edmond

A GREAT PLACE TO GROW

50 Year Water Supply Plan - Fin

May 2009

Prepared by CD

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List of Acronyms and Abbreviations

ACOE	Army Corps of Engineers
ACOG	Association of Central Oklahoma Governments
AF	acre-feet
AFM	Acre-Feet Per Month
AFY	Acre-Feet Per Year
As	Arsenic
Avg.	Average
CDM	Camp Dresser & McKee Inc.
CDP	Criterium Decision Plus
Cfs	cubic feet per second
City	City of Edmond
DEP	Department of Environmental Protection
EPA	U.S. Environmental Protection Agency
gpd	gallons per day
gpm	gallons per minute
GW	Groundwater
IRP	Integrated Resource Plan
M&I	Municipal and Industrial
mg	million gallon
mgd	million gallon per day
Mg/L	milligram per liter
mV	Measured Value
NTU	Nephelolometric Turbidity Units
O&M	Operation and Maintenance
ODEQ	Oklahoma Department of Environmental Quality
OKC	Oklahoma City
OPEDS	Oklahoma Pollution Discharge Elimination System
ORP	Oxidation-Reduction Potential

ORWUT	Oklahoma Regional Water Utilities Trust
OWRB	Oklahoma Water Resource Board
PER	Preliminary Engineering Report
pH	Hydrogen potential
ppt	Parts per trillion
RO	Reverse Osmosis
RW	Recycled Water
TDS	total dissolved solids
TN	Total Nitrogen
TP	Total Particulates
TSS	Total suspended solids
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
USACE	U.S. Army Corps of Engineers
WSP	Water Supply Plan
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

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Section 1
Introduction

1.1 Background

The City of Edmond (City) has experienced significant growth in the past three decades and is projected to continue to increase in population in the future. This expected population growth will results in water demands doubling from current levels by the year 2030. The City's current water supply sources include Arcadia Lake, groundwater from the Garber-Wellington Aquifer, and treated water purchases from Oklahoma City (OKC). Figure 1-1 shows the current breakdown of the City's water sources.

In 1999 the City of Edmond (City) hired Camp Dresser & McKee (CDM) to develop a Water System Master Plan to guide the City's water system investments through the next 20 years. The City has been implementing many of the recommendations from that master plan. An important finding from this Master Plan was that water supply from the City's existing supply sources, coupled with conservation, will be sufficient to meet projected demands through 2020.

In recognition that the City will continue to grow beyond the year 2020, and that water supply projects often take many years to develop and construct, a 50-year water supply plan was developed.

Figure 1-1 shows the percentage of the three supply sources for average of the last 10 years.

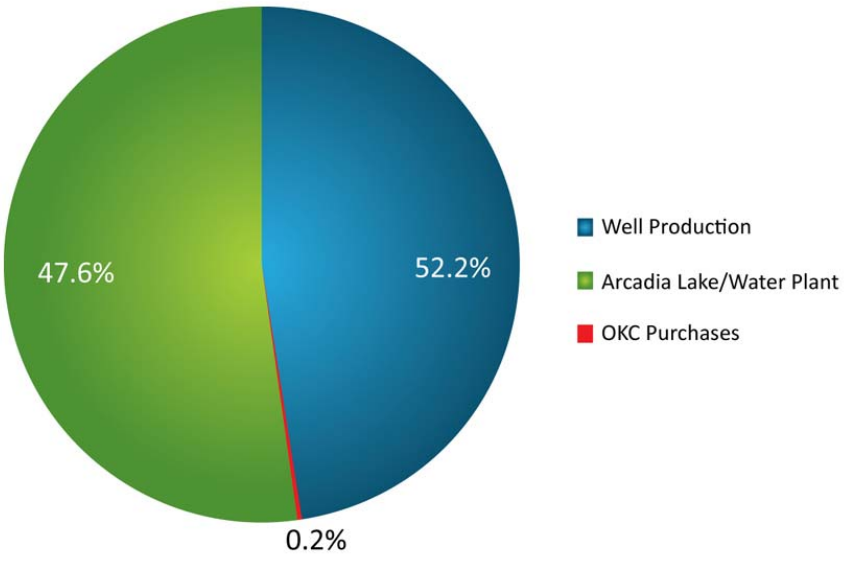


Figure 1-1
Existing City of Edmond Sources

1.2 Purpose of 50-Year Water Supply Plan

The main objective of this 50-Year Water Supply Plan (Supply Plan) was to evaluate a wide range of water supply and demand management alternatives, and to develop an implementation strategy that the City can use in developing new water supplies for the foreseeable future.

This Supply Plan includes the following main components:

- Evaluation of water supply and demand options, such as water reuse, conservation, expanded groundwater, and additional surface water
- Stakeholder involvement, to assure incorporation of citizen concerns in the overall development of the plan
- Use of lifecycle costs to reflect capital costs and O&M costs over the life of potential water supply options
- Incorporation of multiple objectives in decision-making, such as reliability, cost, environmental protection, water quality, flexibility etc.
- Incorporation of risk and uncertainty

1.3 Organization of the Report

This report documents the City's 50 year integrated resource planning process and resulting recommendations, in the following sections:

- Section 1 – Introduction
- Section 2 – Existing Water Supplies
- Section 3 – Water Demands
- Section 4 – Evaluation Framework
- Section 5 – Development of Water Supply Options
- Section 6 – Water Supply Alternatives
- Section 7 – Selection of Preferred Alternatives
- Section 8 – Summary and Implementation Plan
- Section 9 – References
- Technical Appendices

Section 2
Existing Water Supplies

This section describes the City's service area and existing water supplies and facilities. The system described in this section represents the basis for the Water Supply Plan.

2.1 Service Area Description

The City of Edmond is located within the Oklahoma County, just north of Oklahoma City. The boundary of the City encompasses an area of approximately 80 square miles. Figure 2-1 shows the location of the City with respect to other major cities and highways in the area. Within these boundaries, most of the areas to the west are densely populated urban areas and are serviced by City's water. Rural and residential areas, with sparse population, located within the boundaries rely on domestic private wells for their water use. Figure 2-2 shows the general distribution of land use within the City limits.

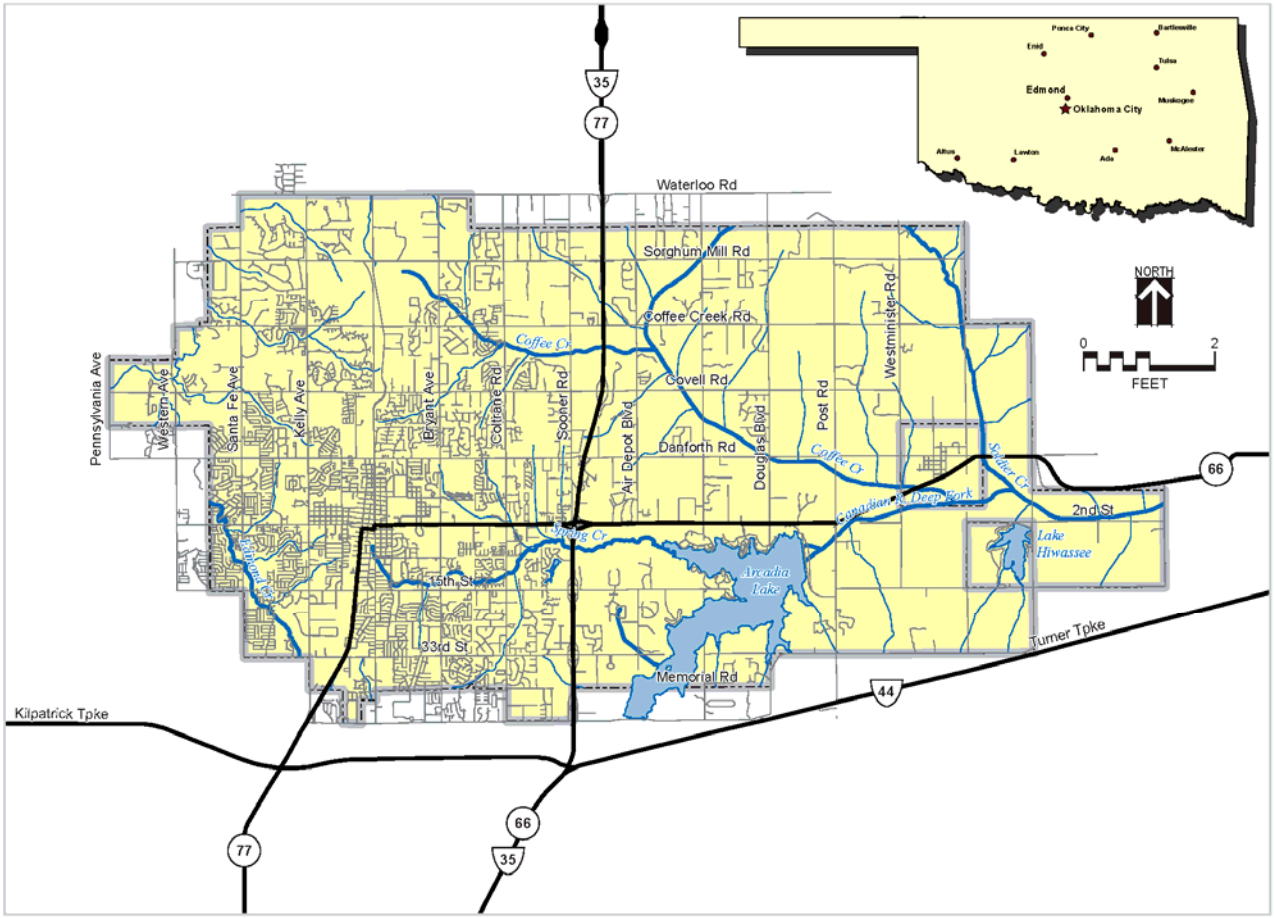


Figure 2-1
City of Edmond's Location Map

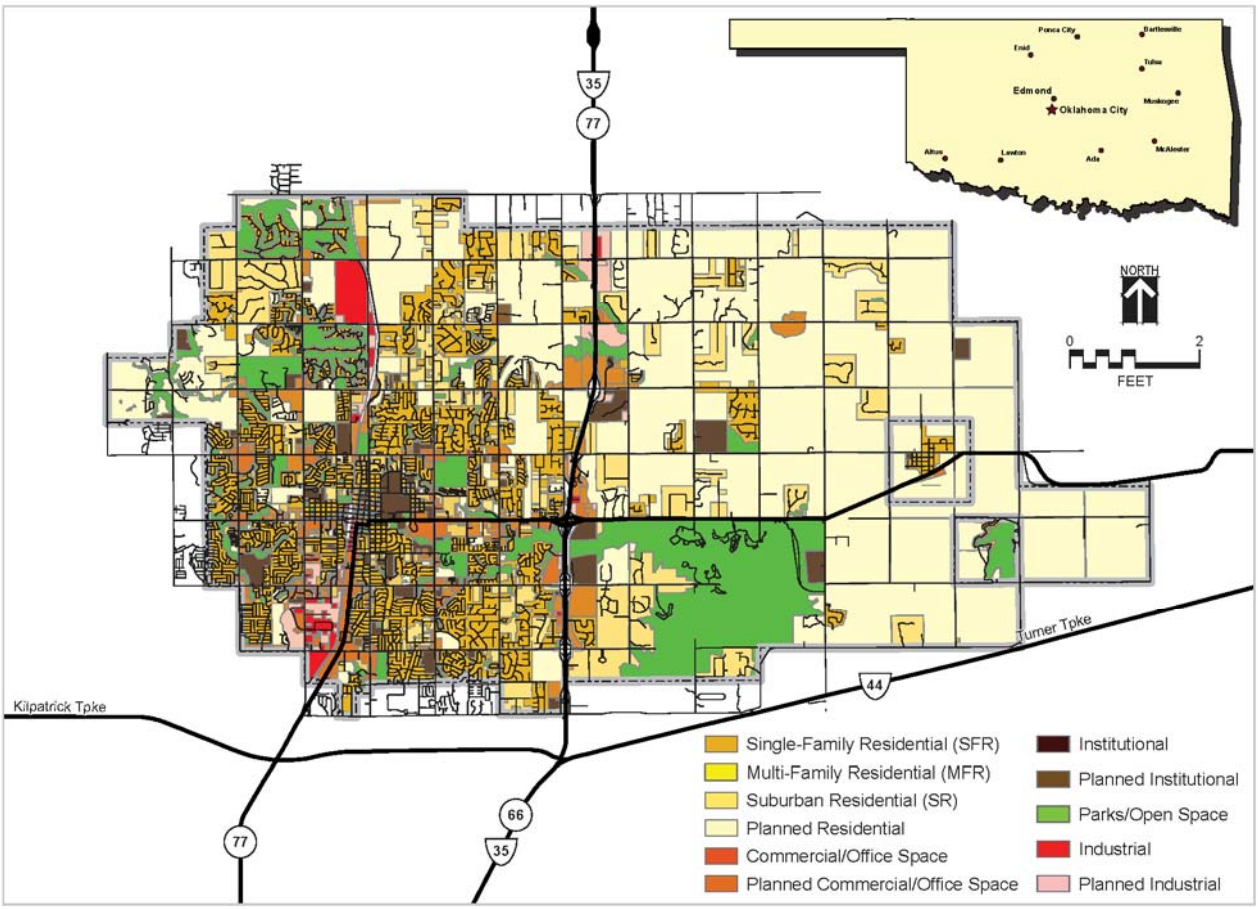


Figure 2-2
City of Edmond's Service Area and Land Use

The total population of the City is about 78,000 with a population density of 802.4 people per square mile. Based on United States Census data, the City has had significant growth since the 1960's. During the 1990's the City grew more than 20 percent. The City had built out conditions in the western portion and cannot expand to the north, west, or south because it is bound by the Logan County on the north and to the west and south by Oklahoma City. The majority of the eastern portion of the City consists of agricultural and rural residential areas. It is anticipated that this area will experience significant urban growth during the 50-year planning period.

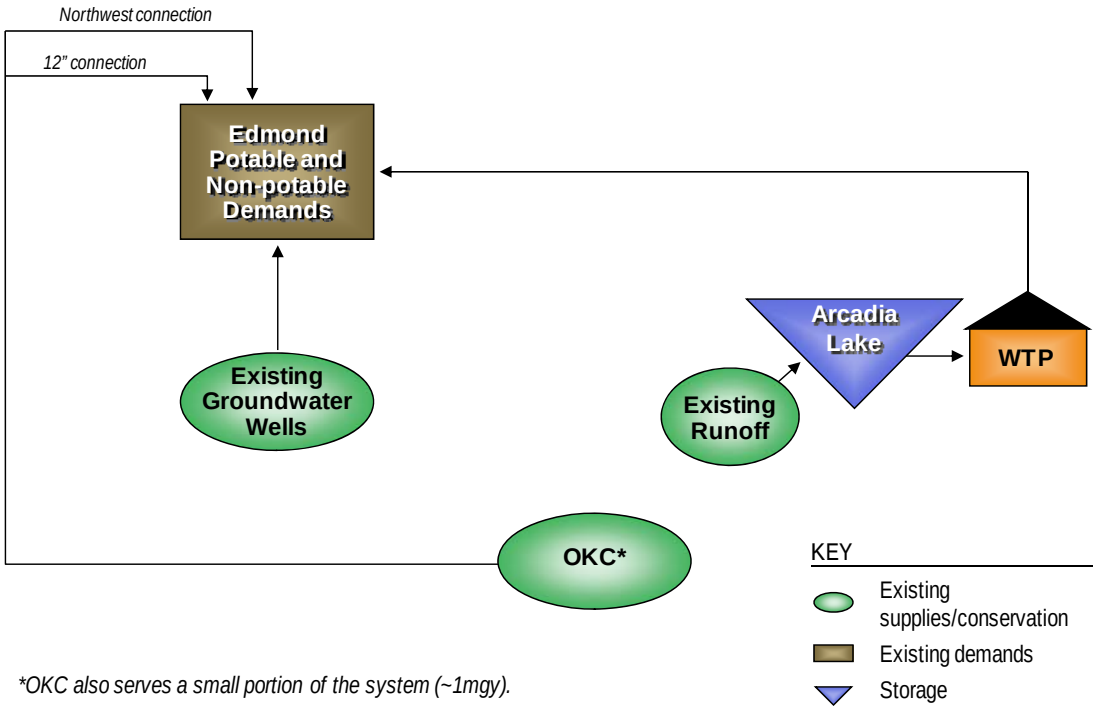
Average temperatures range from 36 ^{o} F in winters to 85 ^{o} F in summers. Annual precipitation is about 33.36 inches per year. Precipitation ranges from 2 inches in winters to 5.5 inches during summers. Average humidity in the City is around 78%.

2.2 Existing Water Supplies and Facilities

Figure 2-3 illustrates the City's existing water supplies including surface water, groundwater, and Oklahoma City treated water. Surface water is obtained from Arcadia Lake, which is located in the metropolitan area of Oklahoma City and Edmond. From 1998 to 2007, Arcadia Lake supplied approximately 47.6 percent of the City's water supplies. Raw water withdrawn from the lake is treated at the Arcadia Lake Water Treatment Plant (WTP).

The City's groundwater is extracted from the Garber-Wellington Formation aquifer and discharged into the City's distribution system. From 1998 to 2007 groundwater consisted of approximately 52.2 percent of the City's water supplies. The City has also historically received small amounts of treated Oklahoma City water through a 12 inch diameter interconnect located south of the City. This water was provided to the City on an as needed basis in 2001, 2003, and 2006.

In addition to these historical Oklahoma City water deliveries, a small area within the southern portion of the City limits receives an average of one million gallon per year of Oklahoma City treated water to supply all of their needs on a regular basis. This area is relatively isolated from the rest of the City's water distribution system and for purposes of this planning effort, is considered independent from the City's water system and so is not evaluated in this Plan.



*OKC also serves a small portion of the system (~1mgy).

Figure 2-3
Conceptual Layout of the City's Existing Water Supply System

Figure 2-4 illustrates the City's raw water production from 1998 to 2007 (City's raw water includes groundwater from wells and surface water from Arcadia Lake). The total average annual production has remained relatively stable with an average raw water production of 10.5 mgd. Production was highest in the years of 1998, 1999, 2001, and 2006. These years were relatively hot dry years resulting in higher customer water demands. Section 3 provides additional information on how the water demands and production has been influenced by weather patterns and population growth over the years.

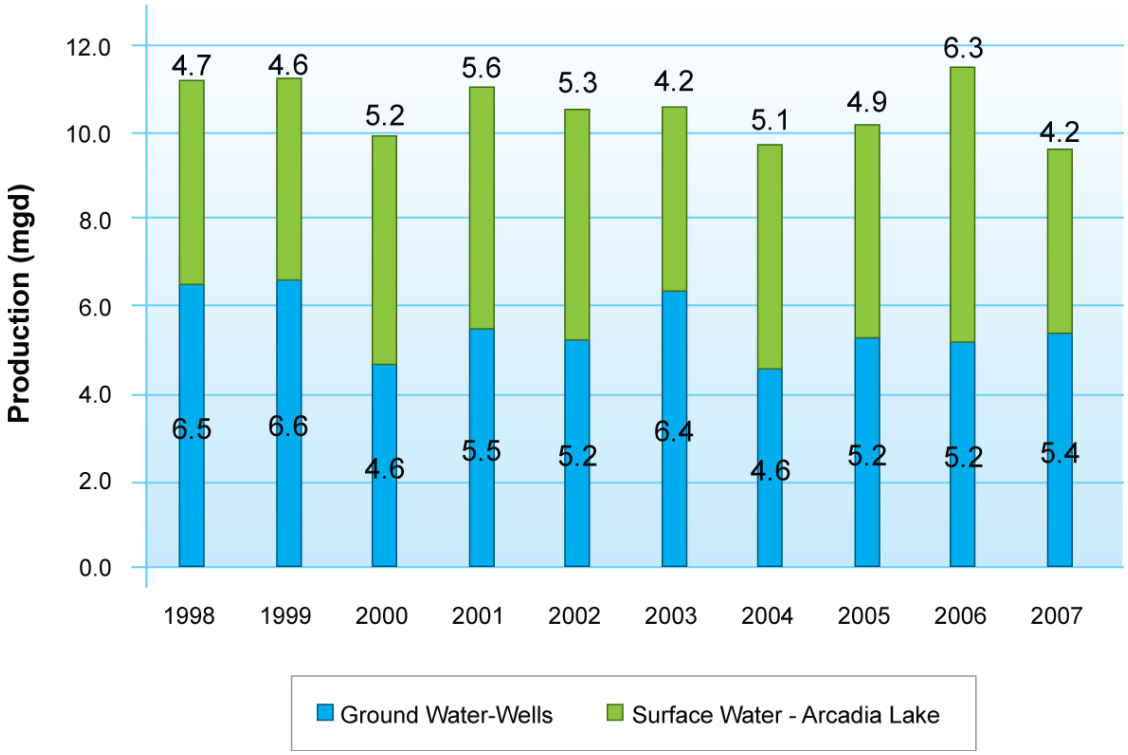


Figure 2-4
City of Edmond's Raw Water Supplies

Additional information on the City's water supply sources are provided in the sections below.

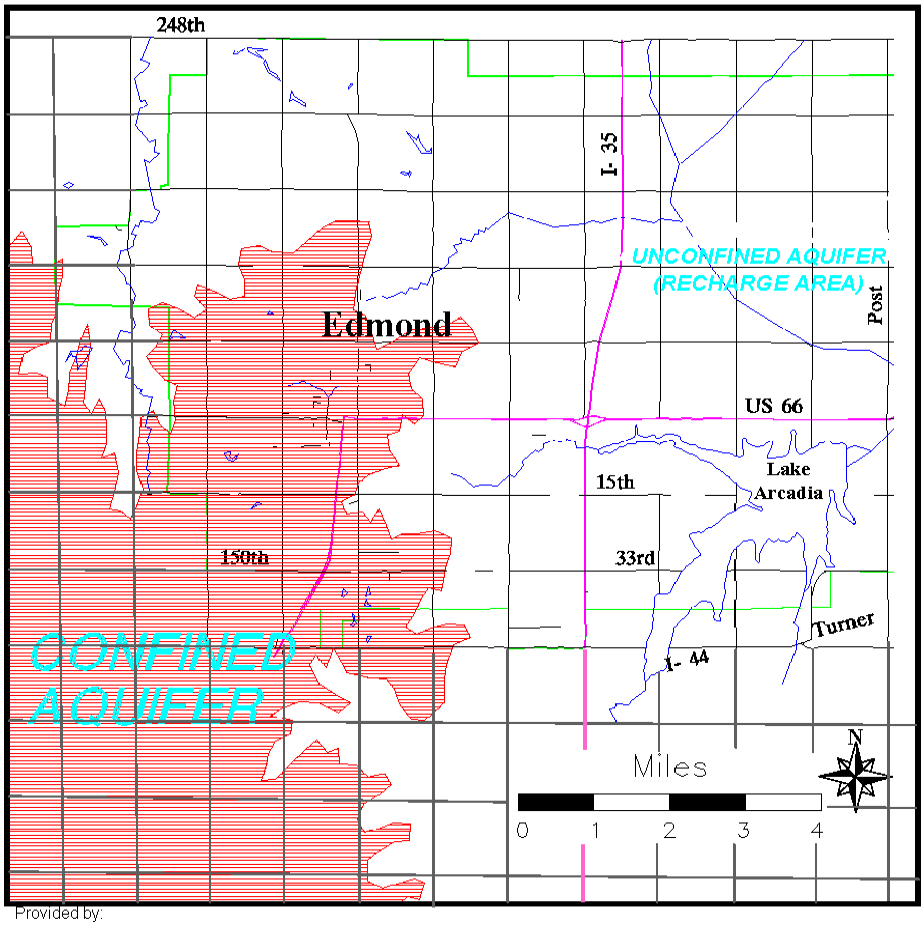
2.2.1 Existing Groundwater System

The information presented in this section is based on review of relevant literature reviews, interviews held with local experts when the City's 1999 water supply master plan was developed, and experience with similar aquifer systems. Estimated aquifer yields and future production rates should be considered approximate, and would require field investigations and testing to more accurately determine exact well placement and production rates.

2.2.1.1 Aquifer Characteristics

The City overlies the Garber-Wellington Formation that outcrops in a north-south trending belt some 6 to 20 miles wide. The belt extends from north of Logan County southward through Oklahoma and Cleveland County and resides under approximately three thousand square miles of land. Regions between the City and Noble are heavily developed. It is predominantly in Oklahoma and Cleveland Counties that the Garber-Wellington Formation is an important source of groundwater (Bingham and Moore, 1975).

In the southwestern quarter of the City, including the original areas of the City, the Hennessey shale overlies the Garber-Wellington Formation at ground surface. The Garber-Wellington Formation dips to the west at 35-60 feet per mile, such that it is overlain by an increasing thickness of the Hennessey shale to the west. The sandstones and shales of the Garber-Wellington Formation outcrop in the eastern portion of the City, shown in Figure 2-5, and include the area where Arcadia Lake was constructed. Arcadia Lake is in the recharge area of the formations, supplying the upper aquifer with potentially large quantities of water.



Provided by:
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Oklahoma Governments

Figure 2-5
Location of Confined and Unconfined Garber-Wellington Formation

Individually, the Garber and Wellington formations have similar water-bearing characteristics. The two formations were formed in similar environments, and both consist of discontinuous lenticular beds of interbedded sandstone, siltstone, and shale. The sandstone beds vary in thickness within short lateral distances. Wells drilled into the water-bearing zones tap many individual beds of sandstone which may be as much as 75 feet thick. Individual wells may penetrate as much as 750 feet of water-bearing sandstone (Simpson, 1993).

The impact of the interbedded shales and sandstones manifests itself in a number of ways. First, the shales act as confining layers to the more productive sandstone zones, insulating the deeper portion of the aquifer from the shallower portion. Where the confining layers exist, which is in the central and western portions of the City, the production wells screened in the deeper portions of the Garber-Wellington Formation may not influence water levels in the shallower portion. The confining layer also limits the amount of recharge to the deeper groundwater production zone that can occur from surface sources such as rainfall, stream infiltration, or impoundments.

Another way that the interbedding manifests itself is in the observation of cascading water found in certain production wells. In these wells, groundwater pumping levels have been drawdown below water bearing sandstone units. As the groundwater drains into the well casing through perforation or screened intervals, it cascades downward until it reaches the saturated zone, thereby entraining air. This can cause minerals to precipitate in the well screens and enhance biological growth, both of which can reduce well production rates and require more frequent well maintenance.

2.2.1.2 Availability of Groundwater

Figure 2-6 shows the location of the Garber-Wellington Formation along with the other aquifers in the area. As per general knowledge of natural conditions in the area and contour maps, it appears that saltwater intrusion has significantly impacted current production of groundwater in western parts of the City. The salt water intrusion is likely due to a combination of naturally occurring upconing from brackish water below and the impacts of secondary and tertiary oil recovery through salt water injection. In the vicinity of the City, the fresh water portion of the Garber-Wellington Formation, the thickness of the fresh water in the Garber-Wellington Formation can be greater than 600 feet in the southern portion of the City.

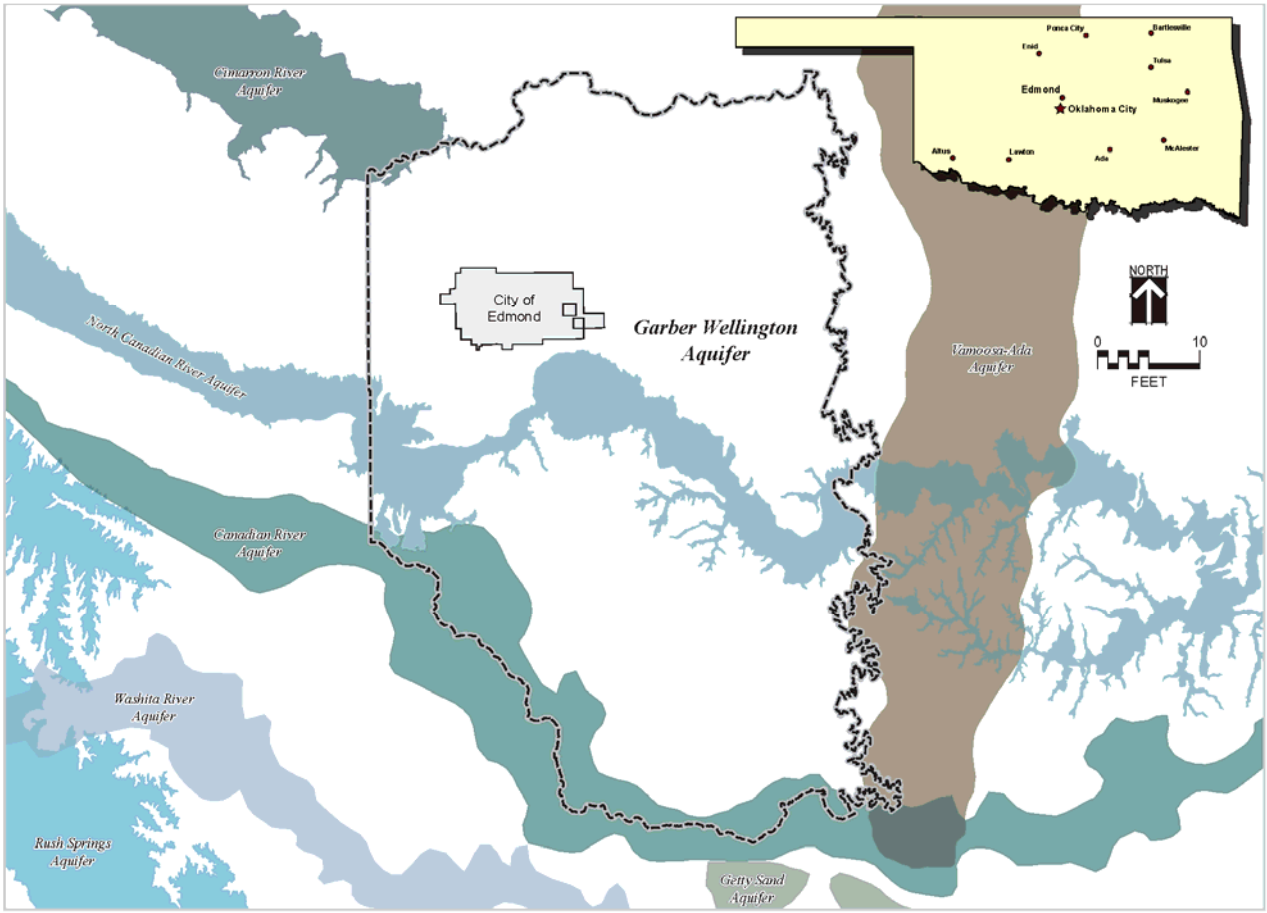


Figure 2-6
Garber-Wellington Formation

2.2.1.3 Hydraulic Properties of the Garber-Wellington Formation

The hydraulic properties of the Garber-Wellington Formation include hydraulic conductivity, transmissivity, and specific capacity. These properties are measures of the rate of water flow and production that can be expected in any aquifer system. Hydraulic conductivity relates to the ability of the aquifer to water. Transmissivity, which is the product of hydraulic conductivity and saturated thickness, is the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. Finally, specific capacity is an approximate measure of the aquifer's yield expressed as a well's pumping rate divided by drawdown.

The hydraulic conductivity of the Garber-Wellington Formation is variable throughout the aquifer. The hydraulic conductivity of the Garber-Wellington Formation has been estimated to be about 35 gallons per day per foot squared (gpd/ft^2) (Burton and Wood, 1968). Given that the lithology of the Garber-Wellington

Formation is considered to vary from sandstones to shales, it is likely that the hydraulic conductivity of the formation may vary over a range of at least 10 to 100 gpd/ft^2. The ratio of horizontal to vertical hydraulic conductivity, likely varies from 100:1 to 10,000:1 (Christenson, 1992). This sizeable difference between horizontal and vertical hydraulic conductivity results from the interbedding of sandstones and shale layers.

The transmissivity of the Garber-Wellington Formation has been estimated by various investigators through the use of pumping tests. For example, a pumping test conducted on community water well located near Oak Tree Golf and Country Club produced an estimated transmissivity of 2,300 gpd/ft (Edwards, 1989). This study also indicated that a valid transmissivity for the Garber-Wellington Formation in the Edmond area is about 2,500 gpd/ft. However transmissivity is variable throughout the aquifer because of aquifer heterogeneities and differences in aquifer saturated thickness

The saturated thickness of the Garber-Wellington Formation groundwater production zone beneath the City is impacted most significantly by two physical characteristics of the aquifer system: the dip of the Garber and Wellington formations, and the elevation of the salt water/fresh water interface. The sandstone/shale interface of the Garber-Wellington Formation, which defines the top of the groundwater production zone in this formation, dips to the west at about 35 to 60 feet per mile, meaning that over the 12 miles from Arcadia Lake to Lake Hefner, the saturated thickness of the water bearing zone in the Garber-Wellington Formation may be reduced by as much as 700 feet. The salt water that underlies the fresh water contained in the Garber-Wellington Formation can "upcone" at production wells and reduce aquifer saturated thickness, and therefore, reduce the transmissivity of the aquifer. The most productive areas of the aquifer are therefore at locations where the saturated thickness and hydraulic conductivity are greatest.

Specific capacity data available for the City wells was summarized and presented by a study conducted by Edwards in 1989. Data from this study indicated that the City wells range in specific capacity from about 0.03 to 3.6 gallons per minute per foot of drawdown (gpm/ft), with an average of about 1.2 gpm/ft.

2.2.1.4 Production of Groundwater

There are a variety of wells within the City limits which include city-owned wells, shallow domestic wells, industrial wells, and irrigation wells.

City Wells

There are currently fifty eight City-owned wells used to supply Garber-Wellington aquifer groundwater. Figure 2-7 shows the City's facilities including the location of the wells. Most of these wells are in the western portion of the City underlying the majority of the development. The City plans to install four additional wells in 2008.

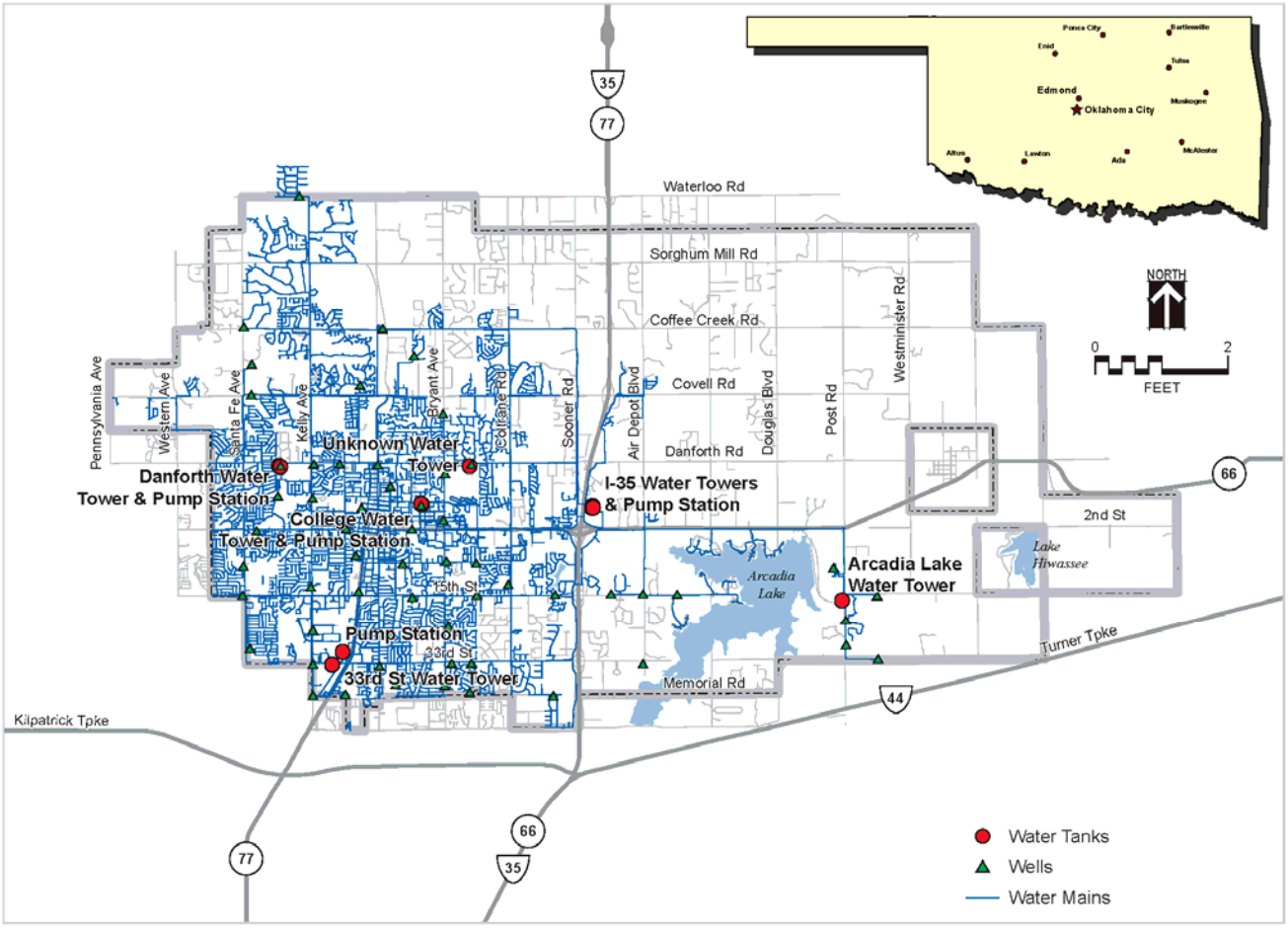


Figure 2-7
Location of City-Owned Wells

Table 2-1 summarizes the total annual production and average daily production from 1988 to 2007. Groundwater production generally increased as the population increased. Peak groundwater production occurred in 1998, 1999, 2003.

Table 2-1 Groundwater Production			
Year	**Total Well Production (million gallons)**	**Average Daily Well Production (mgd)**	**Average Daily Well Production (gpm)**
1988	1,341	3.7	2,569
1989	1,159	3.2	2,222
1990	1,307	3.6	2,500
1991	1,314	3.6	2,500
1992	1,393	3.8	2,639
1993	1,509	4.1	2,847
1994	1,519	4.2	2,917
1995	1,738	4.8	3,333
1996	2,061	5.6	3,889
1997*	1,761	5	3,355
1998	2,361	6.5	4,514
1999	2,411	6.6	4,583
2000	1,695	4.6	3,194
2001	1,994	5.5	3,819
2002	1,906	5.2	3,611
2003	2,320	6.4	4,444
2004	1,662	4.6	3,194
2005	1,913	5.2	3,611
2006	1,888	5.2	3,611
2007	1,959	5.4	3,750

The well production rates for each well vary from about 80 to 340 gallons per minute (gpm), (average yearly production rates for any given well), although the average production rate per well is much less. Table 2-2 summarizes the maximum production rates of each well, date each well was drilled, and the depths of the wells, perforations, and pump set. The existing City owned production wells are generally over 500 feet deep with an average depth of 607 feet.

Table 2-2
Maximum Production and Depths of City Wells

Well #	Date Drilled	Maximum Pumping Rate (gpm)	Well Depth (ft)	Top Perforations (ft)	Lower Perforations (ft)	Depth of Pump Set (ft)
8	1952	140	650	252	442	400
9	1954	225	554	228	425	527
10	1957	181	719	317	713	585
11	1964	190	724	355	722	640
14	1969	119	747	355	694	625
15	1967	268	775	281	766	660
18	1979	173	684	291	662	600
19	1971	176	689	230	669	620
20	1972	180	635	109	630	550
21	1972	117	705	240	0	567
22	1972	200	650	130	585	602
23	1973	235	698	114	690	623
24	1973	205	604	114	604	540
25	1975	180	705	356	680	483
26	1977	268	475	154	398	361
27	1978	201	710	200	585	550
28	1977	187	478	235	406	400
29	1978	203	532	186	464	420
30	1978	250	535	226	535	448
31	1978	100	715	250	695	525
32	1978	275	705	193	632	588
33	1978	200	700	212	560	462
34	1978	265	527	110	472	407
35	1978	189	625	198	518	475
36	1979	169	599	132	595	507
37	1979	340	700	192	694	603
38	1980	162	797	116	772	636
39	1980	256	515	182	460	404
40	1980	225	465	160	437	340
41	1981	80	583	200	490	465
42	1981	150	690	294	676	600
43	1981	185	700	210	632	560

Table 2-2 (cont.) Maximum Production and Depths of City Wells						
Well #	**Date Drilled**	**Maximum Pumping Rate (gpm)**	**Well Depth (ft)**	**Top Perforations (ft)**	**Lower Perforations (ft)**	**Depth of Pump Set**
						(ft)
45	1982	133	570	121	542	490
46	1982	207	590	200	585	525
47	1984	150	720	180	620	550
48	1984	175	720	180	620	471
49	1985	170	600	210	534	529
50	1985	120	600	200	500	515
51	1985	188	670	200	670	610
52	1986	140	590	210	486	483
53	1986	216	535	210	520	490
54	1986	175	652	210	638	557
55	1992	246	675	248	590	650
56	1992	304	640	226	620	625
57	2001	200	525	220	490	475
58	2001	150	425	256	405	385
59	2001	120	425	254	396	387
60	2002	171	385	216	360	320
61	2002	200	475	232	460	360
62	2005	100	442	300	412	330
63	2005	90	420	214	392	330
64	2005	-	420	214	416	340
Average	**n/a**	**186**	**607**	**214**	**548**	**502**

Domestic Wells

There are hundreds of shallow domestic wells inside the City limits with depths ranging from 75 to 300 feet in depth with gravel packs beginning at as shallow as 10 feet below ground surface. These domestic wells draw water from the Henessey Formation shales and the shallow Garber Formation sandstone in the west and from the Garber Formation only in the central and east.

A common concern of citizens living in the immediate vicinity of a new municipal well is that pumping from this well will result in the dry-up of their domestic well. Generally, domestic wells are drilled to a depth of no greater than one hundred and fifty feet. These shallow domestic wells pump water from the very top of the aquifer. The common practice for municipal well projects in the Garber-Wellington Aquifer is to withdraw water from deeper levels of the aquifer thus ensuring that local wells are not impacted.

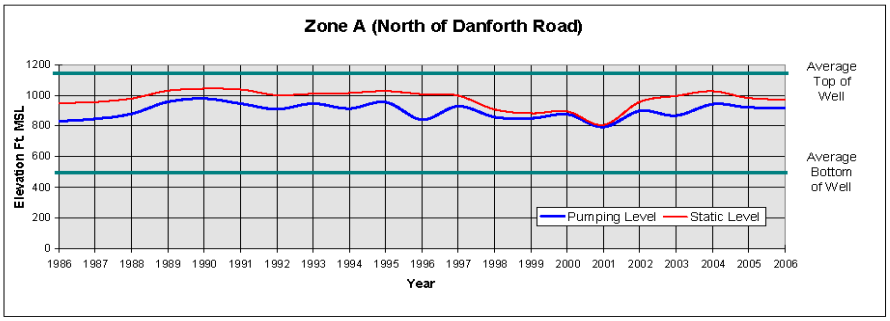
In the southern region of the Garber-Wellington Aquifer, underlying eastern Norman, monitoring wells have been installed at the same time as new municipal well installations to monitor and provide evidence that the new municipal wells do not have an impact on local domestic wells. Drawdown testing has shown that shallow wells have not been affected by the heavy demands placed upon the lower portions of the aquifer by the municipal wells. The purpose of this effort was to demonstrate to the citizens in the region that their individual domestic wells would not be impacted by the municipal operations. The same situation is likely in Edmond due to the similar aquifer setting.

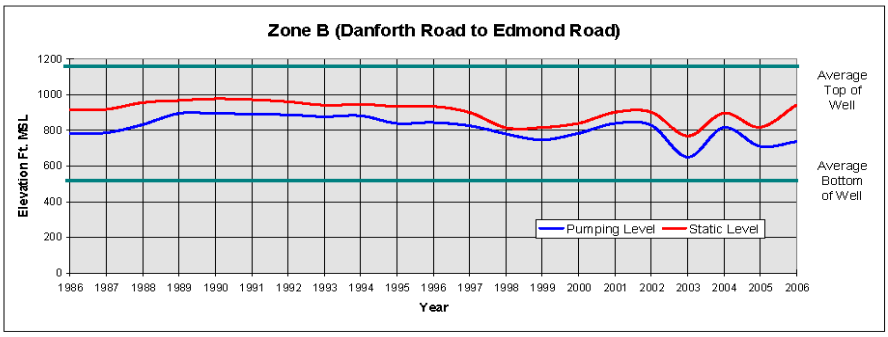
Industrial and Irrigation Wells

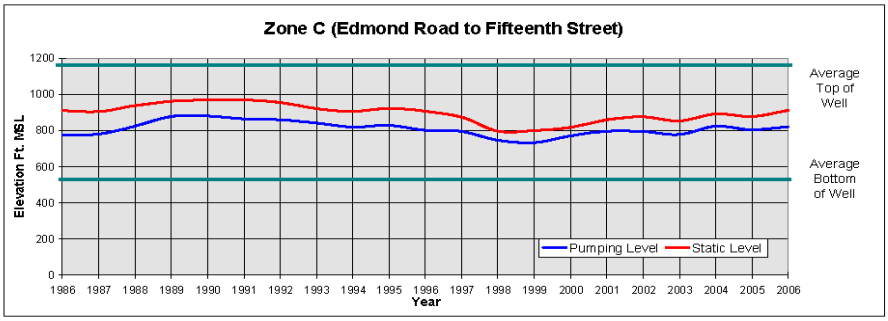
The industrial and irrigation wells have not been well documented within the City limits; however it is estimated from available records that these wells vary in depth from 100 to 750 feet. These wells typically tap the shallow, medium and deep portions of the Garber-Wellington Formation.

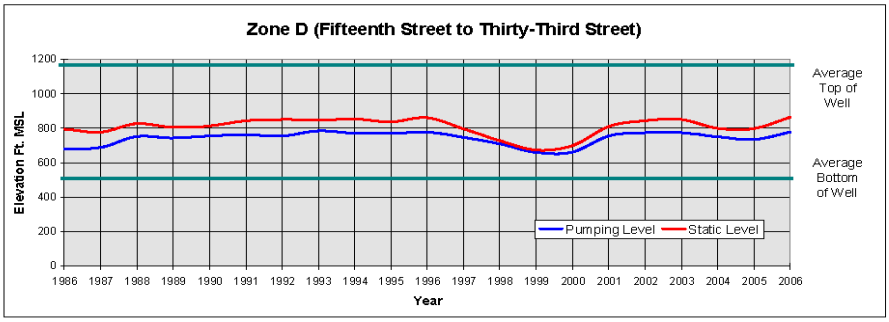
2.2.1.5 Current Aquifer Yield

Figure 2-8 presents water level data over time for the five locations in the Garber-Wellington Formation for the period of 1986 through 2006. Although there is variability among the zones shown in Figures 2-8 & 2-9 , these data indicate that groundwater levels tend to fluctuate with groundwater production with the lowest groundwater levels occurring generally during the peak groundwater production years of 1996, 1998, 1999 and 2003. However, despite this drawdown, groundwater levels tend to rebound within one to two years.









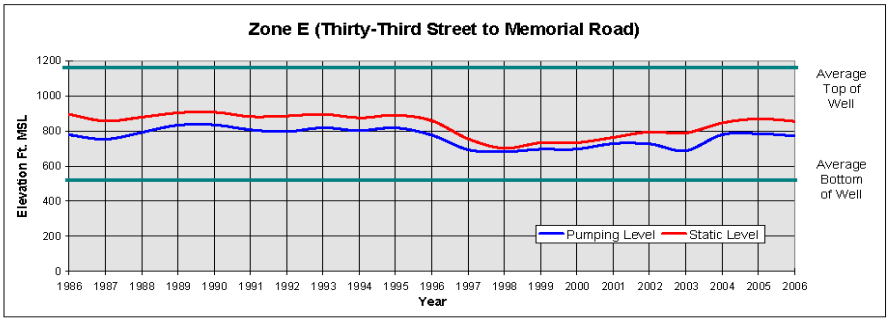


Figure 2-8
Water Well Static and Pumping Groundwater Levels

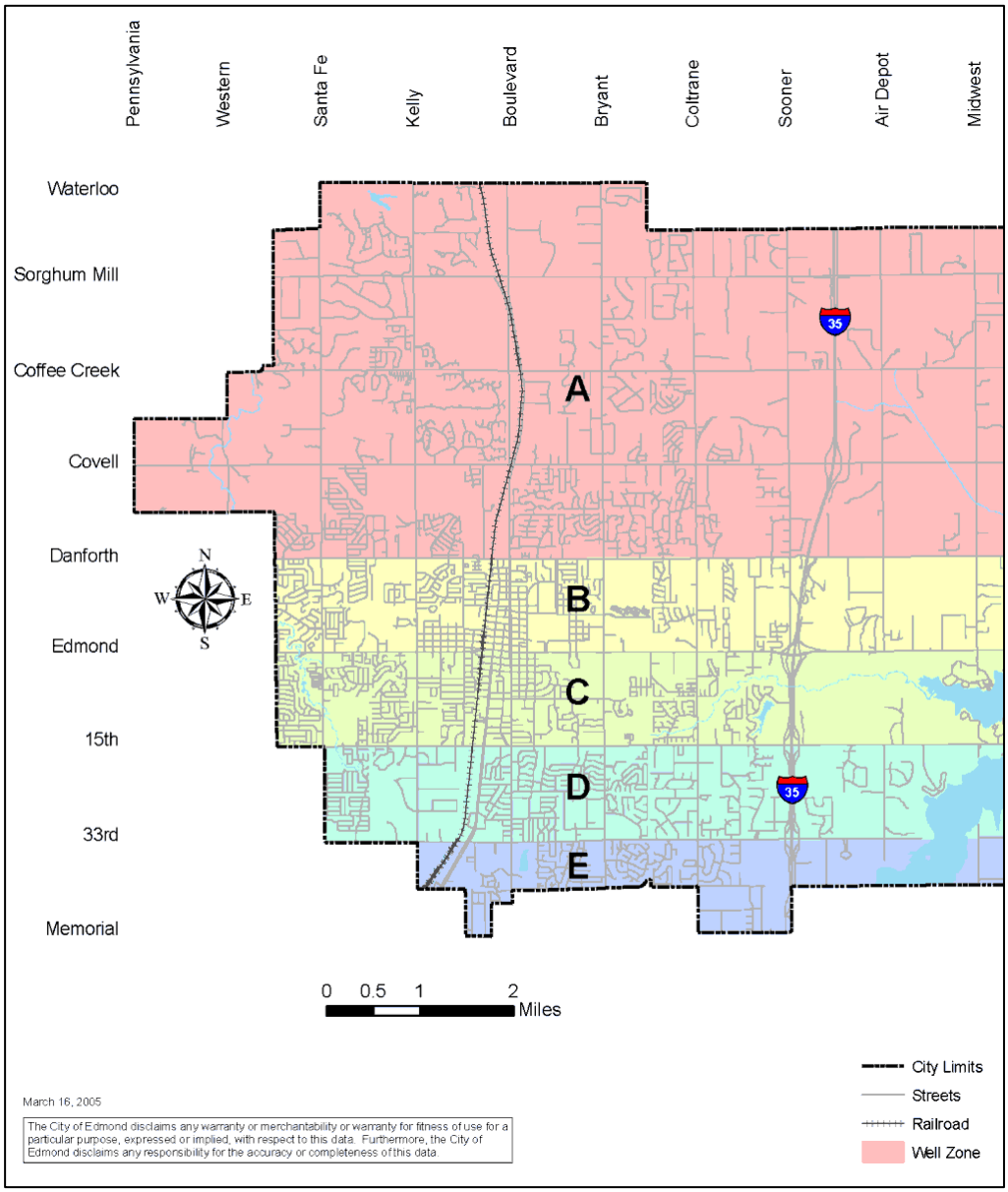


Figure 2-9
Water Well Zones
(Source: City of Edmonds's 2006 Annual Report)

These data suggest that the recharge that is currently percolating into the Garber-Wellington Formation beneath the City of Edmond and the rate of the existing groundwater production appear to be in balance, such that at least 6.5 million gallons of groundwater (peak groundwater production in 1999) can be produced as long as average or near average recharge conditions persist. In other words, the aquifer does not appear to be mined with current production operations.

