.12		189	
7/28/2010	7:30	5.9	0.1229	0.0	0.0	0.0	0.0000	4.5	0.0938	1162.4	-0.0187	1165.4	-0.0039	1165.5	0.0033	1.5	0.0313	0.27		-0.13		192	
7/28/2010	8:00	5.7	0.1188	0.0	0.0	0.0	0.0000	4.4	0.0917	1162.5	0.0037	1165.4	0.0000	1167.0	0.0250	1.4	0.0292	0.21		-0.07		152	
7/28/2010	8:30	5.5	0.1146	0.0	0.0	0.0	0.0000	4.3	0.0896	1162.4	-0.0037	1165.5	0.0013	1169.3	0.0383	1.2	0.0250	0.19		-0.05		139	
7/28/2010	9:00	3.3	0.0688	0.0	0.0	0.0	0.0000	0.7	0.0146	1162.4	0.0000	1165.9	0.0053	1172.6	0.0550	1.5	0.0313	0.05	0.08			39	
7/28/2010	9:30	3.4	0.0708	0.0	0.0	0.0	0.0000	0.0	0.0000	1162.3	-0.0037	1165.4	-0.0066	1169.2	-0.0567	1.0	0.0208	0.16		-0.02		114	
7/28/2010	10:00	5.0	0.1042	0.0	0.0	0.0	0.0000	0.0	0.0000	1162.3	0.0000	1165.4	0.0000	1168.4	-0.0133	0.9	0.0188	0.14	0.00			98	
7/28/2010	10:30	4.7	0.0979	0.0	0.0	0.0	0.0000	1.6	0.0333	1162.3	0.0000	1165.4	0.0000	1169.9	0.0250	0.6	0.0125	0.12	0.02			85	
7/28/2010	11:00	5.1	0.1063	0.0	0.0	0.0	0.0000	1.7	0.0354	1163.7	0.0525	1165.4	0.0000	1169.7	-0.0033	1.0	0.0208	0.11	0.03			82	
7/28/2010	11:30	5.0	0.1042	0.0	0.0	0.0	0.0000	3.2	0.0667	1165.1	0.0525	1165.5	0.0013	1169.2	-0.0083	0.0	0.0000	0.13	0.01			90	
7/28/2010	12:00	2.3	0.0479	0.0	0.0	0.0	0.0000	4.5	0.0938	1165.8	0.0262	1165.4	-0.0013	1169.0	-0.0033	0.0	0.0000	0.12	0.02			86	
7/28/2010	12:30	2.2	0.0458	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.2	0.0150	1165.4	0.0000	1169.1	0.0017	0.0	0.0000	0.09	0.05			67	
7/28/2010	13:00	2.3	0.0479	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.5	0.0112	1165.4	0.0000	1169.0	-0.0017	0.0	0.0000	0.10	0.04			74	
7/28/2010	13:30	2.3	0.0479	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.7	0.0075	1165.4	0.0000	1169.1	0.0017	0.0	0.0000	0.10	0.04			74	
7/28/2010	14:00	2.3	0.0479	0.0	0.0	0.0	0.0000	3.1	0.0646	1167.0	0.0112	1165.4	0.0000	1169.3	0.0033	0.0	0.0000	0.10	0.04			70	
7/28/2010	14:30	2.3	0.0479	0.0	0.0	0.0	0.0000	3.1	0.0646	1167.1	0.0037	1165.4	0.0000	1169.5	0.0033	0.0	0.0000	0.11	0.03			76	
7/28/2010	15:00	2.3	0.0479	0.0	0.0	0.2	0.0042	3.1	0.0646	1167.0	-0.0037	1165.4	0.0000	1169.7	0.0033	0.0	0.0000	0.12	0.02			84	
7/28/2010	15:30	2.3	0.0479	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.5	-0.0187	1167.2	0.0237	1169.3	-0.0067	0.0	0.0000	0.11	0.02			82	
7/28/2010	16:00	2.3	0.0479	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.3	-0.0075	1168.2	0.0132	1169.3	0.0000	0.0	0.0000	0.11	0.03			77	
7/28/2010	16:30	5.0	0.1042	0.0	0.0	0.0	0.0000	3.0	0.0625	1167.9	0.0600	1168.3	0.0013	1170.6	0.0217	0.0	0.0000	0.08	0.06			60	
7/28/2010	17:00	3.2	0.0667	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.1	0.0450	1168.3	0.0000	1171.7	0.0183	0.0	0.0000	0.07	0.07			49	
7/28/2010	17:30	2.2	0.0458	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.5	0.0150	1168.3	0.0000	1172.2	0.0083	0.0	0.0000	0.09	0.05			63	
7/28/2010	18:00	2.2	0.0458	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.5	0.0000	1168.3	0.0000	1172.4	0.0033	0.0	0.0000	0.11	0.03			77	
7/28/2010	18:30	2.2	0.0458	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.5	0.0000	1168.2	-0.0013	1172.5	0.0017	0.0	0.0000	0.11	0.03			79	
7/28/2010	19:00	2.2	0.0458	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.5	0.0000	1168.3	0.0013	1172.5	0.0000	0.0	0.0000	0.11	0.03			79	
7/28/2010	19:30	2.3	0.0479	0.0	0.0	0.0	0.0000	3.0	0.0625	1169.4	-0.0037	1168.2	-0.0013	1172.5	0.0000	0.0	0.0000	0.12	0.02			83	
7/28/2010	20:00	2.7	0.0563	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.6	0.0075	1168.3	0.0013	1172.5	0.0000	0.0	0.0000	0.11	0.03			81	
7/28/2010	20:30	2.8	0.0583	0.0	0.0	0.0	0.0000	3.1	0.0646	1169.6	0.0000	1168.2	-0.0013	1172.6	0.0017	0.0	0.0000	0.12	0.02			88	
7/28/2010	21:00	0.0	0.0000	0.0	0.0	0.0	0.0000	3.1	0.0646	1168.7	-0.0337	1168.2	0.0000	1172.0	-0.0100	0.0	0.0000	0.11	0.03			78	
7/28/2010	21:30	0.0	0.0000	0.0	0.0	0.0	0.0000	3.1	0.0646	1166.8	-0.0712	1168.0	-0.0026	1170.6	-0.0233	0.0	0.0000	0.16		-0.02		116	
7/28/2010	22:00	0.0	0.0000	0.0	0.0	0.0	0.0000	3.1	0.0646	1165.0	-0.0675	1167.4	-0.0079	1169.3	-0.0217	0.0	0.0000	0.16		-0.02		116	
7/28/2010	22:30	0.0	0.0000	0.0	0.0	0.0	0.0000	3.1	0.0646	1163.3	-0.0637	1166.3	-0.0145	1168.0	-0.0217	0.0	0.0000	0.16		-0.03		118	
7/28/2010	23:00	2.7	0.0563	0.0	0.0	0.0	0.0000	3.1	0.0646	1162.6	-0.0262	1166.1	-0.0026	1167.2	-0.0133	0.0	0.0000	0.16		-0.02		117	
7/28/2010	23:30	4.6	0.0958	0.0	0.0	0.0	0.0000	3.1	0.0646	1163.0	0.0150	1166.1	0.0000	1166.9	-0.0050	0.0	0.0000	0.15		-0.01		108	
																		0.14	0.88	-0.88	13.3	116	6.67


City of Lawrence, Kansas
7-28-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
July 29, 2010 Diurnal Data
West Hills Pressure Zone

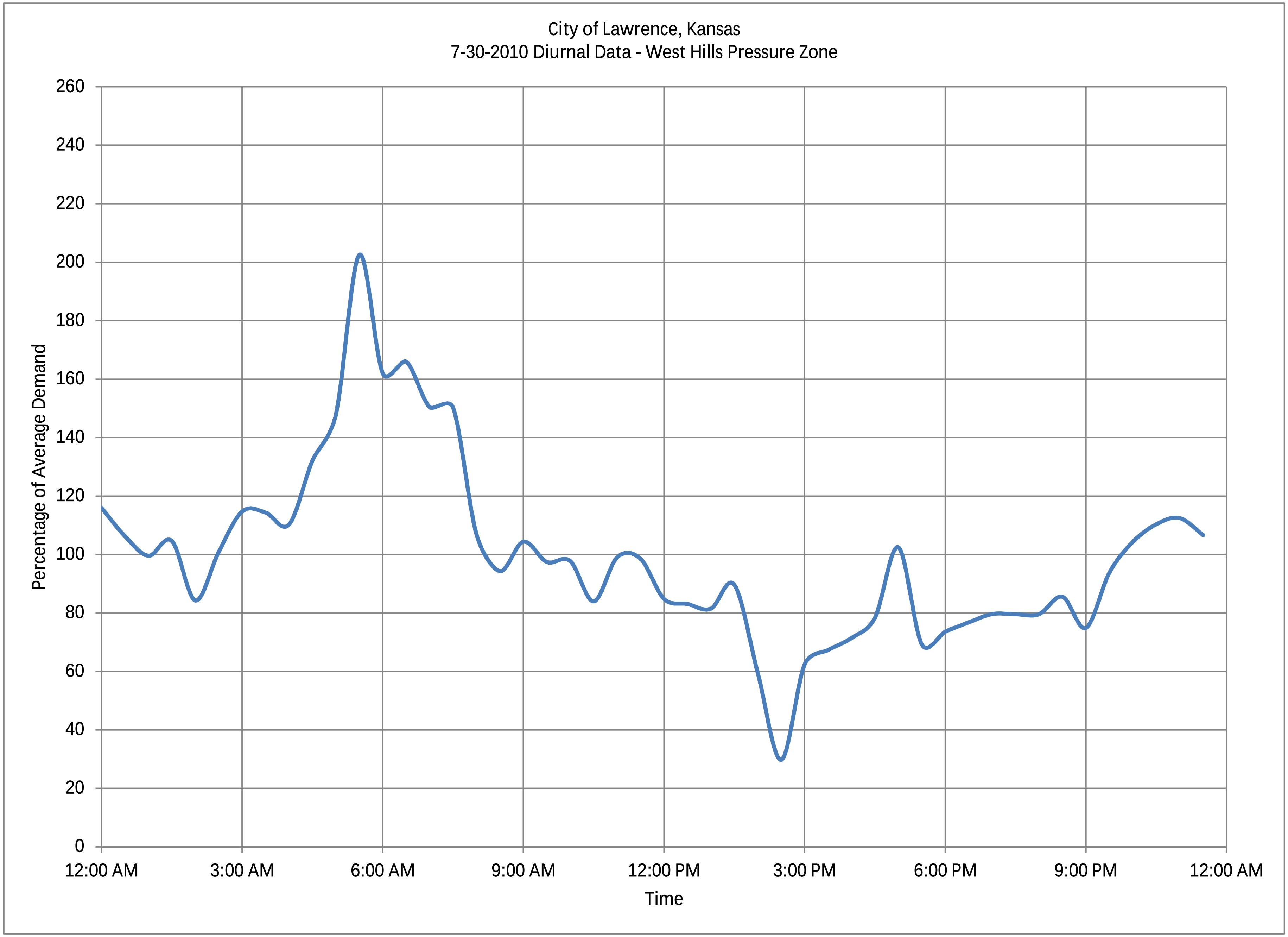
		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG Elevated Tank		6th & Kasold 0.5 MG Elevated Tank		Stratford 0.5 MG Elevated Tank		19th and Kasold BPS Booster Pump Station		Total Demand	Equalization Storage		Equalization Factor	Diurnal	Total Daily Demand
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS											Fill	Draft			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/29/2010	0:00	4.6	0.0958	0.0	0.0	0.0	0.0	3.1	0.0646	1164.1	0.0000	1166.1	0.0000	1167.2	0.0000	0.0	0.0000	0.16		-0.02		116	
7/29/2010	0:30	4.6	0.0958	0.0	0.0	0.0	0.0	3.1	0.0646	1164.7	0.0225	1167.0	0.0118	1167.1	-0.0017	0.0	0.0000	0.13	0.01			93	
7/29/2010	1:00	4.5	0.0938	0.0	0.0	0.0	0.0	3.1	0.0646	1165.0	0.0112	1167.7	0.0092	1167.2	0.0017	0.0	0.0000	0.14	0.00			99	
7/29/2010	1:30	4.5	0.0938	0.0	0.0	0.0	0.0	3.1	0.0646	1165.5	0.0187	1168.3	0.0079	1167.5	0.0050	0.0	0.0000	0.13	0.01			92	
7/29/2010	2:00	4.5	0.0938	0.0	0.0	0.0	0.0	3.1	0.0646	1166.3	0.0300	1168.2	-0.0013	1168.1	0.0100	0.0	0.0000	0.12	0.02			87	
7/29/2010	2:30	4.5	0.0938	0.0	0.0	0.0	0.0	3.1	0.0646	1167.2	0.0337	1168.3	0.0013	1168.9	0.0133	0.0	0.0000	0.11	0.03			80	
7/29/2010	3:00	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1168.0	0.0300	1168.2	-0.0013	1169.7	0.0133	0.0	0.0000	0.11	0.02			83	
7/29/2010	3:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1168.7	0.0262	1168.3	0.0013	1170.5	0.0133	0.0	0.0000	0.12	0.02			84	
7/29/2010	4:00	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1169.3	0.0225	1168.3	0.0000	1171.3	0.0133	0.0	0.0000	0.12	0.02			87	
7/29/2010	4:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1169.2	-0.0037	1168.2	-0.0013	1171.6	0.0050	0.0	0.0000	0.16		-0.02		113	
7/29/2010	5:00	2.4	0.0500	0.0	0.0	0.0	0.0	3.1	0.0646	1168.5	-0.0262	1168.2	0.0000	1171.4	-0.0033	0.0	0.0000	0.14		-0.01		105	
7/29/2010	5:30	2.5	0.0521	0.0	0.0	0.0	0.0	3.1	0.0646	1166.8	-0.0637	1168.2	0.0000	1170.1	-0.0217	0.0	0.0000	0.20		-0.06		147	
7/29/2010	6:00	2.6	0.0542	0.0	0.0	0.0	0.0	3.1	0.0646	1165.2	-0.0600	1167.9	-0.0039	1169.4	-0.0117	2.0	0.0417	0.24		-0.10		171	
7/29/2010	6:30	2.6	0.0542	0.0	0.0	0.0	0.0	3.1	0.0646	1163.7	-0.0562	1167.0	-0.0118	1168.4	-0.0167	2.0	0.0417	0.25		-0.11		178	
7/29/2010	7:00	4.2	0.0875	0.0	0.0	0.0	0.0	3.1	0.0646	1162.4	-0.0487	1166.1	-0.0118	1167.4	-0.0167	2.0	0.0417	0.27		-0.13		197	
7/29/2010	7:30	4.2	0.0875	0.0	0.0	0.0	0.0	3.1	0.0646	1161.7	-0.0262	1165.4	-0.0092	1166.2	-0.0200	2.0	0.0417	0.25		-0.11		181	
7/29/2010	8:00	4.2	0.0875	0.0	0.0	0.0	0.0	3.1	0.0646	1161.3	-0.0150	1165.2	-0.0026	1165.4	-0.0133	2.0	0.0417	0.22		-0.09		163	
7/29/2010	8:30	4.1	0.0854	0.0	0.0	0.0	0.0	3.1	0.0646	1161.1	-0.0075	1164.9	-0.0039	1164.7	-0.0117	1.9	0.0396	0.21		-0.07		154	
7/29/2010	9:00	3.6	0.0750	0.0	0.0	0.0	0.0	3.1	0.0646	1161.0	-0.0037	1164.7	-0.0026	1164.2	-0.0083	1.4	0.0292	0.18		-0.05		133	
7/29/2010	9:30	0.0	0.0000	0.0	0.0	0.0	0.0	3.2	0.0667	1160.2	-0.0300	1163.7	-0.0132	1163.3	-0.0150	0.0	0.0000	0.12	0.01			91	
7/29/2010	10:00	5.6	0.1167	0.0	0.0	0.0	0.0	3.0	0.0625	1160.7	0.0187	1163.6	-0.0013	1163.1	-0.0033	0.0	0.0000	0.17		-0.03		120	
7/29/2010	10:30	4.1	0.0854	0.0	0.0	0.0	0.0	3.1	0.0646	1160.7	0.0000	1163.6	0.0000	1165.0	0.0317	0.0	0.0000	0.12	0.02			86	
7/29/2010	11:00	4.0	0.0833	0.0	0.0	0.0	0.0	3.1	0.0646	1160.6	-0.0037	1163.6	0.0000	1167.0	0.0333	0.0	0.0000	0.12	0.02			86	
7/29/2010	11:30	4.2	0.0875	0.0	0.0	0.0	0.0	1.6	0.0333	1160.7	0.0037	1163.6	0.0000	1168.1	0.0183	0.0	0.0000	0.10	0.04			72	
7/29/2010	12:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1161.8	0.0412	1163.7	0.0013	1166.3	-0.0300	0.0	0.0000	0.14		-0.01		104	
7/29/2010	12:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1163.0	0.0450	1163.7	0.0000	1164.9	-0.0233	0.0	0.0000	0.13	0.00			98	
7/29/2010	13:00	5.5	0.1146	0.0	0.0	0.0	0.0	0.0	0.0000	1164.1	0.0412	1163.7	0.0000	1164.4	-0.0083	0.0	0.0000	0.08	0.06			59	
7/29/2010	13:30	5.5	0.1146	0.0	0.0	0.0	0.0	0.0	0.0000	1164.0	-0.0037	1163.7	0.0000	1165.1	0.0117	0.0	0.0000	0.11	0.03			77	
7/29/2010	14:00	5.6	0.1167	0.0	0.0	0.0	0.0	0.0	0.0000	1163.9	-0.0037	1163.7	0.0000	1166.1	0.0167	0.0	0.0000	0.10	0.03			75	
7/29/2010	14:30	5.0	0.1042	0.0	0.0	0.0	0.0	0.0	0.0000	1163.8	-0.0037	1164.5	0.0105	1165.6	-0.0083	0.0	0.0000	0.11	0.03			77	
7/29/2010	15:00	5.8	0.1208	0.0	0.0	0.0	0.0	0.0	0.0000	1163.8	0.0000	1165.7	0.0158	1165.0	-0.0100	0.0	0.0000	0.12	0.02			84	
7/29/2010	15:30	5.7	0.1188	0.0	0.0	0.0	0.0	0.0	0.0000	1164.0	0.0075	1167.3	0.0211	1165.5	0.0083	0.0	0.0000	0.08	0.06			59	
7/29/2010	16:00	5.7	0.1188	0.0	0.0	0.0	0.0	0.0	0.0000	1164.8	0.0300	1167.3	0.0000	1164.4	-0.0183	0.0	0.0000	0.11	0.03			78	
7/29/2010	16:30	6.9	0.1438	0.0	0.0	0.0	0.0	0.0	0.0000	1165.8	0.0375	1167.7	0.0053	1164.0	-0.0067	0.0	0.0000	0.11	0.03			78	
7/29/2010	17:00	4.9	0.1021	0.0	0.0	0.0	0.0	0.0	0.0000	1166.1	0.0112	1168.1	0.0053	1164.3	0.0050	0.0	0.0000	0.08	0.06			58	
7/29/2010	17:30	5.5	0.1146	0.0	0.0	0.0	0.0	0.0	0.0000	1166.1	0.0000	1168.1	0.0000	1164.5	0.0033	0.0	0.0000	0.11	0.03			81	
7/29/2010	18:00	4.9	0.1021	0.0	0.0	0.0	0.0	0.0	0.0000	1166.1	0.0000	1168.1	0.0000	1165.7	0.0200	1.3	0.0271	0.11	0.03			79	
7/29/2010	18:30	4.9	0.1021	0.0	0.0	0.0	0.0	0.0	0.0000	1166.0	-0.0037	1168.2	0.0013	1166.3	0.0100	1.3	0.0271	0.12	0.02			88	
7/29/2010	19:00	5.0	0.1042	0.0	0.0	0.0	0.0	0.0	0.0000	1166.1	0.0037	1168.0	-0.0026	1167.0	0.0117	1.3	0.0271	0.12	0.02			86	
7/29/2010	19:30	4.9	0.1021	0.0	0.0	0.0	0.0	0.0	0.0000	1166.2	0.0037	1168.0	0.0000	1168.2	0.0200	1.3	0.0271	0.11	0.03			77	
7/29/2010	20:00	5.1	0.1063	0.0	0.0	0.0	0.0	0.0	0.0000	1167.0	0.0300	1167.9	-0.0013	1168.3	0.0017	1.3	0.0271	0.10	0.03			75	
7/29/2010	20:30	5.1	0.1063	0.0	0.0	0.0	0.0	0.0	0.0000	1167.8	0.0300	1168.0	0.0013	1167.6	-0.0117	0.0	0.0000	0.09	0.05			63	
7/29/2010	21:00	5.1	0.1063	0.0	0.0	0.0	0.0	0.0	0.0000	1168.3	0.0187	1167.9	-0.0013	1167.0	-0.0100	0.0	0.0000	0.10	0.04			72	
7/29/2010	21:30	5.7	0.1188	0.0	0.0	0.0	0.0	0.0	0.0000	1168.2	-0.0037	1168.0	0.0013	1166.0	-0.0167	0.0	0.0000	0.14	0.00			100	
7/29/2010	22:00	5.7	0.1188	0.0	0.0	0.0	0.0	1.7	0.0354	1168.2	0.0000	1167.9	-0.0013	1165.3	-0.0117	0.0	0.0000	0.17		-0.03		121	
7/29/2010	22:30	5.7	0.1188	0.0	0.0	0.0	0.0	1.7	0.0354	1168.4	0.0075	1168.0	0.0013	1166.0	0.0117	0.0	0.0000	0.13	0.00			97	
7/29/2010	23:00	5.7	0.1188	0.0	0.0	0.0	0.0	1.7	0.0354	1168.6	0.0075	1167.9	-0.0013	1166.7	0.0117	0.0	0.0000	0.14	0.00			99	
7/29/2010	23:30	5.6	0.1167	0.0	0.0	0.0	0.0	1.7	0.0354	1168.8	0.0075	1167.9	0.0000	1167.3	0.0100	0.0	0.0000	0.13	0.00			98	
																		0.14	0.83	-0.83	12.6	116	6.61

City of Lawrence, Kansas
7-29-2010 Diurnal Data - West Hills Pressure Zone



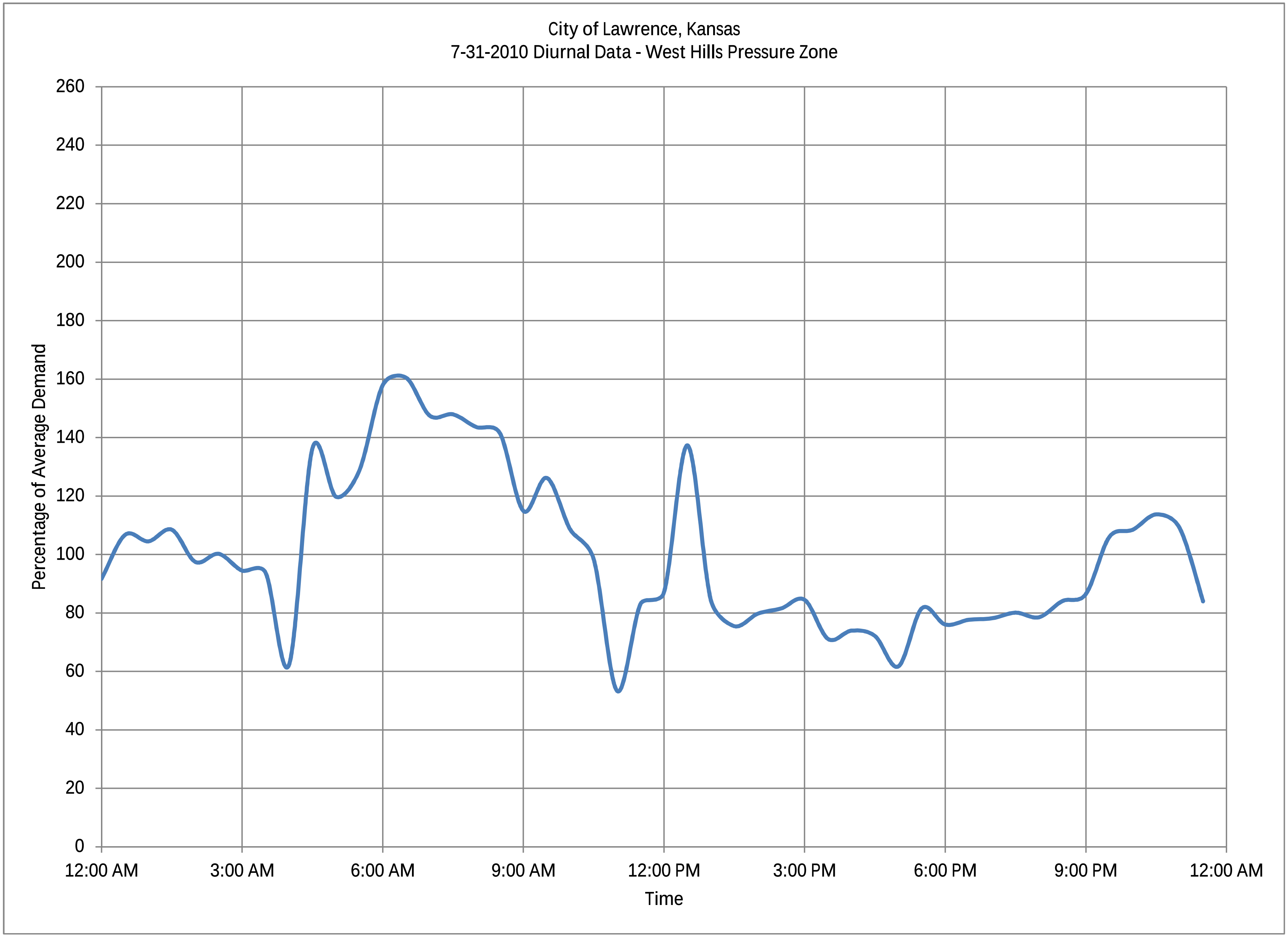
City of Lawrence, Kansas - 2011 Water Master Plan
July 30, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG Elevated Tank		6th & Kasold 0.5 MG Elevated Tank		Stratford 0.5 MG Elevated Tank		19th and Kasold BPS Booster Pump Station		Total Demand	Equalization Storage		Equalization Factor	Diurnal	Total Daily Demand
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS											Fill	Draft			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/30/2010	0:00	5.7	0.1188	0.0	0.0000	0.0	0.0000	1.7	0.0354	1168.9	0.0000	1167.9	0.0000	1167.8	0.0000	0.0	0.0000	0.15		-0.02		116	
7/30/2010	0:30	5.7	0.1188	0.0	0.0000	0.0	0.0000	1.7	0.0354	1169.1	0.0075	1167.8	-0.0013	1168.2	0.0067	0.0	0.0000	0.14		-0.01		106	
7/30/2010	1:00	5.7	0.1188	0.0	0.0000	0.0	0.0000	1.6	0.0333	1169.5	0.0150	1167.9	0.0013	1168.4	0.0033	0.0	0.0000	0.13	0.00			100	
7/30/2010	1:30	5.6	0.1167	0.0	0.0000	0.0	0.0000	1.6	0.0333	1169.7	0.0075	1167.9	0.0000	1168.6	0.0033	0.0	0.0000	0.14		-0.01		105	
7/30/2010	2:00	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.0	0.0112	1167.9	0.0000	1168.2	-0.0067	0.0	0.0000	0.11	0.02			84	
7/30/2010	2:30	5.7	0.1188	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.0	0.0000	1168.0	0.0013	1167.2	-0.0167	0.0	0.0000	0.13	0.00			101	
7/30/2010	3:00	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.3	0.0112	1167.9	-0.0013	1167.2	0.0000	2.2	0.0458	0.15		-0.02		115	
7/30/2010	3:30	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.4	0.0037	1167.9	0.0000	1167.6	0.0067	2.2	0.0458	0.15		-0.02		114	
7/30/2010	4:00	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.6	0.0075	1167.9	0.0000	1168.1	0.0083	2.2	0.0458	0.15		-0.01		110	
7/30/2010	4:30	5.6	0.1167	0.0	0.0000	0.0	0.0000	0.0	0.0000	1170.2	-0.0150	1168.0	0.0013	1168.0	-0.0017	2.1	0.0438	0.18		-0.04		132	
7/30/2010	5:00	5.0	0.1042	0.0	0.0000	0.0	0.0000	0.0	0.0000	1169.3	-0.0337	1167.9	-0.0013	1167.3	-0.0117	2.2	0.0458	0.20		-0.06		148	
7/30/2010	5:30	4.2	0.0875	0.0	0.0000	0.0	0.0000	1.7	0.0354	1167.3	-0.0750	1167.6	-0.0039	1166.0	-0.0217	2.2	0.0458	0.27		-0.14		203	
7/30/2010	6:00	4.3	0.0896	0.0	0.0000	0.0	0.0000	1.7	0.0354	1165.7	-0.0600	1167.0	-0.0079	1165.9	-0.0017	1.0	0.0208	0.22		-0.08		162	
7/30/2010	6:30	4.4	0.0917	0.0	0.0000	0.0	0.0000	1.7	0.0354	1163.9	-0.0675	1165.9	-0.0145	1165.2	-0.0117	0.0	0.0000	0.22		-0.09		166	
7/30/2010	7:00	4.3	0.0896	0.0	0.0000	0.0	0.0000	1.7	0.0354	1162.5	-0.0525	1165.2	-0.0092	1164.4	-0.0133	0.0	0.0000	0.20		-0.07		150	
7/30/2010	7:30	5.9	0.1229	0.0	0.0000	0.0	0.0000	1.7	0.0354	1161.8	-0.0262	1164.8	-0.0053	1163.8	-0.0100	0.0	0.0000	0.20		-0.07		150	
7/30/2010	8:00	5.8	0.1208	0.0	0.0000	0.0	0.0000	1.7	0.0354	1162.0	0.0075	1164.8	0.0000	1164.2	0.0067	0.0	0.0000	0.14		-0.01		107	
7/30/2010	8:30	5.8	0.1208	0.0	0.0000	0.0	0.0000	1.7	0.0354	1162.6	0.0225	1164.8	0.0000	1164.7	0.0083	0.0	0.0000	0.13	0.01			94	
7/30/2010	9:00	5.6	0.1167	0.0	0.0000	0.0	0.0000	1.6	0.0333	1162.8	0.0075	1164.7	-0.0013	1165.0	0.0050	0.0	0.0000	0.14		-0.01		104	
7/30/2010	9:30	5.0	0.1042	0.0	0.0000	0.0	0.0000	1.7	0.0354	1162.8	0.0000	1164.7	0.0000	1165.6	0.0100	0.0	0.0000	0.13	0.00			97	
7/30/2010	10:00	0.0	0.0000	2.7	0.0563	2.7	0.0563	1.6	0.0333	1162.6	-0.0075	1164.7	0.0000	1167.0	0.0233	0.0	0.0000	0.13	0.00			98	
7/30/2010	10:30	0.0	0.0000	2.7	0.0563	2.6	0.0542	1.6	0.0333	1162.7	0.0037	1164.7	0.0000	1168.7	0.0283	0.0	0.0000	0.11	0.02			84	
7/30/2010	11:00	0.0	0.0000	2.7	0.0563	2.9	0.0604	1.7	0.0354	1163.4	0.0262	1165.9	0.0158	1167.4	-0.0217	0.0	0.0000	0.13	0.00			99	
7/30/2010	11:30	0.0	0.0000	2.8	0.0583	2.8	0.0583	1.7	0.0354	1164.1	0.0262	1166.9	0.0132	1166.3	-0.0183	0.0	0.0000	0.13	0.00			98	
7/30/2010	12:00	0.0	0.0000	2.8	0.0583	2.8	0.0583	1.7	0.0354	1165.0	0.0337	1167.7	0.0105	1166.0	-0.0050	0.0	0.0000	0.11	0.02			85	
7/30/2010	12:30	0.0	0.0000	2.8	0.0583	2.8	0.0583	1.7	0.0354	1165.8	0.0300	1168.2	0.0066	1166.3	0.0050	0.0	0.0000	0.11	0.02			83	
7/30/2010	13:00	0.0	0.0000	2.8	0.0583	2.8	0.0583	1.7	0.0354	1166.7	0.0337	1168.2	0.0000	1166.9	0.0100	0.0	0.0000	0.11	0.02			81	
7/30/2010	13:30	4.3	0.0896	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.7	0.0000	1168.1	-0.0013	1167.2	0.0050	0.0	0.0000	0.12	0.01			90	
7/30/2010	14:00	4.1	0.0854	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.7	0.0000	1168.2	0.0013	1169.5	0.0383	0.0	0.0000	0.08	0.05			59	
7/30/2010	14:30	2.7	0.0563	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.7	0.0000	1168.2	0.0000	1170.5	0.0167	0.0	0.0000	0.04	0.09			30	
7/30/2010	15:00	2.8	0.0583	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.7	0.0000	1168.1	-0.0013	1169.1	-0.0233	0.0	0.0000	0.08	0.05			62	
7/30/2010	15:30	2.8	0.0583	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.5	-0.0075	1168.2	0.0013	1167.6	-0.0250	0.0	0.0000	0.09	0.04			67	
7/30/2010	16:00	2.8	0.0583	0.0	0.0000	0.0	0.0000	0.0	0.0000	1166.1	-0.0150	1168.2	0.0000	1166.3	-0.0217	0.0	0.0000	0.09	0.04			71	
7/30/2010	16:30	3.5	0.0729	0.0	0.0000	0.0	0.0000	0.0	0.0000	1165.7	-0.0150	1168.1	-0.0013	1165.4	-0.0150	0.0	0.0000	0.10	0.03			78	
7/30/2010	17:00	4.2	0.0875	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.6	-0.0037	1168.1	0.0000	1164.7	-0.0117	0.0	0.0000	0.14	0.00			102	
7/30/2010	17:30	4.1	0.0854	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.6	0.0000	1168.1	0.0000	1166.3	0.0267	0.0	0.0000	0.09	0.04			69	
7/30/2010	18:00	3.7	0.0771	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.5	-0.0037	1168.2	0.0013	1167.2	0.0150	0.0	0.0000	0.10	0.04			74	
7/30/2010	18:30	3.8	0.0792	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.6	0.0037	1168.2	0.0000	1167.6	0.0067	0.0	0.0000	0.10	0.03			77	
7/30/2010	19:00	3.8	0.0792	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.5	-0.0037	1168.1	-0.0013	1168.3	0.0117	0.0	0.0000	0.11	0.03			80	
7/30/2010	19:30	3.9	0.0813	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.6	0.0037	1168.1	0.0000	1168.6	0.0050	0.0	0.0000	0.11	0.03			80	
7/30/2010	20:00	3.9	0.0813	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.1	0.0187	1168.1	0.0000	1168.0	-0.0100	0.0	0.0000	0.11	0.03			80	
7/30/2010	20:30	3.9	0.0813	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.3	0.0075	1168.1	0.0000	1167.6	-0.0067	0.0	0.0000	0.11	0.02			86	
7/30/2010	21:00	3.9	0.0813	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.7	0.0150	1168.1	0.0000	1167.6	0.0000	0.0	0.0000	0.10	0.03			75	
7/30/2010	21:30	4.0	0.0833	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.7	0.0000	1168.0	-0.0013	1167.2	-0.0067	0.0	0.0000	0.12	0.01			94	
7/30/2010	22:00	4.0	0.0833	0.0	0.0000	0.0	0.0000	1.6	0.0333	1166.3	-0.0150	1168.1	0.0013	1166.7	-0.0083	0.0	0.0000	0.14		-0.01		104	
7/30/2010	22:30	4.0	0.0833	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.8	-0.0187	1168.0	-0.0013	1166.1	-0.0100	0.0	0.0000	0.15		-0.01		110	
7/30/2010	23:00	4.0	0.0833	0.0	0.0000	0.0	0.0000	1.6	0.0333	1165.1	-0.0262	1168.0	0.0000	1165.7	-0.0067	0.0	0.0000	0.15		-0.02		112	
7/30/2010	23:30	4.4	0.0917	0.0	0.0000	0.0	0.0000	1.6	0.0333	1164.9	-0.0075	1167.8	-0.0026	1165.3	-0.0067	0.0	0.0000	0.14		-0.01		107	
																		0.13	0.69	-0.69	10.9	92	6.38


City of Lawrence, Kansas
7-30-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

