EXPERT REPORT: Case No. 18 WATER 14014

for

Scott Macey, Water Resources Engineer, City of Wichita Public Works & Utilities

a) Consulted for: current and historical water use trends, current City treatment processes and infrastructure planning, and technical tools and models used for water resource decision making
b) The grounds for Scott Macey's opinions are knowledge of pertinent information presented in City of Wichita's Response to Production Request of Equus Beds Groundwater Management District No.2 and City of Wichita's Responses to Intervener's Production Requests, as referenced in the summaries of the respective opinions below, and in several cases, excerpted and attached for convenience of reference.
c) Scott Macey's factual observations and opinions, as presented in the Proposal documents and summarized herein, include:
    i. Expert opinions based on factual observations:
        - 2.2 City of Wichita - Future Raw Water Demand Assessment
            - <u>Projected future demands are based on a medium-growth forecasted population.</u>

              Section 6: Conclusions of the 2013 Water Demand Assessment provides a projected annual water demand for 2060. This excerpt is provided as Attachment A and was provided as Attachment D of the Proposal.

            - <u>Future demands will be decreased by progressive water conservation efforts.</u>

              On several occasions in 2014, Wichita City Council considered a Strategic Plan in which improvements to the City's water supply were contemplated. During this process, it was determined that ongoing conservation efforts were an integral strategy for future drought protection. On August 5, 2014, the Council approved the Strategic Plan and its implementation through a Special Question Election.

              Presentations and other documents considered during development of the Strategic Plan are presented in the Exhibits: Strategic Plan.

              Excerpted pages 28-31 of Exhibits: Strategic Plan are presented as Attachment B.
    ii. Expert opinions based on scientific analyses:

- 2.3 Integrated Water Resources Management During a 1% Drought Using MODSIM-DSS
    - The model was updated to reflect 1% drought conditions including hydrologic components, projected future demand, and water resources assumptions.

      The MODSIM-DSS model developed by HCH was modified to utilize varying water resource blends as Cheney levels decline, including ASR recharge credits when needed.

      Future water demands implemented in the model were calculated assuming ongoing conservation efforts. Projections were subsequently evaluated in Section 3 of the 2016 Water Master Plan, which provides comparative analyses of the projections.

      The excerpted Section 3 of the 2016 Water Master Plan was provided as an Exhibit, and is enclosed with this Report as Attachment C.

      Daily water demand on the water resources was calculated using historical annual trends, and reduced when Drought Response measures are anticipated.

      Changes to the model were peer-reviewed by HCH.
- Table 2-3: MODSIM-DSS simulation results for the 1% drought utilizing projected 2060 demands
    - Table 2-3 of the Proposal presents an annual summary of daily calculated results of the MODSIM-DSS modeled conditions.

      Modeled demand for water during the drought is reduced by the Drought Response Plan.

      Cheney Reservoir is used throughout the drought.

      Use of groundwater is modulated based on the availability of surface water.

      Use of ASR credits varies, and is limited to allowed withdrawal rates.

      Table 2-3 is provided as Attachment D.
- Figure 2 - Simulated Conditions of 1% Drought Demand on Cheney Reservoir
    - Figure 2 of the Proposal demonstrates:

      Using both ASR credits and reductions of demand, Cheney Reservoir will not be depleted in the modeled 1% drought.

      Figure 2 is provided as Attachment E.
- Exhibits: Aquifer Profiles

- Cross-section profiles of the aquifer lithology in the Wichita wellfield area were prepared to demonstrate proposed water levels in locations beyond the Index wells, as well as predevelopment (1940) and 1993 conditions. This document, as well as the unmodified originals from Section VII of the 2000 Concept Design Study, have been provided previously in Exhibits.
- The Aquifer profiles are provided as Attachment F.

d) Scott Macey is a City of Wichita employee; his compensation is publicly available.

e) Scott Macey's qualifications are as presented in the City of Wichita's Preliminary Expert Disclosure.

f) Scott Macey's factual observations and opinions are as presented above in this Expert Report, ASR Permit Modification Proposal, cover letter, and supporting appendices.

Scott Macey, Water Resources Engineer, City of Wichita Public Works & Utilities

Section 6
CONCLUSIONS

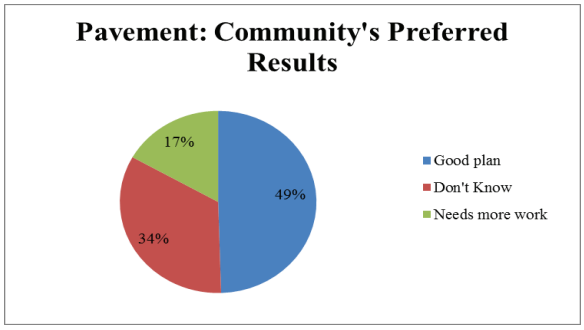
The population of the WWSA is expected to increase through 2060 and the area served by Wichita Water Utilities is expected to expand, leading to an increase in annual and peak day water demand.

Based on three growth scenarios, the annual water demand by 2060 varies from 63.7 MGD (71,370 Ac-Ft/Yr) for the low growth scenario to 94.5 MGD (105,858 Ac-Ft/Yr) for the high growth scenario. The medium growth scenario, which is anticipated to be the most likely representation, forecasts 78.2 MGD (87,597 Ac-Ft/Yr) by 2060.

The peak day water demand is also expected to increase over time. The highest peak day demand (high growth/high peak) is forecasted to be 195.3 MGD. The lowest peak day demand (low growth/medium peak) is predicted to be 116.7 MGD.

There are other variables that may affect future water demand. The variables addressed in this assessment include new wholesale service areas, private well drilling, and conservation measures. These variables are addressed in the appendices, but it is uncertain if they will play a role in future water demand. As such, they are not assumed to occur and have been removed from the water demand projections.

Pavement Maintenance Proposal Feedback



Pavement Maintenance Proposal Feedback - *Themes*

- Critical Need
- Future Funding Source
- Specific Functions

Summary of Feedback – Community Information Meetings

- Overall, the responses were favorable to the plans being a needed investment for the public good and for an opportunity for a better community for the next generation.
- All plans indicated significant overall support of community investment as either critical or good idea.
  Water – 93% (Critical or good idea)
  Jobs – 86%
  Public Transit – 89%
  Pavement Maintenance – 91%

Engagement – Activate Wichita

- The questions from the community information meeting comment cards were used as the premise for the Activate Wichita engagement.
- **102** participants and **99** responses
- Results:
  - Responses indicated overall support for community investment plans by identifying each as either critical or a good idea
    - Water Supply: **80%**
    - Jobs: **69%**
    - Public Transit: **72%**
    - Pavement Maintenance: **84%**

Conclusion

Information received through participant responses to comment card questions in the **Sales Tax Proposal Community Information Meetings** and **Activate Wichita** engagement continue to support the previous work of the **Community Investments Plan Survey** and the **ACT ICT** engagement project.

Water Supply

Water Supply Issues

- Based on growth and consumption projections, current supplies will not be adequate through the planning horizon (2060).
- Current supplies would require significant quality of life disruptions in the event of a 1% drought.
- Funding a supply option, coupled with moderate conservation, will provide 1% drought protection, and provide adequate supplies through 2060.

Water Supply Objectives and Strategies

	Current	Goal
Final Year of 1% Drought Protection	**2011**	**2060**
Strategies Combination of new water supply and long-term conservation is necessary		
Add New Water Supply	**---**	**10 MGD**
Strategies Secure a cost-effective new water source for the Wichita system		
Annual Water Conservation	**---**	**0.35%**
Strategies Rebate programs, landscaping incentives, private well usage, targeted re-use, etc.		

Explanation of Water Supply Options

Treated Water from El Dorado

- Drinking water would be sent from El Dorado Lake to a northeast pump station.
- Pre-payment of water would end between 2021 and 2024.

Raw Water from El Dorado

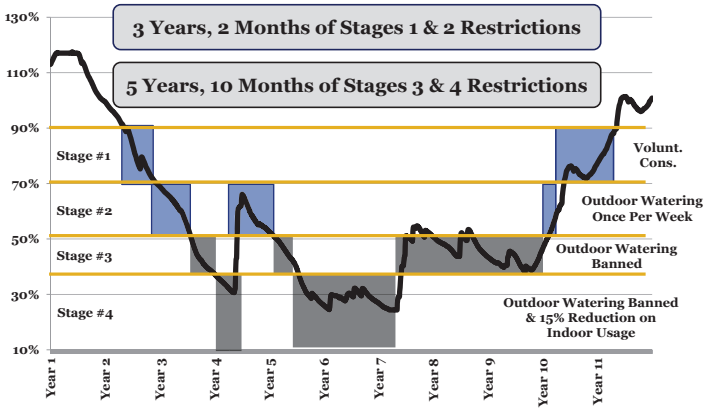
- Untreated water would be delivered from El Dorado to the City of Wichita main treatment plant.
- Water would be pre-paid until 2051.

Explanation of Water Supply Options

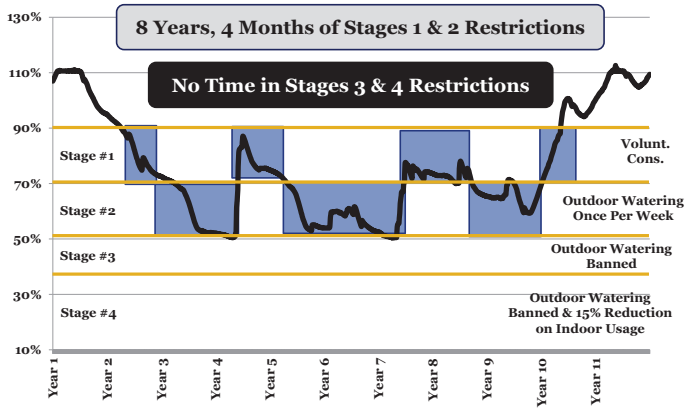
Aquifer Storage & Recovery (ASR) Improvements

- Drills additional wells and constructs a sidestream storage reservoir.
- Allows the availability of more water to be pumped through the existing treatment plant.

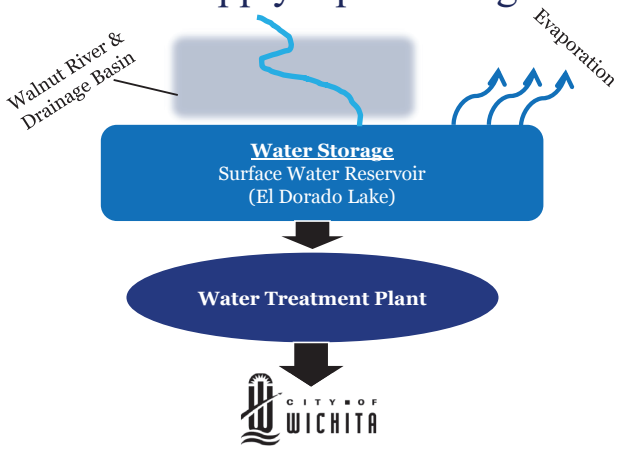
1% Drought Without New Supply



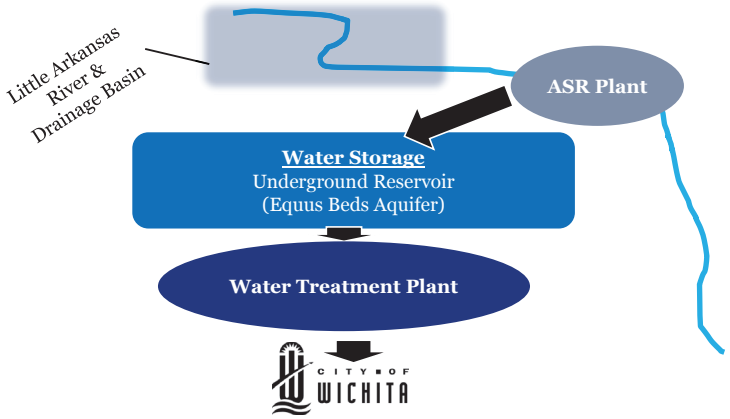
1% Drought – With New Supply



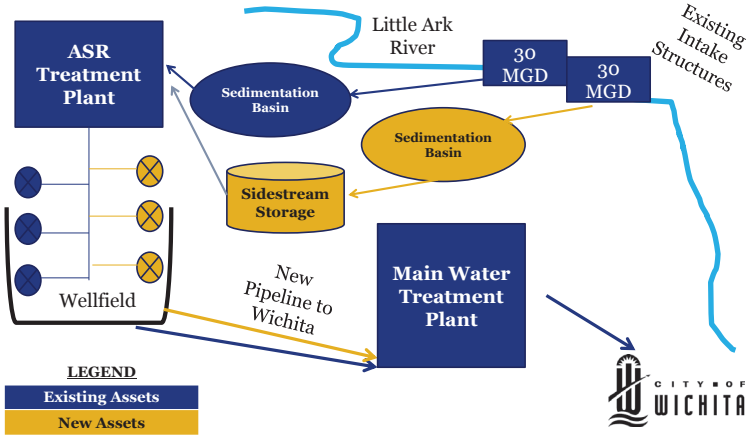
El Dorado Supply Option Diagram



ASR Water Supply Option Diagram



New ASR Improvements



Process Timeline

Jan. 2013 — DEVELOPMENT OF WATER SUPPLY OPTIONS — July 2014

- Demand projections created by PEC with data from the MAPD
- Water supply and drought scenario models created by SAIC
- River modeling created by High Country Hydrology, with data from CSU and Burns & McDonnell
- Data provided by the US Geological Survey on river flows and Equus Beds Hydrology
- Nine water supply options presented to Council on April 8th

Process Timeline

Jan. 2013 — DEVELOPMENT OF WATER SUPPLY OPTIONS — July 2014

- Nine options presented on April 8th, resulting from input of seven different independent experts
- Water economists at Metering Technology Consultants and Water DM reviewed financial analysis model and role of conservation
- Water planning narrowed to two options that count on long-term conservation coupled with new supplies from El Dorado Lake or an ASR project
- Engineers from Black & Veatch and Burns & McDonnell worked through analysis, while Burns & McDonnell developed 1% ASR design

Final Cost Comparison

	Aquifer Storage & Recovery (ASR)	El Dorado Treated Water	El Dorado Raw Water
Yield	**10 MGD [1]**	**10 MGD [2]**	**10 MGD [2]**
Year Drought Protection Ends with No Conservation	2030	2030	2030
Required Annual Conservation for 1% Drought Protection	0.35%	0.35%	0.35%
Total Cost from 2015 - 2060	**$421 million**	**$700 million**	**$375 million**

[1] A 1% engineering design showed this is a conservative estimate, and the project may yield more water.