2.2.1.6 Water Quality and Treatment

Historically, the Garber-Wellington Aquifer has provided ample supplies of water that meet drinking water standards enforced by the U.S. Environmental Protection Agency (EPA) and the Oklahoma Department of Environmental Quality (ODEQ).

The structure of the Garber-Wellington Aquifer is one of varying layers of Garber Sandstone and Wellington Shale. Water is not present in the Wellington Shale layers in sufficient quantities and the chemistry of the water varies with depth in the aquifer. The quality of water within individual layers of sandstone has been shown to have unique chemical properties.

Within the Garber-Wellington Aquifer, multiple naturally-occurring elements exist that are of long-term concern. The presence of naturally-occurring chromium, selenium, arsenic, and uranium in some regions of the aquifer has the potential to significantly impact groundwater acceptability for drinking water purposes if the allowable drinking water limits are reduced. For instance, the reduction of the arsenic drinking water standard from the current limit of 10 mg/L to 3 mg/L would likely cause some of the City's wells that exceed the 3 mg/L standard to be put off production.

The groundwater quality can be classified as soft to very hard water. Water hardness can cause scaling in the distribution system, which affects water system operation and consumers served. However, water hardness is not currently associated with any significant adverse human health effects. Groundwater naturally contains a number of different dissolved inorganic constituents. The major constituents are typically chloride, sulfate, carbonate, and bicarbonate. These major constituents constitute the bulk of the mineral matter contributing to TDS. In addition, there may be minor constituents present, including, but not limited to, iron, manganese, fluoride, and nitrate.

Groundwater naturally contains a number of different dissolved inorganic constituents. The major constituents are typically chloride, sulfate, carbonate, and bicarbonate. These major constituents constitute the bulk of the mineral matter contributing to TDS. In addition, there may be minor constituents present, including, but not limited to, iron, manganese, fluoride, and nitrate. City produced groundwater ranges in TDS concentrations from 224 to 568 mg/L (CDM, 1999) which is considered to be freshwater. Excessive groundwater production could result in the upconing of the underlying brackish groundwater which would result in elevated levels of TDS in the City extracted groundwater.

Another concern of groundwater quality is that of possible contamination with organic compounds. Contamination from organics may be due to commercial, industrial, and residential discharges, controlled or uncontrolled, of such compounds. Laboratory results from groundwater sampling events, performed in 1995, 1996, and

1997, for regulated organic compounds show non-detectable (less than 0.5 µg/L) concentrations present in the groundwater from the City's wells (CDM, 1999).

Naturally occurring radioactive compounds such as uranium, and gross alpha and beta activity exist in the shales of the Garber-Wellington Formation and have been detected in groundwater produced from the City's wells. Construction methods utilized by well drillers attempt to minimize the impacts of radionuclides on the produced groundwater by selectively placing blank screen across the shale zones encountered. Construction of new groundwater supply wells must be completed with this potential impact in mind.

The City treats extracted groundwater through disinfection at the wellheads. Sodium hypochlorite is used for disinfection purposes. The extracted groundwater is currently of sufficient quality where no other treatment is necessary to meet drinking water standards. If drinking water standards are lowered (e.g. arsenic standard), City wells may be taken out of production or additional treatment may be necessary to meet standards.

2.2.2 Existing Arcadia Lake Water

The City contracted with the U.S. Army Corps of Engineers (USACE) for the design and construction of Arcadia Lake. This lake is approximately 12 miles northeast of Oklahoma City on the Deep Fork River. Construction started in October of 1980 and the first diversions began in April of 1985.

The primary function of the lake is to serve as a flood control device. Secondarily, the lake serves as a water supply source for the City and lastly, the lake provides recreational benefits to the residents of central Oklahoma, and fish/wildlife benefits. The lake drains approximately 105 square miles with an area of 1,820 acres and a shoreline length of 26 miles. The lake is owned by the United States Government and operated by the USACE's Tulsa District. The recreational development and its associated operation and maintenance are contracted to the City through the Edmond Public Works Authority. The amount of water storage entitled for the City's use is based on allocations established by the Corp and the City's water rights administered by the Oklahoma Water Resource Board (OWRB).

2.2.2.1 Storage Allocations of Arcadia Lake

Arcadia Lake provides a total of 92,000 AF of storage; however, for storage allocation purposes this total storage amount was adjusted to 85,600 AF by the Corp to account for 100-years of sedimentation. Figure 2-10 conceptually shows the allocation of storage as three pools, inactive, conservation, and flood control pool. The amounts and elevations presented in this figure were originally developed by the Corp. The flood control pool is used by the Corp for flood control purposes while the conservation pool provides storage for the City.

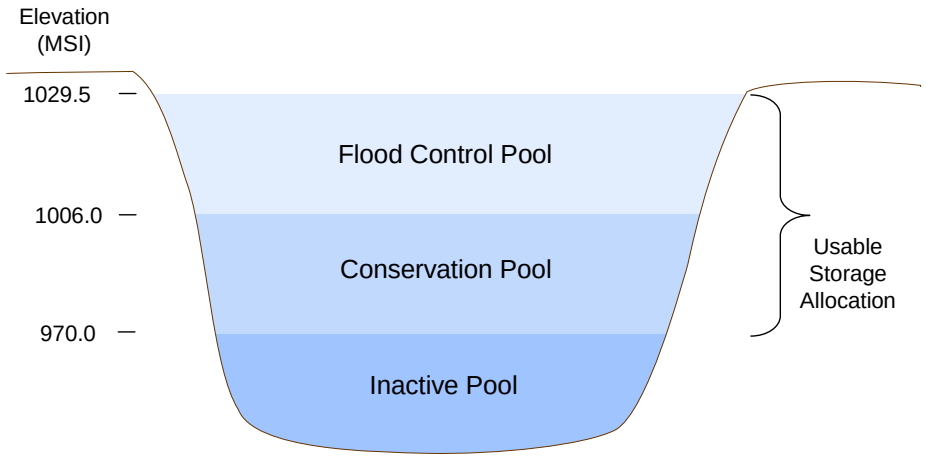


Figure 2-10
Arcadia Lake Storage Allocation

In 1983, 1986, 1997, and 2007 surveys were conducted to assess the rate of sedimentation and storage losses in Arcadia Lake storage due to sedimentation. Results from the OWRB 2007 hydrographic survey indicated that a minor amount of sedimentation has occurred in Arcadia Lake, yet the rate of sedimentation could not be quantified due to measurement error and the inconsistent methodologies used to conduct previous surveys. The direct comparison of survey profiles indicated that the greatest amount of sedimentation of about three feet has occurred in the Deep Fork arm of the lake. The OWRB recommends that the same survey methodologies applied in the 2007 hydrographic survey be applied in 2017. The comparison of these two surveys may provide a more accurate representation of sedimentation rates.

Table 2-3 summarizes the Corp allocated usable storage pools in Arcadia Lake. The City may store 23,090 AF. Of this 23,090 AF, approximately 8,460 AF, or 36.6 percent of 23,090 AF, was originally allocated for Present Use water supply. The remaining 63.4 percent approximately 14,630 AF was allocated for Future Use water supply. Based on the USACE design projections, the 8,460 AF originally allocated as Present Use would produce an annual average yield of 4 mgd whereas the 14,630 AF of Future Use would produce an additional 7 mgd. This provides a total annual yield of 11 mgd for the City. These estimates are based on the USACE projected storage to yield curve assuming 30 percent urbanization of the watershed.

Table 2-3 Storage Allocation - Adjusted for 100-Year Sedimentation

Table 2-3 Storage Allocation - Arcadia Lake			
Feature	**Elevation** **ft, msl**	**Usable Storage Allocation** **AF**	**Percentage of Total Storage**
Flood Control Pool	1,006.0 - 1,029.5	62,510	73%
Conservation Pool	970.0 – 1,006.0	23,090	27%
Total Usable Storage	**970.0 - 1029.5**	**85,600**	**100%**

The City WTP's average production from 1998 to 2007 was 5 mgd with a maximum average production rate of 6.3 mgd in 2006. This exceeds the 4 mgd Present Use storage allotment of 8,460 AF (water usage exceeds 4 mgd). Consequently, the City is using full allotment of Present Use storage and a portion of its Future Use allocated storage. The City's WTP may treat up to 10.5 mgd, enabling the City to use a greater portion of its Future Use allocated storage in the future without needing additional infrastructure.

2.2.2.2 Arcadia Lake and Water Rights

In May of 1974, a permit (permit number P74-175) was filed for the City relative to Arcadia Lake. The OWRB permit gave the City water rights to 12,500 AFY of water in Arcadia Lake. The OWRB permit restricts withdrawal of the 12,500 AFY of water to a maximum of 8,000 gallons per minute (approximately 11.5 mgd). It should be noted that the OWRB did not reference the USACE storage yield projections for the permit. Essentially, the storage and yield allocations identified in the contract and the OWRB permits are independent, or stand alone, rights. The permit, in addition to allocating storage and yield rights, set forth a schedule for the City's use of the water. The schedule of use sets the minimum percent of water storage that must be put to beneficial use. As such, the schedule states that 100 percent (or 12,500 AF) of the water must be applied to beneficial use by the year 2030.

2.2.2.3 Water Quality and Treatment

The Arcadia Lake raw water can be characterized as turbid, hard water, which is not uncommon of surface water supplies in the South Central U.S. Table 2-4 summarizes the water quality parameters in Arcadia Lake according to a lake sampling study done in 2006-2007 under the Oklahoma's Beneficial Use Program. During this study water quality samples were collected at five sites from the lake's surface for a period of four quarters, from October 2006 to August 2007.

Table 2-4 Water Quality - Arcadia Lake	
Characteristic	**Values**
Salinity Range (ppt)	0.10-0.20
pH Range	7.32-8.47
Spec. Conductivity Range (µS/cm)	209.7-422
ORP Range (measure Value (mV)	148-415
Total Nitrogen (TN Avg.)	0.98 mg/L
Total Phosphorous (TP Avg.)	0.064 mg/L
TN:TP	15:1
Turbidity (Avg.)	42 NTU
Color	53 Color Units

The Arcadia Lake watershed is an unprotected, urbanized watershed and is potentially prone to contamination from industrial and sewer waste. Although the raw water currently does not reflect poor quality due to urbanization, the watershed area is continuing to develop, which increases the source waters exposure to contamination.

The City's WTP was constructed in 1987 and received major upgrades in 2004. The WTP is designed to treat up to 12 mgd of Arcadia Lake water yet operationally performs at a maximum of 10.5 mgd. Lime softening, filtration, activated carbon adsorption, and disinfection with ozone are the major treatment processes. The WTP is operated 24 hours per day seven days a week.

2.2.3 City of Oklahoma Treated Water

2.2.3.1 Historical Oklahoma City Purchases

As discussed in the section earlier, the City has also historically received small amounts of treated Oklahoma City water through a 12 inch diameter interconnect located south of the City. This is the result of a 1996 purchase agreement with Oklahoma City. Since this agreement, the City has purchased treated water from Oklahoma City in 2001, 2003, and 2006 as a supplement to their supplies. Table 2-5 shows the amount of water purchased during those years. The City may transfer a maximum of 1.5 mgd through this 12 inch interconnect and distribution pipeline. Currently the treated Oklahoma City water is directly transferred into the City's system with no additional treatment.

Table 2-5 Purchases of Oklahoma City Water	
Year	**Oklahoma City Purchased (MG)**
2001	25.4
2003	34
2006	16.1
Total	75.5

2.2.3.2 Other Purchases

In 2004, the City entered a new purchase contract with Oklahoma City and secured the purchase of up to 15 mgd of Oklahoma City water treated by Oklahoma City's Hefner Road WTP. This agreement also included the construction of a pipeline from Hefner Road along Western Avenue to the City's Northwest Complex. This newly constructed pipeline may convey up to 15 mgd of treated Oklahoma City water to the Northwest Complex completed in 2006. This complex is comprised of a 2 million gallon storage tank and pumping system with a pumping capacity of up to 20 mgd.

The Northwest Complex also includes a chlorine breakpoint unit to address the differences in disinfection of Oklahoma City and City water. The City uses chlorine (sodium hypochlorite) as a residual disinfectant in their distribution system while Oklahoma City uses chloramines. The mixing of these dissimilar disinfectant residuals often results in taste and odor issues. The past purchases of Oklahoma City water shown in Table 2-5 were of small enough quantity to not cause the residual effects of the blending of disinfectants. However, the direct blending of 15 mgd of Oklahoma City water with City water without treatment could result in taste and odor problems. The Northwest Complex chlorine breakpoint unit adds chlorine to the Oklahoma City treated water to remove ammonia from the chloramines Oklahoma City uses for disinfection. This improves the compatibility of the blended Oklahoma City and City water reducing potential of taste and odor issues.

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Section 3
Water Demands

3.1 Historical Water Demands

Historical water demands are based on total water production data for the City's existing water supplies including surface water, groundwater, and Oklahoma City treated water. Figure 3-1 shows historical water demands in the City from 1998 through 2007 (City of Edmond, 2007). Water demands vary from year to year, as they are dependent on weather conditions. For example, in hot and dry weather conditions water demands are higher mainly due to more landscaping water use.

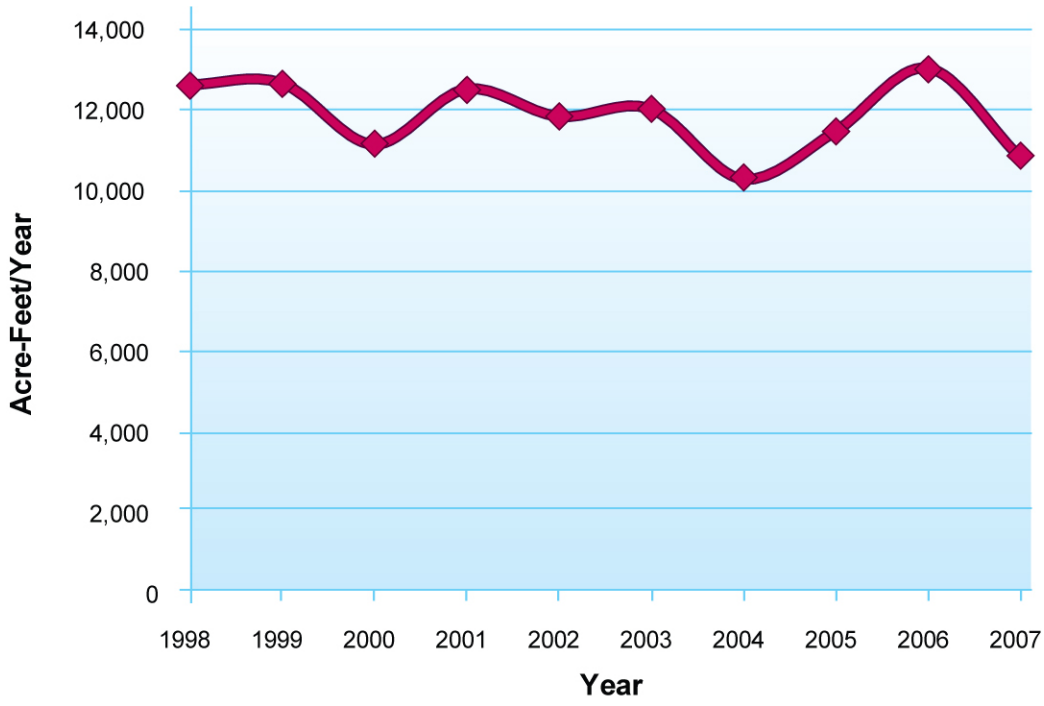

Figure 3-1
City of Edmond Historical Water Demands

3.2 Projected Water Demands

Projecting water demands allows the City to determine future water supply investments. The water demand projections can also be used to schedule these investments in order to minimize cost impacts. The water demand projections support development of this 50-year Water Supply Plan and provide the context for recommendation of alternatives.

3.2.1 Forecast Method

A water demand forecast model was developed for the City. The data used in the model included historical water production, weather data for precipitation and temperature, and population. In the City water demand forecast model, regression

analysis was applied to the monthly data to determine relationships between monthly water production and precipitation, maximum temperature, population served and number of accounts. Regression analysis determines the function that provides the 'best fit' to the data. The water demand forecast model was used to estimate historical annual demand in order to analyze model accuracy. Appendix E summarizes the demand model inputs, outputs and regressions statistics.

3.2.2 Estimated 2060 Water Demands

Projected water demands were estimated in 5-year intervals up to 2060. Results of the demand forecast are shown in Figure 3-2.

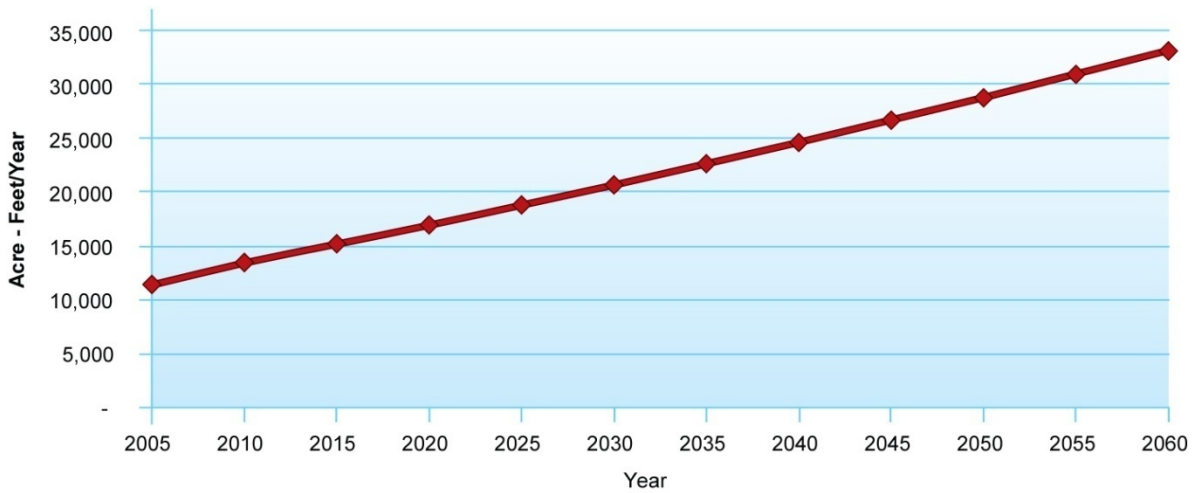

Figure 3-2
Average Annual Water Demand

3.3 Weather Impacts and Peaking

Annual and seasonal changes in weather affect water demands. Although weather is unpredictable, understanding its range of impacts on water demands can improve water supply planning.

3.3.1 Annual Weather Impacts

To determine the impacts of weather on annual water demand, a statistical regression model was developed using rainfall and temperature as explanatory variables.

Monthly weather data included the total monthly precipitation and the monthly mean maximum daily temperature from January 1970 through December 2007 (hydrology sequence). The Edmond weather station did not have complete data for this time period, thus weather data were also obtained from the Guthrie weather station which is located approximately 30 miles north of Edmond.

The regression model estimated the "actual" monthly demand for the hydrology sequence based on a constant population and observed "actual" monthly weather data; and, the "normal" monthly demand based on the same population and the long-term average monthly weather data. The annual average "actual" demand for the hydrology sequence and the annual average "normal" demand was then calculated from the monthly data.

A weather factor, expressed as a ratio of actual to normal annual average demand, indicates how much demand would change with increases or decreases in rainfall and temperature. The model calculates the weather factor for each hydrology year based on the following equation:

Weather factor = average annual actual demand / average annual normal demand

A weather factor greater than 1.0 is indicative of a dry, hot year; and a weather factor less than 1.0 is indicative of a wet, cool year. Figure 3-3 shows weather demand factors for each hydrology year from 1970 to 2007.

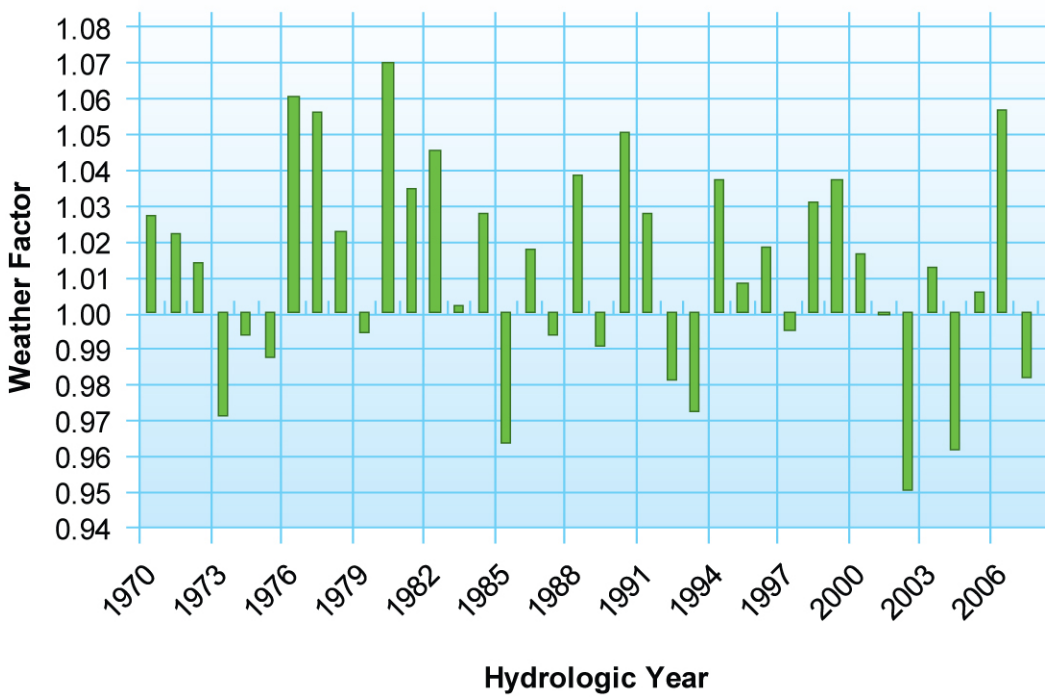

Figure 3-3
Weather Factors for Edmond Water Demands

3.3.2 Seasonal (Monthly) Impacts

Water demands not only vary from year to year due to weather, but also month to month. Monthly variations in demand will be sensitive to rainfall and temperature. To determine the seasonal monthly pattern of water demands, the Water Supply Plan analyzed historical monthly production data from 1988 to 2007. Figure 3-4 shows the monthly distribution of demands for the City of Edmond.

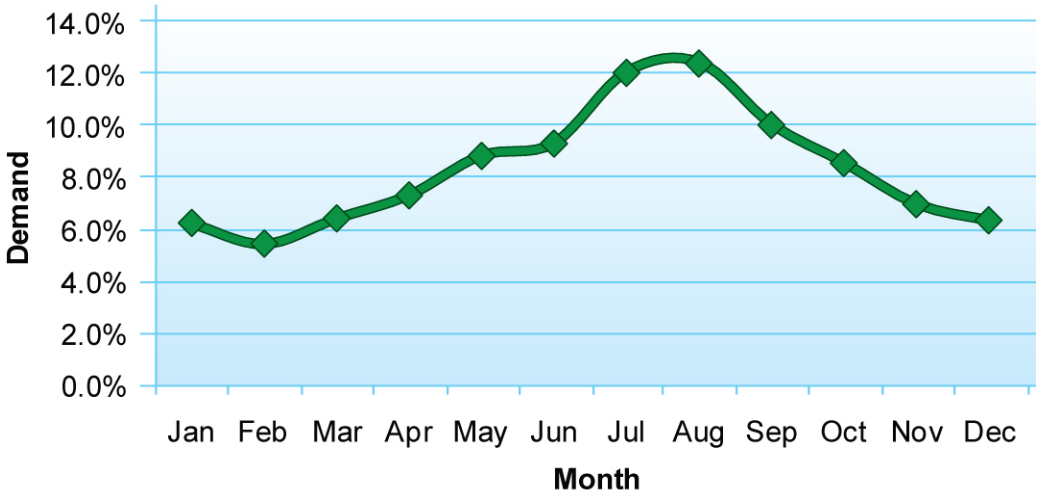

Figure 3-4
Monthly Pattern of Edmond Water Demand

Water demands peak during July and August, at about 12 percent of total annual demand. Demands are lowest during the winter months primarily because less water is required from irrigation purposes. The lowest demand is in February at about 5 percent of total annual demand.

3.3.3 Peak Day Demands

Because the City's infrastructure (e.g., pipelines and pump stations) have limited capacity, peak day demands measure in cubic feet per second (cfs) need to be estimated. According to the 1999 Water System Master Plan, peak day water demands are 2.2 times greater than average annual demands. Figure 3-5 shows the current and projected peak day demands for the City. Peak day water demands are expected to increase from the current 35 cfs to 97 cfs by year 2060.

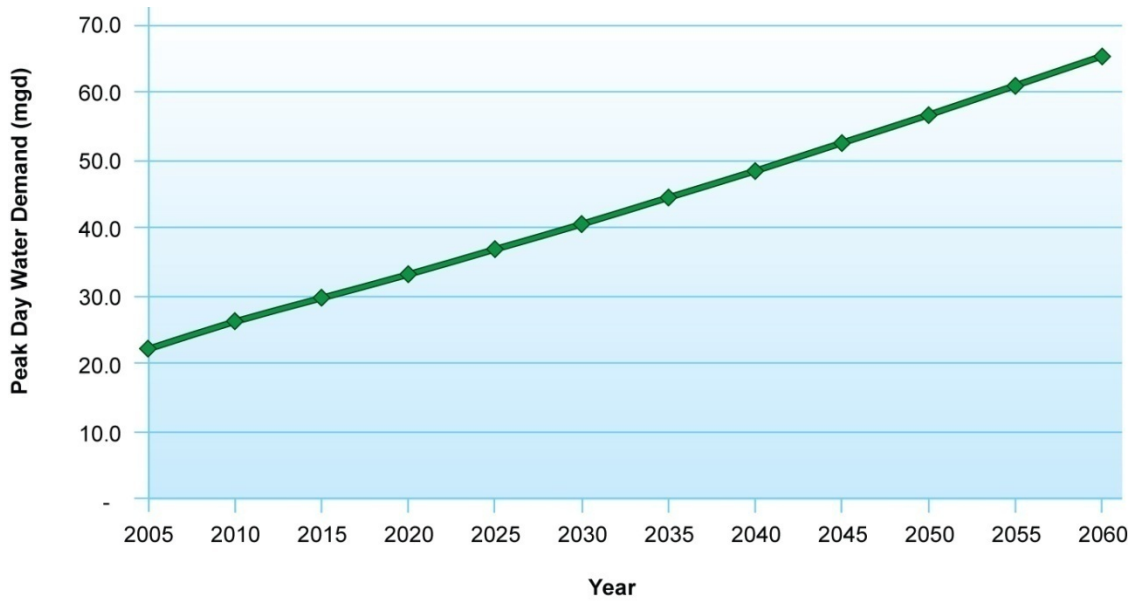

Figure 3-5
Peak Day Water Demands for Edmond

3.4 Comparison of Projected Demands and Existing Supplies

As discussed in Section 2, the City's existing water supplies include surface water, groundwater, and Oklahoma City treated water. The surface water supply is currently limited by the operational WTP capacity of 10.5 mgd. And, the Oklahoma City treated water supply is limited by the contract to purchase up to 16.5 mgd (15 mgd via the Northwest Complex and 1.5 mgd via the 12-inch interconnect located south the City). To estimate future groundwater supply from existing groundwater wells, a well service life of 50 years was assumed. Figure 3-6 presents the estimated future groundwater supply.

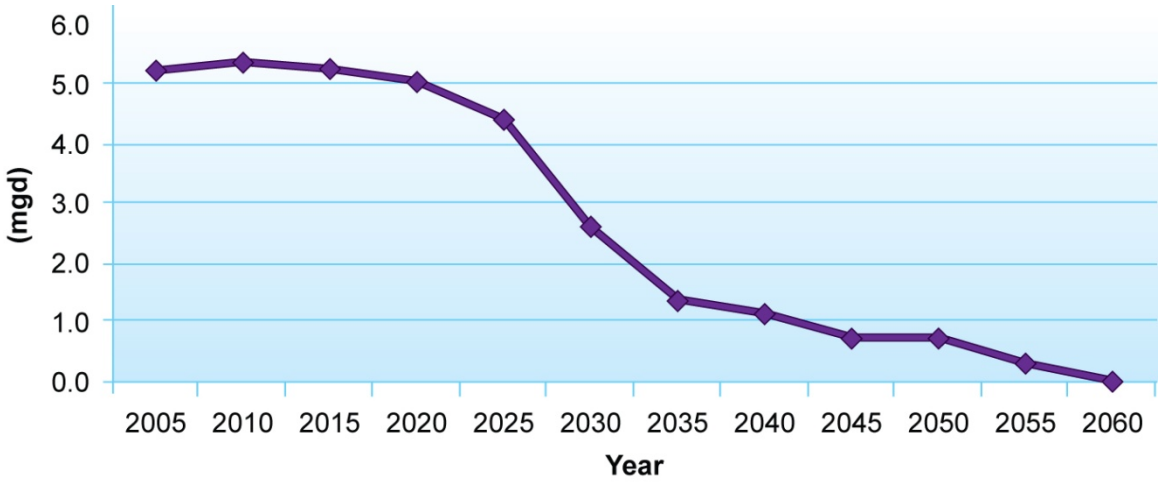

Figure 3-6
Future Groundwater Supply

Figure 3-7 shows the average annual demand projection and projected supply mix for the City assuming no additional water supplies through the year 2060. As can be seen with this "no action" scenario, an average annual supply gap of 2.7 mgd would exist in 2060.

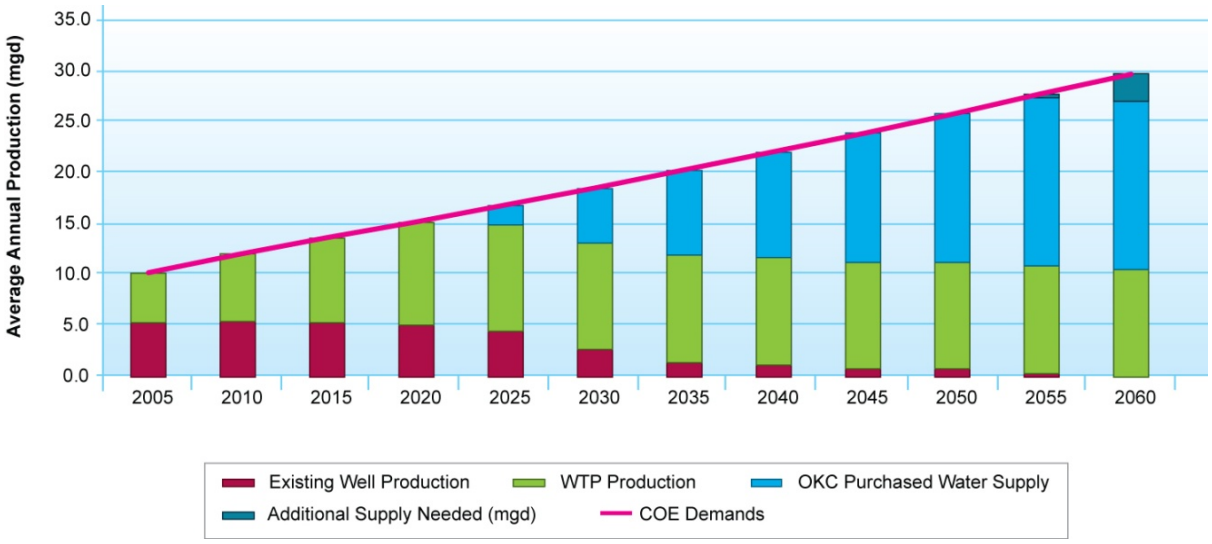

Figure 3-7
Projected Average Annual Water Supply for Edmond

Figure 3-8 shows the peak day demand projection and projected supply mix for the City assuming no additional water supplies through the year 2060. Because peak day demands are 2.2 times higher than average annual, a supply gap is projected to be seen as early as 2020.

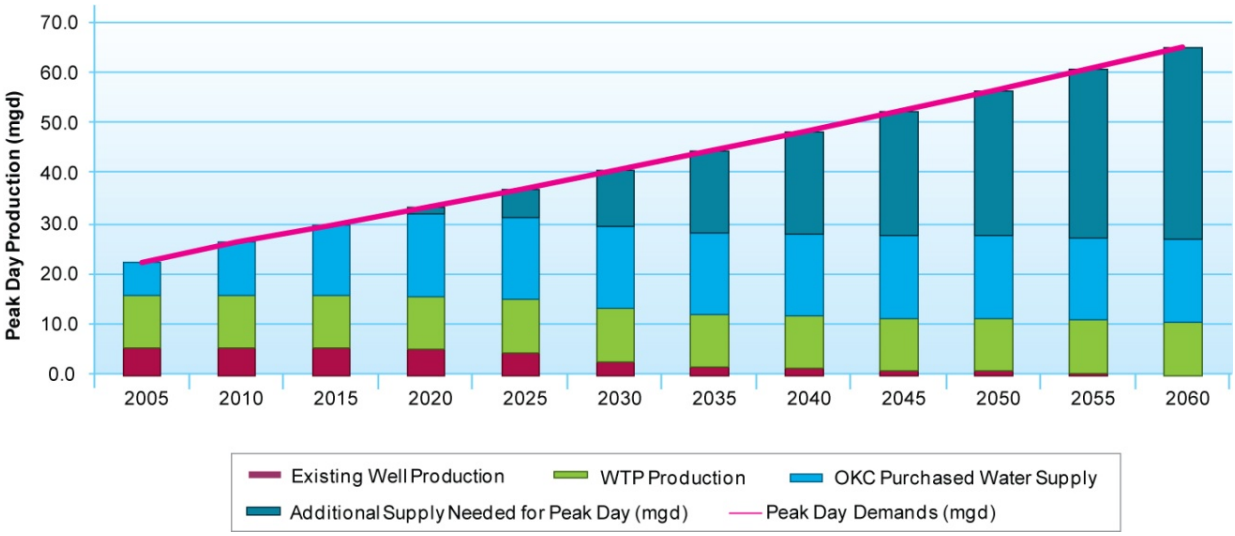

Figure 3-8
Projected Peak Day Water Supply for Edmond

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Section 4
Evaluation Framework

4.1 Evaluation Process

The Water Supply Plan for the City followed an Integrated Resource Plan (IRP) approach and proceeded initially along two parallel paths: the objectives path and the supply options path. The objectives path develops the *"why's"* in the Water Supply Plan – *why is the planning being undertaken?, why would one option be selected over another?, etc.* These questions are answered by explicitly defining planning objectives. Planning objectives are of fundamental importance to a successful Water Supply Plan as they describe, in this case, what the City aims to achieve with regard to its long-term management of water resources.

The supply options path develops the "*how's*" in the Water Supply Plan – these are the specific alternatives that the City can choose from as means of meeting its water supply needs. Individual supply options can be projects, programs, or contracts with other agencies and the water supplies for these options can be from sources such as groundwater, recycled water, surface water, etc. Since no single supply option is going to be able to meet all of the City's objectives, separate supply options must be combined into alternatives. The alternatives, because of their multiple sources, can increase diversity and can better meet multiple objectives.

In order to be able to use the objectives and supply options together, there needs to be a means of quantifying the importance of the objectives relative to one another, as well as a means of quantifying how well different supply options satisfy those objectives. Characterizing the relative importance of the objectives is done by giving them weights. Quantifying the ability of the supply options to satisfy the objectives is done by defining performance measures, which are specific and measurable attributes related to the objectives.

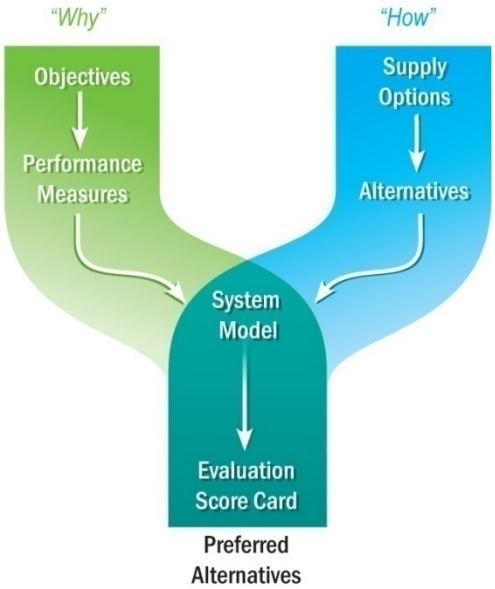

Figure 4-1
"Why" and "How" Parallel Paths in the Water Supply Plan

All of the planning objectives, weights, and performance measures are put together in a water supply plan in what is known as a value model. Here, goals are explicitly stated and elaborated with the objectives, and the importance of the objectives relative to one another is characterized by the objective weighting. Alternatives (or different combinations of supply options) can be evaluated against the objectives through the specific performance measures. Ultimately, the analysis results in the selection of a preferred alternative. Figure 4-1 depicts the generic process followed in a water supply plan. This process is further described in the Sections that follow.

4.1.1 Objectives and Performance Measures

As part of the Water Supply Plan, the City staff and selected stakeholders worked on defining planning objectives consistent with the City's strategic planning goals, but specific to the development of the Water Supply Plan. The objectives serve as the goals or reasons "why" the Water Supply Plan is being undertaken.

Objectives are usually categorized into primary and secondary (with the secondary objectives being termed *sub-objectives*). Primary objectives are more general; while secondary help define the primary objectives in more specific terms.

For each sub-objective, a performance measure is required. The performance measure is used to indicate whether an objective is being achieved.

The following example illustrates the hierarchy of objectives, sub-objectives, and performance measures.

Primary Objective	Sub-objectives	Performance Measures
Maximize System Flexibility	Maximize flexibility through diversity of sources.	Total number of supply sources
	Maximize operational flexibility.	Total number of "take points"

Principles of good decision-making indicate that primary objectives should be developed such that they are:

- ***Distinctive***: objectives should be developed to distinguish between one project (or portfolio) and another
- ***Measurable***: objectives should be able to be measured, either quantitatively or qualitatively, in order to determine if they are being achieved
- ***Non-Redundant***: objectives should not overlap with each other
- ***Understandable***: objectives should be easily explainable
- ***Concise***: objectives should be kept to manageable numbers

The objectives, sub-objectives and performance measures defined by the City are shown in Table 4-1. Some of the objectives apply to the individual supply options (such as "Meet or Exceed Water Quality Standards") while other objectives are more applicable to the overall combination of supply options included in a specific portfolio. This distinction is represented in the analysis.

Table 4-1
Edmond Objectives, Sub-objectives and Performance Measures

Objective	Sub-objective	Performance Measure
Ensure Supply Reliability	Provide sufficient yield to meet 100% of demands in average year.	Average Annual Deficit (AFY)
		Max Day Deficit (mgd)
	Provide sufficient yield to meet 100% of demands during droughts.	Dry Year Deficit (AFY)
	Maximize security.	Security Score
	Certainty of long-term sustainability.	Sustainability Score
Maximize System Flexibility	Maximize flexibility through diversity of sources.	Percent Contribution of Largest Source on Annual Basis
		Number of Sources
	Maximize operational flexibility.	Number of "Take Points"
Meet or Exceed Water Quality Standards	Minimize level of treatment.	Water Quality Score (TDS, source quality and Arsenic)
	Maximize compatibility of water quality with exiting quality of supplies.	Compatibility Score (quality)
Maximize Cost Effectiveness	Minimize capital costs.	Total Capital Cost
	Minimize O&M costs.	Total O&M Cost
Protect Environmental and Natural Resources	Minimize environmental impacts.	Environmental Impacts Score
	Minimize construction and operational impacts.	Construction and Operational Impacts Score
Maximize Implementation Potential	Political and institutional acceptability.	Political and Institutional Acceptability Score
	Regulatory hurdles and ease of permitting.	Regulatory and Permitting Ease Score
	Technical likelihood of supply development.	Technical Implementation Score
	Public support or opposition.	Public Support or Opposition Score

4.1.2 Weighting Objectives

In any decision-making process, the objectives are generally not equally important for every stakeholder. Some objectives may be more relevant for one stakeholder than others (e.g., for a given individual, operational flexibility may be more important than environmental and institutional constraints). Thus, weighting objectives is necessary to better reflect the values and preferences of stakeholders and decision-makers.

For the Water Supply Plan, the objectives were weighted using a method known as "forced-paired comparison." This method simplifies the comparison of numerous

planning objectives by looking at the relative importance of only two objectives at a time. This relative comparison is performed for all the possible pairs of objectives, and the results can be aggregated using simple algorithms to determine the overall importance of every objective. Overall weights can be obtained for each individual participant, as well as for the group as a whole. For the case of the Water Supply Plan, objectives were weighed individually by each stakeholder (see Appendix A for the results of this exercise). Each stakeholder's individual weightings for the objectives were preserved and used to rank alternatives (later described in Section 7).

Figure 4-2 presents an example result from this exercise for one stakeholder, where: (1) the vertical line represents the range of weights assigned to each objective by all stakeholders; (2) the horizontal line marker shows the average weight for all stakeholders; and (3) the diamond marker represents the weight for this example decision maker. The minimum and maximum weights of the group of stakeholders indicate that there is a very large spread in terms of objective importance.

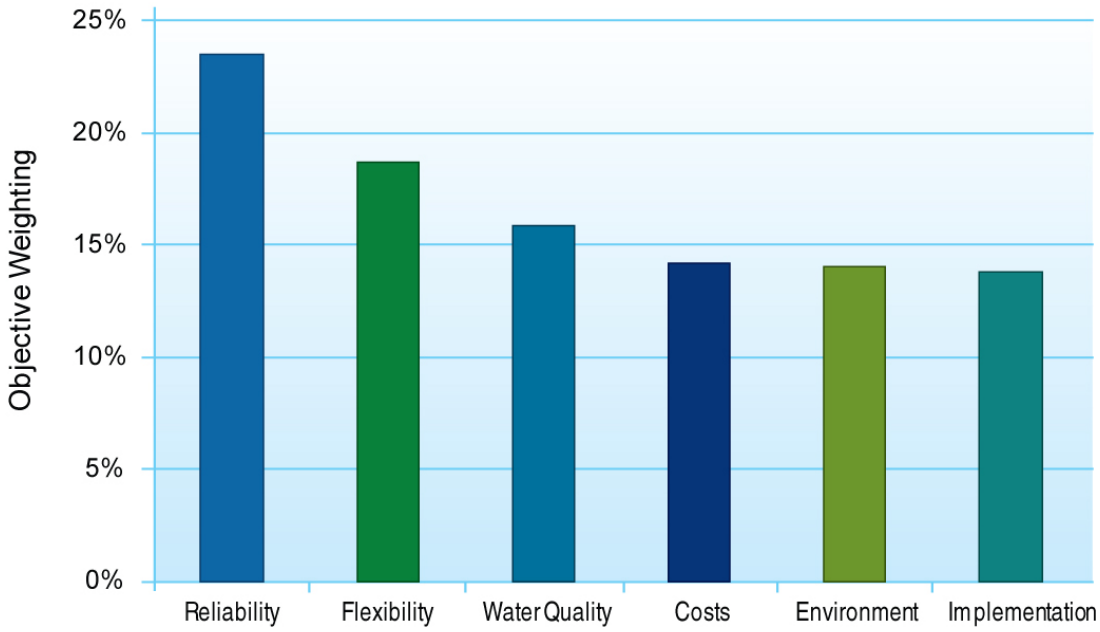

Figure 4-2
Example Objective Weighting for One Stakeholder

Since the results of the weighting exercise were maintained for each stakeholder, the Water Supply Plan planning team developed 18 different (15 stakeholders and 3 City staff) profiles for the objective weightings. For comparison purposes only, the Water Supply Plan planning team aggregated results into two set of weights: stakeholders and senior staff members (see Figure 4-3). In general, the weights appear to be similar for the stakeholders and the City staff.

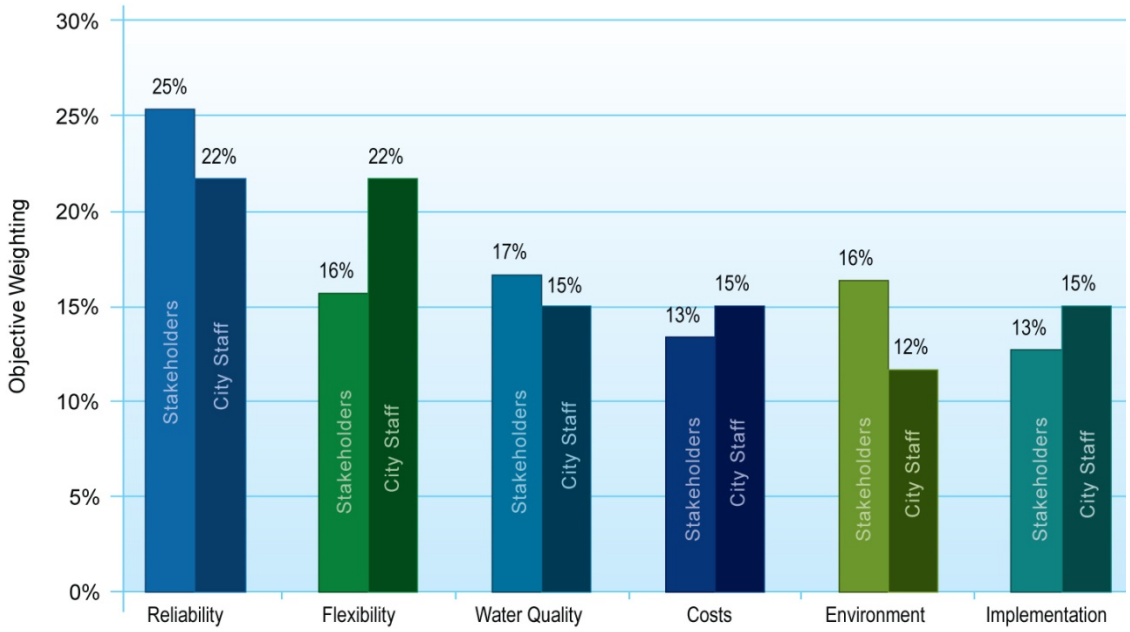

Figure 4-3
Comparison of Average Objective Weightings

4.1.3 Identify Options and Create Alternatives

The planning objectives represent essential reasons or purposes "why" the City is undertaking the Water Supply Plan; however, they do not specify "how" the City should move forward to meet these objectives. Supply options represent the individual projects and programs that are the potential means for accomplishing the planning objectives. The Water Supply Plan used these options as building blocks to develop integrated alternatives with the potential to meet the planning objectives.

Even with a relatively small number of options, the different combinations to form alternatives could be fairly large. Therefore, initial alternatives are developed that tend to push the boundaries of the objectives. In other words, the first round of alternatives is developed to optimize specific objectives. But since the purpose of a Water Supply Plan is to find a solution that balances all the objectives, it is understood that these initial alternatives may not be the best overall performers.

By examining the performance of these initial alternatives, trade-offs can be seen, such as maximizing supply reliability but at very high cost. Understanding these trade-offs can be useful in developing final alternatives, which take the best elements from top-scoring initial alternatives in order to create better performing alternatives.

4.2 Alternatives Evaluation Method

After developing objectives and alternatives, the next step in the planning process is to evaluate each alternative. The Water Supply Plan planning team developed and used a systems model programmed with the commercial software STELLA® to evaluate the Water Supply Plan alternative. In general, the systems model simulates water demands and supplies under different hydrologic and operating scenarios. The systems model can output raw performance, such as supply reliability, cost, water quality, etc. in order to see how well a specific alternative meets the objectives.

Because the systems model outputs raw performance measured in different units (e.g., reliability measured in AFY and cost measured in dollars), another decision tool is often needed to rank the alternative.

The Water Supply Plan planning team used the commercial software Criterium Decision Plus (CDP), developed by Infoharvest Inc., to rank the alternative. This software tool converts raw performance measured in different units into standardized scores so that the performance measures can be added together in order to rank alternative. This technique is called Multi-Attribute Rating and is illustrated in Figure 4-4.