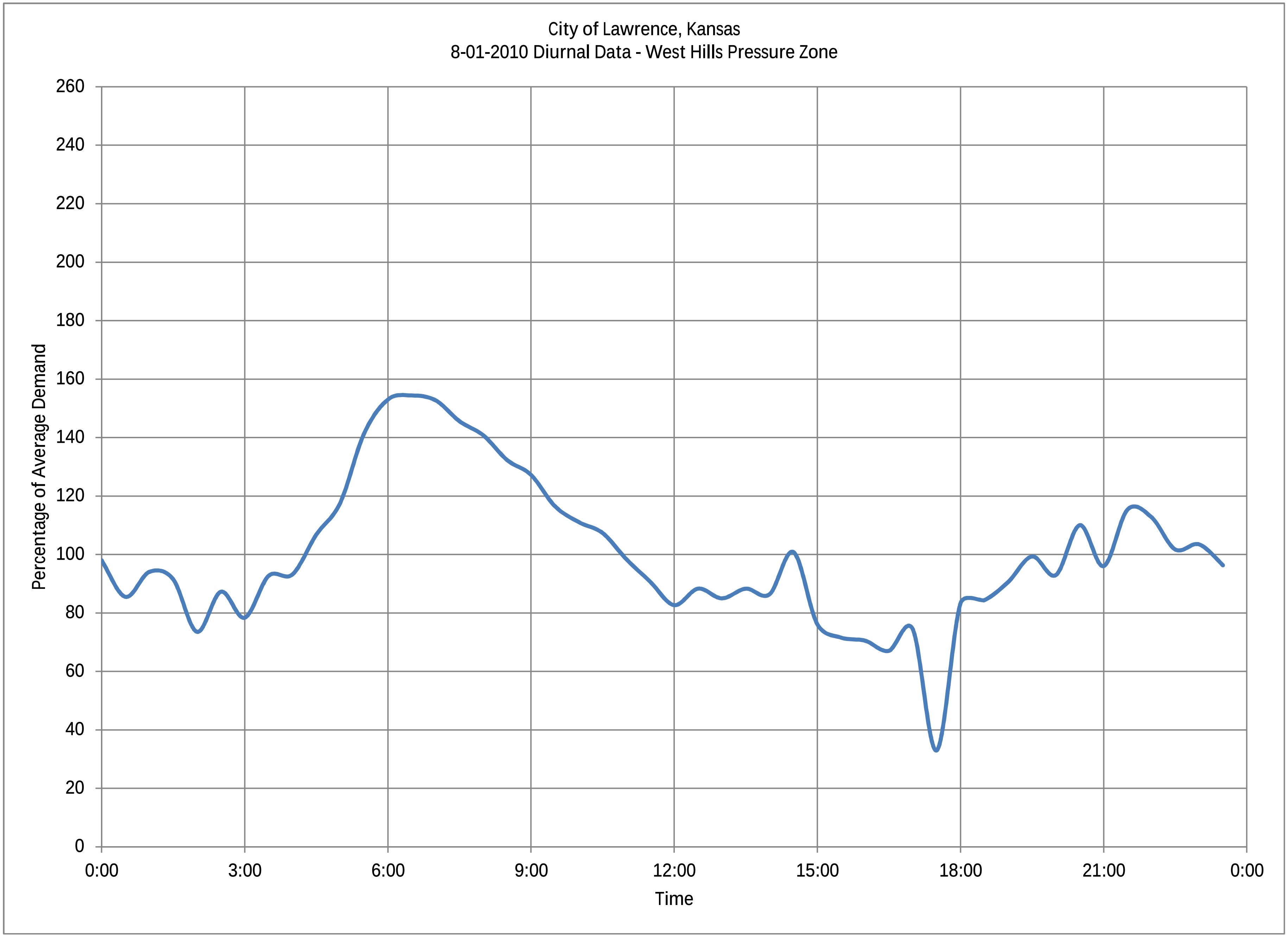
City of Lawrence, Kansas - 2011 Water Master Plan
July 31, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
		Flow	Volume	Flow	Volume	Flow	Volume	Flow	Volume		Volume		Volume		Volume	Flow	Volume						
Date	Time	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	(MGD)	(MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/31/2010	0:00	4.4	0.0917	0.0	0.0	0.0	0.0	1.6	0.0333	1164.7	0.0000	1167.8	0.0000	1165.1	0.0000	0.0	0.0000	0.13	0.01			92	
7/31/2010	0:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.2	0.0667	1164.9	0.0075	1167.7	-0.0013	1165.5	0.0067	0.0	0.0000	0.15		-0.01		107	
7/31/2010	1:00	4.4	0.0917	0.0	0.0	0.0	0.0	3.2	0.0667	1165.1	0.0075	1167.7	0.0000	1166.0	0.0083	0.0	0.0000	0.14		-0.01		104	
7/31/2010	1:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.2	0.0667	1165.2	0.0037	1167.7	0.0000	1166.4	0.0067	0.0	0.0000	0.15		-0.01		108	
7/31/2010	2:00	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1165.6	0.0150	1167.7	0.0000	1166.9	0.0083	0.0	0.0000	0.13	0.00			97	
7/31/2010	2:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1165.9	0.0112	1167.7	0.0000	1167.4	0.0083	0.0	0.0000	0.14	0.00			100	
7/31/2010	3:00	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1166.4	0.0187	1167.6	-0.0013	1168.0	0.0100	0.0	0.0000	0.13	0.01			94	
7/31/2010	3:30	4.4	0.0917	0.0	0.0	0.0	0.0	3.1	0.0646	1166.9	0.0187	1167.7	0.0013	1168.5	0.0083	0.0	0.0000	0.13	0.01			94	
7/31/2010	4:00	4.5	0.0938	0.0	0.0	0.0	0.0	0.0	0.0000	1167.1	0.0075	1167.8	0.0013	1168.5	0.0000	0.0	0.0000	0.08	0.05			62	
7/31/2010	4:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.6	0.0333	1166.8	-0.0112	1167.7	-0.0013	1167.6	-0.0150	0.0	0.0000	0.19		-0.05		136	
7/31/2010	5:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.6	0.0333	1166.8	0.0000	1167.7	0.0000	1167.3	-0.0050	0.0	0.0000	0.16		-0.03		120	
7/31/2010	5:30	6.0	0.1250	0.0	0.0	0.0	0.0	0.0	0.0000	1166.1	-0.0262	1167.5	-0.0026	1166.0	-0.0217	0.0	0.0000	0.18		-0.04		129	
7/31/2010	6:00	6.0	0.1250	0.0	0.0	0.0	0.0	0.0	0.0000	1165.4	-0.0262	1166.9	-0.0079	1164.5	-0.0250	1.5	0.0313	0.22		-0.08		158	
7/31/2010	6:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.9	-0.0187	1166.8	-0.0013	1164.7	0.0033	2.0	0.0417	0.22		-0.08		160	
7/31/2010	7:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.8	-0.0037	1166.9	0.0013	1164.9	0.0033	2.0	0.0417	0.20		-0.06		148	
7/31/2010	7:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.8	0.0000	1166.8	-0.0013	1165.0	0.0017	2.0	0.0417	0.20		-0.07		148	
7/31/2010	8:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1164.7	-0.0037	1166.9	0.0013	1165.4	0.0067	2.0	0.0417	0.20		-0.06		144	
7/31/2010	8:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.6	0.0333	1164.7	0.0000	1166.9	0.0000	1165.7	0.0050	1.9	0.0396	0.19		-0.06		141	
7/31/2010	9:00	6.0	0.1250	0.0	0.0	0.0	0.0	0.0	0.0000	1164.6	-0.0037	1166.9	0.0000	1166.4	0.0117	1.9	0.0396	0.16		-0.02		115	
7/31/2010	9:30	5.8	0.1208	0.0	0.0	0.0	0.0	0.0	0.0000	1164.6	0.0000	1166.9	0.0000	1166.2	-0.0033	2.3	0.0479	0.17		-0.04		126	
7/31/2010	10:00	5.7	0.1188	0.0	0.0	0.0	0.0	0.0	0.0000	1164.5	-0.0037	1166.8	-0.0013	1167.5	0.0217	2.2	0.0458	0.15		-0.01		109	
7/31/2010	10:30	5.6	0.1167	0.0	0.0	0.0	0.0	0.0	0.0000	1164.5	0.0000	1166.8	0.0000	1169.2	0.0283	2.2	0.0458	0.13	0.00			98	
7/31/2010	11:00	2.9	0.0604	0.0	0.0	0.0	0.0	0.0	0.0000	1164.3	-0.0075	1166.5	-0.0039	1170.9	0.0283	1.4	0.0292	0.07	0.06			53	
7/31/2010	11:30	2.4	0.0500	0.0	0.0	0.0	0.0	0.0	0.0000	1163.9	-0.0150	1166.5	0.0000	1168.0	-0.0483	0.0	0.0000	0.11	0.02			83	
7/31/2010	12:00	2.5	0.0521	0.0	0.0	0.0	0.0	0.0	0.0000	1163.4	-0.0187	1165.9	-0.0079	1165.6	-0.0400	0.0	0.0000	0.12	0.02			87	
7/31/2010	12:30	5.7	0.1188	0.0	0.0	0.0	0.0	1.6	0.0333	1163.1	-0.0112	1165.6	-0.0039	1164.4	-0.0200	0.0	0.0000	0.19		-0.05		137	
7/31/2010	13:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1163.9	0.0300	1165.6	0.0000	1165.2	0.0133	0.0	0.0000	0.12	0.02			84	
7/31/2010	13:30	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1164.9	0.0375	1165.6	0.0000	1165.4	0.0033	0.0	0.0000	0.10	0.03			75	
7/31/2010	14:00	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1165.7	0.0300	1165.6	0.0000	1165.7	0.0050	0.0	0.0000	0.11	0.03			80	
7/31/2010	14:30	5.8	0.1208	0.0	0.0	0.0	0.0	1.7	0.0354	1166.6	0.0337	1165.7	0.0013	1166.3	0.0100	0.0	0.0000	0.11	0.03			82	
7/31/2010	15:00	5.8	0.1208	0.0	0.0	0.0	0.0	1.7	0.0354	1167.0	0.0150	1167.3	0.0211	1166.6	0.0050	0.0	0.0000	0.12	0.02			84	
7/31/2010	15:30	4.5	0.0938	0.0	0.0	0.0	0.0	1.6	0.0333	1167.3	0.0112	1168.1	0.0105	1167.1	0.0083	0.0	0.0000	0.10	0.04			71	
7/31/2010	16:00	3.7	0.0771	0.0	0.0	0.0	0.0	1.7	0.0354	1167.3	0.0000	1168.1	0.0000	1167.8	0.0117	0.0	0.0000	0.10	0.04			74	
7/31/2010	16:30	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1167.2	-0.0037	1168.1	0.0000	1168.5	0.0117	0.0	0.0000	0.10	0.04			72	
7/31/2010	17:00	3.0	0.0625	0.0	0.0	0.0	0.0	1.7	0.0354	1167.3	0.0037	1168.1	0.0000	1169.1	0.0100	0.0	0.0000	0.08	0.05			62	
7/31/2010	17:30	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1167.3	0.0000	1168.1	0.0000	1168.8	-0.0050	0.0	0.0000	0.11	0.03			82	
7/31/2010	18:00	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1167.2	-0.0037	1168.2	0.0013	1169.1	0.0050	0.0	0.0000	0.10	0.03			76	
7/31/2010	18:30	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1167.2	0.0000	1168.1	-0.0013	1169.2	0.0017	0.0	0.0000	0.11	0.03			78	
7/31/2010	19:00	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1167.2	0.0000	1168.2	0.0013	1169.1	-0.0017	0.0	0.0000	0.11	0.03			78	
7/31/2010	19:30	3.4	0.0708	0.0	0.0	0.0	0.0	1.7	0.0354	1167.2	0.0000	1168.1	-0.0013	1169.0	-0.0017	0.0	0.0000	0.11	0.03			80	
7/31/2010	20:00	4.2	0.0875	0.0	0.0	0.0	0.0	1.6	0.0333	1167.3	0.0037	1168.1	0.0000	1169.6	0.0100	0.0	0.0000	0.11	0.03			79	
7/31/2010	20:30	4.3	0.0896	0.0	0.0	0.0	0.0	1.7	0.0354	1167.3	0.0000	1168.0	-0.0013	1170.3	0.0117	0.0	0.0000	0.11	0.02			84	
7/31/2010	21:00	4.3	0.0896	0.0	0.0	0.0	0.0	1.6	0.0333	1167.7	0.0150	1168.0	0.0000	1169.7	-0.0100	0.0	0.0000	0.12	0.02			86	
7/31/2010	21:30	4.3	0.0896	0.0	0.0	0.0	0.0	1.7	0.0354	1167.5	-0.0075	1168.1	0.0013	1168.9	-0.0133	0.0	0.0000	0.14		-0.01		106	
7/31/2010	22:00	4.3	0.0896	0.0	0.0	0.0	0.0	1.7	0.0354	1167.2	-0.0112	1168.1	0.0000	1168.2	-0.0117	0.0	0.0000	0.15		-0.01		108	
7/31/2010	22:30	4.4	0.0917	0.0	0.0	0.0	0.0	1.7	0.0354	1166.8	-0.0150	1168.0	-0.0013	1167.5	-0.0117	0.0	0.0000	0.16		-0.02		114	
7/31/2010	23:00	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1166.8	0.0000	1168.0	0.0000	1167.2	-0.0050	0.0	0.0000	0.15		-0.01		109	
7/31/2010	23:30	5.1	0.1063	0.0	0.0	0.0	0.0	1.7	0.0354	1167.4	0.0225	1168.1	0.0013	1167.4	0.0033	0.0	0.0000	0.11	0.02			84	
																		0.14	0.72	-0.72	11.0	98	6.55


City of Lawrence, Kansas
7-31-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

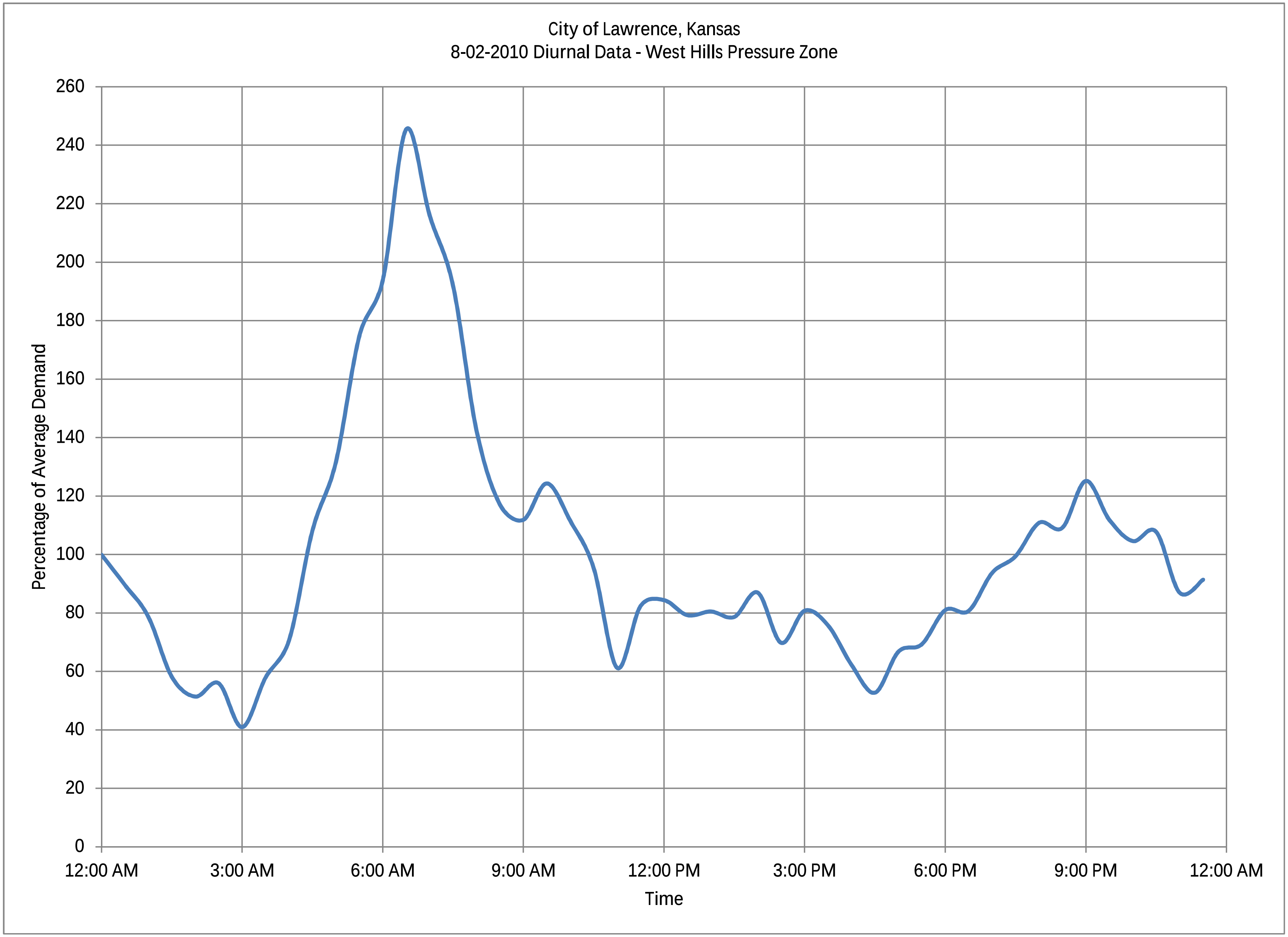
City of Lawrence, Kansas - 2011 Water Master Plan
August 1, 2010 Diurnal Data
West Hills Pressure Zone

		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
8/1/2010	0:00	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1167.9	0.0000	1168.0	0.0000	1167.6	0.0000	0.0	0.0000	0.14	0.00			98	
8/1/2010	0:30	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1168.3	0.0150	1168.0	0.0000	1167.8	0.0033	0.0	0.0000	0.13	0.02			86	
8/1/2010	1:00	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1168.5	0.0075	1168.0	0.0000	1167.7	-0.0017	0.0	0.0000	0.14	0.01			94	
8/1/2010	1:30	5.2	0.1083	0.0	0.0	0.0	0.0	1.7	0.0354	1168.7	0.0075	1167.9	-0.0013	1167.9	0.0033	0.0	0.0000	0.13	0.01			92	
8/1/2010	2:00	4.4	0.0917	0.0	0.0	0.0	0.0	1.7	0.0354	1169.0	0.0112	1168.0	0.0013	1168.3	0.0067	0.0	0.0000	0.11	0.04			74	
8/1/2010	2:30	4.3	0.0896	0.0	0.0	0.0	0.0	1.6	0.0333	1168.9	-0.0037	1167.9	-0.0013	1168.3	0.0000	0.0	0.0000	0.13	0.02			87	
8/1/2010	3:00	4.3	0.0896	0.0	0.0	0.0	0.0	1.7	0.0354	1169.0	0.0037	1168.0	0.0013	1168.6	0.0050	0.0	0.0000	0.11	0.03			78	
8/1/2010	3:30	4.4	0.0917	0.0	0.0	0.0	0.0	1.7	0.0354	1168.8	-0.0075	1167.9	-0.0013	1168.6	0.0000	0.0	0.0000	0.14	0.01			93	
8/1/2010	4:00	4.4	0.0917	0.0	0.0	0.0	0.0	1.7	0.0354	1168.5	-0.0112	1167.9	0.0000	1168.7	0.0017	0.0	0.0000	0.14	0.01			93	
8/1/2010	4:30	4.4	0.0917	0.0	0.0	0.0	0.0	1.7	0.0354	1167.9	-0.0225	1168.0	0.0013	1168.2	-0.0083	0.0	0.0000	0.16		-0.01		107	
8/1/2010	5:00	4.5	0.0938	0.0	0.0	0.0	0.0	1.7	0.0354	1167.1	-0.0300	1168.0	0.0000	1167.4	-0.0133	0.0	0.0000	0.17		-0.03		118	
8/1/2010	5:30	5.0	0.1042	0.0	0.0	0.0	0.0	1.7	0.0354	1165.9	-0.0450	1167.8	-0.0026	1166.2	-0.0200	0.0	0.0000	0.21		-0.06		141	
8/1/2010	6:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1165.4	-0.0187	1167.5	-0.0039	1165.6	-0.0100	1.5	0.0313	0.22		-0.08		153	
8/1/2010	6:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.8	-0.0225	1167.2	-0.0039	1165.1	-0.0083	1.5	0.0313	0.23		-0.08		154	
8/1/2010	7:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.3	-0.0187	1166.8	-0.0053	1164.6	-0.0083	1.5	0.0313	0.22		-0.08		153	
8/1/2010	7:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.0	-0.0112	1166.5	-0.0039	1164.2	-0.0067	1.5	0.0313	0.21		-0.07		146	
8/1/2010	8:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1163.8	-0.0075	1166.2	-0.0039	1164.0	-0.0033	1.5	0.0313	0.21		-0.06		141	
8/1/2010	8:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1163.6	-0.0075	1166.4	0.0026	1164.9	0.0150	2.3	0.0479	0.19		-0.05		132	
8/1/2010	9:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1163.6	0.0000	1166.5	0.0013	1166.0	0.0183	2.3	0.0479	0.19		-0.04		127	
8/1/2010	9:30	5.8	0.1208	0.0	0.0	0.0	0.0	1.6	0.0333	1163.7	0.0037	1166.4	-0.0013	1167.6	0.0267	2.2	0.0458	0.17		-0.02		117	
8/1/2010	10:00	5.6	0.1167	0.0	0.0	0.0	0.0	1.6	0.0333	1163.6	-0.0037	1166.4	0.0000	1169.8	0.0367	2.2	0.0458	0.16		-0.02		111	
8/1/2010	10:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1164.3	0.0262	1166.5	0.0013	1168.2	-0.0267	0.0	0.0000	0.16		-0.01		107	
8/1/2010	11:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1165.2	0.0337	1166.4	-0.0013	1167.1	-0.0183	0.0	0.0000	0.14	0.00			98	
8/1/2010	11:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1166.1	0.0337	1166.4	0.0000	1166.6	-0.0083	0.0	0.0000	0.13	0.01			91	
8/1/2010	12:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1167.0	0.0337	1166.4	0.0000	1166.8	0.0033	0.0	0.0000	0.12	0.03			83	
8/1/2010	12:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1167.6	0.0225	1166.5	0.0013	1167.1	0.0050	0.0	0.0000	0.13	0.02			88	
8/1/2010	13:00	5.9	0.1229	0.0	0.0	0.0	0.0	0.0	0.0000	1167.9	0.0112	1166.4	-0.0013	1166.4	-0.0117	0.0	0.0000	0.12	0.02			85	
8/1/2010	13:30	5.9	0.1229	0.0	0.0	0.0	0.0	0.0	0.0000	1168.0	0.0037	1166.5	0.0013	1165.7	-0.0117	0.0	0.0000	0.13	0.02			88	
8/1/2010	14:00	5.8	0.1208	0.0	0.0	0.0	0.0	0.0	0.0000	1168.1	0.0037	1166.4	-0.0013	1165.2	-0.0083	0.0	0.0000	0.13	0.02			86	
8/1/2010	14:30	5.8	0.1208	0.0	0.0	0.0	0.0	1.7	0.0354	1168.2	0.0037	1166.5	0.0013	1165.4	0.0033	0.0	0.0000	0.15	0.00			101	
8/1/2010	15:00	5.8	0.1208	0.0	0.0	0.0	0.0	1.7	0.0354	1168.9	0.0262	1166.5	0.0000	1166.5	0.0183	0.0	0.0000	0.11	0.03			76	
8/1/2010	15:30	5.8	0.1208	0.0	0.0	0.0	0.0	1.7	0.0354	1169.7	0.0300	1166.6	0.0013	1167.7	0.0200	0.0	0.0000	0.10	0.04			72	
8/1/2010	16:00	5.7	0.1188	0.0	0.0	0.0	0.0	1.6	0.0333	1170.5	0.0300	1166.5	-0.0013	1168.9	0.0200	0.0	0.0000	0.10	0.04			71	
8/1/2010	16:30	5.7	0.1188	0.0	0.0	0.0	0.0	1.6	0.0333	1171.4	0.0337	1166.5	0.0000	1170.1	0.0200	0.0	0.0000	0.10	0.05			67	
8/1/2010	17:00	5.7	0.1188	0.0	0.0	0.0	0.0	1.6	0.0333	1172.1	0.0262	1166.5	0.0000	1171.1	0.0167	0.0	0.0000	0.11	0.04			74	
8/1/2010	17:30	1.8	0.0375	0.0	0.0	0.0	0.0	1.6	0.0333	1171.9	-0.0075	1166.5	0.0000	1172.9	0.0300	0.0	0.0000	0.05	0.10			33	
8/1/2010	18:00	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1170.3	-0.0600	1166.5	0.0000	1171.3	-0.0267	0.0	0.0000	0.12	0.02			83	
8/1/2010	18:30	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1168.7	-0.0600	1166.5	0.0000	1169.6	-0.0283	0.0	0.0000	0.12	0.02			84	
8/1/2010	19:00	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1166.9	-0.0675	1166.5	0.0000	1167.8	-0.0300	0.0	0.0000	0.13	0.01			91	
8/1/2010	19:30	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1164.9	-0.0750	1166.1	-0.0053	1166.0	-0.0300	0.0	0.0000	0.15	0.00			99	
8/1/2010	20:00	0.0	0.0000	0.0	0.0	0.0	0.0	1.7	0.0354	1163.2	-0.0637	1165.3	-0.0105	1164.4	-0.0267	0.0	0.0000	0.14	0.01			93	
8/1/2010	20:30	5.4	0.1125	0.0	0.0	0.0	0.0	1.7	0.0354	1163.0	-0.0075	1165.1	-0.0026	1164.2	-0.0033	0.0	0.0000	0.16		-0.01		110	
8/1/2010	21:00	5.3	0.1104	0.0	0.0	0.0	0.0	1.7	0.0354	1163.0	0.0000	1165.1	0.0000	1164.5	0.0050	0.0	0.0000	0.14	0.01			96	
8/1/2010	21:30	6.1	0.1271	0.0	0.0	0.0	0.0	1.7	0.0354	1163.0	0.0000	1165.1	0.0000	1164.1	-0.0067	0.0	0.0000	0.17		-0.02		115	
8/1/2010	22:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1162.9	-0.0037	1165.1	0.0000	1163.9	-0.0033	0.0	0.0000	0.17		-0.02		113	
8/1/2010	22:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1163.1	0.0075	1165.1	0.0000	1164.0	0.0017	0.0	0.0000	0.15	0.00			102	
8/1/2010	23:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.7	0.0354	1163.0	-0.0037	1165.0	-0.0013	1164.7	0.0117	0.0	0.0000	0.15		-0.01		103	
8/1/2010	23:30	5.8	0.1208	0.0	0.0	0.0	0.0	1.7	0.0354	1163.0	0.0000	1165.0	0.0000	1165.6	0.0150	0.0	0.0000	0.14	0.01			96	
																		0.15	0.66	-0.66	9.3	100	7.04


City of Lawrence, Kansas
8-01-2010 Diurnal Data - West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Time

City of Lawrence, Kansas - 2011 Water Master Plan
August 2, 2010 Diurnal Data
West Hills Pressure Zone

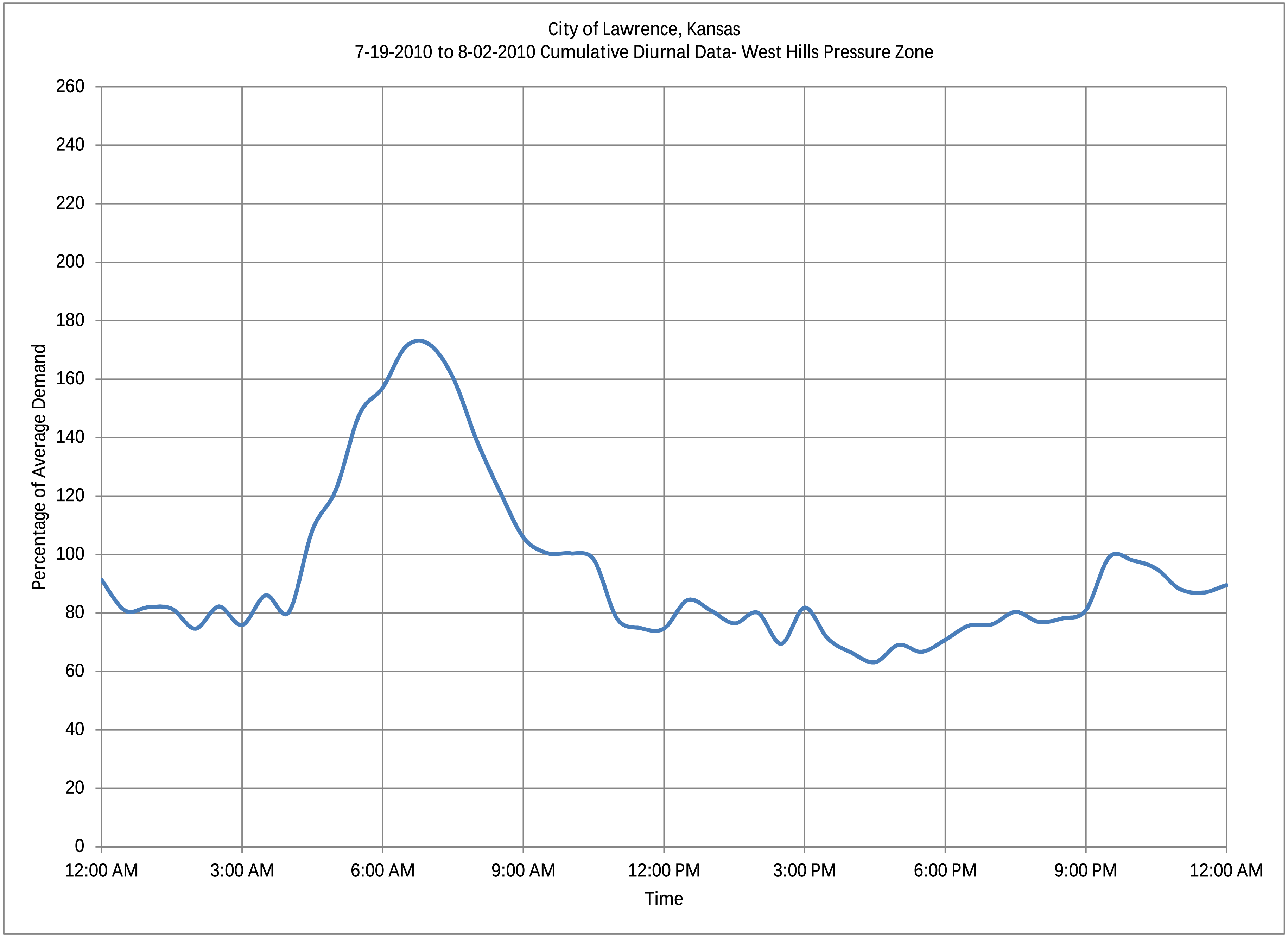
		Clinton Contribution						Kaw Contribution		Stoneridge 1.5 MG		6th & Kasold 0.5 MG		Stratford 0.5 MG		19th and Kasold BPS		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS 1 (a)		HSPS		Elevated Tank		Elevated Tank		Elevated Tank		Booster Pump Station		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Flow (MGD)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
8/2/2010	0:00	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1163.4	0.0000	1165.0	0.0000	1166.1	0.0000	0.0	0.0000	0.16	0.00			100	
8/2/2010	0:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.2	0.0300	1165.0	0.0000	1165.3	-0.0133	0.0	0.0000	0.14	0.02			90	
8/2/2010	1:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1165.0	0.0300	1165.0	0.0000	1165.3	0.0000	0.0	0.0000	0.13	0.03			79	
8/2/2010	1:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1166.1	0.0412	1165.0	0.0000	1166.6	0.0217	0.0	0.0000	0.09	0.07			58	
8/2/2010	2:00	5.8	0.1208	0.0	0.0	0.0	0.0	1.6	0.0333	1167.3	0.0450	1165.0	0.0000	1168.2	0.0267	0.0	0.0000	0.08	0.08			51	
8/2/2010	2:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1167.9	0.0225	1167.2	0.0289	1169.1	0.0150	0.0	0.0000	0.09	0.07			56	
8/2/2010	3:00	5.9	0.1229	0.0	0.0	0.0	0.0	0.0	0.0000	1168.7	0.0300	1168.0	0.0105	1170.1	0.0167	0.0	0.0000	0.07	0.09			41	
8/2/2010	3:30	5.8	0.1208	0.0	0.0	0.0	0.0	0.0	0.0000	1169.3	0.0225	1167.9	-0.0013	1170.5	0.0067	0.0	0.0000	0.09	0.07			58	
8/2/2010	4:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1170.0	0.0262	1167.9	0.0000	1171.5	0.0167	0.0	0.0000	0.11	0.05			71	
8/2/2010	4:30	5.8	0.1208	0.0	0.0	0.0	0.0	1.6	0.0333	1169.8	-0.0075	1168.0	0.0013	1170.7	-0.0133	0.0	0.0000	0.17		-0.01		108	
8/2/2010	5:00	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1168.9	-0.0337	1167.9	-0.0013	1169.5	-0.0200	0.0	0.0000	0.21		-0.05		132	
8/2/2010	5:30	5.9	0.1229	0.0	0.0	0.0	0.0	1.6	0.0333	1166.8	-0.0787	1167.1	-0.0105	1167.4	-0.0350	0.0	0.0000	0.28		-0.12		175	
8/2/2010	6:00	6.1	0.1271	0.0	0.0	0.0	0.0	1.7	0.0354	1164.4	-0.0900	1165.3	-0.0237	1165.3	-0.0350	0.0	0.0000	0.31		-0.15		194	
8/2/2010	6:30	7.5	0.1563	0.0	0.0	0.0	0.0	1.7	0.0354	1162.0	-0.0900	1163.6	-0.0224	1162.9	-0.0400	2.4	0.0500	0.39		-0.23		245	
8/2/2010	7:00	9.6	0.2000	0.0	0.0	0.0	0.0	1.7	0.0354	1161.0	-0.0375	1163.3	-0.0039	1161.7	-0.0200	2.4	0.0500	0.35		-0.19		216	
8/2/2010	7:30	9.4	0.1958	0.0	0.0	0.0	0.0	1.6	0.0333	1160.5	-0.0187	1163.0	-0.0039	1161.2	-0.0083	2.3	0.0479	0.31		-0.15		192	
8/2/2010	8:00	8.8	0.1833	0.0	0.0	0.0	0.0	1.6	0.0333	1160.4	-0.0037	1163.1	0.0013	1163.5	0.0383	2.3	0.0479	0.23		-0.07		142	
8/2/2010	8:30	9.4	0.1958	0.0	0.0	0.0	0.0	1.6	0.0333	1160.6	0.0075	1163.0	-0.0013	1165.6	0.0350	0.0	0.0000	0.19		-0.03		117	
8/2/2010	9:00	9.2	0.1917	0.0	0.0	0.0	0.0	1.6	0.0333	1161.9	0.0487	1163.0	0.0000	1165.4	-0.0033	0.0	0.0000	0.18		-0.02		112	
8/2/2010	9:30	9.1	0.1896	0.0	0.0	0.0	0.0	1.6	0.0333	1163.4	0.0562	1163.0	0.0000	1165.8	0.0067	1.9	0.0396	0.20		-0.04		124	
8/2/2010	10:00	9.0	0.1875	0.0	0.0	0.0	0.0	1.6	0.0333	1165.1	0.0637	1163.2	0.0026	1166.7	0.0150	1.9	0.0396	0.18		-0.02		112	
8/2/2010	10:30	8.8	0.1833	0.0	0.0	0.0	0.0	1.6	0.0333	1167.3	0.0825	1163.0	-0.0026	1168.1	0.0233	1.9	0.0396	0.15	0.01			95	
8/2/2010	11:00	8.6	0.1792	0.0	0.0	0.0	0.0	1.6	0.0333	1169.6	0.0862	1163.1	0.0013	1169.7	0.0267	0.0	0.0000	0.10	0.06			61	
8/2/2010	11:30	7.4	0.1542	0.0	0.0	0.0	0.0	0.0	0.0000	1170.0	0.0150	1165.4	0.0303	1168.3	-0.0233	0.0	0.0000	0.13	0.03			82	
8/2/2010	12:00	7.3	0.1521	0.0	0.0	0.0	0.0	0.0	0.0000	1170.3	0.0112	1167.2	0.0237	1167.2	-0.0183	0.0	0.0000	0.14	0.03			84	
8/2/2010	12:30	7.3	0.1521	0.0	0.0	0.0	0.0	0.0	0.0000	1170.8	0.0187	1168.3	0.0145	1166.7	-0.0083	0.0	0.0000	0.13	0.03			79	
8/2/2010	13:00	7.2	0.1500	0.0	0.0	0.0	0.0	0.0	0.0000	1171.3	0.0187	1168.2	-0.0013	1166.9	0.0033	0.0	0.0000	0.13	0.03			80	
8/2/2010	13:30	7.2	0.1500	0.0	0.0	0.0	0.0	0.0	0.0000	1171.8	0.0187	1168.2	0.0000	1167.2	0.0050	0.0	0.0000	0.13	0.03			79	
8/2/2010	14:00	6.6	0.1375	0.0	0.0	0.0	0.0	1.6	0.0333	1172.1	0.0112	1168.2	0.0000	1168.4	0.0200	0.0	0.0000	0.14	0.02			87	
8/2/2010	14:30	4.0	0.0833	0.0	0.0	0.0	0.0	1.6	0.0333	1171.7	-0.0150	1168.3	0.0013	1169.5	0.0183	0.0	0.0000	0.11	0.05			70	
8/2/2010	15:00	3.9	0.0813	0.0	0.0	0.0	0.0	1.6	0.0333	1171.2	-0.0187	1168.2	-0.0013	1169.8	0.0050	0.0	0.0000	0.13	0.03			81	
8/2/2010	15:30	4.0	0.0833	0.0	0.0	0.0	0.0	1.6	0.0333	1170.9	-0.0112	1168.3	0.0013	1170.1	0.0050	0.0	0.0000	0.12	0.04			76	
8/2/2010	16:00	3.9	0.0813	0.0	0.0	0.0	0.0	1.6	0.0333	1170.9	0.0000	1168.4	0.0013	1170.9	0.0133	0.0	0.0000	0.10	0.06			62	
8/2/2010	16:30	1.9	0.0396	0.0	0.0	0.0	0.0	1.6	0.0333	1170.4	-0.0187	1168.3	-0.0013	1171.4	0.0083	0.0	0.0000	0.08	0.08			53	
8/2/2010	17:00	2.0	0.0417	0.0	0.0	0.0	0.0	1.6	0.0333	1169.8	-0.0225	1168.2	-0.0013	1170.9	-0.0083	0.0	0.0000	0.11	0.05			67	
8/2/2010	17:30	2.1	0.0438	0.0	0.0	0.0	0.0	1.6	0.0333	1169.2	-0.0225	1168.2	0.0000	1170.2	-0.0117	0.0	0.0000	0.11	0.05			69	
8/2/2010	18:00	2.2	0.0458	0.0	0.0	0.0	0.0	1.7	0.0354	1168.3	-0.0337	1168.2	0.0000	1169.3	-0.0150	0.0	0.0000	0.13	0.03			81	
8/2/2010	18:30	2.3	0.0479	0.0	0.0	0.0	0.0	1.6	0.0333	1167.5	-0.0300	1168.2	0.0000	1168.2	-0.0183	0.0	0.0000	0.13	0.03			81	
8/2/2010	19:00	2.4	0.0500	0.0	0.0	0.0	0.0	1.7	0.0354	1166.3	-0.0450	1168.2	0.0000	1167.0	-0.0200	0.0	0.0000	0.15	0.01			94	
8/2/2010	19:30	2.5	0.0521	0.0	0.0	0.0	0.0	1.7	0.0354	1165.2	-0.0412	1167.5	-0.0092	1165.7	-0.0217	0.0	0.0000	0.16	0.00			99	
8/2/2010	20:00	5.3	0.1104	0.0	0.0	0.0	0.0	1.7	0.0354	1164.7	-0.0187	1167.5	0.0000	1164.9	-0.0133	0.0	0.0000	0.18		-0.02		111	
8/2/2010	20:30	6.0	0.1250	0.0	0.0	0.0	0.0	1.7	0.0354	1164.5	-0.0075	1167.7	0.0026	1164.3	-0.0100	0.0	0.0000	0.18		-0.01		109	
8/2/2010	21:00	7.9	0.1646	0.0	0.0	0.0	0.0	1.7	0.0354	1164.8	0.0112	1166.9	-0.0105	1164.2	-0.0017	0.0	0.0000	0.20		-0.04		125	
8/2/2010	21:30	7.9	0.1646	0.0	0.0	0.0	0.0	1.7	0.0354	1165.3	0.0187	1166.9	0.0000	1164.3	0.0017	0.0	0.0000	0.18		-0.02		112	
8/2/2010	22:00	7.5	0.1563	0.0	0.0	0.0	0.0	1.6	0.0333	1165.3	0.0000	1166.9	0.0000	1165.6	0.0217	0.0	0.0000	0.17		-0.01		105	
8/2/2010	22:30	7.5	0.1563	0.0	0.0	0.0	0.0	1.6	0.0333	1165.2	-0.0037	1166.8	-0.0013	1166.9	0.0217	0.0	0.0000	0.17		-0.01		108	
8/2/2010	23:00	7.9	0.1646	0.0	0.0	0.0	0.0	0.0	0.0000	1165.6	0.0150	1166.8	0.0000	1167.5	0.0100	0.0	0.0000	0.14	0.02			87	
8/2/2010	23:30	7.8	0.1625	0.0	0.0	0.0	0.0	0.0	0.0000	1166.6	0.0375	1166.8	0.0000	1166.2	-0.0217	0.0	0.0000	0.15	0.01			91	
																		0.16	1.19	-1.19	15.4	97	7.71