[2] Discussions with the El Dorado team have not confirmed that this water would be available exclusively to Wichita in a 1% drought.

- ASR costs have changed compared to previous estimates due to the inclusion of additional funds for annual renewal and replacement costs and a revision to the capital costs based on a 1% engineering study.

ASR Estimated Capital Cost

One-Time Costs	
Raw Water Facility	$9,515,921
Sidestream Storage	$29,784,833
New Wells & Improvements	$68,221,224
Parallel Pipeline	$86,579,022
Other Improvements	$5,899,000
TOTAL CAPITAL COSTS	**$200,000,000**

The capital costs shown are preliminary and based on a 1% engineering study. Since final design and scope will determine actual project costs, the proposed sales tax allocation is maintained at $250 million.

ASR Est. Annual Operating Costs

Annual Costs	
Chemicals at ASR & Filter Plant	$654,895
Electricity at ASR & Filter Plant	$945,105
Staffing/Renewal & Replacements	$1,200,000
TOTAL OPERATING COSTS	**$2,800,000**

Recommendation: ASR Improvements

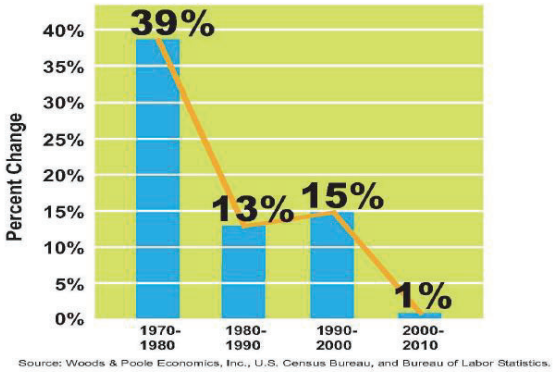
- Lower amount of sales tax funding could be needed.
- More certainty that ASR can yield 10 MGD to provide critical drought protection.
- Potential for lower future costs for improvements to add next new water source.
- Fights chloride migration into one of City's two existing water supplies (Equus Beds).
- Additional ASR usage will increase efficiency, allowing ASR to operate closer to design capacity.

Jobs Initiative

Jobs Initiative Issues

- Job growth in the last decade was only 1%
- Since the recession, job growth in Wichita has not kept up with regional peer cities
- Neighboring communities and states are aggressively pursuing jobs

Sedgwick County Employment – Growth by Decade



2016 Water & Sewer Master Plans

City of Wichita, Kansas

Water Master Plan
Burns & McDonnell Project No. 90341

July 2017

2016 Water & Sewer Master Plans

prepared for

City of Wichita, Kansas

Water Master Plan
Burns & McDonnell Project No. 90341

July 2017

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

3.0 WATER DEMANDS

This section of the report characterizes the City's water service area, evaluates the historical retail and wholesale water usage, summarizes historical water demands, summarizes the range of the City-approved water demand projections from the 2013 Water Demand Assessment (WDA, by others), and develops the water demand projection applied to the master planning and hydraulic modeling efforts for this project/report.

3.1 Water Service

The Wichita water service area is represented by the City's retail and wholesale customer classifications. In 2015, the retail service area included approximately 145,000 customer accounts (or meters with unique premise numbers in the customer billing system). Retail customers reside within the City limits and represent over 91 percent of the total water sales for the water service area. Wholesale water sales is represented by ten customer accounts that receive potable water from a single location, or master meter, and one customer, the City of Bentley, which receives non-potable water from the Equus Beds Well Field (EBWF). The potable water wholesale customers represented approximately 9 percent of the total water sales in 2015. For clarity, the City does not own or operate the water distribution network downstream of the wholesale customer master meter connection points and, therefore, there is no reference to a "wholesale service area" because water service from the City stops at a master meter. Additionally, all references to wholesale customers are in regard to the wholesale potable water users from this point forward in the report.

3.2 Retail Water Usage

Retail water sales include both residential and commercial customer classes and collectively represented an average sales of approximately 92 percent of the total sales volume from 2006 to 2015. Water sales for a City Use-type classification is sequestered, as the sales volume between 2006 and 2015 only ranged between 0.1 and 0.2 percent of the total retail sales; therefore, City Use is included in the commercial customer class which is also consistent with its billing classification.

Historical data representing residential and commercial meter counts, average day sales, and metered water usage (represented in gallons per meter-day (gpmd)) is listed in Table 3.1. The average commercial metered usage (1,600 gpmd) from 2006 to 2011 is approximately 8 times greater than the average residential metered usage (203 gpmd). During the same period, the residential and commercial average day sales are approximately 56 percent and 44 percent, respectively, of the retail water sales. The commercial customer class has a large impact on water demands in the distribution system which is

Table 3.1
Historical Retail Water Usage

Year	Meter Count[1,2]			Average Day Sales[1,2] (MGD)			Metered Usage (gpmd)		
	Residential	Commercial	Total	Residential	Commercial	Total	Residential	Commercial	Combined
1991	--	--	118,447	--	--	61.2	--	--	517
1992	--	--	116,498	--	--	55.5	--	--	477
1993	--	--	127,964	--	--	57.1	--	--	447
1994	--	--	116,499	--	--	57.0	--	--	489
1995	--	--	179,594	--	--	53.3	--	--	297
1996	--	--	126,163	--	--	54.5	--	--	432
1997	--	--	128,341	--	--	52.4	--	--	409
1998	--	--	130,257	--	--	61.0	--	--	469
1999	--	--	132,260	--	--	55.0	--	--	416
2000	--	--	132,260	--	--	60.8	--	--	460
2001	--	--	132,228	--	--	61.3	--	--	464
2002	--	--	135,552	--	--	57.5	--	--	424
2003	--	--	133,487	--	--	55.4	--	--	415
2004	--	--	133,791	--	--	54.9	--	--	410
2005	--	--	137,234	--	--	59.9	--	--	436
2006	121,942	12,182	134,124	29.4	22.8	52.2	241	1,868	389
2007	123,608	12,347	135,955	26.4	21.4	47.7	213	1,729	351
2008	125,064	12,510	137,574	24.7	20.5	45.2	198	1,638	329
2009	126,002	12,638	138,640	25.0	19.4	44.4	198	1,535	320
2010	126,874	12,733	139,607	26.8	20.8	47.6	211	1,630	341
2011	127,279	12,844	140,123	28.4	21.3	49.8	223	1,660	355
2012	128,144	12,973	141,117	27.6	21.0	48.6	216	1,620	345
2013	128,934	13,078	142,012	22.5	18.6	41.1	174	1,423	289
2014	130,127	13,242	143,369	23.7	19.5	43.2	182	1,473	301
2015	131,550	13,435	144,985	22.2	19.2	41.4	169	1,428	286

Notes:

1. Data from 1991 to 2005 collected from the City's Annual Water Use Reports.
2. Data from 2006 to 2015 collected from the City's customer billing system; meter count is determined as the unique premise number tied to each customer account in the customer billing system.

evidenced by accounting for nearly half of the total average day sales from only about 9 percent of the total meters in the distribution system.

There is a steady, but escalating, trend in meter counts on an annual basis since 2006 and is illustrated in Figure 3.1. The average increase in residential meters from 2006 to 2015 and from 2011 to 2015 is the same at approximately 1,068 meters per year. The average increase in commercial meters from 2006 to 2015 and from 2011 to 2015 is approximately 139 and 148 meters per year. In conclusion, residential customer additions have been consistently increasing over the last 10 years and commercial meter additions have slightly accelerated over the last 5 years.

The average day sales and metered water usage has been declining since 2006 and is illustrated in Figure 3.2. An escalating meter count coupled with declining average day sales and metered water usage can be representative of successful water conservation strategies, water efficient fixtures, public education, and water rate structures.

3.3 Wholesale Customers

The City's wholesale customers include Rural Water District (RWD) No.'s 1, 3, 5, and 8 (RWD No.'s 5 and 8 are evaluated as a single wholesale customer) and the cities of Bel Aire, Park City, Kechi, Benton, Rose Hill, Valley Center, and Derby. Water is delivered to each wholesale customer from the City's distribution system to a master meter which and, for the purposes of this report, is considered the end of the line with respect to the City's responsibility for providing contracted quantities of water at adequate pressure, where applicable, and in compliance with Safe Drinking Water Act (SDWA) as stated in each contract. For clarity, there are no wholesale customer contracts with specific conditional pressure requirements other than generalizing it as adequate pressure. A general summary of the contract terms for water supply of each wholesale customer is listed in Table 3.2.

The historical average day sales for each wholesale customer is listed in Table 3.3. Since 2006, the average day sales for Derby represent approximately 54 percent of the total wholesale customer sales on an annual basis. Review of the table indicates that average day sales have been relatively stable since 2006 across all wholesale customers. The minimum, average, and peak sales from 2006 to 2015 are 3.6 MGD, 4.1 MGD, and 4.8 MGD, respectively, for all wholesale customers combined. Additionally, excluding years 2011 and 2012, which are representative of dry years, the net change in average day sales is approximately 121 gpm.

