OWRB / USACE TULSA DISTRICT

WATER FOR 2060 - PHASE 2

TECHNICAL MEMORANDUM NO. 3
WATER FOR 2060 HOT SPOT BASIN
MARGINAL QUALITY WATER ANALYSES

FINAL
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OWRB / USACE TULSA DISTRICT

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NO. 3

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1.0 INTRODUCTION

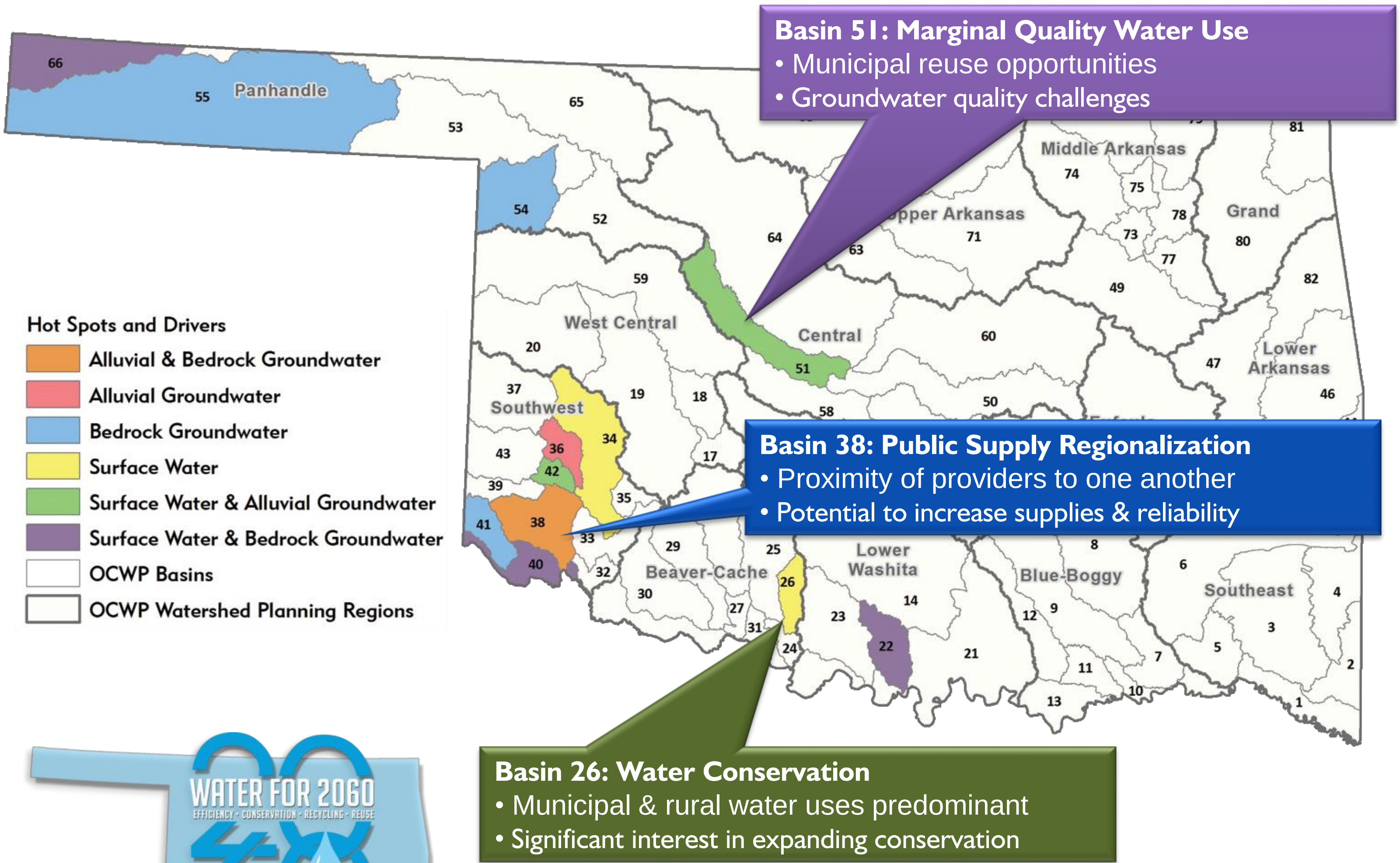
The Governor of Oklahoma signed the Water for 2060 Act into law in 2012. It set a statewide goal of consuming no more fresh water in 2060 than was consumed in 2012, while continuing to grow the state’s population and economy. Water for 2060 emphasizes the use of education and incentives, rather than mandates, to achieve this ambitious goal without limiting Oklahoma’s future growth and prosperity. Toward this goal, the Oklahoma Water Resources Board (OWRB) is promoting water efficiency in partnership with the U.S. Army Corps of Engineers (USACE) through a series of Water for 2060 activities, with an emphasis on potential means of alleviating the water shortages projected in the 2012 Update of the Oklahoma Comprehensive Water Plan (OCWP).