Step 1 is to compare the raw performance of a given objective for all the alternatives. In this example, Alternative 6 has a raw cost (or performance) of $10 million.

Step 2 standardizes the raw performance score for each objective into comparable numeric scores (the higher the score the better the performance). In this example, Alternative 6 has relatively high costs when compared to the other portfolios, so the standardized score for this objective (between 0 and 10) is 3.4, a fairly low performance.

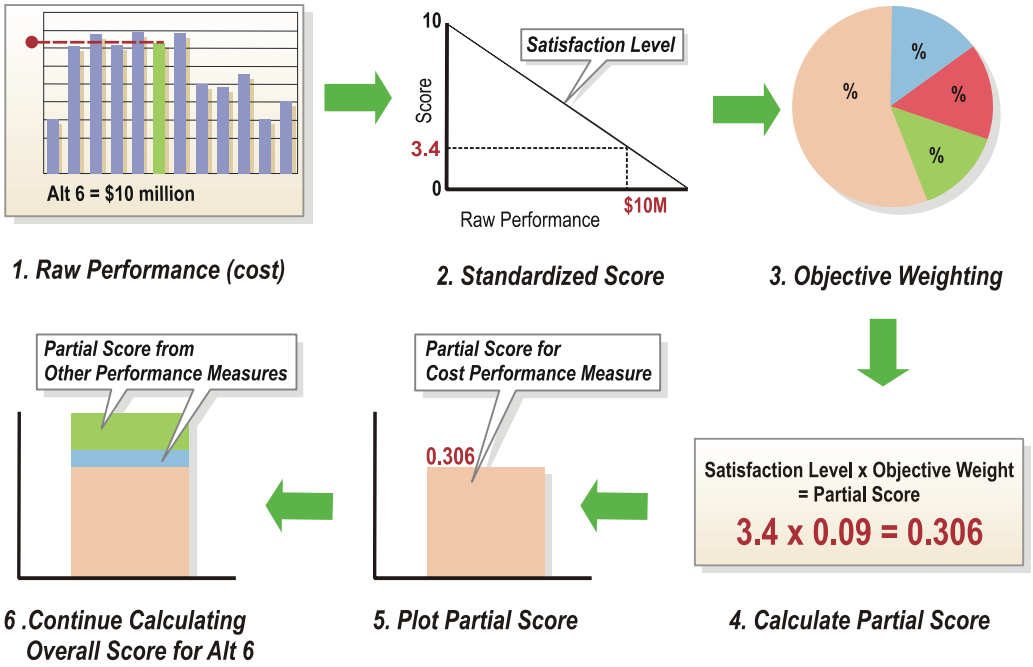

Figure 4-4
Multi-Attribute Rating Method

Steps 3 and 4 calculate the partial score for the alternative, based on the standardized score and the weight for the objective being calculated. In this example, the cost objective was given a weight of 9 percent (out of a possible 100 percent). The partial score for this objective is represents the standardized score (3.4) multiplied by the objective weight (0.09) which equals 0.306.

Step 5 plots the partial score of 0.306 for Portfolio 6, and this procedure repeats for all of the other objectives for Alternative 6 until a total score for the project is calculated (see Step 6).

The Water Supply Plan planning team used this process to develop overall scores for each alternative and using each stakeholder's unique objective weights in order to get 18 different rankings. In this way, the number of times an alternative was ranked as the Top 1, 2, or 3 could be calculated to determine the top performing alternative.

4.3 Systems Simulation Model

The planning team developed a systems model to simulate water demands and supplies for Water Supply Plan alternative with the year 2060 planning horizon. The systems model was used to evaluate the potential benefits and costs of implementing potential future water supply options to meet anticipated water demands.

4.3.1 Conceptual Model

The systems model performs a water balance based on the City's projected demands, existing water supplies, and potential future water supply options. The model was programmed to simulate future water supplies and demands for any year between 2010 and 2060. The simulation time step was specified as one month to be able to analyze important seasonality elements of the supply and demand in the project area. However, given the importance of the projected peak day deficits, two separate calculations were performed simultaneously by the model: (1) monthly scenario and (2) peak day scenario.

Due to the probabilistic nature of hydrology and the fact that some important elements in this project are hydrology dependent (e.g., local runoff into Arcadia Lake), the systems model was programmed to simulate a single planning year over a historical hydrology year sequence. This allows the model to determine the system performance for any type of hydrology condition.

The systems model included a number of different water supply options and physical delivery systems, such as existing supplies from the Garber-Wellington groundwater aquifer, existing Arcadia Lake surface water storage, and potential future surface water and groundwater supplies. In addition to the physical delivery of water supplies, the systems model included water conservation to offset the potable water demands. The physical system was represented in the model at a conceptual level only – i.e. the model did not simulate any hydraulic or hydrologic routing. Current water supply options in the model followed the conceptual representation depicted in Figure 4-5. Potential water supply options in the model followed the conceptual representation depicted in Figure 4-6.

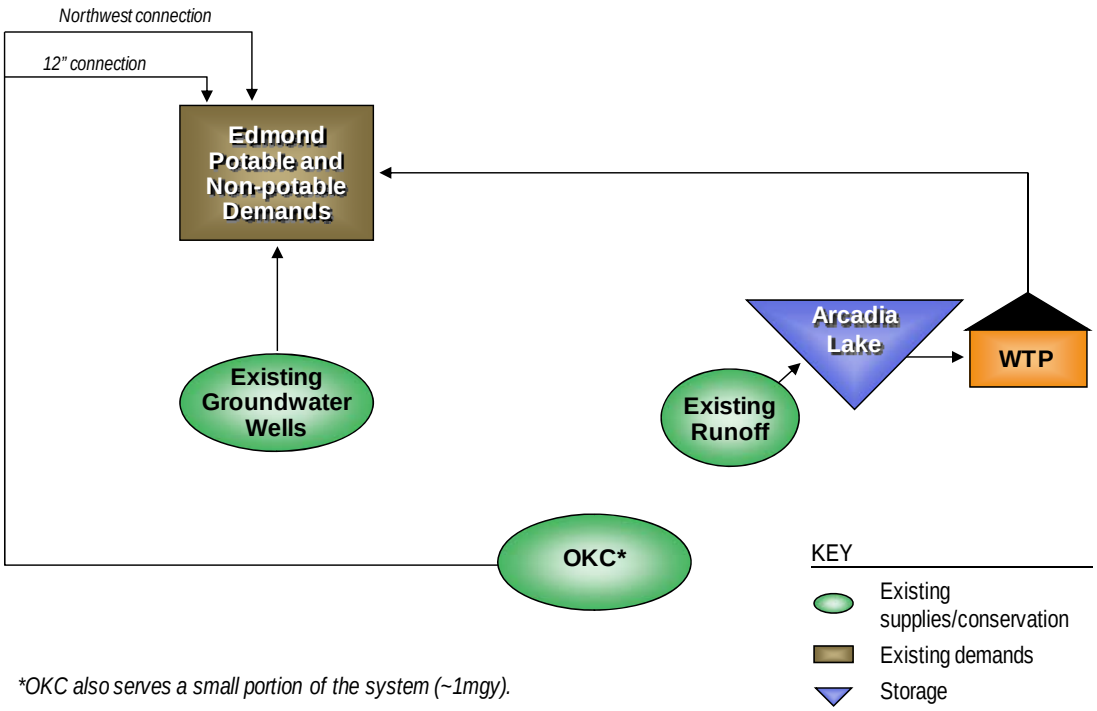

Figure 4-5
Conceptual Schematic of the City's Existing Water Supply

The model development process included: (1) identifying the City's water supply structure, including the groundwater system, surface water rights, contracts, major conveyance facilities, water treatment capacity, and costs of water sources; (2) defining the water management objectives and associated performance measures; (3) defining the water management options to include in the model; (4) defining the model outputs required; (5) identifying the relationships between the future water management options and existing system components; (6) collecting associated data and defining the response functions; (7) programming; and (8) performing a validation protocol.

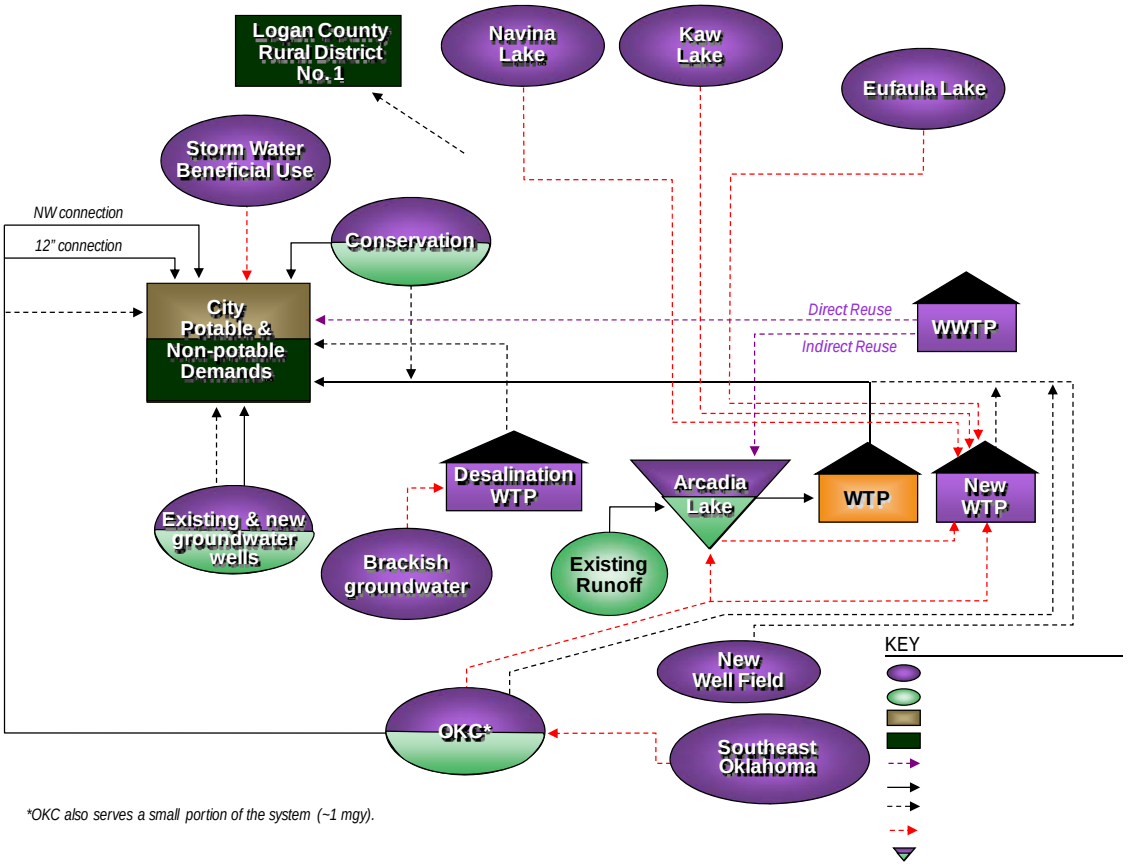

Figure 4-6
Conceptual Schematic of the City's Existing and Potential Water Supply Options

4.3.2 Model Elements

The model element include: projected water demands (refer to Section 3), existing water supplies (refer to Section 2), potential water supply options (refer to Section 5), and all performance measures, such as cost and water quality (described below in Section 4.3.5).

Water Demands

The City's forecasted water demands were included in the model from the year 2010 to 2060. Demands are included in the model as both monthly and peak day demands.

Hydrology

Modeling hydrology requires addressing several aspects. One of the most common challenges in modeling a water supply and delivery system is the use of averages for the representation of inherently probabilistic variables, such as precipitation, runoff into a stream or reservoir, or natural groundwater recharge. Another hurdle to be overcome is that what typically drives water demands upward (warm, dry weather) also drives supply downward.

To avoid these problems, simulations of water demand and various supplies were modeled using historical hydrologic records from 1970 to 2007. These records were used to generate weather demand factors that were applied to long-term averages (as described in Section 3.3.1). This allowed estimation of the variability in annual demand and supply under different hydrological conditions.

Seasonal factors were also generated to model monthly variations in data that were sensitive to rainfall and temperature (as described in Section 3.3.2). The seasonal factors were applied to average annual demand and average annual groundwater production to obtain monthly data for each.

Local runoff to Arcadia Lake was modeled by using United States Geologic Survey streamflow gage data from January 1970 through March 1985 (prior to the Arcadia Lake dam construction) and lake inflow data from the Army Corps of Engineers (ACOE) from April 1985 through December 2007.

ACOE records also provided historical data for evaporation from Arcadia Lake. Monthly average evaporation values in units of inches were calculated to generate a realistic seasonal trend for evaporation. A hydrographic survey of Arcadia Lake prepared by the Oklahoma Water Resource Board provided a relationship between the lake's surface area and volume to be able to define a function to calculate evaporation in units of flow based on the model predicted lake volume for each time step.

Priorities for the Use of Water Supply Options

Priorities were set to establish an order in which each supply is utilized to satisfy the City's demands. This is necessary for the model to know where to "stop" the supply and compute the supply mix and all associated outputs. The following is the priority order in which the supplies are activated in the model:

- Conservation
- Non-potable reuse
- Stormwater beneficial use
- Existing groundwater wells
- Replace existing groundwater wells
- Arcadia Lake to Edmond WTP
- Oklahoma City raw water to Edmond WTP
- Kaw Lake to Edmond WTP
- Navina Lake to Edmond WTP

- Eufaula Lake to Edmond WTP
- New groundwater wells outside Edmond
- Brackish groundwater
- Treated water from Southeast Oklahoma
- Treated water from Oklahoma City

The priorities for the use of water supply options were generally based on the marginal operating cost of water, with the assumption that once all the options are in place (i.e., capital investments have been made to establish a water supply option), the marginal operating cost of water dictates the decision on whether or not the supply is used in a specific year. In addition to the marginal cost rule, the type of supply was a factor for prioritization, taking into account the objective of maximizing local control of the supply. Figure 4-7 presents the proposed priorities programmed in the model.

Figure 4-7
Water Supply Priorities

4.3.3 Quality Control and Model Validation

Model development was subject to a quality control process. All data used in the model was obtained from information developed or complied by technical staff, and was reviewed by senior staff. The overall model structure and the modeling approach were discussed with the City in various work sessions and reviewed by an internal technical committee.

The model was subject to a detailed review for mass conservation, dimensionality, and response under extreme input conditions. The model was also tested for unit consistency.

4.3.4 Simulation Process

The input process for the systems model is facilitated by the use of a graphical interface based on switches that turn options on and off. Figure 4-8 shows a section of the graphical management panel developed for the systems model.

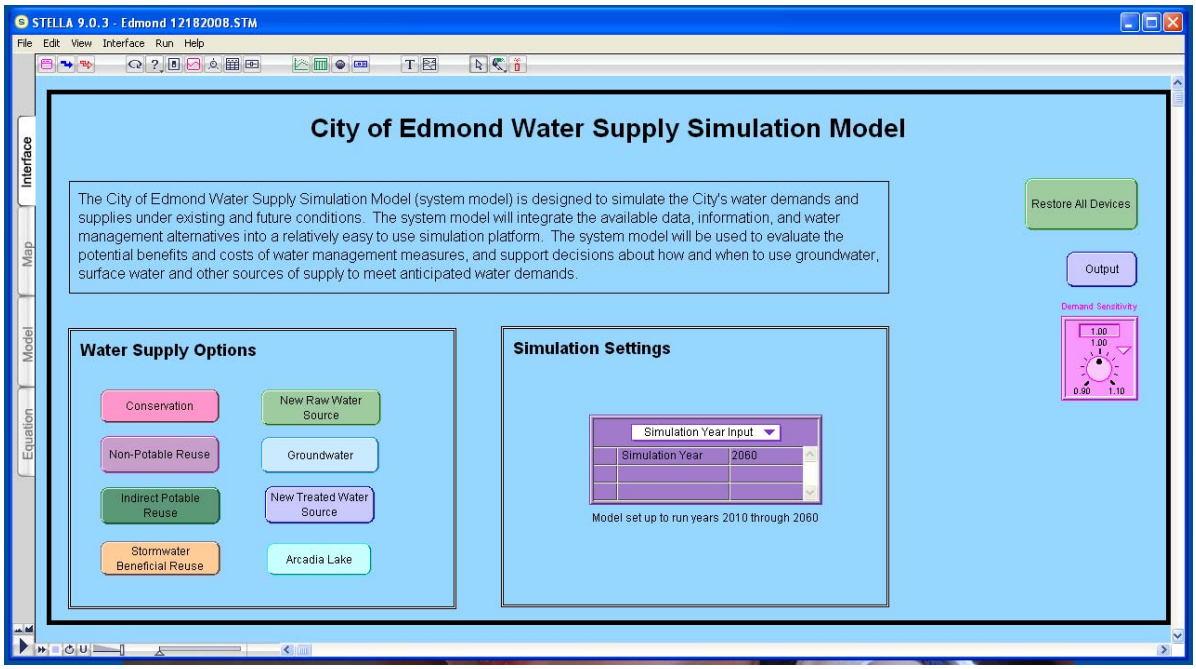

Figure 4-8
Management Panel Screenshot from STELLA Model

The following options were included in the model as management decisions:

- Conservation – selection of Level 1 and Level 2
- Non-potable reuse
  - Yield potential as a percent of non-potable demand
  - On-line year
- Indirect potable reuse
  - Yield potential in units of mgd
  - On-line year
- Stormwater beneficial use
  - Yield potential in units of mgd
  - On-line year
- New raw water options (i.e., Oklahoma City, Kaw Lake, Navina Lake , Eufaula Lake)
  - Permitted yield potential
  - On-line year
  - Selection to convey water to Arcadia Lake or directly to the Edmond WTP
- Groundwater
  - Yield potential
  - On-line year
- Treated water options
  - Yield potential for supply from Southeast Oklahoma
  - Allow additional capacity for supply from Oklahoma City
  - On-line year

To run the model, the user "switches on" desired water supply options for the portfolio by clicking on the appropriate buttons (the green square in the middle of the switch indicates that the option is "on").

Each project alternative was represented by a unique set of inputs to the model, which were entered in to the model through the management panel. Microsoft Excel was used to develop a spreadsheet-based output file that could be updated at the end of each simulation which was linked dynamically to the alternatives scorecard file.

4.3.5 Performance Measures

Performance measures are used to indicate whether an objective is being achieved. They generally answer the question "How well is a portfolio meeting the objectives?" and can be either quantitative or qualitative in nature. Refer to Table 4-1 for a list of the objectives and associated performance measures that were established for this Water Supply Plan. The following discussion explains how the alternative's score was calculated for the performance measures, both qualitatively and quantitatively.

4.3.5.1 Qualitative Performance Measures

For the model to provide output for the qualitative performance measures, a scoring system was established to quantify the performance measure.

Qualitative scores were used for the following performance measures:

- Security
- Sustainability
- Water quality
- Compatibility
- Environmental Impacts
- Construction and Operational Impacts
- Political and Institutional Acceptability
- Regulatory Hurdles and Ease of Permitting
- Technical Implementation
- Public Support or Opposition

Each qualitative performance measure has a rating scale of 1-5 (1 being the worst and 5 being the best). The alternative score for the qualitative performance measures is calculated as the weighted average of the ratings (or scores) for the options.

The weighted average is based upon the annual potential yield of the options included in the alternative. See Appendix D for the individual options' ratings.

$$PortfolioScore = \frac{(Score)_{Option(1)} * (Flow)_{Option(1)} + ... + (Score)_{Option(N)} * (Flow)_{Option(N)}}{\sum_{i=1}^{N} (Flow)_{Option(i)}}$$

4.3.5.2 Quantitative Performance Measures

The calculation methods of the portfolio scores for the quantitative performance measures differ from one another, and are discussed as follows:

Ensure Supply Reliability

There are three quantitative performance criteria defined for this objective: (1) average annual deficit, (2) peak day deficit, and (3) dry year deficit. The model calculated a monthly deficit and peak day deficit based on the difference in supply versus demand. The dry year deficit was based on the results for the hydrology year with the maximum deficit among the alternatives that actually have a deficit.

Percent Contribution of Largest Source to Total Supply

Diversifying the supply sources can help the City in the event that one of the supply sources is unavailable, such as imported water purchases from Oklahoma City. By increasing the number of sources for the City, the reliance on one particular source is reduced. This performance measure is calculated as the percentage of the largest potential annual yield from a source to the total annual supply.

Total Number of Sources

System diversity of the alternative was measured by the number of sources for water. The following were considered separate sources:

- Conservation
- Non-potable reuse
- Indirect potable reuse
- Stormwater beneficial use
- Raw water from Oklahoma City
- Raw water from Eufaula Lake
- Raw Water from Navina Lake
- Raw water from Kaw Lake

- Replace existing groundwater wells (only a separate source if the simulation year was set to be 2060 when all existing groundwater wells expect to be expired)
- New groundwater wells outside the City
- Brackish groundwater
- Treated water from Southeast Oklahoma
- Treated water from Oklahoma City
- Flow from Arcadia Lake minus inflow from other raw water sources
- Existing groundwater wells

Total Number of Take Points

System flexibility of the portfolio was measured by the number of take points, or major conveyance routes, to receive water. In some cases, several sources of water may be conveyed by one pipeline for delivery. Table 4-2 summarizes the take points defined by the model.

Table 4-2
Summary of Take Points

Supply Option	Separate Take Point	Explanation
Conservation	No	
Non-potable reuse	Yes	
Indirect potable reuse	No	Would go through Arcadia Lake
Stormwater beneficial use	Yes	
Recycled Water from Oklahoma City	No	Enters system at same point as “Arcadia minus other projects”
Recycled Water from Eufaula	No	Enters system at same point as “Arcadia minus other projects”
Recycled Water from Navina	Yes	Enters system to the north
Recycled Water from Kaw	Yes	Enters system to the north
Replace existing groundwater wells	No if Sim Year <2060, Yes if Sim Year = 2060	Same as existing groundwater
New groundwater wells outside City	No	Enters system same location as Arcadia WTP effluent
Brackish groundwater	Yes	
Treated Water from Sardis	No	Enters system same location as TW from Oklahoma City
Treated Water from Oklahoma City	Yes	Only count SE connection; do not count 1.5 mgd from the south since all alternatives will include this
Arcadia minus “other projects”	Yes	
Existing groundwater	Yes	

Total Capital Costs

This performance measure for affordability was calculated by adding the capital cost (in today's dollars) of all new supply options included in the alternative. For purposes of alternative comparison, implementation of the supply options was assumed to occur at the same time, and at the start of the planning period. Therefore, the capital costs for the options are equivalent to today's dollars.

Total O&M Costs

This performance measure for affordability was calculated by adding the O&M costs (in today's dollars) of all new supply options included in the alternative. Total O&M costs included a fixed cost to account for typical maintenance costs and a variable cost to account for actual operations' costs. An annual inflation rate of 3% was assumed for the O&M costs of all options. The total annual O&M costs were discounted back to today's dollars at an annual rate of 6% to calculate the annual O&M costs.

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Section 5
Development of Water Supply Options

Parallel to the definition and development of planning objectives, water supply options were identified that could be used by the City to meet their long-term water management objectives. The process of developing supply options was collaborative between the City and CDM. Potential options were identified by both parties; and through discussion and refinement, a diverse list of realistic options was agreed upon. Supply options can be projects, programs, or contractual arrangements with other agencies; they are the building blocks for the water supply alternatives (discussed in Section 6). The potential options can be broken down into categories based on the source of the water and the processes required before the water can be used. The categories of supply options include: conservation, reuse, surface water storage, groundwater, Oklahoma City water.

Following the identification of potential supply options, each option was characterized in terms of the conceptual mode of operation, facilities required for implementation, expected reliable yield, capital and operating costs, and issues related to water quality, environmental impact, and institutional coordination. It should be noted that the costs, yields, and other characteristics of the supply options are intended for planning level analysis and modeling. Although every attempt was made to obtain reasonable data, in some cases, certain estimates had to be made based on prior studies and/or professional engineering judgment. Before any supply option is actually implemented, a detailed investigation may be required.

The new supply options are described in the sections that follow. Table 5-1 summarizes the potential yields and costs for each new supply option.

Table 5-1
Summary of New Supply Options

Option	Average Annual Yield	Peak Day Yield	Capital Cost	Fixed O&M Cost	Variable O&M Cost	Imported O&M Cost
Level 1 Conservation	2,240 AFY	2.0 mgd	$410K	--	--	--
Level 2 Conservation	4,480 AFY	4.0 mgd	$3.8M	--	--	--
Stormwater Beneficial Use	560 AFY	0.5 mgd	$1.4M	$28K per year	$128 per AF	--
Non-potable Reuse	6,720 AFY	6.0 mgd	$15M	$302K per year	$1,153 per AF	--
Indirect Potable Reuse	5,000 AFY	4.5 mgd	$38M	$755K per year	$871 per AF	--
Increase Arcadia Lake Yield*	32,000 AFY	48 mgd	$107M	$10.7M per year	$117 per AF	--
Navina Lake	16,800 AFY	15.0 mgd	$297M	$13M per year	$1,450 per AF	--
Kaw Lake	16,800 AFY	15.0 mgd	$457M	$14M per year	$1,798 per AF	--
Eufaula Lake*	22,000 AFY	38.3 mgd	$1,021M	$29M per year	$1,760 per AF	--
Sardis Lake*	22,000 AFY	38.3 mgd	$268M	$1.7M per year	$154 per AF	--
Treated Water from Oklahoma City	**	**	**	**	**	$1,424 per AF
Raw Water from Oklahoma City *	22,000 AFY	38.3 mgd	$268M	$1.7M per year	$154 per AF	--

All unit cost assumptions are provided in Appendix C.
**Maximum yield and costs to "fill the gap" without any other new supply options.*
***Dependent on the alternative ("fill the gap" supply option always used with other new supply options).*

A list of all the options evaluated, along with information regarding their yields, costs, and qualitative performance measure scores, is provided in a summary table located in Appendix B. The cost estimates for each option and unit cost assumptions can be found in Appendix C.

In addition to developing yields and costs, each supply option was evaluated for its performance with respect to the qualitative performance measures, which is presented in Appendix D. The supply option ratings summarized in Appendix D are later used to calculate overall scores for the water supply alternatives.

5.1 Conservation

The City's existing conservation program consists of public education, measures to improve water distribution and metering, and water rationing on an as needed basis. Increasing water conservation could defer water supply needs by reducing demands. The proposed conservation option incorporates a two-tiered water conservation approach that could be implemented in addition to the City's existing conservation program. These are based on general concepts of future water saving and costs. Potential water conservation programs that are likely to produce the assumed level of water use reductions are outlined below. The estimated savings are derived from the expected demand forecast presented in Section 3. Analysis of historical monthly production data suggested that about 63 percent of annual water use is non-seasonal use. It was reasonably assumed that this represents the percent of annual water use that is indoor water use. The remainder (37 percent of annual use) was assumed to be outdoor water use.

5.1.1 Level 1 Conservation

The Level 1 Conservation effort was assumed to create a 5 percent efficiency in indoor water use and a 10 percent efficiency in outdoor water use. By the year 2060, this would equate to approximately 1 mgd of indoor water use savings and 1 mgd of outdoor water use savings.

Water conservation measures that could be implemented by the City that would result in such savings include:

- Distribution of water conservation education and awareness material to customers and in schools.
- Distribution of dye tablet kits with instructions for detection and correction of leaky toilets.
- Provide instructions to customers on proper setting adjustments of irrigation controllers.
- Distribution of moisture sensors for use with irrigation controllers.

- Provide water audits of residential customer properties on request, and target high water using customers.

Based on a review and analysis of similar conservation programs throughout the U.S., it is expected that these programs can be implemented and administered for $0.20 or less per gallon per day of water savings. The expected Level 1 savings and the associated costs are shown in Table 5-2.

Table 5-2
Level 1 Conservation Savings and Costs

Year	Water Savings (mgd)	Cost
2010	0.8	$160K
2020	1.0	$200K
2030	1.2	$250K
2040	1.5	$300K
2050	1.8	$350K
2060	2.0	$410K

5.1.2 Level 2 Conservation

The Level 2 conservation effort is assumed to reduce demand by 20 percent in combination with the Level 1 effort. By the year 2060, this would equate to a total of approximately 6 mgd of water use savings (2 mgd for Level 1 and 4 mgd for Level 2).

Water conservation measures that could be implemented by the City that would result in such savings include:

- Provide rebates for installation of dual-flush toilets.
- Provide rebates for water efficient clothes washers.
- Provide rebates for landscape irrigation sensors and controllers.
- Provide rebates for landscape changes that result in water savings.
- Provide incentives for turf replacement/removal.
- Provide rebates for irrigation sensors and controllers.
- Perform landscape audits to identify water leaks in irrigation systems and more efficient practices.
- Implement an inclining block rate structure wherein higher-volume users are billed more than lower-volume users.
- Provide rebates for non-water using urinals.

- Impose ordinance eliminating single-pass cooling technology. This technology transfers heat from the equipment to the water prior to discharge. The water is subsequently lost down the drain rather than recycled.

It is expected that these programs can be implemented and administered for $1 or less per gallon per day of water savings. The expected forecast with Level 2 savings and the associated costs are shown in Table 5-3. The total savings and costs of Levels 1 and 2 combined are shown in Table 5-4.

Table 5-3
Level 2 Conservation Savings and Costs

Year	Water Savings (mgd)	Cost
2010	0.4	$200K
2020	0.6	$300K
2030	1.2	$600K
2040	1.8	$1.6M
2050	2.4	$2.2M
2060	4.0	$3.8M

Table 5-4
Level 1 and Level 2 Combined Conservation Savings and Costs

Year	Water Savings (mgd)	Cost
2010	1.2	$360K
2020	1.6	$500K
2030	2.5	$850K
2040	3.3	$1.9M
2050	4.2	$2.6M
2060	6.0	$4.3M

5.2 Reuse Options

The potential future water reuse supply options involve the use of reclaimed water and stormwater urban runoff. Recycled or reclaimed water is a potential water resource that would otherwise be discarded.

5.2.1 Stormwater Beneficial Reuse

The stormwater beneficial reuse option involves the collection of stormwater runoff within the City limits, treatment of the runoff, and reuse of this water to meet the City's non-potable irrigation demands. The potential yield assumed for this supply option was 0.5 mgd. Figure 5-1 conceptually illustrates this supply option.

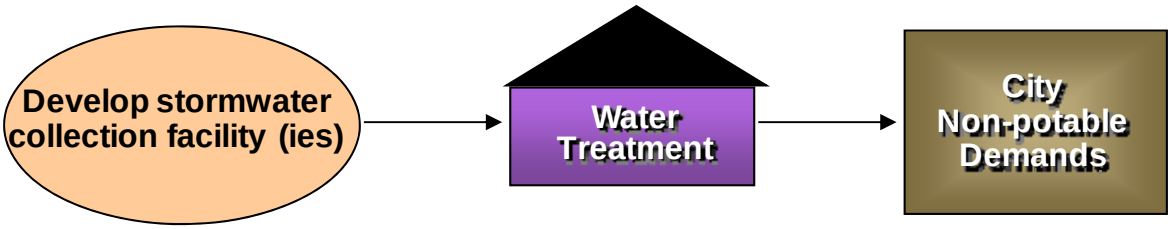

Figure 5-1
Stormwater Beneficial Reuse Option

The infrastructure included in this option was a collection basin (storage facility) and water treatment facility. For this study, the non-potable irrigation demands were assumed to be adjacent to the existing facilities and, therefore, infrastructure (pipeline and pump station) needed to convey water to these specific areas were not accounted for.

Costs for the stormwater beneficial reuse option include:

- Land needed for collection basin and treatment facility
- Stormwater collection basin
- Water treatment facility which would include dissolved air floatation and microfiltration.

The capital cost to implement this option was estimated to be $1.4 million. The fixed O&M cost was estimated to be $28,000 per year. And, the variable O&M cost was estimated to be $128 per acre-foot.

It is anticipated that the Oklahoma Department of Environmental Quality (ODEQ) would need to permit the project. This is an unprecedented project that may be a challenge to permit. In addition, implementation of this project would need to begin as a demonstration project to determine a feasible location.

5.2.2 Non-Potable Reuse

The City's wastewater treatment plant, Coffee Creek WWTP, has a design capacity of 9 mgd. The WWTP is operated under the Oklahoma Pollution Discharge Elimination System (OPEDS) permit. The treated effluent is currently discharged into Coffee Creek under a wastewater discharge permit issued by the ODEQ. The permit requires the City maintain best management practices for control and containment of material that could contaminate plant effluent.

Cities and agencies at various locations throughout the country are reusing treated effluent to achieve considerable costs savings and reduce the water needs of the provider. A portion or all of the City's treated effluent could theoretically be reused for non-potable irrigation purposes, instead of being discharged into Coffee Creek. The City does not have any legal return flow water obligations downstream of the WWTP discharge point.

Under this water supply option, treated wastewater effluent would be diverted at the Coffee Creek WWTP and conveyed through an independent non-potable distribution system for the irrigation of parks, golf courses, etc. Figure 5-2 provides a conceptual illustration of this option.

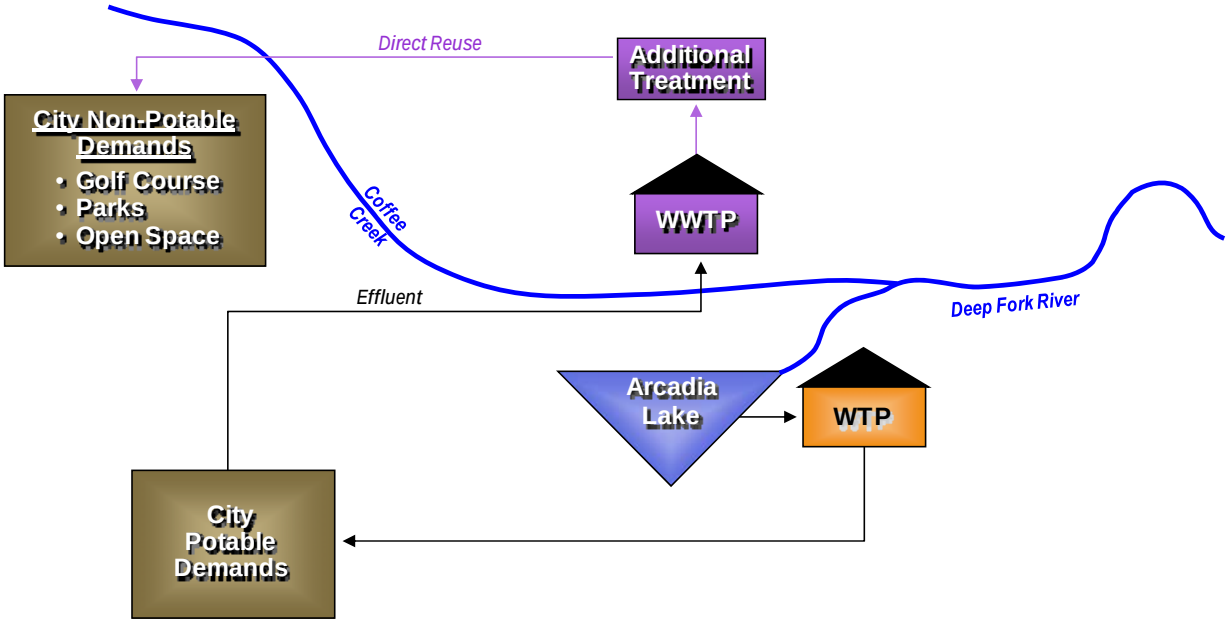

Figure 5-2
Non-Potable Reuse Option

The potential yield of this water supply option is dependent on both the amount of reclaimed water available for reuse and the non-potable demand. The City's Coffee Creek WWTP effluent discharge rate averaged 7.1 mgd (2,574 MG/year) from 2000 to 2007. Figure 5-3 presents the average daily wastewater effluent production by month of the WWTP from 2000 to 2007. Assuming 85 percent of this could be recovered, approximately 6 mgd (2,190 MG/year) would be available for reuse.

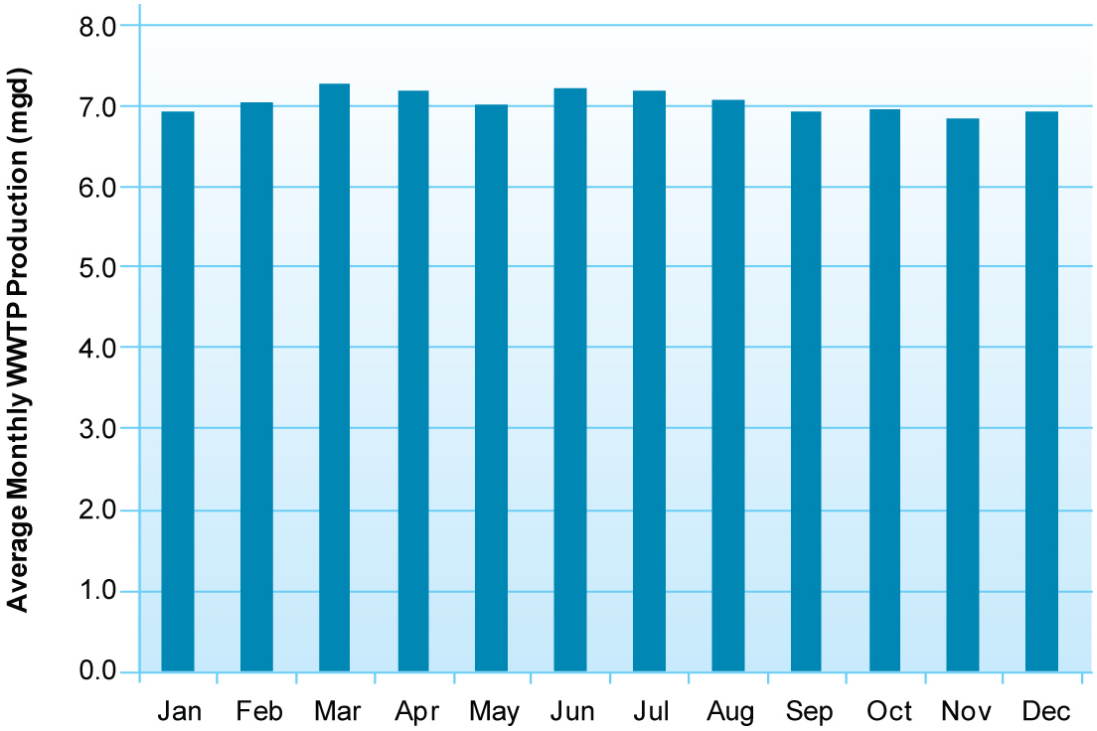

Figure 5-3
Average Daily Wastewater Production by Month

In order to estimate non-potable demands, it was assumed that the minimum monthly historical water production is the potable demand and monthly water production in excess of the minimum represents the non-potable demand. Based on this assumption, the 2005 potable and non-potable demands were estimated to be 6.1 mgd and 4.1 mgd, respectively, where non-potable demands are 40 percent of total demands. Assuming that Edmond will maintain this percentage of non-potable demands, forecasted non-potable demands were estimated to be 40 percent of forecasted total demands. Figure 5-4 presents the forecasted total demands and non-potable demands.

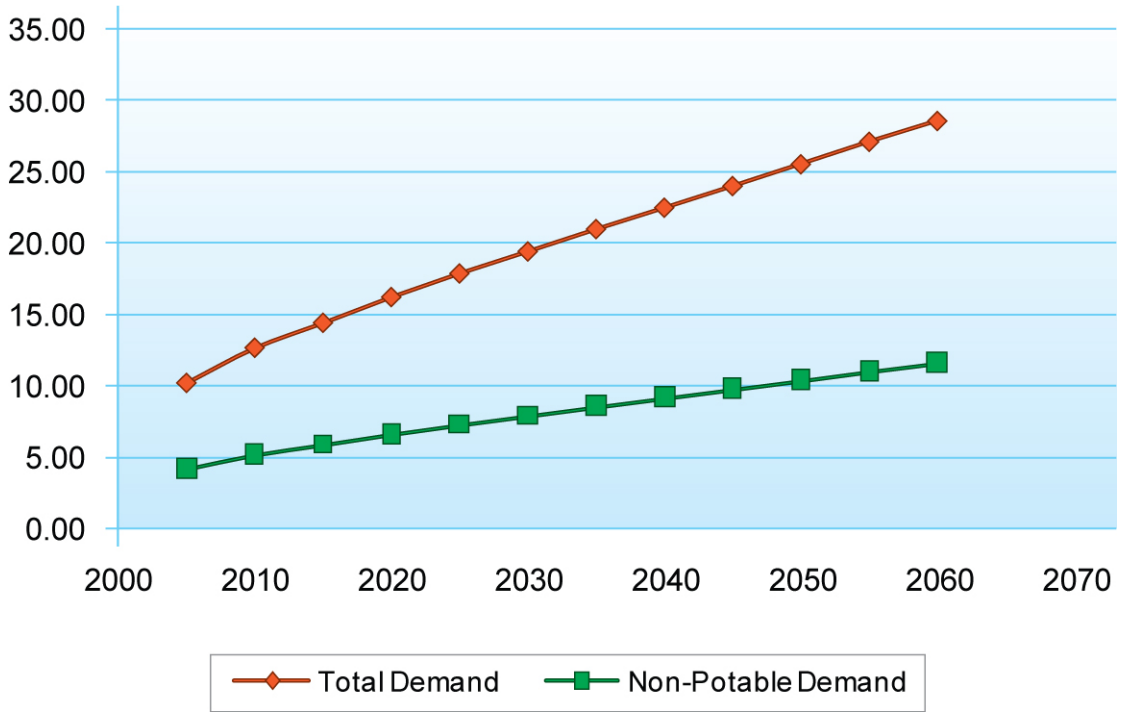

Figure 5-4
Total and Non-Potable Demand

The potential annual yield for the non-potable reuse option was assumed to be 6 mgd (or 55 percent of the 2060 non-potable demand). Similar to potable demands, non-potable demands are seasonal where demands peak during the summer months when irrigation demands are highest. Therefore, the seasonal factors (refer to Section 3) were used to estimate the monthly non-potable demands.

An August 2002 preliminary economic analysis was conducted to estimate the costs of delivering reuse water from the Coffee Creek WWTP to the Kickingbird Golf Course. This analysis concluded that the following infrastructure would be needed in order to upgrade the Coffee Creek WWTP for a reuse application:

- Reuse water pump station at Coffee Creek WWTP – This would be needed to convey the reclaimed water through a non-potable distribution system.
- Chlorination improvements at Coffee Creek WWTP including redundant chlorinators, chlorine residual analyzers, and closed-loop controls – These chlorination improvements would be needed to ensure that the treated effluent is sufficiently disinfected for irrigation purposes.

A non-potable distribution system independent of the City's potable system would also be needed to distribute the reclaimed water for irrigation. The layout of this system would need to be designed once specific locations for non-potable irrigation customers have been identified. For calculating the cost it was assumed that the demands lie adjacent to the Kickingbird Golf Course.

Costs for this option include:

- Chlorination improvements
- Non-potable distribution pipeline to demand areas adjacent to Kickingbird Golf Course
- Pump station

The capital cost to implement this option was estimated to be $15.1 million. The fixed O&M cost was estimated to be $302,000 per year. And, the variable O&M cost was estimated to be $1,150 per acre-foot.

In accordance with the Oklahoma Department of Environmental Quality (ODEQ) rules and regulations (252:621), a permit must be filed for all operation and maintenance related to non-industrial land application systems. This permit application requires a detailed set of data on both the treated effluent that would be applied as well as on the specific area of application. The data that would be needed includes: laboratory analyses of wastewater characteristics, wastewater production, legal land use descriptions, site topography, soil characteristics, access control, depth to groundwater, estimated application rate, nutrient assessment, emergency response plan, etc.

According to ODEQ regulations (252:621-5-2), all applications on a multi-purpose area (e.g. golf courses) must receive secondary treatment or equivalent, be disinfected, and be applied during times of non-use. Land application may not occur when the soil is saturated, frozen, or during periods of precipitation. Application is also limited to lands with a minimal slope and to areas where there is not a high potential for skin to ground contact. The landowner is required to maintain records on the following: location, timing, and method of application, analytical data on loading rates and volume of wastewater applied, weather conditions during the application period, and monitoring records of all samples taken (252:621-7-1). See ODEA Chapter 621 for further details on the rules and regulations.

Public perception is a factor to consider for implementation of this option. The City generally has a demographic of relatively high educated people. Generally this demographic is relatively accepting of the application of treated wastewater effluent for non-potable irrigation. A public education campaign is recommended to notify the public on the benefits associated with the reuse of treated effluent for irrigation and the areas where non-potable irrigation is proposed.

5.2.3 Indirect Potable Reuse

The indirect potable reuse option would involve the conveyance of reclaimed water from the Coffee Creek WWTP to Arcadia Lake for terminal storage and eventual finished treatment at the City's WTP prior to redistribution. Figure 5-5 provides a conceptual illustration of this option. The potential annual yield for this option was assumed to be 4.5 mgd.

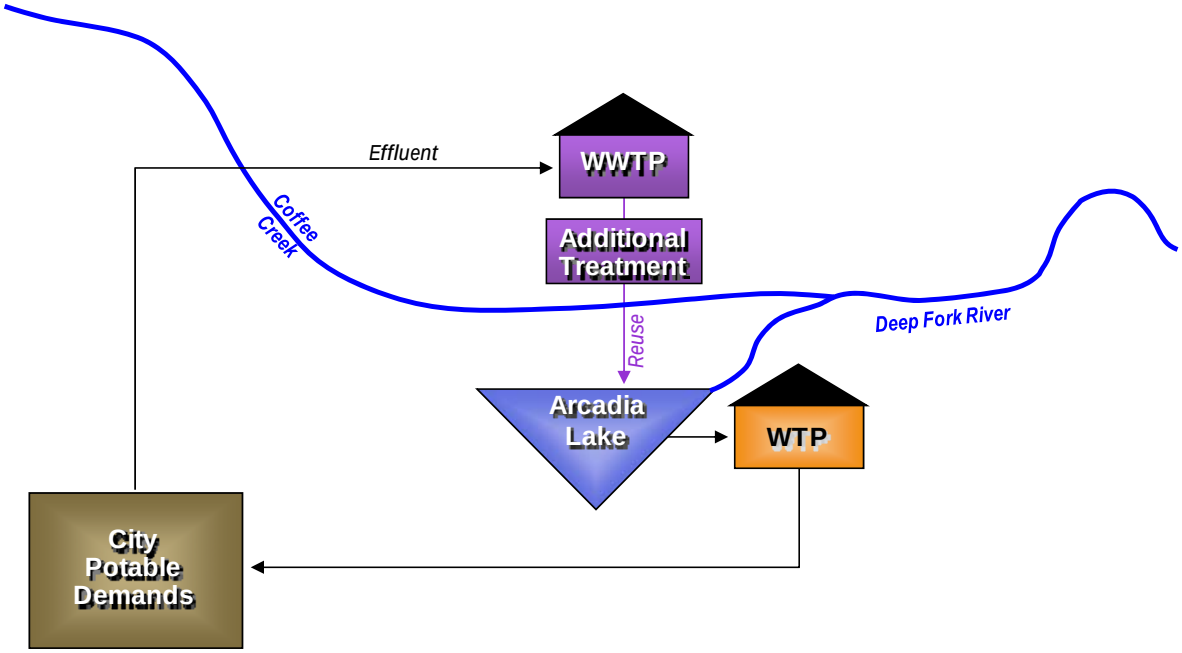

Figure 5-5
Indirect Potable Reuse Option

The implementation of an indirect potable water system would require an advanced treatment facility (e.g., membrane treatment followed by chlorination) for the WWTP secondary effluent, conveyance infrastructure (i.e., pipeline and pump station) from the treatment facility to Arcadia Lake, and a brine disposal pipeline to the confined aquifer.

Costs for this option include:

- Advanced treatment
- Conveyance pipeline and pump station
- Brine disposal pipeline

The capital cost to implement this option was estimated to be $38.1 million. The fixed O&M cost was estimated to be $755,000 per year. And, the variable O&M cost was estimated to be $871 per acre-foot.

Indirect potable reuse has not been directly applied in the State of Oklahoma and there is not a formal permitting or review process to assess indirect potable reuse. A significant amount of effort and coordination would be needed between the City, ODEQ, and the Army Corps of Engineers (USACE) in order to develop a permit and/or review process and, ultimately, for the City to obtain approval.

Public perception is a significant factor to consider for implementation of this option. Although the City may be relatively accepting of the application of reclaimed water for non-potable irrigation, the blending of treated reclaimed water with raw water for potable reuse is not a common practice in Oklahoma and would likely confront some public opposition. A public campaign would be needed to educate the public on the benefits associated with the reuse of reclaimed water for potable use and the low level of health and environmental risks.

5.3 Surface Water Options

Currently, the only surface water supply option for the City of Edmond is from Arcadia Lake which is located within the City limits. In addition to assessing the potential to increase the yield from Arcadia Lake, reservoirs outside City limits were considered to supply raw water for treatment at the City's WTP. This Section describes these surface water supply options.

5.3.1 Increase Arcadia Lake Yield Option

As discussed in Section 2, the City is limited in the use of Arcadia Lake as a water resource because: (1) the City is currently permitted to withdraw only 11 mgd and (2) the WTP intake and process capacity is 10.5 mgd. During the systems model development, it was recognized that Arcadia Lake has significantly more potential as a water resource than what is currently utilized. The option to increase the yield of Arcadia proposes the following:

- Increase the potential withdrawal rate by improving infrastructure
- Increase the capacity of the WTP intake structure and the treatment facility

There are two potential approaches to increase the yield and the permitted withdrawal rate:

1. Increase the amount that the City can withdraw by performing a 50% (or greater) urbanization study. The USACE's allocation of approximately 23,500 AF with a production of 11 mgd is based on an assumed 30% urbanization. Urbanization is likely more than this and if a formal assessment can confirm this, the City's maximum withdrawal would then need to be increased from a

regulatory perspective. This would involve changing the USACE's maximum withdrawal amount as well as negotiating with the OWRB to increase its water rights.