Figure 3.1
Historical Retail Meter Counts

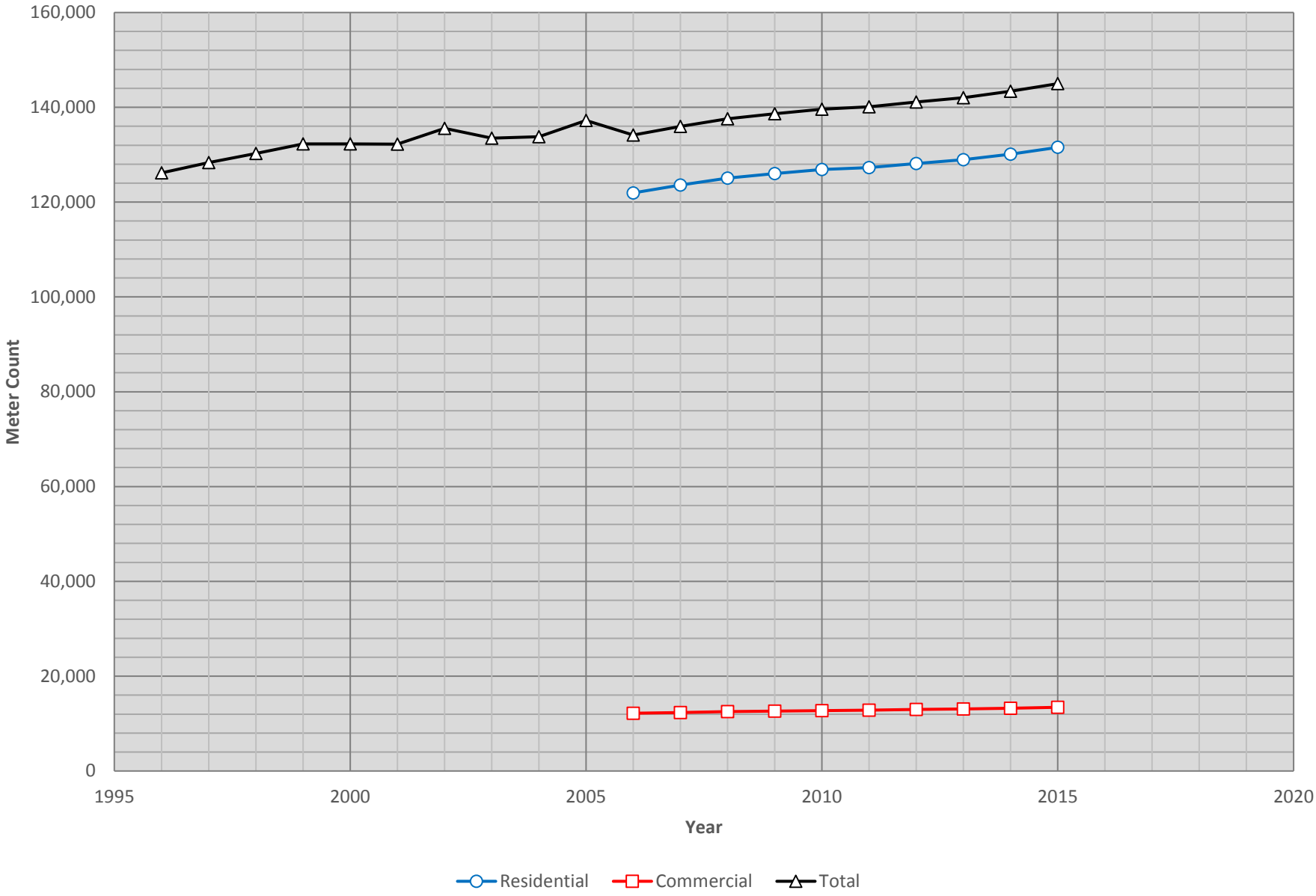


Figure 3.2
Historical Retail Sales & Metered Usage

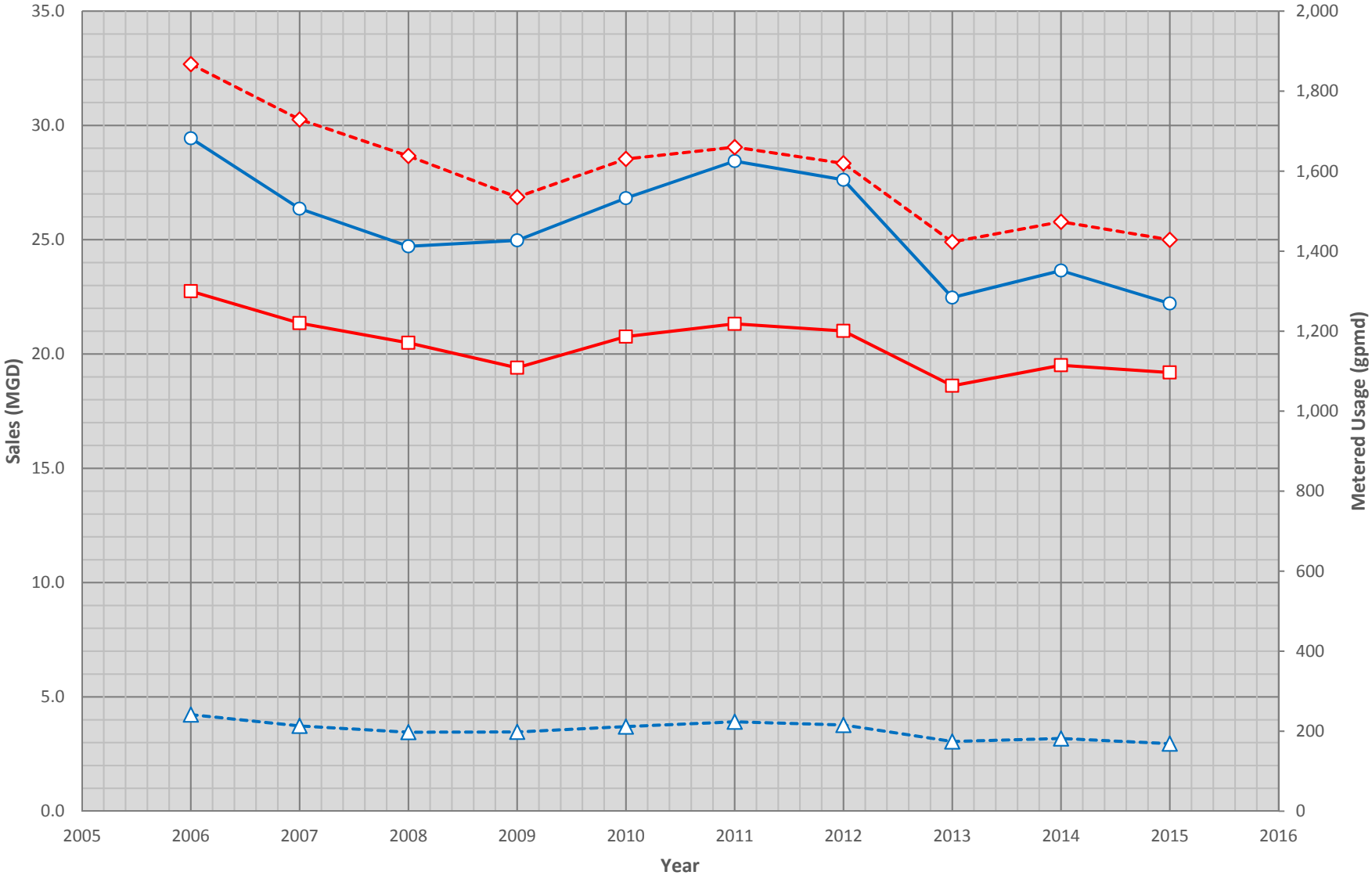


Table 3.2

Wholesale Customer Contract Conditions[1]

Customer	Average Daily Contract Amount (gpm) by Planning Period[2]				Contract Conditions					
	2015	2020	2035	2045	Supply Type	2015 Annual Volume (MG)	Pressure	Start Year	End Year	Type
RWD No. 1	71	81	Note 3	Note 3	Annual Volume	37.4	Adequate	2010	2030	Take or Pay 50%
RWD No. 3	342	371	Note 3	Note 3	Annual Volume	179.7	Not Applicable	1996	2016	Take or Pay 50%
RWD No.'s 5 & 8	73	84	Note 3	Note 3	Annual Volume	38.3	Not Applicable	1996	2016	Take or Pay 50%
Bel Aire	546	603	Note 3	Note 3	Annual Volume	287.0	Adequate	2008	2028	Take or Pay 50%
Park City	1,185	1,402	Note 3	Note 3	Annual Volume	623.1	Not Applicable	1985	2025	Pay as you go
Kechi	124	133	Note 3	Note 3	Annual Volume	65.0	Not Applicable	1997	2024	Take or Pay 50%
Benton	63	Note 3	Note 3	Note 3	Annual Volume	33.0	Not Applicable	1975	2015	Pay as you go
Rose Hill	628	723	Note 3	Note 3	Annual Volume	330.0	Adequate	1982	2022	Pay as you go
Valley Center	594	Note 3	Note 3	Note 3	Annual Volume	312.2	Not Applicable	1997	2016	Take or Pay 50%
Derby	1,735	1,870	Note 3	Note 3	Annual Volume	912.0	Adequate	2001	2022	Take or Pay 100%

Notes:

1. The contract conditions listed in this table are intended to be a general summary of the conditions relative to this Water Master Plan and are not all inclusive.
2. Planning periods listed represent the years evaluated in this Water Master Plan.
3. Contract expires before the planning period indicated in the column.

Table 3.3
Historical Wholesale Customer Sales

Year	Average Day Sales[1,2] (gpm)										Total (gpm)	Total (MGD)
	RWD No. 1	RWD No. 3	RWD No. 5 & 8	Bel Aire	Park City	Kechi	Benton	Rose Hill	Valley Center	Derby		
1991	51	99	0	343	124	40	42	194	0	0	893	1.3
1992	1	106	0	267	104	41	40	179	0	0	738	1.1
1993	60	20	0	289	73	41	40	184	0	0	707	1.0
1994	52	1	57	365	82	49	43	217	0	0	866	1.2
1995	53	0	60	340	79	50	45	205	0	0	832	1.2
1996	57	1	55	374	77	58	49	219	0	0	889	1.3
1997	51	0	0	0	0	0	48	215	0	0	315	0.5
1998	0	0	0	0	0	0	0	0	0	0	0	0.0
1999	53	3	62	0	0	0	49	213	0	0	380	0.5
2000	64	1	62	507	72	77	58	247	366	0	1,453	2.1
2001	39	14	62	514	87	90	49	225	507	0	1,588	2.3
2002	66	5	67	490	97	97	52	233	421	0	1,527	2.2
2003	18	1	90	300	45	96	54	228	421	0	1,254	1.8
2004	16	0	55	272	79	87	48	205	384	0	1,147	1.7
2005	21	5	58	255	88	98	53	221	432	1,412	2,645	3.8
2006	59	1	66	245	72	102	0	228	440	1,475	2,689	3.9
2007	56	2	60	221	101	96	0	216	396	1,400	2,550	3.7
2008	48	16	58	273	87	82	0	210	377	1,333	2,483	3.6
2009	50	0	56	192	100	101	0	201	384	1,420	2,504	3.6
2010	61	10	60	234	102	112	0	218	424	1,558	2,779	4.0
2011	64	249	72	199	161	114	13	197	401	1,840	3,310	4.8
2012	62	319	67	262	186	117	48	209	405	1,665	3,340	4.8
2013	51	261	65	266	99	92	42	204	358	1,425	2,863	4.1
2014	54	267	62	241	108	103	44	191	365	1,563	2,997	4.3
2015	52	255	60	214	106	93	41	192	308	1,492	2,812	4.0

Notes:

1. Data from 1991 to 2005 collected from the City's Annual Water Use Reports.
2. Data from 2006 to 2015 collected from the City's customer billing system; meter count is determined as the unique premise number tied to each customer account in the customer billing system.

The historical metered consumption and contract water supply volumes from 2006 to 2015 for each wholesale customer are illustrated in Figure 3.3. On average since 2011, RWD No.'s 1, 3, 5/8, Kechi and Derby utilized over 80 percent of their respective contract amounts. Bel Aire, Benton, Rose Hill, and Valley Center utilized between 34 and 65 percent over the same period; and Park City utilized approximately 12 percent of the contract amount. The metered consumption portion of the contract amount on annual basis for each wholesale customer is listed in Table 3.4; maximum, average, and minimum portions for the data ranges from 2006 to 2015 and from 2011 to 2015 are also listed in Table 3.4.

3.4 Seasonal Water Consumption

Monthly average day sales data from 2006 to 2015 was evaluated to determine seasonal characteristics for water consumption. The average day sales by month during this period is listed in Table 3.5. Four demand seasons were sequestered by averaging monthly sales and evaluating a running total for all 12 months within a 3 month selection. This evaluation identifies the months that fall into the categories listed below:

- High demand season: July, August, and September;
- Moderately high demand season: April, May, and June;
- Moderately low demand season: October, November, and December; and
- Low demand season: January, February, and March.

Recent historical monthly average day sales from 2011 to 2015 for the residential, commercial, wholesale, and utility customer classifications is illustrated in Figures 3.4, 3.5, 3.6, and 3.7; the total for all customer classes is illustrated in Figure 3.8. The residential, commercial, and wholesale customer classifications reflect the seasonal demand characteristics described in the paragraphs above. The utility classification is fairly consistent, but does include periodic months in which the average day sales double. Utility average day sales represent a fraction of the total; since 2006 average day sales have not exceeded more than 0.16 percent of the total.

3.5 Large Users

The top twenty large users from 2011 to 2015 were filtered from the average day sales data provided by the City to compare rankings from year to year and is illustrated in Figure 3.9. This data format exposes significant increases or losses in average day sales that is representative of customer gains and losses. Approximately 75 percent of the large users over this time period have average day sales ranging from approximately 35 gpm to 100 gpm. The top 2 large users have held their ranking since 2011; their

Figure 3.3
Historical Contract Amounts vs. Metered Consumption

Table 3.4
Metered Consumption Portion of Water Supply Contract Amount

Year(s)	RWD No. 1	RWD No. 3	RWD No. 5 & 8	Bel Aire	Park City	Kechi	Benton	Rose Hill	Valley Center	Derby
2006	--	--	68%	70%	9%	95%	--	50%	56%	97%
2007	--	--	61%	62%	12%	88%	--	45%	81%	91%
2008	--	--	58%	57%	10%	74%	--	42%	75%	85%
2009	--	--	--	40%	11%	89%	--	39%	75%	90%
2010	99%	3%	59%	47%	11%	97%	--	41%	81%	97%
2011	102%	78%	111%	40%	16%	98%	20%	36%	75%	112%
2012	95%	98%	101%	51%	18%	98%	77%	37%	73%	100%
2013	76%	79%	95%	51%	9%	76%	66%	35%	63%	85%
2014	78%	79%	87%	45%	10%	84%	70%	31%	63%	91%
2015	73%	75%	82%	39%	9%	75%	66%	31%	52%	86%
Data Range										
2006-2015										
Max	102%	98%	111%	70%	18%	98%	77%	50%	81%	112%
Average	87%	69%	80%	50%	11%	87%	60%	39%	70%	93%
Min	73%	3%	58%	39%	9%	74%	20%	31%	52%	85%
2011-2015										
Max	102%	98%	111%	51%	18%	98%	77%	37%	75%	112%
Average	85%	82%	95%	45%	12%	86%	60%	34%	65%	95%
Min	73%	75%	82%	39%	9%	75%	20%	31%	52%	85%

Notes:

1. The metered consumption portions listed above are based on the data illustrated in Figure 2.3 with respect to the annual contract amounts.

Table 3.5
Seasonal Demand Evaluation

Year	Demand Season (MGD)											
	Low			Moderately High			High			Moderately Low		
	January	February	March	April	May	June	July	August	September	October	November	December
2006	43.6	39.2	45.9	46.8	55.6	67.4	72.8	78.3	67.6	66.6	47.2	40.6
2007	36.0	46.2	49.4	40.0	41.8	54.4	54.0	78.8	65.1	64.9	52.3	33.8
2008	50.8	49.5	40.1	37.5	45.8	47.8	57.2	65.1	63.4	51.9	31.7	44.1
2009	47.0	40.0	40.3	42.6	39.0	63.6	63.5	60.9	56.7	48.8	42.5	30.8
2010	40.2	39.9	41.9	40.1	41.0	63.3	69.2	74.6	64.2	57.8	46.6	39.7
2011	36.7	42.9	48.9	43.2	43.0	67.8	65.1	94.5	66.8	64.6	47.7	32.9
2012	45.1	39.0	38.9	38.3	53.3	59.9	82.9	84.5	61.1	54.9	48.9	33.2
2013	46.4	33.6	36.3	38.2	35.9	47.3	59.6	53.6	58.6	54.7	39.9	37.5
2014	40.4	37.0	37.6	37.6	49.0	56.6	55.4	57.1	61.4	57.0	38.0	41.8
2015	38.2	34.1	38.9	41.9	40.1	46.9	60.1	56.1	48.6	53.8	44.2	41.8
Monthly Average[1]	42.4	40.1	41.8	40.6	44.5	57.5	64.0	70.4	61.3	57.5	43.9	37.6
Running Total[2]	124.4			142.6			195.7			139.0		
Seasonal Average[3]	41.5			47.5			65.2			46.3		

Notes:

1. Monthly average is based on years 2006 through 2015.
2. Running total is the summation of the monthly averages within the respective demand season
3. Seasonal average is based on the monthly average within the respective demand season