City of Lawrence, Kansas
8-02-2010 Diurnal Data - West Hills Pressure Zone

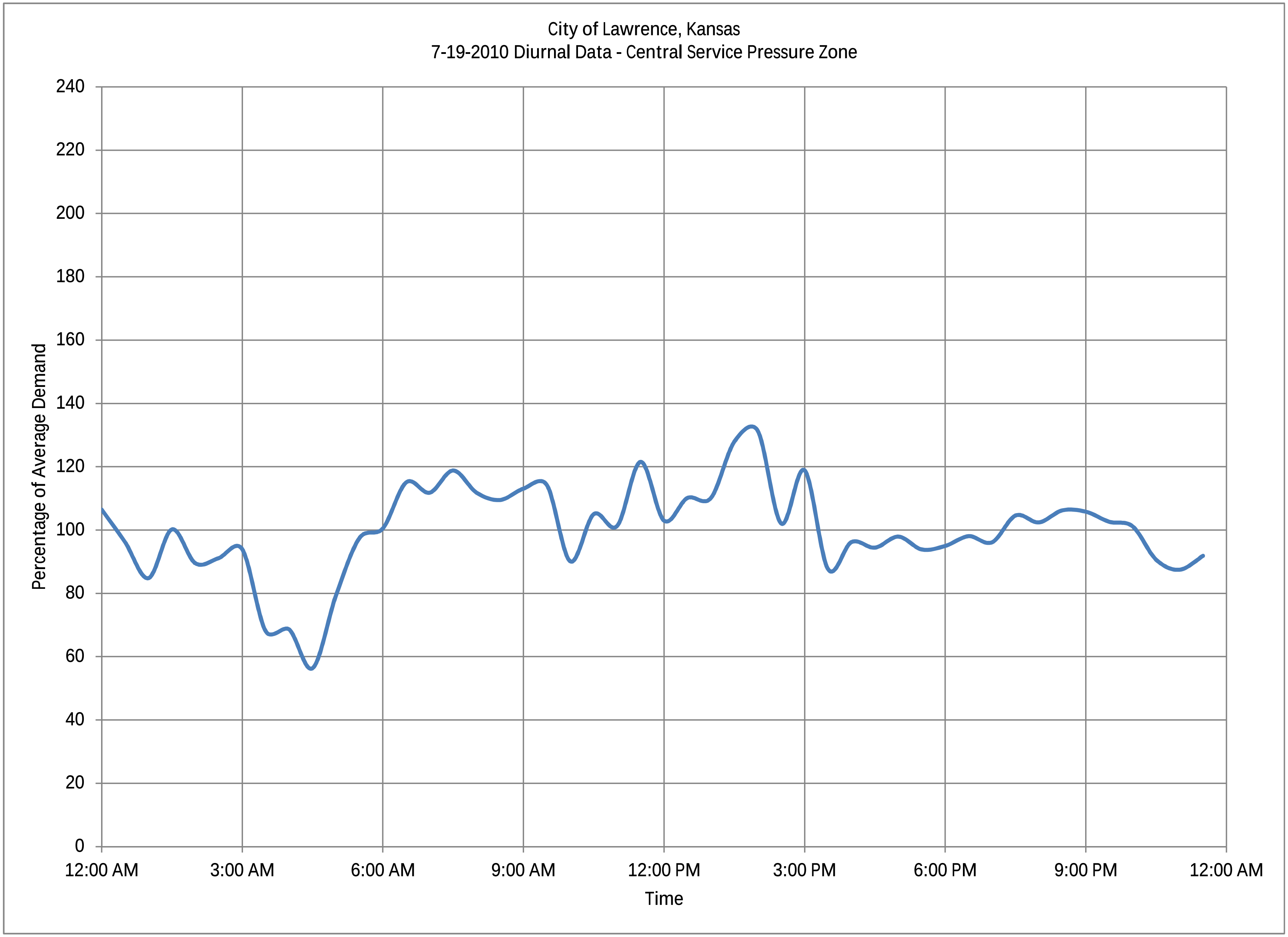
City of Lawrence, Kansas - 2011 Water Master Plan
Cumulative Diurnal Data
West Hills Pressure Zone

Time	Sum	Diurnal (%)
0:00	1369	91
0:30	1212	81
1:00	1229	82
1:30	1221	81
2:00	1045	75
2:30	1151	82
3:00	1138	76
3:30	1290	86
4:00	1205	80
4:30	1625	108
5:00	1832	122
5:30	2218	148
6:00	2357	157
6:30	2569	171
7:00	2577	172
7:30	2407	160
8:00	2087	139
8:30	1823	122
9:00	1588	106
9:30	1507	100
10:00	1506	100
10:30	1474	98
11:00	1170	78
11:30	1122	75
12:00	1120	75
12:30	1266	84
13:00	1213	81
13:30	1146	76
14:00	1201	80
14:30	1042	69
15:00	1227	82
15:30	1067	71
16:00	996	66
16:30	947	63
17:00	1036	69
17:30	1001	67
18:00	1062	71
18:30	1135	76
19:00	1142	76
19:30	1205	80
20:00	1154	77
20:30	1172	78
21:00	1214	81
21:30	1487	99
22:00	1470	98
22:30	1427	95
23:00	1235	88
23:30	1217	87
0:00	1343	90


City of Lawrence, Kansas
7-19-2010 to 8-02-2010 Cumulative Diurnal Data- West Hills Pressure Zone
Percentage of Average Demand
260
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

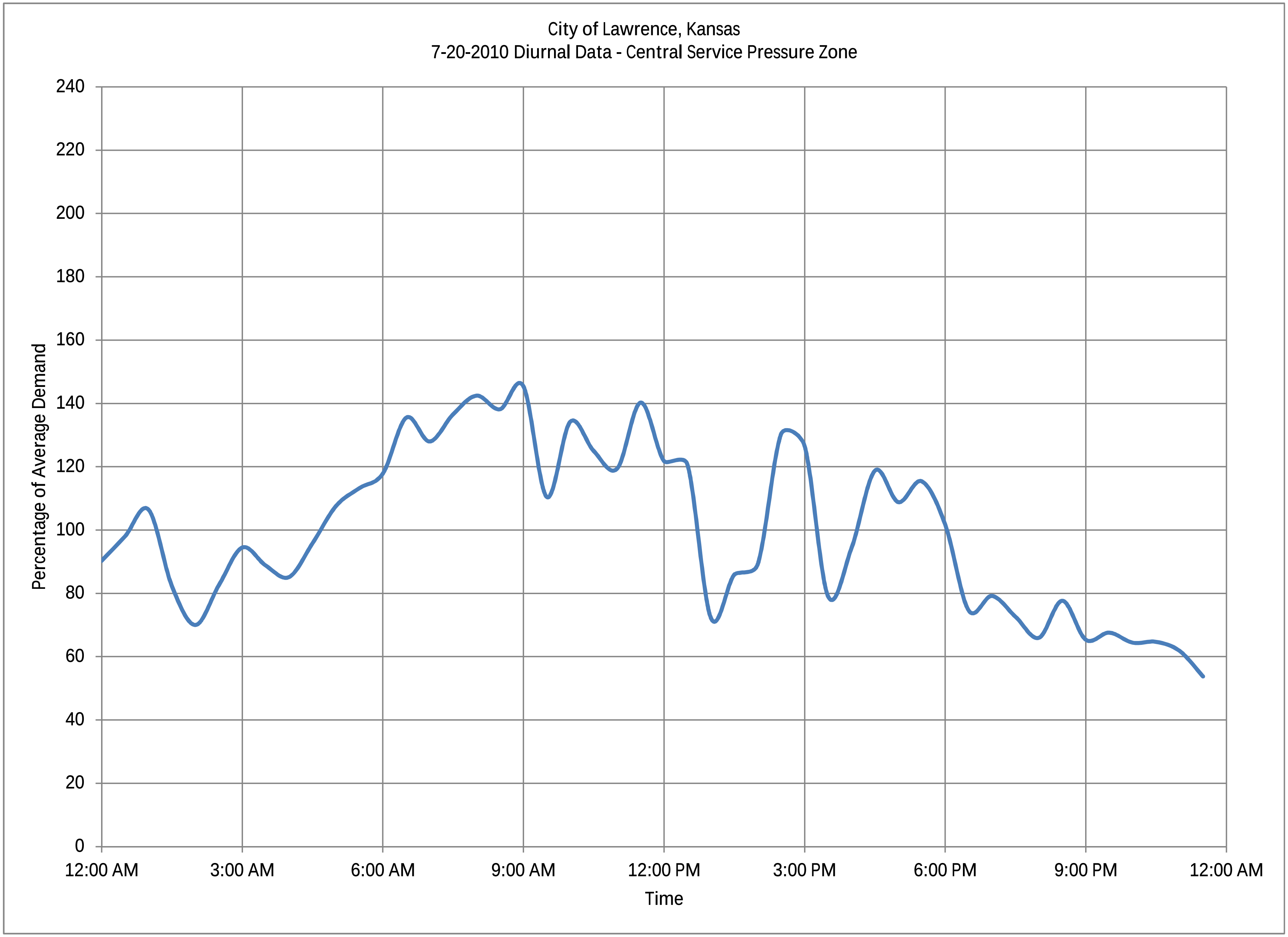
City of Lawrence, Kansas - 2011 Water Master Plan
July 19, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/19/2010	0:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1009.6	0.0000	1010.6	0.0000	1011.0	0.0000	0.16		-0.01		106	
7/19/2010	0:30	4.6	0.0958	0.0	0.0	3.3	0.0688	1009.7	0.0013	1010.6	0.0000	1011.2	0.0166	0.15	0.01			96	
7/19/2010	1:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1009.7	0.0000	1010.6	0.0000	1011.6	0.0331	0.13	0.02			85	
7/19/2010	1:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1009.8	0.0013	1010.6	0.0000	1011.7	0.0083	0.15	0.00			100	
7/19/2010	2:00	5.3	0.1104	0.0	0.0	3.3	0.0688	1009.7	-0.0013	1010.7	0.0025	1012.2	0.0414	0.14	0.02			89	
7/19/2010	2:30	5.3	0.1104	0.0	0.0	3.3	0.0688	1009.6	-0.0013	1010.7	0.0000	1012.7	0.0414	0.14	0.01			91	
7/19/2010	3:00	5.3	0.1104	0.0	0.0	6.5	0.1354	1011.2	0.0211	1011.3	0.0153	1013.5	0.0662	0.14	0.01			94	
7/19/2010	3:30	5.2	0.1083	0.0	0.0	3.3	0.0688	1012.9	0.0224	1012.0	0.0178	1013.9	0.0331	0.10	0.05			68	
7/19/2010	4:00	5.2	0.1083	0.0	0.0	3.3	0.0688	1014.0	0.0145	1012.0	0.0000	1014.6	0.0579	0.10	0.05			69	
7/19/2010	4:30	4.8	0.1000	0.0	0.0	3.3	0.0688	1014.0	0.0000	1012.0	0.0000	1015.6	0.0828	0.09	0.07			56	
7/19/2010	5:00	4.1	0.0854	0.0	0.0	3.3	0.0688	1014.0	0.0000	1012.0	0.0000	1016.0	0.0331	0.12	0.03			79	
7/19/2010	5:30	3.9	0.0813	0.0	0.0	3.3	0.0688	1014.1	0.0013	1011.6	0.0000	1016.0	0.0000	0.15	0.00			97	
7/19/2010	6:00	3.9	0.0813	0.0	0.0	3.4	0.0708	1014.0	-0.0013	1010.0	0.0000	1016.0	0.0000	0.15	0.00			101	
7/19/2010	6:30	4.0	0.0833	0.0	0.0	3.3	0.0688	1014.1	0.0013	1008.5	0.0000	1015.7	-0.0248	0.18		-0.02		115	
7/19/2010	7:00	3.3	0.0688	0.0	0.0	3.3	0.0688	1014.1	0.0000	1006.9	0.0000	1015.3	-0.0331	0.17		-0.02		112	
7/19/2010	7:30	3.2	0.0667	0.0	0.0	3.4	0.0708	1014.0	-0.0013	1005.3	0.0011	1014.8	-0.0414	0.18		-0.03		119	
7/19/2010	8:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1014.0	0.0000	1003.8	0.0000	1014.4	-0.0331	0.17		-0.02		112	
7/19/2010	8:30	3.1	0.0646	0.0	0.0	3.3	0.0688	1014.0	0.0000	1002.3	0.0006	1014.0	-0.0331	0.17		-0.01		109	
7/19/2010	9:00	3.3	0.0688	0.0	0.0	0.0	0.0000	1012.4	-0.0211	1000.8	0.0000	1013.0	-0.0828	0.17		-0.02		113	
7/19/2010	9:30	3.3	0.0688	0.0	0.0	0.0	0.0000	1011.2	-0.0158	1000.2	-0.0153	1012.1	-0.0745	0.17		-0.02		114	
7/19/2010	10:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1011.2	0.0000	1000.2	0.0000	1012.1	0.0000	0.14	0.02			90	
7/19/2010	10:30	3.1	0.0646	0.0	0.0	3.4	0.0708	1011.2	0.0000	1000.2	0.0000	1011.8	-0.0248	0.16		-0.01		105	
7/19/2010	11:00	3.1	0.0646	0.0	0.0	3.4	0.0708	1011.0	-0.0026	1000.2	0.0000	1011.6	-0.0166	0.15	0.00			101	
7/19/2010	11:30	5.9	0.1229	0.0	0.0	3.4	0.0708	1011.0	0.0000	1000.2	0.0000	1011.7	0.0083	0.19		-0.03		122	
7/19/2010	12:00	6.0	0.1250	0.0	0.0	2.4	0.0500	1011.1	0.0013	1000.2	0.0000	1011.9	0.0166	0.16	0.00			103	
7/19/2010	12:30	6.0	0.1250	0.0	0.0	2.4	0.0500	1011.0	-0.0013	1000.2	0.0000	1012.0	0.0083	0.17		-0.02		110	
7/19/2010	13:00	6.0	0.1250	0.0	0.0	2.4	0.0500	1010.9	-0.0013	1000.2	0.0000	1012.1	0.0083	0.17		-0.02		110	
7/19/2010	13:30	6.3	0.1313	0.0	0.0	2.4	0.0500	1011.1	0.0026	1000.2	0.0000	1011.9	-0.0166	0.20		-0.04		128	
7/19/2010	14:00	6.3	0.1313	0.0	0.0	2.4	0.0500	1010.9	-0.0026	1000.2	0.0000	1011.7	-0.0166	0.20		-0.05		131	
7/19/2010	14:30	6.0	0.1250	0.0	0.0	3.4	0.0708	1010.8	-0.0013	1000.2	0.0000	1012.2	0.0414	0.16	0.00			102	
7/19/2010	15:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1010.8	0.0000	1000.2	0.0000	1012.4	0.0166	0.18		-0.03		119	
7/19/2010	15:30	5.9	0.1229	0.0	0.0	3.3	0.0688	1010.8	0.0000	1000.2	0.0000	1013.1	0.0579	0.13	0.02			88	
7/19/2010	16:00	6.1	0.1271	0.0	0.0	3.3	0.0688	1010.8	0.0000	1000.5	0.0076	1013.6	0.0414	0.15	0.01			96	
7/19/2010	16:30	6.3	0.1313	0.0	0.0	3.3	0.0688	1010.7	-0.0013	1002.1	0.0407	1013.8	0.0166	0.14	0.01			94	
7/19/2010	17:00	6.1	0.1271	0.0	0.0	3.3	0.0688	1010.7	0.0000	1003.6	0.0381	1013.9	0.0083	0.15	0.00			98	
7/19/2010	17:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1010.7	0.0000	1005.1	0.0381	1014.1	0.0166	0.14	0.01			94	
7/19/2010	18:00	6.1	0.1271	0.0	0.0	3.3	0.0688	1010.8	0.0013	1006.4	0.0331	1014.3	0.0166	0.14	0.01			95	
7/19/2010	18:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1010.7	-0.0013	1007.7	0.0331	1014.5	0.0166	0.15	0.00			98	
7/19/2010	19:00	6.0	0.1250	0.0	0.0	3.3	0.0688	1010.7	0.0000	1008.9	0.0305	1014.7	0.0166	0.15	0.01			96	
7/19/2010	19:30	6.1	0.1271	0.0	0.0	3.3	0.0688	1010.7	0.0000	1010.0	0.0280	1014.8	0.0083	0.16		-0.01		105	
7/19/2010	20:00	5.3	0.1104	0.0	0.0	3.3	0.0688	1010.7	0.0000	1010.9	0.0229	1014.8	0.0000	0.16	0.00			102	
7/19/2010	20:30	4.9	0.1021	0.0	0.0	3.3	0.0688	1011.9	0.0158	1011.6	0.0178	1014.5	-0.0248	0.16		-0.01		106	
7/19/2010	21:00	4.9	0.1021	0.0	0.0	3.3	0.0688	1013.1	0.0158	1012.0	0.0102	1014.3	-0.0166	0.16		-0.01		106	
7/19/2010	21:30	3.8	0.0792	0.0	0.0	3.3	0.0688	1013.7	0.0079	1012.0	0.0000	1014.1	-0.0166	0.16	0.00			103	
7/19/2010	22:00	3.8	0.0792	0.0	0.0	3.4	0.0708	1014.0	0.0039	1012.0	0.0000	1014.0	-0.0083	0.15	0.00			101	
7/19/2010	22:30	3.7	0.0771	0.0	0.0	3.4	0.0708	1014.1	0.0013	1012.0	0.0000	1014.1	0.0083	0.14	0.01			91	
7/19/2010	23:00	3.8	0.0792	0.0	0.0	3.4	0.0708	1014.1	0.0000	1012.0	0.0000	1014.3	0.0166	0.13	0.02			87	
7/19/2010	23:30	3.7	0.0771	0.0	0.0	3.3	0.0688	1013.9	-0.0026	1012.0	0.0000	1014.4	0.0083	0.14	0.01			92	
														0.15	0.37	-0.37	5.0	90	7.32


City of Lawrence, Kansas
7-19-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

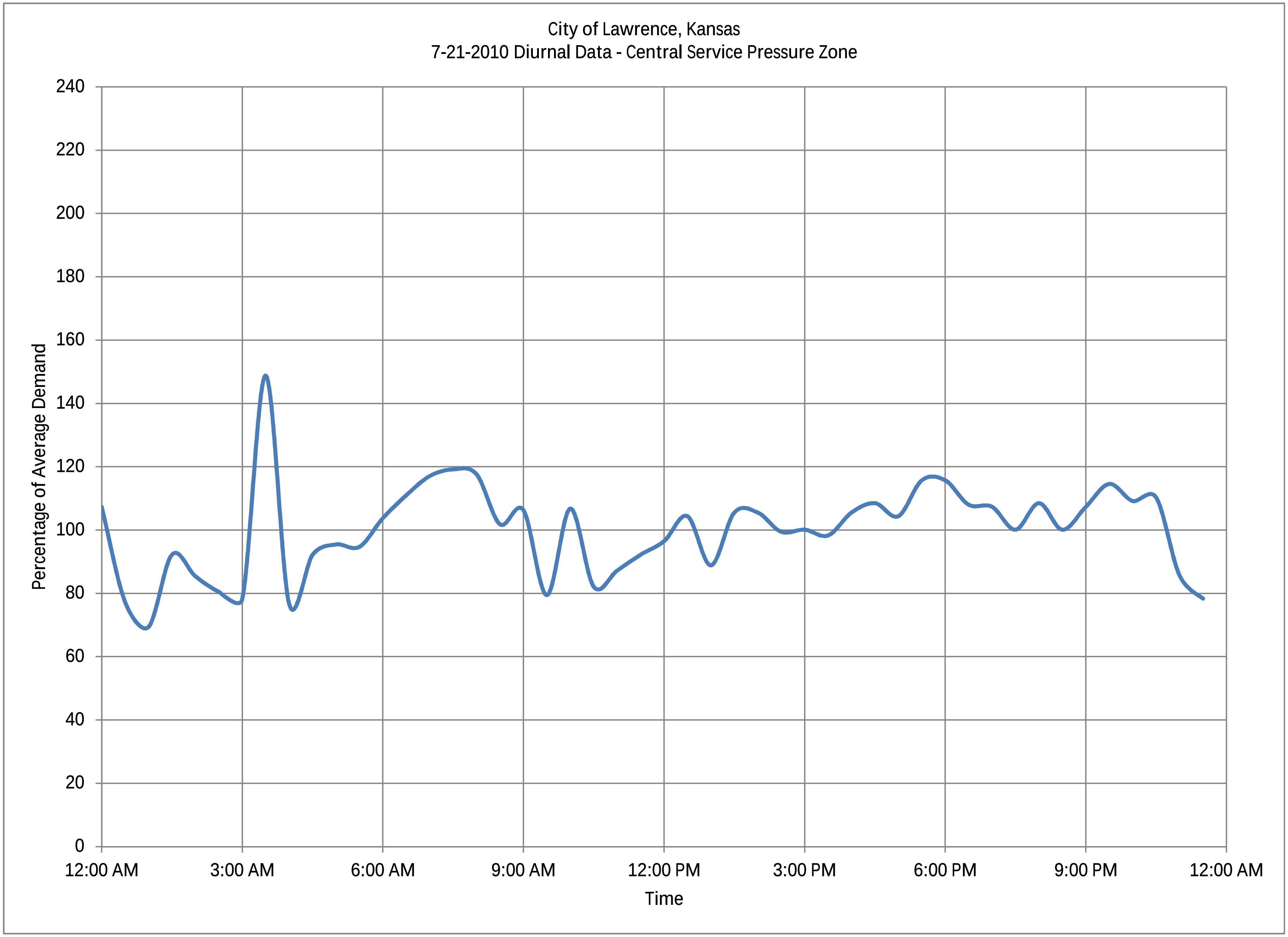
City of Lawrence, Kansas - 2011 Water Master Plan
July 20, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/20/2011	0:00	3.7	0.0770	0.0	0.0	3.3	0.0688	1013.8	0.0000	1012.0	0	1014.3	0.0000	0.15	0.02			90	
7/20/2011	0:30	3.7	0.0778	0.0	0.0	3.4	0.0708	1013.7	-0.0013	1012.0	0.0000	1014.2	-0.0083	0.16	0.00			98	
7/20/2011	1:00	3.4	0.0709	0.0	0.0	6.5	0.1354	1013.8	0.0013	1012.0	0.0000	1014.6	0.0331	0.17		-0.01		106	
7/20/2011	1:30	2.7	0.0554	0.0	0.0	6.5	0.1354	1013.8	0.0000	1012.0	0.0000	1015.3	0.0579	0.13	0.03			82	
7/20/2011	2:00	2.6	0.0542	0.0	0.0	6.4	0.1333	1013.8	0.0000	1012.0	0.0000	1016.2	0.0745	0.11	0.05			70	
7/20/2011	2:30	2.7	0.0570	0.0	0.0	3.2	0.0667	1013.7	-0.0013	1012.0	0.0000	1016.1	-0.0083	0.13	0.03			83	
7/20/2011	3:00	3.3	0.0693	0.0	0.0	3.2	0.0667	1013.7	0.0000	1012.0	0.0000	1015.9	-0.0166	0.15	0.01			94	
7/20/2011	3:30	3.3	0.0697	0.0	0.0	3.2	0.0667	1013.8	0.0013	1012.0	0.0000	1015.8	-0.0083	0.14	0.02			89	
7/20/2011	4:00	3.4	0.0708	0.0	0.0	3.2	0.0667	1013.8	0.0000	1012.0	0.0000	1015.8	0.0000	0.14	0.02			85	
7/20/2011	4:30	3.4	0.0715	0.0	0.0	3.2	0.0667	1013.8	0.0000	1012.0	0.0000	1015.6	-0.0166	0.15	0.01			96	
7/20/2011	5:00	3.4	0.0718	0.0	0.0	3.3	0.0688	1013.8	0.0000	1012.0	0.0000	1015.2	-0.0331	0.17		-0.01		108	
7/20/2011	5:30	4.4	0.0913	0.0	0.0	3.2	0.0667	1013.8	0.0000	1012.0	0.0000	1014.9	-0.0248	0.18		-0.02		113	
7/20/2011	6:00	4.7	0.0988	0.0	0.0	3.2	0.0667	1013.8	0.0000	1012.0	0.0000	1014.6	-0.0248	0.19		-0.03		118	
7/20/2011	6:30	5.2	0.1073	0.0	0.0	3.3	0.0688	1013.7	-0.0013	1011.6	0.0000	1014.1	-0.0414	0.22		-0.06		136	
7/20/2011	7:00	5.5	0.1138	0.0	0.0	3.2	0.0667	1013.6	-0.0013	1010.0	0.0000	1013.8	-0.0248	0.21		-0.05		128	
7/20/2011	7:30	5.4	0.1121	0.0	0.0	3.3	0.0688	1013.1	-0.0066	1008.5	0.0000	1013.4	-0.0331	0.22		-0.06		137	
7/20/2011	8:00	5.5	0.1148	0.0	0.0	3.3	0.0688	1012.8	-0.0039	1006.9	0.0011	1012.9	-0.0414	0.23		-0.07		142	
7/20/2011	8:30	5.5	0.1146	0.0	0.0	3.3	0.0688	1012.3	-0.0066	1005.4	0.0000	1012.5	-0.0331	0.22		-0.06		138	
7/20/2011	9:00	5.5	0.1156	0.0	0.0	3.3	0.0688	1011.7	-0.0079	1003.8	0.0011	1012.0	-0.0414	0.23		-0.07		145	
7/20/2011	9:30	5.5	0.1138	0.0	0.0	2.3	0.0479	1011.7	0.0000	1002.3	0.0000	1011.8	-0.0166	0.18		-0.02		110	
7/20/2011	10:00	6.1	0.1265	0.0	0.0	2.3	0.0479	1011.2	-0.0066	1002.2	-0.0025	1011.4	-0.0331	0.22		-0.06		134	
7/20/2011	10:30	6.0	0.1251	0.0	0.0	2.3	0.0479	1010.9	-0.0039	1002.2	0.0000	1011.1	-0.0248	0.20		-0.04		125	
7/20/2011	11:00	6.1	0.1266	0.0	0.0	3.3	0.0688	1010.9	0.0000	1002.3	0.0025	1011.1	0.0000	0.19		-0.03		119	
7/20/2011	11:30	6.2	0.1289	0.0	0.0	3.3	0.0688	1010.6	-0.0039	1002.3	0.0000	1010.8	-0.0248	0.23		-0.06		140	
7/20/2011	12:00	6.1	0.1279	0.0	0.0	3.3	0.0688	1010.6	0.0000	1002.3	0.0000	1010.8	0.0000	0.20		-0.04		122	
7/20/2011	12:30	6.1	0.1261	0.0	0.0	3.3	0.0688	1010.6	0.0000	1002.3	0.0000	1010.8	0.0000	0.19		-0.03		121	
7/20/2011	13:00	5.9	0.1231	0.0	0.0	3.2	0.0667	1010.5	-0.0013	1002.3	0.0000	1011.7	0.0745	0.12	0.04			72	
7/20/2011	13:30	5.8	0.1217	0.0	0.0	3.2	0.0667	1010.5	0.0000	1002.3	0.0000	1012.3	0.0497	0.14	0.02			86	
7/20/2011	14:00	5.7	0.1187	0.0	0.0	3.2	0.0667	1010.5	0.0000	1002.3	0.0000	1012.8	0.0414	0.14	0.02			89	
7/20/2011	14:30	5.6	0.1169	0.0	0.0	3.3	0.0688	1010.5	0.0000	1002.3	0.0000	1012.5	-0.0248	0.21		-0.05		130	
7/20/2011	15:00	5.6	0.1163	0.0	0.0	3.3	0.0688	1010.3	-0.0026	1002.3	0.0000	1012.3	-0.0166	0.20		-0.04		127	
7/20/2011	15:30	5.4	0.1120	0.0	0.0	3.2	0.0667	1010.4	0.0013	1002.3	0.0000	1012.9	0.0497	0.13	0.03			79	
7/20/2011	16:00	5.1	0.1056	0.0	0.0	2.3	0.0479	1010.5	0.0013	1002.3	0.0000	1012.9	0.0000	0.15	0.01			94	
7/20/2011	16:30	5.3	0.1107	0.0	0.0	2.3	0.0479	1010.4	-0.0013	1003.0	0.0178	1012.3	-0.0497	0.19		-0.03		119	
7/20/2011	17:00	5.3	0.1112	0.0	0.0	2.3	0.0479	1010.6	0.0026	1004.2	0.0305	1011.7	-0.0497	0.18		-0.01		109	
7/20/2011	17:30	5.5	0.1141	0.0	0.0	2.3	0.0479	1010.4	-0.0026	1005.3	0.0280	1011.1	-0.0497	0.19		-0.02		115	
7/20/2011	18:00	5.3	0.1109	0.0	0.0	3.2	0.0667	1010.5	0.0013	1006.1	0.0203	1011.0	-0.0083	0.16	0.00			102	
7/20/2011	18:30	5.3	0.1096	0.0	0.0	3.3	0.0688	1010.5	0.0000	1006.1	0.0000	1011.7	0.0579	0.12	0.04			75	
7/20/2011	19:00	5.3	0.1095	0.0	0.0	3.2	0.0667	1010.4	-0.0013	1006.1	0.0000	1012.3	0.0497	0.13	0.03			79	
7/20/2011	19:30	5.3	0.1098	0.0	0.0	3.2	0.0667	1010.5	0.0013	1006.1	0.0000	1013.0	0.0579	0.12	0.04			73	
7/20/2011	20:00	5.2	0.1086	0.0	0.0	3.2	0.0667	1010.5	0.0000	1006.2	0.0025	1013.8	0.0662	0.11	0.05			66	
7/20/2011	20:30	5.4	0.1129	0.0	0.0	3.2	0.0667	1012.3	0.0237	1007.4	0.0305	1013.8	0.0000	0.13	0.04			78	
7/20/2011	21:00	3.8	0.0800	0.0	0.0	3.2	0.0667	1013.5	0.0158	1008.4	0.0254	1013.8	0.0000	0.11	0.06			65	
7/20/2011	21:30	2.9	0.0603	0.0	0.0	3.3	0.0688	1014.1	0.0079	1009.2	0.0203	1013.7	-0.0083	0.11	0.05			68	
7/20/2011	22:00	2.9	0.0608	0.0	0.0	3.2	0.0667	1014.1	0.0000	1009.8	0.0153	1013.8	0.0083	0.10	0.06			64	
7/20/2011	22:30	2.8	0.0592	0.0	0.0	3.3	0.0688	1014.1	0.0000	1010.4	0.0153	1013.9	0.0083	0.10	0.06			65	
7/20/2011	23:00	2.8	0.0580	0.0	0.0	3.2	0.0667	1014.2	0.0013	1011.0	0.0153	1014.0	0.0083	0.10	0.06			62	
7/20/2011	23:30	2.8	0.0576	0.0	0.0	3.2	0.0667	1014.2	0.0000	1011.5	0.0127	1014.3	0.0248	0.09	0.07			54	
														0.16	0.88	-0.88	11.3	107	7.75


City of Lawrence, Kansas
7-20-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

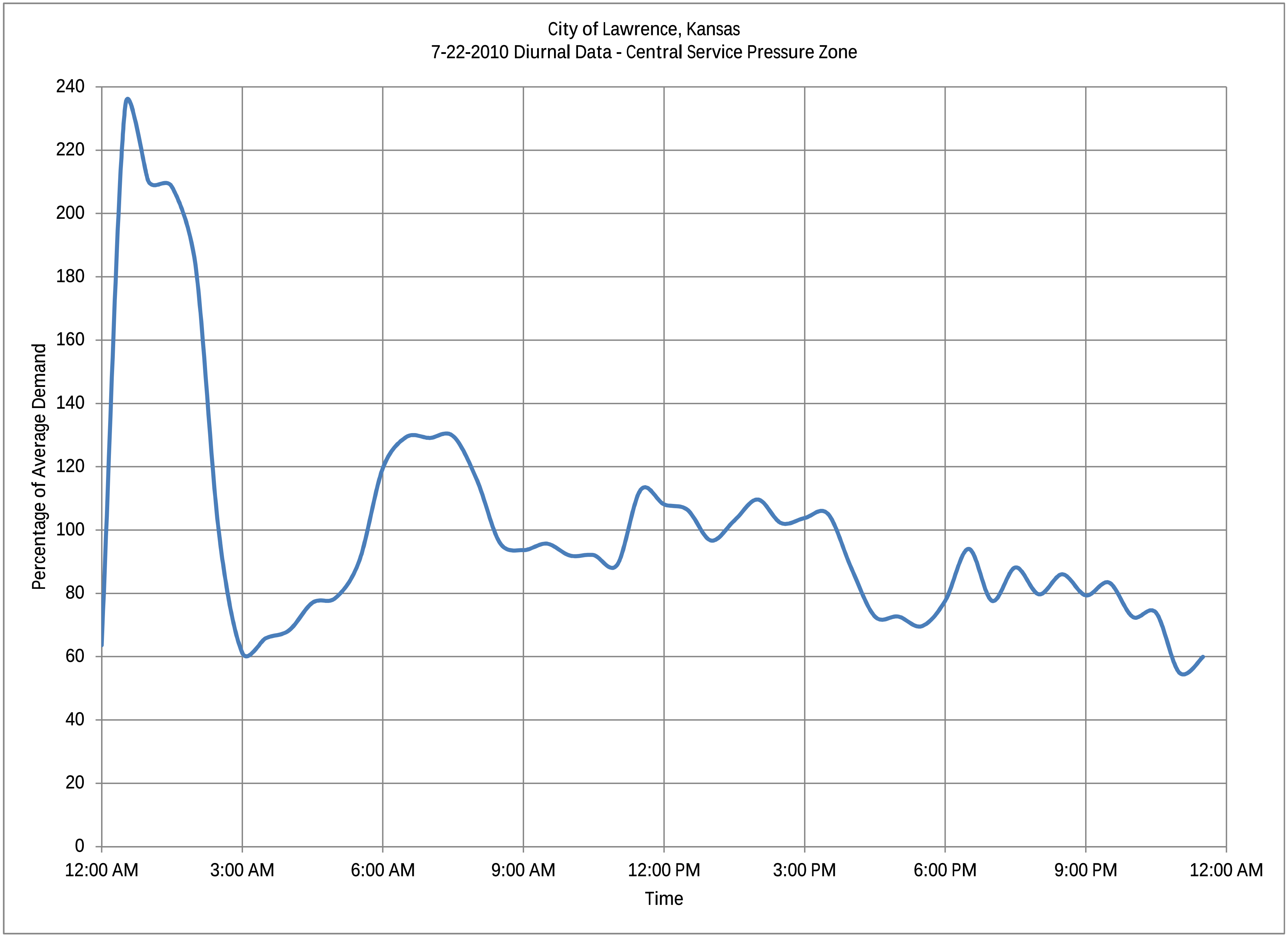
City of Lawrence, Kansas - 2011 Water Master Plan
July 21, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total Demand (MG)	Equalization Storage		Equalization Factor (%)	Diurnal (%)	Total Daily Demand (MGD)
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir			Fill (MG)	Draft (MG)			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)						
7/21/2010	0:00	2.7	0.0563	0.0	0.0	3.2	0.0667	1014.2	0.0000	1012.0	0.0000	1014.6	0.0000	0.12		-0.01		107	
7/21/2010	0:30	2.7	0.0563	0.0	0.0	3.2	0.0667	1014.3	0.0013	1012.0	0.0000	1015.0	0.0331	0.09	0.03			77	
7/21/2010	1:00	2.6	0.0542	0.0	0.0	3.2	0.0667	1014.3	0.0000	1012.0	0.0000	1015.5	0.0414	0.08	0.04			69	
7/21/2010	1:30	2.6	0.0542	0.0	0.0	3.2	0.0667	1014.2	-0.0013	1012.0	0.0000	1015.7	0.0166	0.11	0.01			92	
7/21/2010	2:00	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.3	0.0013	1011.7	-0.0076	1015.4	-0.0248	0.10	0.02			85	
7/21/2010	2:30	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.2	-0.0013	1011.4	-0.0076	1015.2	-0.0166	0.09	0.02			80	
7/21/2010	3:00	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.3	0.0013	1011.1	-0.0076	1015.0	-0.0166	0.09	0.02			78	
7/21/2010	3:30	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.3	0.0000	1010.7	-0.0102	1014.6	-0.0331	0.17		-0.06		149	
7/21/2010	4:00	3.0	0.0625	0.0	0.0	3.2	0.0667	1014.2	-0.0013	1011.4	0.0178	1014.9	0.0248	0.09	0.03			77	
7/21/2010	4:30	3.0	0.0625	0.0	0.0	3.2	0.0667	1014.4	0.0026	1011.9	0.0127	1015.0	0.0083	0.11	0.01			92	
7/21/2010	5:00	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.3	-0.0013	1012.0	0.0025	1015.2	0.0166	0.11	0.01			95	
7/21/2010	5:30	2.8	0.0583	0.0	0.0	3.2	0.0667	1014.3	0.0000	1012.0	0.0000	1015.4	0.0166	0.11	0.01			95	
7/21/2010	6:00	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.3	0.0000	1012.0	0.0000	1015.5	0.0083	0.12	0.00			104	
7/21/2010	6:30	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.3	0.0000	1012.0	0.0000	1015.5	0.0000	0.13		-0.01		111	
7/21/2010	7:00	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.4	0.0013	1012.0	0.0000	1015.4	-0.0083	0.13		-0.02		117	
7/21/2010	7:30	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.4	0.0000	1010.4	0.0011	1015.3	-0.0083	0.14		-0.02		119	
7/21/2010	8:00	2.9	0.0604	0.0	0.0	3.2	0.0667	1014.5	0.0013	1008.9	0.0006	1015.2	-0.0083	0.13		-0.02		118	
7/21/2010	8:30	2.7	0.0563	0.0	0.0	3.2	0.0667	1014.4	-0.0013	1007.4	0.0006	1015.3	0.0083	0.12	0.00			102	
7/21/2010	9:00	4.2	0.0875	0.0	0.0	3.2	0.0667	1014.4	0.0000	1007.7	0.0076	1015.6	0.0248	0.12		-0.01		106	
7/21/2010	9:30	5.1	0.1063	0.0	0.0	0.0	0.0000	1014.5	0.0013	1008.9	0.0305	1015.4	-0.0166	0.09	0.02			79	
7/21/2010	10:00	6.2	0.1292	0.0	0.0	0.0	0.0000	1014.4	-0.0013	1010.2	0.0331	1015.1	-0.0248	0.12		-0.01		107	
7/21/2010	10:30	6.1	0.1271	0.0	0.0	0.0	0.0000	1014.4	0.0000	1011.5	0.0331	1015.1	0.0000	0.09	0.02			82	
7/21/2010	11:00	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.4	0.0000	1012.0	0.0127	1015.2	0.0083	0.10	0.01			87	
7/21/2010	11:30	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.3	-0.0013	1012.0	0.0000	1015.4	0.0166	0.11	0.01			92	
7/21/2010	12:00	5.7	0.1188	0.0	0.0	0.0	0.0000	1014.3	0.0000	1012.0	0.0000	1015.5	0.0083	0.11	0.00			96	
7/21/2010	12:30	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.4	0.0013	1012.0	0.0000	1015.5	0.0000	0.12	0.00			104	
7/21/2010	13:00	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.4	0.0000	1012.1	0.0025	1015.7	0.0166	0.10	0.01			89	
7/21/2010	13:30	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.4	0.0000	1012.1	0.0000	1015.7	0.0000	0.12		-0.01		106	
7/21/2010	14:00	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.4	0.0000	1012.1	0.0000	1015.7	0.0000	0.12		-0.01		106	
7/21/2010	14:30	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.3	-0.0013	1012.1	0.0000	1015.8	0.0083	0.11	0.00			99	
7/21/2010	15:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.3	0.0000	1012.1	0.0000	1015.9	0.0083	0.11	0.00			100	
7/21/2010	15:30	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.3	0.0000	1012.1	0.0000	1016.0	0.0083	0.11	0.00			98	
7/21/2010	16:00	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.3	0.0000	1012.1	0.0000	1016.0	0.0000	0.12		-0.01		106	
7/21/2010	16:30	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.2	-0.0013	1012.1	0.0000	1016.0	0.0000	0.12		-0.01		108	
7/21/2010	17:00	5.8	0.1208	0.0	0.0	0.0	0.0000	1014.3	0.0013	1012.1	0.0000	1016.0	0.0000	0.12	0.00			104	
7/21/2010	17:30	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.2	-0.0013	1012.1	0.0000	1015.9	-0.0083	0.13		-0.02		116	
7/21/2010	18:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.1	-0.0013	1012.1	0.0000	1015.8	-0.0083	0.13		-0.02		116	
7/21/2010	18:30	6.0	0.1250	0.0	0.0	0.0	0.0000	1014.2	0.0013	1012.1	0.0000	1015.8	0.0000	0.12		-0.01		108	
7/21/2010	19:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.2	0.0000	1012.1	0.0000	1015.8	0.0000	0.12		-0.01		107	
7/21/2010	19:30	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.2	0.0000	1012.1	0.0000	1015.9	0.0083	0.11	0.00			100	
7/21/2010	20:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.1	-0.0013	1012.1	0.0000	1015.9	0.0000	0.12		-0.01		108	
7/21/2010	20:30	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.1	0.0000	1012.1	0.0000	1016.0	0.0083	0.11	0.00			100	
7/21/2010	21:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.1	0.0000	1012.1	0.0000	1016.0	0.0000	0.12		-0.01		107	
7/21/2010	21:30	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.1	0.0000	1012.1	0.0000	1015.9	-0.0083	0.13		-0.02		115	
7/21/2010	22:00	6.0	0.1250	0.0	0.0	0.0	0.0000	1014.1	0.0000	1012.1	0.0000	1015.9	0.0000	0.13		-0.01		109	
7/21/2010	22:30	6.0	0.1250	0.0	0.0	0.0	0.0000	1014.0	-0.0013	1012.1	0.0000	1015.9	0.0000	0.13		-0.01		110	
7/21/2010	23:00	5.9	0.1229	0.0	0.0	0.0	0.0000	1014.0	0.0000	1012.1	0.0000	1016.2	0.0248	0.10	0.02			86	
7/21/2010	23:30	5.1	0.1063	0.0	0.0	0.0	0.0000	1014.0	0.0000	1012.1	0.0000	1016.4	0.0166	0.09	0.02			78	
														0.11	0.29	-0.29	5.3	64	5.50