This Technical Memorandum (TM) No. 3 provides information regarding the potential benefits and costs of implementing marginal quality water (MQW) on a local scale. MQW is defined in the OCWP as waters of lower quality that have historically not been widely used for supplying Oklahoma's water needs, like brackish or saline contaminated waters, stormwater runoff, or treated wastewater. The use of MQW to meet appropriate water needs can offset fresh water demands. The hot spot basin analyses described herein focus on beneficial use of recycled water in Basin 51 in the Central Region, but also serve as a demonstration of water reuse that communities across Oklahoma with wastewater treatment facilities could implement to reduce demands on fresh water supplies statewide.

The analyses are presented on an informational basis only. Public water supply systems discussed in this analysis are offered this information as a resource to support local planning efforts. However, there is no requirement for any public water supply system to implement any project contemplated in this TM.

2.0 BACKGROUND

OWRB, in partnership with USACE, is implementing a phased set of activities to support the Water for 2060 goals. More information on the overall program is available at www.owrb.ok.gov/2060. Phase 2 services focus on mitigating the projected surface water supply gaps and groundwater depletions in the “hot spot” basins, defined in the OCWP as those basins with the greatest future water supply challenges. Figure 3.1 illustrates the OCWP hot spot basins and those selected as part of Water for 2060 Phase 2 to demonstrate how conservation, MQW supplies, and public water supply system regionalization strategies can address the local water needs. This TM focuses on the MQW analyses. Other TMs address the conservation and regionalization demonstration projects.



WATER FOR 2060 PHASE 2, BASIN LEVEL DEMONSTRATION ANALYSES

FIGURE 3.1

OWRB/USACE TULSA DISTRICT

WATER FOR 2060 HOT SPOT BASIN MARGINAL QUALITY WATER ANALYSES

Basin 51 showed a high potential for use of MQW to address its future needs. Basin 51 is located in the OCWP Central Watershed Planning Region and is generally located along the North Canadian River between Lake Canton and Lake Overholser. Basin 51 accounts for approximately 7 percent of the Central Watershed Planning Region current demand. Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are expected by 2020, as summarized in Table 3.1.

Table 3.1 Magnitude and Probability of Annual Gaps and Storage Depletions in Central Region, Basin 51

	Maximum Gap/Storage Depletions (acre-feet per year [AFY])			Probability of Gaps/Storage Depletions (%)	
Planning Horizon	**Surface Water**	**Alluvial GW**	**Bedrock GW**	**Surface Water**	**Alluvial GW**
2020	420	670	600	76	76
2030	550	950	280	79	79
2040	840	1,490	160	81	81
2050	1,190	2,100	80	81	81
2060	1,580	2,810	110	81	81

Notes:
(1) From OCWP Central Watershed Planning Region Report (www.owrb.ok.gov/supply/ocwp).

Basin 51 was identified as an OCWP hot spot basin because of the expected magnitude and frequency of both surface water gaps and alluvial groundwater depletions. Surface water gaps are expected both from a lack of physically available water and lack of permit availability. OCWP groundwater depletions are focused on physical availability of water, but Basin 51, using more recent water quality information, also has elevated levels of key constituents, like nitrate and total dissolved solids, that limit groundwater use (without advanced treatment) for drinking water.