2. Allow the City to utilize releases required to maintain the empty flood pool without including it as part of the permitted withdrawal amount.

The potential annual yield is dependent on the hydrology year where the total usable volume would remain at 25,000 AF (the conservation pool). The costs estimated for this option were developed as a per mgd cost, depending on the additional facility capacity selected for the alternative. The capital cost to implement this option was estimated to be $2.8 million per mgd. The fixed O&M cost was estimated to be $279,000 per mgd per year. And, the variable O&M cost was estimated to be $117 per acre-foot.

5.3.2 Navina Lake

In 1977, a feasibility investigation was initiated to study the water resources of the Cottonwood Creek basin to formulated plans for the development of those resources to meet identified needs in the study area. The cities of Edmond and Guthrie were the only two communities identified as potential users of water from the potential project. Two dam sites were identified along Cottonwood Creek to develop surface water reservoirs: Navina and Seward. According to the concluding report, the Navina dam site was less expensive, therefore, Navina Lake was included as part of this Water Supply Plan as a potential new surface water supply option. Figure 5-6 shows the location of this proposed lake in relation to the City.

Navina Lake would drain 220 square miles with conservation storage of 111,846 AF and yield 34,600 AFY (30.9 mgd). It was assumed that the cities of Guthrie and Edmond would share the yield and costs of this water resource. The raw water would be treated at a new water treatment plant shared by each of the participants near the reservoir and then conveyed to the participants directly for consumption.

The implementation of this option would require the construction of a dam for Navina Lake, a new treatment facility, conveyance pipeline and pump station.

Costs for this option include:

- Dam for the new reservoir
- Treatment facility
- Conveyance pipeline and pump station

The capital cost to implement this option was estimated to be $297 million. The fixed O&M cost was estimated to be $13 million per year. And, the variable O&M cost was estimated to be $1,450 per acre-foot.

Figure 5-6
Surface Water Options

As discussed above, Guthrie and the City have expressed interest in developing this reservoir. All payment and construction efforts of the reservoir, water treatment facility, and conveyance infrastructure would need to be coordinated among the participants. Operations involving the reservoir maintenance, treatment, and delivery of the water would also need to be coordinated among the two entities. Permits for yields and storage would need to be obtained from OWRB.

5.3.3 Kaw Lake

Kaw Lake is a multipurpose reservoir on the Arkansas River about 8 miles east of Ponca City in Kay and Osage counties and extends into southern Kansas. The project to construct the reservoir was authorized for flood control, water supply, water quality control, recreation, and fish and wildlife by the Flood Control Act of 1962. Construction began in June 1966 and the project was placed in useful operation in May 1976.

Kaw Lake provides 867,310 AF of flood control storage, protecting some 39,000 acres of agricultural land in the Arkansas River Basin. It provides flood protection for the Ponca City area where major floods have occurred several times. It also provides 203,000 AF of water supply and water quality storage. The water supply yield, including water quality storage, is 230,720 AFY (205.4 mgd). (USACE, 2005) In

addition, the Oklahoma Municipal Power Authority installed a 37-megawatt facility utilizing this lake. The unit came on line in August 1989.

About 16, 250 acres of Federal land were made available to the Oklahoma Department of Wildlife Conservation and 4,340 acres were made available to the Kansas Fish and Game Commission as wildlife management areas. In cooperation with Oklahoma and Kansas State agencies to further enhance wildlife habitat, a lake level management plan has been implemented at Kaw Lake.

Kaw Lake was included as part of this Water Supply Plan as a potential new surface water supply option for the City. Figure 5-6 shows the location of this proposed lake in relation to the City.

The potential supply option available for this option was assumed to be 15 mgd. The infrastructure needed for this option would include a treatment facility, conveyance pipeline and pump station.

Costs for this option include:

- Treatment facility
- Conveyance pipeline and pump station

The capital cost to implement this option was estimated to be $297 million. The fixed O&M cost was estimated to be $13 million per year. And, the variable O&M cost was estimated to be $1,450 per acre-foot.

Currently the Kaw Reservoir Authority maintains the rights to the water in the reservoir. Under the responsibility of the Authority, water purchase contracts can be obtained by contractual negotiations with interested parties. For the City of Edmond to obtain water from this project they would have to enter into a contract with the Kaw Reservoir Authority. No state permit is required. Terms of the water contract could be negotiated to meet the needs projected for Edmond.

5.3.4 Eufaula Lake

Eufaula Lake is the largest of five major impoundments in the Southeast Region of Oklahoma. This project was constructed in 1964 for flood control, water supply, navigation, and hydropower. The flood control storage of 1,510,800 acre-feet is credited with preventing over $107 million of flood related damages since becoming operational. The lake is located on the Canadian River about 12 miles east of Eufaula, Oklahoma. The lake is the 15th largest man-made impoundment in the United States with a surface area of 105,500 acres at its normal pool elevation. The lake has a dependable water supply yield of 56,000 acre-feet/year (50 mgd). (USACE, 2005) Figure 5-6 shows the location of this Eufaula Lake in relation to the City.

The systems model was programmed to utilize this option to fill any supply gap. Therefore, the potential annual yield was dependent on the alternative.

The infrastructure needed for this option would include a treatment facility, conveyance pipeline and pump station.

Costs for this option include:

- Treatment facility
- Conveyance pipeline and pump station

According to the Oklahoma State Water Plan, of the 56,000 acre-feet/year of water supply yield, 4,000 acre-feet/year is allocated to Haskell County and 44,000 acre-feet/year is allocated to Pittsburg County. Inter-agency coordination with these agencies would be required to obtain water rights for this supply option. The water is of fair quality and is suitable for most M&I uses.

5.3.5 Sardis Lake (Southeast Oklahoma)

The proposed Oklahoma Regional Water Utilities Trust (ORWUT) is being studied to consider funding the collection and conveyance of water from the Kiamichi River Basin to the stakeholder parties in central Oklahoma. Currently, ten entities have shown interest in becoming a member of the trust, and others may consider joining at a later date. These entities include: Edmond, Oklahoma City, Moore, Norman, Del City, Midwest City, Shawnee, Seminole, Chickasha, and the Central Oklahoma Water Resources Authority (COWRA). (CDM 2009)

Sardis Lake is located in the Kiamichi River Basin in Southwest Oklahoma and is one of the two major reservoirs located in this region. Figure 5-6 shows the location of this lake in relation to the City. Sardis Lake drains a 275-square mile subwatershed of the Kiamichi River Basin, and is located off of the mainstem of the Kiamichi River. It is operated by USACE, primarily for flood control purposes, local supply, and recreation. It has 274,209 AF of conservation storage, of which only 8,269 AFY (7.4 mgd) is currently allocated, and 122,564 AF of flood control storage. The conservation pool ranges from elevation 542 feet to 599 feet (only 124 AF are inaccessible below 542 feet), and the flood control pool extends to 607 feet. Controlled releases of water from the reservoir downstream to the Kiamichi River are primarily limited to flood control purposes. A lake level management plan has been recommended but such a plan does not currently guide decisions on water level management in Sardis Lake.

The systems model was programmed to utilize this option to fill any supply gap. Therefore, the potential annual yield was dependent on the alternative.

The Oklahoma Regional Water Supply Infrastructure Study, completed by CDM for the participating cities identified various water delivery alternatives. For the purpose of this study, it was assumed that the same facilities for conveyance and storage

needed to convey treated water supply from Oklahoma City to Edmond would be required (see Section 5.5.1).

Water rights allocations, cost-sharing programs and operations' responsibilities will be required among all stakeholders involved in the project. There are also a number of environmental regulatory requirements that will need to be addressed prior to receiving approval from regulatory agencies for implementation of the project. These are typical of environmental issues associated with any water transfers and water delivery pipeline construction projects.

5.4 Groundwater Options

The groundwater options involve the use of the City's existing well system as well as the development of new groundwater resources.

5.4.1 Replacing Existing Groundwater Wells

This option involves the City maintaining their current groundwater supply, with its related production wells, wellhead treatment facilities, and distribution. The potential yield for this option assumed that the City would maintain its existing average production rate of 5.2 mgd during the 50-year planning period. This yield is associated with the production capacity of groundwater from City's 58 existing wells. Older wells that have reached the terminus of their service life would be replaced with new wells to maintain production.

For purposes of this analysis, it was assumed that each well has a 50-year service life. Figure 5-7 shows the decrease in annual average groundwater production (5.2 mgd) as the wells reach the end of their service life and are taken out of production.

The only infrastructure required for this option is the development of new wells to replace the old wells taken out of production. New wells would need to be drilled and connected to the City's distribution systems. The capital cost to implement this option by 2060 was estimated to be $2.3 million. The fixed O&M cost was estimated to be $45,000 per year. And, the variable O&M cost was estimated to be $2,173 per acre-foot.

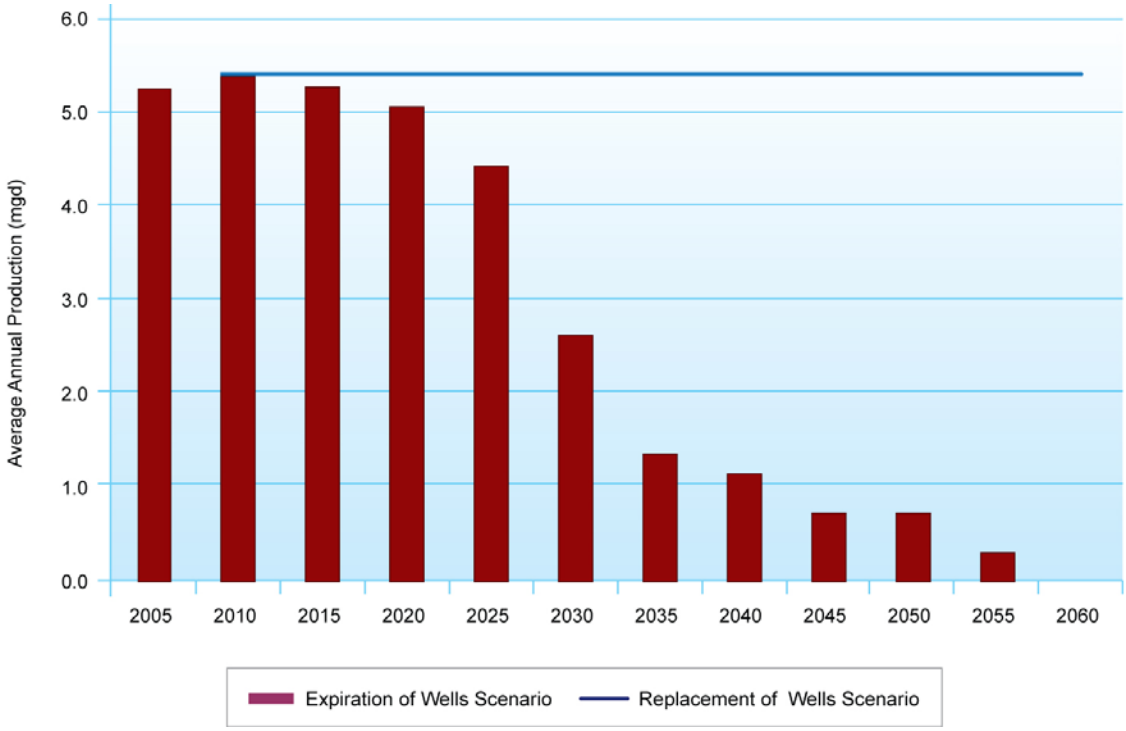

Figure 5-7
Percent Contribution from Largest Source to Total Supply in Alternative

The following are factors to consider for implementation of this option:

- *Potential for saltwater intrusion* - Although area groundwater quality has not, on the average, been declining as a result of current production practices, future groundwater production from the City's wells may be compromised by changes in the brackish/fresh water interface that exists northwest of Edmond and below the City's major production zones. Predicting the movement of the brackish/fresh water interface is beyond the scope of this project. Nonetheless, the movement of the interface is an important feature to identify with respect to its potential negative impact on the sustainable yield from the current configuration of water supply wells. During periods of drought or prolonged pumping over the site aquifer, brackish waters may intrude into the current production zones, impacting the potable water supply produced by the existing well configuration.

- *Natural fluctuations in recharge* - Another noteworthy concern is that average long-term production rates are subject to change if aquifer levels decline in the future due to naturally occurring fluctuations in recharge. If a prolonged drought occurs, it is possible that aquifer yields will decrease, thereby reducing reliable groundwater production to below 6.5 mgd. Although, the proximity of Arcadia

Lake within the recharge zone suggests this is not likely for that portion of the aquifer underlying the City.

- *Permitting and reliability of supplies*
  - Oklahoma's groundwater law requires that all non-domestic uses of groundwater be authorized by permit issued by the OWRB. Since the Garber-Wellington Formation has not yet had a formal hydrologic survey and maximum yield determination completed, OWRB can only issue a temporary permit for production of groundwater to the City. Temporary permits typically authorize the applicant's withdrawal and use of two acre-feet of fresh groundwater for each acre of land owned or leased and dedicated to the application.
  - An aquifer yield study is underway for the Garber-Wellington aquifer. Although not complete, the results from this study could result in the permanent yield rate being reduced. It is not known if Garber-Wellington Aquifer can provide two acre-feet of water per one acre of surface area. Oklahoma state law mandates that temporary permits be issued when aquifer studies have not been completed to verify the capacity of the aquifer in question. Until the Garber-Wellington Aquifer study is completed, all groundwater permits will be issued under the two acre-foot per surface acre presumption.
  - The City's current groundwater actions provide approximately 52 percent of the City's existing water supply needs. However, current production levels could be reduced as a result to changes in permit conditions, saltwater intrusion, and/or reductions in natural recharge. Furthermore, selenium, chromium, and arsenic are naturally occurring metals in the Garber-Wellington Aquifer, and are currently regulated under Oklahoma's Safe Water Drinking Act. Wells exhibiting concentrations of these metals exceeding the regulatory standards would either need to be treated or would need to cease operation.

5.4.2 New Well Field South of the City

This option involves the development of a new well field south of the City and east of I-35. Based on an October 2007 study conducted by Spear Engineering, the area shown in red Figure 5-8 is most conducive for groundwater development. This area consists of approximately 3,000 acres and is generally composed of larger parcels with relatively less development than the surrounding area.

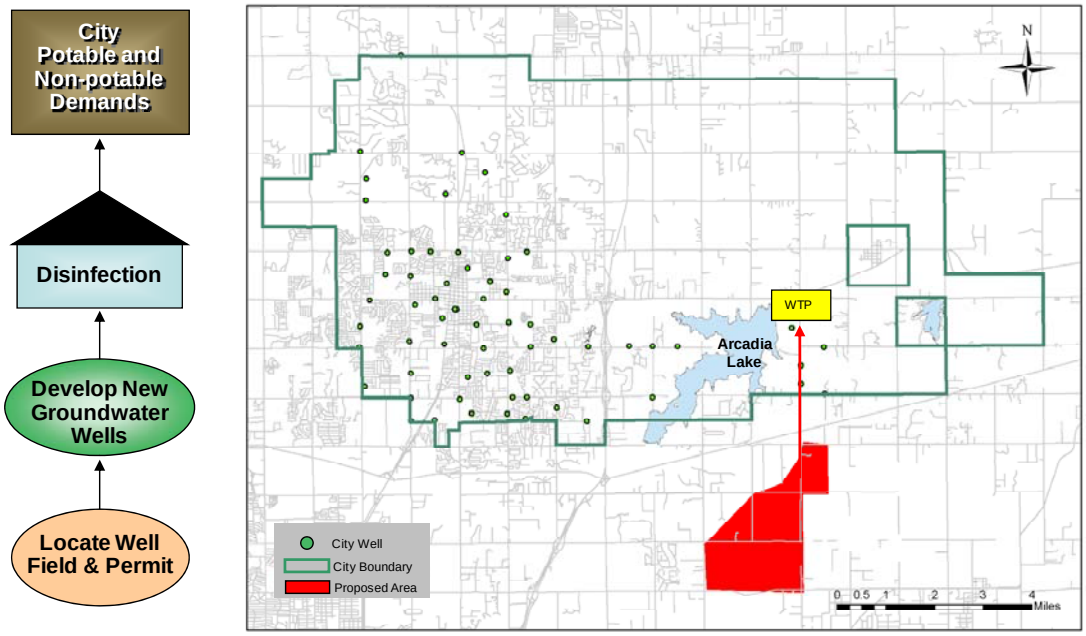

Figure 5-8
Proposed New Well Field South of City

The new production wells would be located on leased property; therefore, the City would need to acquire and service the appropriate amount of property needed for groundwater development. Permits for the new groundwater development would also need to be obtained from OWRB. For the purposes of this analysis, it is assumed that the water rights would be leased for the entire 50-year study period.

The allowable water rights underlying the identified 3,000 acres is almost 2 billion gallons of water per a year. However, only a portion of this water would likely be developed. For purposes of this analysis, it was assumed that an average annual yield of 2.5 mgd may be sustainably extracted from the aquifer and conveyed to the City for disinfection and distribution. This amount assumes that one section of land is developed (640 acres) and that 50% of the "maximum yield" may be sustainably extracted based on OWRB's 2 AF/acre (800 gpm) temporary groundwater extraction permitting limits.

The infrastructure required to implement this option included new extraction wells, interconnection piping, a pipeline adjacent to Post Road to convey supplies to the City's existing WTP for disinfection and distribution, and a pump station to convey supplies to the City's existing WTP.

The capital cost to implement this option was estimated to be $19.3 million. The fixed O&M cost was estimated to be $2.0 million per year. And, the variable O&M cost was estimated to be $257 per acre-foot.

The following are factors to consider for implementation of this option:

- *Land availability* - Groundwater rights are subject to the availability of right-of-ways and easements. Land would need to be available for the new wells, well housing, and construction of the new water distribution system.

- *Placement of production wells* - Future placement and use of production wells, would be dependent upon local geologic and hydrogeologic factors, as well as the availability of water rights for production of groundwater from the Garber-Wellington Formation, the location of existing water transmission lines and distribution systems, and adherence to wellhead protection policies and guidance.

- *Groundwater quality and arsenic* – Development of groundwater wells within the proposed area will likely be free from arsenic based on two independent findings. The proposed area is within a targeted area that is least likely to contain arsenic according to an Arsenic Study conducted in the local area by the Association of Central Oklahoma Governments in 2005 (ACOG, 2005). Furthermore, according to the October 2007 study, water quality samples from recently developed wells within the proposed area (Post Road between 33rd Street and 15th Street) have been below the arsenic mandated limit.

- *General groundwater quality* - The lack of commercial and industrial land use in these areas limits the current potential for future sources of contamination from impacting groundwater supplies. However, there is the potential impact of agricultural chemicals, specifically fertilizers, herbicides, and pesticides on local groundwater quality. Furthermore, the future development of the Arcadia Lake area could increase the risk of urban contamination, especially given that the aquifer within the vicinity of Arcadia Lake if unconfined. Development of production wells in this area may require that local land use or chemical use restrictions be developed and enforced.

5.4.3 Brackish Groundwater

This option involves the development of groundwater wells in deeper, brackish portions of the Garber-Wellington aquifer. The development of wells into the brackish portions would provide additional supplies to the City. However, a desalination treatment process will be needed to treat this water to acceptable potable standards. Figure 5-9 illustrates the general processes involved for the development of wells and treatment of brackish groundwater.

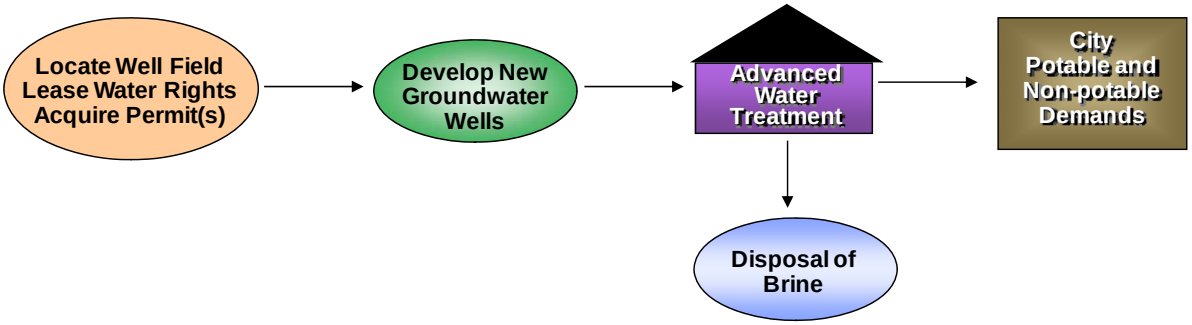

Figure 5-9
Brackish Groundwater Development Water Supply Option

The new brackish groundwater production wells would need to be located on City owned or leased property. If the proposed wellfield is not on City owned or leased property, the City would need to acquire the appropriate amount of property needed for groundwater development. Permits for the new groundwater development would also need to be obtained from OWRB. For this study it was assumed that the wells would be located on leased property and land acquisition costs were included in the analysis.

Field studies beyond this scope of this Plan would be necessary to quantify the yield that could be obtained through the development of groundwater wells in the brackish portion of the aquifer. For the purposes of this analysis it was assumed that an average annual yield of 2.5 mgd may be sustainably extracted from the aquifer for use by the City which is equivalent to the yield assumed for the New Wellfield South of the City water supply option. This allowed for these two water supply options to be compared on an equivalent yield basis assuming that the City would only develop one of these supply options.

New groundwater wells would need to be developed deep into the deeper brackish portions of the Garber-Wellington aquifer. These wells would need to be connected to a conveyance system that would transport the brackish water to a centralized advanced water treatment facility that could treat the highly saline water to sufficient drinking water standards while also satisfying customers' taste and odor expectations. Advanced treatment would involve advanced treatment, which would produce brine requiring disposal. For the analysis it was assumed that the brine would be disposed by using injection wells which would be located at a distance of 10 miles from the treatment plant in the confined portion of the aquifer.

The cost components for this option include:

- Land for drilling new wells
- New extraction and injection wells
- Conveyance pipeline
- Brine disposal pipeline
- Interconnection pipeline between wells
- Treatment facility

The capital cost to implement this option was estimated to be $19.3 million. The fixed O&M cost was estimated to be $268,000 per year. And, the variable O&M cost was estimated to be $257 per acre-foot.

A state permit would be needed to develop brackish groundwater wells. This would be the same type of permit that is attained for the development of shallower wells in fresh water. A permit from OWRB would be required for the brine disposal. In addition, separate ODEQ permits for waste disposal will be required.

The following are factors to consider for implementation of this option:

- *Groundwater quality* – The quality of deeper brackish groundwater in the Garber-Wellington Aquifer has not been studied intensively. It is recommended that a groundwater quality monitoring program sampling the area(s) of interest would be implemented prior to developing the full scale brackish groundwater well field. Naturally occurring elements such as arsenic in addition to the high TDS concentrations in the brackish portion of the aquifer could significantly increase the level of water treatment needed to treat the water to potable or even non-potable application standards.
- *Disposal of waste stream* – The treatment of brackish water would result in a waste stream with high concentrations of brine and possibly other contaminants. The disposal of this waste stream could be challenge both from a technical and regulatory perspective.

5.5 Purchases from Oklahoma City

The options for the City to purchase water from Oklahoma City include both raw water and treated water sources.

5.5.1 Treated Water Purchased from Oklahoma City

As discussed in Section 3, the City may purchase up to 15 mgd of treated Oklahoma City water for conveyance through their Northwest Complex and receive an additional 1.5 mgd through their 12 inch Oklahoma City interconnect for a total yield of 16.5 mgd. This yield is based on the City's 2004 agreement with Oklahoma City and capacity constraints.

This option proposes to increase the capacity and purchase agreement for Oklahoma City treated water. The systems model was programmed to utilize this option to fill any supply gap. Therefore, the potential annual yield was dependent on the alternative. Figure 5-10 presents the conceptual illustration of this option.

The infrastructure required for this option was based on the Preliminary Engineering Report (PER) for the City of Edmond, Oklahoma Water Transmission and Distribution System Improvements, December 2003. The main facilities identified to increase the yield of Oklahoma City treated water were pipeline to convey the water the City's northwest complex and a storage tank. According to the PER, the conveyance pipeline is approximately 4.5 miles (23,500 feet) and a 2 MG storage tank is required for 15 mgd of yield. Therefore, the systems model was programmed to calculate the infrastructure costs for this option based on the size of pipeline and storage tank needed for the required yield. In addition, costs associated with Oklahoma City's treated water rates were included.

Communication between the City and Oklahoma City is needed to coordinate deliveries to the City. A new agreement between the City and Oklahoma City will also be necessary to expand total Oklahoma City deliveries.

The City's reliance on a large quantity of Oklahoma City water would reduce the City's level of independent control over their water supplies. It is recommended that the City develop a payment schedule with Oklahoma City to clearly define water rate costs on an annual basis.

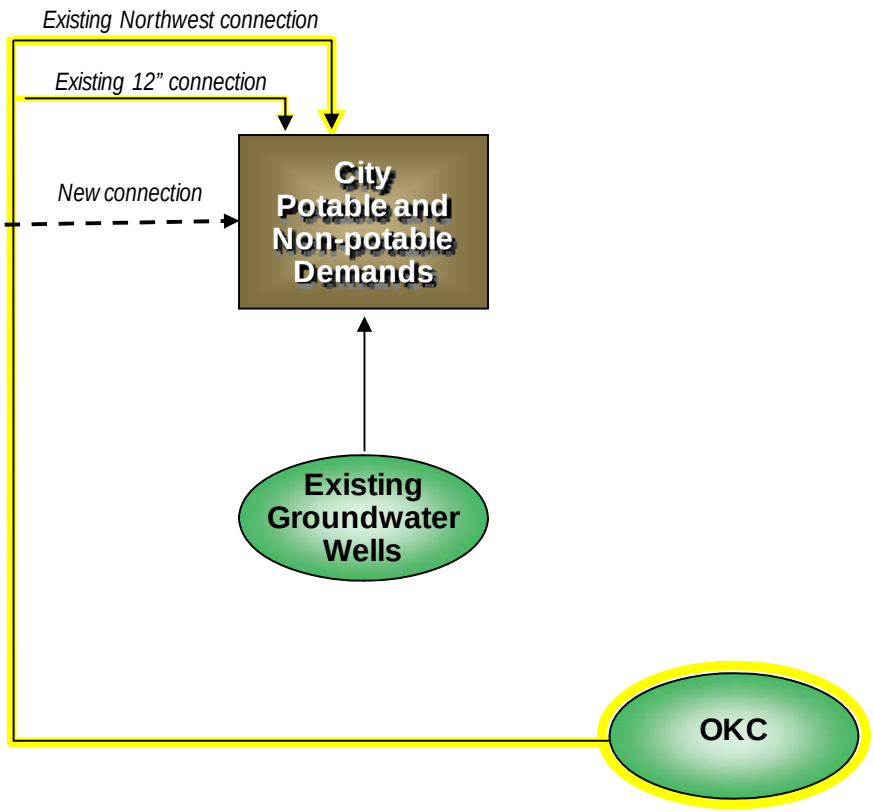

Figure 5-10
Treated Water Supply from Oklahoma City

5.5.2 Raw Water Purchases from Oklahoma City

Oklahoma City is planning to develop a pipeline that will convey water from Stanley Draper Lake to Hefner Lake within the next few years. This option would involve an agreement between Oklahoma City and Edmond where Oklahoma City would deliver raw water supplies through the newly constructed pipeline. This pipeline can either traverse the headwaters of Arcadia Lake or be connected directly to the WTP. Raw Oklahoma City water from this pipeline could be discharged into the Deep Fork River which would then gravity flow to Arcadia Lake. This option assumes that a pipeline would intercept the raw water flow just upstream of Arcadia Lake and convey the water directly to the Edmond WTP. The systems model was programmed to utilize this option to fill any supply gap. Therefore, the potential annual yield was dependent on the alternative. Figure 5-11 presents the conceptual illustration of this option.

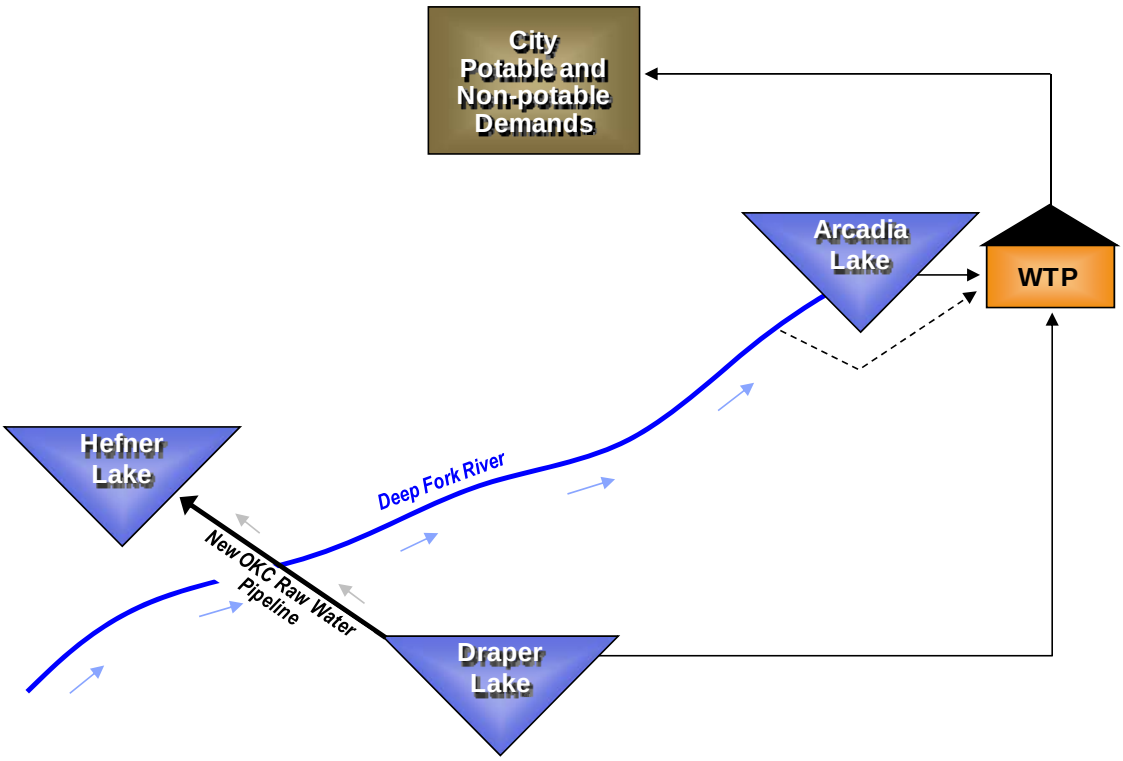

Figure 5-11
Raw Water Supply Option from Oklahoma City

The infrastructure required for this option would be a conveyance pipeline from the Deep Fork River just upstream of Arcadia Lake to the Edmond WTP. In addition, the City's existing WTP would need to be expanded.

Costs for this option include:

- Conveyance pipeline
- Expansion of Edmond WTP
- Raw water rate

An agreement between the City and Oklahoma City would be needed to define the payment schedule and general operations. Communication between the City and Oklahoma City would be needed to coordinate deliveries to the City and payment. Coordination on the construction of the raw water pipeline and the City's turnout would also be needed.

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Section 6
Development and Evaluation of Water Supply Alternatives

The interrelationships between individual water supply options (both existing and new) require that the entire water system be examined in a comprehensive fashion. The first step in modeling the water system is to develop comprehensive alternatives that represent combinations of supply options. These alternatives are then analyzed and compared according to their overall performance in meeting the city's objectives. Just as stocks and bonds may be pulled together to maximize gain and minimize risk as part of a successful investment strategy, so too can water supply options be combined very effectively into comprehensive water resource alternatives.

Some of the individual supply sources are sufficient for meeting the City's needs in the future. Therefore, alternatives were constructed to assess the performance of some individual new supply options in combination with existing supply sources. Additionally, alternatives were constructed using a variety of new supply sources. The following describes each alternative and presents the supply mix for the year 2060 under the dry hydrology year.

Individual supply options were described in Section 6. This section uses the cost estimates developed for the individual supply options and estimates the costs for the overall alternative. Tables are presented with the cost estimates for each alternative.

6.1 No Action Alternative

The No Action Alternative represents the City's current operations carried into the future. The current supply mix includes existing groundwater and no replacement of wells as they die-off when reaching their useful life (which results on a progressive reduction in groundwater use until no groundwater is supplied by the year 2060, see Section 5.4.1), surface water from Arcadia Lake, and treated water from Oklahoma City. This alternative does not assume and expansion of Oklahoma City treated water contract and infrastructure so it actually results in deficits in the future, particularly during dry years. Figure 6-1 shows monthly water supplies for the year 2060 under the dry year hydrology. This figure illustrates how existing supply options would only meet demands five months out of the year during a dry hydrology year. Table 6-1 summarizes the capital and O&M costs for the alternative.

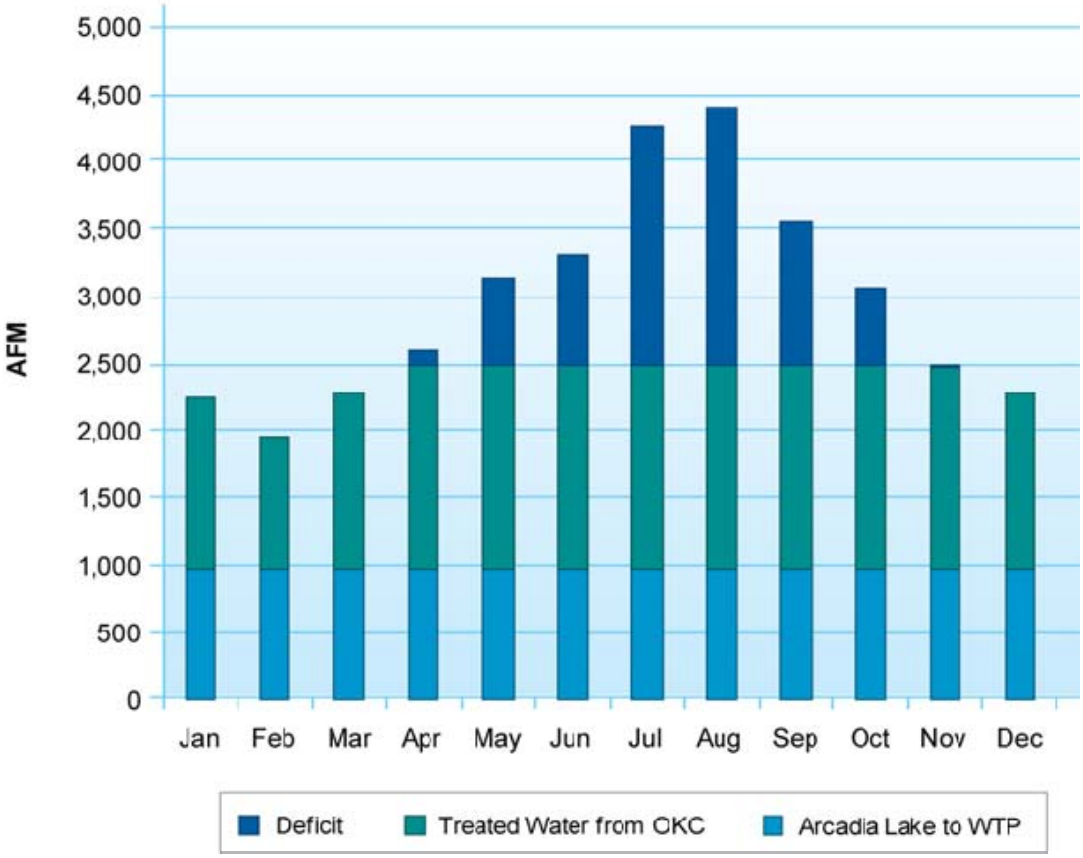

Figure 6-1
Dry Year Monthly Supplies for No Action Alternative, Projected for Year 2060

Table 6-1 **Costs for No Action Alternative**	
Capital Cost	--
Annual Fixed O&M Cost	$3M
Annual Variable O&M Cost	$1M
Annual Imported O&M Cost	$23M
Total Annual O&M Cost	$27M

6.2 Alternatives Based on a Specific Category of Supply Options

These alternatives focus on increasing a specific water supply (e.g., groundwater or surface water), or maximizing demand management. Each alternative in this group includes the existing water supply sources (represented by the No Action Alternative) in addition to new water supply sources.

6.2.1 Demand Management Alternatives

The demand management alternatives focus on implementing demand management options (i.e., conservation and water reuse options). Two variations of this alternative were developed, one with indirect potable reuse and the other without.

6.2.1.1 Maximize Demand Management A Alternative

In addition to existing water supply sources, the Maximize Demand Management A Alternative includes the following new supply options:

- Level 1 conservation
- Level 2 conservation
- Non-potable reuse
- Stormwater beneficial use

Table 6-2 summarizes the capital and O&M costs for the alternative. Figure 6-2 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how in addition to the new water supply options (conservation, non-potable reuse, and stormwater beneficial use), treated water purchases from Oklahoma City would be needed throughout the year during a dry hydrology year.

Table 6-2
Costs for Maximize Demand Management A Alternative

Capital Cost	$3M
Annual Fixed O&M Cost	$3M
Annual Variable O&M Cost	$9M
Annual Imported O&M Cost	$11M
Total Annual O&M Cost	$23M

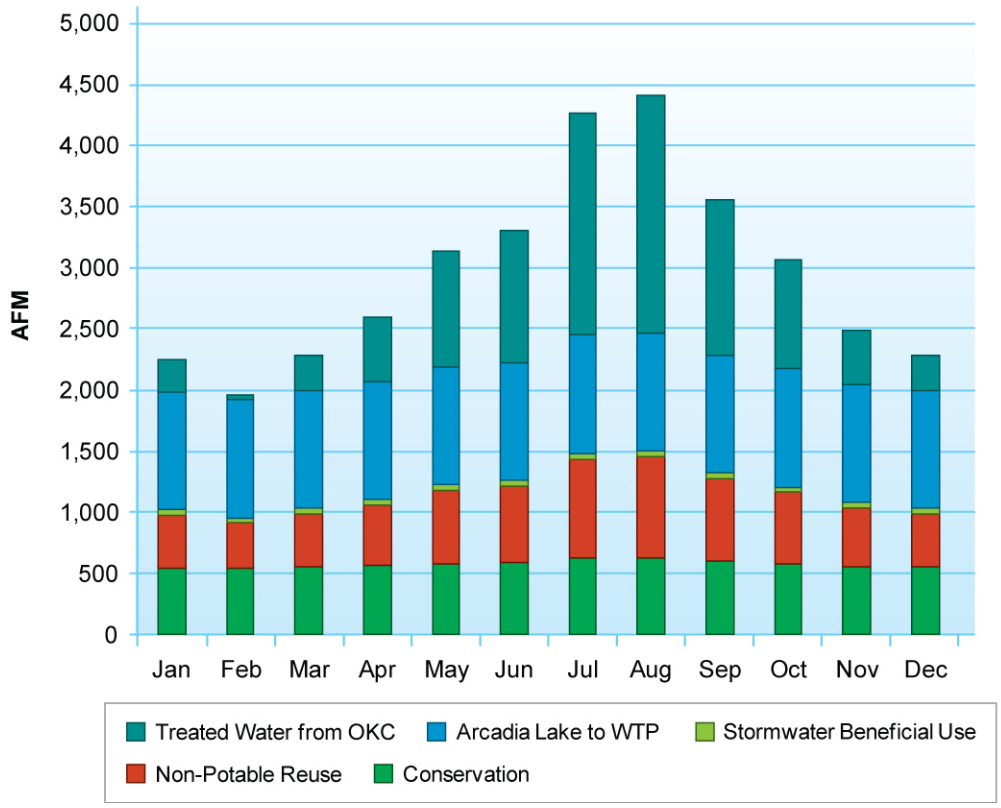

Figure 6-2
Dry Year Monthly Supplies for Maximize Demand Management A Alternative, Projected for Year 2060

6.2.1.2 Maximize Demand Management B Alternative

In addition to existing water supply sources, the Maximize Demand Management A Alternative includes the following new supply options:

- Level 1 conservation
- Level 2 conservation
- Non-potable reuse
- Indirect potable reuse
- Stormwater beneficial use

Figure 6-3 shows monthly water supplies for the year 2060 under the dry year hydrology. It should be noted that the indirect potable reuse option does not appear as a separate supply in the supply mix figure since the supply would be stored in Arcadia Lake with subsequent use as a raw water to the Arcadia water treatment plant. The figure illustrates how in addition to the new water supply options (conservation, non-potable reuse, and stormwater beneficial use), treated water purchases from Oklahoma City would be needed throughout the year during a dry hydrology year. Table 6-3 summarizes the capital and O&M costs for the alternative.

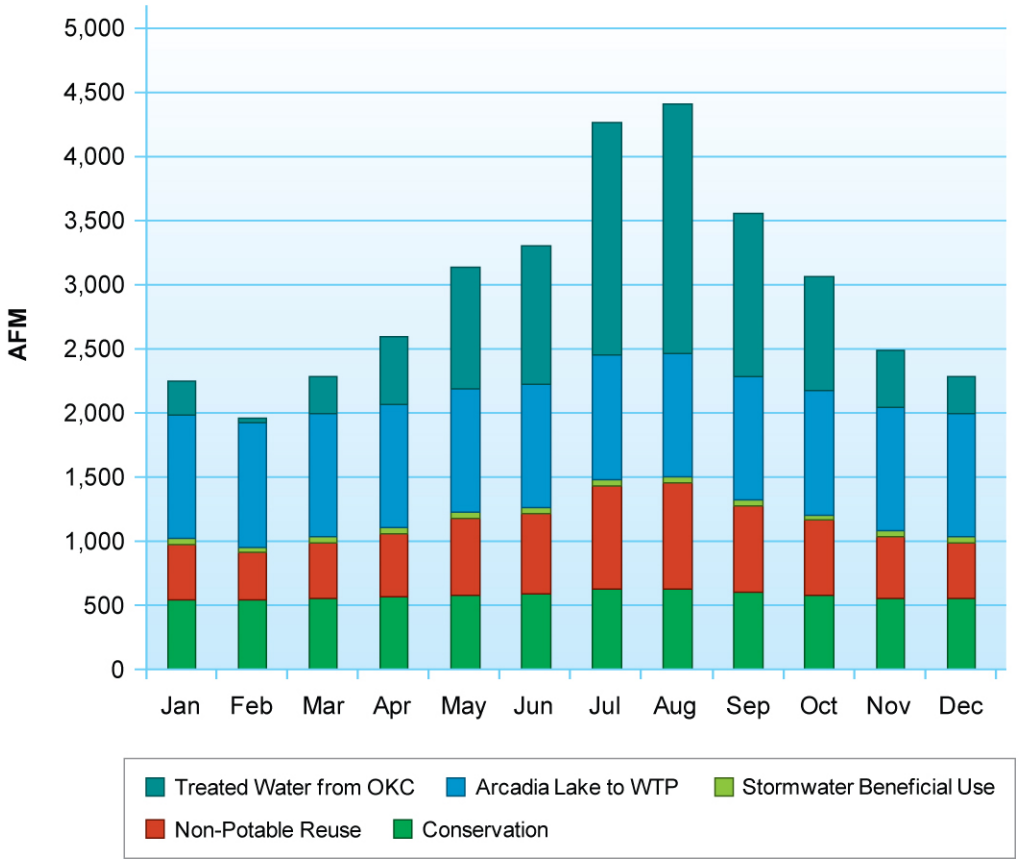

Figure 6-3
Dry Year Monthly Supplies for Maximize Demand Management B Alternative, Projected for Year 2060

Table 6-3 Costs for Maximize Demand Management B Alternative	
Capital Cost	$7M
Annual Fixed O&M Cost	$4M
Annual Variable O&M Cost	$12M
Annual Imported O&M Cost	$11M
Total Annual O&M Cost	$27M

6.2.2 Groundwater Alternatives

The groundwater alternatives focus on implementing new groundwater supply options. Two variations of this alternative were developed, one with groundwater wells outside City limits and the other without.

6.2.2.1 Maximize Groundwater A Alternative

In addition to existing water supply sources, the Maximize Groundwater A Alternative includes the following new water supply options:

- Replace existing groundwater wells within City limits
- Brackish groundwater
- Additional capacity for treated water from Oklahoma City

Figure 6-4 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how in addition to the new water supply options (replacing existing groundwater wells and brackish groundwater), treated water purchases from Oklahoma City would be needed throughout the year during a dry hydrology year. Table 6-4 summarizes the capital and O&M costs for the alternative.

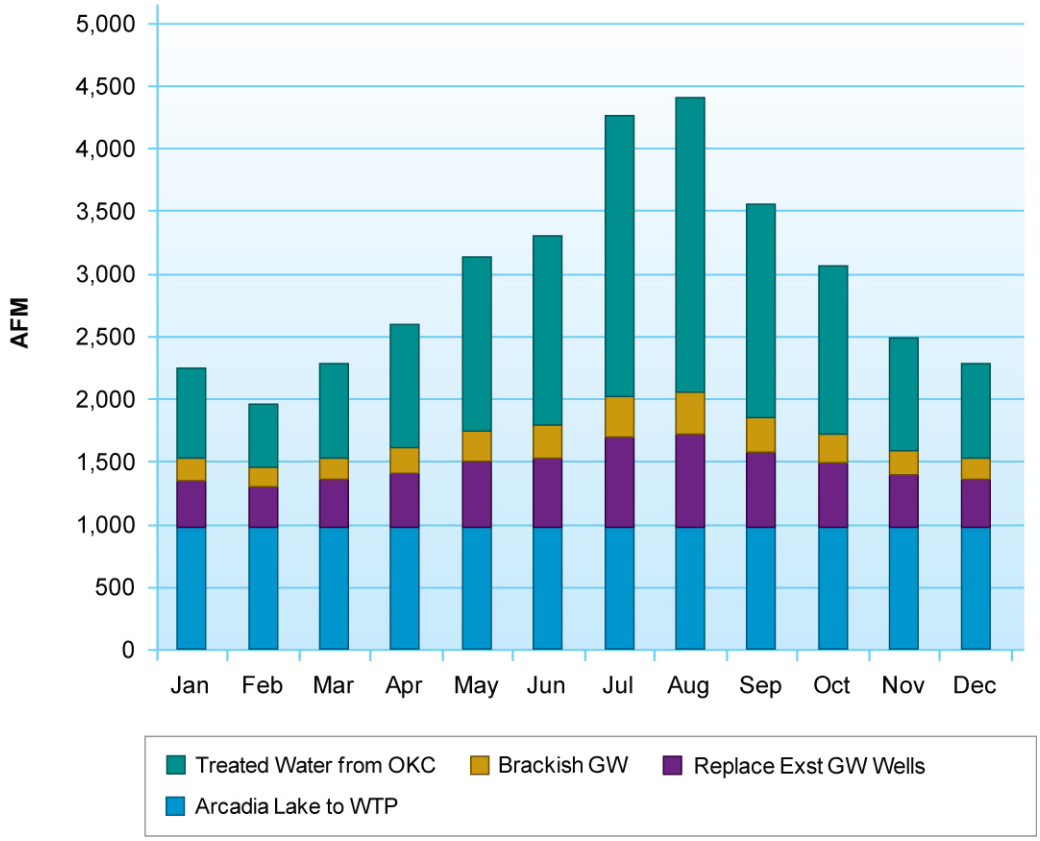

Figure 6-4
Dry Year Monthly Supplies for Maximize Groundwater A Alternative, Projected for Year 2060

Table 6-4 **Costs for Maximize Groundwater A Alternative**	
Capital Cost	$5M
Annual Fixed O&M Cost	$4M
Annual Variable O&M Cost	$19M
Annual Imported O&M Cost	$19M
Total Annual O&M Cost	$42M

6.2.2.2 Maximize Groundwater B Alternative

In addition to existing water supply sources, the Maximize Groundwater B Alternative includes the following new water supply options:

- Replace existing groundwater wells within City limits
- Groundwater wells outside City limits
- Brackish groundwater

- Additional capacity for treated water from Oklahoma City

Figure 6-5 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how in addition to the new water supply options (replacing existing groundwater wells, new groundwater well field, and brackish groundwater), treated water purchases from Oklahoma City would be needed throughout the year during a dry hydrology year. Table 6-5 summarizes the capital and O&M costs for the alternative

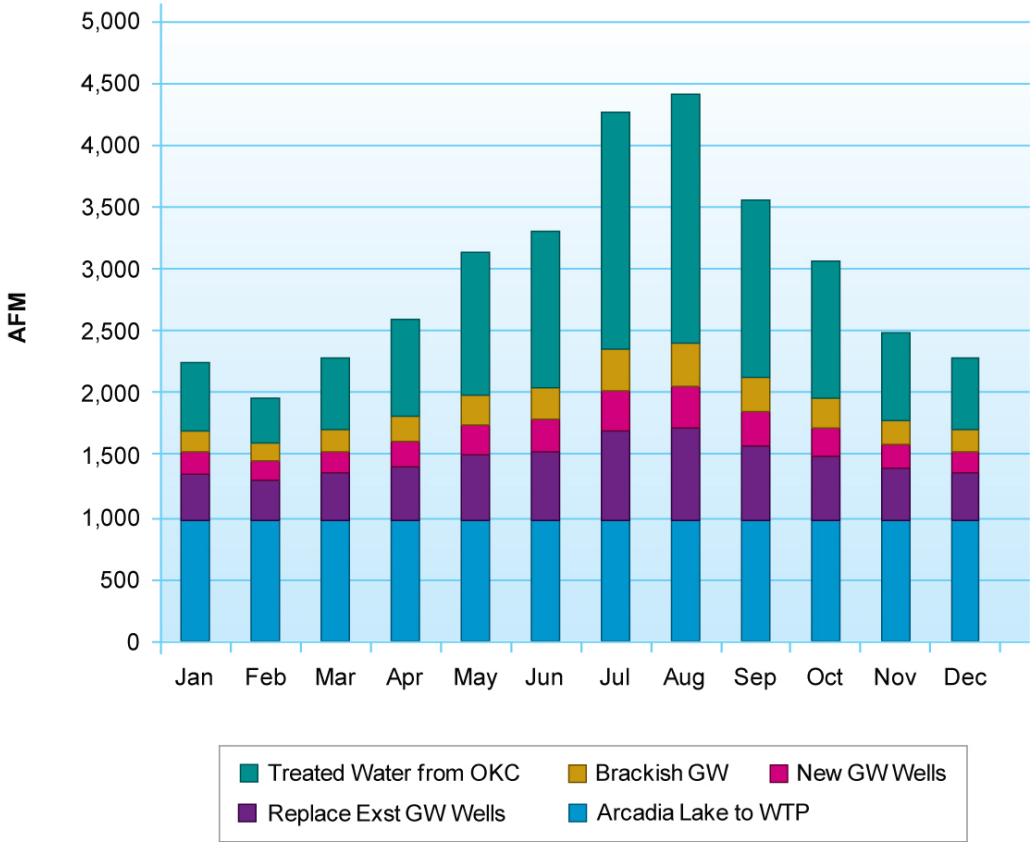

Figure 6-5
Dry Year Monthly Supplies for Maximize Groundwater B Alternative, Projected for Year 2060

Table 6-5 **Costs for Maximize Groundwater B Alternative**	
Capital Cost	$6M
Annual Fixed O&M Cost	$6M
Annual Variable O&M Cost	$20M
Annual Imported O&M Cost	$15M
Total Annual O&M Cost	$41M

6.2.3 Surface Water Alternatives

The surface water alternatives focus on implementing new water supply options that propose the utilization of various surface water supplies that the City does not currently have water rights. Four variations of this alternative were developed, each with the addition of a single supply source from a surface water reservoir.