Figure 3.4
Seasonal Demand Characteristics: Residential Customer Class

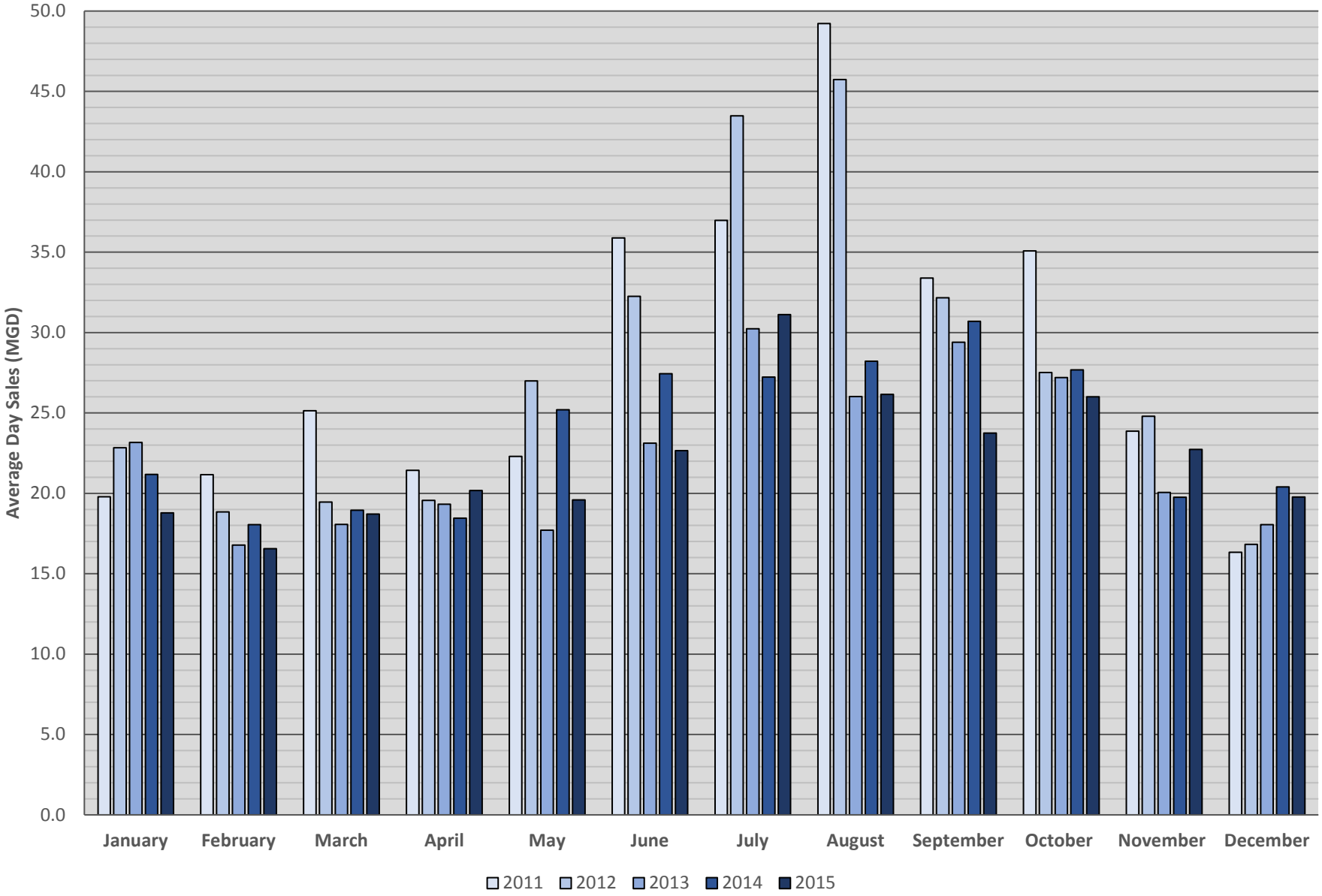


Figure 3.5
Seasonal Demand Characteristics: Commercial Customer Class

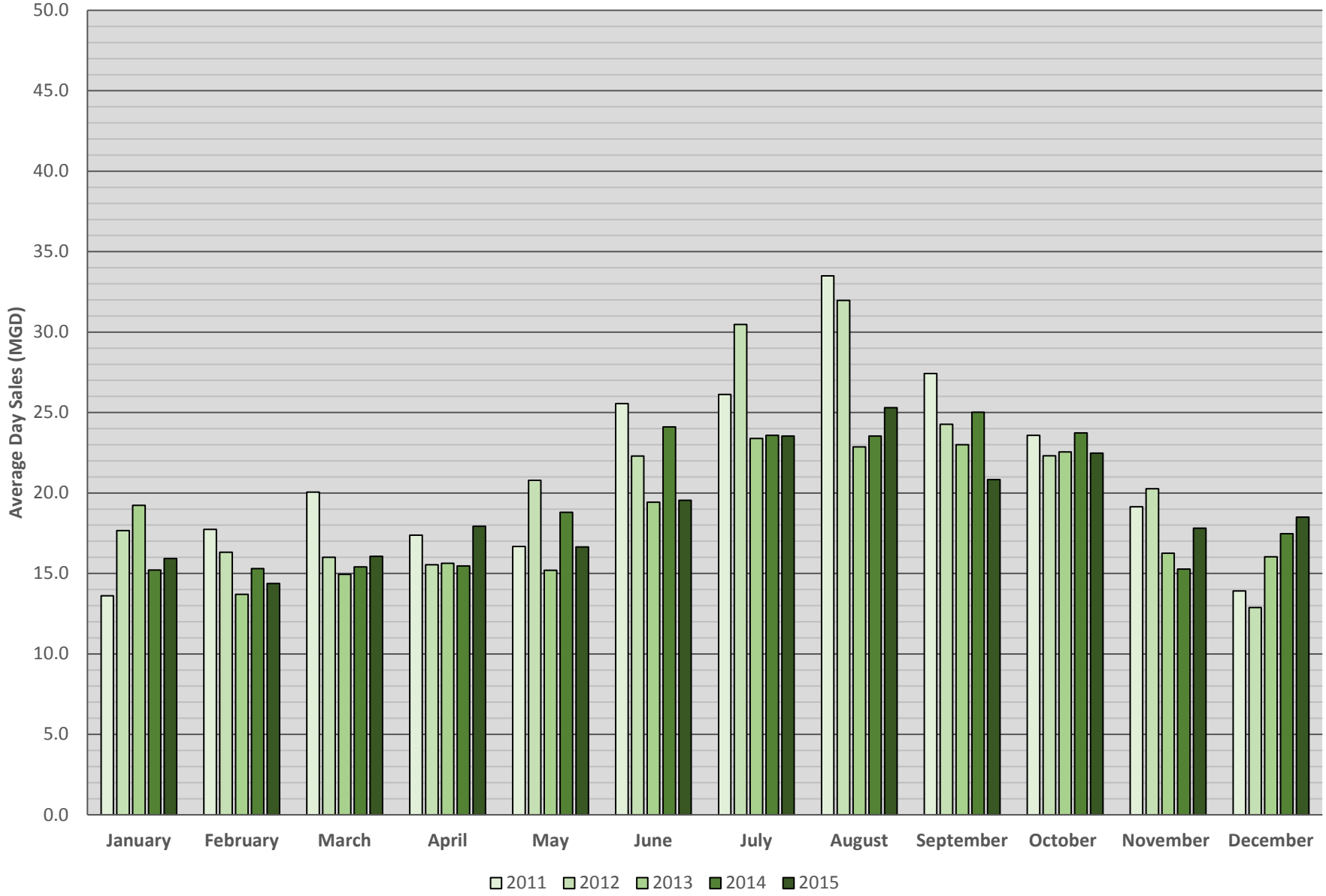


Figure 3.6
Seasonal Demand Characteristics: Wholesale Customer Class

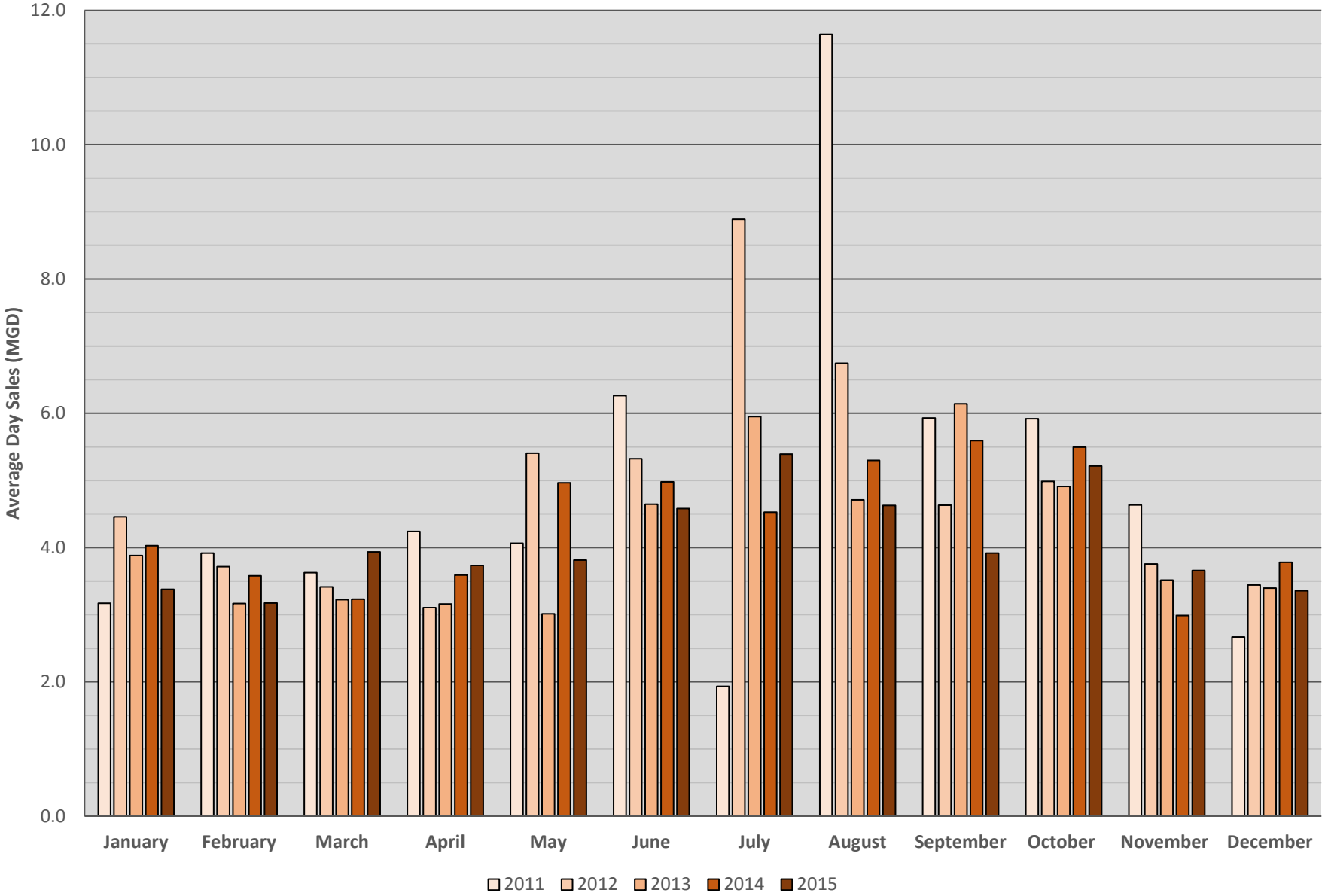


Figure 3.7
Seasonal Demand Characteristics: Utility Customer Class

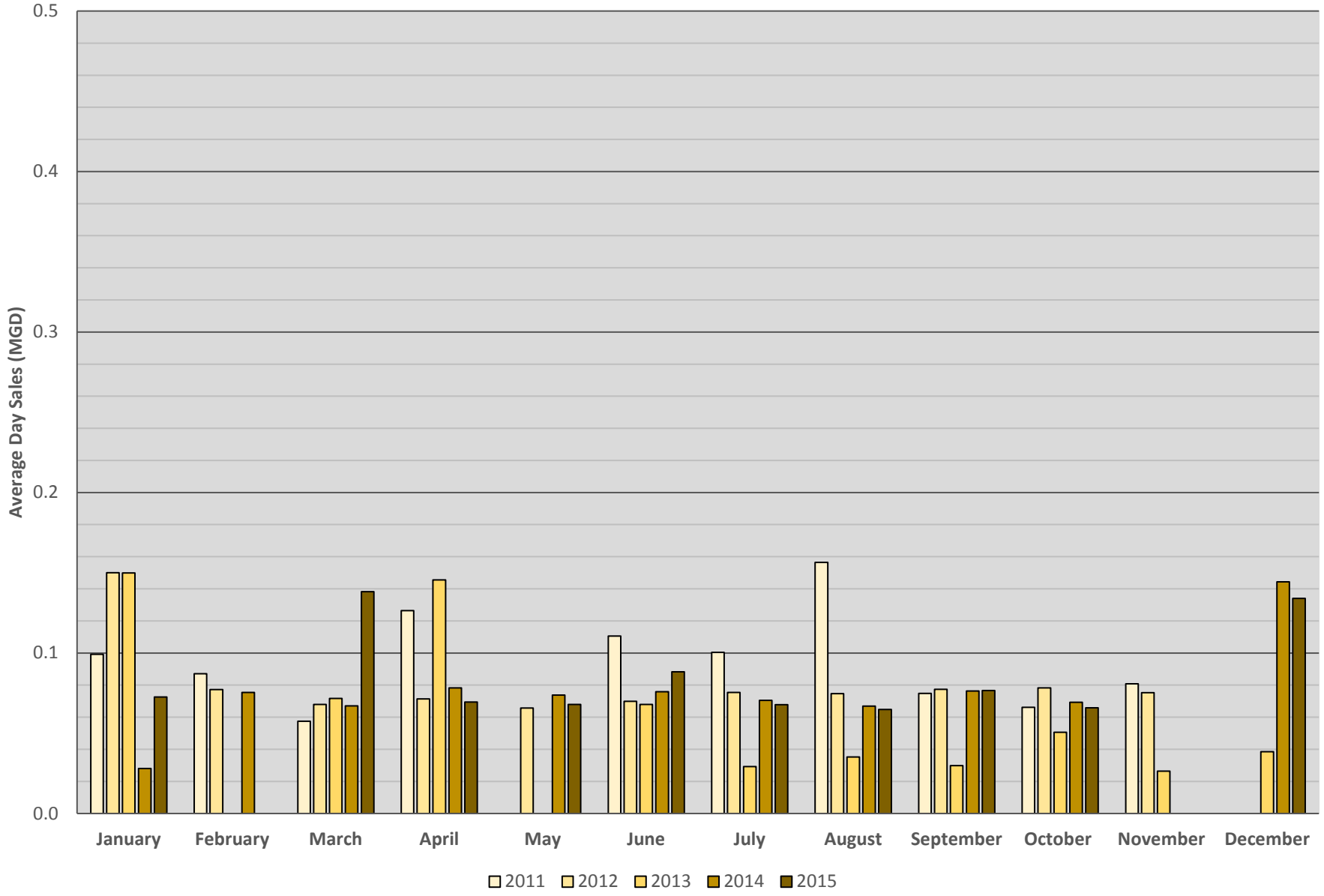


Figure 3.8
Seasonal Demand Characteristics: All Customer Classes

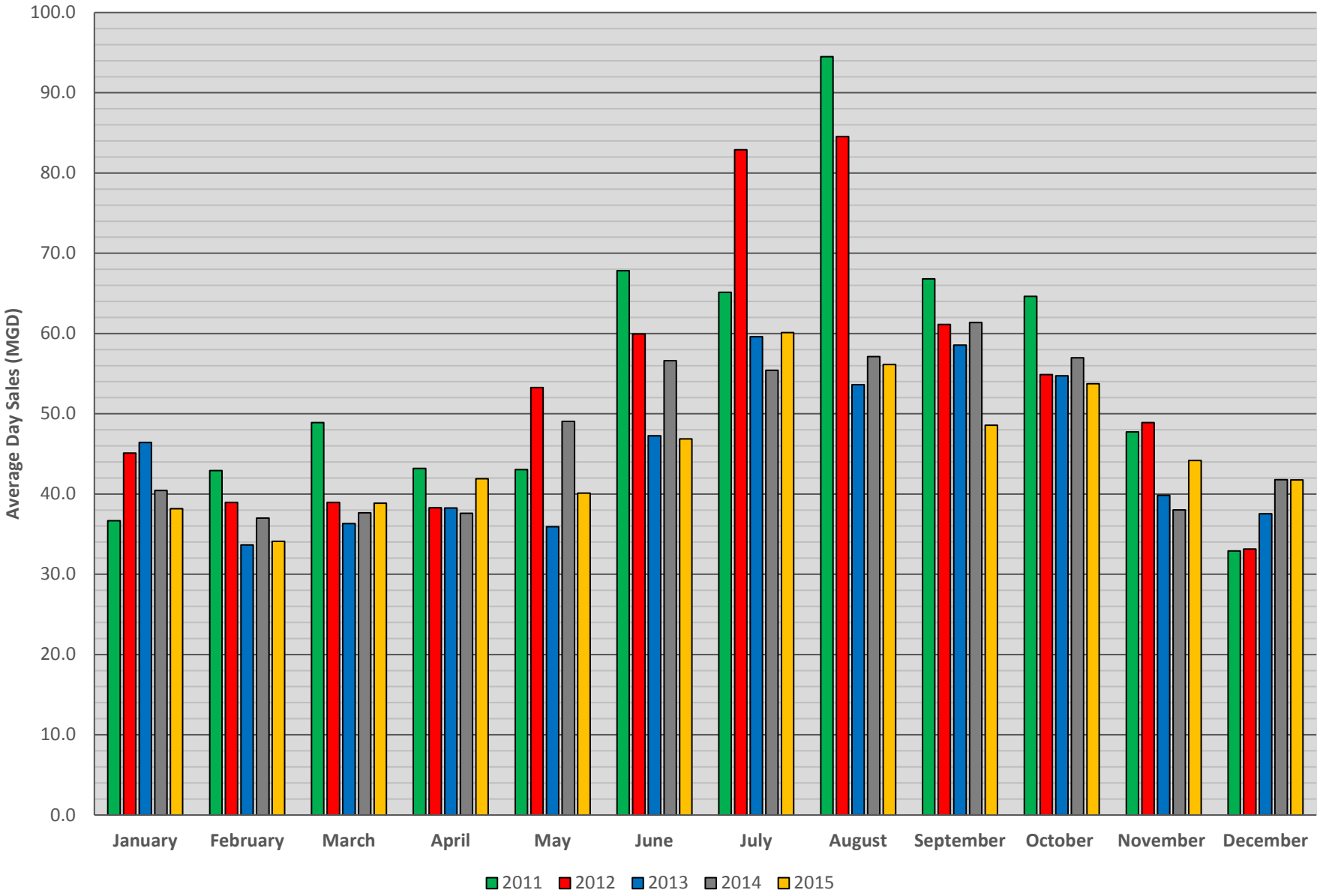
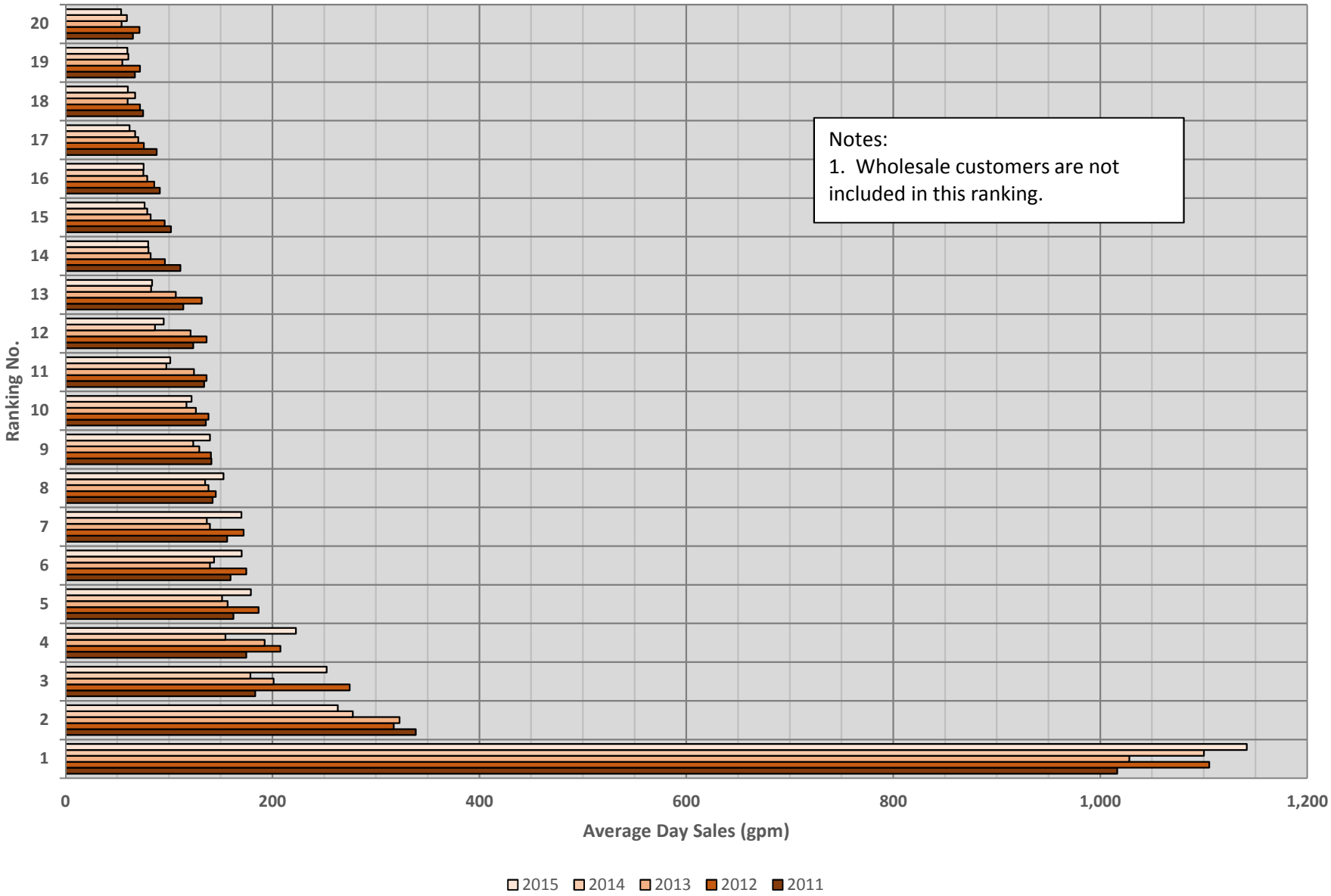


Figure 3.9
Historical Top 20 Large Users



premise numbers are 33450 and 34883 respectively. The demand allocation in the model for the top twenty large users is done manually for quality assurance.

3.6 Water Demand Projections

The 2013 WDA developed a range of population-based water demand projections through 2060; references to information from the 2013 WDA in this report are tied to the planning periods evaluated in this Water Master Plan (WMP) for years 2015, 2020, 2035, and 2045. High, medium, and low growth water demand projections were developed in the 2013 WDA for the entire service area (retail and wholesale combined). The City also prepared average day demand projections that were presented in the 2015 Water Resources Plan through 2060.

A population-based approach is an effective method for projecting a range of potential water demands at a low level and a good secondary check if other approaches are used; however, there are inherent inconsistencies with a population-based projection as it relates to the City of Wichita which are described below:

- Population-based demand projections assume the entire population is served by the City and the entire population uses City water for all water use needs;
- Population-based demand projections do not consider customers that provide their own law watering irrigation systems from private wells, industrial customers, or acknowledge the impact commercial customers have on the total demand and the distribution system;
- Dry year water usage is not incorporated; gpcd only considers metered WTP flow for a selected year for the entire projection period;
- The projection granularity is insufficient for master planning with respect to wholesale customers because it requires a projection for each wholesale customer so they are evaluated at their respective metering locations; and
- A gpcd value can overestimate water demand for wholesale customers with little or no commercial presence in their communities.