3.0 WATER FOR 2060 MARGINAL QUALITY WATER ANALYSES

Basin 51 was selected for MQW analyses in part because of its potential to demonstrate water reuse in a municipal setting. Water demands in Basin 51 are predominantly driven by municipal and industrial (M&I) water use, offering opportunities to offset potentially significant quantities of fresh water use in the basin with a nontraditional MQW source through water reuse. There is currently no water reuse program in place in any community in Basin 51. This analysis focused on non-potable water reuse, and primarily on irrigation-based non-potable water reuse sites, as three communities in Basin 51 have wastewater treatment facilities compatible with at least some degree of non-potable water reuse without further upgrades: Yukon, El Reno, and Watonga.

While other MQW applications are certainly possible, non-potable water reuse is arguably the most feasible MQW solution that could be implemented in the near-term in Basin 51.

Potable water reuse – whether indirect potable reuse accomplished through augmenting surface water or groundwater drinking water supplies, or direct potable reuse that bypasses such an "environmental buffer" and instead plumbs treated effluent directly to advanced treatment and subsequent distribution – requires significantly more advanced treatment and monitoring. (Refer to Section 5.3 for additional discussion on potable reuse.) Moreover, non-potable water reuse has been in place in some communities in Oklahoma for many years and has a defined regulatory structure, whereas potable reuse is just now evolving in the state. Potable reuse and other applications that could match up available MQW supplies with water demands in Basin 51 are discussed in later sections of this TM.

3.1 Treatment Requirements for Non-Potable Water Reuse

Non-potable water reuse applications identified in each community were assigned to Oklahoma Department of Environmental Quality (ODEQ) Categories 2 and 3. The analyses conducted in this investigation did not identify significant demand associated with reuse applications eligible for the lower water quality Categories 4 and 5 in the communities studied, and Category 6 (when approved) will authorize only limited quantities of reuse at water reclamation facilities (WRF). The reuse categories and basic requirements are outlined in Table 3.2.

Table 3.2 ODEQ Reuse Categories, Uses, and Treatment Requirements

Reclaimed Water Category(1)	Allowed Uses	Treatment Requirements
1	• Reserved	• Reserved
2	• Uses allowed under Categories 3, 4, and 5 • Drip irrigation on orchards or vineyards • Spray or drip irrigation on sod farms, public access landscapes and public use areas/sports complexes, including unrestricted access golf courses • Toilet and urinal flushing • Fire protection • Commercial closed-loop air condition systems • Vehicle and equipment washing (excluding self-service car washes) • Range cattle watering	• Secondary treatment • Nutrient removal(3) • Coagulation • Filtration • Continuous turbidity monitoring • Disinfection

Table 3.2 ODEQ Reuse Categories, Uses, and Treatment Requirements		
Reclaimed Water Category[(1)]	**Allowed Uses**	**Treatment Requirements**
3	• Uses allowed under Categories 4 and 5 • Subsurface irrigation of orchards or vineyards • Restricted access landscape irrigation • Irrigation of livestock pasture • Concrete mixing • Dust control • Aggregate washing/sieving • New restricted access golf course irrigation systems • Industrial cooling towers and once-through cooling systems • Restricted access irrigation of sod farms	• Secondary treatment • Nutrient removal[(3)] • Disinfection
4	• Uses allowed under Category 5 • Soil compaction and similar construction activities • Existing restricted access golf course irrigation systems	• Primary treatment • Storage detention • Disinfection
5	• Restricted access pasture irrigation for range cattle • Restricted access irrigation of fiber, seed, forage and similar crops • Irrigation of silviculture	• Primary treatment
6[(2)]	• Permits reclaimed water use at wastewater treatment plants (or WRFs)	• To be determined

Notes:
(1) From ODEQ Title 252, Chapter 656, Subchapter 27 Wastewater Reuse.
(2) Modifications to the existing regulation, including the addition of new Category 6, are expected in 2015.
(3) Systems may be exempt from the requirement to remove nutrients when documentation is provided to show that nutrients are utilized based on the agronomic and/or crop uptake rates of the final use.

The requirements for water quality, monitoring, and use management specific to each reuse category and each specific reuse application are further detailed in the ODEQ reuse regulations.