City of Lawrence, Kansas
7-21-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

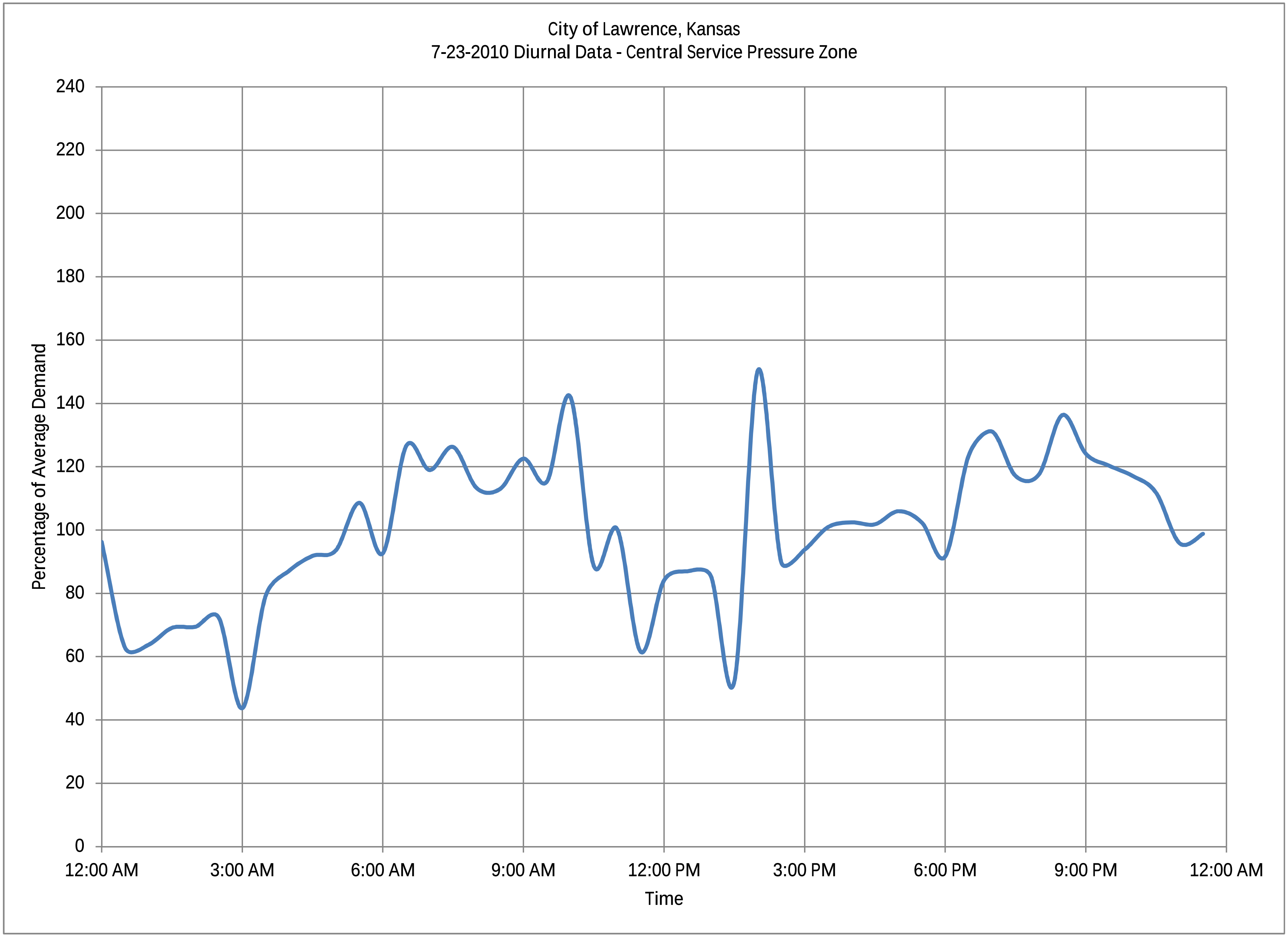
City of Lawrence, Kansas - 2011 Water Master Plan
July 22, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper Tank		Kasold Reservoir		Oread Reservoir		Total Demand (MG)	Equalization Storage		Equalization Factor (%)	Diurnal (%)	Total Daily Demand (MGD)
		HSPS 2		HSPS 1		HSPS									Fill (MG)	Draft (MG)			
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)						
7/22/2010	0:00	5.0	0.1042	0.0	0.0	0.0	0.0000	1014.1	0.0000	1012.1	0.0000	1016.4	0.0000	0.10	0.06			64	
7/22/2010	0:30	5.7	0.1188	0.0	0.0	0.0	0.0000	1010.5	-0.0474	1011.4	-0.0178	1014.0	-0.1986	0.38		-0.22		234	
7/22/2010	1:00	5.8	0.1208	0.0	0.0	0.0	0.0000	1007.8	-0.0355	1010.2	-0.0305	1012.1	-0.1572	0.34		-0.18		210	
7/22/2010	1:30	5.8	0.1208	0.0	0.0	0.0	0.0000	1005.5	-0.0303	1008.9	-0.0331	1010.2	-0.1572	0.34		-0.18		208	
7/22/2010	2:00	5.8	0.1208	0.0	0.0	3.3	0.0688	1004.8	-0.0092	1007.8	-0.0280	1009.3	-0.0745	0.30		-0.14		184	
7/22/2010	2:30	6.1	0.1271	0.0	0.0	3.3	0.0688	1006.0	0.0158	1007.5	-0.0076	1009.6	0.0248	0.16	0.00			99	
7/22/2010	3:00	6.1	0.1271	0.0	0.0	3.3	0.0688	1007.6	0.0211	1007.5	0.0000	1010.5	0.0745	0.10	0.06			61	
7/22/2010	3:30	6.0	0.1250	0.0	0.0	3.3	0.0688	1009.1	0.0197	1007.5	0.0000	1011.3	0.0662	0.11	0.06			66	
7/22/2010	4:00	5.9	0.1229	0.0	0.0	3.2	0.0667	1010.6	0.0197	1007.5	0.0000	1012.0	0.0579	0.11	0.05			68	
7/22/2010	4:30	6.0	0.1250	0.0	0.0	3.2	0.0667	1011.8	0.0158	1007.5	0.0000	1012.6	0.0497	0.13	0.04			77	
7/22/2010	5:00	6.0	0.1250	0.0	0.0	3.2	0.0667	1012.8	0.0132	1007.5	0.0000	1013.2	0.0497	0.13	0.03			79	
7/22/2010	5:30	6.0	0.1250	0.0	0.0	3.2	0.0667	1013.6	0.0105	1007.5	0.0000	1013.6	0.0331	0.15	0.02			90	
7/22/2010	6:00	6.2	0.1292	0.0	0.0	3.2	0.0667	1013.6	0.0000	1007.3	0.0000	1013.6	0.0000	0.20		-0.03		120	
7/22/2010	6:30	6.3	0.1313	0.0	0.0	0.0	0.0000	1012.5	-0.0145	1006.9	0.0000	1012.8	-0.0662	0.21		-0.05		129	
7/22/2010	7:00	6.2	0.1292	0.0	0.0	3.3	0.0688	1012.1	-0.0053	1006.5	0.0000	1012.7	-0.0083	0.21		-0.05		129	
7/22/2010	7:30	6.2	0.1292	0.0	0.0	3.2	0.0667	1012.1	0.0000	1006.1	0.0000	1012.5	-0.0166	0.21		-0.05		130	
7/22/2010	8:00	6.1	0.1271	0.0	0.0	3.3	0.0688	1012.0	-0.0013	1006.7	0.0153	1012.4	-0.0083	0.19		-0.03		116	
7/22/2010	8:30	6.1	0.1271	0.0	0.0	3.3	0.0688	1012.0	0.0000	1007.9	0.0305	1012.5	0.0083	0.16	0.01			96	
7/22/2010	9:00	6.3	0.1313	0.0	0.0	3.2	0.0667	1012.0	0.0000	1009.0	0.0280	1012.7	0.0166	0.15	0.01			94	
7/22/2010	9:30	6.0	0.1250	0.0	0.0	3.2	0.0667	1011.9	-0.0013	1010.1	0.0280	1012.8	0.0083	0.16	0.01			96	
7/22/2010	10:00	6.0	0.1250	0.0	0.0	3.3	0.0688	1011.8	-0.0013	1011.2	0.0280	1013.0	0.0166	0.15	0.01			92	
7/22/2010	10:30	5.9	0.1229	0.0	0.0	3.3	0.0688	1012.1	0.0039	1012.0	0.0203	1013.2	0.0166	0.15	0.01			92	
7/22/2010	11:00	4.8	0.1000	0.0	0.0	3.2	0.0667	1011.8	-0.0039	1012.0	0.0000	1013.5	0.0248	0.15	0.02			89	
7/22/2010	11:30	4.8	0.1000	0.0	0.0	3.2	0.0667	1011.7	-0.0013	1012.0	0.0000	1013.3	-0.0166	0.18		-0.02		113	
7/22/2010	12:00	5.2	0.1083	0.0	0.0	3.3	0.0688	1011.7	0.0000	1012.0	0.0000	1013.3	0.0000	0.18		-0.01		108	
7/22/2010	12:30	5.1	0.1063	0.0	0.0	3.2	0.0667	1011.6	-0.0013	1012.0	0.0000	1013.3	0.0000	0.17		-0.01		106	
7/22/2010	13:00	4.8	0.1000	0.0	0.0	3.2	0.0667	1011.6	0.0000	1012.0	0.0000	1013.4	0.0083	0.16	0.01			97	
7/22/2010	13:30	4.4	0.0917	0.0	0.0	3.3	0.0688	1011.6	0.0000	1012.0	0.0000	1013.3	-0.0083	0.17	0.00			103	
7/22/2010	14:00	4.5	0.0938	0.0	0.0	3.2	0.0667	1011.4	-0.0026	1012.0	0.0000	1013.1	-0.0166	0.18		-0.02		110	
7/22/2010	14:30	4.4	0.0917	0.0	0.0	3.3	0.0688	1011.5	0.0013	1012.0	0.0000	1013.0	-0.0083	0.17	0.00			102	
7/22/2010	15:00	4.4	0.0917	0.0	0.0	3.3	0.0688	1011.4	-0.0013	1012.0	0.0000	1012.9	-0.0083	0.17		-0.01		104	
7/22/2010	15:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1011.3	-0.0013	1012.0	0.0000	1012.8	-0.0083	0.17		-0.01		105	
7/22/2010	16:00	4.5	0.0938	0.0	0.0	3.2	0.0667	1011.3	0.0000	1012.0	0.0000	1013.0	0.0166	0.14	0.02			88	
7/22/2010	16:30	4.5	0.0938	0.0	0.0	3.2	0.0667	1011.3	0.0000	1012.0	0.0000	1013.5	0.0414	0.12	0.04			73	
7/22/2010	17:00	4.5	0.0938	0.0	0.0	3.2	0.0667	1011.3	0.0000	1012.0	0.0000	1014.0	0.0414	0.12	0.04			73	
7/22/2010	17:30	3.8	0.0792	0.0	0.0	3.2	0.0667	1011.2	-0.0013	1012.0	0.0000	1014.4	0.0331	0.11	0.05			70	
7/22/2010	18:00	3.7	0.0771	0.0	0.0	3.2	0.0667	1011.2	0.0000	1012.0	0.0000	1014.6	0.0166	0.13	0.04			78	
7/22/2010	18:30	3.4	0.0708	0.0	0.0	3.2	0.0667	1011.2	0.0000	1012.0	0.0000	1014.4	-0.0166	0.15	0.01			94	
7/22/2010	19:00	3.3	0.0688	0.0	0.0	3.2	0.0667	1011.2	0.0000	1012.0	0.0000	1014.5	0.0083	0.13	0.04			78	
7/22/2010	19:30	3.4	0.0708	0.0	0.0	3.2	0.0667	1011.3	0.0013	1012.0	0.0000	1014.4	-0.0083	0.14	0.02			88	
7/22/2010	20:00	3.4	0.0708	0.0	0.0	3.2	0.0667	1011.2	-0.0013	1012.0	0.0000	1014.5	0.0083	0.13	0.03			80	
7/22/2010	20:30	3.4	0.0708	0.0	0.0	3.2	0.0667	1012.2	0.0132	1012.0	0.0000	1014.3	-0.0166	0.14	0.02			86	
7/22/2010	21:00	3.3	0.0688	0.0	0.0	3.3	0.0688	1013.4	0.0158	1012.0	0.0000	1014.2	-0.0083	0.13	0.03			79	
7/22/2010	21:30	3.4	0.0708	0.0	0.0	3.2	0.0667	1014.1	0.0092	1012.0	0.0000	1014.1	-0.0083	0.14	0.03			83	
7/22/2010	22:00	3.3	0.0688	0.0	0.0	3.2	0.0667	1014.1	0.0000	1012.0	0.0000	1014.3	0.0166	0.12	0.04			73	
7/22/2010	22:30	3.3	0.0688	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1014.5	0.0166	0.12	0.04			74	
7/22/2010	23:00	3.1	0.0646	0.0	0.0	3.2	0.0667	1014.1	0.0000	1012.0	0.0000	1015.0	0.0414	0.09	0.07			55	
7/22/2010	23:30	3.1	0.0646	0.0	0.0	3.2	0.0667	1014.1	0.0000	1012.0	0.0000	1015.4	0.0331	0.10	0.07			60	
														0.16	0.99	-0.99	12.6	96	7.86


City of Lawrence, Kansas
7-22-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
July 23, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/23/2010	0:00	3.1	0.0646	0.0	0.0	3.2	0.0667	1014.1	0.0000	1012.0	0.0000	1016.0	0.0000	0.13	0.01			96	
7/23/2010	0:30	2.5	0.0521	0.0	0.0	3.2	0.0667	1014.1	0.0000	1012.0	0.0000	1016.4	0.0331	0.09	0.05			63	
7/23/2010	1:00	2.5	0.0521	0.0	0.0	3.2	0.0667	1014.0	-0.0013	1012.0	0.0000	1016.8	0.0331	0.09	0.05			64	
7/23/2010	1:30	2.7	0.0563	0.0	0.0	3.2	0.0667	1014.1	0.0013	1012.1	0.0025	1017.1	0.0248	0.09	0.04			69	
7/23/2010	2:00	2.6	0.0542	0.0	0.0	3.2	0.0667	1014.2	0.0013	1012.1	0.0000	1017.4	0.0248	0.09	0.04			69	
7/23/2010	2:30	2.6	0.0542	0.0	0.0	3.2	0.0667	1014.0	-0.0026	1012.1	0.0000	1017.7	0.0248	0.10	0.04			72	
7/23/2010	3:00	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.1	0.0013	1012.0	-0.0025	1017.8	0.0083	0.06	0.08			44	
7/23/2010	3:30	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.1	0.0000	1012.0	0.0000	1017.3	-0.0414	0.11	0.03			79	
7/23/2010	4:00	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.1	0.0000	1011.9	-0.0025	1016.7	-0.0497	0.12	0.02			87	
7/23/2010	4:30	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.0	-0.0013	1011.6	-0.0076	1016.1	-0.0497	0.13	0.01			92	
7/23/2010	5:00	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.1	0.0013	1011.1	-0.0127	1015.5	-0.0497	0.13	0.01			94	
7/23/2010	5:30	0.0	0.0000	0.0	0.0	3.2	0.0667	1014.1	0.0000	1010.5	-0.0153	1014.7	-0.0662	0.15		-0.01		109	
7/23/2010	6:00	3.1	0.0646	0.0	0.0	3.3	0.0688	1014.0	-0.0013	1008.9	0.0000	1014.8	0.0083	0.13	0.01			93	
7/23/2010	6:30	3.0	0.0625	0.0	0.0	3.3	0.0688	1014.0	0.0000	1007.3	0.0000	1014.3	-0.0414	0.17		-0.04		127	
7/23/2010	7:00	3.0	0.0625	0.0	0.0	3.2	0.0667	1014.0	0.0000	1005.8	0.0000	1013.9	-0.0331	0.16		-0.03		119	
7/23/2010	7:30	2.9	0.0604	0.0	0.0	3.2	0.0667	1013.8	-0.0026	1004.2	0.0011	1013.4	-0.0414	0.17		-0.04		126	
7/23/2010	8:00	2.8	0.0583	0.0	0.0	3.3	0.0688	1013.6	-0.0026	1002.7	0.0000	1013.1	-0.0248	0.15		-0.02		113	
7/23/2010	8:30	3.0	0.0625	0.0	0.0	0.0	0.0000	1012.3	-0.0171	1001.3	0.0000	1012.2	-0.0745	0.15		-0.02		113	
7/23/2010	9:00	2.9	0.0604	0.0	0.0	0.0	0.0000	1011.2	-0.0145	1000.6	-0.0178	1011.3	-0.0745	0.17		-0.03		123	
7/23/2010	9:30	4.2	0.0875	0.0	0.0	0.0	0.0000	1010.3	-0.0118	1000.6	0.0000	1010.6	-0.0579	0.16		-0.02		115	
7/23/2010	10:00	4.1	0.0854	0.0	0.0	3.3	0.0688	1009.8	-0.0066	1000.6	0.0000	1010.2	-0.0331	0.19		-0.06		142	
7/23/2010	10:30	4.1	0.0854	0.0	0.0	3.3	0.0688	1009.8	0.0000	1000.6	0.0000	1010.6	0.0331	0.12	0.02			89	
7/23/2010	11:00	4.0	0.0833	0.0	0.0	3.3	0.0688	1009.7	-0.0013	1000.6	0.0000	1010.8	0.0166	0.14	0.00			100	
7/23/2010	11:30	0.0	0.0000	0.0	0.0	3.3	0.0688	1009.8	0.0013	1000.6	0.0000	1010.6	-0.0166	0.08	0.05			62	
7/23/2010	12:00	4.5	0.0938	0.0	0.0	6.5	0.1354	1009.6	-0.0026	1001.3	0.0178	1011.8	0.0993	0.11	0.02			84	
7/23/2010	12:30	4.5	0.0938	0.0	0.0	6.6	0.1375	1009.6	0.0000	1002.8	0.0381	1012.7	0.0745	0.12	0.02			87	
7/23/2010	13:00	4.5	0.0938	0.0	0.0	6.5	0.1354	1009.6	0.0000	1004.3	0.0381	1013.6	0.0745	0.12	0.02			85	
7/23/2010	13:30	4.6	0.0958	0.0	0.0	0.0	0.0000	1009.6	0.0000	1005.6	0.0331	1013.5	-0.0083	0.07	0.07			52	
7/23/2010	14:00	4.7	0.0979	0.0	0.0	3.0	0.0625	1009.5	-0.0013	1006.5	0.0229	1012.7	-0.0662	0.21		-0.07		150	
7/23/2010	14:30	4.5	0.0938	0.0	0.0	3.4	0.0708	1009.5	0.0000	1007.5	0.0254	1012.9	0.0166	0.12	0.01			90	
7/23/2010	15:00	4.4	0.0917	0.0	0.0	3.3	0.0688	1009.5	0.0000	1007.8	0.0076	1013.2	0.0248	0.13	0.01			94	
7/23/2010	15:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1009.5	0.0000	1007.8	0.0000	1013.5	0.0248	0.14	0.00			101	
7/23/2010	16:00	4.1	0.0854	0.0	0.0	3.4	0.0708	1009.5	0.0000	1007.8	0.0000	1013.7	0.0166	0.14	0.00			102	
7/23/2010	16:30	3.7	0.0771	0.0	0.0	3.3	0.0688	1009.4	-0.0013	1007.8	0.0000	1013.8	0.0083	0.14	0.00			102	
7/23/2010	17:00	3.7	0.0771	0.0	0.0	3.3	0.0688	1009.5	0.0013	1007.8	0.0000	1013.8	0.0000	0.14		-0.01		106	
7/23/2010	17:30	3.7	0.0771	0.0	0.0	3.4	0.0708	1009.5	0.0000	1007.8	0.0000	1013.9	0.0083	0.14	0.00			102	
7/23/2010	18:00	3.7	0.0771	0.0	0.0	2.3	0.0479	1009.5	0.0000	1007.8	0.0000	1013.9	0.0000	0.13	0.01			92	
7/23/2010	18:30	3.8	0.0792	0.0	0.0	2.3	0.0479	1009.5	0.0000	1007.8	0.0000	1013.4	-0.0414	0.17		-0.03		123	
7/23/2010	19:00	3.8	0.0792	0.0	0.0	2.4	0.0500	1009.5	0.0000	1007.8	0.0000	1012.8	-0.0497	0.18		-0.04		131	
7/23/2010	19:30	3.8	0.0792	0.0	0.0	2.4	0.0500	1009.5	0.0000	1007.9	0.0025	1012.4	-0.0331	0.16		-0.02		117	
7/23/2010	20:00	3.9	0.0813	0.0	0.0	3.4	0.0708	1009.5	0.0000	1007.9	0.0000	1012.3	-0.0083	0.16		-0.02		118	
7/23/2010	20:30	4.0	0.0833	0.0	0.0	3.4	0.0708	1009.6	0.0013	1007.9	0.0000	1011.9	-0.0331	0.19		-0.05		136	
7/23/2010	21:00	4.0	0.0833	0.0	0.0	3.4	0.0708	1010.0	0.0053	1008.4	0.0127	1011.5	-0.0331	0.17		-0.03		124	
7/23/2010	21:30	3.9	0.0813	0.0	0.0	3.4	0.0708	1010.2	0.0026	1008.8	0.0102	1011.2	-0.0248	0.16		-0.03		120	
7/23/2010	22:00	6.2	0.1292	0.0	0.0	3.4	0.0708	1010.7	0.0066	1009.8	0.0254	1011.3	0.0083	0.16		-0.02		117	
7/23/2010	22:30	6.1	0.1271	0.0	0.0	3.3	0.0688	1011.0	0.0039	1010.7	0.0229	1011.5	0.0166	0.15		-0.02		112	
7/23/2010	23:00	6.0	0.1250	0.0	0.0	3.4	0.0708	1011.5	0.0066	1011.7	0.0254	1011.9	0.0331	0.13	0.01			96	
7/23/2010	23:30	5.9	0.1229	0.0	0.0	3.3	0.0688	1012.1	0.0079	1012.0	0.0076	1012.4	0.0414	0.13	0.00			99	
														0.14	0.60	-0.60	9.2	128	6.55

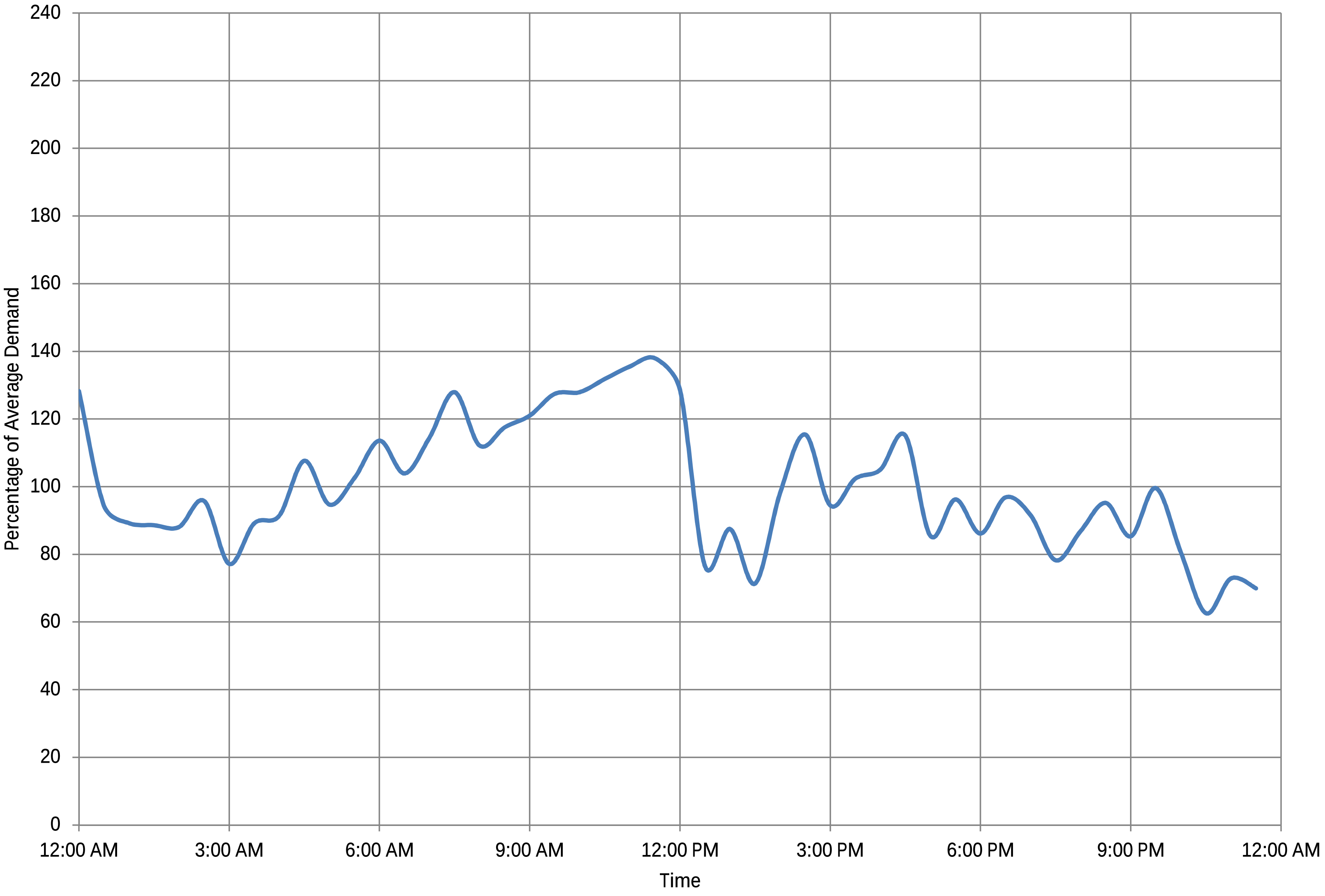


City of Lawrence, Kansas
7-23-2010 Diurnal Data - Central Service Pressure Zone

City of Lawrence, Kansas - 2011 Water Master Plan
July 24, 2010 Diurnal Data
Central Service Pressure Zone

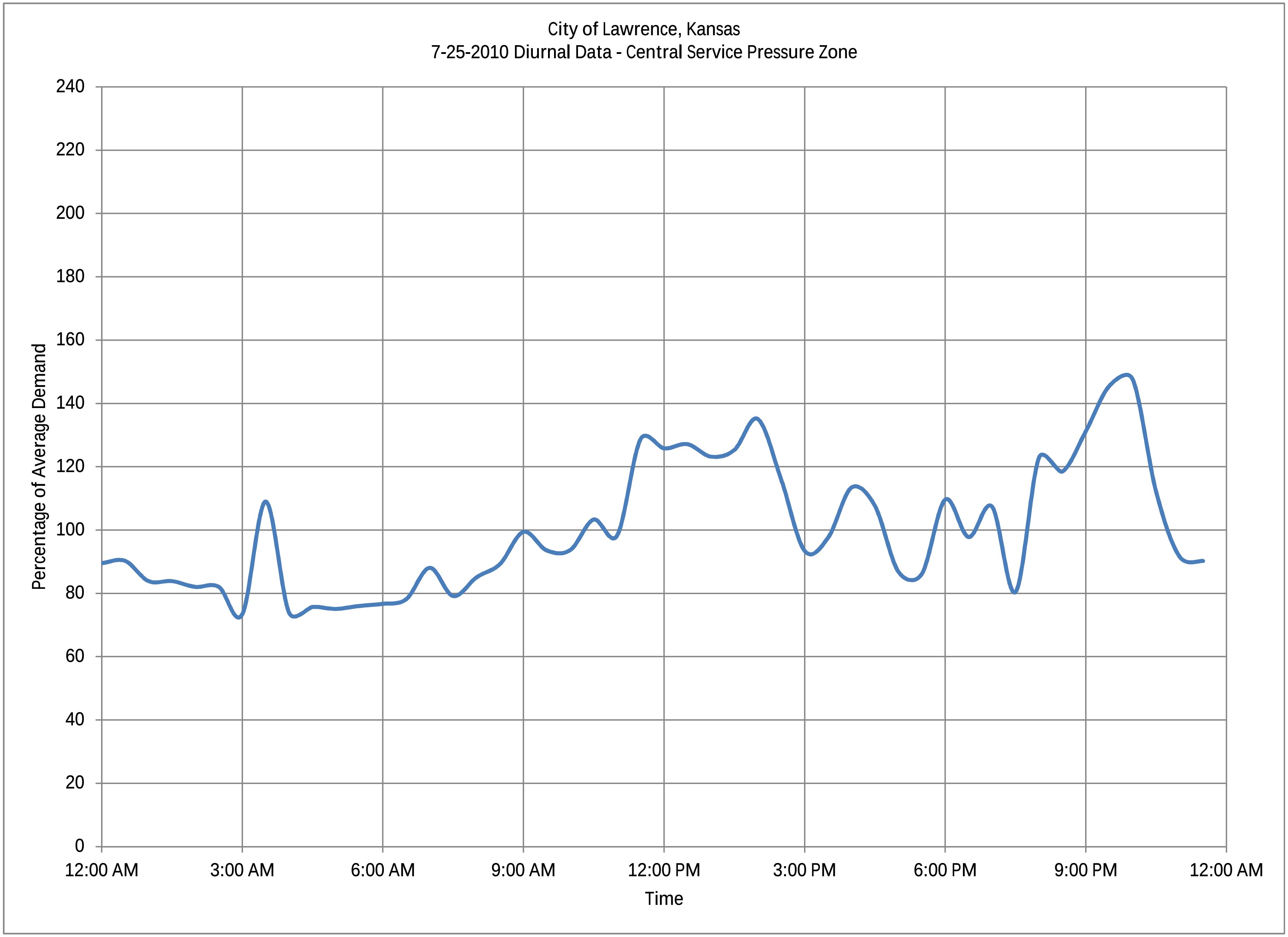
		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/24/2010	0.00	5.9	0.1229	0.0	0.0	3.3	0.0688	1012.80	0.0000	1012.00	0.0000	1013.10	0.0000	0.19		-0.04		128	
7/24/2010	0.02	5.9	0.1229	0.0	0.0	3.3	0.0688	1013.50	0.0092	1012.00	0.0000	1013.60	0.0414	0.14	0.01			94	
7/24/2010	0.04	5.8	0.1208	0.0	0.0	3.3	0.0688	1014.00	0.0066	1012.00	0.0000	1014.20	0.0497	0.13	0.02			89	
7/24/2010	0.06	5.9	0.1229	0.0	0.0	3.3	0.0688	1014.10	0.0013	1012.00	0.0000	1014.90	0.0579	0.13	0.02			89	
7/24/2010	0.08	5.8	0.1208	0.0	0.0	3.3	0.0688	1014.10	0.0000	1012.00	0.0000	1015.60	0.0579	0.13	0.02			88	
7/24/2010	0.10	4.7	0.0979	0.0	0.0	3.3	0.0688	1014.00	-0.0013	1012.00	0.0000	1015.90	0.0248	0.14	0.01			96	
7/24/2010	0.13	2.3	0.0479	0.0	0.0	3.3	0.0688	1014.10	0.0013	1012.00	0.0000	1015.90	0.0000	0.12	0.03			77	
7/24/2010	0.15	2.3	0.0479	0.0	0.0	3.3	0.0688	1014.10	0.0000	1011.90	0.0000	1015.70	-0.0166	0.13	0.02			89	
7/24/2010	0.17	2.4	0.0500	0.0	0.0	3.3	0.0688	1014.00	-0.0013	1010.20	0.0000	1015.50	-0.0166	0.14	0.01			91	
7/24/2010	0.19	2.5	0.0521	0.0	0.0	3.3	0.0688	1014.10	0.0013	1008.50	0.0000	1015.00	-0.0414	0.16		-0.01		108	
7/24/2010	0.21	2.6	0.0542	0.0	0.0	3.4	0.0708	1014.10	0.0000	1006.70	0.0000	1014.80	-0.0166	0.14	0.01			95	
7/24/2010	0.23	2.7	0.0563	0.0	0.0	3.4	0.0708	1014.00	-0.0013	1005.00	0.0000	1014.50	-0.0248	0.15	0.00			103	
7/24/2010	0.25	2.8	0.0583	0.0	0.0	3.3	0.0688	1013.90	-0.0013	1003.30	0.0000	1014.00	-0.0414	0.17		-0.02		114	
7/24/2010	0.27	2.8	0.0583	0.0	0.0	3.4	0.0708	1013.80	-0.0013	1001.60	0.0000	1013.70	-0.0248	0.16		-0.01		104	
7/24/2010	0.29	3.2	0.0667	0.0	0.0	3.3	0.0688	1013.60	-0.0026	999.90	0.0000	1013.30	-0.0331	0.17		-0.02		115	
7/24/2010	0.31	3.0	0.0625	0.0	0.0	3.4	0.0708	1012.30	-0.0171	1000.90	0.0254	1012.50	-0.0662	0.19		-0.04		128	
7/24/2010	0.33	3.1	0.0646	0.0	0.0	3.4	0.0708	1011.50	-0.0105	1002.00	0.0280	1011.90	-0.0497	0.17		-0.02		112	
7/24/2010	0.35	3.1	0.0646	0.0	0.0	3.4	0.0708	1011.20	-0.0039	1002.20	0.0051	1011.40	-0.0414	0.18		-0.03		118	
7/24/2010	0.38	3.1	0.0646	0.0	0.0	3.4	0.0708	1010.70	-0.0066	1002.30	0.0025	1010.90	-0.0414	0.18		-0.03		121	
7/24/2010	0.40	3.9	0.0813	0.0	0.0	3.4	0.0708	1010.30	-0.0053	1002.30	0.0000	1010.50	-0.0331	0.19		-0.04		127	
7/24/2010	0.42	4.0	0.0833	0.0	0.0	3.4	0.0708	1010.00	-0.0039	1002.30	0.0000	1010.10	-0.0331	0.19		-0.04		128	
7/24/2010	0.44	5.2	0.1083	0.0	0.0	3.4	0.0708	1009.90	-0.0013	1002.30	0.0000	1009.90	-0.0166	0.20		-0.05		132	
7/24/2010	0.46	5.8	0.1208	0.0	0.0	3.4	0.0708	1009.70	-0.0026	1002.30	0.0000	1009.80	-0.0083	0.20		-0.05		136	
7/24/2010	0.48	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.70	0.0000	1002.30	0.0000	1009.70	-0.0083	0.21		-0.06		138	
7/24/2010	0.50	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.50	-0.0026	1002.30	0.0000	1009.80	0.0083	0.19		-0.04		129	
7/24/2010	0.52	4.7	0.0979	0.0	0.0	3.3	0.0688	1009.70	0.0026	1002.30	0.0000	1010.40	0.0497	0.11	0.04			77	
7/24/2010	0.54	4.8	0.1000	0.0	0.0	3.4	0.0708	1009.70	0.0000	1002.90	0.0153	1010.70	0.0248	0.13	0.02			87	
7/24/2010	0.56	4.8	0.1000	0.0	0.0	3.4	0.0708	1009.60	-0.0013	1004.50	0.0407	1011.00	0.0248	0.11	0.04			71	
7/24/2010	0.58	5.9	0.1229	0.0	0.0	3.4	0.0708	1009.60	0.0000	1005.70	0.0305	1011.20	0.0166	0.15	0.00			98	
7/24/2010	0.60	5.4	0.1125	0.0	0.0	3.4	0.0708	1009.60	0.0000	1005.80	0.0025	1011.30	0.0083	0.17		-0.02		115	
7/24/2010	0.63	5.3	0.1104	0.0	0.0	3.4	0.0708	1009.50	-0.0013	1005.80	0.0000	1011.80	0.0414	0.14	0.01			94	
7/24/2010	0.65	4.8	0.1000	0.0	0.0	3.4	0.0708	1009.60	0.0013	1005.80	0.0000	1012.00	0.0166	0.15	0.00			102	
7/24/2010	0.67	4.9	0.1021	0.0	0.0	2.3	0.0479	1009.70	0.0013	1005.80	0.0000	1011.90	-0.0083	0.16		-0.01		105	
7/24/2010	0.69	5.1	0.1063	0.0	0.0	2.3	0.0479	1009.60	-0.0013	1005.80	0.0000	1011.70	-0.0166	0.17		-0.02		115	
7/24/2010	0.71	4.4	0.0917	0.0	0.0	2.4	0.0500	1009.40	-0.0026	1005.80	0.0000	1011.90	0.0166	0.13	0.02			85	
7/24/2010	0.73	3.8	0.0792	0.0	0.0	2.4	0.0500	1009.40	0.0000	1006.20	0.0102	1011.60	-0.0248	0.14	0.01			96	
7/24/2010	0.75	3.4	0.0708	0.0	0.0	3.3	0.0688	1009.50	0.0013	1006.90	0.0178	1011.50	-0.0083	0.13	0.02			86	
7/24/2010	0.77	3.4	0.0708	0.0	0.0	3.3	0.0688	1009.40	-0.0013	1007.40	0.0127	1011.30	-0.0166	0.14	0.00			97	
7/24/2010	0.79	4.3	0.0896	0.0	0.0	3.4	0.0708	1009.40	0.0000	1008.00	0.0153	1011.40	0.0083	0.14	0.01			92	
7/24/2010	0.81	4.3	0.0896	0.0	0.0	3.3	0.0688	1009.50	0.0013	1008.60	0.0153	1011.70	0.0248	0.12	0.03			78	
7/24/2010	0.83	4.3	0.0896	0.0	0.0	3.4	0.0708	1009.60	0.0013	1009.10	0.0127	1011.90	0.0166	0.13	0.02			87	
7/24/2010	0.85	4.4	0.0917	0.0	0.0	3.4	0.0708	1010.80	0.0158	1009.60	0.0127	1011.80	-0.0083	0.14	0.01			95	
7/24/2010	0.88	4.4	0.0917	0.0	0.0	3.3	0.0688	1011.90	0.0145	1010.00	0.0102	1011.90	0.0083	0.13	0.02			85	
7/24/2010	0.90	6.3	0.1313	0.0	0.0	3.4	0.0708	1012.90	0.0132	1010.60	0.0153	1012.20	0.0248	0.15	0.00			100	
7/24/2010	0.92	6.1	0.1271	0.0	0.0	3.4	0.0708	1013.90	0.0132	1011.50	0.0229	1012.70	0.0414	0.12	0.03			81	
7/24/2010	0.94	5.9	0.1229	0.0	0.0	3.3	0.0688	1014.10	0.0026	1012.00	0.0127	1013.70	0.0828	0.09	0.06			63	
7/24/2010	0.96	5.9	0.1229	0.0	0.0	3.3	0.0688	1014.10	0.0000	1012.00	0.0000	1014.70	0.0828	0.11	0.04			73	
7/24/2010	0.98	4.5	0.0938	0.0	0.0	3.3	0.0688	1014.10	0.0000	1012.00	0.0000	1015.40	0.0579	0.10	0.04			70	
														0.15	0.55	-0.55	7.7	90	7.17