The water demand projections are based on projected meter counts by customer class for the retail consumption, a combination of contract maximums and escalating projections from current sales to the contract maximums for wholesale customers, nonrevenue water, and dry year water use adder. This approach removes inherent inconsistencies described above and accounts for:

- The metered population purchasing water from the City;
- Specific water use trending for residential and commercial customer classes;

- Allocating future demand based on development characteristics for residential versus commercial;
- Historical consumption trending paired with contracted amounts for wholesale customer usage; and
- Recent historical review of wet and dry years to develop a dry year water use adder for both residential and commercial customer classes.

A comprehensive historical summary since 2006 of the retail and wholesale average day sales, average day and maximum day demands, nonrevenue water, and the water demand projections with the dry year adder described above is listed in Table 3.6 and illustrated in Figure 3.10.

3.6.1 Retail Component

The retail customer component of the water demand projections is based on recent historical water usage in gallons per meter day (gpmd) and meter projections. The average water usage since 2013 is approximately 175 gpmd and is the baseline for the projecting water demand beginning in 2016. The recent high water use period occurred in 2011 and 2012 and is applied in the dry year water use component of the demand projections. Retail meter projections are based on 1,070 meters per year with a baseline of 131,550 meters from the year 2015.

The commercial customer component of the water demand projections is consistent with retail component. The average water usage since 2013 is 1,287 gpmd and is the baseline for projecting water demand beginning in 2016. Commercial meter projections are based on 150 meters per year with a baseline of 13,435 meters from the year 2015.

Spirit is the City's largest commercial water user and has averaged approximately 1.6 MGD annually since 2011. Beginning in 2017, Spirit's water supply needs will be accomplished with 40 percent reuse water and in 2018 and beyond the long term plan includes 70 percent reuse. However, the City is still responsible for providing Spirit's entire water supply need on an emergency basis if reuse water is unavailable. Therefore, the average day demand projections include the reduction in water supply due to reuse and the maximum day demand projections include their recent historical peak demand of approximately 2.5 MGD (no reuse present) which occurred in 2013.