3.2 Methodology and Assumptions for Conveyance and Treatment Infrastructure

The Cities of Watonga, El Reno, and Yukon participated in the MQW analyses. These are the only three cities in Basin 51 that have or plan to have a mechanical WRF that produces effluent capable of meeting ODEQ Category 3 reclaimed water regulations. Watonga and

Yukon have mechanical treatment facilities; El Reno is constructing a sequencing batch reactor-based mechanical treatment facility. Working with city staff in each of these communities, sites that could potentially use either Category 3 or the more stringent Category 2 reclaimed water quality were identified.

In lieu of available site-specific data from within the basin, unit irrigation demands (acre-feet of water applied per acre of irrigated landscaping per year, or inches of water per year) were estimated using historical irrigation data from Edmond and Norman. Edmond is located in Basin 64 and Norman is located in Basin 58. As with Basin 51, both are part of the OCWP Central Watershed Planning Region and are expected to have precipitation and outdoor water demands generally similar to those prevalent in Basin 51. Local and site-specific practices should be further confirmed before implementing reuse projects in any community. Table 3.3 presents the irrigation application rate used to estimate irrigation demands. The land area of each irrigation site was either provided by city staff or estimated using aerial images.

Table 3.3 Irrigation Application Rates

Month	Application Rate (inches per month)
January	0
February	0
March	0
April	0.02
May	1.0
June	1.1
July	4.5
August	6.6
September	1.9
October	1.4
November	0.6
December	0.05
Annual Total Irrigation	17.0

The analyses focused on identifying a "Phase 1" reuse project that could be implemented to serve Category 3 sites in each community without requiring the coagulation and filtration process upgrades and higher water quality that are required when serving Category 2 sites. Category 2 sites, by definition, have higher potential for human contact with the recycled water. However, the Phase 1 infrastructure was conceptually laid out and sized with sufficient capacity to allow the communities to serve Category 2 sites in the future, if they decided to implement the treatment upgrades necessary to do so.

It was assumed that all flow from the WRF is available for reuse (i.e., no flow is required to be discharged to the receiving stream for downstream water rights or any potential instream flow goal). However, any WRF flow not used for reuse would be discharged to the receiving stream.

Generally, a single reclaimed water pipeline in each community was routed to target large demand sites or the most sites (identified as the "Phase 1" pipeline in figures), in order to most cost-effectively serve an initial set of sites with an initial set of infrastructure. To serve all potential reclaimed water use sites, additional piping would be needed, but future phases of reclaimed piping expansion were not assessed in this analysis (either for costing or routing/layout). Reclaimed water pipeline sizing was based on:

- Peak day flow for Category 3 sites and Category 2 sites (to allow the cities to serve Category 2 sites in the future without paralleling the pipeline in the future) along the identified Phase 1 pipeline route.
- Maintaining a peak flow velocity in the pipeline of 4 to 6 feet per second.
- Hazen-Williams roughness coefficient of 120.
- Onsite piping or connections (e.g., retrofitting connections to convert from potable service to reclaimed water service) are not included.

It was assumed that a single pump station located at the WRF is needed to transport water from the existing WRF to the irrigation sites. An overall wire to water efficiency (efficiency of a pump and motor together) of 65 percent was used for estimating pump station sizing.

Upgrades at the WRFs to meet Category 2 requirements are included in the cost for future expansion phases. Project sizing was based on the following assumptions.

- It was assumed that all flow directed to reuse (Categories 2 and 3) would receive the additional treatment needed to meet Category 2 standards, since the recycled water would be conveyed through a single combined transmission pipe to the Category 3 and 2 sites in the community.
- Treatment was sized to accommodate peak day demands from selected Category 2 and 3 sites (assuming that if there were multiple sites, irrigation would occur on alternating days). For example, in El Reno there were two selected Phase 1 project sites. The treatment improvements would be sized to meet the average peak day demand of these two sites (655,000 gallons per day [gpd]).
- Treatment improvements assumed the addition of coagulation and filtration at the WRF for only the portion of the plant's flow that would be directed to the non-potable water reuse system. The portion of the plant's flow not directed to reuse will not receive additional treatment.
- New reclaimed water storage was sized to meet peak day demand (in 100,000-gallon increments). For example, in El Reno, the Phase 1 Category 3 peak day demand is 0.74 million gallons per day (mgd); storage is sized at 800,000 gallons. Providing storage allows meeting the variable timing of recycled water demands while minimizing treatment capacity. Storage capacity would need to be expanded as additional sites are added.