City of Lawrence, Kansas
7-24-2010 Diurnal Data - Central Service Pressure Zone



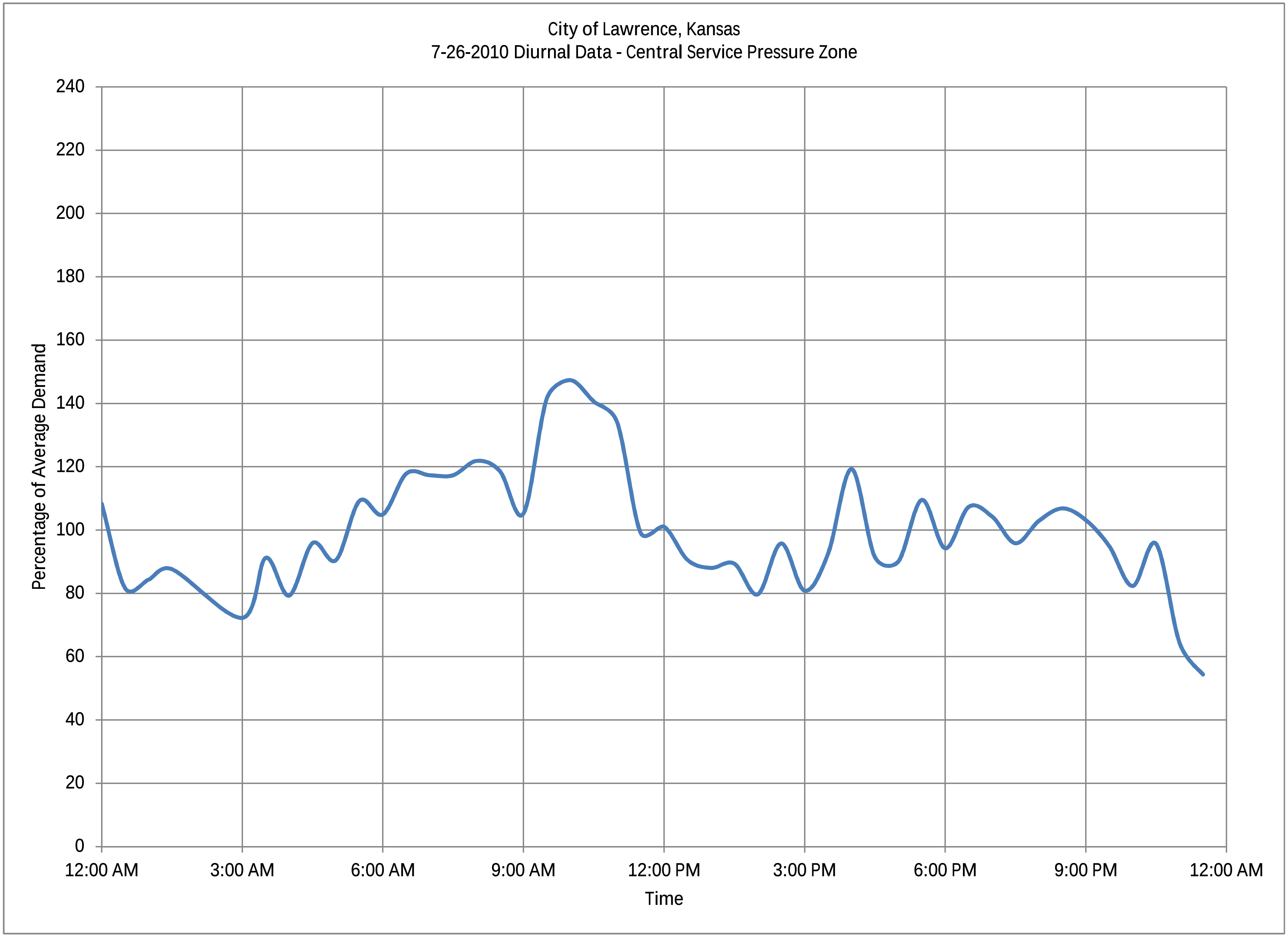
City of Lawrence, Kansas - 2011 Water Master Plan
July 25, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/25/2010	0:00	2.7	0.0563	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1015.9	0.0000	0.13	0.01			90	
7/25/2010	0:30	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1011.7	-0.0076	1015.3	-0.0497	0.13	0.01			90	
7/25/2010	1:00	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1011.1	-0.0153	1014.9	-0.0331	0.12	0.02			84	
7/25/2010	1:30	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1010.5	-0.0153	1014.5	-0.0331	0.12	0.02			84	
7/25/2010	2:00	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1010.0	-0.0127	1014.1	-0.0331	0.11	0.03			82	
7/25/2010	2:30	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1009.5	-0.0127	1013.7	-0.0331	0.11	0.03			82	
7/25/2010	3:00	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.2	0.0013	1009.1	-0.0102	1013.4	-0.0248	0.10	0.04			73	
7/25/2010	3:30	3.3	0.0688	0.0	0.0000	3.3	0.0688	1014.1	-0.0013	1008.9	-0.0051	1013.3	-0.0083	0.15		-0.01		109	
7/25/2010	4:00	3.3	0.0688	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1009.6	0.0178	1013.5	0.0166	0.10	0.04			74	
7/25/2010	4:30	3.3	0.0688	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1010.2	0.0153	1013.7	0.0166	0.11	0.03			76	
7/25/2010	5:00	3.2	0.0667	0.0	0.0000	3.3	0.0688	1014.2	0.0013	1010.7	0.0127	1013.9	0.0166	0.10	0.03			75	
7/25/2010	5:30	3.2	0.0667	0.0	0.0000	3.3	0.0688	1014.2	0.0000	1011.2	0.0127	1014.1	0.0166	0.11	0.03			76	
7/25/2010	6:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1014.2	0.0000	1011.5	0.0076	1014.3	0.0166	0.11	0.03			77	
7/25/2010	6:30	3.1	0.0646	0.0	0.0000	3.3	0.0688	1014.2	0.0000	1011.8	0.0076	1014.5	0.0166	0.11	0.03			78	
7/25/2010	7:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1014.2	0.0000	1010.7	0.0000	1014.6	0.0083	0.12	0.02			88	
7/25/2010	7:30	2.8	0.0583	0.0	0.0000	3.3	0.0688	1014.2	0.0000	1008.9	0.0000	1014.8	0.0166	0.11	0.03			79	
7/25/2010	8:00	2.8	0.0583	0.0	0.0000	3.3	0.0688	1014.2	0.0000	1007.2	0.0000	1014.9	0.0083	0.12	0.02			85	
7/25/2010	8:30	2.9	0.0604	0.0	0.0000	3.3	0.0688	1014.3	0.0013	1007.0	-0.0051	1015.0	0.0083	0.12	0.01			89	
7/25/2010	9:00	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.2	-0.0013	1006.9	-0.0025	1014.2	-0.0662	0.14	0.00			99	
7/25/2010	9:30	0.0	0.0000	0.0	0.0000	3.3	0.0688	1013.9	-0.0039	1006.9	0.0000	1013.5	-0.0579	0.13	0.01			94	
7/25/2010	10:00	0.0	0.0000	0.0	0.0000	3.4	0.0708	1013.5	-0.0053	1006.7	-0.0051	1012.9	-0.0497	0.13	0.01			94	
7/25/2010	10:30	0.0	0.0000	0.0	0.0000	3.4	0.0708	1012.9	-0.0079	1006.4	-0.0076	1012.2	-0.0579	0.14	0.00			103	
7/25/2010	11:00	0.0	0.0000	4.2	0.0875	3.3	0.0688	1012.7	-0.0026	1006.6	0.0051	1012.4	0.0166	0.14	0.00			98	
7/25/2010	11:30	0.0	0.0000	4.2	0.0875	3.3	0.0688	1012.8	0.0013	1006.3	0.0000	1012.1	-0.0248	0.18		-0.04		129	
7/25/2010	12:00	0.0	0.0000	4.3	0.0896	3.4	0.0708	1012.9	0.0013	1005.7	0.0000	1011.9	-0.0166	0.18		-0.04		126	
7/25/2010	12:30	0.0	0.0000	4.2	0.0875	3.4	0.0708	1012.7	-0.0026	1004.8	0.0000	1011.7	-0.0166	0.18		-0.04		127	
7/25/2010	13:00	0.0	0.0000	4.1	0.0854	3.3	0.0688	1012.6	-0.0013	1004.0	0.0000	1011.5	-0.0166	0.17		-0.03		123	
7/25/2010	13:30	0.0	0.0000	0.0	0.0000	3.4	0.0708	1011.2	-0.0184	1002.0	0.0029	1010.5	-0.0828	0.17		-0.04		125	
7/25/2010	14:00	3.1	0.0646	0.0	0.0000	3.4	0.0708	1010.3	-0.0118	1000.2	0.0000	1010.0	-0.0414	0.19		-0.05		135	
7/25/2010	14:30	3.2	0.0667	0.0	0.0000	2.4	0.0500	1010.2	-0.0013	1000.1	-0.0025	1009.5	-0.0414	0.16		-0.02		116	
7/25/2010	15:00	3.9	0.0813	0.0	0.0000	2.3	0.0479	1010.1	-0.0013	1000.1	0.0000	1009.5	0.0000	0.13	0.01			93	
7/25/2010	15:30	4.6	0.0958	0.0	0.0000	2.4	0.0500	1010.2	0.0013	1000.1	0.0000	1009.6	0.0083	0.14	0.00			98	
7/25/2010	16:00	5.6	0.1167	0.0	0.0000	2.4	0.0500	1010.2	0.0000	1000.1	0.0000	1009.7	0.0083	0.16		-0.02		113	
7/25/2010	16:30	5.9	0.1229	0.0	0.0000	3.3	0.0688	1010.2	0.0000	1000.1	0.0000	1010.2	0.0414	0.15		-0.01		108	
7/25/2010	17:00	5.7	0.1188	0.0	0.0000	3.3	0.0688	1010.2	0.0000	1000.1	0.0000	1011.0	0.0662	0.12	0.02			87	
7/25/2010	17:30	3.6	0.0750	0.0	0.0000	3.3	0.0688	1010.1	-0.0013	1000.1	0.0000	1011.3	0.0248	0.12	0.02			86	
7/25/2010	18:00	3.7	0.0771	0.0	0.0000	3.4	0.0708	1010.1	0.0000	1001.2	0.0280	1010.9	-0.0331	0.15		-0.01		110	
7/25/2010	18:30	4.1	0.0854	0.0	0.0000	3.4	0.0708	1010.1	0.0000	1002.3	0.0280	1010.8	-0.0083	0.14	0.00			98	
7/25/2010	19:00	4.1	0.0854	0.0	0.0000	3.4	0.0708	1010.1	0.0000	1003.2	0.0229	1010.6	-0.0166	0.15		-0.01		107	
7/25/2010	19:30	4.2	0.0875	0.0	0.0000	0.0	0.0000	1010.1	0.0000	1003.0	0.0000	1010.3	-0.0248	0.11	0.03			80	
7/25/2010	20:00	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.8	-0.0039	1001.9	0.0009	1010.3	0.0000	0.17		-0.03		123	
7/25/2010	20:30	4.5	0.0938	0.0	0.0000	3.4	0.0708	1009.8	0.0000	1000.8	0.0009	1010.3	0.0000	0.17		-0.03		118	
7/25/2010	21:00	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.8	0.0000	1000.0	0.0000	1010.1	-0.0166	0.18		-0.04		131	
7/25/2010	21:30	4.7	0.0979	0.0	0.0000	3.4	0.0708	1009.7	-0.0013	1000.2	0.0000	1009.7	-0.0331	0.20		-0.06		145	
7/25/2010	22:00	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.7	0.0000	1001.1	0.0229	1009.5	-0.0166	0.21		-0.07		148	
7/25/2010	22:30	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.6	-0.0013	1002.2	0.0280	1009.3	-0.0166	0.16		-0.02		112	
7/25/2010	23:00	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.6	0.0000	1003.4	0.0305	1009.4	0.0083	0.13	0.01			92	
7/25/2010	23:30	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.5	-0.0013	1004.4	0.0254	1009.6	0.0166	0.13	0.01			90	
														0.14	0.57	-0.57	8.5	108	6.70


City of Lawrence, Kansas
7-25-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

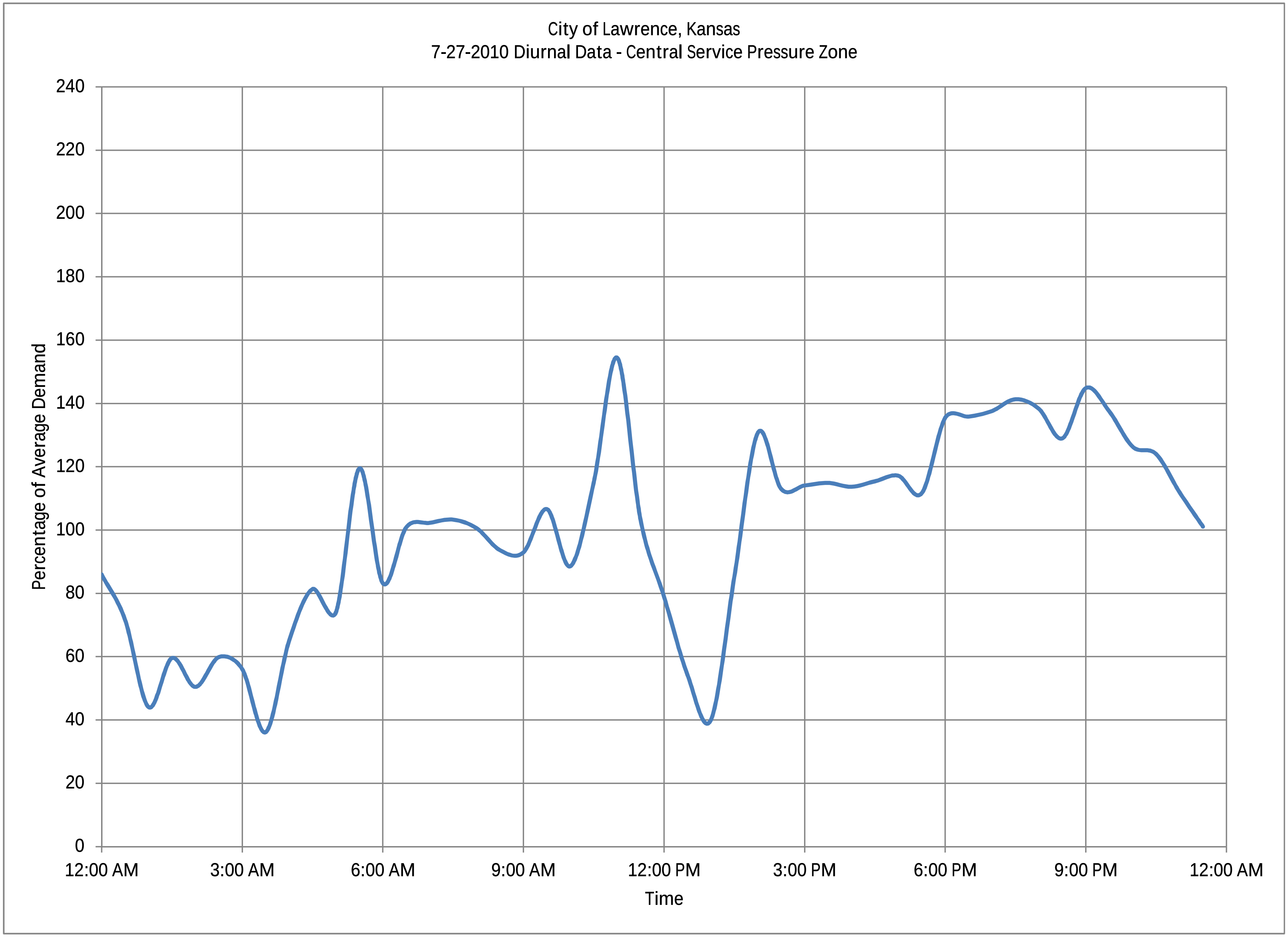
City of Lawrence, Kansas - 2011 Water Master Plan
July 26, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/26/2010	0:00	4.6	0.0958	0.0	0.0000	3.4	0.0708	1009.5	0.0000	0.0000	0.0000	1009.8	0.0000	0.17		-0.01		108	
7/26/2010	0:30	4.4	0.0917	0.0	0.0000	3.4	0.0708	1009.5	0.0000	0.0000	0.0203	1010.0	0.0166	0.13	0.03			82	
7/26/2010	1:00	4.2	0.0875	0.0	0.0000	3.4	0.0708	1009.5	0.0000	0.0000	0.0203	1010.1	0.0083	0.13	0.02			84	
7/26/2010	1:30	4.2	0.0875	0.0	0.0000	3.4	0.0708	1009.5	0.0000	0.0000	0.0153	1010.2	0.0083	0.13	0.02			88	
7/26/2010	2:00	5.0	0.1042	0.0	0.0000	3.4	0.0708	Bad	Bad	Bad	Bad	Bad	Bad						
7/26/2010	2:30	5.0	0.1042	0.0	0.0000	3.4	0.0708	1009.5	Bad	0.0000	Bad	1010.9	Bad						
7/26/2010	3:00	6.1	0.1271	0.0	0.0000	3.3	0.0688	1009.6	0.0013	0.0000	0.0254	1011.6	0.0579	0.11	0.04			72	
7/26/2010	3:30	6.1	0.1271	0.0	0.0000	3.3	0.0688	1010.0	0.0053	0.0000	0.0254	1011.9	0.0248	0.14	0.01			91	
7/26/2010	4:00	5.9	0.1229	0.0	0.0000	3.4	0.0708	1011.2	0.0158	0.0000	0.0229	1012.3	0.0331	0.12	0.03			79	
7/26/2010	4:30	6.0	0.1250	0.0	0.0000	3.3	0.0688	1012.2	0.0132	0.0000	0.0000	1012.7	0.0331	0.15	0.01			96	
7/26/2010	5:00	6.0	0.1250	0.0	0.0000	3.3	0.0688	1013.2	0.0132	0.0000	0.0000	1013.2	0.0414	0.14	0.01			90	
7/26/2010	5:30	6.0	0.1250	0.0	0.0000	3.3	0.0688	1013.9	0.0092	0.0000	0.0000	1013.4	0.0166	0.17		-0.01		109	
7/26/2010	6:00	6.1	0.1271	0.0	0.0000	3.3	0.0688	1014.0	0.0013	0.0458	0.0000	1013.8	0.0331	0.16		-0.01		105	
7/26/2010	6:30	5.4	0.1125	0.0	0.0000	3.3	0.0688	1014.0	0.0000	0.0458	0.0000	1013.8	0.0000	0.18		-0.03		118	
7/26/2010	7:00	5.3	0.1104	0.0	0.0000	3.3	0.0688	1013.9	-0.0013	0.0458	0.0000	1013.8	0.0000	0.18		-0.03		117	
7/26/2010	7:30	5.3	0.1104	0.0	0.0000	3.3	0.0688	1013.8	-0.0013	0.0458	0.0000	1013.8	0.0000	0.18		-0.03		117	
7/26/2010	8:00	5.3	0.1104	0.0	0.0000	3.3	0.0688	1013.8	0.0000	0.0458	0.0000	1013.7	-0.0083	0.19		-0.03		122	
7/26/2010	8:30	5.3	0.1104	0.0	0.0000	3.3	0.0688	1013.8	0.0000	0.0292	0.0115	1013.8	0.0083	0.18		-0.03		119	
7/26/2010	9:00	5.2	0.1083	0.0	0.0000	3.3	0.0688	1013.7	-0.0013	0.0292	0.0000	1014.0	0.0166	0.16		-0.01		105	
7/26/2010	9:30	5.5	0.1146	0.0	0.0000	3.3	0.0688	1013.5	-0.0026	0.0000	-0.0153	1013.8	-0.0166	0.22		-0.06		142	
7/26/2010	10:00	6.2	0.1292	0.0	0.0000	3.3	0.0688	1013.2	-0.0039	0.0292	0.0000	1013.5	-0.0248	0.23		-0.07		147	
7/26/2010	10:30	6.1	0.1271	0.0	0.0000	3.3	0.0688	1012.9	-0.0039	0.0271	0.0000	1013.3	-0.0166	0.22		-0.06		141	
7/26/2010	11:00	6.1	0.1271	0.0	0.0000	3.4	0.0708	1012.9	0.0000	0.0271	0.0000	1013.2	-0.0083	0.21		-0.05		134	
7/26/2010	11:30	4.2	0.0875	0.0	0.0000	3.3	0.0688	1012.7	-0.0026	0.0000	0.0229	1013.0	-0.0166	0.15	0.00			99	
7/26/2010	12:00	3.2	0.0667	0.0	0.0000	3.4	0.0708	1012.5	-0.0026	0.0000	0.0178	1012.6	-0.0331	0.16	0.00			101	
7/26/2010	12:30	3.2	0.0667	0.0	0.0000	3.3	0.0688	1012.2	-0.0039	0.0000	0.0000	1012.6	0.0000	0.14	0.01			91	
7/26/2010	13:00	3.2	0.0667	0.0	0.0000	3.3	0.0688	1012.2	0.0000	0.0000	0.0000	1012.6	0.0000	0.14	0.02			88	
7/26/2010	13:30	2.9	0.0604	0.0	0.0000	3.3	0.0688	1012.1	-0.0013	0.0000	0.0178	1012.3	-0.0248	0.14	0.02			89	
7/26/2010	14:00	3.0	0.0625	0.0	0.0000	3.4	0.0708	1012.0	-0.0013	0.0000	0.0203	1012.2	-0.0083	0.12	0.03			80	
7/26/2010	14:30	3.0	0.0625	0.0	0.0000	3.4	0.0708	1012.1	0.0013	0.0000	0.0178	1011.8	-0.0331	0.15	0.01			96	
7/26/2010	15:00	2.9	0.0604	0.0	0.0000	3.4	0.0708	1011.9	-0.0026	0.0000	0.0178	1011.7	-0.0083	0.12	0.03			81	
7/26/2010	15:30	0.0	0.0000	0.0	0.0000	3.4	0.0708	1011.4	-0.0066	0.0000	-0.0153	1011.1	-0.0497	0.14	0.01			93	
7/26/2010	16:00	0.0	0.0000	5.0	0.1042	3.4	0.0708	1011.0	-0.0053	0.0000	0.0051	1011.0	-0.0083	0.18		-0.03		119	
7/26/2010	16:30	0.0	0.0000	5.0	0.1042	3.4	0.0708	1011.0	0.0000	0.0000	0.0178	1011.2	0.0166	0.14	0.01			91	
7/26/2010	17:00	0.0	0.0000	5.0	0.1042	3.3	0.0688	1011.0	0.0000	0.0000	0.0178	1011.4	0.0166	0.14	0.02			90	
7/26/2010	17:30	0.0	0.0000	4.9	0.1021	3.4	0.0708	1011.0	0.0000	0.0000	0.0127	1011.3	-0.0083	0.17		-0.01		110	
7/26/2010	18:00	0.0	0.0000	4.9	0.1021	3.4	0.0708	1010.9	-0.0013	0.0000	0.0127	1011.5	0.0166	0.14	0.01			94	
7/26/2010	18:30	0.0	0.0000	4.9	0.1021	3.3	0.0688	1011.0	0.0013	0.0000	0.0127	1011.4	-0.0083	0.17		-0.01		107	
7/26/2010	19:00	0.0	0.0000	5.0	0.1042	3.4	0.0708	1010.9	-0.0013	0.0000	0.0076	1011.5	0.0083	0.16		-0.01		104	
7/26/2010	19:30	0.0	0.0000	4.9	0.1021	3.4	0.0708	1011.0	0.0013	0.0000	0.0076	1011.7	0.0166	0.15	0.01			96	
7/26/2010	20:00	0.0	0.0000	4.9	0.1021	3.4	0.0708	1010.9	-0.0013	0.0000	0.0076	1011.8	0.0083	0.16	0.00			103	
7/26/2010	20:30	0.0	0.0000	4.9	0.1021	3.4	0.0708	1011.6	0.0092	0.0000	0.0076	1011.7	-0.0083	0.16		-0.01		107	
7/26/2010	21:00	0.0	0.0000	4.9	0.1021	3.4	0.0708	1012.1	0.0066	0.0000	0.0076	1011.7	0.0000	0.16	0.00			103	
7/26/2010	21:30	0.0	0.0000	4.9	0.1021	3.4	0.0708	1012.5	0.0053	0.0000	0.0051	1011.9	0.0166	0.15	0.01			95	
7/26/2010	22:00	2.9	0.0604	0.0	0.0000	3.4	0.0708	1012.8	0.0039	0.0000	-0.0076	1012.0	0.0083	0.13	0.03			82	
7/26/2010	22:30	3.0	0.0625	0.0	0.0000	3.3	0.0688	1012.8	0.0000	0.0000	-0.0076	1011.9	-0.0083	0.15	0.01			96	
7/26/2010	23:00	2.9	0.0604	0.0	0.0000	3.3	0.0688	1013.2	0.0053	0.0000	0.0000	1012.2	0.0248	0.10	0.05			64	
7/26/2010	23:30	2.8	0.0583	0.0	0.0000	3.3	0.0688	1013.6	0.0053	0.0000	0.0051	1012.6	0.0331	0.08	0.07			54	
														0.15	0.51	-0.51	7.2	86	7.08


City of Lawrence, Kansas
7-26-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

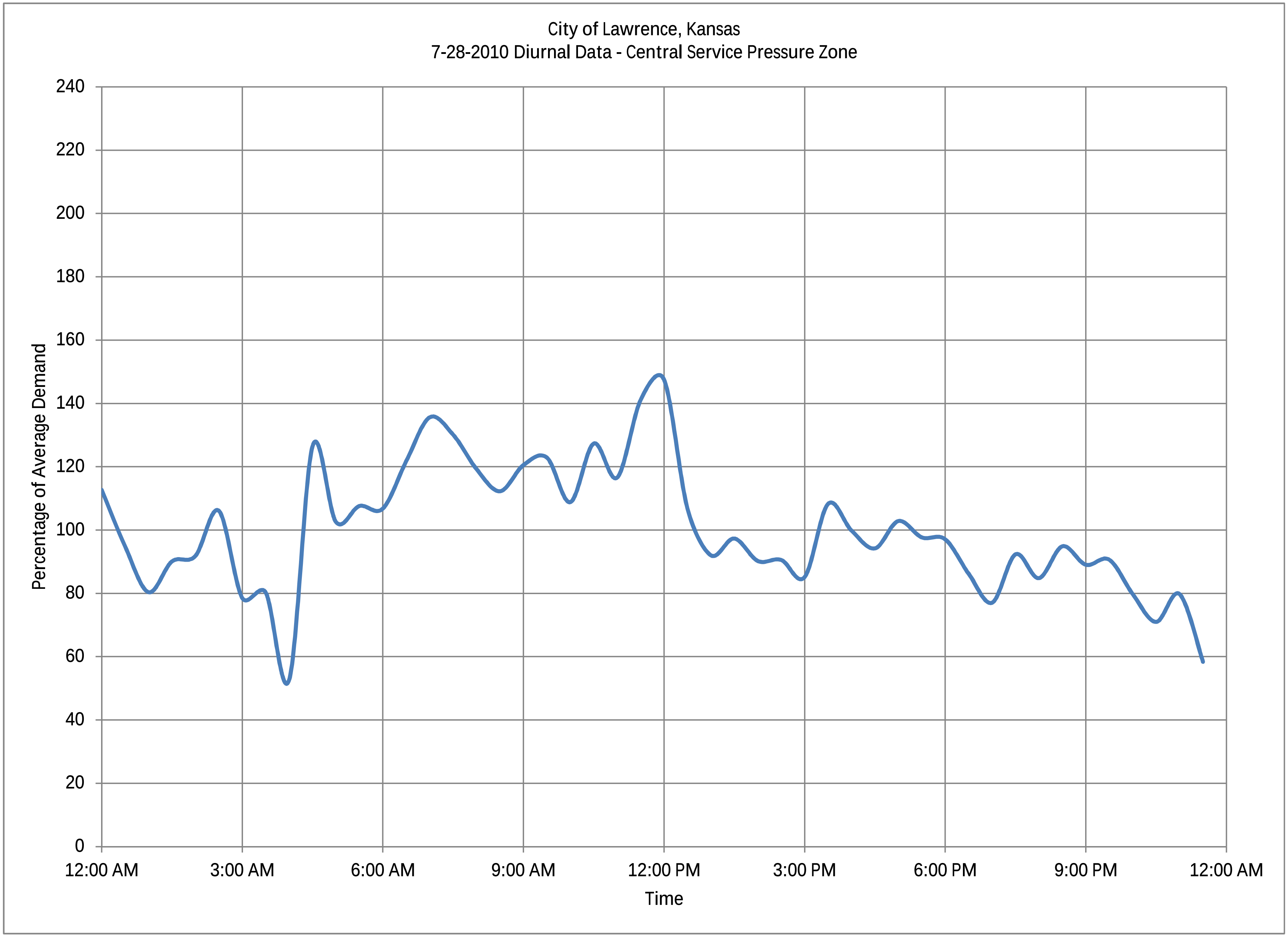
City of Lawrence, Kansas - 2011 Water Master Plan
July 27, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/27/2010	0:00	2.8	0.0583	0.0	0.0000	3.3	0.0688	1014.0	0.0000	1011.4	0.0000	1012.9	0.0000	0.13	0.02			86	
7/27/2010	0:30	2.7	0.0563	0.0	0.0000	3.3	0.0688	1014.0	0.0000	1011.5	0.0025	1013.1	0.0166	0.11	0.04			72	
7/27/2010	1:00	2.7	0.0563	0.0	0.0000	3.3	0.0688	1014.0	0.0000	1011.9	0.0102	1013.7	0.0497	0.07	0.08			44	
7/27/2010	1:30	2.7	0.0563	0.0	0.0000	3.3	0.0688	1014.1	0.0013	1012.0	0.0025	1014.1	0.0331	0.09	0.06			60	
7/27/2010	2:00	2.6	0.0542	0.0	0.0000	3.3	0.0688	1014.0	-0.0013	1012.0	0.0000	1014.7	0.0497	0.07	0.07			50	
7/27/2010	2:30	2.6	0.0542	0.0	0.0000	3.3	0.0688	1014.1	0.0013	1012.0	0.0000	1015.1	0.0331	0.09	0.06			60	
7/27/2010	3:00	2.6	0.0542	0.0	0.0000	3.3	0.0688	1014.0	-0.0013	1012.0	0.0000	1015.6	0.0414	0.08	0.06			56	
7/27/2010	3:30	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0013	1011.9	-0.0025	1015.8	0.0166	0.05	0.09			36	
7/27/2010	4:00	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1011.8	-0.0025	1015.5	-0.0248	0.10	0.05			65	
7/27/2010	4:30	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1011.4	-0.0102	1015.0	-0.0414	0.12	0.03			81	
7/27/2010	5:00	0.0	0.0000	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1011.1	-0.0076	1014.6	-0.0331	0.11	0.04			74	
7/27/2010	5:30	3.1	0.0646	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1010.7	-0.0102	1014.2	-0.0331	0.18		-0.03		119	
7/27/2010	6:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1014.1	0.0000	1010.7	0.0000	1014.3	0.0083	0.12	0.02			83	
7/27/2010	6:30	3.0	0.0625	0.0	0.0000	3.3	0.0688	1014.0	-0.0013	1009.6	0.0000	1014.1	-0.0166	0.15	0.00			101	
7/27/2010	7:00	3.0	0.0625	0.0	0.0000	3.4	0.0708	1013.9	-0.0013	1008.4	0.0000	1013.9	-0.0166	0.15	0.00			102	
7/27/2010	7:30	2.9	0.0604	0.0	0.0000	3.3	0.0688	1014.0	0.0013	1007.3	0.0000	1013.6	-0.0248	0.15	0.00			103	
7/27/2010	8:00	2.9	0.0604	0.0	0.0000	3.4	0.0708	1014.0	0.0000	1006.2	0.0009	1013.4	-0.0166	0.15	0.00			101	
7/27/2010	8:30	2.8	0.0583	0.0	0.0000	3.3	0.0688	1013.8	-0.0026	1005.2	0.0004	1013.3	-0.0083	0.14	0.01			94	
7/27/2010	9:00	2.8	0.0583	0.0	0.0000	3.3	0.0688	1013.8	0.0000	1004.3	0.0020	1013.2	-0.0083	0.14	0.01			93	
7/27/2010	9:30	3.0	0.0625	0.0	0.0000	2.3	0.0479	1013.5	-0.0039	1003.9	-0.0102	1012.8	-0.0331	0.16		-0.01		107	
7/27/2010	10:00	2.9	0.0604	0.0	0.0000	2.4	0.0500	1013.2	-0.0039	1003.9	0.0000	1012.6	-0.0166	0.13	0.02			89	
7/27/2010	10:30	0.0	0.0000	0.0	0.0000	0.9	0.0188	1010.7	-0.0329	1003.8	-0.0025	1011.2	-0.1159	0.17		-0.02		115	
7/27/2010	11:00	6.1	0.1271	0.0	0.0000	0.9	0.0188	1009.8	-0.0118	1003.3	-0.0127	1010.5	-0.0579	0.23		-0.08		154	
7/27/2010	11:30	0.0	0.0000	6.4	0.1333	0.0	0.0000	1009.6	-0.0026	1003.3	0.0000	1010.3	-0.0166	0.15	0.00			103	
7/27/2010	12:00	0.0	0.0000	8.2	0.1708	3.3	0.0688	1009.5	-0.0013	1003.3	0.0000	1011.8	0.1241	0.12	0.03			79	
7/27/2010	12:30	0.0	0.0000	8.1	0.1688	3.3	0.0688	1009.5	0.0000	1003.3	0.0000	1013.7	0.1572	0.08	0.07			54	
7/27/2010	13:00	0.0	0.0000	8.4	0.1750	0.0	0.0000	1009.5	0.0000	1003.3	0.0000	1015.1	0.1159	0.06	0.09			40	
7/27/2010	13:30	0.0	0.0000	6.9	0.1438	0.0	0.0000	1009.6	0.0013	1003.3	0.0000	1015.3	0.0166	0.13	0.02			85	
7/27/2010	14:00	0.0	0.0000	7.3	0.1521	3.3	0.0688	1010.3	0.0092	1003.7	0.0102	1015.4	0.0083	0.19		-0.05		131	
7/27/2010	14:30	0.0	0.0000	4.8	0.1000	3.3	0.0688	1011.5	0.0158	1005.1	0.0356	1014.8	-0.0497	0.17		-0.02		113	
7/27/2010	15:00	0.0	0.0000	4.8	0.1000	3.3	0.0688	1011.9	0.0053	1006.2	0.0280	1014.4	-0.0331	0.17		-0.02		114	
7/27/2010	15:30	0.0	0.0000	4.8	0.1000	3.3	0.0688	1012.4	0.0066	1007.2	0.0254	1014.0	-0.0331	0.17		-0.02		115	
7/27/2010	16:00	0.0	0.0000	4.8	0.1000	3.3	0.0688	1012.6	0.0026	1008.1	0.0229	1013.7	-0.0248	0.17		-0.02		114	
7/27/2010	16:30	0.0	0.0000	4.8	0.1000	3.3	0.0688	1012.8	0.0026	1008.9	0.0203	1013.4	-0.0248	0.17		-0.02		115	
7/27/2010	17:00	0.0	0.0000	5.1	0.1063	3.3	0.0688	1012.6	-0.0026	1009.4	0.0127	1013.3	-0.0083	0.17		-0.03		117	
7/27/2010	17:30	0.0	0.0000	5.1	0.1063	2.3	0.0479	1012.4	-0.0026	1009.4	0.0000	1013.2	-0.0083	0.17		-0.02		112	
7/27/2010	18:00	0.0	0.0000	5.2	0.1083	2.3	0.0479	1012.2	-0.0026	1009.4	0.0000	1012.7	-0.0414	0.20		-0.05		135	
7/27/2010	18:30	0.0	0.0000	5.1	0.1063	2.3	0.0479	1011.8	-0.0053	1009.4	0.0000	1012.2	-0.0414	0.20		-0.05		136	
7/27/2010	19:00	0.0	0.0000	5.1	0.1063	2.3	0.0479	1011.2	-0.0079	1009.4	0.0000	1011.7	-0.0414	0.20		-0.06		138	
7/27/2010	19:30	0.0	0.0000	5.2	0.1083	2.4	0.0500	1010.5	-0.0092	1009.0	0.0000	1011.2	-0.0414	0.21		-0.06		141	
7/27/2010	20:00	0.0	0.0000	5.2	0.1083	3.4	0.0708	1010.4	-0.0013	1007.9	0.0009	1010.9	-0.0248	0.20		-0.06		138	
7/27/2010	20:30	0.0	0.0000	5.1	0.1063	3.4	0.0708	1010.4	0.0000	1006.8	0.0030	1010.7	-0.0166	0.19		-0.04		129	
7/27/2010	21:00	0.0	0.0000	5.1	0.1063	3.4	0.0708	1010.1	-0.0039	1006.8	0.0000	1010.3	-0.0331	0.21		-0.07		145	
7/27/2010	21:30	0.0	0.0000	5.5	0.1146	3.4	0.0708	1010.0	-0.0013	1006.8	0.0000	1010.1	-0.0166	0.20		-0.06		137	
7/27/2010	22:00	0.0	0.0000	5.5	0.1146	3.4	0.0708	1009.9	-0.0013	1006.8	0.0000	1010.1	0.0000	0.19		-0.04		126	
7/27/2010	22:30	0.0	0.0000	5.4	0.1125	3.4	0.0708	1009.9	0.0000	1006.8	0.0000	1010.1	0.0000	0.18		-0.04		124	
7/27/2010	23:00	0.0	0.0000	5.5	0.1146	3.3	0.0688	1010.0	0.0013	1006.8	0.0000	1010.3	0.0166	0.17		-0.02		112	
7/27/2010	23:30	0.0	0.0000	5.4	0.1125	3.3	0.0688	1009.9	-0.0013	1006.8	0.0000	1010.7	0.0331	0.15	0.00			101	
														0.15	0.87	-0.87	12.2	113	7.10