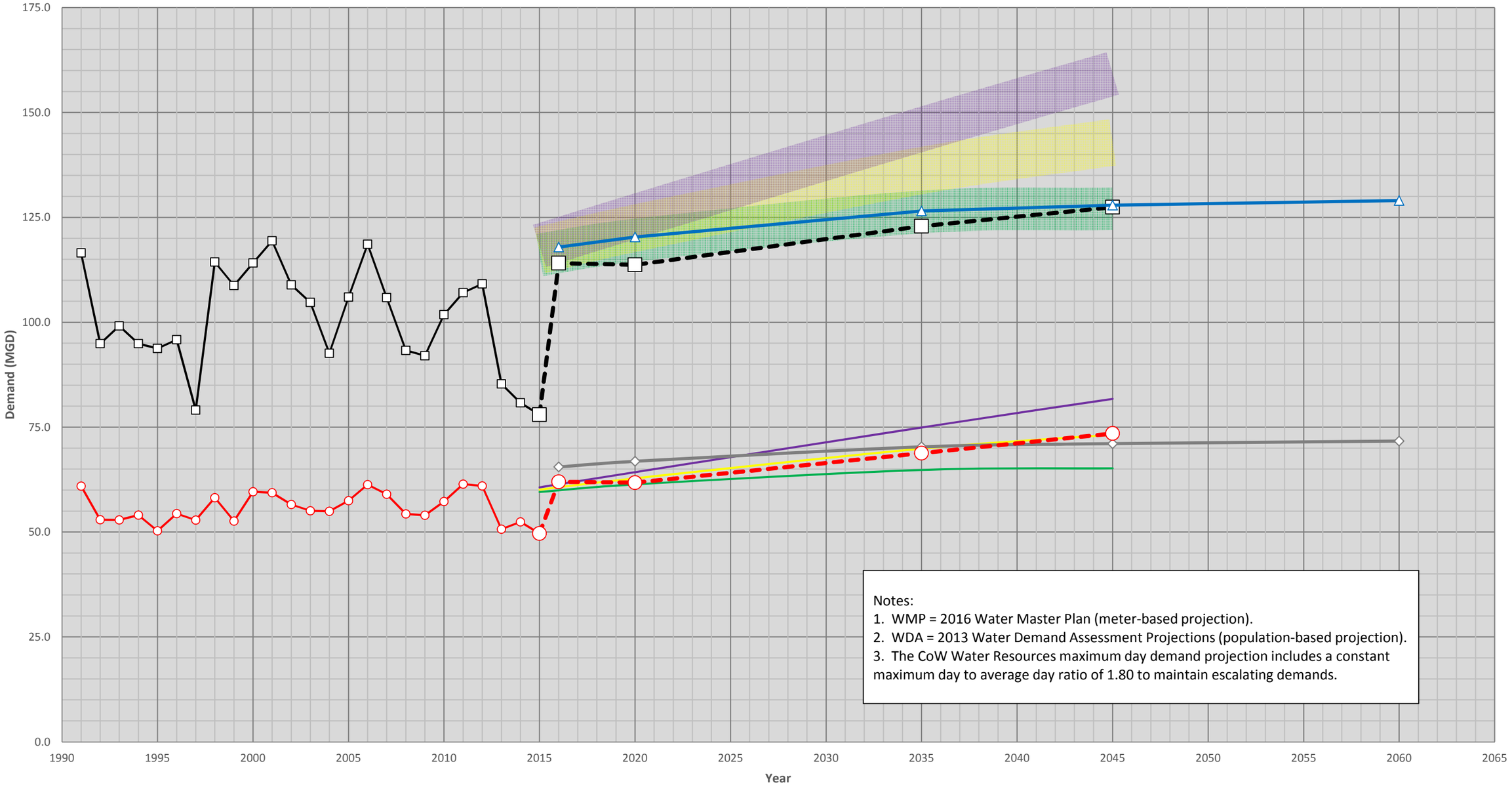
Table 3.6
Water Demand Projections

Year	Meter-Based Projections																				Water Resources Plan Projections		
	Retail											Retail & Wholesale Average Day Sales (MGD)					Nonrevenue Amount	Nonrevenue (MGD)	Average Day (MGD)	Maximum Day[3] (MGD)	Maximum Day Factor	Average Day (MGD)	Maximum Day[3] (MGD)	Maximum Day Factor
	Meter Count			Metered Usage (gpmd)			Dry Year Adder (gpmd)		Projected Water Usage (gpmd)														
	Residential	Commercial	Spirit	Residential	Commercial	Spirit[1]	Residential	Commercial	Residential	Commercial	Spirit	Residential	Commercial	Spirit	Wholesale[2]	Total								
2006	121,942	12,182	--	241	1,868	--	--	--	--	--		29.4	22.8		3.9	56.1	9%	5.2	61.3	118.6	1.94	--	--	--
2007	123,608	12,347	--	213	1,729	--	--	--	--	--		26.4	21.4		3.7	51.4	13%	7.6	59.0	105.9	1.79	--	--	--
2008	125,064	12,510	--	198	1,638	--	--	--	--	--		24.7	20.5		3.6	48.8	10%	5.5	54.3	93.3	1.72	--	--	--
2009	126,002	12,638	--	198	1,535	--	--	--	--	--		25.0	19.4		3.6	48.0	11%	6.0	54.0	92.0	1.70	--	--	--
2010	126,874	12,733	14	211	1,630	195,576	--	--	--	--		26.8	20.8	2.7	4.0	54.3	5%	3.0	57.3	101.8	1.78	--	--	--
2011	127,279	12,830	14	223	1,253	180,682	--	--	--	--		28.4	16.1	2.5	4.8	51.8	16%	9.6	61.4	107.1	1.74	--	--	--
2012	128,144	12,959	14	216	1,245	177,307	--	--	--	--		27.6	16.1	2.5	4.8	51.0	16%	9.9	61.0	109.2	1.79	--	--	--
2013	128,934	13,064	14	174	1,228	183,143	--	--	--	--		22.5	16.0	2.6	4.1	45.2	11%	5.5	50.7	85.3	1.68	--	--	--
2014	130,127	13,228	14	182	1,190	204,703	--	--	--	--		23.7	15.7	2.9	4.3	46.6	11%	5.9	52.4	80.8	1.54	--	--	--
2015	131,550	13,421	14	169	1,160	217,625	--	--	--	--		22.2	15.6	3.0	4.0	44.9	10%	4.8	49.7	78.0	1.57	--	--	--
2016	132,620	13,571	14	175	1,193	192,692	45	56	220	1,249	192,692	29.1	16.9	2.70	7.0	55.8	11%	6.1	62.0	114.1	1.80	65.5	117.9	1.80
2020	136,900	14,171	14	175	1,193	57,808	45	56	220	1,249	57,808	30.1	17.7	0.81	7.0	55.6	11%	6.1	61.8	113.7	1.80	66.9	120.3	1.80
2035	152,950	16,421	14	175	1,193	57,808	45	56	220	1,249	57,808	33.6	20.5	0.81	7.0	62.0	11%	6.8	68.8	122.9	1.75	70.3	126.5	1.80
2045	163,650	17,921	14	175	1,193	57,808	45	56	220	1,249	57,808	36.0	22.4	0.81	7.0	66.2	11%	7.3	73.5	127.4	1.70	71.1	127.9	1.80

Notes:

1. Projected Spirit water usage assumes 40 percent reuse beginning in 2017 and 70 percent reuse in 2018 through 2045; this is eqivalent to 60 percent and 30 percent of the historical average in 2017 and 2018 through 2045. Spirit's 2016 metered usage is based on the historical average from 2011 to 2015.
2. RWD No.'s 1, 3, 5/8, Kechi, Benton, Valley Center, and Derby projections at the contract maximimum. Bel Air and Rose Hill projections are estimated at 75 percent of their contract maximum. Park City projection estimated at 25 percent of the contract maximum.
3. Maximum day demand projections include 2.5 MGD for Spirit; CoW is responsible for providing all Spirit water demand if reuse capability cannot be provided. The maximum day demand for Spirit in 2013 was 2.47 MGD.

Figure 3.10
Water Demand Projections



3.6.2 Dry Year Water Use Adder

Incorporating a dry year water use adder in the demand projections is a conservative approach because a dry year will eventually reoccur. Representative dry and wet periods have occurred in the last 5 years. In 2011 and 2012, the metered water usage (in gallons per meter-day, gpmd) peaked and represents a dry period; the average water usage was 219 gpmd and 1,325 for residential and commercial respectively. From 2013 to 2014, the metered water usage was at a 10-year low and, more specifically, 2014 and 2015 were wet years; the average water usage from 2013 to 2015 was 175 gpm and 1,287 gpmd for residential and commercial respectively. The dry year water use adder is the difference between average water use between the dry and wet periods described above. The water demand projections are based on the water usage listed below for retail customers:

- Residential:
    - Base water usage = 175 gpmd;
    - Dry year water use adder = 45 gpmd; and
    - Projected water usage = 220 gpmd.
- Commercial:
    - Base water usage = 1,287 gpmd;
    - Dry year water use adder = 37 gpmd; and
    - Projected water usage = 1,325 gpmd.

3.6.3 Wholesale Component

The wholesale customer component of the water demand projections is based on historical average and maximum metrics for average day sales pairings by two time periods between 2006 and 2015 and from 2011 to 2015 relative to their maximum contract amounts. The demand projections are based on the criteria listed below; the corresponding wholesale customers that apply are also listed with their projection:

- If the average sales amount is greater than 50 percent and the maximum amount is greater than 70 percent in either time period (from 2006 to 2015 or from 2011 to 2015), then the maximum contract amount is applied:
    - RWD No. 1 = 81 gpm;
    - RWD No. 3 = 371 gpm;
    - RWD No. 5/8 = 84 gpm;
    - Kechi = 133 gpm;
    - Benton = 63 gpm;
    - Valley Center = 594 gpm;

    - Derby = 1,870 gpm.
- If the average sales amount is between 30 and 50 percent and the maximum amount is between 50 and 70 percent in either time period, then 75 percent of the maximum contract amount is applied:
    - Bel Aire = 452 gpm;
    - Rose Hill = 542 gpm.
- If the average sales amount is between 10 and 30 percent and the maximum amount is between 10 and 50 percent in either time period, then 50 percent of the maximum contract amount is applied:
    - Park City = 701 gpm.

For clarity, the demand projections listed above apply to all planning periods evaluated in this Water Master Plan.

3.6.4 Nonrevenue Water

Nonrevenue water is determined as the difference between the WTP HSPS metered flow and the total customer metered sales (retail and wholesale). Nonrevenue water ranged from 8 percent to 13 percent since 2006 and averaged approximately 11 percent. Since 2011, nonrevenue water is descending, from 11 percent to 8 percent, and can be related, but not limited to, the decline in average day sales. The nonrevenue component included in the water demand projections is 11 percent based on recent historical information and the assumption that demand projections will escalate as the City grows to the 2045 planning period.

3.6.5 Maximum Day Demand Factor

Since 2006, the maximum day to average day ratio (or maximum day factor) ranged from 1.54 to 1.94, with an average of 1.73. Recent historical maximum day factors since 2012 include a value of 1.79 occurring in 2012; 2014 and 2015 are representative of wet years and recorded the lowest factors since 2006 of 1.54 and 1.57 respectively. Since 2006, the maximum day factor has been descending, therefore, the projections begin conservatively with a high factor of 1.80 beginning in 2016 and the trend of descending factors is anticipated to continue through the planning periods evaluated. The factors for each planning period are as follows:

- Year 2020 at 1.80;
- Year 2035 at 1.75; and
- Year 2045 at 1.70.

3.6.6 Conclusion

The meter-based water demand projections discussed in Section 3.6 and the population-based water demand projections from the 2013 WDA are illustrated Figure 3.10. The average day demand projection (meter-based) most closely follows the medium growth projection from the 2013 WDA. The maximum day demand projection (meter-based) falls within the low growth projection range through 2045.

The City also developed an average day water demand projection as part of the 2015 Water Resources Plan and includes a 1 percent drought and targets a 0.35 percent conservation effort through year 2060. In 2014, the City decided on a 1 percent drought tolerance to provide greater water supply resiliency. Water conservation is also part of the City's long term strategy to reduce the need for a new water supply source. Additionally, conservation efforts have reduced the base demand over the last 5 years as stated in the Water Resources Plan. Applying a constant maximum day to average day factor of 1.80 throughout the planning period is representative of the meter-based water demand projection. The average day and maximum day demand projections developed in the Water Resources Plan are listed below, listed in Table 3.6, and illustrated in Figure 3.10:

- 2016 at approximately 66 MGD and 118 MGD respectively.
- 2020 at approximately 67 MGD and 120 MGD respectively.
- 2035 at approximately 70 MGD and 127 MGD respectively.
- 2045 at approximately 71 MGD and 128 MGD respectively.
- For information only, in 2060 at approximately 72 MGD and 129 MGD respectively.

The meter-based average day and maximum day demand projections by planning period are summarized below for comparison to the Water Resources Plan projections:

- 2016 at approximately 62 MGD and 114 MGD respectively.
- 2020 at approximately 63 MGD and 115 MGD respectively.
- 2035 at approximately 70 MGD and 125 MGD respectively.
- 2045 at approximately 75 MGD and 129 MGD respectively.

After review of the meter-based water demand projections and comparison with the Water Resources Plan, City staff concludes the projections from Water Resources Plan are adequate for the hydraulic modeling and evaluation for the development of capital improvements in this Water Master Plan.

* * * * *

- **Updated Outcome-Based Goals**
  - Prevent economic distress of consumers due to occurrence of DRP Stages 3 and 4
  - Must maintain both Cheney Reservoir and EBWF as viable resources at all times
  - Utilize 40,000 AF per year from EBWF prior to use of ASR Recharge Credits

By running MODSIM-DSS with the updated 1% drought simulation variables, an optimized daily raw water demand is generated for each water resource. The results of the 1% drought MODSIM-DSS simulation indicate that both the EBWF and Cheney Reservoir can be kept viable through the drought by utilizing ASR recharge credits and the City's DRP (Table 2-3). Under these conditions the City must maintain the availability of all raw water resources (EBWF, ASR Recharge Credits, and Cheney Reservoir) to meet daily drought demands and prevent implementation of Stage 3 water restrictions. Further review of the reservoir accounting results indicates that Cheney Reservoir can be balanced such that the calculated minimum reservoir condition during the eight-year drought period is 42% of conservation pool, with an average of 62% (see Figure 2).

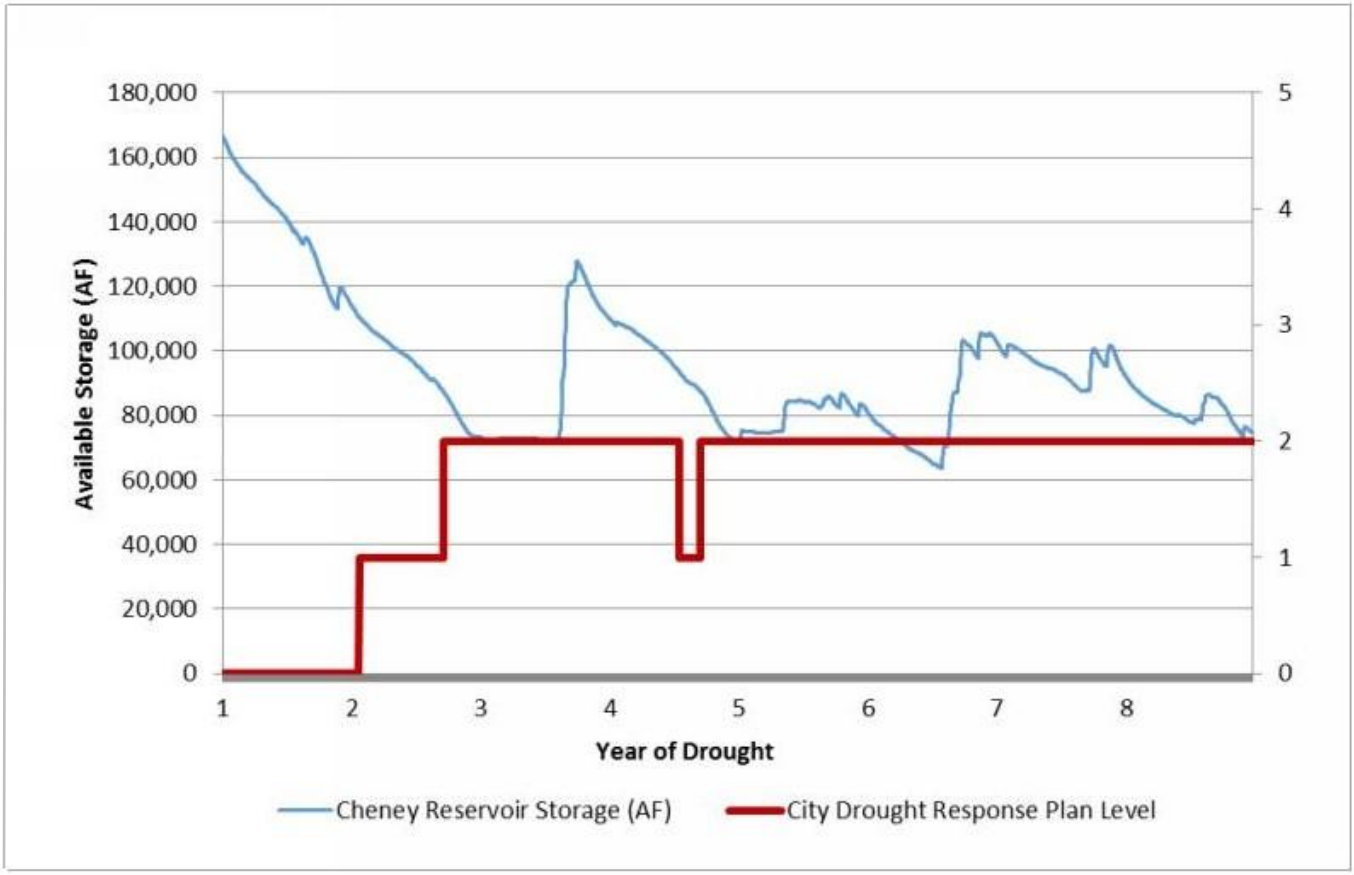
Table 2-3: *MODSIM-DSS simulation results for the 1% drought utilizing projected 2060 demands*