- Potential property acquisition requirements (e.g., for storage, treatment improvements, or pipeline installation) were not included in this analysis.

It was assumed for purposes of this analysis that recycled water would be applied primarily to turfgrass. It was further assumed that it would be applied at or below the turfgrass agronomic uptake rate for nutrients, such that nutrient removal capabilities would not need to be added to any of the three communities' WRF (regardless of whether the facilities were serving Category 3 and/or Category 2 reclaimed water sites).

To validate this assumption, and in lieu of specific guidance from ODEQ, the Colorado Department of Public Health and Environment Policy "Guidelines for the Determination of Agronomic Rate for Application of Reclaimed Water Under Colorado Regulation No. 84" were referenced. Those guidelines cite a turfgrass uptake rate of 174 pounds of nitrogen per acre per year, and specify that phosphorous loading is assumed to not govern agronomic uptake considerations due to the immobility of phosphorous in soil types typically irrigated with reclaimed water. The 174 pounds of nitrogen per acre per year is measured as total inorganic nitrogen (TIN). TIN is the sum of ammonia (measured as nitrogen, or N), nitrate (as N) and nitrite (as N).

None of the discharge permits for the WRFs in the three cities analyzed in this investigation requires nitrogen removal (i.e., full nitrification and denitrification), so the facilities were not designed with that capability and there is likely little change in the TIN from the influent raw wastewater (with TIN primarily in the form of ammonia) to treated effluent (with TIN primarily in the form of nitrate for plants that nitrify).

At an annual agronomic uptake rate of 174 pounds of nitrogen per year and an annual irrigation rate of 17 inches per year, the allowable TIN concentration in the influent (which likely is similar to the TIN concentration in the plants' influent) is approximately 45 milligrams per liter (mg/L). Typical ammonia in raw municipal wastewater is below this level – around 30 to 35 mg/L (as N) – suggesting that it is appropriate to assume that nutrient removal will not be necessary for Categories 2 or 3 reuse in the communities evaluated in this investigation. However, these concentrations and the intended annual irrigation rates should be confirmed before implementation of a reuse program.

3.3 Cost Estimating Guidance

Cost estimates were developed using a Class 5 order of magnitude estimate, as established by AACE International. This level of estimate is used for initial planning purposes, including long-range capital planning, and represents a 0 percent to 2 percent level of project definition. The expected accuracy range is -30 percent to +50 percent, meaning the actual cost should fall in the range of 30 percent below the estimate to 50 percent above the estimate.

The following unit costs were used to develop the conceptual level cost estimates, based on regional project experience escalated to current conditions:

- $8.50 per inch pipe diameter per linear foot used to estimate pipeline costs through an alignment that has already been developed (e.g., existing paved streets and existing rights-of-way with potential routing conflicts).

- $4,600 per horsepower (hp) used to estimate pump station costs.
- $1.00 per gallon of storage capacity used to estimate storage costs.
- $0.20 per gallon per day of treatment capacity used to estimate coagulation treatment costs.
- $0.88 per gallon per day of treatment capacity used to estimate filtration costs.
- 20 percent of capital cost subtotal added to account for engineering, legal, and administrative services associated with project.
- 30 percent of capital cost subtotal added for contingency to address any unaccounted for aspects of project.
- $0.09 per kilowatt hour used to estimate annual power costs.

4.0 RESULTS OF NON-POTABLE WATER REUSE ANALYSES

4.1 City of Watonga

The City of Watonga is located in the northwestern portion of Basin 51. It uses groundwater from the North Canadian River Alluvial Aquifer for its potable water supply. Table 3.4 presents the OCWP projections for population and water demand growth in Watonga.