6.2.3.1 Maximize Surface Water A Alternative

In addition to existing water supply sources, the Maximize Surface Water A Alternative includes the new option for purchasing raw water from Oklahoma City. Figure 6-6 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how the new option would fill the demand gap. Table 6-6 summarizes the capital and O&M costs for the alternative.

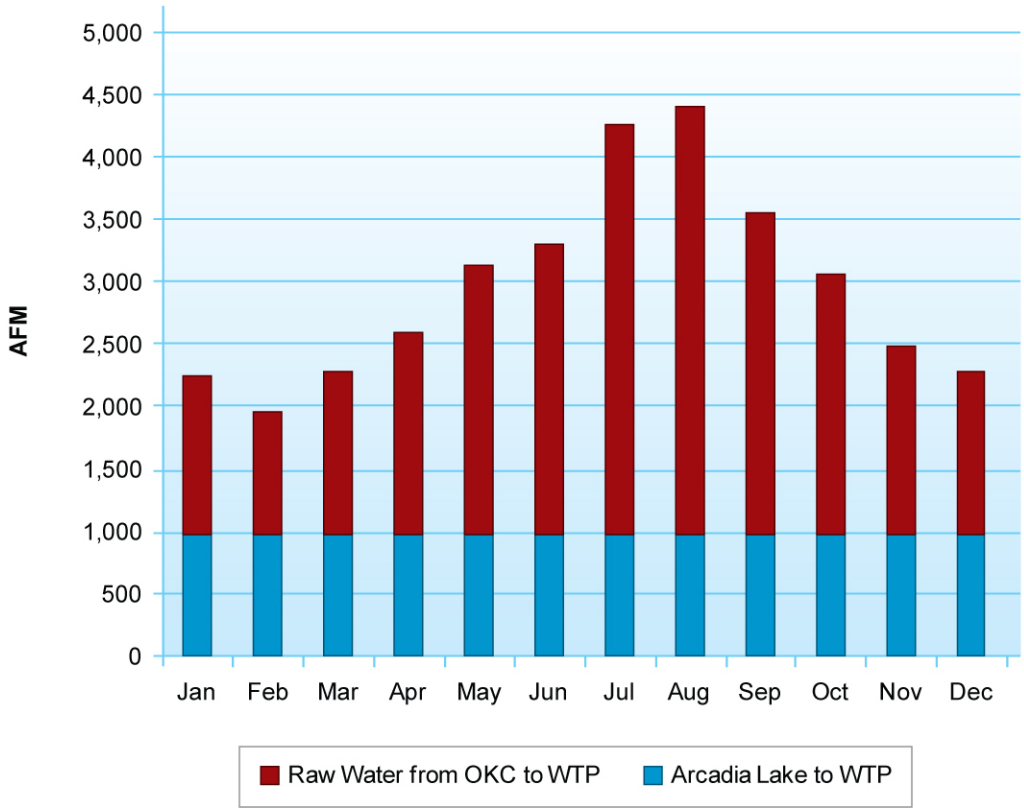

Figure 6-6
Dry Year Monthly Supplies for Maximize Surface Water A Alternative, Projected for Year 2060

Table 6-6 Costs for Maximize Surface Water A Alternative	
Capital Cost	$23M
Annual Fixed O&M Cost	$4M
Annual Variable O&M Cost	$5M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$9M

6.2.3.2 Maximize Surface Water B Alternative

In addition to existing water supply sources, the Maximize Surface Water B Alternative includes the new option to obtain water from Eufaula Lake. Figure 6-7 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how the new option would fill the demand gap. Table 6-7 summarizes the capital and O&M costs for the alternative.

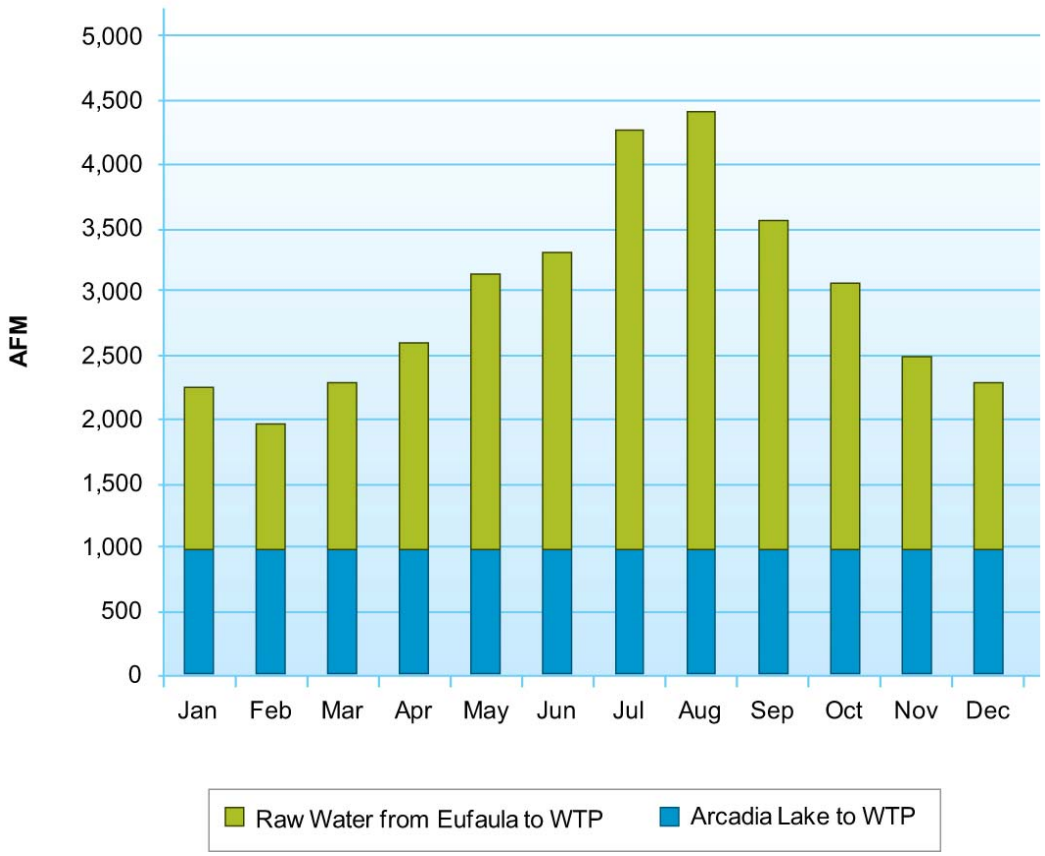

Figure 6-7
Dry Year Monthly Supplies for Maximize Surface Water B Alternative, Projected for Year 2060

Table 6-7 Costs for Maximize Surface Water B Alternative	
Capital Cost	$91M
Annual Fixed O&M Cost	$32M
Annual Variable O&M Cost	$39M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$71M

6.2.3.3 Maximize Surface Water C Alternative

In addition to existing water supply sources, the Maximize Surface Water C Alternative includes the new option to obtain water from Sardis Lake. Figure 6-8 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how the new option would fill the demand gap. Table 6-8 summarizes the capital and O&M costs for the alternative.

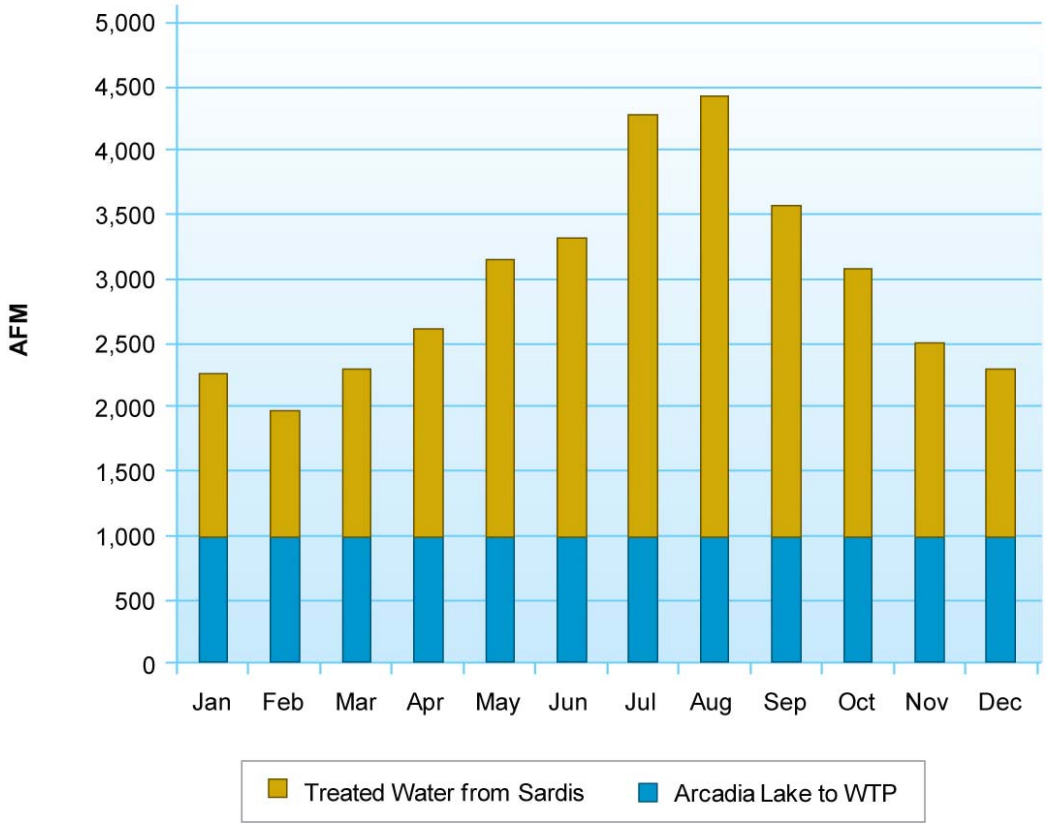

Figure 6-8
Dry Year Monthly Supplies for Maximize Surface Water C Alternative, Projected for Year 2060

Table 6-8 Costs for Maximize Surface Water C Alternative	
Capital Cost	$23M
Annual Fixed O&M Cost	$4M
Annual Variable O&M Cost	$5M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$9M

6.2.3.4 Maximize Local Surface Water Alternative

In addition to existing water supply sources, the Maximize Local Surface Water Alternative includes the new option to obtain additional yield from Arcadia Lake and expanding the existing WTP by an additional 38.3 mgd of capacity (this flow was determined as the additional flow required to meet peak day demands in 2060). This alternative was developed after noticing that Arcadia Lake levels were high for most of the simulated alternatives (see Section 7 and Figure 7-14), but it is an alternative that would require a new permit. All other alternatives presented above and below assume that Arcadia Lake flows are kept at the current permitted yield.

Figure 6-9 shows monthly water supplies for the year 2060 under the dry year hydrology. This dry year hydrology results in the maximum deficit (from July through September). The figure is constructed with actual simulated results of a specific dry year and shows that, due to low runoff flows into Arcadia Lake in that particular simulated sequence, the model predicted the lake volume to be minimal during the winter months and limited withdrawal from the lake to maintain a minimum volume of ten percent of the conservation pool. Therefore, treated water from Oklahoma City is required to meet demands in the winter months during this dry hydrology year. Table 6-9 summarizes the capital and O&M costs for the alternative.

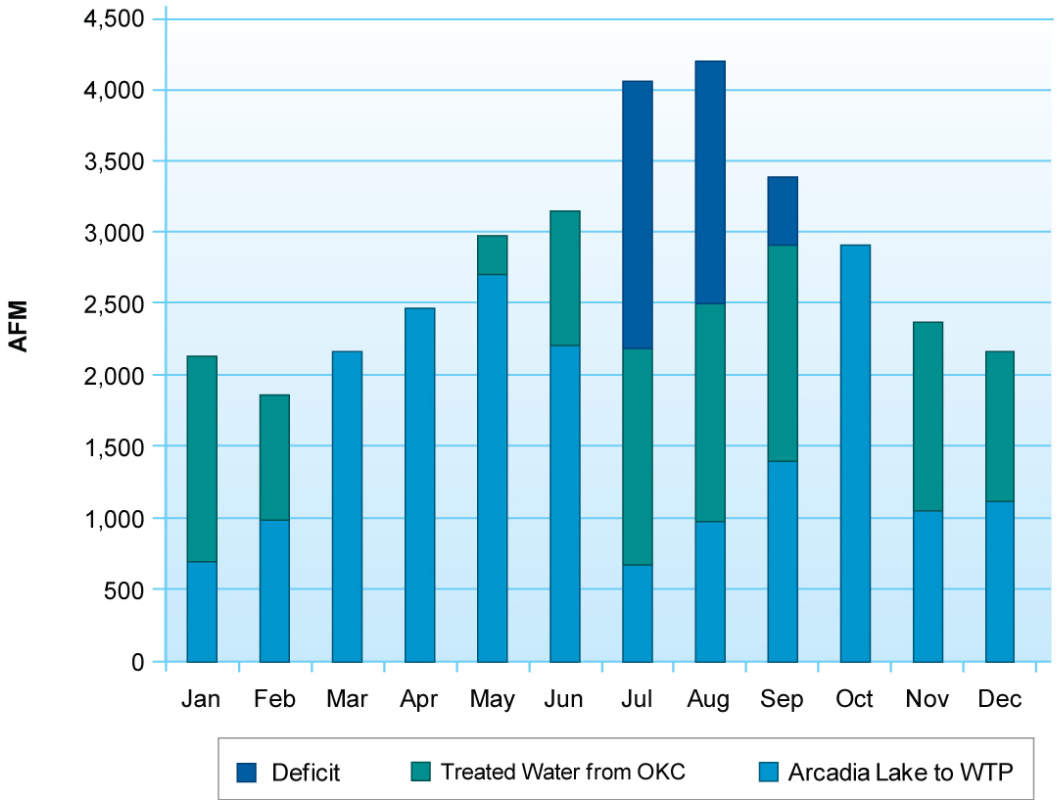

Figure 6-9
Dry Year Monthly Supplies for Maximize Local Surface Water Alternative, Projected for Year 2060

Table 6-9 **Costs for Maximize Local Surface Water Alternative**	
Capital Cost	$9M
Annual Fixed O&M Cost	$13M
Annual Variable O&M Cost	$4M
Annual Imported O&M Cost	$2M
Total Annual O&M Cost	$19M

6.2.4 Maximize Assets Alternatives

The maximize assets alternatives focus on implementing water supply options that take advantage of local water resources (i.e., conservation, groundwater and water reuse options). Two variations of this alternative were developed, one with indirect potable reuse and the other without.

6.2.4.1 Maximize Assets A Alternative

In addition to existing water supply sources, the Maximize Assets A Alternative includes the following new supply options:

- Level 1 conservation
- Level 2 conservation
- Indirect potable reuse
- Replace existing groundwater wells within City limits
- Additional yield from Arcadia Lake and expansion of the existing WTP by an additional 28 mgd of capacity

Figure 6-10 shows monthly water supplies for the year 2060 under the dry year hydrology. It should be noted that the indirect potable reuse option does not appear as a separate supply in the supply mix figure since the supply would be stored in Arcadia Lake for subsequent use as raw water to Arcadia treatment plant. The figure illustrates how the new options would fill the demand gap without the need for treated water purchases from Oklahoma City. Table 6-10 summarizes the capital and O&M costs for the alternative.

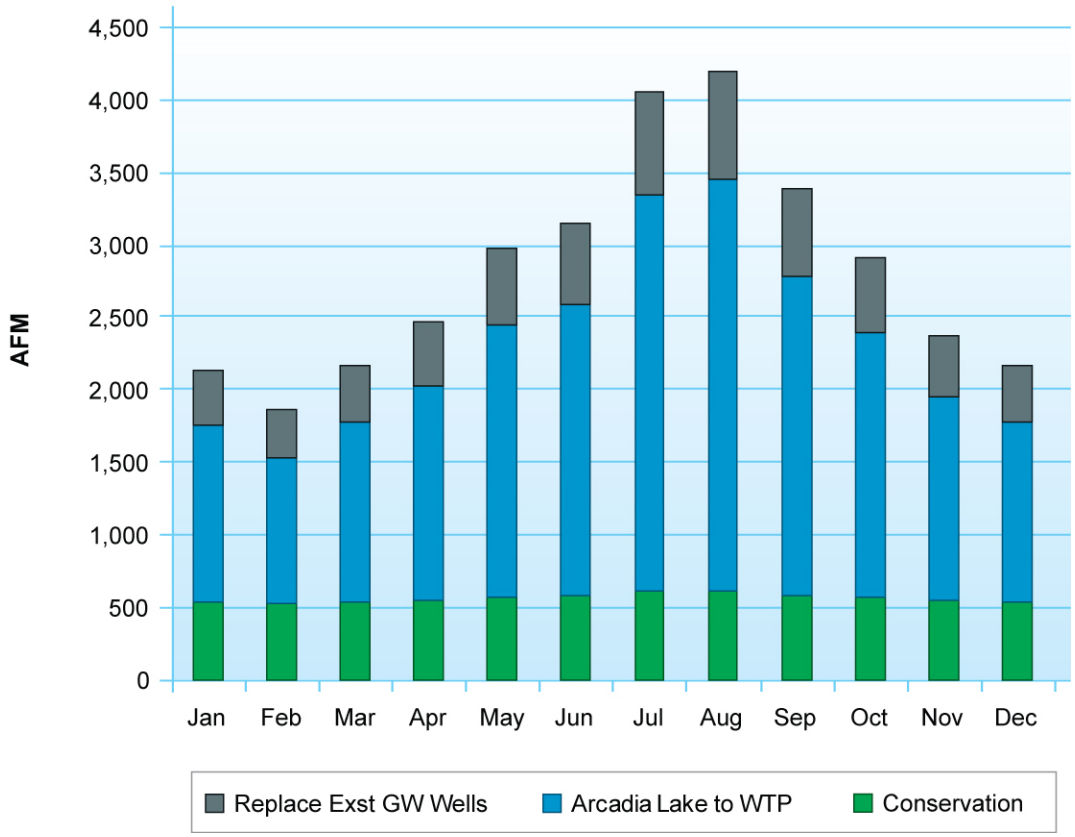

Figure 6-10
Dry Year Monthly Supplies for Maximize Assets A Alternative, Projected for Year 2060

Table 6-10 Costs for Maximize Assets A Alternative	
Capital Cost	$11M
Annual Fixed O&M Cost	$11M
Annual Variable O&M Cost	$18M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$29M

6.2.4.2 Maximize Assets B Alternative

In addition to existing water supply sources, the Maximize Assets B Alternative includes the following new supply options:

- Level 1 conservation
- Level 2 conservation
- Replace existing groundwater wells within City limits
- Additional yield from Arcadia Lake and expansion of the existing WTP by an additional 28 mgd of capacity

Figure 6-11 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how the new options would fill the demand gap without the need for treated water purchases from Oklahoma City. Table 6-11 summarizes the capital and O&M costs for the alternative.

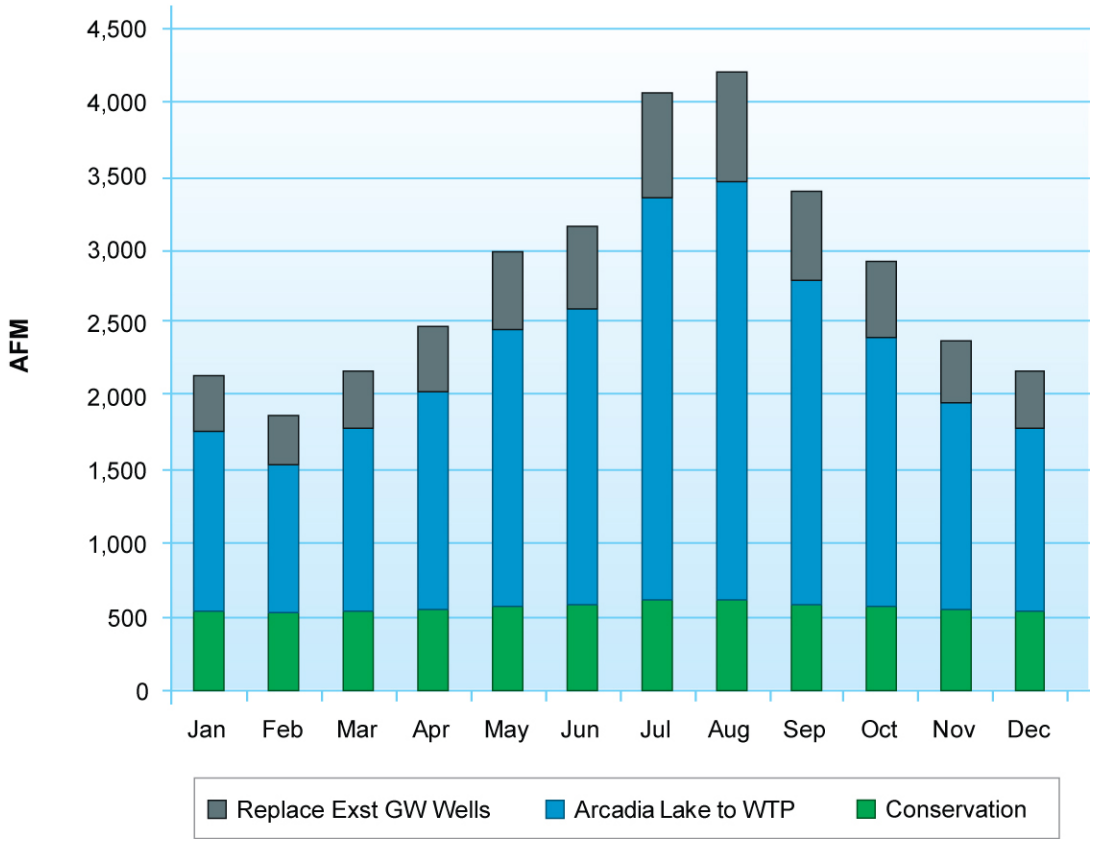

Figure 6-11
Dry Year Monthly Supplies for Maximize Assets B Alternative, Projected for Year 2060

Table 6-11 Costs for Maximize Assets B Alternative	
Capital Cost	$8M
Annual Fixed O&M Cost	$10M
Annual Variable O&M Cost	$15M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$25M

6.2.4.3 Maximize Assets C Alternative

In addition to existing water supply sources, the Maximize Assets C Alternative includes the following new supply options:

- Level 1 conservation
- Level 2 conservation
- Non-potable reuse
- Replace existing groundwater wells within City limits
- Additional yield from Arcadia Lake and expansion of the existing WTP by an additional 23 mgd of capacity

Figure 6-12 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how the new options would fill the demand gap without the need for treated water purchases from Oklahoma City. Table 6-12 summarizes the capital and O&M costs for the alternative.

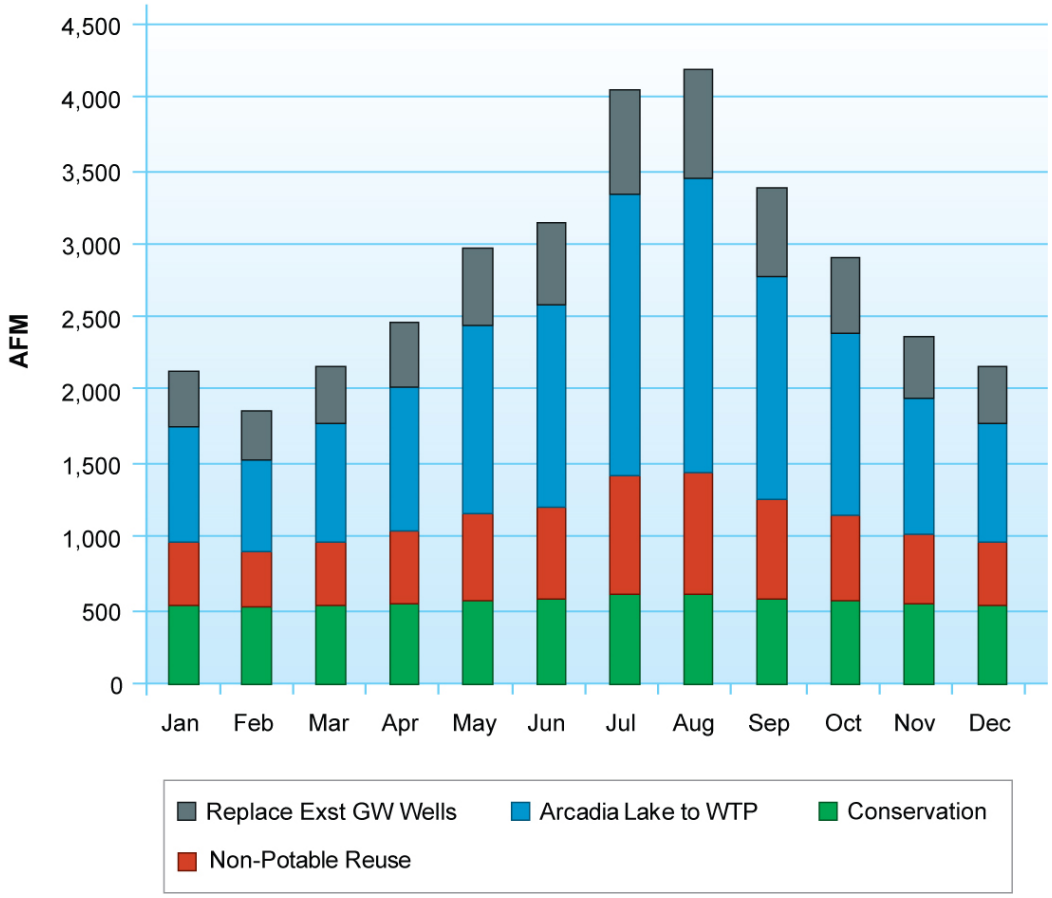

Figure 6-12
Dry Year Monthly Supplies for Maximize Assets C Alternative, Projected for Year 2060

Table 6-12 **Costs for Maximize Assets C Alternative**	
Capital Cost	$8M
Annual Fixed O&M Cost	$9M
Annual Variable O&M Cost	$22M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$29M

6.3 Balanced Alternatives

The planning team developed the balanced alternatives after evaluating the baseline alternatives. Specific feedback from some stakeholders was used in developing some of these balanced alternatives. The balanced alternatives include combining certain features of the baseline alternatives that performed well relative to the planning objectives. The intent of the balanced alternatives was to identify the best path forward for the City to meet all of its water resource and planning needs.

6.3.1 Balanced A Alternative

In addition to existing water supply sources, the Balanced A Alternative includes the following new supply options:

- Level 1 conservation
- Non-potable reuse
- Surface water supply from Navina Lake
- Replace existing groundwater wells within City limits
- Additional capacity for treated water from Oklahoma City

Figure 6-13 shows monthly water supplies for the year 2060 under the dry year hydrology. The supply mix figure illustrates how the treated water supply from Oklahoma City (existing capacity) would only be required during the July and August under the dry year hydrology condition. Table 6-13 summarizes the capital and O&M costs for the alternative.

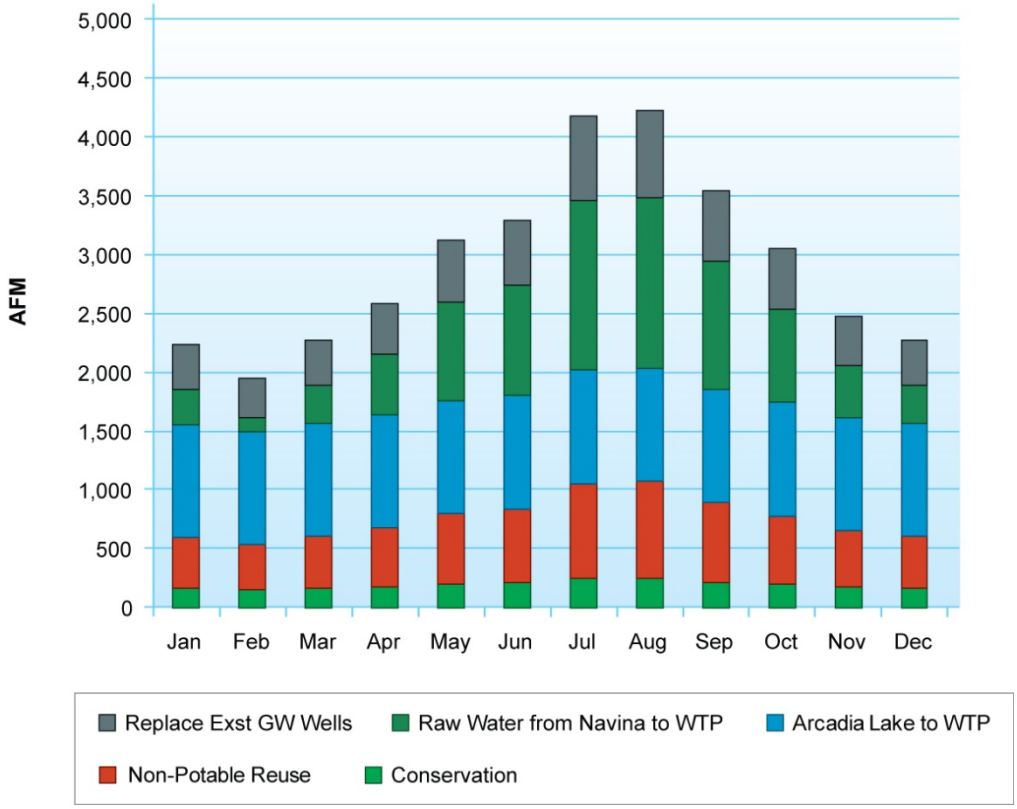

Figure 6-13
Dry Year Monthly Supplies for Balanced A Alternative, Projected for Year 2060

Table 6-13 Costs for Balanced A Alternative	
Capital Cost	$22M
Annual Fixed O&M Cost	$16M
Annual Variable O&M Cost	$32M
Annual Imported O&M Cost	--
Total Annual O&M Cost	$48M

6.3.2 Balanced B Alternative

In addition to existing water supply sources, the Balanced B Alternative includes the following new supply options:

- Level 2 conservation
- Surface water supply from Kaw Lake
- Raw water from Oklahoma City

Figure 6-14 shows monthly water supplies for the year 2060 under the dry year hydrology. The figure illustrates how the new options would fill the demand gap without the need for treated water purchases from Oklahoma City. Table 6-14 summarizes the capital and O&M costs for the alternative.

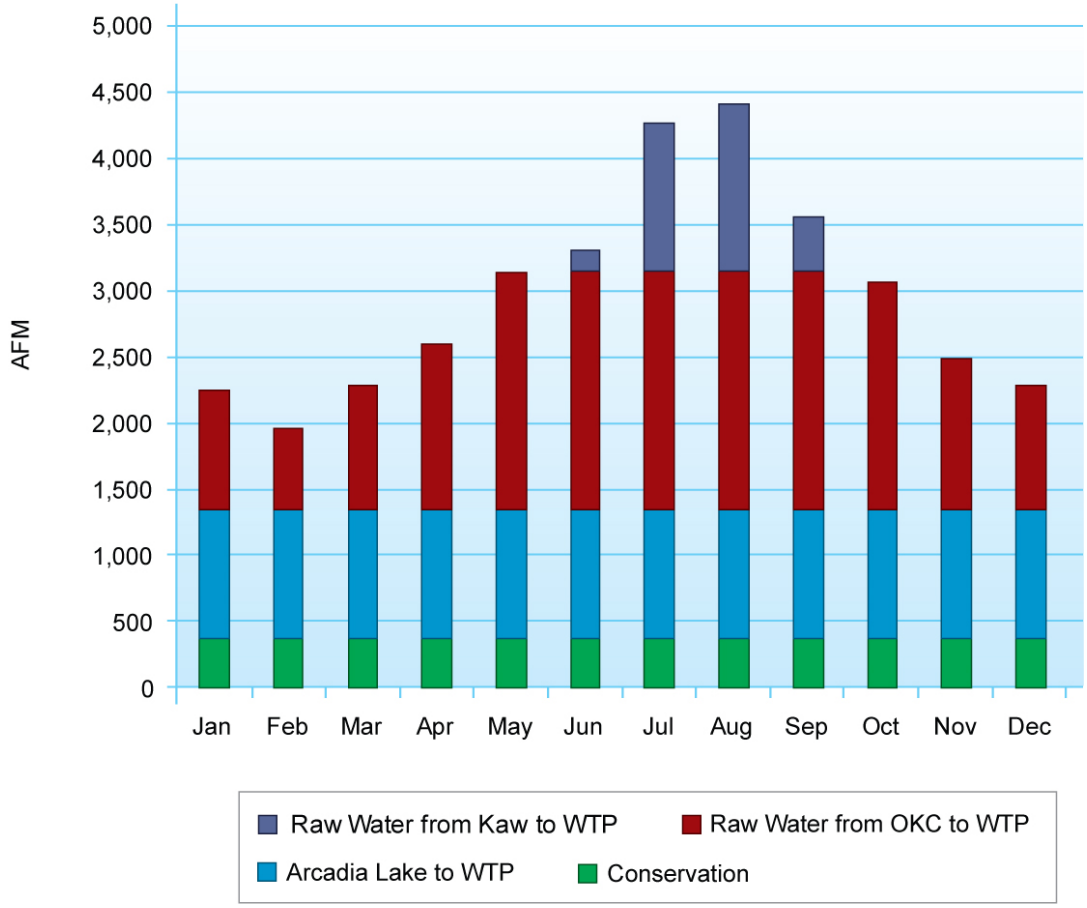

Figure 6-14
Dry Year Monthly Supplies for Balanced B Alternative, Projected for Year 2060

Table 6-14 **Costs for Balanced B Alternative**	
Capital Cost	$49M
Annual Fixed O&M Cost	$27M
Annual Variable O&M Cost	$3M
Annual Imported O&M Cost	$18M
Total Annual O&M Cost	$48M

6.3.3 Balanced C Alternative

In addition to existing water supply sources, the Balanced C Alternative includes the following new supply options:

- Level 1 conservation

- Level 2 conservation
- Non-potable reuse
- Stormwater beneficial use
- Replace existing groundwater wells within City limits
- Additional capacity for treated water from Oklahoma City

Figure 6-15 shows monthly water supplies for the year 2060 under the dry year hydrology. The supply mix figure illustrates how the treated water supply from Oklahoma City (existing capacity) would only be required eight months out of the year under the dry year hydrology condition. Table 6-15 summarizes the capital and O&M costs for the alternative.

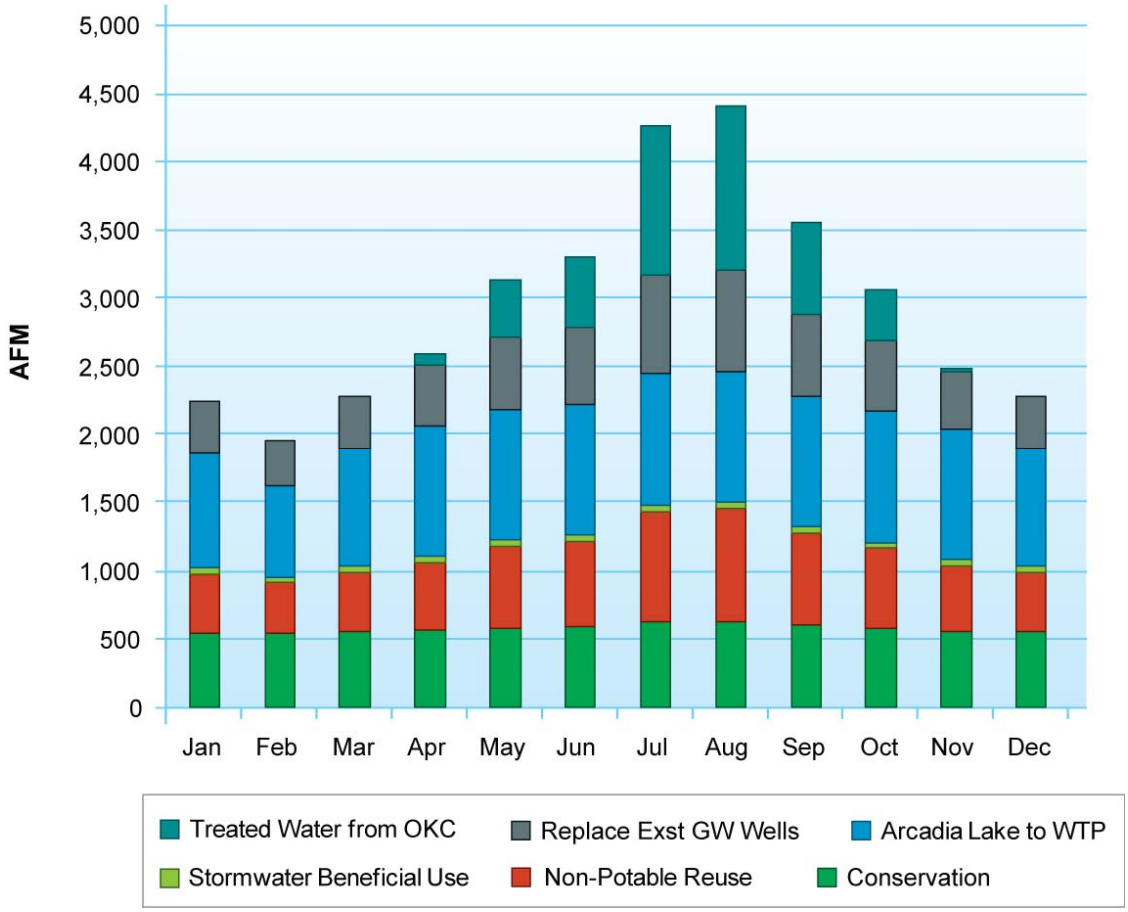

Figure 6-15
Dry Year Monthly Supplies for Balanced C Alternative, Projected for Year 2060

Table 6-15 **Costs for Balanced C Alternative**	
Capital Cost	$4M
Annual Fixed O&M Cost	$3M
Annual Variable O&M Cost	$22M
Annual Imported O&M Cost	$4M
Total Annual O&M Cost	$29M

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Section 7
Selection of Preferred Alternatives

Water supply alternatives were evaluated and ranked using the approach described in Section 4. The method used for the ranking of the alternatives for the City is known as Multi-Attribute Rating Technique. This method involves: (1) defining the objectives the alternatives need to meet; (2) establishing performance measures that indicate how well each objective is being achieved; and (3) determining the relative weight of importance each objective has in terms of influencing the decision.

A systems model was developed for the City's supply options and was the primary tool for determining the raw performance of each alternative in terms of supply reliability, cost, water quality, diversity, flexibility, and other objectives. This information from the systems model was then standardized using a multi-attribute rating tool in order to determine an alternative's overall score.

Finally, alternatives were compared and ranked. Figure 7-1 illustrates the alternative evaluation process. Initial alternatives were evaluated first, and based on their performance; final alternatives were developed and evaluated.

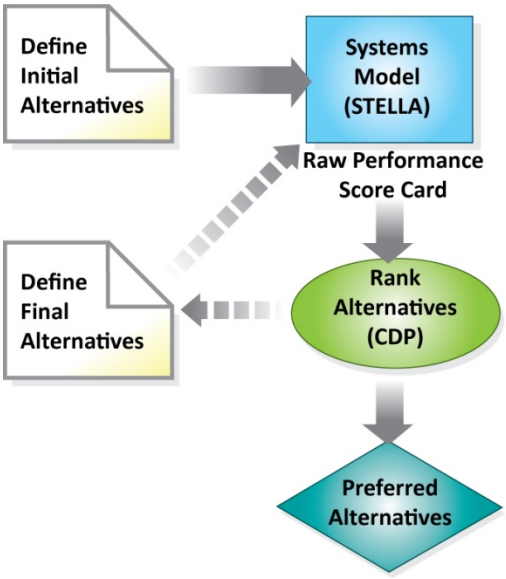

Figure 7-1
Alternatives Evaluation Process

7.1 Alternative Evaluation Results

This section describes the "raw" performance of the alternatives (i.e., the performance prior to ranking them according to the objectives and the weight established by the stakeholders for those planning objectives). Later, Section 7.3 describes how the raw alternative performance is used in conjunction with the objective weights from the stakeholders to rank the alternatives. Appendix D presents the summary of the raw performance of each alternative.

Charts are presented below for most of the performance measures. In reading the bar charts in this section it is important to keep in mind that the units for the performance measures are different, which means that in some cases a tall bar indicates good performance (e.g., unitless scores) and in some cases a tall bar means poor performance (e.g., AFY of deficit, dollars).

7.1.1 Water Supply Reliability Evaluation

One of the objectives of any water supply plan is to improve supply reliability. The ability of each alternative to meet projected future demands was evaluated under various hydrology conditions. In addition, alternatives were evaluated under extreme

drought conditions. The water reliability objective for the alternatives was evaluated based on the following four performance measures: 1) Performance to meet demands under normal conditions (average year); 2) Performance to meet demands under emergency conditions (drought year); 3) Maximize security (of having the water even under droughts more sever or extended than the drought of record) and; 4) Ensure long-term sustainability.

Initial alternative results shows that most of the alternatives (except No Action and Maximize Local Surface Water) could reliably meet demands under "average" conditions (meaning normal hydrology, non-emergency conditions). Figure 7-2 shows the average annual deficit (AFY) for all the alternatives.

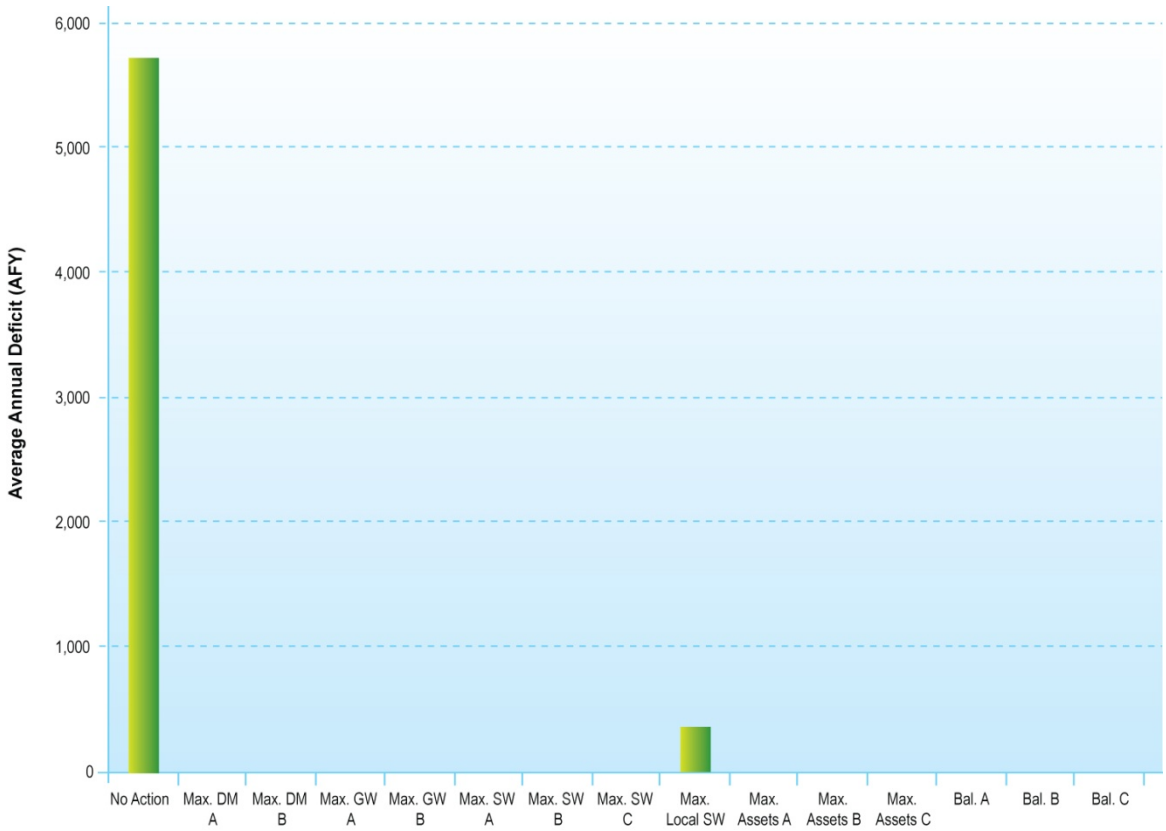

Figure 7-2
Average Annual Deficit under Average Conditions (a measure of Alternative Reliability)

Water demands are typically higher under critically dry conditions than normal hydrology conditions, since natural rainfall is not available to provide the consumptive use of plants for irrigation areas. The evaluated drought condition accounts for these annual increases in demands based on historical correlations between demands and hydrology for the area. Additionally, and most importantly, a

drought condition represents a period where surface water supplies are diminished compromising water supply.

Figure 7-3 shows the largest deficit observed in the period of record simulated in the system for each alternative. This largest deficit generally coincides with either the driest year on record or a dry year at the end of a sequence of dry years (the final year of a drought). As can be seen in the figure all alternatives can be considered drought reliable except for the No Action and Maximize Local Surface Water alternatives. It should be noted that some of the deficiency could probably be met through system operational decisions to optimize the available supply, or through drought emergency sources.

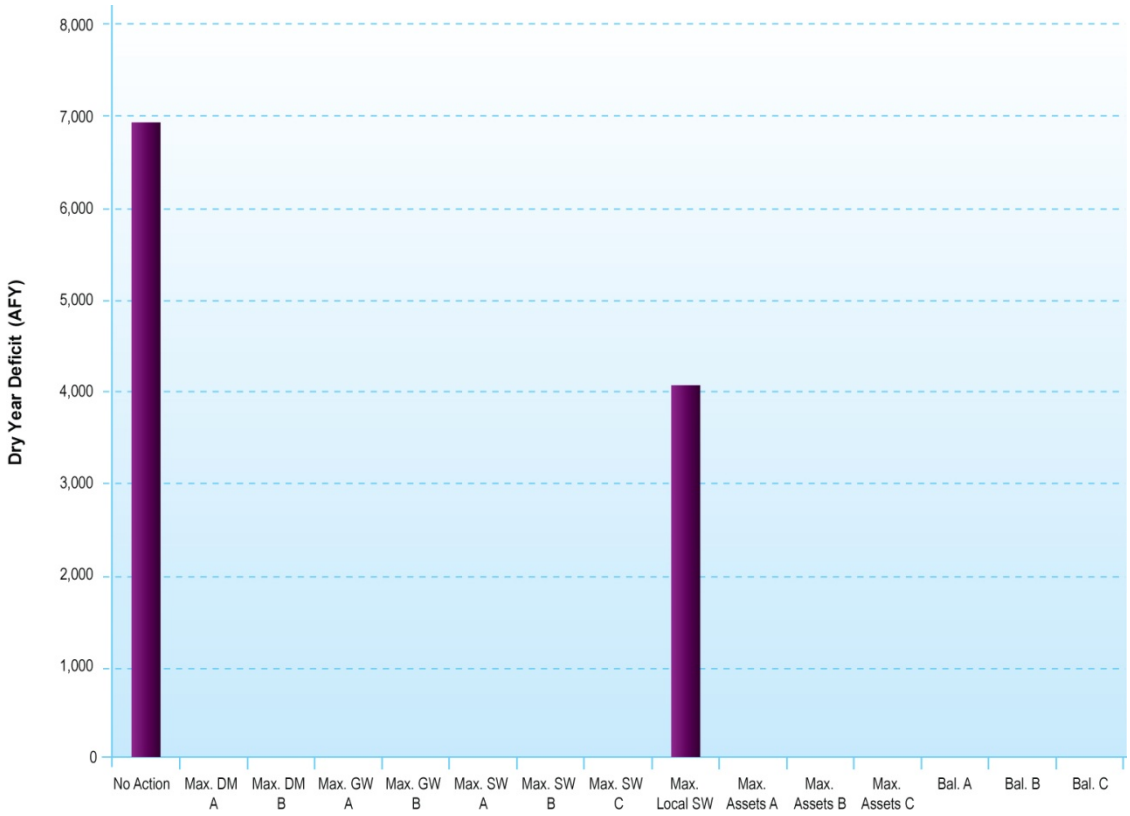

Figure 7-3
Dry Year Deficit under Drought Conditions (a measure of Alternative Reliability)

The No Action alternative depends largely upon imported treated water from Oklahoma City and assumes no expansion of the existing contract and infrastructure and the Maximize Local Surface Water alternative depends almost completely on Arcadia Lake and hence would be affected under drought conditions. Other alternatives perform well for under this criterion as they have a mix of supply coming from local sources, such as groundwater, recycled, and conservation savings.