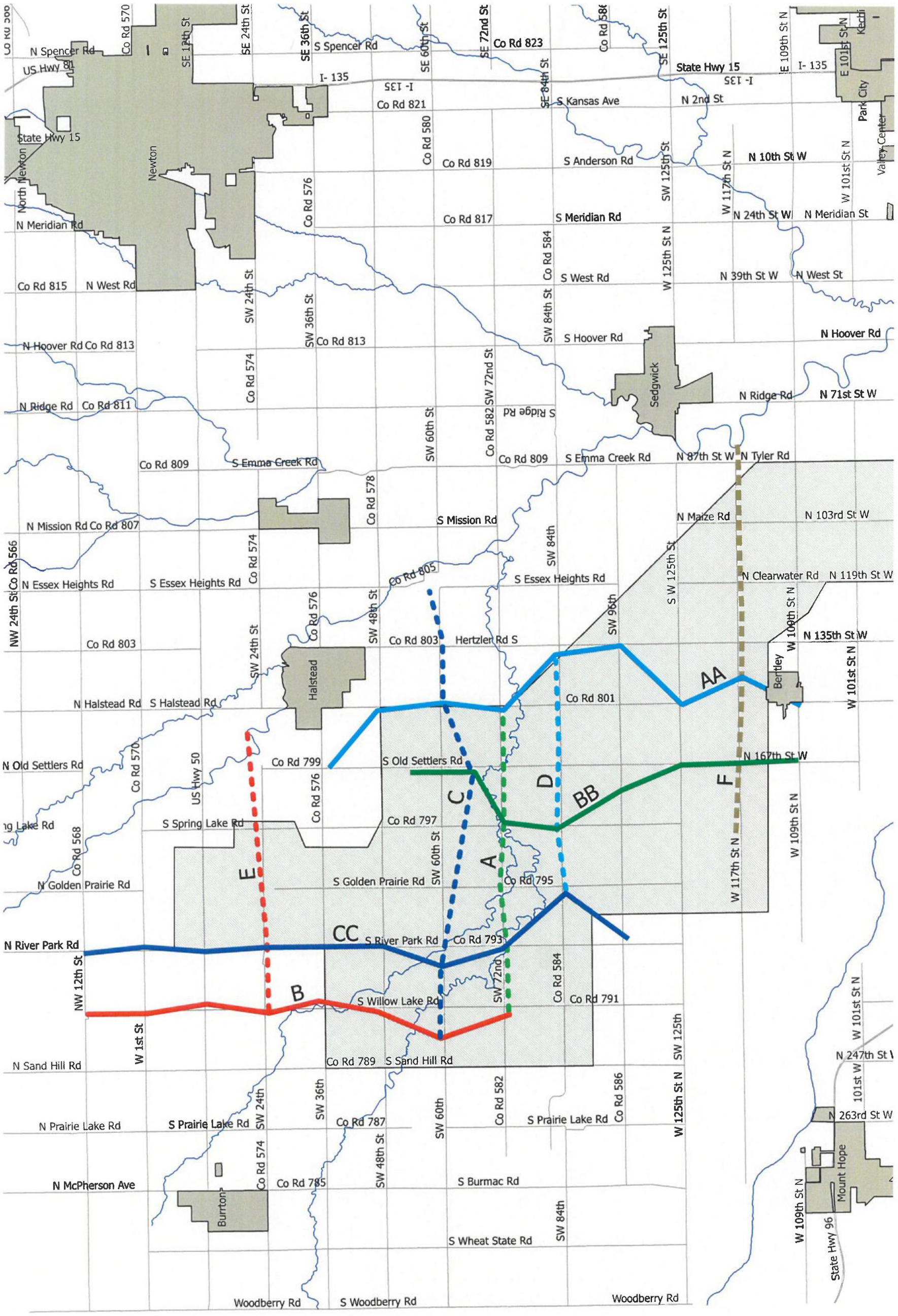
MODSIM-DSS Variable	Drought Year 1	Drought Year 2	Drought Year 3	Drought Year 4	Drought Year 5	Drought Year 6	Drought Year 7	Drought Year 8
Baseline City Demand (AF)	81,690	81,690	81,690	81,690	81,690	81,690	81,690	81,690
Simulated Calendar Year of Drought	1933	1934	1935	1936	1937	1938	1939	1940
Revised City Demand from Drought Response Plan (AF)	81,262	72,492	71,116	71,890	70,812	70,811	71,116	70,664
City Demand Assigned to EBWF & ASR	34,202	45,651	59,907	46,732	56,579	41,980	39,308	39,491
City Demand Assigned to Cheney Reservoir	47,060	26,841	11,209	25,158	14,233	28,831	31,808	31,173
Cheney % of Conservation Pool 12 Month Average	110%	92%	62%	59%	62%	53%	53%	63%

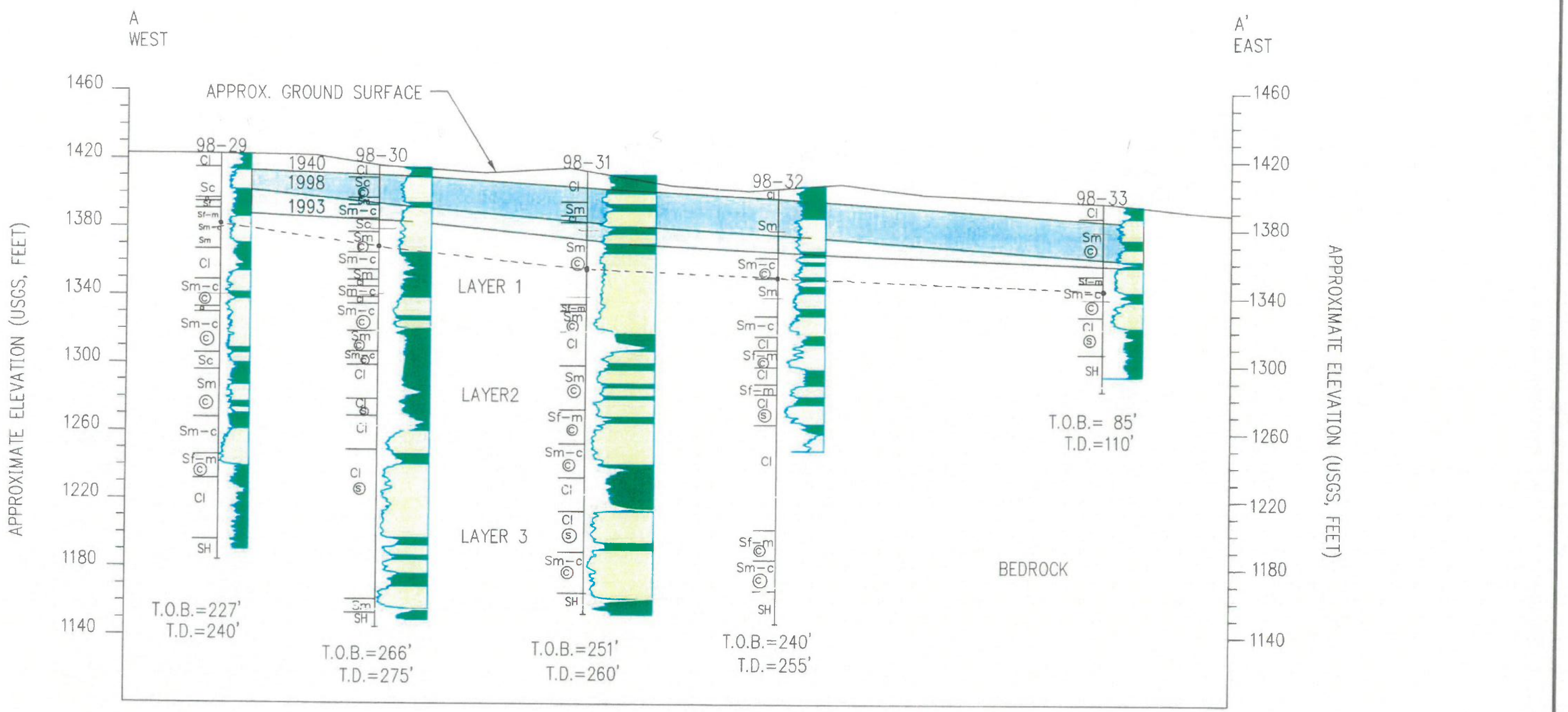
2.4 Groundwater Modeling Setup - 1% Drought Simulation

In 2009, to better understand the regional Equus Beds Aquifer and the effects on water levels due to current and planned ASR activities, the City contracted a study by the USGS. This study developed a three-dimensional finite-difference groundwater-flow model based on MODFLOW-2000. MODFLOW software is broadly recognized as the standard for simulation and prediction of groundwater conditions.

Figure 2 - *Results of 1% drought simulation using MODSIM-DSS, indicates Cheney Reservoir can be maintained viable through the drought utilizing by ASR credits and various levels of the City's adopted Drought Response Plan*




N Spencer Rd
US Hwy 81
Co Rd 570
SE 12th St
SE 24th St
SE 36th St
S Spencer Rd
I- 135
SE 60th St
SE 72nd St
Co Rd 823
Co Rd 821
SE 84th St
S Kansas Ave
SE 125th St
State Hwy 15
I- 135
E 109th St N
E 101st St N
Kechi
Park City
Valley Center
N 2nd St
State Hwy 15
North Newton
Newton
Co Rd 580
Co Rd 819
S Anderson Rd
SW 125th St
W 117th St N
N 10th St W
W 101st St N
N Meridian Rd
Co Rd 576
Co Rd 817
S Meridian Rd
N 24th St W
N Meridian St
Co Rd 815
N West Rd
SW 24th St
SW 36th St
Co Rd 813
Co Rd 584
S West Rd
W 125th St N
N 39th St W
N West St
SW 84th St
N Hoover Rd Co Rd 813
S Hoover Rd
N Hoover Rd
Co Rd 574
SW 72nd St
Sedgwick
N Ridge Rd
N 71st St W
N Ridge Rd Co Rd 811
S Ridge Rd
SW 60th St
Co Rd 582
Co Rd 809
S Emma Creek Rd
N 87th St W
N Tyler Rd
Co Rd 809
S Emma Creek Rd
Co Rd 578
S Mission Rd
N Maize Rd
N 103rd St W
N Mission Rd Co Rd 807
NW 24th St Co Rd 566
N Essex Heights Rd
S Essex Heights Rd
Co Rd 574
Co Rd 805
SW 84th
S W 125th St
N Clearwater Rd
N 119th St W
W 109th St N
Co Rd 803
Co Rd 576
SW 48th St
Co Rd 803
Hertzler Rd S
SW 96th
N 135th St W
W 101st St N
SW 24th St
Halstead
Bentley
AA
N Halstead Rd
S Halstead Rd
Co Rd 801
N Old Settlers Rd
Co Rd 570
US Hwy 50
Co Rd 799
S Old Settlers Rd
N 167th St W
Co Rd 576
C
D
BB
F
Co Rd 797
S Spring Lake Rd
W 109th St N
Co Rd 568
SW 60th St
E
A
N Golden Prairie Rd
S Golden Prairie Rd
Co Rd 795
W 117th St N
CC
N River Park Rd
S River Park Rd
Co Rd 793
NW 12th St
B
S Willow Rd
SW 72nd
Co Rd 584
Co Rd 791
W 1st St
SW 125th
W 101st St N
N 247th St
Co Rd 789
S Sand Hill Rd
N Sand Hill Rd
SW 36th
SW 60th
Co Rd 582
Co Rd 586
S Prairie Lake Rd
W 125th St N
101st W
N 263rd St W
N Prairie Lake Rd
S Prairie Lake Rd
SW 24th
Co Rd 787
SW 48th St
Co Rd 574
Co Rd 785
S Burmac Rd
Mount Hope
W 109th St N
N McPherson Ave
Burrton
SW 84th
S Wheat State Rd
State Hwy 96
Woodberry Rd
S Woodberry Rd
Woodberry Rd



CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm, H — SAND, CLAY, SAND, CLAY

GAMMA LOG RESPONSE

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

SCALE 1 IN = 3000 FEET
VERTICAL EXAGGERATION: 50

Burns & McDonnell

Figure VII-8

WICHITA EQUUS BEDS
RECHARGE PROJECT
CROSS-SECTION A-A'

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B

SOUTH

B'

NORTH

APPROX. GROUND SURFACE

APPROXIMATE ELEVATION (USGS, FEET)

1460 1420 1380 1340 1300 1260 1220 1180 1140

98-29 98-27 98-12 98-25 98-24 98-23 98-22 98-21

1940 1998 1993

LAYER 1

LAYER 2

LAYER 3

T.O.B.=227'
T.D.=240'

T.O.B.=218'
T.D.=240'

T.O.B.=246'
T.D.=260'

T.O.B.=269'
T.D.=280'

T.O.B.=215'
T.D.=220'

T.O.B.=198'
T.D.=215'

T.O.B.=261.5'
T.D.=270'

T.O.B.=190'
T.D.=200'

BEDROCK

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm / Cl

GAMMA LOG RESPONSE — SAND / CLAY / SAND / CLAY

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

SCALE 1 IN = 3000 FEET
VERTICAL EXAGGERATION: 50

Burns & McDonnell

Figure VII-9
WICHITA EQUUS BEDS
RECHARGE PROJECT
CROSS-SECTION B-B'

C

WEST

C'

EAST

APPROX. GROUND SURFACE

APPROXIMATE ELEVATION (USGS, FEET)

1460
1420
1380
1340
1300
1260
1220
1180
1140

98-27
98-13
98-34
98-14
98-15
98-6

1940
1998
1993

LAYER 1

LAYER 2

LAYER 3

BEDROCK

T.O.B.=218'
T.D.=240'

T.O.B.=256'
T.D.=270'

T.O.B.=192'
T.D.=200'

T.D.=156'

T.O.B.=130'
T.D.=140'

T.O.B.=165'
T.D.=170'

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm / Cl

GAMMA LOG RESPONSE — SAND / CLAY / SAND / CLAY

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

SCALE 1 IN = 3000 FEET
VERTICAL EXAGGERATION: 50

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

Burns & McDonnell

Figure VII-10

WICHITA EQUUS BEDS
RECHARGE PROJECT
CROSS-SECTION C-C'