City staff reported that it is necessary to rotate the use of wells to manage elevated nitrate levels and maintain blended concentrations below the 10 mg/L drinking water standard, particularly in summer after extended use of individual wells. Increased demands could exacerbate this issue, and while OCWP projections indicate the potential for moderate growth in demand over time, City staff has observed little or no growth in service area population and demand in recent years. Implementing water reuse could help ease demands on the City's wells and potentially reduce nitrate concerns associated with extended summertime pumping.

Table 3.4 OCWP Population and Water Demand Projections for Watonga

Projection	2020	2030	2040	2050	2060
Population	5,208	5,667	6,127	6,576	7,074
Demand (AFY)	1,137	1,237	1,337	1,436	1,544

Notes:
(1) From OCWP Central Watershed Planning Region Report (www.owrb.ok.gov/supply/ocwp).

The City of Watonga's WRF had an average flow of 0.3 mgd in 2012. More recent data were not readily available for a full calendar year, but City staff reported observing no significant changes or trends in plant flows over that time period. The treatment process includes screening, primary clarification, bio-tower, secondary clarification, and disinfection using chlorine (with disinfection required by permit from April through September only). Staff indicated that the plant is nitrifying (converting ammonia to nitrate), but it is unclear whether the plant also is denitrifying (converting nitrate to nitrogen gas), as there is no permit limit for nitrate and the City therefore does not monitor nitrate. Table 3.5 lists the average flow by month used in this analysis, based on data provided by the City.

Table 3.5 Watonga WRF 2012 Monthly Flow

Month	Flow (mgd)
January	0.28
February	0.32
March	0.32
April	0.32
May	0.35
June	0.39
July	0.40
August	0.33
September	0.28
October	0.26
November	0.25
December	0.27
Annual Average Daily Flow	0.31
Annual Reclaimed Water Treated at WRF (AFY)	352

Two sites were identified as potentially suitable candidates for using reclaimed water for non-potable irrigation. No candidates for commercial or industrial non-potable water use were identified in the community. The non-potable irrigation sites are illustrated on Figure 3.2. Table 3.6 summarizes site characteristics and water demands.

Table 3.6 Watonga Candidate Water Reuse Sites

Potential Site	Served in Phase 1 Project?	ODEQ Reclaimed Water Category	Annual Demand (AFY)	Peak Day Demand (mgd)
Watonga Golf Club	Yes	3	67	0.66
Ball Fields	No(1)	2	48	0.46

Notes:

(1) Site is located in close proximity to Phase 1 pipeline alignment. To serve this site, treatment improvements are necessary. However, the Phase 1 pipeline was sized with sufficient capacity to serve this site.

SITES CONSIDERED FOR USING RECLAIMED WATER AND PROPOSED REUSE PIPELINE IN WATONGA

FIGURE 3.2

OWRB/USACE TULSA DISTRICT WATER FOR 2060 HOT SPOT BASIN MARGINAL QUALITY WATER ANALYSES

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Planning level costs for the Phase 1 pipeline include a 2.8-mile long pipeline that would be used to convey recycled water north to the Phase 1 reuse site (i.e., the golf course). Costs were developed based on the conceptually-identified route for the new pipeline segment and demands served along the existing pipeline, excluding costs for onsite piping, connections, and irrigation systems.

The golf course is served in the proposed Phase 1 project. Through serving this site with reclaimed water, Watonga can reduce its annual fresh water use by approximately 6 percent of 2020 demand (67 AFY). Table 3.7 presents the capital cost associated with the proposed Phase 1 project, which includes a new pipeline, pump station, and reclaimed water storage.

Table 3.7 Watonga Phase 1 Water Reuse Project Costs

Description	Costing Factors	Cost
Pipeline(2)	10-inch diameter, 2.8 miles	$1,230,000
Pump Station(3)	120 hp	$550,000
Reclaimed Water Storage(4)	700,000 gallons	$700,000
	Subtotal	**$2,480,000**
Engineering, Legal, and Administration	20%	$500,000
Contingency	30%	$740,000
	Total Capital Cost	**$3,720,000**
Estimated Annual Power	15,000 kilowatts per hour (kWh)	$1,400

Notes:
(1) All costs in 2015 dollars. Sums may differ slightly from totals due to rounding.
(2) Sized to accommodate initial Category 3 flows and future Category 2 flows.
(3) Sized to accommodate initial Category 3 flows. Assumed that design of pump station would facilitate replacement of pumps with larger ones sized to meet Categories 2 and 3 demands in the future.
(4) Sized to meet peak day demand in 100,000 gallon increments.