An important consideration in this analysis is that surface water reservoirs from other parts of the state (Kaw, Eufala, etc.) were not evaluated to the same level of detail than Arcadia Lake. The lakes were not included in the city's system model and the assumptions was made that water would be available (and infrastructure was sized according to that assumption). The fact is, however, that those alternatives that use these lakes in other parts of the state are more vulnerable than alternatives that do not rely heavily on surface water and may be subject to deficits during extreme droughts. This is reflected in the Security performance measure presented below.

The performance of the various alternatives in terms of security under extreme drought conditions and sustainability can be seen in Figure 7-4. Security scores are lower for alternatives that rely heavily on surface water and are higher for alternatives that use demand management options and groundwater options. The Sustainability performance measure in the context of this water supply plan reflects only the sustainability of the supply itself. In other words, the term "sustainability" in this performance measure is not used to reflect the social, economic and environmental factors associated to the bigger concept of sustainability. The social, economic and environmental factors are addressed by the collection of performance measures and objectives in this plan so the Water Supply Plan is a plan driven by sustainability principles, but the chart in Figure 7-4 only reflects the supply sustainability (i.e., will we have the water in the long-term?). That is the reason for generally lower sustainability scores for alternatives that rely more on groundwater, since groundwater can be subject to overdraft and long-term decline, whereas surface water is a replenished supply.

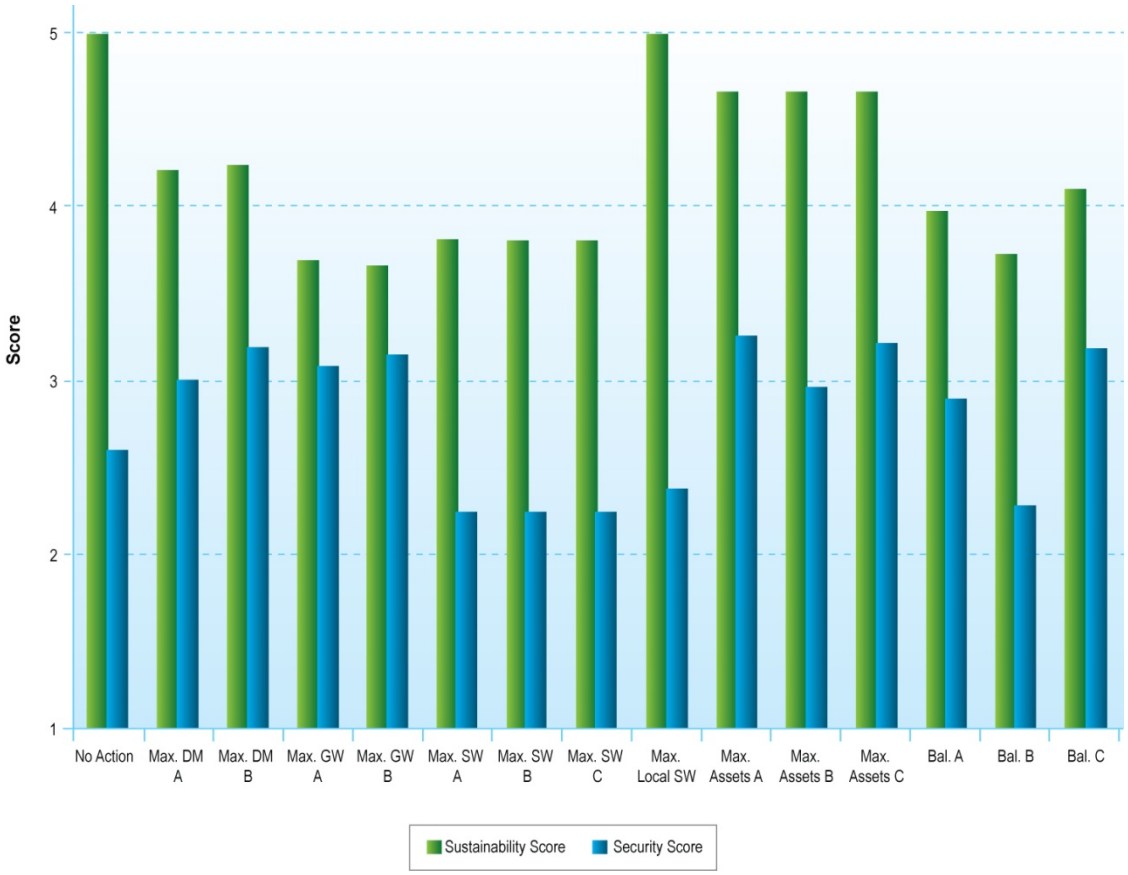

Figure 7-4
Supply Sustainability and Security Scores (measures of Alternative Reliability)

7.1.2 System Flexibility and Diversity Evaluation

System diversity and flexibility are important attributes of a water supply alternative. These objectives help to improve overall operational reliability by increasing the number of water sources, contractual rights for water use, and take points into the system. Diversity and flexibility reduce the system's dependence on one source or facility, respectively. If a source or facility is offline, overall water system could still potentially satisfy all demands with the use of other supply options in the alternative.

The operational flexibility of the alternative was measured in terms of the number of take points into the system. The flexibility through diverse sources was measured in two ways: (1) number of sources, and (2) percent contribution of largest source to total supply. The alternative scores for these performance measures are shown in Figures 7-5 and 7-6.

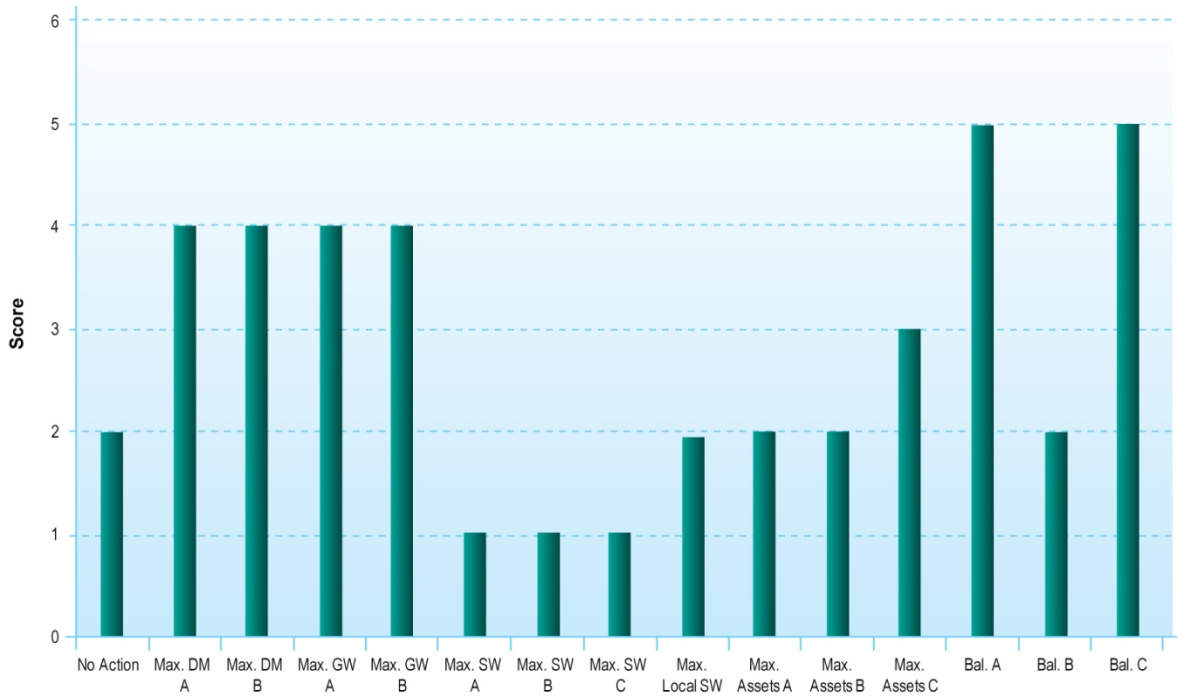

Figure 7-5
Number of Take Points in Alternative

In Figure 7-5, it is clear that all most of the alternatives (except the Surface Water alternatives since the new water was conceptually determined to enter the system in at the same point as Arcadia water) increase the number of take points over the No Action Alternative. The alternatives with the largest number of take points are the Balanced A and Balanced C alternatives.

Figure 7-6 shows the number of sources for each alternative. Note that the supply options included in all the alternatives are listed in Appendix D. As can be seen in the figure, Balanced A, Balanced C and Maximum Demand Management B have more variety with number of sources which include a combination of conservation savings, recycled water and treated water from Oklahoma City for the demand management scenario and a combination of conservation savings, recycled water and groundwater for the balanced scenarios.

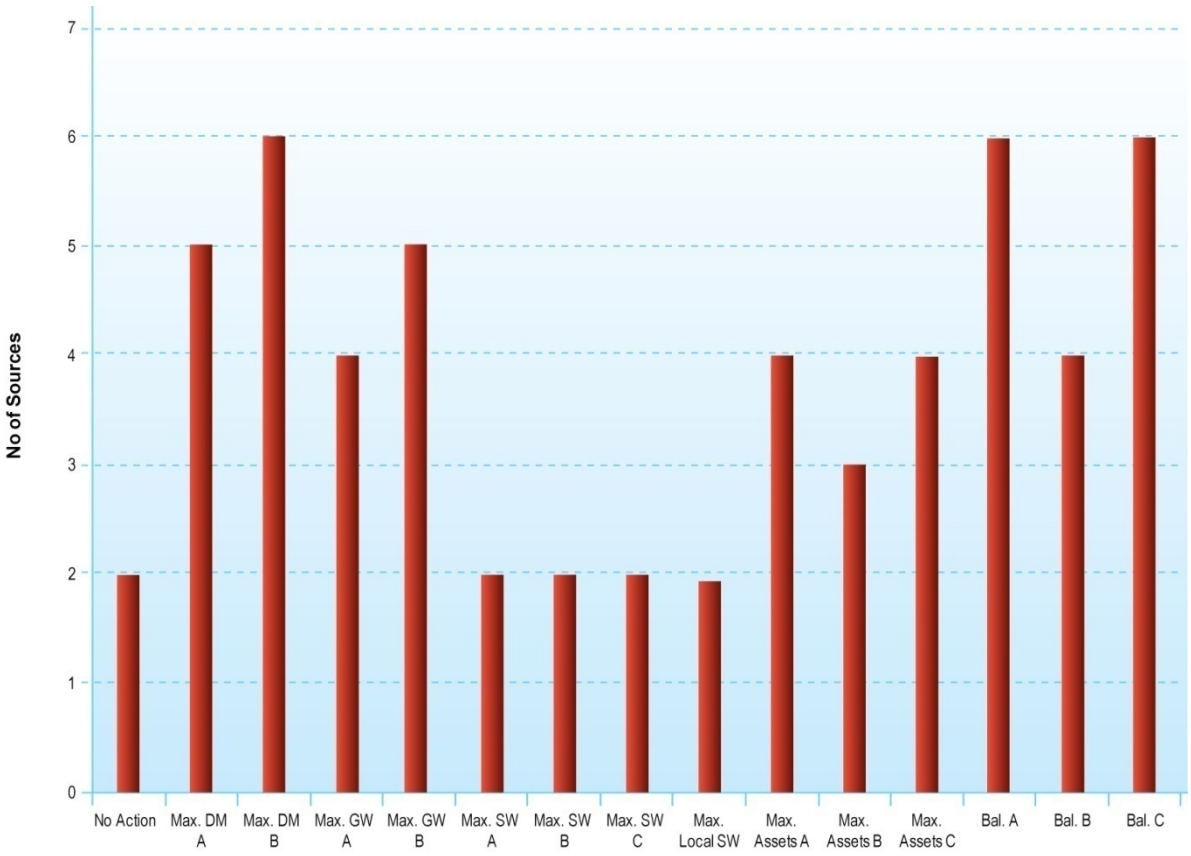

Figure 7-6
Number of Sources in Alternative

The percentage contribution from the largest source values for the alternatives can be seen in Figure 7-7. The figure shows that demand management, groundwater and balanced alternatives reduce the percent contribution of the largest source from the No Action Alternative. However, others increase this contribution as compared to the No Action Scenario. In this case, a lower percentage is viewed as a better score. The alternatives that scored well in this performance measure typically relied less on treated imported water and were dependent upon a mix of supply sources rather than banking on a single source to meet the demands.

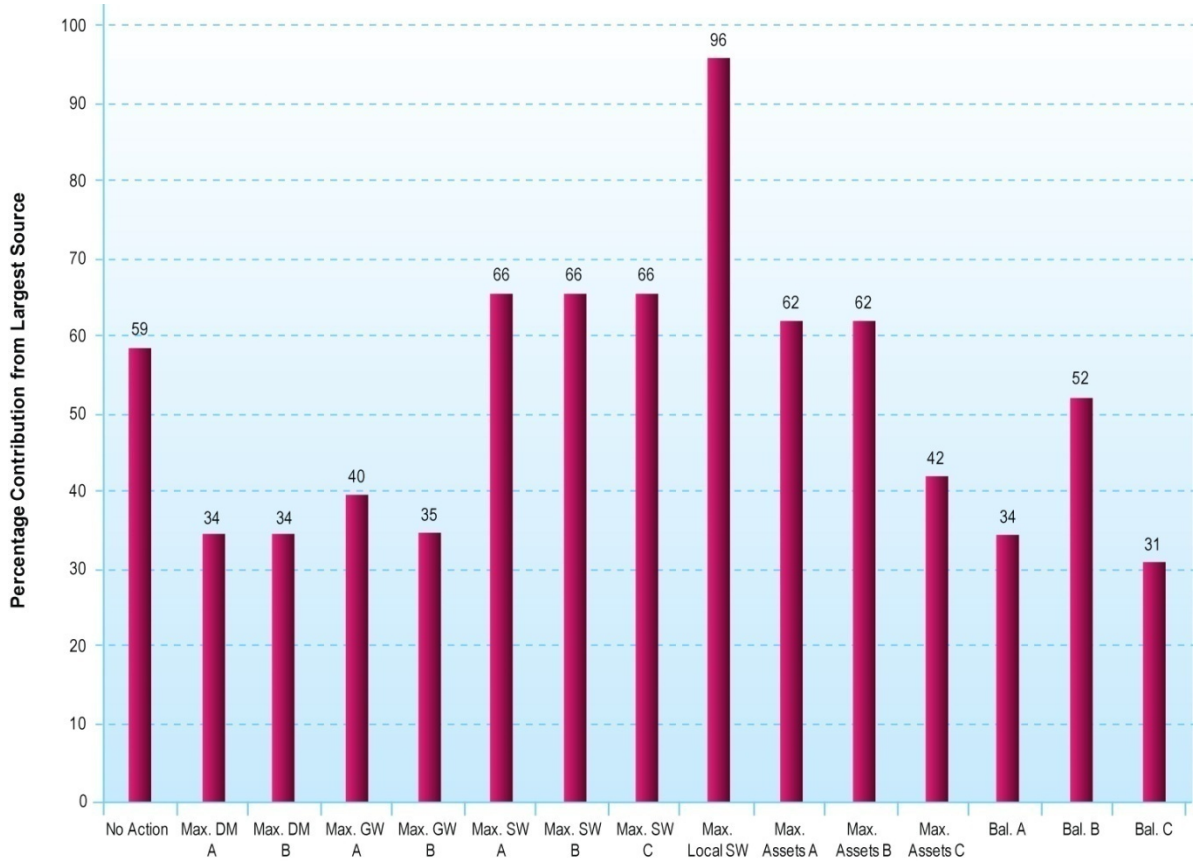

Figure 7-7
Percent Contribution from Largest Source to Total Supply in Alternative

7.1.3 Water Quality

For this Water Supply Plan, the water quality objective was considered in two ways: (1) potential issues with high salinity water, poor source water quality and Arsenic (Arsenic can increase the level of treatment required or force sources to be abandoned), and (2) compatibility with other sources for blending prior to distribution.

Total Dissolved Solids, Source Water Quality and Arsenic

For the first performance measure, minimizing the issues associated with TDS, source water quality and Arsenic for the supply option was considered a favorable score. Figure 7-8 shows the Water Quality scores for the alternatives. Maximize Surface Water B scenario has a lower score because it would receive majority of its water from Eufala reservoir which is known to have poor quality water at the source and would require more treatment than the others. Water from Oklahoma City and Sardis is of high quality and alternatives which use these have higher scores.

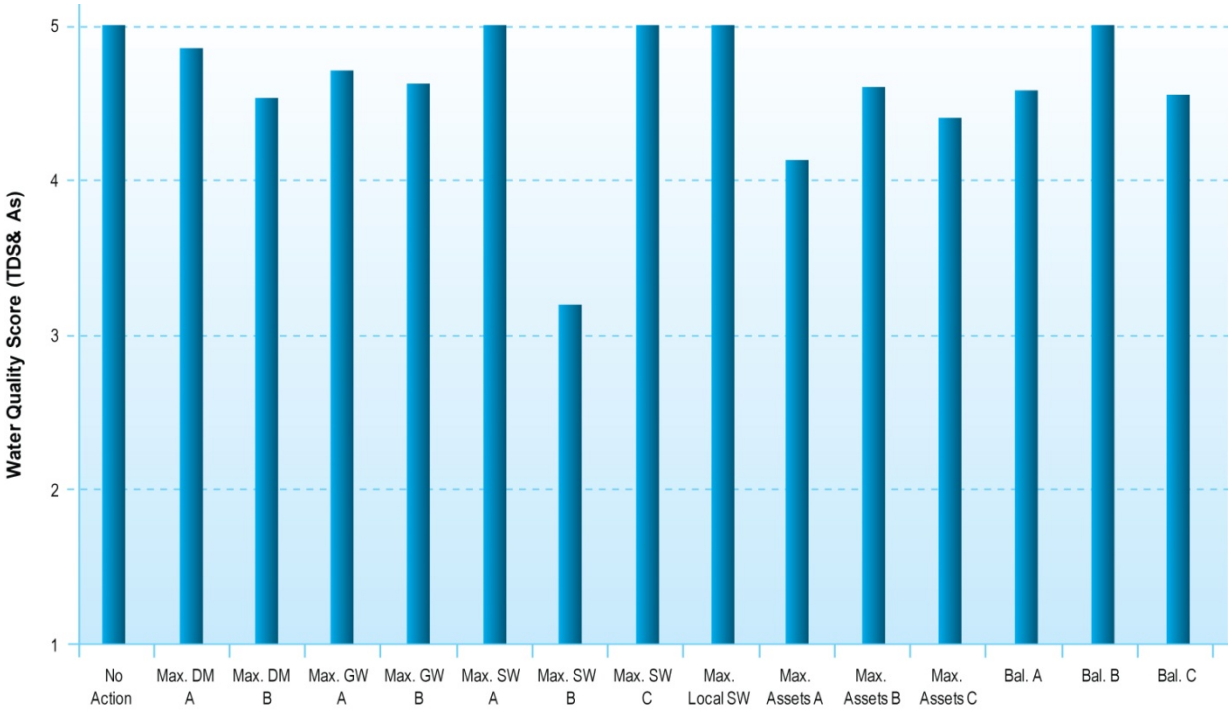

Figure 7-8
Water Quality Scores (TDS and As) for Alternatives

Compatibility with Other Sources

Figure 7-9 illustrates the qualitative scores for water quality related to compatibility with the City's existing water supply system.

The results show that the demand management scenarios scored slightly lower than the others in the figure above. This is because they have a mix of supply from recycled water options as well as treated water from Oklahoma City. Alternatives with supply from single sources perform well as there is no mixing of sources and hence no compatibility issues. Groundwater alternatives also score slightly lesser than others as they have a mix of supply from brackish and groundwater wells as well as treated water from Oklahoma City. The compatibility of brackish groundwater with imported water is unknown and further investigation may be required prior to implementation.

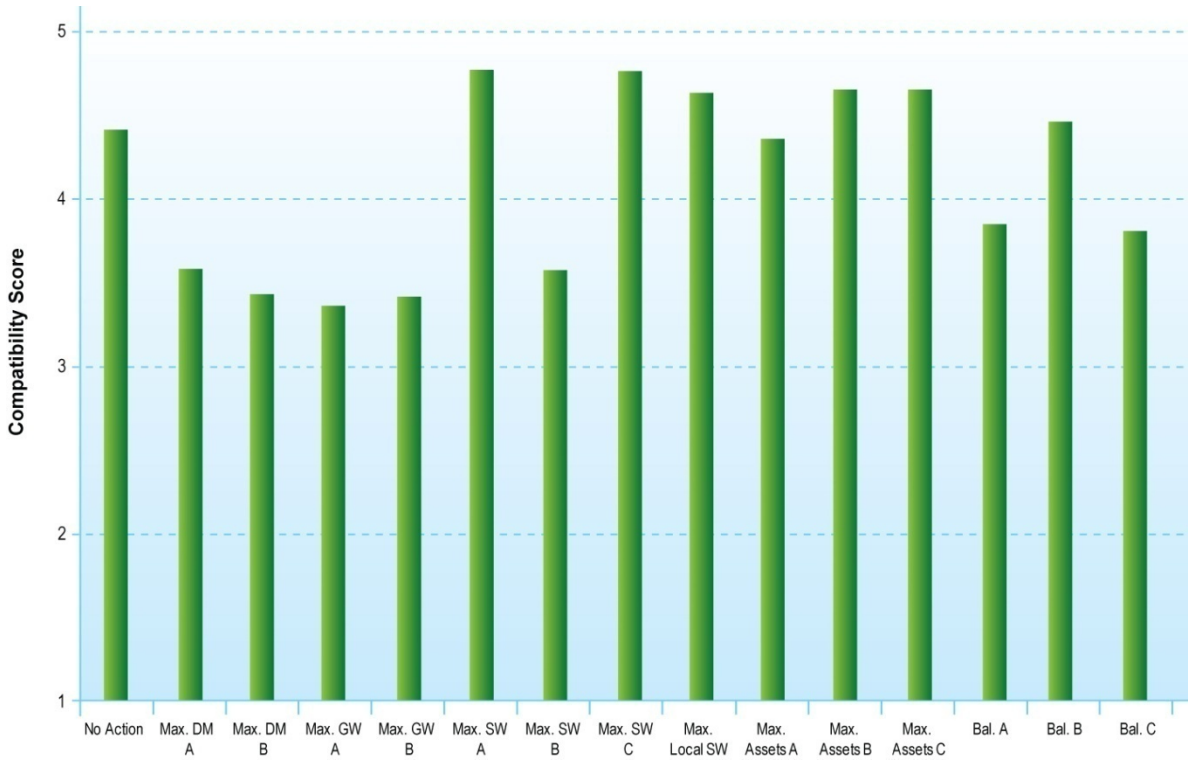

Figure 7-9
Compatibility Score for Alternatives

7.1.4 Cost Evaluation

The performance of the alternatives in terms of affordability was measured with total capital costs, as well as Operational and Maintenance (O&M) cost in millions of dollars. For alternative comparison purposes, it was assumed that all projects would be implemented at the same time. Therefore, the capital costs are presented in today's dollars (without inflation). Once the preferred alternatives have been selected, the timing of project implementation will be evaluated, to help minimize costs and develop the implementation plan described in Section 9.

For purposes of alternative evaluation, any existing or planned capital costs associated with the baseline system (No Action Scenario) were not included in the cost of the water supply alternative. Therefore, only the capital costs incurred with new supply options are shown. The total capital costs for each alternative are presented in Figure 7-10.

As can be seen from the figure the alternative with the highest capital costs is Maximize Surface Water B scenario. This is due to the fact that most of the water will be imported from Eufaula Lake. Since these are at a considerable distance from the City, large amount of new conveyance infrastructure would be required for this option. The cost estimates for this option also assume no partnerships with other cities for project implementation, minimizing opportunities for economies of scale. Maximize Demand Management A, Maximize Surface Water C perform very well in terms of cost. The other Balanced Scenarios (Balanced A and Balanced B) are good alternatives but don't fare very well on the cost scale.

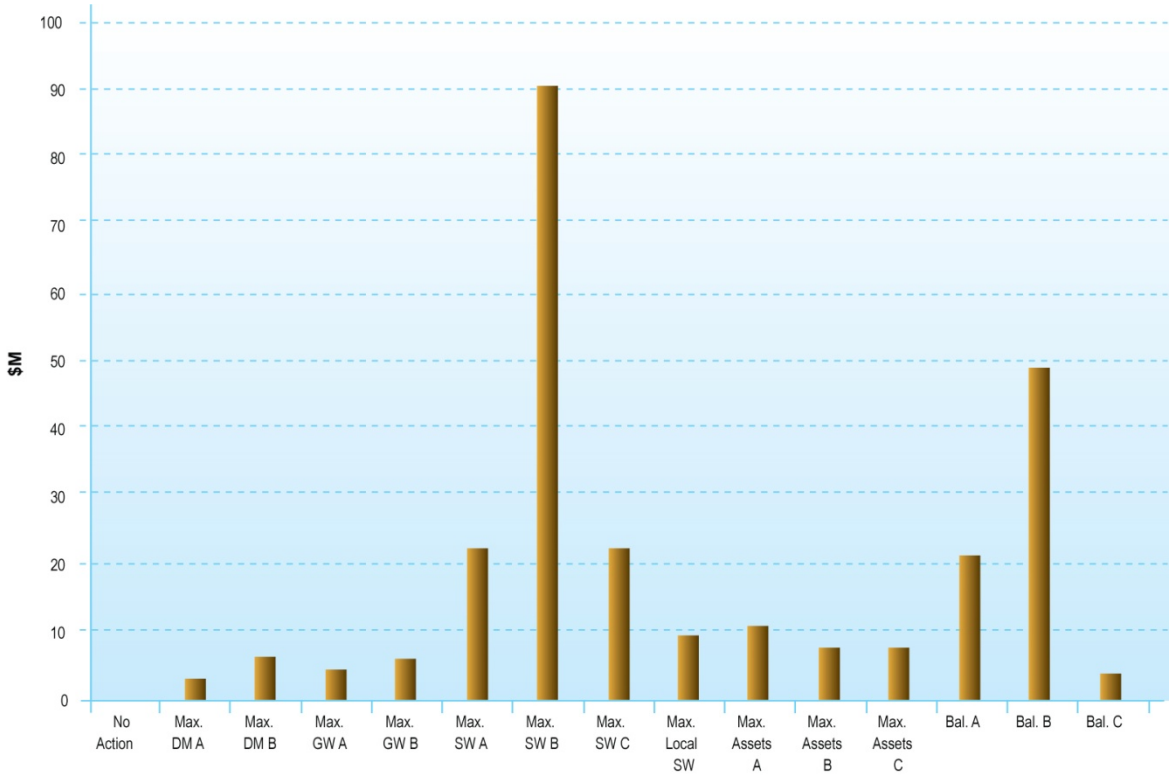

Figure 7-10
Annual Capital Costs for Alternatives

Figure 7-11 shows O&M Costs (in terms of fixed, variable and imported costs) for the alternatives. As can be seen in the figure Maximize Surface Water B is the most costly alternative in terms of O&M cost. This is due to the fact that all its supply comes from the Eufaula reservoirs and would have a considerable amount of maintenance costs associated with it.

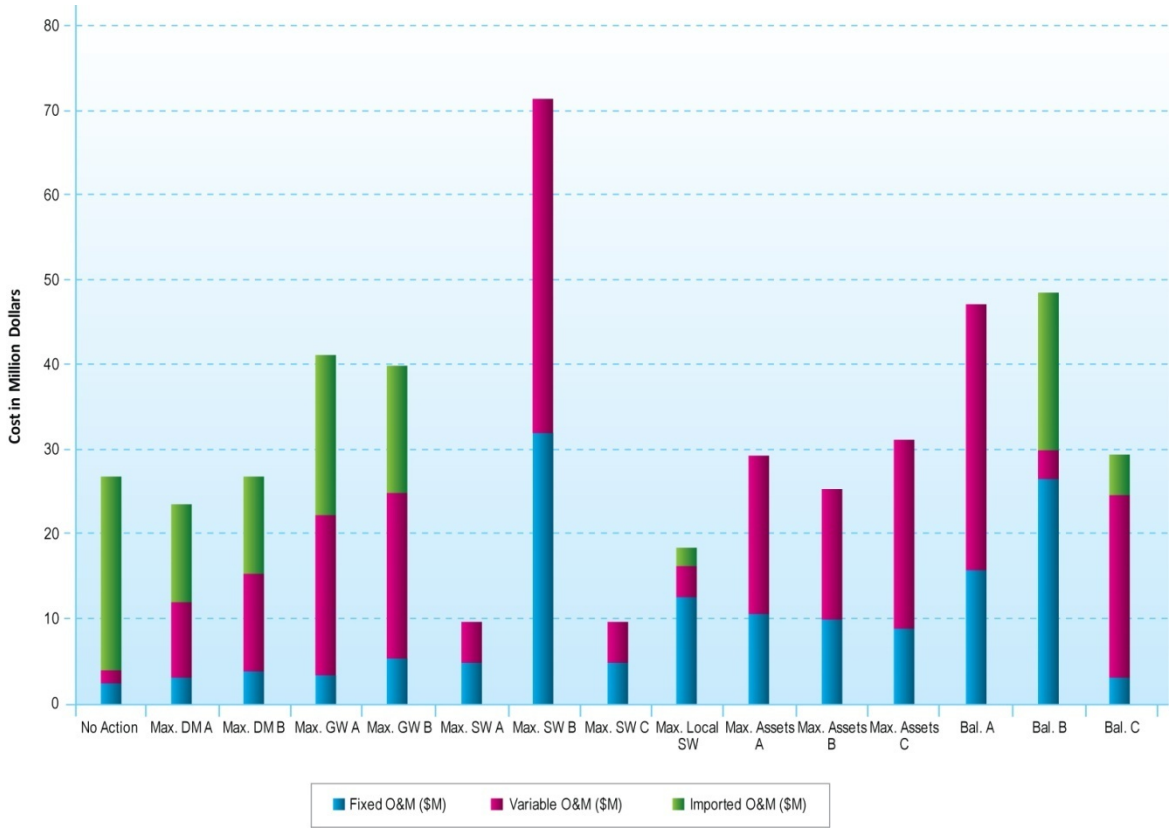

Figure 7-11
Annual O&M Costs for Alternatives

Table 7-1 gives a summary of the Capital and O&M costs for the alternatives in millions of dollars.

Table 7-1
Cost Estimates for Water Supply Plan Alternatives

Alternative	Total Capital Costs ($M)	Total O&M Costs ($M)	Fixed O&M ($M)	Variable O&M ($M)	Imported O&M ($M)	Unit Cost $/AF
No Action	0	25	2.76	1.32	22.73	905
Max Demand Mgt A	3	22	3.36	8.96	11.24	759
Max Demand Mgt B	7	25	4.10	11.53	11.24	948
Max Groundwater A	5	39	3.57	18.98	18.53	1,285
Max Groundwater B	6	38	5.53	19.67	14.71	1,298
Max Surface Water A	23	8	4.38	4.64	0.00	929
Max Surface Water B	91	67	32.22	39.23	0.00	4,695
Max Surface Water C	23	8	4.38	4.64	0.00	929

Table 7-1 (cont.)
Cost Estimates for Water Supply Plan Alternatives

Alternative	Total Capital Costs ($M)	Total O&M Costs ($M)	Fixed O&M ($M)	Variable O&M ($M)	Imported O&M ($M)	Unit Cost $/AF
Max Local Surface Water	9	17	12.83	3.65	1.86	784
Maximize Assets A	11	28	10.90	18.43	0.00	1,152
Maximize Assets B	8	24	10.17	15.10	0.00	941
Maximize Assets C	8	29	9.15	21.91	0.00	1,106
Balanced A	22	45	16.11	31.56	0.05	1,976
Balanced B	49	46	26.82	3.33	18.30	2,815
Balanced C	4	28	3.38	21.55	4.47	942

7.1.5 Environmental and Natural Resources Evaluation

For this objective, two performance measures were evaluated to compare the alternatives: (1) minimize impacts related to construction and operation, (2) minimize environmental impacts beyond construction. A qualitative scale was used for these performance measures, and a higher score indicates that the alternative performed well (fewer or less significant impacts are likely). The scores for these performance measures are shown in Figure 7-12.

In general, most of the alternatives score well for the Constructional and Operational performance measure as well as the Environmental Impacts performance measure except for the alternatives with imported raw water. Balanced B has the lowest score since it has a combination of imported raw water both from Oklahoma City and Kaw Lake.

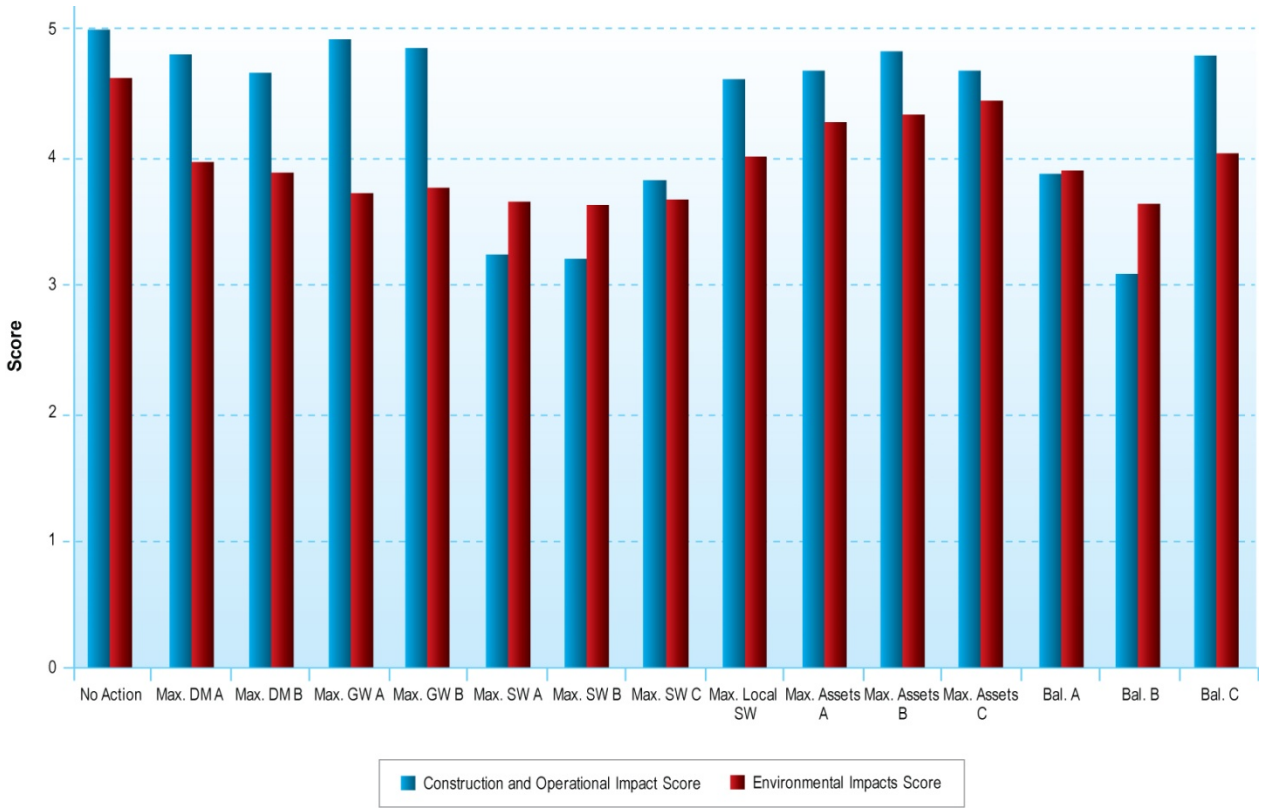

Figure 7-12
Alternative Scores for Environmental and Institutional Constraints

7.1.6 Implementation Potential Evaluation

This objective was measured in terms of the following four performance measures: (1) Political and Institutional Acceptability, (2) Regulatory score, (3) Technical Implementation score, and (4) Public Support or Opposition score. A qualitative scale was used for these performance measures as well, and a higher score indicates that the alternative performed well (better likelihood of expedient implementation).

The scores for these performance measures are shown in Figure 7-13. Generally, alternatives that require larger scale infrastructure and particularly with trans-basin water imports are likely to face greater resistance from a public and institutional perspective and likely to face greater challenges from a regulatory perspective. Local and smaller scale projects are more likely to face smaller and fewer implementation obstacles. The alternatives ranking presented later in the section was tested in terms of its sensitivity to these qualitative scores, given that the actual score given to an alternative is somewhat subjective. The ranking did not show to be sensitive to these scores.

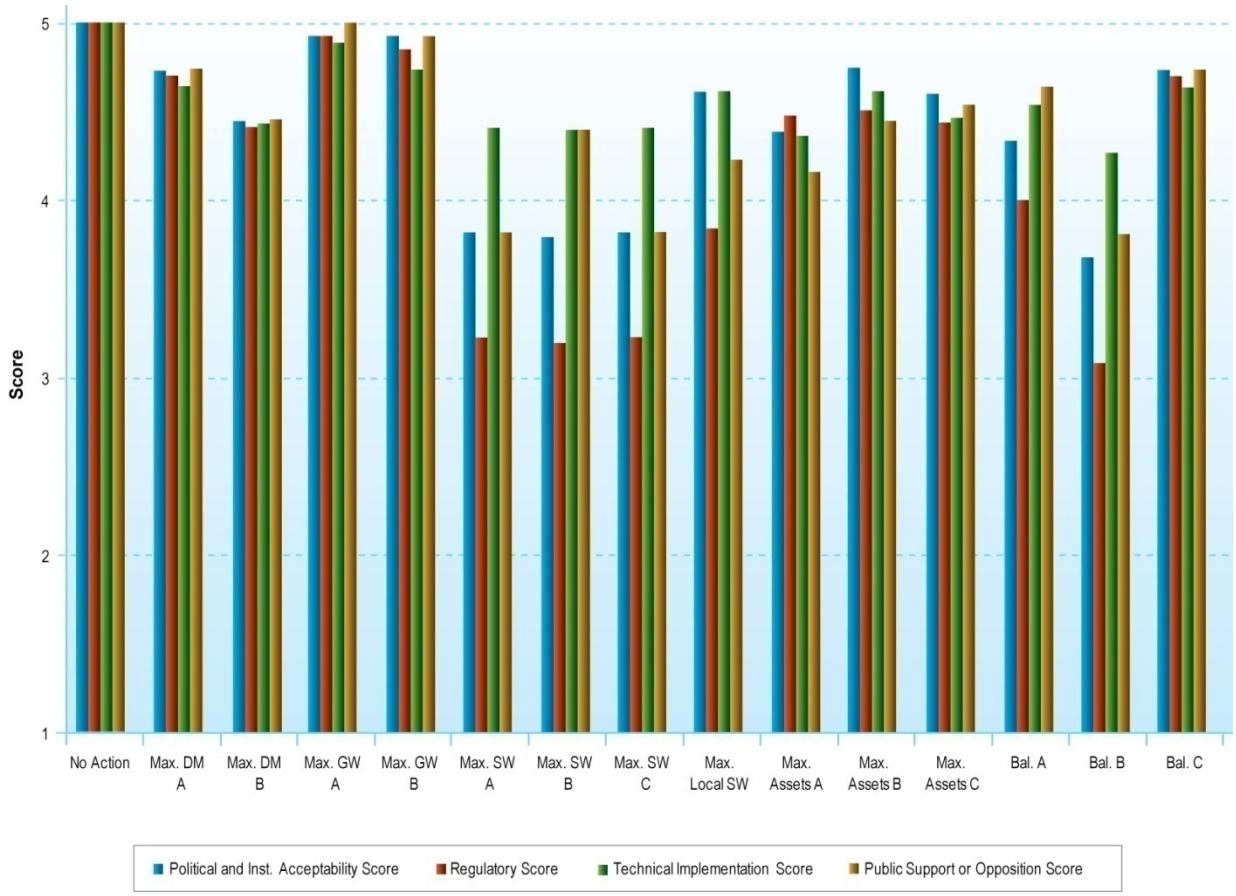

Figure 7-13
Implementation Potential Scores for Alternatives

7.1.7 Alternative Performance Summary

A summary of the raw performance scores for every alternative is presented in Appendix D. Section 7.3 discusses how these raw scores were used in conjunction with stakeholder's objective weightings to rank the alternatives.

The model used for the analysis of alternatives included the simulation of Arcadia Lake based on the hydrology of record for the lake. The model is able to track the storage in the lake for a simulation period of about 40 years. An important finding about the lake based on the modeling results is that storage seems to be available under most of the hydrology conditions, for all alternatives that constrained the use of Arcadia Lake to its current permit. The only alternative that does not include that constraint was Maximize Local Surface Water. Figure 7-14 has presents the storage levels in what is called an exceedance probability chart. What the figure indicates is that 40 percent of the time (based on the period of record simulated), the conservation pool is full. The conservation pool is almost full half the time and it is over 20,000 AF

about 70 percent of the time. This is a significant finding indicating that Arcadia Lake may have potential as an expanded source for the city.

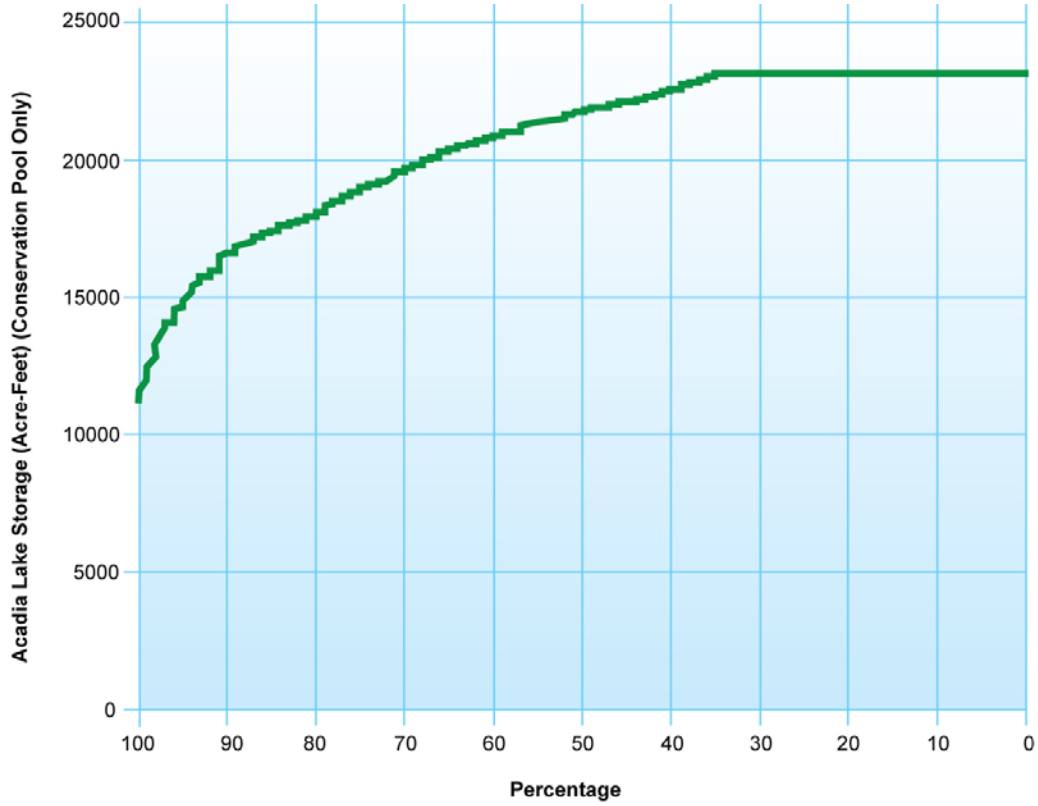

Figure 7-14
Arcadia Lake Storage
(Conservation Pool Only)

7.2 Alternatives Ranking

The commercial software Criterium Decision Plus (CDP), developed by Infoharvest Inc., was selected to rank the alternatives because of its ease of understanding and use, its ability to conduct sensitivity analyses and display results graphically.

Using the alternative raw performance scores in Table 7-1, the alternatives were ranked with the multi-attribute rating method. A ranking of the alternatives was developed for each stakeholder, based on the raw performance measures discussed in Section 7.1 and the relative weights that the stakeholder placed on each objective. This method allows individual results to be tracked in order to see where consensus can be achieved. This approach can be very powerful, as a majority of stakeholders can arrive at the same conclusion (a set of preferred alternatives) for different reasons.

Figure 7-15 shows the rankings of alternatives for a selected set of weights from the stakeholders, and illustrates how the ranking results are created. The figure not only

indicates which alternative had the greatest overall score, but also the make-up of that score. Each color segment represents the major objectives discussed in Section 4.

Two factors determine the size of each color segment for a given bar, or alternative: (1) the raw performance of the alternative for that objective; and (2) the weight of the objective assigned by the stakeholders. In all cases, for a given stakeholder, if the color segment is larger, then the raw performance was better.

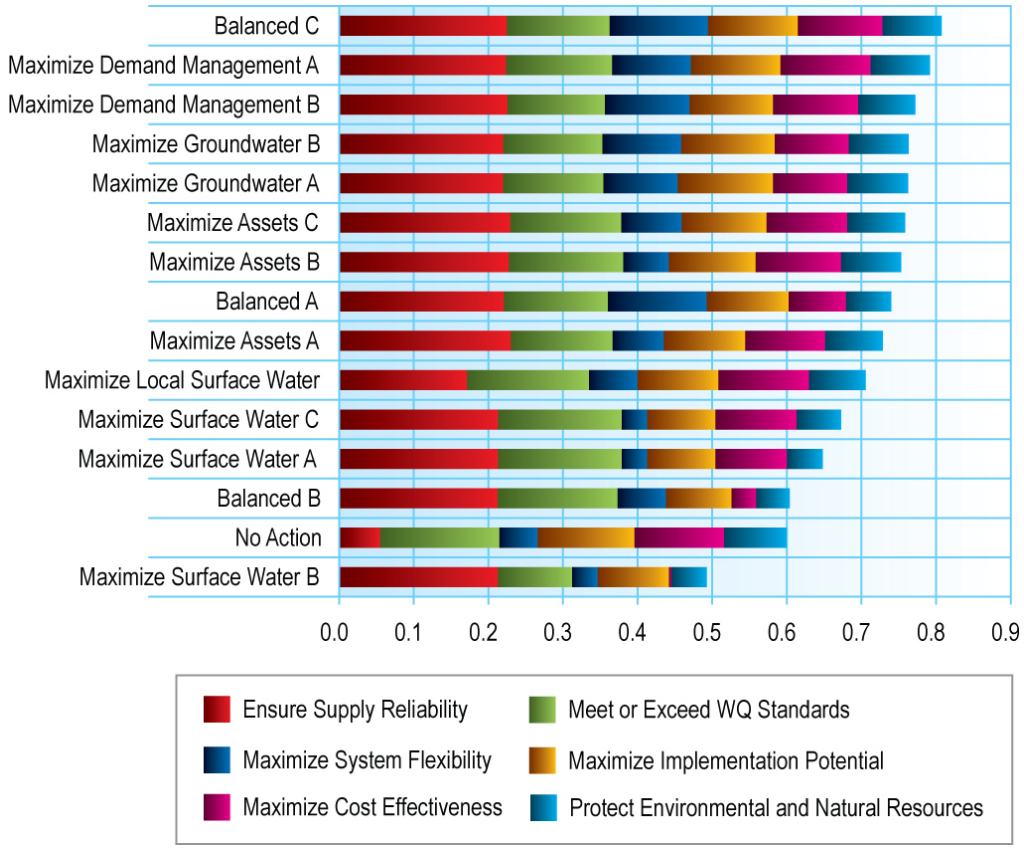

Figure 7-15
Alternative Ranking for Sample Stakeholder Weights

7.3 Preferred Alternatives

The chart shown in Figure 7-15 illustrates how ranking results are created for one set of weights. In order to determine the preferred alternative and see if consensus truly exists among stakeholders, analysis is required of all of the individual stakeholders' rankings. To do this, the number of times an alternative was ranked number 1, number 2, or number 3 by all stakeholders was counted. This is shown in Figures 7-16 and 7-17.

The top preferred alternatives in Figure 7-16 are clearly Balanced C, Maximize Demand Management A. Almost all stakeholders counted these alternatives as the top 1 alternative. When looking into whether an alternative was ranked number 1, 2, or 3 for each stakeholder, the top preferred alternatives (Figure 7-17) are Balanced C, Maximize Demand Management A and Maximize Demand Management B. Most stakeholders counted these alternatives as preferred.

This ranking provides valuable information and insights to develop a long-term strategy for the city. By comparing the common elements in the preferred alternatives, a strategy can be developed that accounts for the uncertainty associated with specific projects that may be included in the more clearly preferred alternative. The process of developing a strategy is presented in Section 8.