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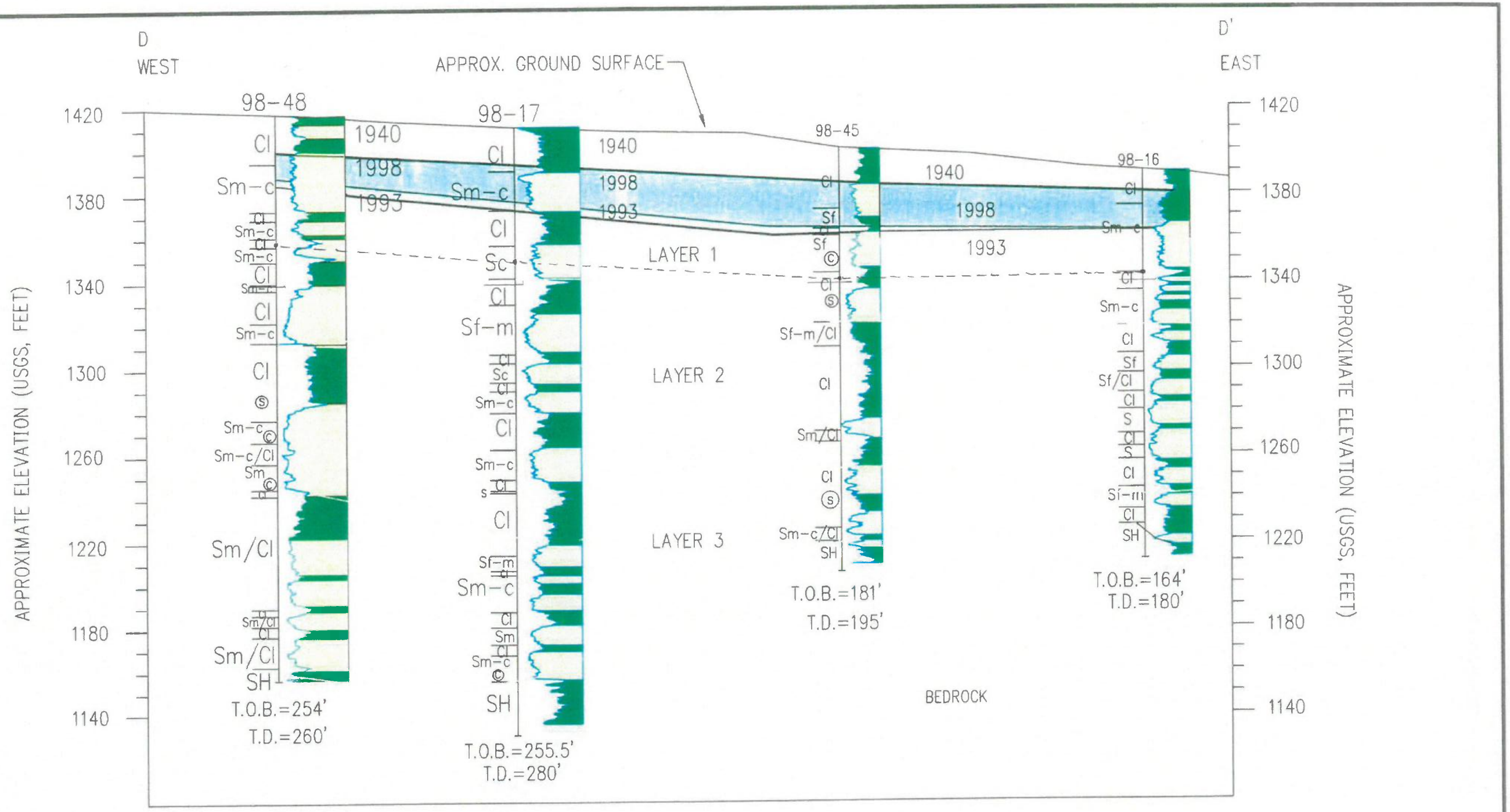

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm / GAMMA LOG RESPONSE — SAND / CLAY

1940	1940 WATER LEVEL ELEVATION
1993	1993 WATER LEVEL ELEVATION
1998	1998 WATER LEVEL ELEVATION
	DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

SCALE 1 IN = 2500 FEET
VERTICAL EXAGGERATION: 50

Burns & McDonnell SINCE 1898

Figure VII-11

WICHITA EQUUS BEDS RECHARGE PROJECT
CROSS-SECTION D-D'

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E

WEST

E'

EAST

APPROXIMATE ELEVATION (USGS, FEET)

APPROX. GROUND SURFACE

98-24

98-42

98-2

TH-04-95

98-72

1940

1998

1993

LAYER 1

LAYER 2

LAYER 3

T.O.B.=215'
T.D.=220'

T.O.B.=190'
T.D.=205'

T.O.B.=118'
T.D.=140'

T.O.B.=118'
T.D.=125'

T.O.B.=120'
T.D.=129'

1460
1420
1380
1340
1300
1260
1220
1180
1140

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm
GAMMA LOG RESPONSE — SAND / CLAY / SAND / CLAY

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

SCALE 1 IN = 3000 FEET
VERTICAL EXAGGERATION: 50

Burns & McDonnell

Figure VII-12

WICHITA EQUUS BEDS
RECHARGE PROJECT
CROSS-SECTION E-E'

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F

WEST

F'

EAST

APPROX. GROUND SURFACE

1940

1998

1993

LAYER 1

LAYER 2

LAYER 3

BEDROCK

98-68

T.O.B.=244'

T.D.=260'

98-57

T.O.B.=231'

T.D.=240'

98-58

T.O.B.=202'

T.D.=220'

98-62

T.O.B.=136'

T.D.=147'

TH-11-95

T.O.B.=153'

T.D.=158'

98-73

T.O.B.=136'

T.D.=150'

APPROXIMATE ELEVATION (USGS, FEET)

1420

1380

1340

1300

1260

1220

1180

1140

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm — SAND — CLAY — SAND — CLAY

GAMMA LOG RESPONSE

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

SCALE 1 IN = 3000 FEET

VERTICAL EXAGGERATION: 50

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

Burns & McDonnell

Figure VII-13

WICHITA EQUUS BEDS RECHARGE PROJECT

CROSS-SECTION F-F'

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G

NORTHWEST

G'

SOUTHEAST

APPROXIMATE ELEVATION (USGS, FEET)

1420
1380
1340
1300
1260
1220
1180

TH-07-95
TH-08-95
TH-09-95
98-04
98-08
98-28
98-09
TH-12-95

APPROX. GROUND SURFACE

1940
1998
1983

LAYER 1
LAYER 2
LAYER 3

T.O.B.=144'
T.D.=151'

T.O.B.=144'
T.D.=148'

T.O.B.=159'
T.D.=165'

T.O.B.=127'
T.D.=130'

T.O.B.= 88'
T.D.=100'

T.O.B.=104'
T.D.=115'

T.O.B.=105'
T.D.=115'

T.O.B.= 63'
T.D.= 70'

BEDROCK

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm — SAND / CLAY / SAND / CLAY

GAMMA LOG RESPONSE

1940 1940 WATER LEVEL ELEVATION

1993 1993 WATER LEVEL ELEVATION

1998 1998 WATER LEVEL ELEVATION

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

SCALE 1 IN = 3000 FEET
VERTICAL EXAGGERATION: 50

Burns & McDonnell

Figure VII-14

WICHITA EQUUS BEDS RECHARGE PROJECT
CROSS-SECTION G-G'
RIVER

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AA

SOUTH

AA'

NORTH

APPROX. GROUND SURFACE

APPROXIMATE ELEVATION (USGS, FEET)

1420
1380
1340
1300
1260
1220
1180
1140

98-19
98-57
98-56
98-54
98-16
98-33
98-14
98-36
98-37

1940
1998
1993

LAYER 1
LAYER 2
LAYER 3

T.O.B.=231'
T.D.=240'

T.O.B.=231'
T.D.=240'

T.O.B.=218'
T.D.=230'

T.O.B.=200'
T.D.=210'

T.O.B.=164'
T.D.=180'

T.O.B.= 85'
T.D.=110'

T.D.=156'

T.O.B.= 176'
T.D.=180'

T.O.B.= 182'
T.D.=190'

BEDROCK

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm — SAND — CLAY — SAND — CLAY — GAMMA LOG RESPONSE

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

SCALE 1 IN = 3600 FEET
VERTICAL EXAGGERATION: 60

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

Burns & McDonnell

Figure VII-15

WICHITA EQUUS BEDS
RECHARGE PROJECT
CROSS-SECTION AA-AA'

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BB

SOUTH

BB'

NORTH

APPROX. GROUND SURFACE

APPROXIMATE ELEVATION (USGS, FEET)

1420
1380
1340
1300
1260
1220
1180
1140

98-67
98-70
98-17
98-32
98-34
98-35

1940
1998
1993

LAYER 1

LAYER 2

LAYER 3

T.O.B.=226'
T.D.=235'

T.O.B.=261'
T.D.=270'

T.O.B.=255.5'
T.D.=280'

T.O.B.=240'
T.D.=255'

T.O.B.=192'
T.D.=200'

T.O.B.=194'
T.D.=220'

BEDROCK

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm

GAMMA LOG RESPONSE — SAND / CLAY / SAND / CLAY

1940 — 1940 WATER LEVEL ELEVATION

1993 — 1993 WATER LEVEL ELEVATION

1998 — 1998 WATER LEVEL ELEVATION

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

SCALE 1 IN = 3000 FEET
VERTICAL EXAGGERATION: 50

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

Burns & McDonnell SINCE 1898

Figure VII-16

WICHITA EQUUS BEDS RECHARGE PROJECT
CROSS-SECTION BB-BB'

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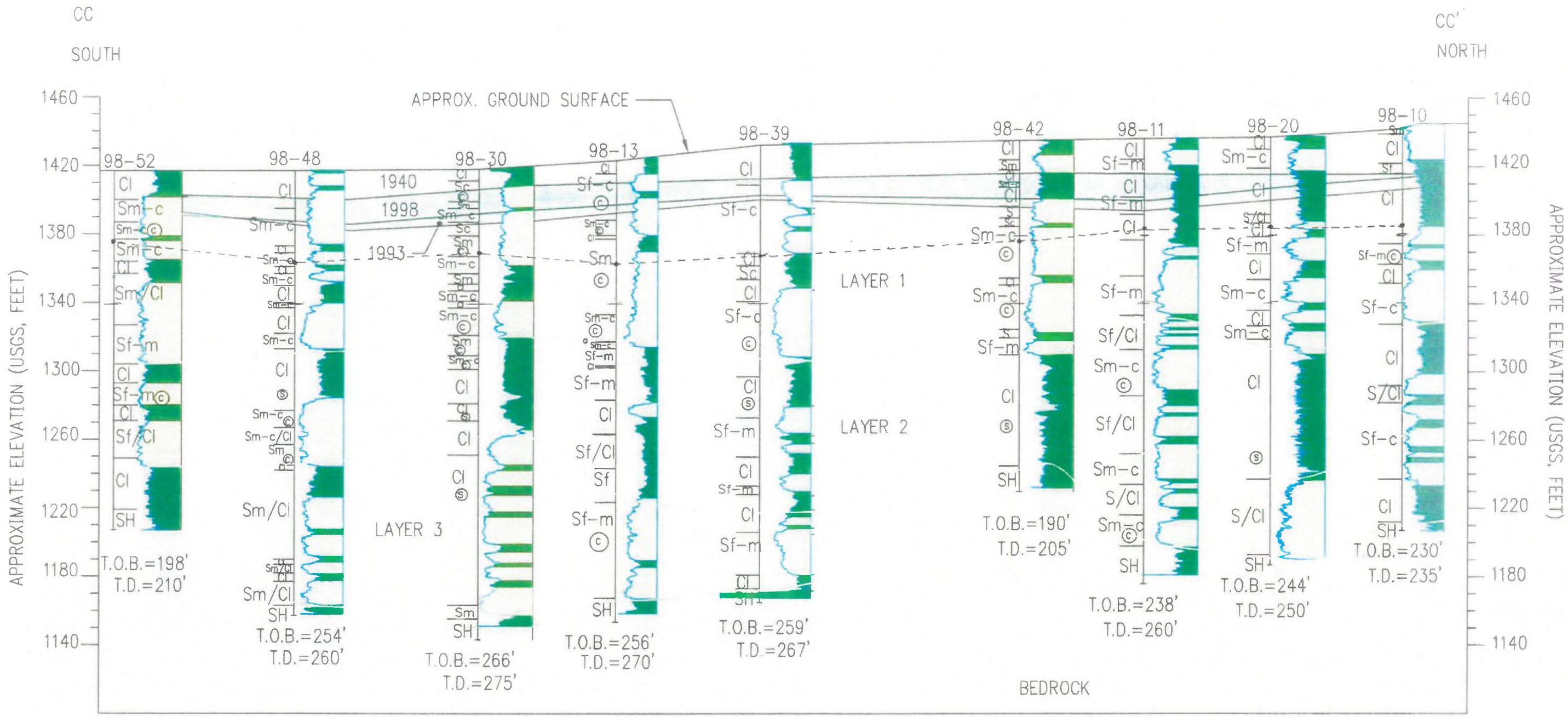

CROSS-SECTION INDEX

DRILLING LOG INFORMATION — Sm, SAND, CLAY, SAND, CLAY
GAMMA LOG RESPONSE

1940 **1940 WATER LEVEL ELEVATION**

1993 **1993 WATER LEVEL ELEVATION**

1998 **1998 WATER LEVEL ELEVATION**

DIFFERENCE IN WATER ELEVATION FROM 1940-1998, AND 1993-1998

LEGEND

T.O.B.	TOP OF BEDROCK
Cl	CLAY
Sf	FINE SAND (MED., m COARSE, c)
Sf-m	FINE TO MEDIUM SAND
Sm-C	MED. TO COARSE SAND
(C)	TRACE OF CLAY
(S)	TRACE OF SAND
T.D.	TOTAL DEPTH
SH	SHALE

SCALE 1 IN = 4200 FEET
VERTICAL EXAGGERATION: 70

NOTE: ELEVATION ESTIMATED FROM 7.5' USGS QUADRANGLE MAPS.

Burns & McDonnell SINCE 1898

Figure VII-17
WICHITA EQUUS BEDS RECHARGE PROJECT
CROSS-SECTION CC-CC'

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