Applying recycled water to the Watonga Ball Fields (in addition to the golf course) would require the addition of coagulation and filtration at the WRF due to the elevated potential for public contact with recycled water at the Ball Fields, as defined in the ODEQ regulations. These treatment upgrades (sized to meet average peak day flow of 560,000 gpd) would have an estimated capital cost of $605,000, which in turn would allow the City to offset an additional 58 AFY of fresh water use in Watonga. An additional 0.7 miles of pipeline and slightly larger (150 hp reuse pumps also are required to supply Category 2 demands. Peak day demands at both the golf course and ball fields exceed the annual average (and summer month average) flow from the WRF and would require storage, alternating day irrigation, and likely the use of a potable water supply connection as backup to confidently ensure that irrigation demands are met.

4.2 City of El Reno

The City of El Reno is located in the southeast portion of Basin 51. It uses groundwater from the North Canadian River Alluvial Aquifer for its potable water supply and supplements supply by purchasing treated water from Oklahoma City. Table 3.8 presents the OCWP projections for population and water demand growth in El Reno. In addition, El Reno wholesales water to Union City and Heaston Rural Water Corporation and provides emergency supplies to the Town of Minco.

Table 3.8 OCWP Population and Water Demand Projections for El Reno

Projection	2020	2030	2040	2050	2060
Population	20,723	22,161	23,400	24,544	25,709
Demand (AFY)	4,586	4,883	5,156	5,408	5,665

Notes:
(1) From OCWP Central Watershed Planning Region Report (www.owrb.ok.gov/supply/ocwp).
(2) AFY: acre-feet per year

The City of El Reno is currently constructing a new 2-mgd WRF. To meet its anticipated discharge permit limits, the new plant will use a sequencing batch reactor (SBR) process to achieve secondary treatment with nitrification, and will use ultraviolet (UV) light technology for disinfection. El Reno provided wastewater flow data. Table 3.9 lists the average flow by month used in this analysis.

Table 3.9 El Reno WRF 2014 Monthly Flow

Month	Flow (mgd)
January	1.1
February	1.1
March	1.1
April	1.1
May(1)	1.6
June	2.1
July	1.6
August	1.6
September	1.2
October	1.5
November	0.90
December	0.84
Annual Average Daily Flow	1.3
Annual Reclaimed Water Treated at WRF (AFY)	1,468

Notes:
(1) May 2014 flow was linearly interpolated from April and June 2014 historical data.

Five sites were identified as potentially suitable candidates for using reclaimed water for non-potable irrigation. No candidates for commercial or industrial non-potable water use were identified in the community. The non-potable irrigation sites are illustrated on Figure 3.3. Table 3.10 summarizes site characteristics and water demands.

Table 3.10 El Reno Candidate Water Reuse Sites

Potential Site	Served in Phase 1 Project?	ODEQ Reclaimed Water Category	Annual Demand (AFY)	Peak Day Demand (mgd)
El Reno Cemetery	No	3	81	0.79
Frank Knight Park	No	3	6.8	0.07
Burton Park	No	2	6.5	0.06
Crimson Creek Park	Yes	3	76	0.74
Adams Park	No(1)	2	58	0.57

Notes:

(1) Site is located in close proximity to Phase 1 pipeline alignment. To serve this site, treatment improvements are necessary. However, the Phase 1 pipeline was sized with sufficient capacity and the existing pipeline has sufficient capacity to serve this site.

Planning level costs for the Phase 1 pipeline include a short (0.63-mile) new line to convey flows from El Reno's new WRF to its existing 4.4-mile pipeline, which would be used to convey recycled water westerly to the Phase 1 reuse sites. Costs were developed based on the conceptually-identified route for the new pipeline segment and demands served along the existing pipeline, excluding costs for rehabilitating the existing pipeline, onsite piping, connections, and irrigation systems.