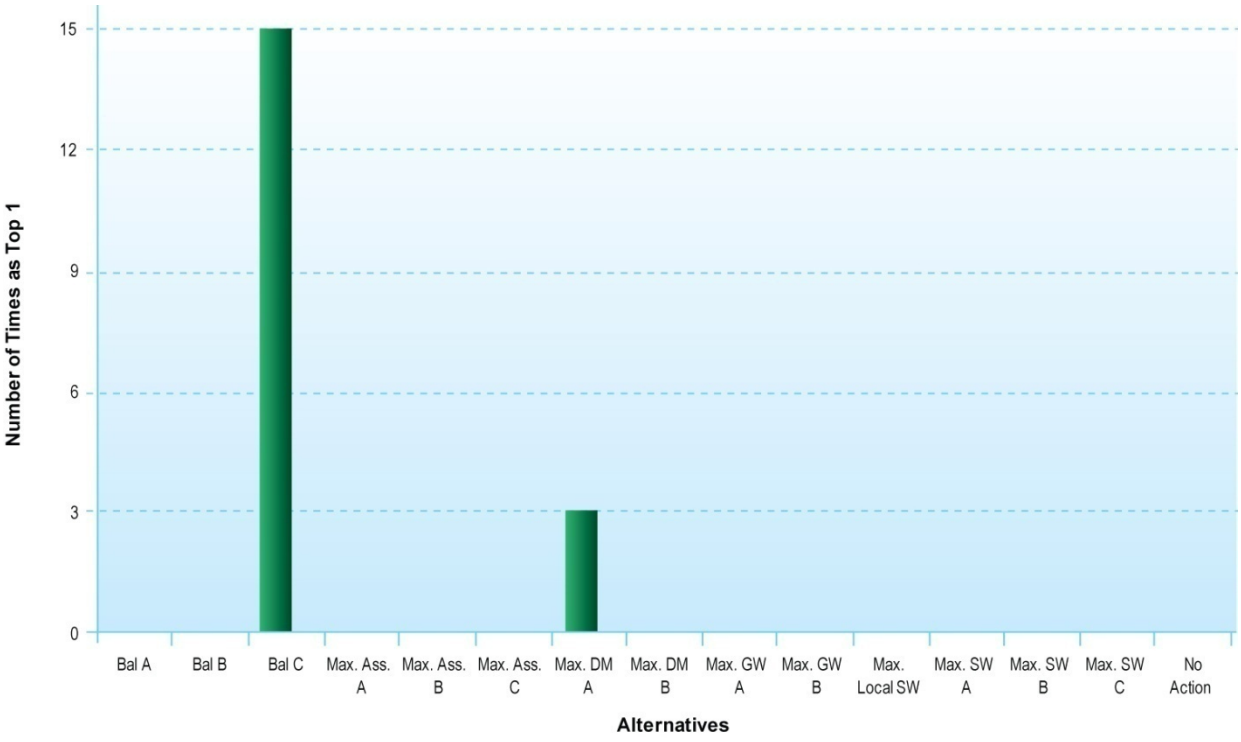

Figure 7-16
Number of Times an Alternative was Ranked Number 1

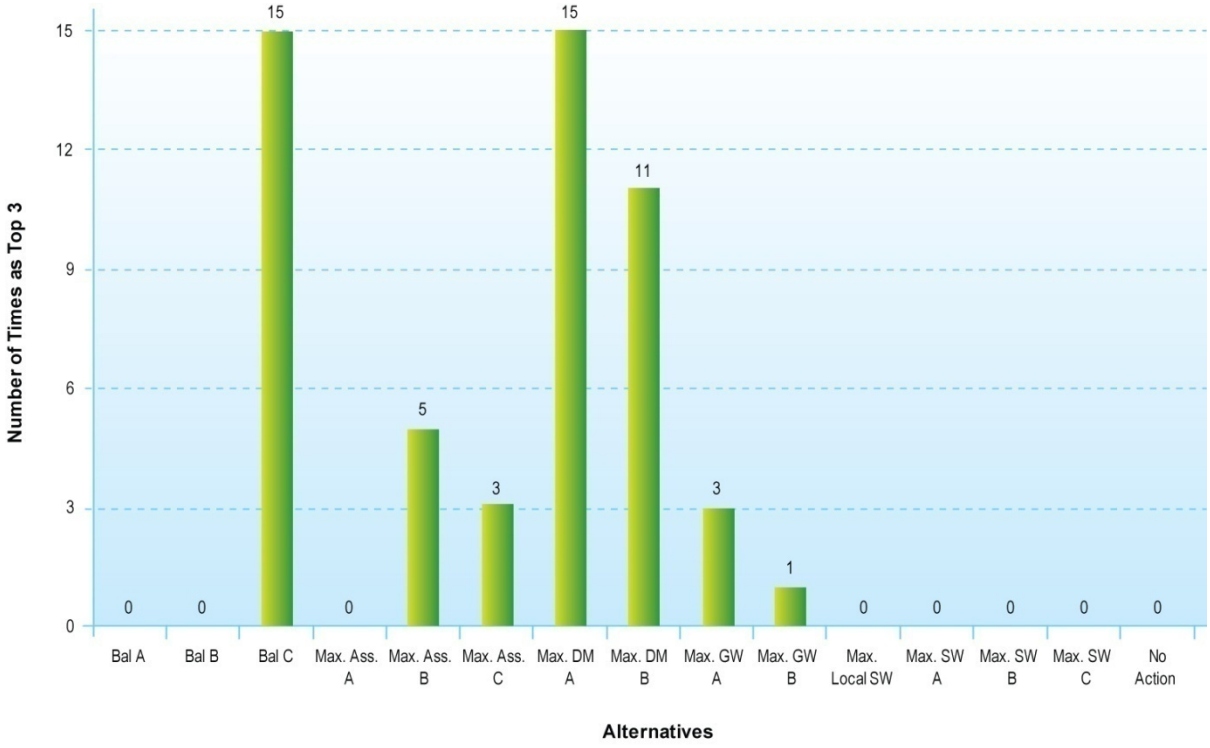

Figure 7-17
Number of Times an Alternative was Ranked Number in Top 3

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Section 8
Summary and Implementation Plan

Implementing a long-term water supply strategy necessarily faces uncertainty associated with different elements of the plan, including the demand growth rate, the level of success of demand management options, regulatory risk, technical uncertainties, energy costs, etc. The long-term plan of the City formalizes the analysis of certain elements of uncertainty related to the supply options included in the preferred alternatives.

8.1 Implementation Plan

The alternatives that consistently ranked high for stakeholders, such as Balanced C and Demand Management A include a number of common elements:

- Level 1 conservation
- Level 2 conservation
- Non potable reuse
- Stormwater beneficial use
- Additional capacity for treated water from Oklahoma City

A strategy for the long-term supply of the City should try to incorporate those elements that have shown to provide cost-effective reliability under droughts and under peak conditions, flexibility, and other objectives of the plan.

The analysis of the supply options presented in Section 5 and the analysis of the alternatives presented in Section 7 presents some elements that are not necessarily reflected in the alternative ranking results but are important to consider for long-term implementation. One such element is the fact that groundwater, and particularly the City's existing wells, shows to be an asset for the City. The analysis of the water levels in the conservation pool in Arcadia Lake (see Figure 7-14) shows that surface local water is also an asset that could be better utilized. The conservation pool is generally at high levels and the lake could likely yield more water than currently permitted. Additionally, Oklahoma City's contract water is a common resource in all the alternatives that rank high for stakeholders.

These additional considerations that are not directly derived from the alternatives ranking have been taken into account in developing the strategy presented in conceptually in Figure 8-1. The strategy shows that the City should implement short-term actions and implement mid- and long-term actions based on the outcome of certain implementation steps for some of the less certain supply options. The strategy presented in Figure 8-1 requires specific short-term that set the foundation of future implementation steps towards a diverse water supply portfolio.

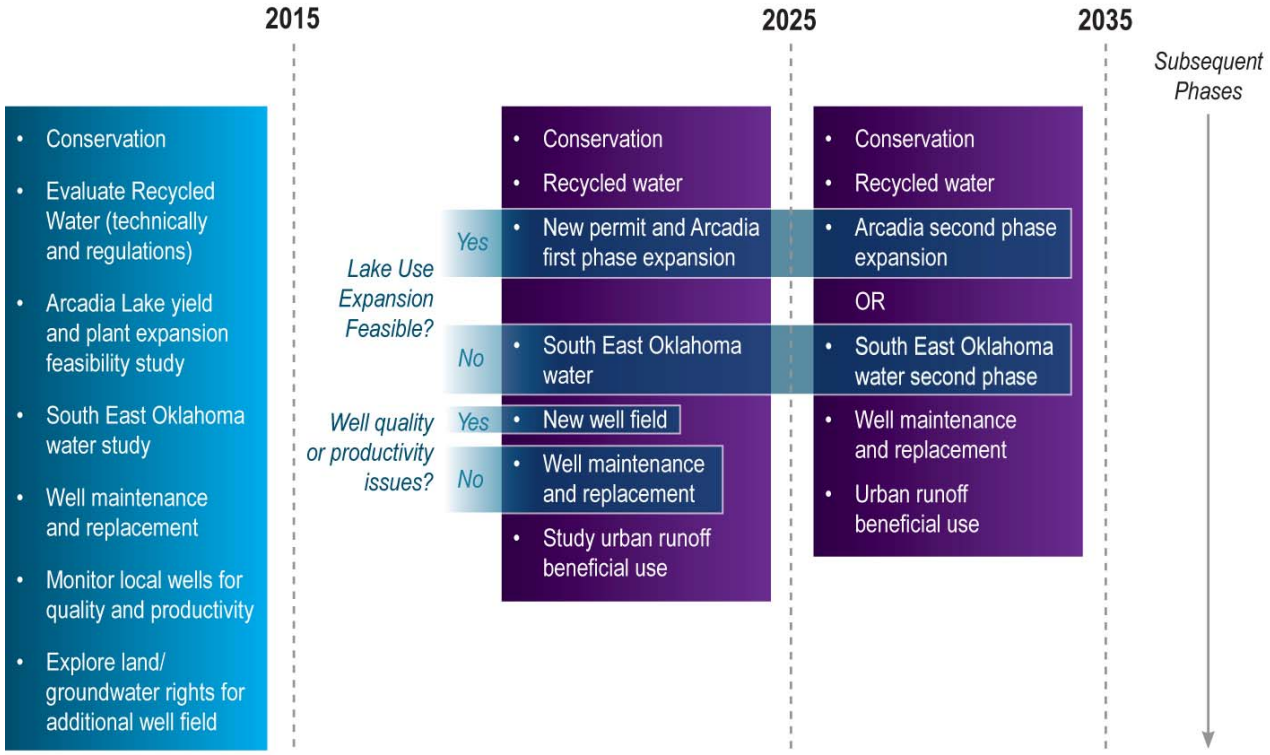

Figure 8-1
Implementation Strategy

Short-term actions include steps towards implementing additional water conservation measures. This can include specific management practices to increase the water savings from conservation programs but also the establishment of mid- and long-term conservation goals and the analysis of rate structures in addition to education and indoor and outdoor fixtures that could help the City achieve water savings.

The City should also start a more detailed assessment of recycled water as a source of non-potable demands. This detail evaluation needs to include coordination with ODEQ to closely follow the development of regulations and their implementation and enforcement in the State. In addition to the regulatory assessment, technical evaluation of the option should be started with a recycled water master plan effort (which would focus on technical elements only, given the insipient regulatory framework for the implementation of this option).

The yield from Arcadia lake needs to be studied. Yield definition and a lake optimization study should be part of the short-term actions since local surface water has the potential to reduce costs significantly compared to other large-scale supply options.

City of Edmond should continue to be involved in the efforts from central Oklahoma cities and agencies to explore the possibility of implementing a project to convey water from Southeast Oklahoma to central Oklahoma. The alternatives favored by the stakeholders all include water from Oklahoma City and in the long-term, that water could be water from the Kiamichi River basin.

Groundwater wells should be replaced and maintained at every step of the implementation, to the extent that the water quality does not deteriorate beyond a point where treating it can be feasible and cost effective. In addition to the existing wells, however, the City should continue to explore the possibility of leasing land for the development of a well field.

After the first five years, and having implemented a yield study and explored the permit options for Arcadia Lake, the option should be implemented if feasible, to a level consistent with the City's demands at that point. If the option is not feasible, the balance of demands could be met by additional Oklahoma City water, which by then will likely be originated in Southeast Oklahoma.

A second path of action after the first five years (after 2015) would include the implementation of additional well rehabilitation and replacement for city wells and the implementation of an additional well field if the city wells are at that point presenting significant productivity and/or quality issues.

Recycled water can also be implemented by 2015 according to plans and regulations established in the short-term, and sustained conservation measures should continue. The use of urban runoff can also be explored.

Beyond 2025, conservation, recycled water and urban runoff can be a part of the City's portfolio with groundwater as a primary source and Oklahoma City water and or expanded use of Arcadia Lake water as the two main sources. Beyond 2035, the last phases of large-scale options such as Arcadia Lake use should be implemented.

The implementation of this strategy will ultimately result in a long-term water supply portfolio for the City that will clearly resemble the preferred alternatives presented in Sections 6 and 7, accomplishing the objectives defined for this long-term supply study. When putting this strategy in more detailed timeline, and comparing it to demand projections, the transition of the City's supply from the current conditions to a much more diverse portfolio is more clearly defined, as presented in Figure 8-2.

Figure 8-2 shows how the City could transition to a scenario in which the 2060 supply is diverse and well balanced, including demand management options, non-potable sources used for non-potable demands, surface and groundwater.

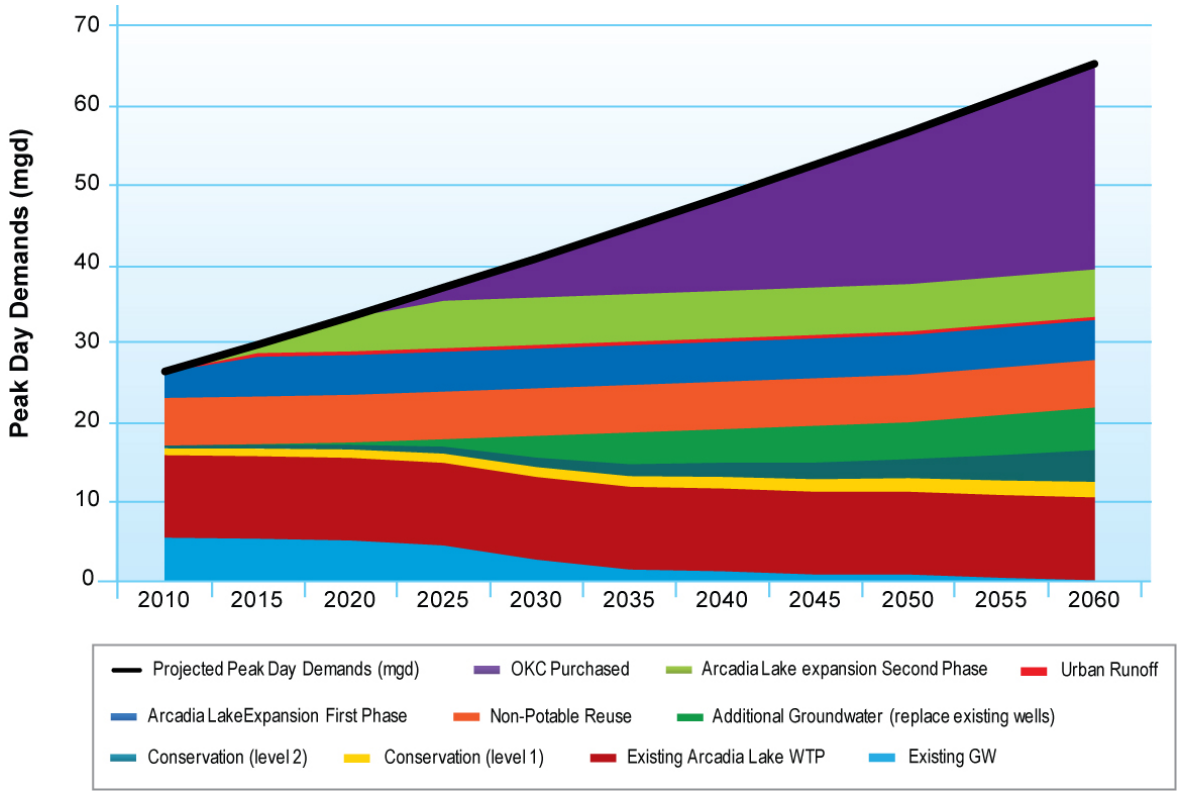

Figure 8-2
Supply Sources as per Implementation Strategy

Section 9
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Attachment A
Objective Weighting Results

Scores

Stakeholders

Person	Ensure Supply Reliability	Maximize System Flexibility	Meet or Exceed Water Quality Standards	Maximize Cost Effectiveness	Protect Environmental and Natural Resources	Maximize Implementation Potential
Don Bown	30%	10%	10%	20%	15%	15%
Elizabeth Waner	15%	10%	25%	15%	25%	10%
Gene Woods	25%	15%	25%	10%	15%	10%
Sharlene Wulf	25%	20%	20%	10%	15%	10%
Caleb McCaleb	30%	20%	10%	10%	10%	20%
Bret Towne	25%	15%	20%	15%	15%	10%
Mike McGinnis	20%	30%	15%	15%	10%	10%
Joe Ralston	30%	20%	20%	10%	10%	10%
Bob Nall	20%	20%	20%	10%	20%	10%
Mary Ann Karns	45%	15%	10%	10%	10%	10%
Carl Reherman	20%	10%	15%	20%	10%	25%
Dyke Hoppe	30%	10%	15%	10%	25%	10%
Stacey Trumbo	25%	10%	25%	15%	15%	10%
Wayne Pettigrew	30%	20%	10%	20%	10%	10%
Russell Wantland	10%	10%	10%	10%	40%	20%

Attachment B
Supply Options Summary Table

Supply Options Summary

Option	Avg Annual Yield (AFY)	Peak Day Yield (mgd)	Capital Cost	Fixed O&M per yr	Variable O&M per AF	Imported O&M per AF	NPV per AF	Security Score	Sustainability Score	Water Quality Score	Compatibility Score	Construction and Operational Impacts Score	Political and Institutional Acceptability Score	Regulatory Implementation Score	Technical Implementation Score	Public Support or Opposition Score	Environmental Impacts Score
Level 1 Conservation	2,240	2	$410,000	--	--	--	$391	4	5	5	5	5	5	5	4	4	5
Level 2 Conservation	4,480	4	$480,000	--	--	--	$3,429	4	5	5	5	5	4	5	3	3	5
Non-potable Reuse	6,720	6	$15,112,566	$302,251	$1,153	--	$799	4	5	3.5	5	3	3	2	3	4	4
Stormwater Reuse	560	0.5	$1,404,861	$28,097	$128	--	$154	1	5	3.5	5	4	3	3	3	4	4
Indirect Potable Reuse	5,000	4.5	$38,081,600	$755,172	$871	--	$967	5	5	0.5	2	3	1	1	2	1	3
RW from OKC	19,824	38.3	$267,922,000	$1,662,293	$154	--	$423	2	3	5	5	2	3	2	4	3	3
Treated Water from Sardis	19,824	38.3	$267,922,000	$1,662,293	$154	--	$423	2	3	5	3	3	3	2	4	3	3
RW from Kaw	16,800	15.0	$456,524,820	$13,833,188	$1,798	--	$2,862	2	3	5	3	2	3	2	4	4	3
RW from Navina	16,800	15.0	$297,065,982	$13,135,808	$1,450	--	$539	2	3	5	3	1	3	2	4	4	3
RW from Eufala/Parker	19,824	38.3	$1,021,308,392	$28,955,578	$1,760	--	$2,587	2	3	2	3	2	3	2	4	4	3
New GW outside COE	2,800	2.5	$19,311,935	$2,036,466	$257	--	$910	5	2	2.5	3	3	5	3	1	3	4
New GW inside COE	5,824	5.2	$2,250,000	$45,000	$2,174	--	$1,270	5	2	1.5	5	5	5	5	5	5	4
Brackish GW	2,800	2.5	$23,649,499	$472,040	$1,843	--	$1,576	5	2	5	5	3	3	3	2	5	2
Addt'l Treated Water from OKC								3	3	5	2	5	5	5	5	5	3
Maximize Demand Management A	9,180	27.6	$15,430,385	$253,800	--	$1,424	$853										
Maximize Demand Management B	4,180	17.8	$11,945,193	$211,500	--	$1,424	$867										
Groundwater A	11,196	30.6	$17,545,385	$296,100	--	$1,424	$853										
Groundwater B	8,396	28.1	$15,430,385	$253,800	--	$1,424	$852										
Balanced A	0	14.8	$9,830,193	$169,200	--	$1,424	$870										
Exst Groundwater	0	0	--	--	--	--	--	5	2	1	5	5	5	5	5	5	4
City of Edmond WTP - exst capacity	11,760	10.5	--	$2,926,550	$117	--	$210	2	5	5	5	5	5	5	5	5	4
City of Edmond WTP - addt'l capacity	19,824	38.3	$107,276,519	$10,674,940	$117	--	$143	2	5	5	5	4	4	2 or 4	4	3	3
Exst TW from OKC	18,480	16.5	--	--	--	$1,424	$817	3	5	5	4	5	5	5	5	5	5

Attachment C
Supply Options Cost Estimates

Conservation (based on Bill Davis memo 9/9/08 - see Appendix F)

Level 1 Savings:	Indoor Conservation =	1 mgd	5% efficiency
	Outdoor Conservation =	1 mgd	10% efficiency
Level 2 Savings:	Addt'l Conservation =	0 mgd	10% efficiency in 2010
		4 mgd	20% efficiency in 2060

	Level 1 Savings (mgd) Indoor*	Level 1 Savings (mgd) Outdoor*	Level 1 Cost**	Level 2 Savings (mgd) Indoor**	Level 2 Cost**	Unit Cost ($/AF)	Level 2 Savings (mgd) Additional***	Level 2 Cost**	Total Savings (mgd)
2010	0.38	0.44	$160,000	0.4	$200,000	$446	0.0	$0	1.2
2020	0.48	0.56	$200,000	0.5	$250,000	$446	0.1	$50,000	1.6
2030	0.58	0.68	$250,000	0.6	$300,000	$446	0.6	$300,000	2.5
2040	0.69	0.82	$300,000	0.7	$360,000	$459	1.1	$1,232,000	3.3
2050	0.81	0.95	$350,000	0.8	$420,000	$469	1.6	$1,792,000	4.2
2060	0.94	1.10	$410,000	1.0	$480,000	$429	3.0	$3,360,000	6.0

*Based on B. Davis spreadsheet "Monthly conservation reductions with 63%.xls"
**Based on Conservation Memo
***Based on 20% demand reduction in 2060 and 10% reduction in 2010; cost is $1000 per AF; per B. Davis email 11/21/08 (source: Colorado project)
***Additional savings' cost based on marginal cost of Level 2 Indoor savings at $1000/AF when the total savings >3mgd (per discussion with ELC 11/25/08)

	Level 1 Indoor Savings (mgd)	Level 1 Outdoor Savings (mgd)	Level 1 Cost	Level 2 Indoor Savings (mgd)	Level 2 Cost	Addt'l Savings (mgd)	Cost	Level 1 Savings (AFY)	Level 1 Cost	Level 2 Savings (AFY)	Level 2 Cost
2010	0.38	0.44	$160,000	0.40	$200,000	0.00	$0	920	160000	448	200000
2011	0.39	0.46	$164,000	0.41	$205,000	0.01	$5,000	945	164000	470	210000
2012	0.40	0.47	$168,000	0.42	$210,000	0.02	$10,000	969	168000	493	220000
2013	0.41	0.48	$172,000	0.43	$215,000	0.03	$15,000	993	172000	515	230000
2014	0.42	0.49	$176,000	0.44	$220,000	0.04	$20,000	1017	176000	538	240000
2015	0.43	0.50	$180,000	0.45	$225,000	0.05	$25,000	1041	180000	560	250000
2016	0.44	0.51	$184,000	0.46	$230,000	0.06	$30,000	1065	184000	582	260000
2017	0.45	0.53	$188,000	0.47	$235,000	0.07	$35,000	1089	188000	605	270000
2018	0.46	0.54	$192,000	0.48	$240,000	0.08	$40,000	1113	192000	627	280000
2019	0.47	0.55	$196,000	0.49	$245,000	0.09	$45,000	1137	196000	650	290000
2020	0.48	0.56	$200,000	0.50	$250,000	0.10	$50,000	1162	200000	672	300000
2021	0.49	0.57	$205,000	0.51	$255,000	0.15	$75,000	1187	205000	739	330000
2022	0.50	0.58	$210,000	0.52	$260,000	0.20	$100,000	1213	210000	806	360000
2023	0.51	0.60	$215,000	0.53	$265,000	0.25	$125,000	1239	215000	874	390000
2024	0.52	0.61	$220,000	0.54	$270,000	0.30	$150,000	1264	220000	941	420000
2025	0.53	0.62	$225,000	0.55	$275,000	0.35	$175,000	1290	225000	1008	450000
2026	0.54	0.63	$230,000	0.56	$280,000	0.40	$200,000	1316	230000	1075	480000
2027	0.55	0.65	$235,000	0.57	$285,000	0.45	$225,000	1342	235000	1142	510000
2028	0.56	0.66	$240,000	0.58	$290,000	0.50	$250,000	1367	240000	1210	540000
2029	0.57	0.67	$245,000	0.59	$295,000	0.55	$275,000	1393	245000	1277	570000
2030	0.58	0.68	$250,000	0.60	$300,000	0.60	$300,000	1419	250000	1344	600000
2031	0.59	0.70	$255,000	0.61	$306,000	0.65	$393,200	1446	255000	1411	699200
2032	0.60	0.71	$260,000	0.62	$312,000	0.70	$486,400	1473	260000	1478	798400
2033	0.62	0.72	$265,000	0.63	$318,000	0.75	$579,600	1500	265000	1546	897600
2034	0.63	0.74	$270,000	0.64	$324,000	0.80	$672,800	1528	270000	1613	996800
2035	0.64	0.75	$275,000	0.65	$330,000	0.85	$766,000	1555	275000	1680	1096000
2036	0.65	0.76	$280,000	0.66	$336,000	0.90	$859,200	1582	280000	1747	1195200
2037	0.66	0.78	$285,000	0.67	$342,000	0.95	$952,400	1609	285000	1814	1294400
2038	0.67	0.79	$290,000	0.68	$348,000	1.00	$1,045,600	1636	290000	1882	1393600
2039	0.68	0.80	$295,000	0.69	$354,000	1.05	$1,138,800	1664	295000	1949	1492800
2040	0.69	0.82	$300,000	0.70	$360,000	1.10	$1,232,000	1691	300000	2016	1592000
2041	0.71	0.83	$305,000	0.71	$366,000	1.15	$1,288,000	1720	305000	2083	1654000
2042	0.72	0.84	$310,000	0.72	$372,000	1.20	$1,344,000	1748	310000	2150	1716000
2043	0.73	0.86	$315,000	0.73	$378,000	1.25	$1,400,000	1777	315000	2218	1778000
2044	0.74	0.87	$320,000	0.74	$384,000	1.30	$1,456,000	1806	320000	2285	1840000
2045	0.75	0.88	$325,000	0.75	$390,000	1.35	$1,512,000	1834	325000	2352	1902000
2046	0.76	0.90	$330,000	0.76	$396,000	1.40	$1,568,000	1863	330000	2419	1964000
2047	0.78	0.91	$335,000	0.77	$402,000	1.45	$1,624,000	1892	335000	2486	2026000
2048	0.79	0.93	$340,000	0.78	$408,000	1.50	$1,680,000	1920	340000	2554	2088000
2049	0.80	0.94	$345,000	0.79	$414,000	1.55	$1,736,000	1949	345000	2621	2150000
2050	0.81	0.95	$350,000	0.80	$420,000	1.60	$1,792,000	1978	350000	2688	2212000
2051	0.82	0.97	$356,000	0.82	$426,000	1.74	$1,948,800	2008	356000	2867	2374800
2052	0.84	0.98	$362,000	0.84	$432,000	1.88	$2,105,600	2038	362000	3046	2537600
2053	0.85	1.00	$368,000	0.86	$438,000	2.02	$2,262,400	2068	368000	3226	2700400
2054	0.86	1.01	$374,000	0.88	$444,000	2.16	$2,419,200	2098	374000	3405	2863200
2055	0.87	1.03	$380,000	0.90	$450,000	2.30	$2,576,000	2128	380000	3584	3026000
2056	0.89	1.04	$386,000	0.92	$456,000	2.44	$2,732,800	2158	386000	3763	3188800
2057	0.90	1.06	$392,000	0.94	$462,000	2.58	$2,889,600	2188	392000	3942	3351600
2058	0.91	1.07	$398,000	0.96	$468,000	2.72	$3,046,400	2218	398000	4122	3514400
2059	0.92	1.08	$404,000	0.98	$474,000	2.86	$3,203,200	2248	404000	4301	3677200
2060	0.94	1.10	$410,000	1.00	$480,000	3.00	$3,360,000	2278	410000	4480	3840000

Non-Potable Reuse

Schematic

Cost Calcs

Total Yield (MGD)	6
Facilities	Tertiary Treatment (Media/disc/micro filters, chlorination),Pipeline (Reuse), Reuse Pump Station, Instrumentation and Controls
Capital Cost ($)	15,112,566.44
O&M Cost Fixed($/year)	302,251.33
O&M Cost Variable	1,152.68

* Value from P:\Edmond IRP\Raw Data\Effluent Data\AnnualflowsforCDM.xls (Summary)

Cost Calcs

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Capital Costs		**Cost ($)**
Reuse Pipeline	-	**7,128,000**
Length (miles)	4.5	
Dia (inch)	20	
Unit cost ($/inch/foot of length)	15	
Reuse Pumpstation		**7,984,566.44**
Capacity (hp)	1965	
Unit cost ($/hp)	$ 4,062.50	
Total		**15,112,566.44**

O&M Costs		Cost
Reuse Pumpstation		
Energy	$0.11/kwh	281.77
Chlorine	$0.34/pound	870.92
Fixed		
Pipeline (maintenance)		142,560.00
Pump (maintenance)		159,691.33
Total		**143,712.68**

Notes

1. Demand assumed near Kickingbird Golf Course
2. Refer to Kickingbird Golf Course study for length of pipeline and Chlorination/IC Improvements
3. Pipe diameter cals based on 5ft/sec vel. and 6 MGD flow

Variable O&M Cost (per yr)	$7,746,030
Total O&M Cost (per yr)	$8,048,281
NPV (per AF)	$799

Indirect Potable Reuse

Schematic | Cost Calcs

Total Yield (MGD)	4.46
Facilities	Membrane Treatment (chlorination),Pipeline (Effluent pipeline to Arcadia and Brine pipeine), Pump Station
Capital Cost ($)	38,081,600.00
O&M Cost ($/year)	755,172.00
O&M Variable	870.92

Cost Calcs

Back To Main Panel

Capital Costs		**Cost ($)**
Effluent Pipeline to Arcadia	-	3,801,600.00
Length (miles)	3	
Dia (inch)	16	
Unit cost ($/inch/foot of length)	15	
Treatment Costs		11,150,000.00
Membrane Treatment ($/galperday)	2.5	
Brine Pipeline		11,880,000.00
Length (miles)	10	
Dia (inch)	15	
Unit cost ($/inch/foot of length)	15	
Injection Well		11,250,000.00
Flow	afy	1,350
Flow	mgd	1.21
Flow	ft3/yr	58,806,000
Time Period	days	180
Flow	cfs	4
Flow	gpm	1,694
Well Yield	gpm	1,000
Wells Needed =		1.7
Use		3
Unit Cost	/well	$3,750,000
Total Cost of wells=		$11,250,000
Pump Station		
Capacity (hp)	0	**0.00**
Unit cost ($/hp)	4062.5	
Total		**38,081,600.00**

O&M Costs		**Cost ($/Year)**
Reuse Pumpstation		
Energy	$0.11/kwh	0.00
Chlorine	$0.34/pound	870.92
Fixed		
Pipeline (maintenance)		76,032.00
Pump (maintenance)		0.00
Wells		441,540.00
Brineline		237,600.00
Total Fixed		**755,172.00**

Notes

1. Length of brine line is assumed to be 10 miles (as per Greg) to the confined portion of the aquifer
2. Brine line diameter based on (gravity flow)- 1.2 MGD and 2ft/sec vel.
3. Membrane treatment flow- 5.98 MGD
4. Assume brine recovery to be 25%

Variable O&M Cost (per yr)	$4,350,400
Total O&M Cost (per yr)	$5,105,572
NPV (per AF)	$967

Stormwater Beneficial Use

Schematic | Cost Calcs

Total Yield	0.5	
Facilities	Collection Basin,Water Treatment	Land for Basins
Capital Cost ($)	1,404,861.06	
O&M Cost Fixed($/year)	28,097.22	
O&M Cost Variable	128.15	
Land Cost ($)		2,178.00

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Stormwater Costs Calculations

Yield	0.50	MGD
Yield	0.77	cfs
Yield	560.20	AFY

Costs		
Capital	1,404,861.06	$
Land	2,178.00	$
O&M[1]	71,761.82	$ per year

1. MGD x $/MG x day op / year

Cost Assumptions		
Unit Capital (2001)	1,973,314.22	$ per MGD
Unit Capital (2008)	2,809,722.12	$ per MGD
Unit O&M (2001)[2]	373.33	$ per MG treated
Unit O&M (2008)	531.57	$ per MG treated
Days of Op per Year[3]	270.00	day/year
ENR July 2001[4]	3,854.32	
ENR July 2008	5,488.01	
Land Required[5]	0.05	acres
Unit Land Cost[6]	43,560.00	$ per acre

2. From Los Angeles IPWP, 2001 -- 2001 costs (ADJUSTED for $0.11 per kW energy costs ($0.08 used for LA))
3. Assume operation for all days except wet season-Check
4. ENR Construction Costs, Dallas TX
5. Assume Land req is proportional to plant flow rate. (Use LA IPWP land area for 5 MGD plant = 0.5 acres)
6. Assume $1 /sq foot
7. Land Calcs based on LA IPWP (5MGD plant=0.5 acres)
8. ENR CCI cost assumed for Dallas, Tx

Cost Conversion	LA Costs	Equivalent Dallas Costs		ENR LA 2001	ENR Dallas 2001
Unit Capital Cost	3,700,000.00	1973314.22		7226.92	3854.32
Unit O&M	700.00	373.3297172		7226.92	3854.32

Source: Escondido creek Calcs- SFID also refer Los Angeles IPWP, 2001 -- 2001 costs (ADJUSTED to use 30% contingency and 25% LAE)
Facility includes Dissolved Air Flotation, microfiltration, and pumping

Variable O&M Cost (per yr)	$280
Total O&M Cost (per yr)	$28,377
NPV (per AF)	$154

Arcadia (City of Edmond) WTP

Exst WTP Capacity = 10.5 mgd

	Treatment	Intake	Total
Capital Cost (per mgd addt'l cap)	$2,370,000	$430,954	$2,800,954
Fixed O&M Cost (per mgd-yr total capacity)	$270,100	$8,619	$278,719
Variable O&M Cost (per AF)	$117	$0	$117

Assuming no additional WTP capacity:

Variable O&M Cost (per yr)	$1,379,429
Total O&M Cost (per yr)	$4,305,979
NPV (per AF)	$210

Assuming additional capacity of 38.3 mgd:

Capital Cost =	$107,276,519
Fixed O&M Cost (per year) =	$10,674,940
NPV (per AF) =	$143

Eufaula Lake

Yield fill the supply gap

Infrastructure

	Pump Station	Pipeline	Treatment	Total
Capacity (mgd)	38.3	38.3	38.3	
Calc Pipe Diameter (in)	--	47	--	
Req'd Pipe Diameter (in)	--	48		
Length (mi)	--	140	--	
Elev (ft)	1,949	--	--	
Power (hP)	98,046	--	--	
Power (kW)	73,143	--	--	
Capital Cost	$398,313,392	$532,224,000	$90,771,000	$1,021,308,392
Fixed O&M Cost (per yr)	$7,966,268	$10,644,480	$10,344,830	$28,955,578
Variable O&M Cost (per AF)	$1,643	--	$117	$1,760

Variable O&M Cost (per yr)	$75,511,835
Total O&M Cost (per yr)	$104,467,413
NPV (per AF)	$2,587

Capital Cost (per AFM)	$285,707
Fixed O&M Cost (per AFM-year)	$8,100

Kaw Lake

Yield 15 mgd

Infrastructure

	Pump Station	Pipeline	Treatment	Total
Capacity (mgd)	15	15	15	
Calc Pipe Diameter (in)	--	29	--	
Req'd Pipe Diameter (in)	--	30	--	
Length (mi)	--	110	--	
Elev (ft)*	1994	--	--	
Power (hP)	39,290	--	--	
Power (kW)	29,310	--	--	
Capital Cost	$159,614,820	$261,360,000	$35,550,000	$456,524,820
Fixed O&M Cost (per yr)	$7,966,268	$1,815,420	$4,051,500	$13,833,188
Variable O&M Cost (per AF)	$1,681	--	$117	$1,798

Variable O&M Cost (per yr)	$30,213,914
Total O&M Cost (per yr)	$44,047,102
NPV (per AF)	$2,862

Capital Cost (per AFM)	$326,089
Fixed O&M Cost (per AFM-year)	$9,881

Navina Lake

Yield 15.5 mgd

Infrastructure

	Dam	Pump Station	Pipeline	Treatment	Total
Capacity (mgd)	--	15.5	15.5	15.5	
Calc Pipe Diameter (in)	--	--	30	--	
Req'd Pipe Diameter (in)	--	--	24	--	
Length (mi)	--	--	24	--	
Elev (ft)*	--	1580	--	--	
Power (hP)	--	32,082	--	--	
Power (kW)	--	23,933	--	--	
Capital Cost	$84,483,210	$130,334,375	$45,619,200	$36,629,196	$297,065,982
Fixed O&M Cost (per yr)	$82,664.20	$7,966,268	$912,384	$4,174,492	$13,135,808
Variable O&M Cost (per AF)	--	$1,332	--	$117	$1,450

Variable O&M Cost (per yr)	$25,092,660
Total O&M Cost (per yr)	$38,228,468
NPV (per AF)	$539

Capital Cost (per AFM)	$205,938
Fixed O&M Cost (per AFM-year)	$9,106

Dam Costs based on *Concluding Report on Seward Project, Dec 1981*

Capital cost of Dam = $60,680,000 1979 prices

O&M cost per yr = $64,000 1980 prices

Assume: cost split between Edmond and Guthrie

OKC Raw Water

Yield

fills the supply gap 38.3 mgd

All Costs obtained from the Regional Raw Water Supply Study for Central Oklahoma - March 2009

Note: these costs were finalized after the last Steering Committee on Feb 5, 2009

Infrastructure

	Total
Capacity (mgd)	
Capital Cost	$267,922,000
Fixed O&M Cost (per yr)	$1,662,293
Variable O&M Cost (per AF)	$154

Variable O&M Cost (per yr)	$6,623,476
Total O&M Cost (per yr)	$8,285,769
NPV (per AF)	$423

Capital Cost (per AFM)	$74,950
Fixed O&M Cost (per AFM-year)	$465

Brackish Groundwater

Schematic | Cost Calcs

Total Yield (MGD)	2.5
Facilities	Pipeline to WTP, Pumps, New wells, land, RO treatment, Brine Disposal
Capital Cost ($)	23,649,499.20
O&M Fixed	472,040.00
O&M Variable	1,843.33

Infrastructure

	Land	Desal-Wells	RO Facility	Interconnect Pipeline	Pump Station	Conveyance Pipeline	Brine Disposal	Total
Capital Cost	$57,499	$3,000,000	$8,250,000	$440,000	$810,000	$4,752,000	$6,340,000	$23,649,499
Fixed O&M Cost (per yr)	--	$60,000	$165,000	$9,000	$16,200	$95,040	$126,800	$472,040
Variable O&M Cost (per AF-yr)	--	$1,287	$533	--	$22	--	--	$1,843

Land Acquisition		
Unit Cost Land	$/acre	4.36E+04
Land Required		
Wells	acres	0.6
RO Plant	acres	0.72
	acres	
TOTAL	acres	1.32
Cost	$	5.75E+04

Back To Main Panel

Interwell Connection Piping					
Flow/well =	gpm	1000	Total Length	ft	1000
Flow/well =	cfs	2.23	Pipe Cost	$/in-ft	10
Velocity	ft/s	5	Pipe Cost (Loade	$/in-ft	20
Pipe Diameter	ft	0.8	**Total Pipe Cost**		**$100,000**
Pipe Diameter	**inches**	**10.0**	Total Pipe Cost (Loaded)		$200,000
			O&M Use		**$4,000**
Flow/well =	gpm	2000	Total Length	ft	1000
Flow/well =	cfs	4.46	Pipe Cost	$/in-ft	10
Velocity	ft/s	5	Pipe Cost (Loade	$/in-ft	20
Pipe Diameter	ft	1.1	**Total Pipe Cost**		**$120,000**
Pipe Diameter	**inches**	**12.8**	Total Pipe Cost (Loaded)		$240,000
Use	**inches**	**12**	**O&M Use**		**$5,000**

Brackish Groundwater

TOTAL Cap	**$440,000**	
Total OM	**$9,000**	

Desal Costs Wells		
Capital-Wells		
Flow	afy	**2,750**
Flow	mgd	2.5
Flow	ft3/yr	119,790,000
Extraction Period	days	180
Flow Over Extraction Period	cfs	8
Flow Over Extraction Period	gpm	3,451
Well Yield	gpm	1,000
Wells Needed =		3.5
Use		4
Unit Cost	/well	$750,000
Total =		**$3,000,000**
O&M =		**$60,000**
Pumping Costs		
TDH	ft	400
Flow per well		863
All Wells	hp	124
KW	KW	93
Over 6 months	kw-hr	403,333
Unit Cost	$/kw-hr	0.11
O&M Pumping Costs		**$ 576,767**

Line from RO Plant to Distribution System		
Pressure Pipe		
Velocity	ft/s	5
Max Amount through Pipe	AFY=	2,750
Amount to be recharged	ft3/yr	119,790,000
Production Period	days	365
Q over recharge period	cfs	3.8
Q over recharge period	gpm	1704.8
Q over recharge period (95% eff)	gpm	1794.5
Pipe Diameter	ft	1.0
Pipe Diameter	inches	11.8
Use	inches	12
Length =	ft	26,400
Use L =	ft	26400
Pipe Cost	$/in-ft	15
Total Pipe Cost	**Dollars**	**$4,752,000**
O&M		**$95,040**

Pumping Costs		
HGL of Distribution System	ft	1123
Elevation of Plant	ft	1013
Plosses	ft	26.4
Pelevation	ft	110

Brackish Groundwater

Ptotal	ft	136.4
Ptotal	psi	59
HP	hp	88
Use HP	hp	200
KW	kw	66
Unit Price	$/hp	4062.5
Capital Pumping Cost		**$ 810,000**
Pumping O&M (capital)		$ 16,200
Pumping O&M (energy)		$ 62,941

RO Facility		
Flow	afy	3734
Flow	mgd	3.3
Flow	ft3/yr	162,653,040
Time	days	365.0
Flow	cfs	5.2
Flow	afy	3734.0
Flow	mgd	3.3
Price	gal/day	$2.5
unit price O&M	/afy	$400.0
Total =		**$8,250,000**
O&M		**$1,493,600**

Brine Disposal		
New Line from RO plant to Aquifer		
Gravity Flow Pipe		
Length =	feet	52800
Use Length =	feet	52800
Flow	afy	700
Flow	mgd	0.6
Flow	ft3/yr	30,492,000
Time	days	365.0
Flow	cfs	1.0
Flow	gpm	433.2
Velocity	ft/s	4
Q	cfs	1.0
Pipe Diameter	ft	0.6
Pipe Diameter	inches	6.7
Use	inches	8
Unit Cost	/in-ft	15
Total Cost		$6,340,000
O&M Cost		$126,800

Variable O&M Cost (per yr)	$5,161,332
Total O&M Cost (per yr)	$5,633,372
NPV (per AF)	$1,576

New Well Field Outside City Limits

Schematic | Cost Calcs

Total Yield(MGD)	2.5
Facilities	Pipeline to WTP, Pumps, New wells, land
Capital Cost ($)	19,311,934.82
O&M Fixed	2,036,465.74
O&M Variable	257.48

Infrastructure

	Land	Wells	Interconnect Pipelin	Pump Station	Pipeline	Treatment	Total
Capacity (mgd)	--			2.5	2.5	2.5	
Calc Pipe Diameter (in)	--			--	12	--	
Req'd Pipe Diameter (in)	--			--	24	--	
Length (mi)	--			--	5	--	
Elev (ft)*	--			49	--	--	
Power (hP)	--			200	--	--	
Power (kW)	--			149	--	--	
Capital Cost	--	$2,850,000	$220,000	$812,935	$9,504,000	$5,925,000	$19,311,935
Fixed O&M Cost (per yr)	$1,768,725	$57,000.00	$4,400	$16,259	$190,080	$2	$2,036,466
Variable O&M Cost (per AF-yr)	--	$205.99	--	$51	--	$0	$257

Land Lease		
Unit Cost Land	$/acre	$2,764
Land Required		
Well field	acres	640
TOTAL	acres	640
Cost	$	1.77E+06

Back To Main Panel

New Well Field Outside City Limits

Interwell Connection Pipeline					
Flow/well =	gpm	1000	Total Length	ft	1000
Flow/well =	cfs	2.23	Pipe Cost	$/in-ft	10
Velocity	ft/s	5	Pipe Cost (Loaded)	$/in-ft	20
Pipe Diameter	ft	0.8	**Total Pipe Cost**		**$100,000**
Pipe Diameter	**inches**	**10.0**	Total Pipe Cost (Loaded)		$200,000
			O&M Use		**$4,000**
Flow/well =	gpm	2000	Total Length	ft	1000
Flow/well =	cfs	4.46	Pipe Cost	$/in-ft	10
Velocity	ft/s	5	Pipe Cost (Loaded)	$/in-ft	20
Pipe Diameter	ft	1.1	**Total Pipe Cost**		**$120,000**
Pipe Diameter	**inches**	**12.8**	Total Pipe Cost (Loaded)		$240,000
Use	**inches**	**12**	**O&M Use**		**$5,000**

Total Interwell Capital		$220,000
Total Interwell O&M		$4,400

Extraction Wells		
Capital		
Flow	afy	**2,750**
Flow	mgd	2.5
Flow	ft3/yr	119,790,000
Extraction Period	days	180
Flow Over Extraction Period	cfs	8
Flow Over Extraction Period	gpm	3,451
Well Yield	gpm	1,000
Wells Needed =		3.5
Use		4
Unit Cost	/well	$713,040
Total =		**$2,850,000**
O&M =		**$57,000**
Pumping Costs		
TDH	ft	400
Flow per well		863
All Wells	hp	124
Use	3 x 20hp	60
KW	KW	93
Over 6 months	kw-hr	403,333
Unit Cost	$/kw-hr	0.11
O&M Pumping Costs		**$ 576,767**

Variable O&M Cost (per yr)	$720,941
Total O&M Cost (per yr)	$2,757,407
NPV (per AF)	$910

Replace Existing Groundwater Wells

Schematic | Cost Calcs

Total Yield	5.2
Facilities	New replaced wells
Capital Cost ($)	2,250,000.00
O&M Fixed	45,000.00
O&M Variable	2,173.59

Infrastructure

		Extraction Wells including Pumping		**Total**
Capital Cost		$2,250,000.00		$2,250,000.00
Fixed O&M Cost (per yr)		$45,000.00		$45,000.00
Variable O&M Cost (per AF-yr)		$2,173.59		$2,173.59

Extraction Wells			Extraction Wells			
Capital			Capital		Capital Cost	Cumalative
Flow	afy	**2,900**	Well development cost	per well	$750,000.00	
Flow	mgd	2.6	No. of wells to be replaced			
Flow	ft3/yr	126,324,000	2010	3	$2,250,000.00	$2,250,000.00
Extraction Period	days	180	2015	1	$750,000.00	$3,000,000.00
Flow Over Extraction Period	cfs	8	2020	2	$1,500,000.00	$4,500,000.00
Flow Over Extraction Period	gpm	3,639	2025	7	$5,250,000.00	$9,750,000.00
Well Yield	gpm	500	2030	16	$12,000,000.00	$21,750,000.00
Wells Needed =		7.3	2035	11	$8,250,000.00	$30,000,000.00
Use		8	2040	3	$2,250,000.00	$32,250,000.00
Unit Cost	/well	$750,000	2045	2	$1,500,000.00	$33,750,000.00
Total =		**$6,000,000**	2050	0	$0.00	$33,750,000.00
O&M =		**$120,000**	2055	5	$3,750,000.00	$37,500,000.00
			2060	1	$750,000.00	$38,250,000.00
Pumping Costs						
TDH	ft	400				
Flow per well		455				
All Wells	hp	2,732				
KW	KW	2,049				
Over 6 months	kw-hr	8,852,423				
Unit Cost	$/kw-hr	0.11				
O&M Pumping Costs		**$ 12,658,965**				

* assume 50% of the wells have been replaced

Variable O&M Cost (per yr)	$12,658,965
Total O&M Cost (per yr)	$12,703,965
NPV (per AF)	$1,270

Sardis Lake Treated Water

Yield fills the supply gap 38.3 mgd

All Costs obtained from the Regional Raw Water Supply Study for Central Oklahoma - March 2009
Note: these costs were finalized after the last Steering Committee on Feb 5, 2009

Infrastructure

	Total
Capital Cost	$267,922,000
Fixed O&M Cost (per yr)	$1,662,293
Variable O&M Cost (per AF)	$154

Variable O&M Cost (per yr)	$6,623,476
Total O&M Cost (per yr)	$8,285,769
NPV (per AF)	$423

Capital Cost (per AFM)	$74,950
Fixed O&M Cost (per AFM-year)	$465

Oklahoma City Treated Water

	Alternative	Yield (mgd)
Yield	Maximize Demand Mangagment A	27.6
	Maximize Demand Mangagment B	17.8
	Maximize Groundwater A	30.6
	Maximize Groundwater B	28.1
	Balanced A	14.8

Existing Infrastructure	12" conn exst contract up to	1.5	mgd	
	NW conn exst contract up to	15	mgd	
	NW Connection capacity =	20.0	mgd	per P. Spitzer (30" pipeline)
	NW Connection length =	23,500	ft	per P. Spitzer
	Storage Tank (for 15 mgd) =	2.0	MG	per PDR

Note: assume OKC would be responsible for pumping infrastructure from OKC to Edmond
(cost would be included in TW rate)

Infrastructure (Maximize Demand Management A Alternative)

	Storage Tank	Pipeline	TW rate	Total
Capacity (mgd)	--	22.6	--	--
No. of 2 MG tanks	2		--	--
Calc Pipe Diameter (in)	--	36	--	--
Req'd Pipe Diameter (in)	--	36	--	--
Length (mi)	--	4.5	--	--
Capital Cost	$2,740,385	$12,690,000	--	$15,430,385
Fixed O&M Cost (per yr)	--	$253,800	--	$253,800
Variable O&M Cost (per AF)	--	--	$1,424	$1,424

Variable O&M Cost (per yr)	$36,041,044
Total O&M Cost (per yr)	$36,294,844
NPV (per AF)	$853

Infrastructure (Maximize Demand Management A Alternative)

	Storage Tank	Pipeline	TW rate	Total
Capacity (mgd)	--	12.8	--	--
No. of 2 MG tanks	1		--	--
Calc Pipe Diameter (in)	--	27	--	--
Req'd Pipe Diameter (in)	--	30	--	--
Length (mi)	--	4.5	--	--
Capital Cost	$1,370,193	$10,575,000	--	$11,945,193
Fixed O&M Cost (per yr)	--	$211,500	--	$211,500
Variable O&M Cost (per AF)	--	--	$1,424	$1,424