City of Lawrence, Kansas
7-27-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
July 28, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
		Flow	Volume	Flow	Volume	Flow	Volume		Volume		Volume		Volume						
Date	Time	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/28/2010	0:00	0.0	0.0000	5.6	0.1167	3.3	0.0688	1009.9	0.0000	1006.8	0.0000	1011.0	0.0000	0.19		-0.02		113	
7/28/2010	0:30	0.0	0.0000	5.5	0.1146	3.3	0.0688	1009.8	-0.0013	1007.6	0.0203	1011.1	0.0083	0.16	0.01			95	
7/28/2010	1:00	0.0	0.0000	5.4	0.1125	3.3	0.0688	1009.9	0.0013	1008.5	0.0229	1011.4	0.0248	0.13	0.03			80	
7/28/2010	1:30	0.0	0.0000	5.4	0.1125	3.3	0.0688	1009.8	-0.0013	1009.2	0.0178	1011.6	0.0166	0.15	0.02			90	
7/28/2010	2:00	0.0	0.0000	5.6	0.1167	3.3	0.0688	1009.8	0.0000	1009.9	0.0178	1011.8	0.0166	0.15	0.01			92	
7/28/2010	2:30	0.0	0.0000	5.5	0.1146	6.6	0.1375	1011.0	0.0158	1010.7	0.0203	1012.3	0.0414	0.17		-0.01		106	
7/28/2010	3:00	0.0	0.0000	5.5	0.1146	6.6	0.1375	1012.5	0.0197	1011.5	0.0203	1013.3	0.0828	0.13	0.04			79	
7/28/2010	3:30	0.0	0.0000	5.1	0.1063	6.5	0.1354	1014.2	0.0224	1012.0	0.0127	1014.2	0.0745	0.13	0.03			80	
7/28/2010	4:00	0.0	0.0000	5.1	0.1063	3.3	0.0688	1014.0	-0.0026	1012.0	0.0000	1015.3	0.0910	0.09	0.08			53	
7/28/2010	4:30	0.0	0.0000	5.1	0.1063	3.3	0.0688	1014.0	0.0000	1012.0	0.0000	1014.9	-0.0331	0.21		-0.04		126	
7/28/2010	5:00	0.0	0.0000	4.8	0.1000	3.3	0.0688	1014.0	0.0000	1012.0	0.0000	1014.9	0.0000	0.17	0.00			103	
7/28/2010	5:30	0.0	0.0000	4.8	0.1000	3.3	0.0688	1014.0	0.0000	1012.0	0.0000	1014.8	-0.0083	0.18		-0.01		108	
7/28/2010	6:00	0.0	0.0000	4.8	0.1000	3.3	0.0688	1014.1	0.0013	1012.0	0.0000	1014.7	-0.0083	0.18		-0.01		107	
7/28/2010	6:30	0.0	0.0000	4.9	0.1021	3.4	0.0708	1013.9	-0.0026	1012.0	0.0000	1014.4	-0.0248	0.20		-0.04		122	
7/28/2010	7:00	0.0	0.0000	4.9	0.1021	3.3	0.0688	1013.7	-0.0026	1011.0	0.0000	1013.8	-0.0497	0.22		-0.06		136	
7/28/2010	7:30	0.0	0.0000	4.8	0.1000	3.3	0.0688	1013.4	-0.0039	1009.8	0.0000	1013.3	-0.0414	0.21		-0.05		130	
7/28/2010	8:00	0.0	0.0000	4.8	0.1000	3.3	0.0688	1013.2	-0.0026	1008.7	0.0000	1013.0	-0.0248	0.20		-0.03		119	
7/28/2010	8:30	0.0	0.0000	4.9	0.1021	3.3	0.0688	1013.0	-0.0026	1007.6	0.0030	1012.9	-0.0083	0.18		-0.02		112	
7/28/2010	9:00	0.0	0.0000	4.9	0.1021	3.3	0.0688	1012.8	-0.0026	1006.7	0.0000	1012.6	-0.0248	0.20		-0.03		121	
7/28/2010	9:30	0.0	0.0000	4.9	0.1021	0.0	0.0000	1011.2	-0.0211	1005.7	0.0046	1011.7	-0.0745	0.20		-0.04		123	
7/28/2010	10:00	0.0	0.0000	5.9	0.1229	0.0	0.0000	1010.2	-0.0132	1004.9	0.0016	1011.2	-0.0414	0.18		-0.01		109	
7/28/2010	10:30	0.0	0.0000	6.0	0.1250	3.4	0.0708	1010.0	-0.0026	1004.3	0.0028	1011.1	-0.0083	0.21		-0.04		127	
7/28/2010	11:00	0.0	0.0000	7.0	0.1458	3.4	0.0708	1010.0	0.0000	1003.6	0.0000	1011.4	0.0248	0.19		-0.03		117	
7/28/2010	11:30	0.0	0.0000	8.2	0.1708	3.4	0.0708	1010.0	0.0000	1003.0	-0.0153	1011.7	0.0248	0.23		-0.07		141	
7/28/2010	12:00	0.0	0.0000	8.5	0.1771	6.6	0.1375	1010.0	0.0000	1004.2	0.0305	1012.2	0.0414	0.24		-0.08		147	
7/28/2010	12:30	0.0	0.0000	8.7	0.1813	3.4	0.0708	1010.0	0.0000	1005.9	0.0432	1012.6	0.0331	0.18		-0.01		107	
7/28/2010	13:00	0.0	0.0000	8.6	0.1792	3.4	0.0708	1010.0	0.0000	1007.5	0.0407	1013.3	0.0579	0.15	0.01			92	
7/28/2010	13:30	0.0	0.0000	8.6	0.1792	3.3	0.0688	1010.0	0.0000	1009.0	0.0381	1013.9	0.0497	0.16	0.00			97	
7/28/2010	14:00	0.0	0.0000	8.5	0.1771	3.3	0.0688	1010.1	0.0013	1010.5	0.0381	1014.6	0.0579	0.15	0.02			90	
7/28/2010	14:30	0.0	0.0000	8.4	0.1750	3.3	0.0688	1010.0	-0.0013	1012.0	0.0381	1015.3	0.0579	0.15	0.02			91	
7/28/2010	15:00	0.0	0.0000	8.1	0.1688	2.2	0.0458	1010.0	0.0000	1012.0	0.0000	1016.2	0.0745	0.14	0.02			85	
7/28/2010	15:30	0.0	0.0000	8.1	0.1688	2.3	0.0479	1012.3	0.0303	1012.0	0.0000	1016.3	0.0083	0.18		-0.01		108	
7/28/2010	16:00	0.0	0.0000	8.1	0.1688	2.3	0.0479	1014.2	0.0250	1012.1	0.0025	1016.6	0.0248	0.16	0.00			100	
7/28/2010	16:30	0.0	0.0000	7.0	0.1458	2.3	0.0479	1014.0	-0.0026	1012.1	0.0000	1017.1	0.0414	0.16	0.01			94	
7/28/2010	17:00	0.0	0.0000	4.7	0.0979	3.3	0.0688	1014.0	0.0000	1012.0	-0.0025	1017.1	0.0000	0.17	0.00			103	
7/28/2010	17:30	0.0	0.0000	4.6	0.0958	3.3	0.0688	1014.1	0.0013	1012.1	0.0025	1017.1	0.0000	0.16	0.00			98	
7/28/2010	18:00	0.0	0.0000	4.7	0.0979	3.3	0.0688	1014.0	-0.0013	1012.1	0.0000	1017.2	0.0083	0.16	0.00			97	
7/28/2010	18:30	0.0	0.0000	4.7	0.0979	3.3	0.0688	1014.0	0.0000	1012.1	0.0000	1017.5	0.0248	0.14	0.02			86	
7/28/2010	19:00	2.6	0.0542	0.0	0.0000	3.3	0.0688	1013.9	-0.0013	1012.0	-0.0025	1017.5	0.0000	0.13	0.04			77	
7/28/2010	19:30	2.8	0.0583	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1017.2	-0.0248	0.15	0.01			92	
7/28/2010	20:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1017.1	-0.0083	0.14	0.03			85	
7/28/2010	20:30	3.0	0.0625	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1016.8	-0.0248	0.16	0.01			95	
7/28/2010	21:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1014.0	0.0013	1012.0	0.0000	1016.6	-0.0166	0.15	0.02			89	
7/28/2010	21:30	3.0	0.0625	0.0	0.0000	3.3	0.0688	1013.9	-0.0013	1012.0	0.0000	1016.4	-0.0166	0.15	0.02			91	
7/28/2010	22:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1016.4	0.0000	0.13	0.03			80	
7/28/2010	22:30	3.1	0.0646	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1016.6	0.0166	0.12	0.05			71	
7/28/2010	23:00	3.0	0.0625	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1016.6	0.0000	0.13	0.03			80	
7/28/2010	23:30	2.9	0.0604	0.0	0.0000	3.3	0.0688	1013.9	0.0000	1012.0	0.0000	1017.0	0.0331	0.10	0.07			58	
														0.16	0.62	-0.62	7.9	87	7.90

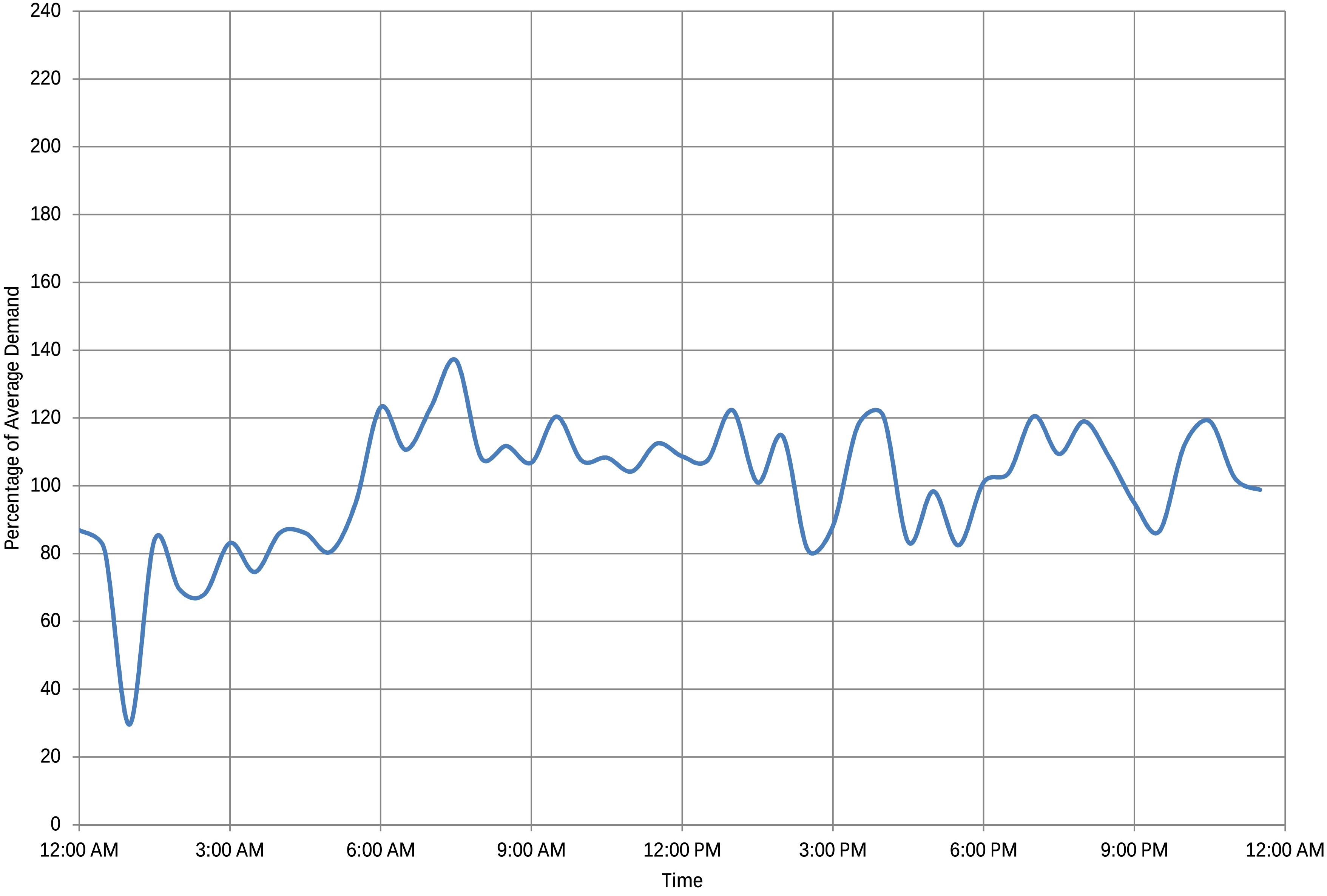


City of Lawrence, Kansas
7-28-2010 Diurnal Data - Central Service Pressure Zone

City of Lawrence, Kansas - 2011 Water Master Plan
July 29, 2010 Diurnal Data
Central Service Pressure Zone

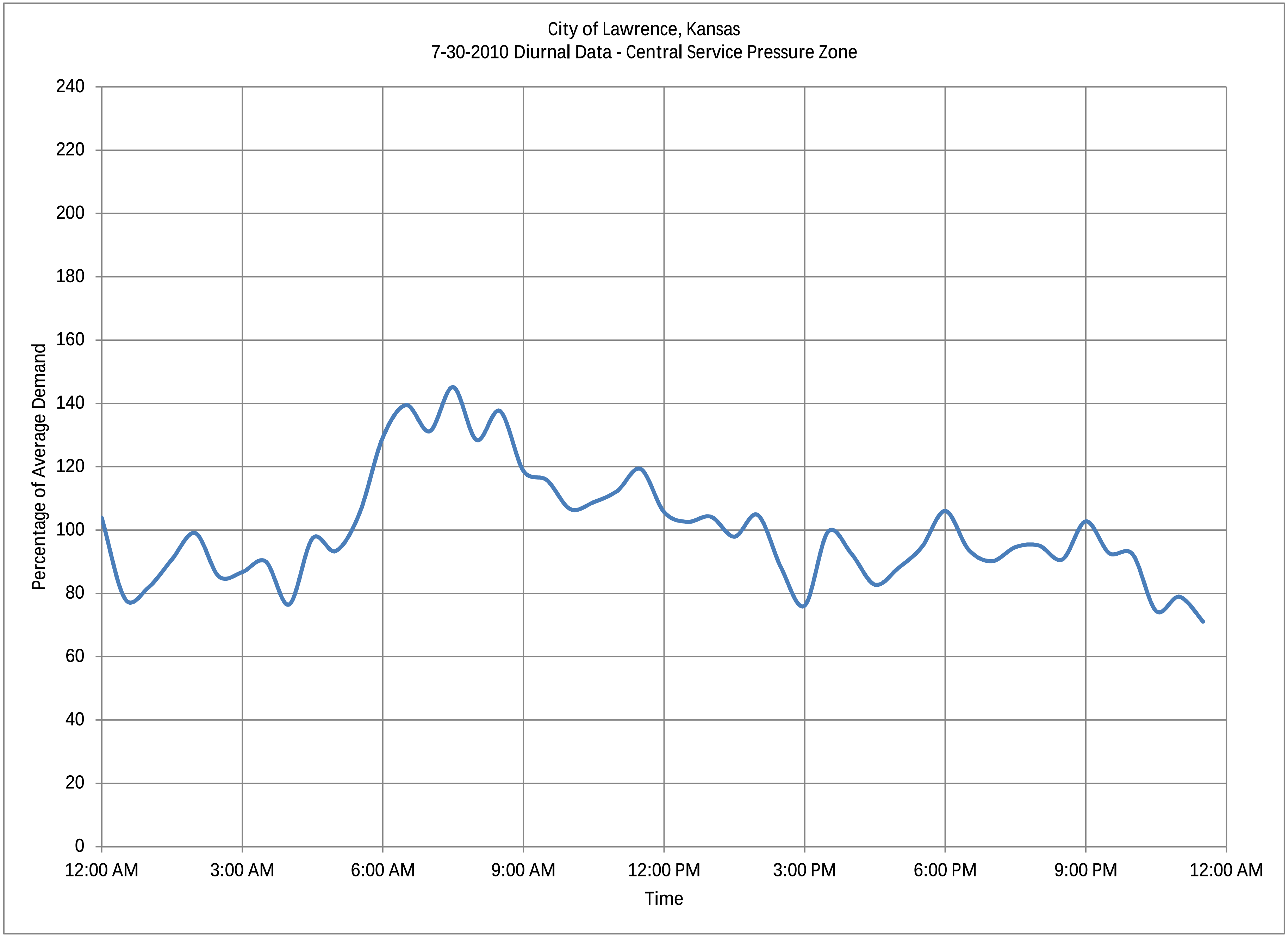
		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/29/2010	0:00	2.9	0.0604	0.0	0.0	3.3	0.0688	1013.9	0.0000	1012	0.0000	1017.3	0.0000	0.13	0.02			87	
7/29/2010	0:30	2.9	0.0604	0.0	0.0	3.3	0.0688	1013.9	0.0000	1012	0.0000	1017.4	0.0083	0.12	0.03			81	
7/29/2010	1:00	0.0	0.0000	0.0	0.0	3.3	0.0688	1013.9	0.0000	1012	0.0000	1017.7	0.0248	0.04	0.10			30	
7/29/2010	1:30	0.0	0.0000	0.0	0.0	3.3	0.0688	1013.8	-0.0013	1011.8	-0.0051	1017.1	-0.0497	0.12	0.02			84	
7/29/2010	2:00	0.0	0.0000	0.0	0.0	3.3	0.0688	1013.9	0.0013	1011.7	-0.0025	1016.7	-0.0331	0.10	0.05			69	
7/29/2010	2:30	0.0	0.0000	0.0	0.0	3.3	0.0688	1013.9	0.0000	1011.4	-0.0076	1016.4	-0.0248	0.10	0.05			68	
7/29/2010	3:00	0.0	0.0000	0.0	0.0	3.3	0.0688	1013.9	0.0000	1011.2	-0.0051	1015.8	-0.0497	0.12	0.03			83	
7/29/2010	3:30	0.0	0.0000	0.0	0.0	3.3	0.0688	1013.8	-0.0013	1010.9	-0.0076	1015.4	-0.0331	0.11	0.04			75	
7/29/2010	4:00	3.0	0.0625	0.0	0.0	3.3	0.0688	1013.8	0.0000	1010.7	-0.0051	1015.5	0.0083	0.13	0.02			86	
7/29/2010	4:30	2.9	0.0604	0.0	0.0	3.3	0.0688	1013.9	0.0013	1010.7	0.0000	1015.5	0.0000	0.13	0.02			86	
7/29/2010	5:00	2.9	0.0604	0.0	0.0	3.3	0.0688	1014	0.0013	1010.7	0.0000	1015.6	0.0083	0.12	0.03			80	
7/29/2010	5:30	3.0	0.0625	0.0	0.0	3.3	0.0688	1013.9	-0.0013	1010.7	0.0000	1015.5	-0.0083	0.14	0.01			95	
7/29/2010	6:00	3.1	0.0646	0.0	0.0	3.3	0.0688	1013.9	0.0000	1009.7	0.0000	1014.9	-0.0497	0.18		-0.03		123	
7/29/2010	6:30	3.0	0.0625	0.0	0.0	3.3	0.0688	1013.9	0.0000	1008.1	0.0000	1014.5	-0.0331	0.16		-0.02		111	
7/29/2010	7:00	3.1	0.0646	0.0	0.0	3.3	0.0688	1013.9	0.0000	1006.5	0.0000	1013.9	-0.0497	0.18		-0.03		123	
7/29/2010	7:30	3.0	0.0625	0.0	0.0	3.4	0.0708	1013.6	-0.0039	1004.9	0.0000	1013.1	-0.0662	0.20		-0.05		137	
7/29/2010	8:00	3.0	0.0625	0.0	0.0	3.4	0.0708	1013.4	-0.0026	1003.4	0.0000	1012.8	-0.0248	0.16		-0.01		108	
7/29/2010	8:30	2.9	0.0604	0.0	0.0	3.3	0.0688	1013.2	-0.0026	1001.8	0.0011	1012.4	-0.0331	0.17		-0.02		112	
7/29/2010	9:00	2.9	0.0604	0.0	0.0	3.4	0.0708	1013	-0.0026	1000.7	0.0000	1012.1	-0.0248	0.16		-0.01		107	
7/29/2010	9:30	3.9	0.0813	0.0	0.0	3.4	0.0708	1012.8	-0.0026	1000.4	-0.0076	1011.9	-0.0166	0.18		-0.03		120	
7/29/2010	10:00	3.8	0.0792	0.0	0.0	3.4	0.0708	1012.7	-0.0013	1000.4	0.0000	1011.8	-0.0083	0.16		-0.01		107	
7/29/2010	10:30	3.8	0.0792	0.0	0.0	3.4	0.0708	1012.5	-0.0026	1000.4	0.0000	1011.7	-0.0083	0.16		-0.01		108	
7/29/2010	11:00	3.7	0.0771	0.0	0.0	3.4	0.0708	1012.6	0.0013	1000.4	0.0000	1011.6	-0.0083	0.15		-0.01		104	
7/29/2010	11:30	3.8	0.0792	0.0	0.0	3.3	0.0688	1012.4	-0.0026	1000.4	0.0000	1011.4	-0.0166	0.17		-0.02		112	
7/29/2010	12:00	3.8	0.0792	0.0	0.0	3.3	0.0688	1012	-0.0053	1000.4	0.0000	1011.3	-0.0083	0.16		-0.01		109	
7/29/2010	12:30	3.8	0.0792	0.0	0.0	3.4	0.0708	1011.9	-0.0013	1000.4	0.0000	1011.2	-0.0083	0.16		-0.01		107	
7/29/2010	13:00	4.9	0.1021	0.0	0.0	3.3	0.0688	1011.7	-0.0026	1000.4	0.0000	1011.1	-0.0083	0.18		-0.03		122	
7/29/2010	13:30	6.1	0.1271	0.0	0.0	3.3	0.0688	1011.8	0.0013	1001.5	0.0280	1011.3	0.0166	0.15	0.00			101	
7/29/2010	14:00	6.0	0.1250	0.0	0.0	3.3	0.0688	1011.7	-0.0013	1002.8	0.0331	1011.2	-0.0083	0.17		-0.02		115	
7/29/2010	14:30	4.8	0.1000	0.0	0.0	3.3	0.0688	1011.6	-0.0013	1004.1	0.0331	1011.4	0.0166	0.12	0.03			81	
7/29/2010	15:00	4.8	0.1000	0.0	0.0	2.3	0.0479	1011.4	-0.0026	1005.2	0.0280	1011.3	-0.0083	0.13	0.02			88	
7/29/2010	15:30	4.7	0.0979	0.0	0.0	1.0	0.0208	1010.7	-0.0092	1005.3	0.0025	1010.7	-0.0497	0.18		-0.03		118	
7/29/2010	16:00	4.8	0.1000	0.0	0.0	2.3	0.0479	1010.2	-0.0066	1005.3	0.0000	1010.4	-0.0248	0.18		-0.03		121	
7/29/2010	16:30	5.7	0.1188	0.0	0.0	2.3	0.0479	1010.3	0.0013	1005.3	0.0000	1010.9	0.0414	0.12	0.02			83	
7/29/2010	17:00	5.7	0.1188	0.0	0.0	3.3	0.0688	1010.3	0.0000	1005.3	0.0000	1011.4	0.0414	0.15	0.00			98	
7/29/2010	17:30	5.0	0.1042	0.0	0.0	3.2	0.0667	1010.2	-0.0013	1005.3	0.0000	1012.0	0.0497	0.12	0.03			82	
7/29/2010	18:00	4.3	0.0896	0.0	0.0	3.3	0.0688	1010.2	0.0000	1004.6	0.0000	1012.1	0.0083	0.15	0.00			101	
7/29/2010	18:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1010.2	0.0000	1003.6	0.0000	1012.2	0.0083	0.15		-0.01		104	
7/29/2010	19:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1010.2	0.0000	1003.7	0.0000	1012.0	-0.0166	0.18		-0.03		121	
7/29/2010	19:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1010.2	0.0000	1003.9	0.0000	1012.0	0.0000	0.16		-0.01		109	
7/29/2010	20:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1011	0.0105	1004	0.0000	1011.7	-0.0248	0.18		-0.03		119	
7/29/2010	20:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1011.6	0.0079	1004.4	0.0102	1011.5	-0.0166	0.16		-0.01		108	
7/29/2010	21:00	4.6	0.0958	0.0	0.0	3.3	0.0688	1011.9	0.0039	1005.5	0.0280	1011.4	-0.0083	0.14	0.01			95	
7/29/2010	21:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1012.1	0.0026	1006.4	0.0229	1011.5	0.0083	0.13	0.02			87	
7/29/2010	22:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1011.5	-0.0079	1007.2	0.0203	1011.3	-0.0166	0.17		-0.02		112	
7/29/2010	22:30	4.6	0.0958	0.0	0.0	3.3	0.0688	1011.1	-0.0053	1007.9	0.0178	1011.0	-0.0248	0.18		-0.03		119	
7/29/2010	23:00	4.6	0.0958	0.0	0.0	3.3	0.0688	1010.9	-0.0026	1008.5	0.0153	1011.0	0.0000	0.15	0.00			102	
7/29/2010	23:30	4.6	0.0958	0.0	0.0	3.3	0.0688	1010.9	0.0000	1009.2	0.0178	1011.0	0.0000	0.15	0.00			99	
														0.15	0.53	-0.53	7.4	104	7.13

City of Lawrence, Kansas
7-29-2010 Diurnal Data - Central Service Pressure Zone



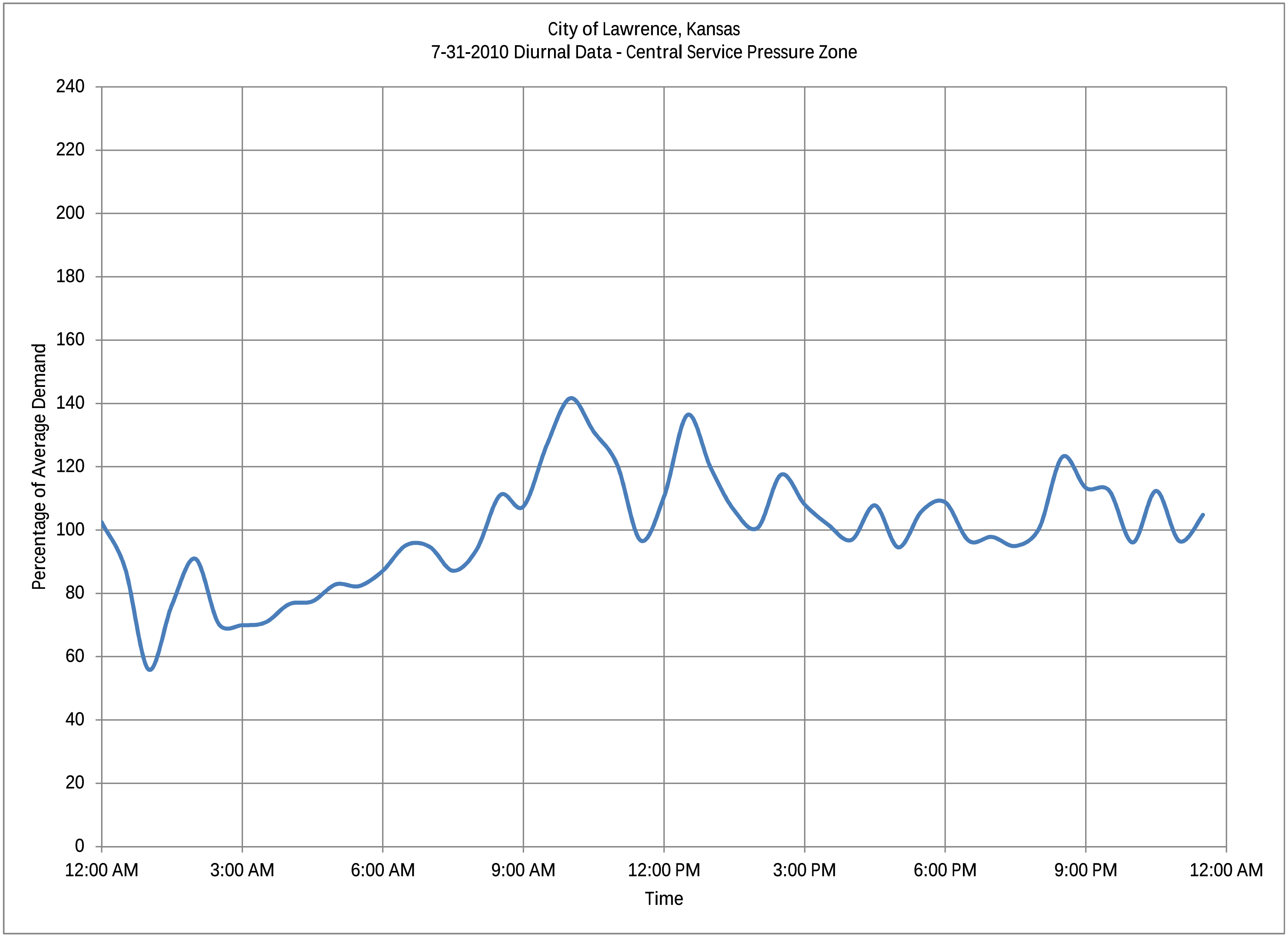
City of Lawrence, Kansas - 2011 Water Master Plan
July 30, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
		Flow	Volume	Flow	Volume	Flow	Volume		Volume		Volume		Volume						
Date	Time	(MGD)	(MG)	(MGD)	(MG)	(MGD)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	Level (ft)	(MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/30/2010	0:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1011.1	0.0000	1009.7	0.0000	1011.0	0.0000	0.16		-0.01		104	
7/30/2010	0:30	4.5	0.0938	0.0	0.0	3.3	0.0688	1011.3	0.0026	1010.2	0.0127	1011.3	0.0248	0.12	0.03			78	
7/30/2010	1:00	4.5	0.0938	0.0	0.0	3.3	0.0688	1011.5	0.0026	1010.8	0.0153	1011.5	0.0166	0.13	0.03			82	
7/30/2010	1:30	4.5	0.0938	0.0	0.0	3.2	0.0667	1011.7	0.0026	1011.1	0.0076	1011.6	0.0083	0.14	0.01			91	
7/30/2010	2:00	5.7	0.1188	0.0	0.0	3.2	0.0667	1011.8	0.0013	1011.6	0.0127	1011.8	0.0166	0.15	0.00			99	
7/30/2010	2:30	5.6	0.1167	0.0	0.0	3.2	0.0667	1012.3	0.0066	1012.0	0.0102	1012.2	0.0331	0.13	0.02			85	
7/30/2010	3:00	5.8	0.1208	0.0	0.0	3.2	0.0667	1013.1	0.0105	1011.1	0.0000	1012.7	0.0414	0.14	0.02			87	
7/30/2010	3:30	5.8	0.1208	0.0	0.0	3.2	0.0667	1013.5	0.0053	1009.3	0.0000	1013.2	0.0414	0.14	0.02			90	
7/30/2010	4:00	5.7	0.1188	0.0	0.0	3.2	0.0667	1014.1	0.0079	1007.6	0.0000	1013.9	0.0579	0.12	0.04			76	
7/30/2010	4:30	5.7	0.1188	0.0	0.0	3.2	0.0667	1014.1	0.0000	1005.9	0.0000	1014.3	0.0331	0.15	0.00			97	
7/30/2010	5:00	5.4	0.1125	0.0	0.0	3.2	0.0667	1014.1	0.0000	1004.2	0.0000	1014.7	0.0331	0.15	0.01			93	
7/30/2010	5:30	4.3	0.0896	0.0	0.0	3.2	0.0667	1014.1	0.0000	1002.5	0.0000	1014.6	-0.0083	0.16		-0.01		105	
7/30/2010	6:00	4.4	0.0917	0.0	0.0	3.4	0.0708	1013.9	-0.0026	1001.2	0.0122	1014.3	-0.0248	0.20		-0.05		129	
7/30/2010	6:30	4.5	0.0938	0.0	0.0	3.4	0.0708	1013.7	-0.0026	1000.5	-0.0178	1013.9	-0.0331	0.22		-0.06		139	
7/30/2010	7:00	4.4	0.0917	0.0	0.0	3.4	0.0708	1013.6	-0.0013	1000.5	0.0000	1013.4	-0.0414	0.21		-0.05		131	
7/30/2010	7:30	4.4	0.0917	0.0	0.0	3.4	0.0708	1013.1	-0.0066	1000.5	0.0000	1012.7	-0.0579	0.23		-0.07		145	
7/30/2010	8:00	4.4	0.0917	0.0	0.0	3.4	0.0708	1012.7	-0.0053	1000.5	0.0000	1012.3	-0.0331	0.20		-0.04		128	
7/30/2010	8:30	4.5	0.0938	0.0	0.0	3.4	0.0708	1012.0	-0.0092	1000.5	0.0000	1011.8	-0.0414	0.22		-0.06		138	
7/30/2010	9:00	4.4	0.0917	0.0	0.0	3.4	0.0708	1011.5	-0.0066	1000.5	0.0000	1011.6	-0.0166	0.19		-0.03		119	
7/30/2010	9:30	5.1	0.1063	0.0	0.0	3.4	0.0708	1011.2	-0.0039	1000.5	0.0000	1011.6	0.0000	0.18		-0.02		116	
7/30/2010	10:00	5.1	0.1063	0.0	0.0	3.3	0.0688	1011.2	0.0000	1000.5	0.0000	1011.7	0.0083	0.17		-0.01		107	
7/30/2010	10:30	5.1	0.1063	0.0	0.0	3.4	0.0708	1011.1	-0.0013	1000.5	0.0000	1011.8	0.0083	0.17		-0.01		109	
7/30/2010	11:00	5.3	0.1104	0.0	0.0	3.4	0.0708	1010.9	-0.0026	1001.8	0.0331	1011.5	-0.0248	0.18		-0.02		112	
7/30/2010	11:30	5.3	0.1104	0.0	0.0	3.4	0.0708	1010.5	-0.0053	1003.1	0.0331	1011.1	-0.0331	0.19		-0.03		119	
7/30/2010	12:00	5.2	0.1083	0.0	0.0	3.4	0.0708	1010.3	-0.0026	1004.4	0.0331	1010.9	-0.0166	0.17		-0.01		106	
7/30/2010	12:30	4.6	0.0958	0.0	0.0	3.4	0.0708	1010.1	-0.0026	1005.4	0.0254	1010.7	-0.0166	0.16	0.00			103	
7/30/2010	13:00	4.6	0.0958	0.0	0.0	3.4	0.0708	1009.9	-0.0026	1006.3	0.0229	1010.5	-0.0166	0.16		-0.01		104	
7/30/2010	13:30	4.5	0.0938	0.0	0.0	3.4	0.0708	1010.0	0.0013	1006.7	0.0102	1010.5	0.0000	0.15	0.00			98	
7/30/2010	14:00	4.4	0.0917	0.0	0.0	3.4	0.0708	1009.9	-0.0013	1006.7	0.0000	1010.5	0.0000	0.16		-0.01		105	
7/30/2010	14:30	4.4	0.0917	0.0	0.0	3.4	0.0708	1009.9	0.0000	1006.7	0.0000	1010.8	0.0248	0.14	0.02			88	
7/30/2010	15:00	4.3	0.0896	0.0	0.0	3.4	0.0708	1009.9	0.0000	1006.7	0.0000	1011.3	0.0414	0.12	0.04			76	
7/30/2010	15:30	4.4	0.0917	0.0	0.0	3.4	0.0708	1009.8	-0.0013	1006.7	0.0000	1011.4	0.0083	0.16	0.00			99	
7/30/2010	16:00	4.4	0.0917	0.0	0.0	3.4	0.0708	1009.9	0.0013	1006.7	0.0000	1011.6	0.0166	0.14	0.01			92	
7/30/2010	16:30	4.4	0.0917	0.0	0.0	3.4	0.0708	1009.9	0.0000	1006.7	0.0000	1012.0	0.0331	0.13	0.03			83	
7/30/2010	17:00	4.0	0.0833	0.0	0.0	3.4	0.0708	1009.9	0.0000	1006.7	0.0000	1012.2	0.0166	0.14	0.02			88	
7/30/2010	17:30	4.1	0.0854	0.0	0.0	3.4	0.0708	1009.9	0.0000	1006.7	0.0000	1012.3	0.0083	0.15	0.01			95	
7/30/2010	18:00	4.1	0.0854	0.0	0.0	3.4	0.0708	1009.8	-0.0013	1006.7	0.0000	1012.2	-0.0083	0.17		-0.01		106	
7/30/2010	18:30	4.1	0.0854	0.0	0.0	3.4	0.0708	1009.9	0.0013	1006.7	0.0000	1012.3	0.0083	0.15	0.01			94	
7/30/2010	19:00	4.1	0.0854	0.0	0.0	3.4	0.0708	1009.8	-0.0013	1006.7	0.0000	1012.5	0.0166	0.14	0.02			90	
7/30/2010	19:30	4.1	0.0854	0.0	0.0	3.4	0.0708	1009.8	0.0000	1006.7	0.0000	1012.6	0.0083	0.15	0.01			95	
7/30/2010	20:00	4.1	0.0854	0.0	0.0	3.4	0.0708	1011.0	0.0158	1006.7	0.0000	1012.5	-0.0083	0.15	0.01			95	
7/30/2010	20:30	4.1	0.0854	0.0	0.0	3.4	0.0708	1011.9	0.0118	1006.8	0.0025	1012.5	0.0000	0.14	0.01			91	
7/30/2010	21:00	4.2	0.0875	0.0	0.0	3.4	0.0708	1012.4	0.0066	1007.1	0.0076	1012.3	-0.0166	0.16	0.00			103	
7/30/2010	21:30	4.2	0.0875	0.0	0.0	3.4	0.0708	1012.5	0.0013	1007.9	0.0203	1012.2	-0.0083	0.14	0.01			93	
7/30/2010	22:00	4.3	0.0896	0.0	0.0	3.4	0.0708	1012.8	0.0039	1008.7	0.0203	1012.1	-0.0083	0.14	0.01			92	
7/30/2010	22:30	4.3	0.0896	0.0	0.0	3.4	0.0708	1013.1	0.0039	1009.3	0.0153	1012.4	0.0248	0.12	0.04			74	
7/30/2010	23:00	4.3	0.0896	0.0	0.0	3.4	0.0708	1013.3	0.0026	1010.0	0.0178	1012.6	0.0166	0.12	0.03			79	
7/30/2010	23:30	3.8	0.0792	0.0	0.0	3.4	0.0708	1013.4	0.0013	1010.5	0.0127	1012.9	0.0248	0.11	0.05			71	
														0.16	0.50	-0.50	6.7	102	7.51