Variable O&M Cost (per yr)	$20,412,627
Total O&M Cost (per yr)	$20,624,127
NPV (per AF)	$867

Infrastructure (Maximize Groundwater A Alternative)

	Storage Tank	Pipeline	TW rate	Total
Capacity (mgd)	--	25.6	--	--
No. of 2 MG tanks	2		--	--
Calc Pipe Diameter (in)	--	38	--	--
Req'd Pipe Diameter (in)	--	42	--	--
Length (mi)	--	4.5	--	--
Capital Cost	$2,740,385	$14,805,000	--	$17,545,385
Fixed O&M Cost (per yr)	--	$296,100	--	$296,100
Variable O&M Cost (per AF)	--	--	$1,424	$1,424

Variable O&M Cost (per yr)	$40,825,254
Total O&M Cost (per yr)	$41,121,354
NPV (per AF)	$853

Infrastructure (Maximize Groundwater B Alternative)

	Storage Tank	Pipeline	TW rate	Total
Capacity (mgd)	--	23.1	--	--
No. of 2 MG tanks	2		--	--
Calc Pipe Diameter (in)	--	36	--	--
Req'd Pipe Diameter (in)	--	36	--	--
Length (mi)	--	4.5	--	--
Capital Cost	$2,740,385	$12,690,000	--	$15,430,385
Fixed O&M Cost (per yr)	--	$253,800	--	$253,800
Variable O&M Cost (per AF)	--	--	$1,424	$1,424

Variable O&M Cost (per yr)	$36,838,413
Total O&M Cost (per yr)	$37,092,213
NPV (per AF)	$852

Oklahoma City Treated Water
Infrastructure (Balanced A Alternative)

	Storage Tank	Pipeline	TW rate	Total
Capacity (mgd)	--	9.8	--	--
No. of 2 MG tanks	1		--	--
Calc Pipe Diameter (in)	--	24	--	--
Req'd Pipe Diameter (in)	--	24	--	--
Length (mi)	--	4.5	--	--
Capital Cost	$1,370,193	$8,460,000	--	$9,830,193
Fixed O&M Cost (per yr)	--	$169,200	--	$169,200
Variable O&M Cost (per AF)	--	--	$1,424	$1,424

Variable O&M Cost (per yr)	$15,628,417
Total O&M Cost (per yr)	$15,797,617
NPV (per AF)	$870

Infrastructure Sizing

Capacity (mgd)	Capacity (AFM)	Pipeline Size (inches)	No. of 2 MG tanks
0	0	0	0
1.1	105	8	1
2.5	237	12	1
5.7	533	18	1
10.2	948	24	1
15.9	1481	30	2
22.8	2132	36	2
31.1	2902	42	3
40.6	3791	48	3
51.4	4798	54	4
63.5	5923	60	5

Existing Groundwater Wells

TDH = 400 ft
173 psi

Sim Yr	Flow AFY	Flow MGY	Fixed O&M Cost per yr	hp	kw	Variable O&M Cost per AF	*Variable O&M Cost per yr*	*Total O&M Cost per yr*	*NPV per AFY*
2010	6006	1957	$1,076,351	528	394	$2.63	$15,816	$1,092,168	$104
2015	5887	1918	$1,055,049	518	386	$2.63	$15,503	$1,070,552	$104
2020	5641	1838	$1,010,941	496	370	$2.63	$14,855	$1,025,796	$104
2025	4932	1607	$883,893	434	323	$2.63	$12,988	$896,882	$104
2030	2916	950	$522,637	256	191	$2.63	$7,680	$530,317	$104
2035	1520	495	$272,310	134	100	$2.63	$4,001	$276,311	$104
2040	1273	415	$228,063	112	83	$2.63	$3,351	$231,414	$104
2045	812	265	$145,541	71	53	$2.63	$2,139	$147,679	$104
2050	812	265	$145,541	71	53	$2.63	$2,139	$147,679	$104
2055	339	111	$60,832	30	22	$2.63	$894	$61,726	$104
2060	0	0	$0	0	0	$0	$0	$0	$0

Sim Yr	Flow AFY	Flow MGY	Fixed O&M Cost per yr	hp	kw	Variable O&M Cost per AF	*Variable O&M Cost per yr*	*Total O&M Cost per yr*	*NPV per AFY*
2008	6054	1972	1084872	532	397	3	15941	1100814	104
2009	6030	1965	1080612	530	395	3	15879	1096491	104
2010	6006	1957	1076351	528	394	3	15816	1092168	104
2011	5982	1949	1072091	526	392	3	15753	1087844	104
2012	5959	1942	1067831	524	391	3	15691	1083521	104
2013	5935	1934	1063570	522	389	3	15628	1079198	104
2014	5911	1926	1059310	520	388	3	15566	1074875	104
2015	5887	1918	1055049	518	386	3	15503	1070552	104
2016	5838	1902	1046228	513	383	3	15373	1061601	104
2017	5789	1886	1037406	509	380	3	15244	1052650	104
2018	5740	1870	1028585	505	376	3	15114	1043699	104
2019	5690	1854	1019763	500	373	3	14985	1034747	104
2020	5641	1838	1010941	496	370	3	14855	1025796	104
2021	5499	1792	985532	483	361	3	14482	1000013	104
2022	5358	1746	960122	471	351	3	14108	974230	104
2023	5216	1699	934713	459	342	3	13735	948447	104
2024	5074	1653	909303	446	333	3	13361	922664	104
2025	4932	1607	883893	434	323	3	12988	896882	104
2026	4529	1476	811642	398	297	3	11926	823569	104
2027	4126	1344	739391	363	271	3	10865	750256	104
2028	3723	1213	667140	327	244	3	9803	676943	104
2029	3320	1082	594888	292	218	3	8741	603630	104
2030	2916	950	522637	256	191	3	7680	530317	104
2031	2637	859	472571	232	173	3	6944	479516	104
2032	2358	768	422506	207	155	3	6208	428714	104
2033	2078	677	372441	183	136	3	5473	377913	104
2034	1799	586	322375	158	118	3	4737	327112	104
2035	1520	495	272310	134	100	3	4001	276311	104
2036	1470	479	263461	129	96	3	3871	267332	104
2037	1421	463	254611	125	93	3	3741	258352	104
2038	1371	447	245762	121	90	3	3611	249373	104
2039	1322	431	236912	116	87	3	3481	240394	104
2040	1273	415	228063	112	83	3	3351	231414	104
2041	1181	385	211558	104	77	3	3109	214667	104
2042	1088	355	195054	96	71	3	2866	197920	104
2043	996	325	178549	88	65	3	2624	181173	104
2044	904	295	162045	79	59	3	2381	164426	104
2045	812	265	145541	71	53	3	2139	147679	104
2046	812	265	145541	71	53	3	2139	147679	104
2047	812	265	145541	71	53	3	2139	147679	104
2048	812	265	145541	71	53	3	2139	147679	104
2049	812	265	145541	71	53	3	2139	147679	104
2050	812	265	145541	71	53	3	2139	147679	104
2051	718	234	128599	63	47	3	1890	130488	104
2052	623	203	111657	55	41	3	1641	113298	104
2053	529	172	94715	46	35	3	1392	96107	104
2054	434	141	77774	38	28	3	1143	78916	104
2055	339	111	60832	30	22	3	894	61726	104
2056	272	88	48665	24	18	2	715	49381	83
2057	204	66	36499	18	13	2	536	37035	63
2058	136	44	24333	12	9	1	358	24690	42
2059	68	22	12166	6	4	1	179	12345	21
2060	0	0	0	0	0	0	0	0	0

Exsting Capacity of TW from OKC

Exst TW Capacity = 16.5 mgd

Fixed O&M Cost (per yr)	$0
Variable O&M Cost (per AF)	$1,424

Variable O&M Cost (per yr)	$26,313,152
Total O&M Cost (per yr)	$26,313,152
NPV (per AF)	$817

Design Criteria

Pumping Head Required = Grade Elev + friction losses + minor losses

Friction losses:

$$h_f = 4.66 * n^2 * \frac{Q^2}{D^{16/3}} * L$$

Assume: n = 0.013

Minor losses: 15% of friction losses

Pumping Power (hP) = Q (gpm) * Pressure (psi) / 1714 / (75% pump efficiency) / (95% motor efficiency)
= mass flow rate (lbm/sec) * head (ft) * gravity (ft/s^2) /550 (ft-lb/sec) * efficiency

"Fill the gap" capacity = 38.3 mgd (assumes use of 10.5 mgd Arcadia WTP and 16.5 OKC T

Pipe Size: based on velocity = 5 fps

20-City ENR CCI

1979	3003
1980	3237
1981	3535
1992	4985
1999	6059
2000	6221
2003	6694
Aug-08	8362

Aug-08 LA CCI = 9342.44
Aug-08 Dallas CCI = 5124.26

Conventional Water Treatment Plant Costs

Source: Bill O'Neil developed for RCWD IRP (2005)

CAPITAL COST EQUATION [a]

Conventional WTP:	Capital Cost = (1.811 * Q^0.86) *(ENR/4985) + 25% Contingency	
	Q = mgd	
ENR CCI (Aug '08)=	8362	
	3.038 * Q^0.86	
Q =	59.3	cfs
	38.3	mgd
Capital Cost (LAENR 2005)=	$69.8	million (w/out 25% contingency but w/ 20% Eng, Legal & Admin)

a. Equation derived from 1992 AWWA Committee data. Memo regarding this was prepared for Tijuana Master Plan (see Salvador)

Unit cost =	$1.8	per gal per day of conventional treatment
	$2.4	per gal per day of conventional treatment

O&M COST EQUATION [b]

Conventional WTP:	O&M Cost ($ million/yr) = (68.1*Q*365)/1000000+0.68	
	Q = mgd	
	(24856.5 *Q)/1000000 + 0.68	
Q =	38.3	mgd
O&M Cost (1999) =	$1.63	million/yr
Inflation		
O&M Cost (2008) =	$2.0	million/yr

b. Equation derived from City of San Diego North City WTP Study (1999)
Non-Labor O&M = Q (in mgd) * $68/mgd
Labor O&M = $0.68 million if <100 mgd (11 staff) or
= $0.805 million if >100 mgd (13 staff)
Energy costs based on $0.061/kw-hr
Inflation rate of 2.5%

Unit cost =	$0.15	per 1000 gal of conventional treatment

Unit Costs

Component	Capital		Maintenance (fixed)		Operations (variable)		Notes
Pipeline	$ 15.00	per inch diameter, per foot of pipe	2%	of capital		n/a	Source: COE
Pumping for Pipeline	$ 4,062.50	per hp capacity	2%	of capital	$ 0.11	per kW-hr	Variable O&M assumes pumping 24 hrs/day, 365 days/yr. Capital cost source: CWA Brine Study.
OKC raw water		n/a		n/a	$ 4.37	per kgal	
OKC treated water		n/a		n/a	$ 4.37	per kgal	The current purchase cost for OKC water is $4.06/kgal. That cost will increase to $4.21/kgal in October 08 and again to $4.37/kgal in October 09. Cost provided by Fred Rice. Need to discuss assumed rate of increase and possible reduction in price if water is "bought in bulk"
Surface water treatment (conventional treatment)	$ 2,370,000	per mgd	$ 0.74	per kgal	$ 0.36	per kgal	Operation cost of $1100/MG was provided by Fred Rice; $0.36/kgal was provided by Diane Kemp from Central OK study for variable (energy and chem). See "Conv WTP" worksheet for capital cost.
Land acquisition	$1	per sq foot		n/a	n/a		Use $1/sq foot Source Steve Lawrence
Well Development (extraction)	$ 713,040	per well	$ 550.00	per MG	$ 0.11	per kW-hr	Maint costs provided by Fred Rice; this includes treatment, pumping, etc. Capital based on recent SoCal projects adjusted for TX ENR CCI. Variable O&M assumes pumping 24 hrs/day, 365 days/yr.
Chlorine cost for pumping					$0.34	per pound	Source: Kickingbird Golf Course Study, 2002- esclated to 2008 value
Chlorination Improvements at WW Plant	$ 50,000	1.6 MGD					Source: Kickingbird Golf Course Study, 2002
I&C Improvements at WW Plant	$ 50,000	1.6 MGD					Source: Kickingbird Golf Course Study, 2002
Advanced Membrane treatment	$2.50	per mgd			$ 400.00	afy	Source:Greg
Injection well	$ 3,750,000.00	per well	2%	of capital	$ 0.11	per kW-hr	Source:Lisa Preito (7500000 per well- 50% reduction)
Ground storage tank	$ 1,370,193	per 2 MG tank		n/a		n/a	Source: City of Edmond, OK Water Transmission and Distribtuion System Improvments PDR, Dec 2003. (Raw Capital = $675K for 2 MG tank)

Contingency	30%		
Legal, Eng, Admin	25%		
Imported Water Inflation Rate	3%		
Inflation Rate	3%		
Interest Rate	6%		
NPV based on	20	yrs	For all options except Navina Lake
NPV based on	100	yrs	For Navina Lake option

Attachment D
Qualitative Performance Measure Scores

City Of Edmond 50-Year Water Supply Plan

Alternatives Score Card

Objective/Sub-objective	Performance Measure	No Action	Max Demand Mgt A	Max Demand Mgt B	Max Groundwater A	Max Groundwater B	Max Surface Water A	Max Surface Water B	Max Surface Water C	Max Local Surface Water	Maximize Assets A	Maximize Assets B	Maximize Assets C	Balanced A	Balanced B	Balanced C
1 a) Provide sufficient yield to meet demands-Avg. Year	Average Annual Deficit (AFY)	5,711	0	0	0	0	0	0	0	354	0	0	0	0	0	0
	Max Day Deficit (MGD)	38	0	0	0	0	0	0	0	1	0	0	1	0	0	0
1b) Provide sufficient yield to meet demands-Droughts	Dry year Deficit (AFY)	6,934	0	0	0	0	0	0	0	4,037	0	0	0	0	0	0
1c) Maximize Security	Security Score	3	3	3	3	3	2	2	2	2	3	3	3	3	2	3
1d) Certainity of long term sustainability	Sustainability Score	5	4	4	4	4	4	4	4	5	5	5	5	4	4	4
2a) Maximize flexibility through diversity of sources	Percentage contribution of largest source	59	34	34	40	35	66	66	66	96	62	62	42	34	46	31
	Number of sources	2	5	6	4	5	2	2	2	2	4	3	4	6	4	6
2b) Maximize Operational Flexibility	Number of "Take Points"	2	4	4	4	4	1	1	1	2	2	2	3	5	2	5
3a) Minimize leve of treatment	Water Quality Score (TDS and As)	5	5	5	5	5	5	3	5	5	4	5	4	5	5	5
3b) Maximize compatibility of WQ with existing quality	Compatibility Score	4	4	3	3	3	5	4	5	5	4	5	5	4	4	4
4a) Minimize Capital costs	Total Capital Costs ($M)	0	3	7	5	6	23	91	23	9	11	8	8	22	44	4
4b) Minimize O&M costs	Total O&M Costs ($M)	25	22	25	39	38	8	67	8	17	28	24	29	45	42	28
5a) Minimize construction and operational impacts	Construction and Operational Impact Score	5	5	5	5	5	3	3	4	5	5	5	5	4	3	5
5a) Minimize Environmental Impacts	Environmental Impacts Score	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4
6a) Political and Inst. Acceptability	Political and Inst. Acceptability Score	5	5	4	5	5	4	4	4	5	4	5	5	4	4	5
6b) Regulatory hurdles and ease of permitting	Regulatory Score	5	5	4	5	5	3	3	3	4	4	5	4	4	3	5
6c) Technical Likelihood of supply development	Technical Implementation Score	5	5	4	5	5	4	4	4	5	4	5	4	5	4	5
6d) Public Support or Opposition	Public Support or Opposition Score	5	5	4	5	5	4	4	4	4	4	4	5	5	4	5
Additional Cost Info	Fixed O&M ($M)	3	3	4	4	6	4	32	4	13	11	10	9	16	22	3
	Variable O&M ($M)	1	9	12	19	20	5	39	5	4	18	15	22	32	7	22
	Imported O&M ($M)	23	11	11	19	15	0	0	0	2	0	0	0	0	16	4

Note: As a reference, the value of $/AF paid by City of Edmond for Oklahoma City Water is approximately $1,420/AF

Attachment E
Demand Model Memorandum

CDM

Memorandum

To: *Brian Mitchell*

From: *Bill Davis*

Date: *April 23, 2008 (analysis completed March 19, 2008)*

Subject: *City of Edmond Water Production Forecast Model*

This memorandum describes the development of the water production (i.e., demand) forecast model for the City of Edmond, Oklahoma (City). This memo discusses the data collected and used to estimate the demand model, the statistical analysis of the data and the resulting water demand model, and the water demand forecast results produced by the model.

Data and Sources

Water production data were obtained from the City. The data was provided as production, water plant/Arcadia Lake production, and water purchased from Oklahoma City in million gallons (MG) per month from January 1988 through December 2007. Water production from the different sources was added into a single total production value for each month. Thus, historical total monthly water production in MG per month was available for 240 months. Some anomalies were observed in the data, particularly in the mid-1990s when the City changed billing/accounting systems.

The monthly water production values were divided by the number of days in each month to derive the daily water production in million gallons per day (MGD) for each month from January 1988 through December 2007. These historical monthly production values are illustrated in Figure 1. Among the 240 months in the data, the average monthly production is 9.2 MGD. The lowest water demand occurred in December 1988 at 4.3 MGD and the highest water demand occurred in July 2001 at 21.0 MGD.

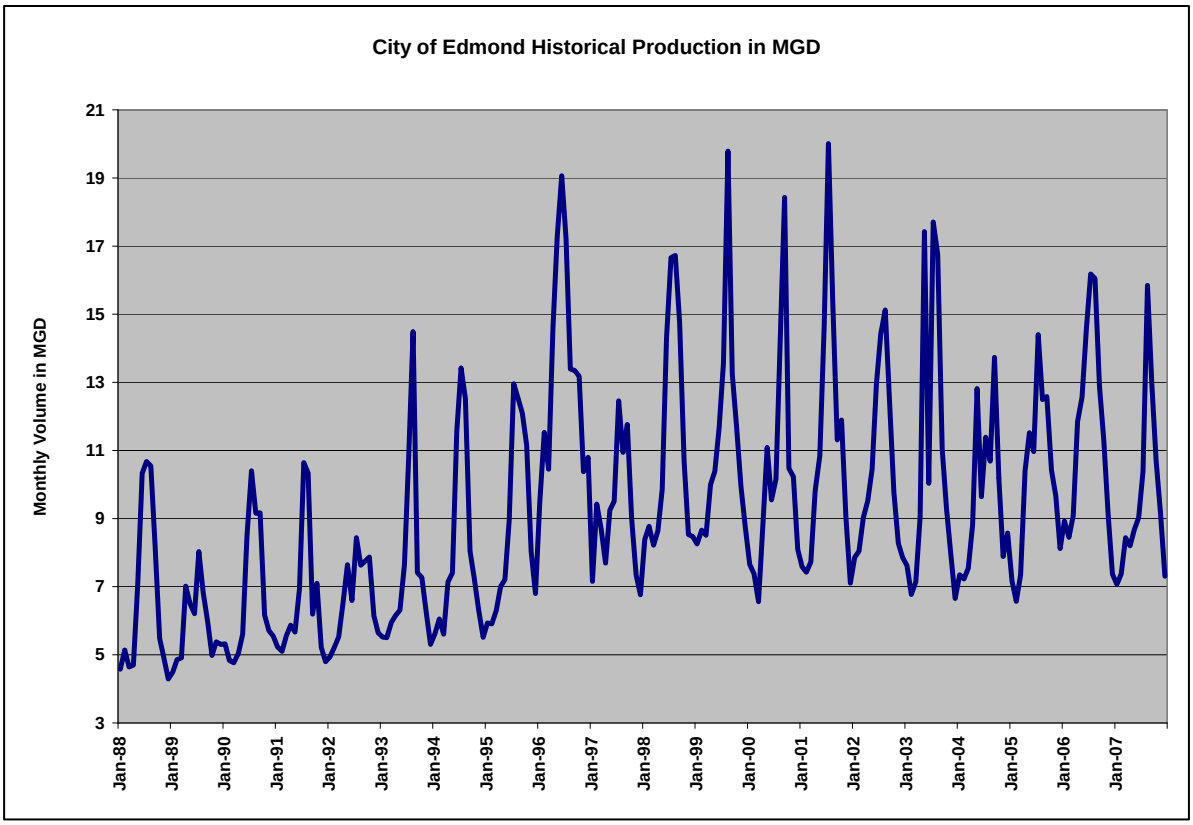

Figure 1

Weather data were collected for the corresponding months (January 1988 – December 2007). The Edmond weather station did not have complete data for this time period, thus weather data were collected from the Guthrie weather station which is located approximately 30 miles south of Edmond. Monthly weather data included the total monthly precipitation in inches per month and the monthly mean maximum daily temperature in degrees Fahrenheit.

In addition to monthly weather data collected for the water production years, historical data were obtained from the Guthrie weather station to determine the long-term average (or *normal*) monthly weather conditions. The 1948 – 2007 monthly normal precipitation and maximum daily temperature are shown in Table 1 and Figure 2.

Table 1
Guthrie Station 1948 - 2007 Monthly Weather Averages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Maximum Temperature	48.9	54.4	63.1	74.0	81.2	88.9	94.9	94.8	86.3	75.6	61.8	51.7	73.0
Total Monthly Precipitation	1.24	1.51	2.60	2.77	5.12	4.47	2.78	2.72	3.82	3.05	2.18	1.55	33.81

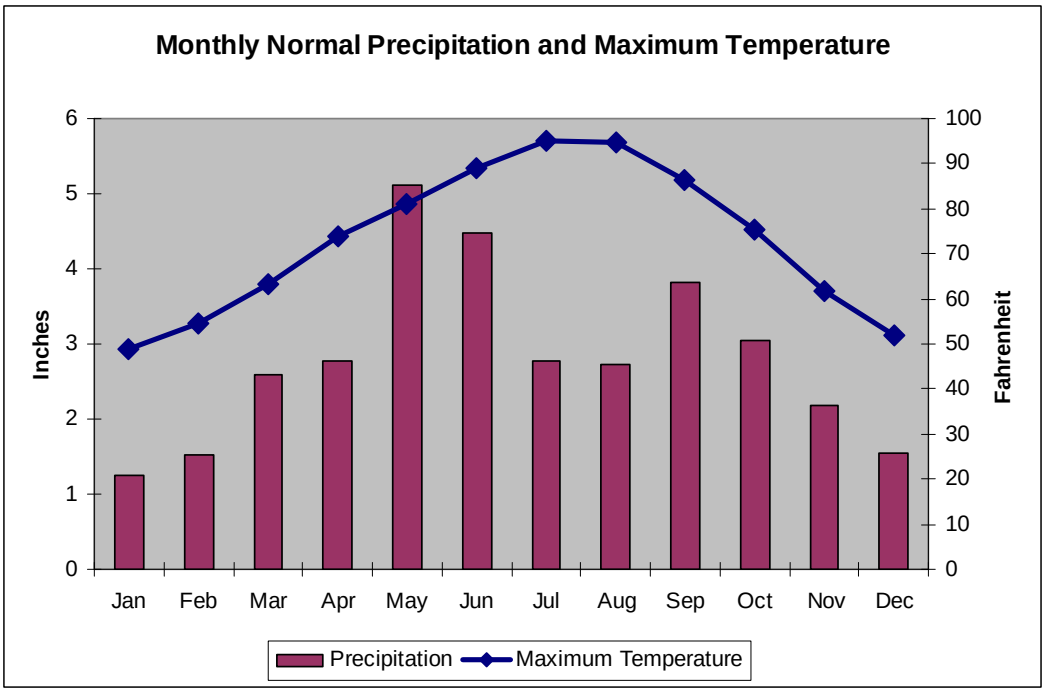

Figure 2

Population data were obtained from the City and used in development of the water production forecast model. As shown in Table 2, the population data included historical and projected city population, percent of population with water service, and service population. Population served for in between years was interpolated from the data. The interpolated estimates of population served from 1988 to 2007 were aligned with the monthly water production and weather data.

Table 2 City of Edmond Historical and Projected Population			
Year	Total City Population	Percent of Population Served	Service Population
1910	2,090	79.8%	1,667
1920	2,452	80.3%	1,968
1930	3,570	80.8%	2,883
1940	4,002	81.3%	3,252
1950	6,086	81.8%	4,975
1960	8,577	82.3%	7,055
1970	16,633	82.8%	13,764
1980	34,673	83.3%	28,865
1990	52,315	83.8%	43,814
2000	68,315	84.3%	57,555
2010	81,180	84.8%	68,800
2020	96,180	85.3%	81,993
2030	111,180	85.8%	95,337
2040	126,180	86.3%	108,830
2050	141,180	86.8%	122,474
2060	156,180	87.3%	136,267

Additional data collected from the City included the number of water-user accounts. The number of accounts from 1990 to 1996 was provided as annual number of accounts. Data from October 1996 through December 2007 were provided as monthly totals.

Thus, the database used to estimate water use demand relationships for the City included monthly water production in MGD, monthly precipitation, monthly maximum daily temperature, concurrent population served, and the number of water-user accounts.

Model Analysis

Overview of Regression Analysis

Regression analysis is used to analyze the variation in a dependent variable (y) in relation to the variation in independent variables (x_1, x_2, x_n). An underlying relationship is assumed to exist between the dependent and independent variables. In the City water production analysis, regression analysis was applied to the monthly data to determine relationships between monthly water production (i.e., the dependent variable) and precipitation, maximum temperature, population served and number of accounts (i.e., the independent, or explanatory variables). It is assumed that each of the independent variables has an impact on monthly water production.

Regression analysis determines the function that provides the 'best fit' to the data. The best fit function minimizes the differences between observed values of the dependent variable and estimated values of the dependent variable as estimated by the regression function. The regression function can be expressed as:

$$E(y) = a + b_1x_1 + b_2x_2 + b_nx_n \qquad \text{Equation 1}$$

where:

E(y) = the expected value of dependent variable (y) as estimated by the function
a = intercept, or the value of (y) when x = 0
b = coefficient of x, or the change in y given a change in x
x = value of the independent variable

There are four assumptions that must be accepted regarding the data used to develop the regression function. These are:

1. The mean (or average) value of the dependent variable (y) is estimated by the regression function. That is: the mean of (y) = E(y).
2. The values of the dependent variable (y) have a normal distribution.
3. The variance of (y) is the same for any choice of independent variable values.
4. The observed values of (y) are from a random sample, have a normal distribution, and each value is independent of other dependent values.

Note that if the underlying function is nonlinear, the Equation 1 can be written as:

$$E(y) = a \cdot x_1^{b1} \cdot x_2^{b2} \cdot x_n^{bn} \qquad \text{Equation 2}$$

or

$$LogE(y) = \log(a) + b_1 \cdot \log(x_1) + b_2 \cdot \log(x_2) + b_2 \cdot \log(x_2) \qquad \text{Equation 3}$$

When the regression function is expressed as Equation 3, the same regression analysis can be used to estimate the regression coefficients as if the function were expressed as in Equation 1. In the log form, the coefficients (*b*) are interpreted as "elasticities" that indicate the percent change in (y) given a percent change in (x).

Regression Analysis Statistics

A number of statistics are generated to evaluate the acceptability, or "goodness of fit" for each function. A review of these statistics allows one to select the best function, or model. The regression analysis statistics include the following:

R^2, or R-squared	R^2 is the coefficient of determination, and is a measure of the variation in (y) explained by the function, or how well the function "fits" the data. An R^2 near 1.00 is better.
Adjusted R^2	The adjusted R-square is used if there are more than one independent variables in the function.
Multiple R	R is the square root of R^2 and indicates the correlation between the observed values of (y) and the estimated values E(y).
Standard Error	The Standard Error of the Regression is the estimated standard deviation of the function error term. A smaller value is better.
Observations	The total number of observation in the data set.

Regression analysis includes an analysis of variance, or ANOVA, to test the relationship between the independent and dependent variables. The ANOVA statistics include "Regression" statistics for the variance that is "explained" by the regression function and statistics for the "Residual" which is the difference between the observed and estimated values of (y). The Residual statistics are sometimes called the "Error" statistics. The ANOVA statistics include the following:

df	Degrees of Freedom (df) is a parameter used to determine the probability of distribution. The Total df is the number of observations minus one (n-1). The Regression df is the number of variables in the function. The Residual df is the Total df minus the Regression df.
SS, Sum of Squares	The Sum of Squares (SS) measures the variability in (y) as explained by the function, or how well the function minimizes the differences between observed values of the dependent variable and estimated values of the dependent variable. The Regression SS should be larger than the Residual SS. Note that the Regression SS divided by the Total SS is equal to the R^2 statistic described above. Thus, the Regression SS measures the portion of the Total SS that is explained by the function. Therefore, the closer the Regression SS comes to equaling the Total SS, the better the function.

MS, Mean Square	The Mean Sum of Squares is the Sum of Squares divided by the degrees of freedom, and is calculated for both the Regression and the Residual. Note that the Regression MS divided by the Residual MS follows an F distribution.
F	The F statistic is a measure of the strength of the relationship between the dependent and independent variables in the function. The F statistic indicates the significance of the function and is calculated as the Regression MS divided by the Residual MS. A larger F statistic is better.
Significance F	This is the probability that the F-statistic is significant. The F-statistic is acceptable with 95 percent confidence when the significance value is 0.05 or less.

The regression statistics also include statistics for each independent variable included in the function. Statistics are included for the intercept as well. Note that the "intercept" value would be the estimated value of (y) if all the independent variables had a value of zero. In a function with more than one independent variable, the intercept value is actually the slope of a plane in a three-dimensional space rather than the intercept value of a line in a two-dimensional space. The standard error and t-statistic for the intercept coefficient have little meaning.

For each independent variable, the regression analysis estimates the following statistics:

Parameter	The parameter, or coefficient, represents the change in the dependent variable (y) corresponding to a change in the independent variable (x). For example, a parameter value of 0.30 indicates that a 10 percent increase in (x) results in a 30 percent increase in (y). The parameter may be positive or negative. A negative parameter indicates that as the value of the independent variable increases, the value of the dependent variable decreases. Note that if the direction of a variable parameter changes with the addition, or subtraction, of other variables to the function, this may indicate a conflict between variables or an unstable function.
SE, Standard Error	The Standard Error of the parameter is used to test the significance of the individual parameter. The SE is also called the standard deviation. A smaller SE is better. A general level of acceptance is an SE less than 0.05.
t-Statistic	The t-statistic is calculated as the parameter divided by the standard error. A larger t-statistic is better. Generally, the t-statistic should be at least 2.00.

P value	The P-value is the probability that the t-statistic is significant. The t-statistic is acceptable with 95 percent confidence when the significance value is 0.05 or less.

Regression Statistics for Edmond Water Production Analysis

Data used in the analysis of weather and production for the City includes the following:

- Natural log of monthly water production from 1988 – 2007 (a total of 240 months, or data points).
- Natural log of monthly mean maximum daily temperature observed at Guthrie station during these months.
- Natural log of monthly total precipitation observed at Guthrie station during these months.
- Natural log of annual population served assigned to each month.
- Natural log of annual/monthly number of connections assigned to each month.
- Binary variables representing anomalies.

In addition to the previously described data, binary variables were created to represent months with unusual characteristics that were suspected of influencing the monthly water production. Binary variables have a value of either zero or one. A value of one indicates that the particular characteristic applies in that month while a value of zero indicates that the characteristic does not apply in that month.

One binary variable was created to indicate the presence of data anomalies in the years 1996, 1998, 1999 and 2001. These anomalies flagged years in which water use restrictions were known to be in effect, as well as when the transition in billing/accounting data occurred.

Other binary variables were created to represent drier than average summer conditions, drier than average spring conditions, and hotter than average summer conditions. Each of these binaries was expected to be correlated with higher monthly water production.

The data set was evaluated using standard regression analysis with SAS (Statistical Analysis Software) version 9.1. Table 3 shows the results of the statistical analysis of the Edmond production dataset. It should be noted that numerous combinations of variables were evaluated in the analysis including different combinations of weather, trend (i.e., population and number of accounts) and binary variables. The regression function shown in Table 3 was deemed the most robust function that contained the requisite explanatory variables: maximum temperature, precipitation, and a trend indicator (i.e., population).

Table 3
Regression Statistics for City of Edmond Production Function

Dependent Variable: Natural Log of Monthly MGD

Number of Observations Read	240
Number of Observations Used	240

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	22.12846	5.53212	192.26	<.0001
Error	235	6.76182	0.02877		
Corrected Total	239	28.89028			

Root MSE	0.16963
Dependent Mean	2.16311
Coeff Var	7.84185
R-Square	0.7659
Adj R-Sq	0.7620

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T-Stastic t Value	P-Value Pr > |t|
Intercept	1	-15.74657	0.87955	-17.90	<.0001
LnMaxTemp	1	0.93264	0.05133	18.17	<.0001
LnPrecip+1	1	-0.10438	0.01892	-5.52	<.0001
LnPopulation	1	1.29042	0.07727	16.70	<.0001
Restrictions (0/1)	1	0.29420	0.04610	6.38	<.0001

Interpretation of Results

The F statistic of 192.26 with a significance probability of less than 0.001 indicates a strong relationship between the dependent and independent variables in the function. The adjusted R-square indicates that about 76 percent of the variance in monthly water production can be explained by the variation in maximum daily temperature, precipitation, population, and restrictions.

The t-statistics and related probability of significance of the t-values for the independent variables indicate that parameter estimates (i.e., elasticities) for all the variables are well within acceptable limits.

The parameter estimate (elasticity) of 0.93 for maximum temperature indicates that a 10 percent increase in monthly average daily temperature results in a 9.3 percent increase in monthly water production. However, a ten percent increase in monthly average maximum daily temperature is extreme and would suggest an average maximum daily temperature in May of 89.3°F rather than 81.2°F, or an average maximum daily temperature in July of 104.4°F rather than 94.8°F.

The parameter estimate (elasticity) of -0.10 for precipitation indicates that a 10 percent increase in monthly total precipitation results in a one percent <u>decrease</u> in monthly water production. This elasticity is not strong.

The parameter estimate (elasticity) of 1.29 for population indicates that a 10 percent increase in city population results in 12.9 percent increase in monthly water production. The importance of this trend variable is that it accounts for general trends in the data so that the relationship between weather and production can be more clearly identified.

The parameter estimate of 0.29 for the binary variable "restrictions" indicates that the data anomalies associated with this binary variable are associated with significant increases in water demand. This binary variable indicates the presence of data anomalies in the years 1996, 1998, 1999 and 2001. These anomalies flagged years in which water use restrictions were known to be in effect, as well as when the transition in billing/accounting data occurred.

Assessment of Regression Results and Model Functionality

The water production forecasting model described above was used to estimate historical annual demand in order to analyze model accuracy. The percent error in annual production was then calculated and is shown in Figure 3. Average annual error for the historical forecast was -2.5 percent with a standard deviation of 11.35 percent, as shown in Figure 4. The standard deviation was utilized to develop a high and low range estimate of future annual demand.

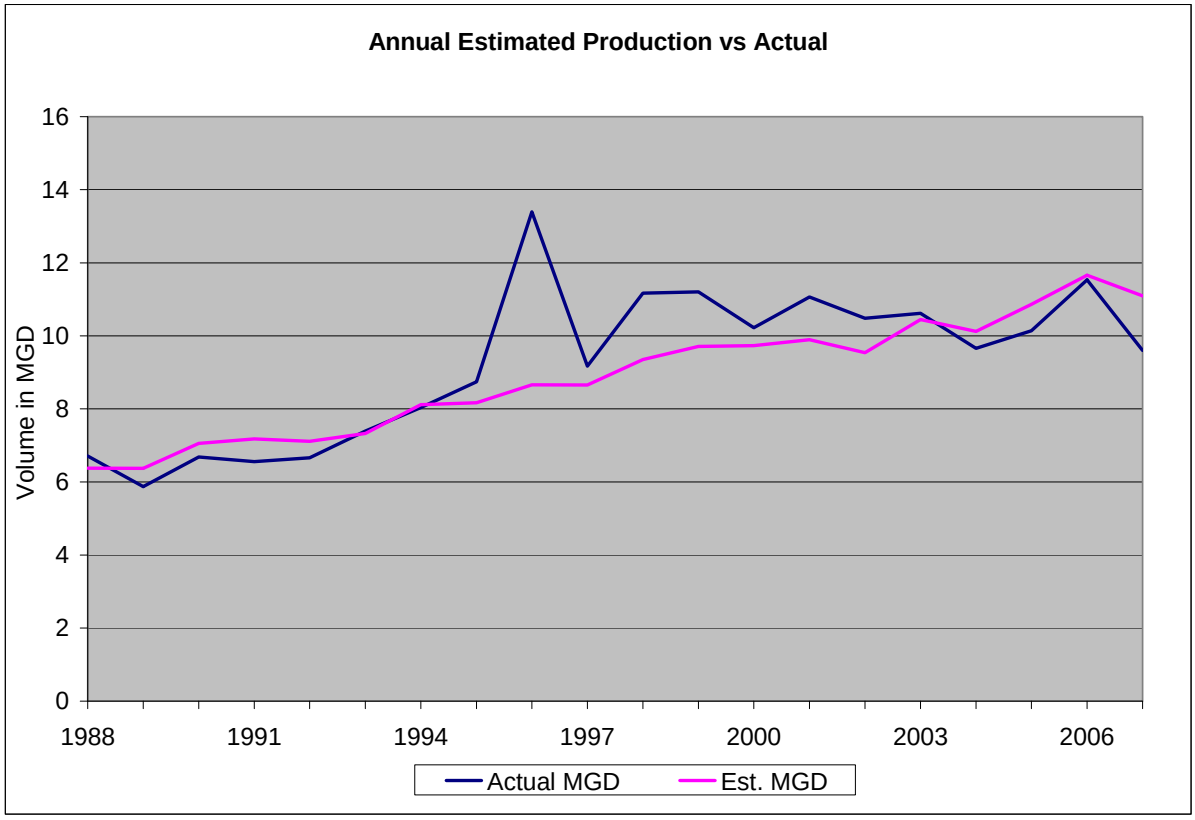
Annual Estimated Production vs Actual
Volume in MGD
16
14
12
10
8
6
4
2
0
1988
1991
1994
1997
2000
2003
2006
Actual MGD
Est. MGD

Figure 3

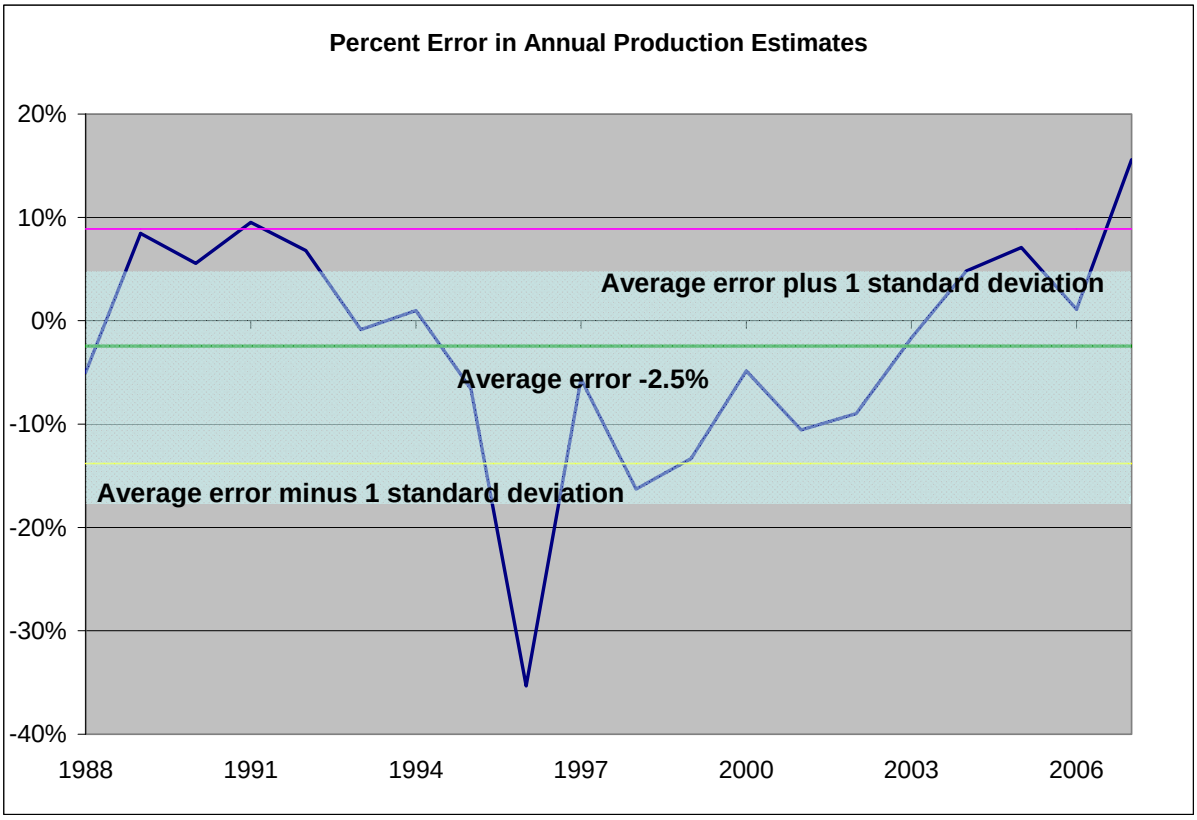

Figure 4

Demand Forecast

The model parameter estimates developed through regression analysis were combined with estimates of future values for model variables (i.e., total monthly precipitation, average maximum daily temperature, and population) in an Excel spreadsheet model to produce future estimates of monthly water demand. The historical average precipitation and maximum temperature for each month are assumed as inputs for estimating future monthly water demand. The binary variable that controls for data anomalies has a value of zero in the future.

The twelve monthly water demand estimates are averaged to provide an annual water demand estimate for each future year. The standard deviation of error (±11.35 percent) was applied to each estimated demand value to develop high and low ranges of possible demand values. Results of the demand forecast on an annual basis are shown in Table 4 and Figure 5.

Table 4 City of Edmond Water Demand Estimate with High and Low Range (MGD)			
Year	**Estimated Demand**	**Low Range (Estimate -1 standard deviation)**	**High Range (Estimate +1 standard deviation)**
2010	12.0	10.7	13.4
2020	15.1	13.4	16.8
2030	18.3	16.3	20.4
2040	21.7	19.3	24.2
2050	25.3	22.5	28.2
2060	29.1	25.8	32.3

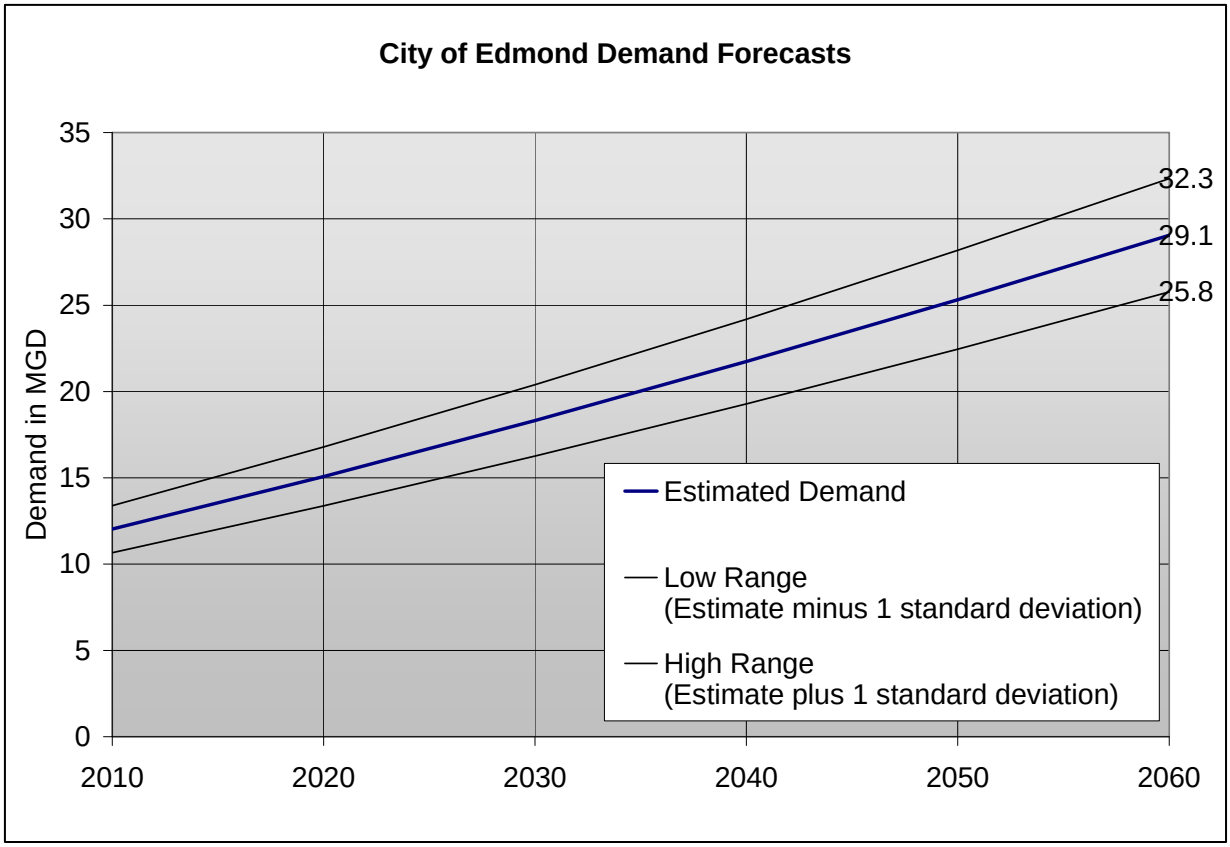

Figure 5

Attachment F
City of Edmond Water Conservation Potential

CDM

Memorandum

To: *Brian Mitchell, Enrique Lopez-Calva*

From: *Bill Davis*

Date: *September 9, 2008*

Subject: *City of Edmond Water Conservation Potential*

This memorandum describes a general estimation of water conservation potential for the City of Edmond (City), Oklahoma. These estimates are very general in nature. It is strongly recommended that the City conduct a more thorough analysis of potential water savings and program costs before implementing water conservation programs.

Demand Forecast

The development of the water demand projections for the City is described in a prior memorandum. The water demand forecast was estimated with an expected, low and high range. These forecasts are shown in Table 1. These forecasts are developed with the inherent assumption that future water use patterns will follow current (i.e., 1988 -2007) water use patterns. Thus, the water conservation effects of existing water conservation programs and building codes are included in this forecast.

Table 1 – City of Edmond Water Demand Estimate with High and Low Range (MGD)

Year	Estimated Demand	Low Range (Estimate -1 standard deviation)	High Range (Estimate +1 standard deviation)
2010	12.0	11.0	13.0
2020	15.1	13.9	16.4
2030	18.5	17.0	20.0
2040	22.0	20.2	23.9
2050	25.8	23.6	27.9
2060	29.7	27.2	32.2

General Conservation Planning Levels

Two levels of water conservation efforts are considered for general planning purposes: Level I and Level II. These are based on general concepts of future water saving and costs. Potential water conservation programs that are likely to produce the assumed level of water use

reductions are outlined below. The estimated savings are derived from the expected forecast shown in Table 1. Analysis of historical monthly production data suggests that about 63 percent of annual water use is non-seasonal use. It is reasonably assumed that this represents the percent of annual water use that is indoor water use. The remainder (37 percent of annual use) is assumed to be outdoor water use.

Level I Conservation Effort

The Level I conservation effort is assumed to create a 5 percent efficiency in indoor water use and a 10 percent efficiency in outdoor water use. By the year 2060, this equates to approximately 1 mgd of indoor water use savings and 1 mgd of outdoor water use savings.

Water conservation measures that could be implemented by the City of Edmond that would result in such savings include:

- Distribution of water conservation education and awareness material to customers and in schools
- Distribution of dye tablet kits with instructions for detection and correction of leaky toilets
- Provide instructions to customers on proper setting adjustments of irrigation controllers
- Distribution of moisture sensors for use with irrigation controllers
- Provide water audits of residential customer properties on request, and target high water using customers

Based on a review and analysis of similar conservation programs throughout the U.S., it is expected that these programs can be implemented and administered for $0.20 or less per gallon per day of water savings. The expected forecast with Level I savings and the associated costs are shown in Table 2.

Table 2 Estimated Level I Forecast, Savings and Cost

	2010	2020	2030	2040	2050	2060
Level I						
MGD	11.2	14.1	17.3	20.6	24.0	27.7
Savings MGD	0.8	1.0	1.2	1.5	1.8	2.0
Cost	$160,000	$200,000	$250,000	$300,000	$350,000	$410,000

Level II Conservation Effort

The Level II conservation effort is assumed to create an additional 5 percent efficiency in indoor water use beyond that achieved by the Level I effort. By the year 2060, this equates to approximately 1 mgd of additional indoor water use savings.

Water conservation measures that could be implemented by the City that would result in such savings include:

- Provide rebates for installation of dual-flush toilets
- Provide rebates for water efficient clothes washers

It is expected that these programs can be implemented and administered for $0.50 or less per gallon per day of water savings. The expected forecast with Level II savings and the associated costs are shown in Table 3. The total savings and costs of Levels I and II combined are also shown in Table 3.

Table 3 Estimated Level II Forecast, Savings and Cost

	2010	2020	2030	2040	2050	2060
Level II						
MGD	10.8	13.6	16.6	19.8	23.2	26.7
Savings MGD	0.4	0.5	0.6	0.7	0.8	1.0
Cost	$200,000	$250,000	$300,000	$360,000	$420,000	$480,000
Total Savings MGD	1.2	1.5	1.8	2.2	2.6	3.0
Total Cost	$360,000	$450,000	$550,000	$660,000	$770,000	$890,000