City of Lawrence, Kansas
7-30-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

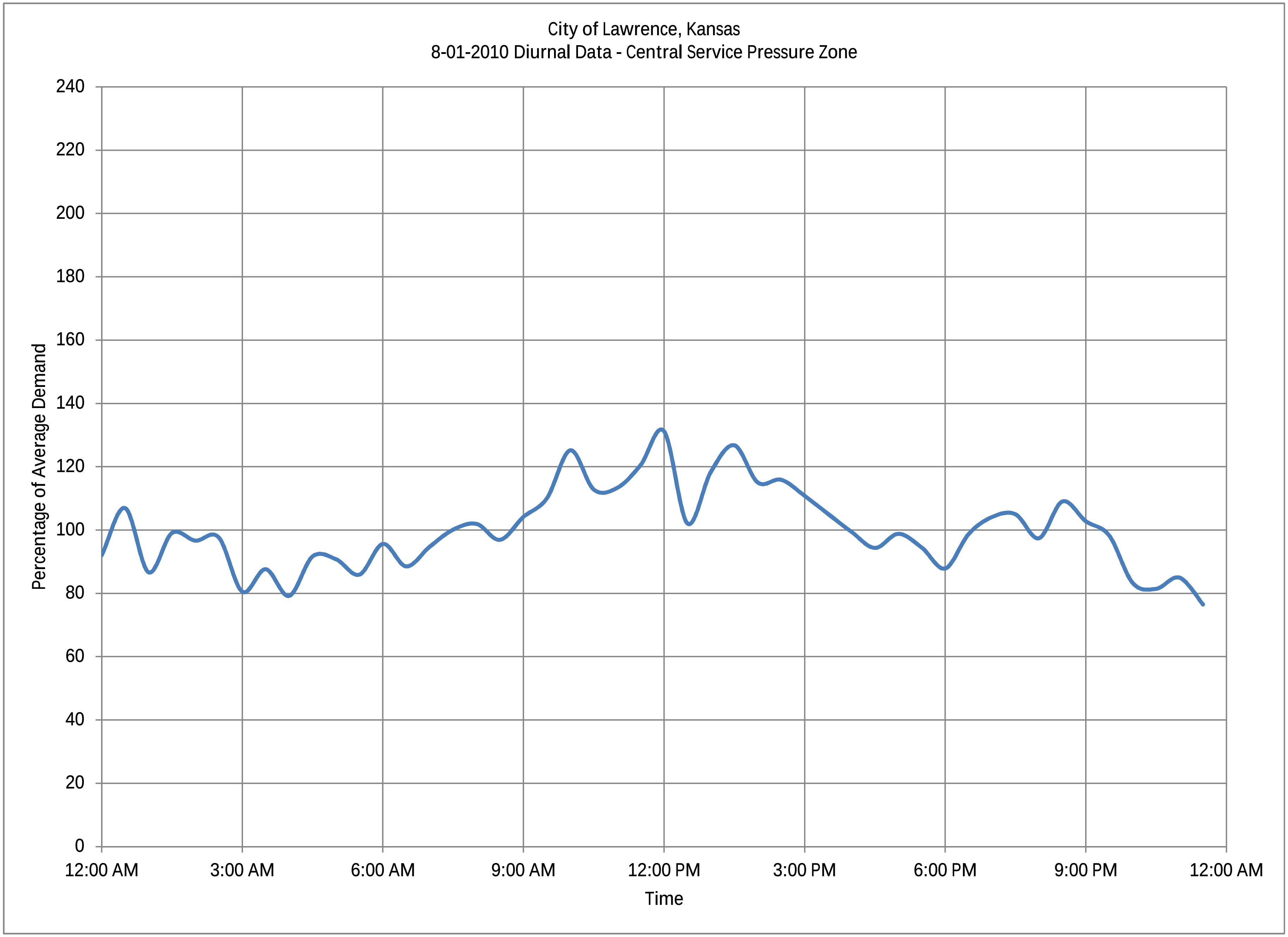
City of Lawrence, Kansas - 2011 Water Master Plan
July 31, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
7/31/2010	0:00	3.7	0.0771	0.0	0.0	3.4	0.0708	1013.7	0.0000	1011.0	0.0000	1013.1	0.0000	0.15	0.00			102	
7/31/2010	0:30	3.7	0.0771	0.0	0.0	3.4	0.0708	1013.9	0.0026	1011.4	0.0102	1013.2	0.0083	0.13	0.02			88	
7/31/2010	1:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1014.1	0.0026	1011.9	0.0127	1013.7	0.0414	0.08	0.06			56	
7/31/2010	1:30	3.2	0.0667	0.0	0.0	3.4	0.0708	1014.1	0.0000	1012.0	0.0025	1014.0	0.0248	0.11	0.03			76	
7/31/2010	2:00	2.9	0.0604	0.0	0.0	3.4	0.0708	1014.1	0.0000	1012.0	0.0000	1014.0	0.0000	0.13	0.01			91	
7/31/2010	2:30	2.7	0.0563	0.0	0.0	3.3	0.0688	1014.0	-0.0013	1012.0	0.0000	1014.3	0.0248	0.10	0.04			70	
7/31/2010	3:00	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.1	0.0013	1012.0	0.0000	1014.6	0.0248	0.10	0.04			70	
7/31/2010	3:30	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1014.9	0.0248	0.10	0.04			71	
7/31/2010	4:00	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1015.1	0.0166	0.11	0.03			77	
7/31/2010	4:30	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.0	-0.0013	1012.0	0.0000	1015.3	0.0166	0.11	0.03			77	
7/31/2010	5:00	2.9	0.0604	0.0	0.0	3.3	0.0688	1014.1	0.0013	1012.0	0.0000	1015.4	0.0083	0.12	0.02			83	
7/31/2010	5:30	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1015.5	0.0083	0.12	0.03			82	
7/31/2010	6:00	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.2	0.0013	1011.9	0.0000	1015.5	0.0000	0.13	0.02			87	
7/31/2010	6:30	2.9	0.0604	0.0	0.0	3.3	0.0688	1014.2	0.0000	1010.6	0.0000	1015.4	-0.0083	0.14	0.01			95	
7/31/2010	7:00	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.1	-0.0013	1009.0	0.0000	1015.3	-0.0083	0.14	0.01			95	
7/31/2010	7:30	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.2	0.0013	1007.4	0.0000	1015.3	0.0000	0.13	0.02			87	
7/31/2010	8:00	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.2	0.0000	1005.8	0.0000	1015.2	-0.0083	0.14	0.01			94	
7/31/2010	8:30	2.8	0.0583	0.0	0.0	3.3	0.0688	1014.2	0.0000	1004.3	0.0000	1014.8	-0.0331	0.16		-0.02		111	
7/31/2010	9:00	2.9	0.0604	0.0	0.0	3.3	0.0688	1014.2	0.0000	1002.7	0.0011	1014.5	-0.0248	0.16		-0.01		107	
7/31/2010	9:30	4.3	0.0896	0.0	0.0	3.3	0.0688	1014.2	0.0000	1002.2	0.0000	1014.2	-0.0248	0.18		-0.04		127	
7/31/2010	10:00	4.3	0.0896	0.0	0.0	3.4	0.0708	1014.0	-0.0026	1001.7	0.0000	1013.7	-0.0414	0.20		-0.06		142	
7/31/2010	10:30	4.3	0.0896	0.0	0.0	3.4	0.0708	1013.7	-0.0039	1001.4	0.0000	1013.4	-0.0248	0.19		-0.04		131	
7/31/2010	11:00	4.1	0.0854	0.0	0.0	3.4	0.0708	1013.6	-0.0013	1000.9	0.0000	1013.2	-0.0166	0.17		-0.03		121	
7/31/2010	11:30	3.3	0.0688	0.0	0.0	3.4	0.0708	1013.6	0.0000	1000.9	0.0000	1013.2	0.0000	0.14	0.00			97	
7/31/2010	12:00	3.4	0.0708	0.0	0.0	3.4	0.0708	1013.5	-0.0013	1000.9	0.0000	1013.0	-0.0166	0.16		-0.02		111	
7/31/2010	12:30	5.1	0.1063	0.0	0.0	3.4	0.0708	1013.5	0.0000	1001.1	0.0051	1012.7	-0.0248	0.20		-0.05		136	
7/31/2010	13:00	5.1	0.1063	0.0	0.0	2.4	0.0500	1012.9	-0.0079	1002.4	0.0331	1012.2	-0.0414	0.17		-0.03		119	
7/31/2010	13:30	5.1	0.1063	0.0	0.0	2.4	0.0500	1012.7	-0.0026	1003.6	0.0305	1011.9	-0.0248	0.15		-0.01		106	
7/31/2010	14:00	5.0	0.1042	0.0	0.0	2.4	0.0500	1012.5	-0.0026	1004.7	0.0280	1011.7	-0.0166	0.15	0.00			101	
7/31/2010	14:30	4.6	0.0958	0.0	0.0	2.4	0.0500	1012.1	-0.0053	1005.6	0.0229	1011.2	-0.0414	0.17		-0.03		117	
7/31/2010	15:00	4.6	0.0958	0.0	0.0	3.4	0.0708	1011.8	-0.0039	1006.5	0.0229	1011.1	-0.0083	0.16		-0.01		108	
7/31/2010	15:30	4.5	0.0938	0.0	0.0	3.4	0.0708	1011.8	0.0000	1007.2	0.0178	1011.1	0.0000	0.15	0.00			102	
7/31/2010	16:00	4.9	0.1021	0.0	0.0	3.4	0.0708	1011.8	0.0000	1007.2	0.0000	1011.5	0.0331	0.14	0.00			97	
7/31/2010	16:30	4.8	0.1000	0.0	0.0	3.4	0.0708	1011.7	-0.0013	1007.2	0.0000	1011.7	0.0166	0.16		-0.01		108	
7/31/2010	17:00	4.8	0.1000	0.0	0.0	3.4	0.0708	1011.8	0.0013	1007.2	0.0000	1012.1	0.0331	0.14	0.01			95	
7/31/2010	17:30	4.8	0.1000	0.0	0.0	3.4	0.0708	1011.9	0.0013	1007.2	0.0000	1012.3	0.0166	0.15		-0.01		106	
7/31/2010	18:00	5.2	0.1083	0.0	0.0	3.4	0.0708	1011.7	-0.0026	1007.2	0.0000	1012.6	0.0248	0.16		-0.01		109	
7/31/2010	18:30	5.2	0.1083	0.0	0.0	3.4	0.0708	1012.2	0.0066	1007.2	0.0000	1013.0	0.0331	0.14	0.00			97	
7/31/2010	19:00	5.2	0.1083	0.0	0.0	3.4	0.0708	1013.2	0.0132	1007.2	0.0000	1013.3	0.0248	0.14	0.00			98	
7/31/2010	19:30	5.3	0.1104	0.0	0.0	3.4	0.0708	1013.9	0.0092	1007.6	0.0102	1013.6	0.0248	0.14	0.01			95	
7/31/2010	20:00	5.3	0.1104	0.0	0.0	3.4	0.0708	1014.1	0.0026	1008.6	0.0254	1013.7	0.0083	0.14	0.00			100	
7/31/2010	20:30	4.2	0.0875	0.0	0.0	3.4	0.0708	1013.6	-0.0066	1009.4	0.0203	1013.3	-0.0331	0.18		-0.03		123	
7/31/2010	21:00	4.2	0.0875	0.0	0.0	3.4	0.0708	1013.3	-0.0039	1010.0	0.0153	1013.1	-0.0166	0.16		-0.02		113	
7/31/2010	21:30	4.2	0.0875	0.0	0.0	3.4	0.0708	1013.1	-0.0026	1010.6	0.0153	1012.9	-0.0166	0.16		-0.02		112	
7/31/2010	22:00	4.2	0.0875	0.0	0.0	3.4	0.0708	1013.0	-0.0013	1011.1	0.0127	1013.0	0.0083	0.14	0.01			96	
7/31/2010	22:30	4.2	0.0875	0.0	0.0	3.4	0.0708	1013.0	0.0000	1011.6	0.0127	1012.8	-0.0166	0.16		-0.02		112	
7/31/2010	23:00	3.4	0.0708	0.0	0.0	3.4	0.0708	1012.8	-0.0026	1011.8	0.0051	1012.8	0.0000	0.14	0.01			96	
7/31/2010	23:30	3.4	0.0708	0.0	0.0	3.4	0.0708	1012.7	-0.0013	1011.8	0.0000	1012.7	-0.0083	0.15		-0.01		105	
														0.14	0.47	-0.47	6.8	92	6.93


City of Lawrence, Kansas
7-31-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

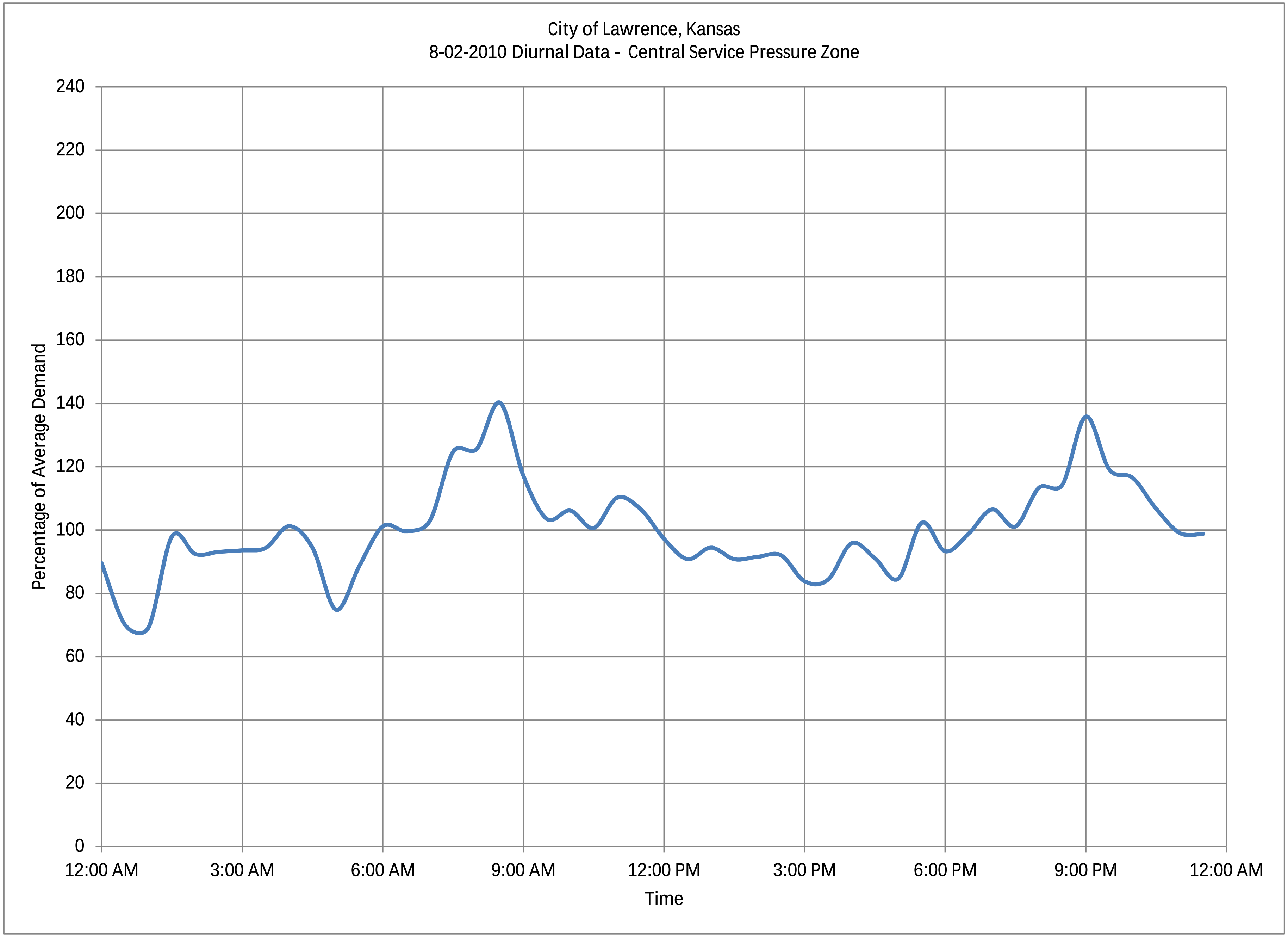
City of Lawrence, Kansas - 2011 Water Master Plan
August 1, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
8/1/2010	0:00	3.4	0.0708	0.0	0.0	3.4	0.0708	1012.6	0.0000	1011.8	0.0000	1012.5	0.0000	0.14	0.01			92	
8/1/2010	0:30	3.4	0.0708	0.0	0.0	3.4	0.0708	1012.5	-0.0013	1011.6	-0.0051	1012.3	-0.0166	0.16		-0.01		107	
8/1/2010	1:00	3.4	0.0708	0.0	0.0	3.4	0.0708	1012.5	0.0000	1011.6	0.0000	1012.4	0.0083	0.13	0.02			87	
8/1/2010	1:30	3.4	0.0708	0.0	0.0	3.4	0.0708	1012.5	0.0000	1011.5	-0.0025	1012.3	-0.0083	0.15	0.00			99	
8/1/2010	2:00	3.8	0.0792	0.0	0.0	3.4	0.0708	1012.4	-0.0013	1011.6	0.0025	1012.3	0.0000	0.15	0.01			97	
8/1/2010	2:30	4.7	0.0979	0.0	0.0	3.4	0.0708	1012.4	0.0000	1012.0	0.0102	1012.4	0.0083	0.15	0.00			98	
8/1/2010	3:00	4.6	0.0958	0.0	0.0	3.4	0.0708	1012.5	0.0013	1012.0	0.0000	1012.9	0.0414	0.12	0.03			81	
8/1/2010	3:30	4.6	0.0958	0.0	0.0	3.4	0.0708	1012.4	-0.0013	1012.0	0.0000	1013.3	0.0331	0.13	0.02			88	
8/1/2010	4:00	4.6	0.0958	0.0	0.0	3.3	0.0688	1012.5	0.0013	1012.0	0.0000	1013.8	0.0414	0.12	0.03			79	
8/1/2010	4:30	4.6	0.0958	0.0	0.0	3.3	0.0688	1012.4	-0.0013	1012.0	0.0000	1014.1	0.0248	0.14	0.01			92	
8/1/2010	5:00	4.5	0.0938	0.0	0.0	3.4	0.0708	1012.4	0.0000	1012.0	0.0000	1014.4	0.0248	0.14	0.01			91	
8/1/2010	5:30	4.6	0.0958	0.0	0.0	3.4	0.0708	1012.5	0.0013	1012.0	0.0000	1014.8	0.0331	0.13	0.02			86	
8/1/2010	6:00	3.7	0.0771	0.0	0.0	3.3	0.0688	1012.4	-0.0013	1011.7	0.0000	1014.8	0.0000	0.15	0.01			96	
8/1/2010	6:30	3.7	0.0771	0.0	0.0	3.3	0.0688	1012.5	0.0013	1010.5	0.0000	1014.9	0.0083	0.14	0.02			89	
8/1/2010	7:00	3.7	0.0771	0.0	0.0	3.3	0.0688	1012.5	0.0000	1009.3	0.0000	1014.9	0.0000	0.15	0.01			95	
8/1/2010	7:30	3.7	0.0771	0.0	0.0	3.3	0.0688	1012.5	0.0000	1008.1	0.0000	1014.8	-0.0083	0.15	0.00			100	
8/1/2010	8:00	3.5	0.0729	0.0	0.0	3.3	0.0688	1012.6	0.0013	1006.9	0.0000	1014.6	-0.0166	0.16	0.00			102	
8/1/2010	8:30	3.4	0.0708	0.0	0.0	3.3	0.0688	1012.5	-0.0013	1005.2	0.0000	1014.5	-0.0083	0.15	0.00			97	
8/1/2010	9:00	3.5	0.0729	0.0	0.0	3.4	0.0708	1012.5	0.0000	1003.4	0.0000	1014.3	-0.0166	0.16		-0.01		104	
8/1/2010	9:30	3.6	0.0750	0.0	0.0	3.4	0.0708	1012.6	0.0013	1001.6	0.0000	1014.0	-0.0248	0.17		-0.02		110	
8/1/2010	10:00	3.8	0.0792	0.0	0.0	3.4	0.0708	1012.5	-0.0013	999.9	0.0000	1013.5	-0.0414	0.19		-0.04		125	
8/1/2010	10:30	3.7	0.0771	0.0	0.0	3.4	0.0708	1012.0	-0.0066	1001.1	0.0305	1012.9	-0.0497	0.17		-0.02		113	
8/1/2010	11:00	3.8	0.0792	0.0	0.0	3.4	0.0708	1011.6	-0.0053	1002.3	0.0305	1012.3	-0.0497	0.17		-0.02		113	
8/1/2010	11:30	3.9	0.0813	0.0	0.0	3.4	0.0708	1010.9	-0.0092	1003.3	0.0254	1011.7	-0.0497	0.19		-0.03		121	
8/1/2010	12:00	3.9	0.0813	0.0	0.0	3.4	0.0708	1010.4	-0.0066	1004.2	0.0229	1010.9	-0.0662	0.20		-0.05		131	
8/1/2010	12:30	3.8	0.0792	0.0	0.0	3.4	0.0708	1010.2	-0.0026	1005.0	0.0203	1010.6	-0.0248	0.16	0.00			102	
8/1/2010	13:00	3.9	0.0813	0.0	0.0	3.4	0.0708	1009.7	-0.0066	1005.7	0.0178	1010.1	-0.0414	0.18		-0.03		118	
8/1/2010	13:30	5.9	0.1229	0.0	0.0	3.4	0.0708	1009.5	-0.0026	1006.4	0.0178	1009.9	-0.0166	0.20		-0.04		127	
8/1/2010	14:00	5.8	0.1208	0.0	0.0	3.4	0.0708	1009.5	0.0000	1007.3	0.0229	1009.8	-0.0083	0.18		-0.02		115	
8/1/2010	14:30	5.8	0.1208	0.0	0.0	3.4	0.0708	1009.4	-0.0013	1008.2	0.0229	1009.7	-0.0083	0.18		-0.02		116	
8/1/2010	15:00	5.7	0.1188	0.0	0.0	3.4	0.0708	1009.3	-0.0013	1009.0	0.0203	1009.7	0.0000	0.17		-0.02		111	
8/1/2010	15:30	5.7	0.1188	0.0	0.0	2.4	0.0500	1009.3	0.0000	1009.6	0.0153	1009.6	-0.0083	0.16		-0.01		105	
8/1/2010	16:00	5.8	0.1208	0.0	0.0	2.4	0.0500	1009.3	0.0000	1010.3	0.0178	1009.6	0.0000	0.15	0.00			99	
8/1/2010	16:30	5.7	0.1188	0.0	0.0	2.4	0.0500	1009.3	0.0000	1010.9	0.0153	1009.7	0.0083	0.15	0.01			94	
8/1/2010	17:00	5.7	0.1188	0.0	0.0	2.4	0.0500	1009.6	0.0039	1011.4	0.0127	1009.7	0.0000	0.15	0.00			99	
8/1/2010	17:30	5.7	0.1188	0.0	0.0	3.4	0.0708	1010.3	0.0092	1011.8	0.0102	1010.0	0.0248	0.15	0.01			94	
8/1/2010	18:00	5.7	0.1188	0.0	0.0	3.4	0.0708	1010.9	0.0079	1012.0	0.0051	1010.5	0.0414	0.14	0.02			88	
8/1/2010	18:30	5.8	0.1208	0.0	0.0	3.4	0.0708	1011.4	0.0066	1012.0	0.0000	1010.9	0.0331	0.15	0.00			99	
8/1/2010	19:00	5.8	0.1208	0.0	0.0	3.4	0.0708	1011.9	0.0066	1012.0	0.0000	1011.2	0.0248	0.16		-0.01		104	
8/1/2010	19:30	5.8	0.1208	0.0	0.0	3.4	0.0708	1012.3	0.0053	1012.0	0.0000	1011.5	0.0248	0.16		-0.01		105	
8/1/2010	20:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1012.8	0.0066	1012.0	0.0000	1012.0	0.0414	0.15	0.00			97	
8/1/2010	20:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1013.2	0.0053	1012.0	0.0000	1012.3	0.0248	0.17		-0.01		109	
8/1/2010	21:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1013.7	0.0066	1012.0	0.0000	1012.7	0.0331	0.16	0.00			103	
8/1/2010	21:30	5.8	0.1208	0.0	0.0	3.3	0.0688	1014.1	0.0053	1012.0	0.0000	1013.1	0.0331	0.15	0.00			98	
8/1/2010	22:00	5.3	0.1104	0.0	0.0	3.3	0.0688	1014.2	0.0013	1012.0	0.0000	1013.7	0.0497	0.13	0.03			83	
8/1/2010	22:30	5.0	0.1042	0.0	0.0	3.4	0.0708	1014.2	0.0000	1012.0	0.0000	1014.3	0.0497	0.13	0.03			81	
8/1/2010	23:00	4.9	0.1021	0.0	0.0	3.3	0.0688	1014.1	-0.0013	1012.0	0.0000	1014.8	0.0414	0.13	0.02			85	
8/1/2010	23:30	4.4	0.0917	0.0	0.0	3.3	0.0688	1014.2	0.0013	1012.0	0.0000	1015.3	0.0414	0.12	0.04			76	
														0.15	0.36	-0.36	4.9	90	7.39


City of Lawrence, Kansas
8-01-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

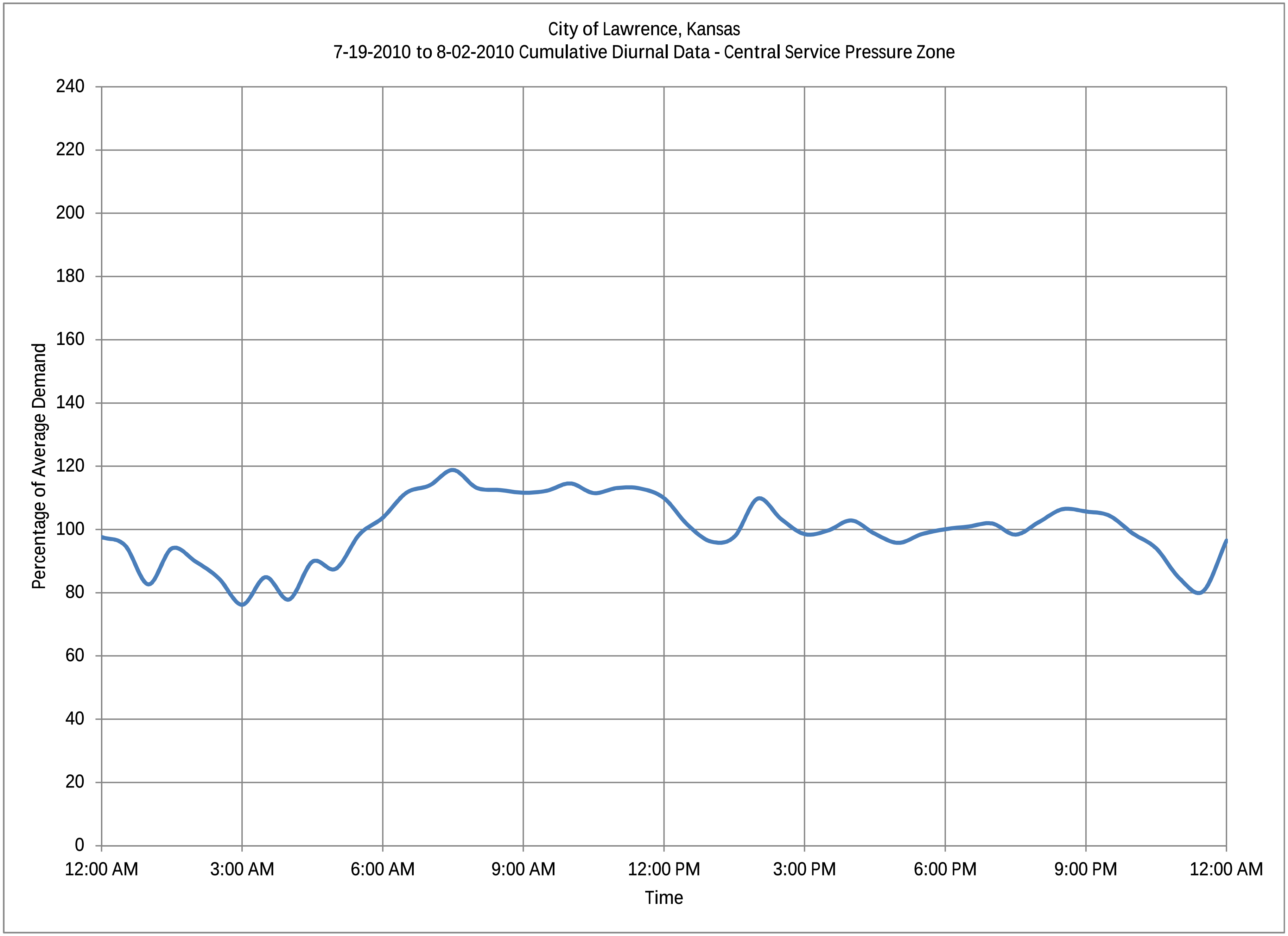
City of Lawrence, Kansas - 2011 Water Master Plan
August 2, 2010 Diurnal Data
Central Service Pressure Zone

		Clinton Contribution				Kaw Contribution		Harper		Kasold		Oread		Total	Equalization Storage		Equalization		Total
		HSPS 2		HSPS 1		HSPS		Tank		Reservoir		Reservoir		Demand	Fill	Draft	Factor	Diurnal	Daily Demand
Date	Time	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Flow (MGD)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	Level (ft)	Volume (MG)	(MG)	(MG)	(MG)	(%)	(%)	(MGD)
8/2/2010	0:00	4.0	0.0833	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1015.9	0.0000	0.15	0.02			90	
8/2/2010	0:30	4.0	0.0833	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.0	0.0000	1016.3	0.0331	0.12	0.05			70	
8/2/2010	1:00	3.6	0.0750	0.0	0.0	3.3	0.0688	1014.2	0.0013	1012.0	0.0000	1016.6	0.0248	0.12	0.05			69	
8/2/2010	1:30	3.5	0.0729	0.0	0.0	3.3	0.0688	1014.2	0.0000	1012.0	0.0000	1016.3	-0.0248	0.17	0.00			98	
8/2/2010	2:00	3.5	0.0729	0.0	0.0	3.3	0.0688	1014.1	-0.0013	1012.1	0.0025	1016.1	-0.0166	0.16	0.01			92	
8/2/2010	2:30	3.5	0.0729	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.1	0.0000	1015.9	-0.0166	0.16	0.01			93	
8/2/2010	3:00	3.6	0.0750	0.0	0.0	3.3	0.0688	1014.2	0.0013	1012.1	0.0000	1015.7	-0.0166	0.16	0.01			94	
8/2/2010	3:30	3.6	0.0750	0.0	0.0	3.3	0.0688	1014.2	0.0000	1012.1	0.0000	1015.5	-0.0166	0.16	0.01			94	
8/2/2010	4:00	3.7	0.0771	0.0	0.0	3.3	0.0688	1014.1	-0.0013	1012.1	0.0000	1015.2	-0.0248	0.17	0.00			101	
8/2/2010	4:30	3.5	0.0729	0.0	0.0	3.4	0.0708	1014.1	0.0000	1012.1	0.0000	1015	-0.0166	0.16	0.01			94	
8/2/2010	5:00	3.2	0.0667	0.0	0.0	3.3	0.0688	1014.1	0.0000	1012.1	0.0000	1015.1	0.0083	0.13	0.04			75	
8/2/2010	5:30	3.2	0.0667	0.0	0.0	3.3	0.0688	1014.2	0.0013	1012.1	0.0000	1014.9	-0.0166	0.15	0.02			89	
8/2/2010	6:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1014.1	-0.0013	1012.1	0.0000	1014.5	-0.0331	0.17	0.00			101	
8/2/2010	6:30	3.2	0.0667	0.0	0.0	3.4	0.0708	1014.2	0.0013	1011.7	0.0000	1014.1	-0.0331	0.17	0.00			100	
8/2/2010	7:00	3.1	0.0646	0.0	0.0	3.3	0.0688	1014.2	0.0000	1009.8	0.0000	1013.6	-0.0414	0.17	0.00			103	
8/2/2010	7:30	3.2	0.0667	0.0	0.0	3.4	0.0708	1013.6	-0.0079	1007.9	0.0004	1012.8	-0.0662	0.21		-0.04		125	
8/2/2010	8:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1012.9	-0.0092	1006.0	0.0004	1012	-0.0662	0.21		-0.04		126	
8/2/2010	8:30	3.2	0.0667	0.0	0.0	3.4	0.0708	1012.4	-0.0066	1004.9	-0.0280	1011.2	-0.0662	0.24		-0.07		140	
8/2/2010	9:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1011.5	-0.0118	1004.9	0.0000	1010.6	-0.0497	0.20		-0.03		117	
8/2/2010	9:30	3.2	0.0667	0.0	0.0	3.4	0.0708	1011.1	-0.0053	1004.3	0.0000	1010.2	-0.0331	0.18		-0.01		104	
8/2/2010	10:00	3.3	0.0688	0.0	0.0	3.4	0.0708	1010.6	-0.0066	1002.7	0.0011	1009.8	-0.0331	0.18		-0.01		106	
8/2/2010	10:30	3.3	0.0688	0.0	0.0	3.4	0.0708	1010.1	-0.0066	1001.2	0.0000	1009.5	-0.0248	0.17	0.00			101	
8/2/2010	11:00	3.2	0.0667	0.0	0.0	3.4	0.0708	1009.7	-0.0053	1000.1	-0.0280	1009.3	-0.0166	0.19		-0.02		110	
8/2/2010	11:30	4.5	0.0938	0.0	0.0	3.4	0.0708	1009.7	0.0000	1000.1	0.0000	1009.1	-0.0166	0.18		-0.01		107	
8/2/2010	12:00	4.8	0.1000	0.0	0.0	3.4	0.0708	1009.5	-0.0026	1000.1	0.0000	1009.2	0.0083	0.17	0.00			97	
8/2/2010	12:30	4.8	0.1000	0.0	0.0	3.4	0.0708	1009.5	0.0000	1000.1	0.0000	1009.4	0.0166	0.15	0.02			91	
8/2/2010	13:00	4.7	0.0979	0.0	0.0	3.4	0.0708	1009.5	0.0000	1000.1	0.0000	1009.5	0.0083	0.16	0.01			94	
8/2/2010	13:30	4.8	0.1000	0.0	0.0	3.4	0.0708	1009.5	0.0000	1000.1	0.0000	1009.7	0.0166	0.15	0.02			91	
8/2/2010	14:00	4.8	0.1000	0.0	0.0	3.0	0.0625	1009.4	-0.0013	1000.1	0.0000	1009.8	0.0083	0.16	0.01			92	
8/2/2010	14:30	5.5	0.1146	0.0	0.0	2.4	0.0500	1009.4	0.0000	1000.1	0.0000	1009.9	0.0083	0.16	0.01			92	
8/2/2010	15:00	5.9	0.1229	0.0	0.0	2.4	0.0500	1009.4	0.0000	1001.3	0.0305	1009.9	0.0000	0.14	0.03			84	
8/2/2010	15:30	6.0	0.1250	0.0	0.0	2.4	0.0500	1009.3	-0.0013	1002.6	0.0331	1009.9	0.0000	0.14	0.03			84	
8/2/2010	16:00	6.0	0.1250	0.0	0.0	3.4	0.0708	1009.3	0.0000	1003.9	0.0331	1009.9	0.0000	0.16	0.01			96	
8/2/2010	16:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.2	-0.0013	1005.0	0.0280	1010.1	0.0166	0.15	0.02			91	
8/2/2010	17:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.3	0.0013	1006.1	0.0280	1010.4	0.0248	0.14	0.03			85	
8/2/2010	17:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.2	-0.0013	1007.1	0.0254	1010.4	0.0000	0.17	0.00			102	
8/2/2010	18:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.2	0.0000	1008.0	0.0229	1010.6	0.0166	0.16	0.01			93	
8/2/2010	18:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.3	0.0013	1008.8	0.0203	1010.7	0.0083	0.17	0.00			99	
8/2/2010	19:00	6.2	0.1292	0.0	0.0	3.4	0.0708	1009.2	-0.0013	1009.6	0.0203	1010.7	0.0000	0.18		-0.01		107	
8/2/2010	19:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.2	0.0000	1010.3	0.0178	1010.8	0.0083	0.17	0.00			101	
8/2/2010	20:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.7	0.0066	1010.9	0.0153	1010.6	-0.0166	0.19		-0.02		113	
8/2/2010	20:30	6.2	0.1292	0.0	0.0	3.4	0.0708	1009.8	0.0013	1011.4	0.0127	1010.5	-0.0083	0.19		-0.02		114	
8/2/2010	21:00	6.2	0.1292	0.0	0.0	3.4	0.0708	1009.2	-0.0079	1011.8	0.0102	1010.1	-0.0331	0.23		-0.06		136	
8/2/2010	21:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.1	-0.0013	1012.0	0.0051	1010	-0.0083	0.20		-0.03		119	
8/2/2010	22:00	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.1	0.0000	1012.0	0.0000	1010	0.0000	0.20		-0.03		116	
8/2/2010	22:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.1	0.0000	1012.0	0.0000	1010.2	0.0166	0.18		-0.01		107	
8/2/2010	23:00	6.0	0.1250	0.0	0.0	3.4	0.0708	1009.3	0.0026	1012.0	0.0000	1010.5	0.0248	0.17	0.00			99	
8/2/2010	23:30	6.1	0.1271	0.0	0.0	3.4	0.0708	1009.7	0.0053	1012.0	0.0000	1010.8	0.0248	0.17	0.00			99	
														0.17	0.42	-0.42	5.1	90	8.16


City of Lawrence, Kansas
8-02-2010 Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
Time

City of Lawrence, Kansas - 2011 Water Master Plan
Cummulative Diurnal Data
Central Service Pressure Zone

Time	Sum	Diurnal (%)
0:00	1463	98
0:30	1425	95
1:00	1240	83
1:30	1410	94
2:00	1259	90
2:30	1184	85
3:00	1143	76
3:30	1274	85
4:00	1168	78
4:30	1347	90
5:00	1314	88
5:30	1476	98
6:00	1556	104
6:30	1673	112
7:00	1709	114
7:30	1782	119
8:00	1698	113
8:30	1687	112
9:00	1674	112
9:30	1684	112
10:00	1718	115
10:30	1673	112
11:00	1697	113
11:30	1694	113
12:00	1649	110
12:30	1523	102
13:00	1443	96
13:30	1465	98
14:00	1646	110
14:30	1549	103
15:00	1478	99
15:30	1495	100
16:00	1543	103
16:30	1479	99
17:00	1436	96
17:30	1478	99
18:00	1501	100
18:30	1514	101
19:00	1528	102
19:30	1476	98
20:00	1535	102
20:30	1596	106
21:00	1585	106
21:30	1566	104
22:00	1481	99
22:30	1411	94
23:00	1268	85
23:30	1207	80
0:00	1447	96


City of Lawrence, Kansas
7-19-2010 to 8-02-2010 Cumulative Diurnal Data - Central Service Pressure Zone
Percentage of Average Demand
240
220
200
180
160
140
120
100
80
60
40
20
0
12:00 AM
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12:00 AM
Time

Appendix G
Insurance Services Office Report for Lawrence

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

PUBLIC PROTECTION CLASSIFICATION

IMPROVEMENT STATEMENTS
FOR
Lawrence
Douglas County, KS

Prepared by
INSURANCE SERVICES OFFICE, INC.
111 North Canal St., Ste 950, Chicago, IL 60606
312-930-0070 FAX 800-711-6431

The following statements are based upon the criteria contained in our Fire Suppression Rating Schedule and upon conditions in Lawrence, KS during October, 1982. They indicate the performance needed to receive full credit for the specific item in the Schedule, and the quantity you have provided. Partial improvement will result in receiving a partial increase in the credit. These statements relate only to the fire insurance classification of your . They are not for property loss prevention or life safety purposes and no life safety or property loss prevention recommendations are made.

RECEIVING AND HANDLING FIRE ALARMS

Credit For Telephone Service (Item 414).

Actual = 0.56%; Maximum = 2.00%

For maximum credit in the Schedule, there should be 4 incoming telephone lines reserved for receiving notification of fires (and other emergency calls). You have 0 lines reserved.

For maximum credit in the Schedule, there should be 4 incoming lines reserved for notification of fires (and other emergency calls) plus 2 additional lines for conducting other fire department business. Since only the emergency number is listed in the telephone directory, 1(one) line has been deducted from the number of creditable reserved emergency lines.

For maximum credit in the Schedule, emergency calls should progress to the business number.

For maximum credit in the Schedule, both the number to report a fire and the fire department business number should be listed under "Fire Department" in the white pages directory (or government section of the white pages). Your fire number is not listed and your business number is not listed under "Fire Department".

For maximum credit in the Schedule, both the number to report a fire and the fire department business number should be listed under the name of the in the white pages directory (or government section of the white pages). Your fire number is not listed and your business number is not listed under the name of the .

For maximum credit in the Schedule, the individual telephone numbers of each fire station should not be listed in the telephone directory.

Credit For Operators (Item 422).

Actual = 3.00%; Maximum = 3.00%

Credit For Dispatch Circuits (Item 432).

Actual = 5.00%; Maximum = 5.00%

Total credit for Receiving and Handling Fire Alarms (Item 440)

Actual = 8.56%; Maximum = 10.00%

FIRE DEPARTMENT

Credit For Engine Companies (Item 513).

Actual = 9.72%; Maximum = 10.00%

For maximum credit in the Schedule, 4 engine companies are needed in your .
These are calculated as follows:

2 for the Basic Fire Flow of 2500 gpm.

2 additional for the method of operation.

Additionally, to improve the Credit for Distribution of Companies (see Item 561), 0 additional engine company location are needed for your .

You have 4 engine companies in service.
These are calculated as follows:

98 percent for Engine 1 because of insufficient equipment.

98 percent for Engine 2 because of insufficient equipment.
92 percent for Engine 3 because of insufficient equipment.
98 percent for Engine 4 because of insufficient equipment.

Credit For Reserve Pumpers (Item 523).

Actual = 0.93%; Maximum = 1.00%

For maximum credit in the Schedule, 1 fully-equipped reserve pumper is needed. You have 1 reserve pumper.
This is calculated as follows:

82 percent for Engine 5 because of insufficient equipment.
56 percent for Engine 6 because of insufficient equipment.
Additionally Engine is lacking: a minimum of 1200' of hose carried (of which 800' needs to be 2½ in. or larger).

Credit For Pump Capacity (Item 532).

Actual = 5.00%; Maximum = 5.00%

Credit For Ladder And Service Companies (Item 549).

Actual = 4.65%; Maximum = 5.00%

For maximum credit in the Schedule, 1 ladder company is needed in your .

This is calculated as follows:

1 ladder company due to method of operation.

You have 1 ladder company.
This is calculated as follows:

92 percent for Ladder1 because of insufficient equipment and insufficient aerial device testing.

Credit For Reserve Ladder And Service Companies (Item 553).

Actual = 0.89%; Maximum = 1.00%

For maximum credit in the Schedule, 1 fully-equipped reserve ladder truck is needed.
You have 1 reserve ladder truck.
This is calculated as follows:

88 percent for Ladder 2 because of insufficient equipment, insufficient aerial device testing and insufficient aerial device length.

Credit For Distribution (Item 561).

Actual = 3.01%; Maximum = 4.00%

For maximum credit in the Schedule, all sections of the with hydrant protection should be within 1½ miles of a fully-equipped engine company and 2½ miles of a fully-equipped ladder, service, engine-ladder or engine-service company. The distance to be measured along all-weather roads.

Credit For Company Personnel (Item 571).

Actual = 9.50%; Maximum = 15.00%

An increase in the on-duty company personnel by one person will increase the fire department credit by 0.5.

Credit For Training (Item 581).

Actual = 6.57%; Maximum = 9.00%

For maximum credit in the Schedule, the training program should be improved. You received 73 percent credit for the current training program and the use of facilities.

For maximum credit in the Schedule, pre-fire planning inspections of each commercial, industrial, institutional and other similar-type building should be made twice a year by company members. Records of the inspections should include complete and up-to-date notes and sketches.

Total credit for Fire Department (Item 590)

Actual = 40.27%; Maximum = 50.00%

WATER SUPPLY

Credit For Supply System (Item 616).

Actual = 32.02%; Maximum = 35.00%

For maximum credit in the Schedule, the needed fire flows should be available at each location in the . Needed fire flows of 2500 gpm and less should be available for 2 hours, 3000 and 3500 gpm for 3 hours and all others for 4 hours. See the attached table for an evaluation of fire flow tests made at representative locations in your .

All AWWA standard hydrants within 1000 feet of a building, measured as hose can be laid by apparatus, are credited; 1000 gpm for hydrants within 300 feet; 670 gpm for 301 to 600 feet; and

250 gpm for 601 to 1000 feet. Credit is reduced when hydrants lack a pumper outlet, and is further reduced when they have only a single 2½-inch outlet.

Credit For Hydrants (Item 621).

Actual = 1.92%; Maximum = 2.00%

For maximum credit in the Schedule, all hydrants should: have a pumper outlet.

Credit For Inspection and Condition of Hydrants (Item 631).

Actual = 2.32%; Maximum = 3.00%

For maximum credit in the Schedule, all hydrants should be inspected twice a year, the inspection should include operation and a test at domestic pressure. Records should be kept of the inspections. Hydrants should be conspicuous, well located for use by a pumper, and in good condition.

Total credit for Water Supply (Item 640)

Actual = 36.26%; Maximum = 40.00%

FIRE FLOW TESTS

Lawrence, KS

Tests witnessed on October 14, 1982

Test No.	Needed Fire Flow† gpm	Limited By Supply Works, gpm	Limited by Distribution Mains (flow tests), gpm	Limited By Hydrant Spacing, gpm
1	2250			
2	2500			
3	2500			
4	2250	1771	550	
5	1000			
6	3000			
7†	4000			
7A	2000			
8	2000			
9	2500		1900	
10	2500			
11	1500			
12	1000			
13	2500		2200	
14	2000			
15	1000			

†Needed fire flows exceeding 3500 gpm are not considered in Item 616 (CSS) Credit for System Supply

INSURANCE SERVICES OFFICE, INC.

CLASSIFICATION DETAILS

Graded Area: Lawrence
County: Douglas State: KS
Date Surveyed: October, 1982 Total Credit: 83.07 Class: 2 Pop.: 52738

RECEIVING AND HANDLING FIRE ALARMS

This section of the Fire Suppression Rating Schedule reviews the facilities provided for the general public to report fires, and for the operator on duty at the communication center to dispatch fire department companies to the fires.

	Credit	
	Actual	Maximum
1. Credit for Telephone Service (Item 414)		
This item reviews the facilities provided for the public to report fires, including the listing of fire and business numbers in the telephone directory.	0.56	2.00
2. Credit for Operators (Item 422)		
This item reviews the number of operators on-duty at the communication center to handle fire calls.	3.00	3.00
3. Credit for Dispatch Circuits (Item 432)		
This item reviews the dispatch circuit facilities used to transmit alarms to fire department members.	5.00	5.00
4. Total Credit for Receiving and Handling Fire Alarms:	8.56	10.00
Relative Classification for Receiving and Handling Fire Alarms:	2	

CLASSIFICATION DETAILS

Graded Area: Lawrence
County: Douglas State: KS
Date Surveyed: October, 1982 Total Credit: 83.07 Class: 2 Pop.: 52738

FIRE DEPARTMENT

This section of the Fire Suppression Rating Schedule reviews the engine and ladder-service companies, equipment carried, response to fires, training and available fire fighters.

	Credit	
	Actual	Maximum
1. Credit for Engine Companies (Item 513)		
This item reviews the number of engine companies and the hose equipment carried.	9.72	10.00
2. Credit for Reserve Pumpers (Item 523)		
This item reviews the number of reserve pumpers, their pump capacity and the hose equipment carried on each.	0.93	1.00
3. Credit for Pump Capacity (Item 532)		
This item reviews the total available pump capacity.	5.00	5.00
4. Credit for Ladder-Service Companies (Item 549)		
This item reviews the number of ladder and service companies and the equipment carried.	4.65	5.00
5. Credit for Reserve Ladder-Service Companies (Item 553)		
This item reviews the number of reserve ladder and service trucks, and the equipment carried.	0.89	1.00

CLASSIFICATION DETAILS

Graded Area: Lawrence
County: Douglas
State: KS
Date Surveyed: October, 1982
Total Credit: 83.07 Class: 2
Pop.: 52738

FIRE DEPARTMENT
(continued)

	Credit	
	Actual	Maximum
6. Credit for Distribution (Item 561)		
This item reviews the percent of the built-upon area of the city which has an adequately-equipped, responding first-due engine company within 1.5 miles and an adequately-equipped, responding ladder-service company within 2.5 miles.	3.01	4.00
7. Credit for Company Personnel (Item 571)		
This item reviews the average number of equivalent fire fighters and company officers on duty with existing companies.	9.50	15.00+
8. Credit for Training (Item 581)		
This item reviews the training facilities and their use.	6.57	9.00
9. Total Credit for Fire Department:	40.27	50.00+
Relative Classification for Fire Department:	2	

+ This indicates that credit for company personnel is open-ended, with no maximum credit for this item.

CLASSIFICATION DETAILS

Graded Area: Lawrence
County: Douglas State: KS
Date Surveyed: October, 1982 Total Credit: 83.07 Class: 2 Pop.: 52738

WATER SUPPLY

This section of the Fire Suppression Rating Schedule reviews the water supply system that is available for fire suppression in the city.

	Credit	
	Actual	Maximum
1. Credit for the Water System (Item 616) This item reviews the supply works, the main capacity and hydrant distribution.	32.02	35.00
2. Credit for Hydrants (Item 621) This item reviews the type of hydrants, and method of installation.	1.92	2.00
3. Credit for Inspection and Condition of Hydrants (Item 631) This item reviews the frequency of inspections of hydrants and their condition	2.32	3.00
4. Total Credit for Water Supply:	36.26	40.00
Relative Classification for Water Supply:	1	

Grading Sheet For: Lawrence, KS
Douglas County
Public Protection Class: 2 Surveyed: October, 1982

Feature	Credit Assigned	Maximum Credit
Receiving and Handling Fire Alarms	8.56%	10.00%
Fire Department	40.27%	50.00%
Water Supply	36.26%	40.00%
*Divergence	-2.02%	
Total Credit	83.07%	100.00%

The Public Protection Class is based on the total percentage credit as follows:

Class	%
1	90.00 or more
2	80.00 to 89.99
3	70.00 to 79.99
4	60.00 to 69.99
5	50.00 to 59.99
6	40.00 to 49.99
7	30.00 to 39.99
8	20.00 to 29.99
9	10.00 to 19.99
10	0 to 9.99

*Divergence is a reduction in credit to reflect a difference in the relative credits for Fire Department and Water Supply.

The above classification has been developed for use in property insurance premium calculations.

Appendix H
Detailed System Improvements Table

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

Water Master Plan Detailed Capital Improvement Plan through Year 2030
Lawrence, Kansas

By Year	Facility	Classification	Reason for Improvement	Item No.	Item	Quantity	Unit	Unit Cost	Const Cost w/ Contingency	Engineering/Other Costs	Subtotal Cost	Category Total	Comments	Contingency
	Distribution		3	1	Oread Storage & BPS	1	LS	2,850,000	2,850,000	570,000	3,420,000		1.75 MG /2 __ Hp pumps 1,000 gpm	
2020	System	Storage & Pumps	3	2	19th & Kasold Pump Station - Pump underground with Building	1	LS	320,000	320,000	60,000	380,000			
			3	3	Harper Booster Station	1	LS	500,000	500,000	100,000	600,000			
			3	4	Tower Coatings (Stratford @ 0.5 MG, 6th @ 0.5 MG, Harper @ 0.5 MG, and Ground Storage at Clinton @ 1.5 MG)	1	LS	3,400,000	4,080,000	-	4,080,000		Per Discussion with City	20%
			3	5	PRV from WH to CS for Fire Flow and Peak Day in CS at I-70, West of Iowa and North	1	LS		60,000	10,000	70,000			
			3	6	Automated Meter Reading for Distribution System	1	LS	8,500,000	8,500,000	-	8,500,000		Plug number - Awaiting cost from Badger	
					Subtotal							17,050,000		
		Transmission	1	1	Future Growth Areas	31.4	MI	506,880	19,880,000	2,980,000	22,860,000		Engineering included	
				2	Brink Tract	1	LS				754,000			
			1	3	31st St. & O'Connell - extend 12" to O'Connell and O'Connell to WWTP (includes river crossing) - New Connection Point for Baldwin & RWD #4	13,600	LF		$1,506,600	301,000	$1,807,600		12" PVC	
			1, 3	4	Kaw 36" WM to North Lawrence (two 30" river crossings) - Phase 1 and Phase 2; & Phase 3	32,500	LF				21,000,000		on-hold - installed in phases	
			3	5	Concrete Main Assessment	1	LS			600,000	600,000			
					Subtotal							47,021,600		
		Distribution	3	1	E. 19th - Maple Ln. to Harper St. (Open Cut in Street, Traffic Control, 30 homes)	1,260	LF		$468,300	94,000	$562,300		12" CI to 12" PVC	
		8" & Larger	3	2	E. 19th - Harper St. to Farmland (Relocation Coordinate with E. 19th Street Reconstruction)	2,650	LF		$476,300	95,000	$571,300		12" CI to 12" PVC	
			3	3	W. 23rd - Iowa to Tennessee (Open Cut, 100% pavement, similar to Iowa,)	6,295	LF		$2,783,600	557,000	$3,340,600		6" & 8" CI to 12" PVC	
			3	4	Michigan - 4th to 7th (Open Cut, traffic control, KDOT bore, 30 houses and/or apartments)	2,025	LF		$434,400	87,000	$521,400		6" & 8" CI to 8" PVC	
			3	5	W. 7th St. - Michigan to Arkansas (Easy open cut on north side, few if any drives and meters)	2,000	LF		$188,700	38,000	$226,700		8" DI to 8" PVC	
			3	6	E. 21st St. - Miller Dr. to Maple Ln. (HDD, Orchard Lane type, 15 homes)	790	LF		$130,700	26,000	$156,700		6" CI to 8" PVC	
			3	7	N. Iowa St. - Riverridge Rd. to Lakeview Rd. (Open Cut, in grass, 3 street crossings (industrial area), 3 meters, 1150 L.F. of parallel sanitary sewer)	1,200	LF		$185,400	37,000	$222,400		12" CI to 12" PVC	
			3	8	Ellis Dr. N of W. 19th St. to Irving Hill Rd. (Open Cut, in grass, 3 sets of meters (but 9 total apartment buildings), sidewalks, 1 street crossing)	1,400	LF		$193,600	39,000	$232,600		6" CI to 8" PVC	
			1	9	Iowa St. - W. 15th St. to W. 19th St. (Open Cut, in grass, no meters, 1 street crossing) - 2013 Road Relocaiton Project	2,600	LF		$430,600	86,000	$516,600		10" CI to 12" PVC	
			1	10	W. 15th St. - Chelsea Pl. to Iowa St. (850 L.F. in 15th St. pvmt, 400 L.F. HDD, rest is Open Cut in Grass, 1 street crossing, 2 driveway crossings) - 2013 Road Relocation Project	2,420	LF		$749,100	150,000	$899,100		10" CI to 12" PVC	
			3	11	Mississippi St. - W. 3rd St. to W. 9th St. (KDOT 6th St. Crossing, ~2680 L.F. HDD, rest is Open Cut in Grass, 66 meters, 31 driveways, 4 street crossings (besides 6th), 600 L.F. of parallel sanitary sewer)	4,005	LF		$687,900	138,000	$825,900		8" CI to 8" PVC	
			3	12	Oxford Rd. - Iowa St. to Hilltop Dr. (HDD likely (not much ROW) or open cut possible in street pvmt, 9 meters, 4 drives, 1 street crossing)	600	LF		$108,300	22,000	$130,300		6" CI to 8" PVC	
			3	13	W. 13th St. - Tennessee to Louisiana (220 L.F. HDD, rest open cut in grass/sidewalk, 1 meter, 2 drives, 2 paved alleys, 1 street crossing)	620	LF		$70,000	14,000	$84,000		8" CI to 8" PVC	
			3	14	E. 15th St. - Cadet to Lindenwood (Prior BG Estimate) (1100 L.F. HDD and 1100 L.F. of open cut in grass, 4 meters, 3 street crossings, 2 drives, parallel sanitary sewer on north side of street (water line on south side of stree	2,210	LF		$352,900	71,000	$423,900		6" CI to 8" PVC	
			3	15	N. 3rd St. - Tanger Mall to 1408 N. 3rd St. - (320 L.F. of HDD rest is open cut in grass/sidewalks, 14 meters, 9 drives, goes under I70 bridge and crosses I70 off-ramp, ~150 L.F. of parallel sanitary sewer)	1,802	LF		$672,200	134,000	$806,200		New 12" PVC	
			3	16	Haskell Ave - South of E. 19th St. (Open Cut, major traffic control, 25% sidewalk R and R 20 residences)	2,750	LF		$399,200	80,000	$479,200		8" CI to 8" PVC	
			3	17	New Hampshire - 8th to 9th (~235 L.F. of HDD, rest open cut, almost entirely sidewalk, 2 drives, 7 meters)	650	LF		$254,100	51,000	$305,100		6" Transite to 12" PVC	
			3	18	N. 3rd St. - Locust to Lincoln (~230 L.F. of HDD, rest open cut (s/w), 4 meters, 3 drives, 2 street crossings)	1,050	LF		$171,500	34,000	$205,500		6" CI to 8" PVC	
			3	19	Louisiana - 1700 Block (HDD, 5 meters (? - two water lines), 1 drive)	350	LF		$55,800	11,000	$66,800		2" GL to 8" PVC	
			3	20	9th St. - Arkansas to Emery (HDD, 5 meters, 1 street crossing)	300	LF		$48,700	10,000	$58,700		6" CI to 8" PVC	
			3	21	Mississippi south from Jayhawk Blvd.	243	LF		$32,400	6,000	$38,400		8" DI to 12" PVC	
			3	22	corner of 2nd & Arkansas - Part 2 - 2nd to 4th	14	LF		$6,400	1,000	$7,400		8" CI to 12" PVC	
			3	23	23rd Street - Vermont to Ohio	1,050	LF		$117,800	24,000	$141,800		6" CI to 8" PVC	
			1	24	Water Main Relocation Program for Road Projects - Beginning in 2014	7	ANNUAL	500,000			3,500,000			
			3	25	Pipeline Replacement Program - 2013 to 2020	8	ANNUAL	1,660,100	1,660,100	-	13,280,800		Engineering included	
					Subtotal							27,603,700		
		Distribution	3	1	Minnesota - W. 3rd to 4th (Open Cut, 10 percent bores, 5 driveways, 10 meters, connections in pavement	630	LF	140	90,000		$90,000		6" CI to 8" PVC	
		8" & Smaller	3	2	Minnesota - W. 5th to 6th (Open Cut, 3 driveways, 250' parking pavement, slightly difficult, KDOT permit, 11 resid meters, 3 commercial meters)	620	LF	140	90,000		$90,000		4" CI to 8" PVC	
		(Potential	3	3	W. 25th St. - Alabama to Louisiana (HDD, 4 connections, multiple FH's, 35 meters, sidewalks)	1,340	LF	140	190,000		$190,000		6" DI to 8" PVC	
		In-House)	3	4	Belle Crest Dr. (HDD, 40 homes, numerous drives, eyebrow)	1,240	LF	140	170,000		$170,000		6"/8" CI/DI to 8" PVC	
			3	5	Ousdahl Rd - W. 21st to W. 23rd (HDD, 1.3 complexity, handful of drives, school)	1,300	LF	140	180,000		$180,000		8" CI to 8" PVC	
			3	6	W. 22nd St. - Ousdahl West (same as Ousdahl, 12 resid meters and drives, cul-de-sac)	970	LF	140	140,000		$140,000		6" CI to 8" PVC	
			3	7	Belle Haven Dr. (HDD, similar to Orchard Lane, 35 homes, a cul de sac)	1,140	LF	140	160,000		$160,000		6" DI to 8" PVC	
			3	8	Missouri St. - W. 24th to W. 25th (HDD, similar to Orchard Lane, 20 houses)	1,000	LF	140	140,000		$140,000		6" DI to 8" PVC	
			3	9	Homestead Ave. (HDD, 20 homes fronting LCC, parallel sewer for a couple hundred feet)	1,500	LF	140	210,000		$210,000		6" CI to 8" PVC	
			3	10	Valley Lane (Open Cut, 100' bore, south spur off University, 6 homes)	390	LF	140	50,000		$50,000		4" CI to 8" PVC	
			3	11	Ponderosa Dr. - E. 27th to E. 28th Terr (HDD, 45 homes, sidewalk, end connects, easy T.C.)	1,200	LF	140	170,000		$170,000		6" CI to 8" PVC	
			3	12	Arkansas St. - W. 2nd to W. 4th (Open Cut, in street, sig traffic control, LMH, 20 houses)	1,200	LF	140	170,000		$170,000		6" CI to 8" PVC	
			3	13	Arkansas St. - 7th to 9th (HDD, 46 meters, 3 drives, 1 street crossing)	1,400	LF	140	200,000		$200,000		8" CI to 8" PVC	
			3	14	W. 10th - Mississippi to Maine (HDD, 5 meters, 3 alleys, 2 street crossings)	1,270	LF	140	180,000		$180,000		6" CI to 8" PVC	
			3	15	W. 5th St. - 1924 W. 5th St. to Iowa and Iowa - W. 4th to W. 5th (HDD, 8 meters, 7 drives, parallel sanitary sewer under Iowa St., ~100 L.F. of directly parallel sanitary sewer)	1,300	LF	140	180,000		$180,000		4" CI to 8" PVC	
			3	16	Massachusetts - W. 23rd to Indian Ave. (HDD, no meter symbols but 14 houses, 12 drives, parallel sanitary sewer the whole length)	950	LF	140	130,000		$130,000		8" CI to 8" PVC	
			3	17	Ousdahl Rd - W. 19th to W. 21st (HDD, 12 meters, 6 drives, 3 street crossings)	1,300	LF	140	180,000		$180,000		8" CI to 8" PVC	
			3	18	Missouri St. - 25th to 27th (250 L.F. open cut in grass, rest HDD, no meter symbols but 23 houses, 8 drives, 1 street crossing)	1,400	LF	140	200,000		$200,000		6" CI to 8" PVC	
			3	19	Sunset - Oxford to Cambridge	266	LF	140	40,000		$40,000		6" Transite to 8" PVC	
			3	20	Miller Wells Acres	6,260	LF	140	880,000		$880,000		RWD mains to City Std.	
			3	21	Maine Street - 19th to 20th	650	LF	140	90,000		$90,000		6" CI to 8" PVC	
			3	22	8" and Smaller Water Main Replacement Program	47,215	LF	140	6,610,000	-	6,610,000		4" and 6" to 8" PVC; Engineering included	
			3	Alt. 1	In-House 8" and Smaller Water Main Replacement Program	74,541	LF	100	7,450,000					
					Subtotal Conventional Construction							10,450,000		
					Subtotal - In-House Design / Construct							7,450,000		
	Kaw WTP	Structural	3	1	Primary / Secondary Total	1	LS		340,000	68,100	409,200			
			3	2	Presedimentation Basin\ Total	1	LS		13,000	2,600	15,800			
			3	3	Carbon Basin Total	1	LS		100,000	20,100	120,700			
			3	4	Blast and Coat Paddle Wheels, Cage, and Rakes	1	LS		50,000	-	50,000			
					Subtotal							596,000		
		Electrical	3	1	MCC1 Replacement (4 sections)	1	LS	180,000	180,000	50,000	230,000			
			3	2	MCC2 Replacement (5 sections)	1	LS	230,000	230,000	60,000	290,000			
			3	3	MCC3 Replacement (4 sections)	1	LS	180,000	180,000	50,000	230,000			
					Subtotal							750,000		
		Process	2, 3	1	Basin Performance Enhancement Tests	1	LS	75,000			75,000			
			2	2	Microcystin and Algal Treatment Evaluation	1	LS	100,000			100,000			
			2	3	Ozone Evaluation and BDR	1	LS	100,000			100,000			
			2	4	Microcystin and Taste & Odor Treatment Measures - Ozone System	1	LS	6,000,000	7,500,000	1,500,000	9,000,000			
			2, 3	5	Filter Media Replacement	1	LS	98,000	122,500	20,000	142,500			
					Subtotal							9,417,500		
		Maintenance	3	1	Annual Plant Improvement Program - $75,000 for Two Years then $300,000	8	ANNUAL	300,000			1,950,000			
					Subtotal							1,950,000		
	Clinton	WTP	1, 3	1	Intake Pump	1	LS	200,000	250,000	50,000	300,000		Replace 3100 gpm with 7100 gpm pump	
			1	2	Building Expansion of Intake - VFDs	1	LS	600,000	750,000	150,000	900,000			
			1, 3	3	Building Expansion of Intake - Generator for 15 MGD of potable water	1	LS	300,000	380,000	80,000	460,000			
			2, 3	3	Process Evaluation	1	LS	200,000	250,000	50,000	300,000			
			2	4	Microcystin and Algal Treatment Evaluation	1	LS	100,000			100,000			
			2	5	Microcystin and Taste & Odor Treatment Measures - Ozone System	1	LS	6,000,000	7,500,000	1,500,000	9,000,000			
			2, 3	6	Filter Media Replacement	1	LS	105,000	130,000	30,000	160,000			
			3	7	South Train Coatings	1	LS	750,000	940,000	190,000	1,130,000			
			3	8	Generator to run 15 MGD at WTP	1	LS	500,000	625,000	130,000	755,000			
			1, 3	9	Process Improvements to Increase Capacity to 25 MGD - will refine with Nathan (additional filter capacity, rapid mix, floc improvements)	1	LS	5,000,000	6,250,000	1,250,000	7,500,000			
			3	10	Annual Plant Improvement Program - $75,000 for Two Years then $300,000	8	ANNUAL	300,000			1,950,000			
					Subtotal							22,555,000		
					2020 Total - Conventional Construction							**137,393,800**		
					2020 Total - In-House Design / Construct							**134,393,800**		
	Distribution			1	Completed by 2020	1	LS		0	0	0			
2030	System	Storage & Pumps												
					Subtotal							-		
		Transmission	1	1	Future Growth Areas	16	MI	506,880	10,140,000	1,520,000	11,660,000			
		(>12")												
					Subtotal							11,660,000		
		Distribution	3	1	Pipeline Replacement Program - 2021 to 2030	10	ANNUAL	1,660,100	1,660,100	-	16,601,000			
		8" & Larger	1	2	Water Main Relocations for Road Projects	10	ANNUAL	500,000			5,000,000			
					Subtotal							21,601,000		
		Distribution												
		8" & Smaller		1	Completed by 2020		LF						4" various to 8" PVC	
		(Potential												
		In-House)												
					Subtotal							-		
	KAW WTP	Structural		1	Completed by 2020	-		0	0	0	0			
					Subtotal							-		
		Electrical		1	Completed by 2020	-		0	0	0	0	-		
					Subtotal							-		
		Process		1	Completed by 2020	-		0	0	0	0			
					Subtotal							-		
		Maintenance	3	1	Annual Plant Improvement Program	10	ANNUAL	300,000			3,000,000			
					Subtotal							3,000,000		
	Clinton	Maintenance	3		Annual Plant Improvement Program	10	ANNUAL	300,000	0	0	3,000,000		per City	
					Subtotal							3,000,000		
	Raw Water		1, 2, 3	1	HCWs (three at 25 MGD total)	1	LS				17,100,000		From Kaw Water Supply Study	
	Supply		1, 2, 3	2	42" Pipeline to Clinton WTP	45,000	LF	336	18,900,000	3,780,000	22,680,000			
			1, 2, 3	3	36" Pipeline to Kaw WTP	1	LS				7,300,000		From Kaw Water Supply Study	
					Subtotal							47,080,000		
					2030 Total							**86,341,000**		
					2020 and 2030 Total - Conventional Construction							**223,734,800**		
					2020 and 2030 Total - In-House Design / Construct							**220,734,800**		

Reason for Improvement
1- Growth
2 - Regulatory
3 - Reliability

Appendix I
Kaw WTP Structure Reports

Water Master Plan

for

Lawrence, Kansas

City of Lawrence, Kansas

BMcD Project No. 59410

City P.O. 002109

Burns & McDonnell Engineering Company, Inc.
9400 Ward Parkway
Kansas City, MO 64114

Field Evaluation Report

Day / Date: Wednesday 09/21/2011.

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plan	**Weather:**	Morning: Partly Sunny, Light Wind & Warm 73 ^{0} F
Engineer on Site: Ken Farmer			Afternoon: Mostly Sunny, Light Wind & Warm 73 ^{0} F

General Notes/Client Comments/Field Assessment

Item	
1	The carbon contact basin's base slab had a large crack running next to the west wall, running north-south for nearly the full length of the structure. The interior wall has a large gap between it and the exterior South wall. The wall, base slab and their connection will need to be evaluated and repaired, to reduce cracking at the floor slab while the basin is empty or full.
2	The base slab has several smaller cracks that appear to have water seeping up through them. The base slab will need to have the cracks repaired and epoxy sealed.
3	The carbon contact's exterior walls, especially the east wall has some localized areas that have hollow areas, cracks or loose concrete that will need to be repaired.
4	Concrete walkway on the secondary basin on the west side near the weir troughs has degraded, developed large cracks, and spalled, exposing the reinforcing steel. Though this does not appear to affect the structural integrity, if not repaired it will. This area will need the loose and degraded concrete removed to sound concrete. If reinforcing is exposed after removal, reinforcing shall be inspected. Suitable reinforcing and concrete shall be clean and concrete shall be repaired.
5	There were several places where the surface of the basin's base slab had deterioration. The surface should be cleaned to sound concrete. Cracks shall be repaired and sealed.
6	Walls in both basins have many places where there was evidence of leakage and surface degradation of the concrete. These do not appear to affect the basin's structural capacity. The walls will require cleaning and removing loose concrete, and epoxy injecting the walls.
7	The basin's north wall had many small holes placed in it from possibly a drill. Some of the holes appeared to be repaired by sealing them with some compound. All of these holes should be cleaned and repaired. Any other existing wall with the same issue will require this as well.
8	There were many places where rust was evident and the coating was missing on the weir plates attached to the concrete walls of the basins troughs. The weir plates will need to be removed, cleaned, repaired and recoated. Prior to replacing the weir, the concrete wall at the connection shall have loose concrete removed and repaired.
9	There were many places where rust was evident and the coating was missing on the weir troughs in the basins. The weir troughs will need to be cleaned, repaired and recoated.
10	The interior wall between the north and south sections of the sedimentation basin appears to be affected by water seeping from near the top of the wall. There is a portion of the wall that has a concrete trough sitting on top of the wall. The walkway is the grating above the trough. This trough is not being used for any part of the process. There is no drain in this trough and water trapped in this trough sits stagnant in this trough. There is a possibility that this water is leaking and causing what we are seeing in the interior wall.
11	Wooden baffle wall's concrete columns have some cracking and will require repair. The metal clips attaching the wall to the column have degraded and will need to be replaced.

Project Photos Taken:	Yes: ☒ No: ☐	See page 2 of this report for details.

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plan	**Date:**	09/21/2011

Photos

Photo # 1

Item #1: Crack in Carbon Contact Basin’s Base Slab

Photo # 2

Item #1: Crack in Carbon Contact Basin’s Base Slab

Photo # 3

Item #1: Crack in Carbon Contact Basin’s Base Slab

Photo # 4

Item #1: Crack in Carbon Contact Basin’s Base Slab

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plan	**Date:**	09/21/2011

Photos

Photo # 5

Item #2: Carbon Contact Basin’s Slab Seepage

Photo # 6

Item #3: Carbon Contact Basin’s East Wall

Photo # 7

Item #4: Secondary Basin’s Elevated Walkway

Photo # 8

Item #5: Cracks in the Secondary Basin’s Base Slab

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plan	**Date:**	09/21/2011

Photos

Photo # 9

Item #6: Basin’s Interior Wall Surface Degradation

Photo # 10

Item #6: Basin’s Interior Wall Surface Degradation

Photo # 11

Item #7: Holes in Basin’s North Wall

Photo # 12

Item #7: Holes in Basin’s North Wall

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plan	**Date:**	09/21/2011

Photos

Photo # 13

Item #8/9: Weir Trough/Plate's Rust and Connection

Photo # 14

Item #9: Weir Troughs Rust and Connection

Photo # 15

Item #11: Cracks in Baffle Walls Concrete Column

Photo # 16

Item #11: Baffle Wall Degraded Metal Support Clip

Burns & McDonnell
SINCE 1898

Field Evaluation Report

Day / Date: Friday 07/29/2011.

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plant	**Weather:**	Morning: Sunny, Light Wind & Hot 92 ^{0} F
Engineer on Site: Ken Farmer			Afternoon: Mostly Sunny, Light Wind & Warm 92 ^{0} F

General Notes/Client Comments/Field Assessment

Item	
1	Handrail existing connection to the concrete structure shall be evaluated. If the handrail connection fails to transfer the International Building Code required handrail loads into the structure, the handrail connection will need to be updated and any damaged concrete repaired.
2	Sections of the concrete walkways on both basins have deteriorated surfaces. The concrete shall be chipped down to sound concrete. The concrete shall be chipped to a minimum depth allowable for repairing concrete with grout.
3	There were a couple places where the concrete steps, for the concrete walkway, at the metal walkway are damaged and deteriorated. The steps will require replacement.
4	Concrete walkway on the secondary basin on the west side near the weir troughs has degraded and developed larges cracks. Though this does not appear to affect the structural integrity, if not repair it will. This area will need the loose and degraded concrete removed to sound concrete. If reinforcing is exposed after removal, reinforcing shall be inspected. Suitable reinforcing and concrete shall be clean and concrete shall be repaired.
5	There were several places where leaking was evident on the walls and base slab of the eastern most trough on the primary basin. The bottom of the base slab had some deterioration to the concrete and large chips on the edges. The base slab and walls will need to have the concrete inspected and repaired as required.
6	There were several places where the surface of the basin's base slab had deterioration. The surface should be cleaned to sound concrete. Cracks shall be repaired and sealed.
7	Walls in both basins have many places where there was evidence of leakage and surface degradation of the concrete. These do not appear to affect the basin's structural capacity. The walls will require cleaning and removing loose concrete, and epoxy injecting the walls.
8	The primary basin's south wall shall be cleaned and epoxy injected to reduce ground water seepage. Any other existing wall with the same issue will require this as well.
9	There were many places where rust was evident and the coating was missing on the weir plates attached to the concrete walls of the basins troughs. There was also cracking and degradation of the concrete at the weir plate connection. The weir plates will need to be removed, cleaned, repaired and recoated. Prior to replacing the weir, the concrete wall at the connection shall have loose concrete removed and repaired.
10	There were many places where rust was evident and the coating was missing on the weir troughs in the basins. The weir troughs will need to be cleaned, repaired and recoated.
11	There were many places on the walls of the pressed basin where leaking was evident. There is not structure problem with this wall. The walls will need to be epoxy injected.
12	There were many cracks in the pressed basin's base slab. The surface will need to be cleaned of loose concrete and the cracks repaired and sealed.
13	The pressed basin's hanging pipe supports are rusting, the rods are bent and some of the nuts are rusting. The pipe supports will need to be repaired or completely replaced.

Project Photos Taken:	Yes: ☒ No: ☐	See page 2 of this report for details.

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plant	**Date:**	07/29/2011

Photos

Photo # 1

Item #1: Handrail to Concrete Connection

Photo # 2

Item #2: Concrete Walkway's at Both Basins

Photo # 3

Item #3: Concrete walkway's stairs

Photo # 4

Item #4: Basin walkway near the weir troughs.

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plant	**Date:**	07/29/2011

Photos

Photo # 5

Item #5: Wall of Primary Basin's Trough

Photo # 6

Item #5: Bottom of Primary Basin Trough's Base Slab

Photo # 7

Item #6: Basin's Base Slab

Photo # 8

Item #7: Basin walls

Project:	Water Master Plan	**Client:**	City of Lawrence, Kansas
Location:	Kaw Water Treatment Plant	**Date:**	07/29/2011

Photos

Photo # 9

Item #9: Basin's weir plate to concrete connection.

Photo # 10

Item #10: Basin's Weir Troughs

Photo # 11

Item #11: Presed Basin Wall

Photo # 12

Item #13: Presed Basin Pipe Support