Crimson Creek Park is served in the proposed Phase 1 project. Through serving this site with reclaimed water, El Reno can reduce its annual fresh water use by approximately 2 percent of 2020 demand (76 AFY). Table 3.11 presents the capital cost associated with the proposed Phase 1 project, which includes a new pipeline (connecting the WRF to the existing pipeline), pump station, and reclaimed water storage.

SITES CONSIDERED FOR USING RECLAIMED WATER AND PROPOSED REUSE PIPELINE IN EL RENO

FIGURE 3.3

OWRB/USACE TULSA DISTRICT

WATER FOR 2060 HOT SPOT BASIN MARGINAL QUALITY WATER ANALYSES

Table 3.11 El Reno Phase 1 Water Reuse Project Costs		
Description	**Costing Factors**	**Cost**
Pipeline(2)	12-inch diameter, 0.63 miles	$340,000
Pump Station(3)	120 hp	$550,000
Reclaimed Water Storage(4)	800,000 gallons	$800,000
	Subtotal	**$1,690,000**
Engineering, Legal, and Administration	20%	$340,000
Contingency	30%	$510,000
	Total Capital Cost	**$2,540,000**
Estimated Annual Power	15,000 kWh	$1,400

Notes:

(1) All costs in 2015 dollars. Sums may differ slightly from totals due to rounding.

(2) Sized to accommodate initial Category 3 flows and future Category 2 flows.

(3) Sized to accommodate initial Category 3 flows. Assumed that design of pump station would facilitate replacement of pumps with larger ones sized to meet Categories 2 and 3 demands in the future.

(4) Sized to meet peak day demand in 100,000 gallon increments.

Applying recycled water to Adams Park (in addition to Crimson Creek Park) would require the addition of coagulation and filtration at the WRF due to the elevated potential for public contact with recycled water at the park, as defined in the ODEQ regulations. These treatment upgrades (sized for average peak day flow of 655,000 gpd) would have an estimated capital cost of $707,000, which in turn would allow the City to offset an additional 58 AFY of fresh water use in El Reno. Slightly larger (200 hp) pumps also would be required.

Significant additional demands could be met using available recycled water supplies by adding a spur pipeline to serve additional sites (El Reno Cemetery, Frank Knight Park, and Burton Park) on the east side of El Reno. Routing and costs for subsequent pipeline phases were not developed for this analysis. Similarly, costs for treatment upgrades associated with these east-side sites – which would be necessary for the entire reuse system delivery capacity if the City served one or more Category 2 sites anywhere in the reclaimed water distribution system – were not estimated in this analysis.

4.3 City of Yukon

The City of Yukon is located in the southeastern corner of Basin 51. It uses groundwater from the North Canadian River Alluvial Aquifer and El Reno Bedrock Aquifer for its potable water supply and supplements supply by purchasing treated water from Oklahoma City. Staff indicated that well management strategies (e.g., blending) are utilized for a few wells with elevated arsenic levels to maintain compliance with drinking water standards. The city is participating in the Central Oklahoma Water Resources Authority (COWRA) evaluation of brackish groundwater treatment, as described later in this TM. Table 3.12 presents the OCWP projections for population and water demand growth in Yukon.

Table 3.12 OCWP Population and Water Demand Projections for Yukon

Projection	2020	2030	2040	2050	2060
Population	23,833	25,478	26,910	28,222	29,561
Demand (AFY)	3,882	4,150	4,383	4,597	4,815

Notes:
(1) From OCWP Central Watershed Planning Region Report (www.owrb.ok.gov/supply/ocwp).
(2) AFY: acre-feet per year

The City of Yukon's WRF had an average flow of 2.7 mgd in 2014. The current treatment process includes screening, activated sludge treatment, secondary clarification, and disinfection using chlorine (with disinfection required by permit from April through September only). Table 3.13 lists the average flow by month used in this analysis.

Table 3.13 Yukon WWTF Monthly Flow

Month	Flow (mgd)(1)
January	2.2
February	2.2
March	2.2
April	2.3
May	3.3
June	4.4
July	3.4
August	3.4
September	2.5
October	3.1
November	1.9
December	1.7
Annual Average Daily Flow	2.7
Annual Reclaimed Water Treated at WRF (AFY)	3,050

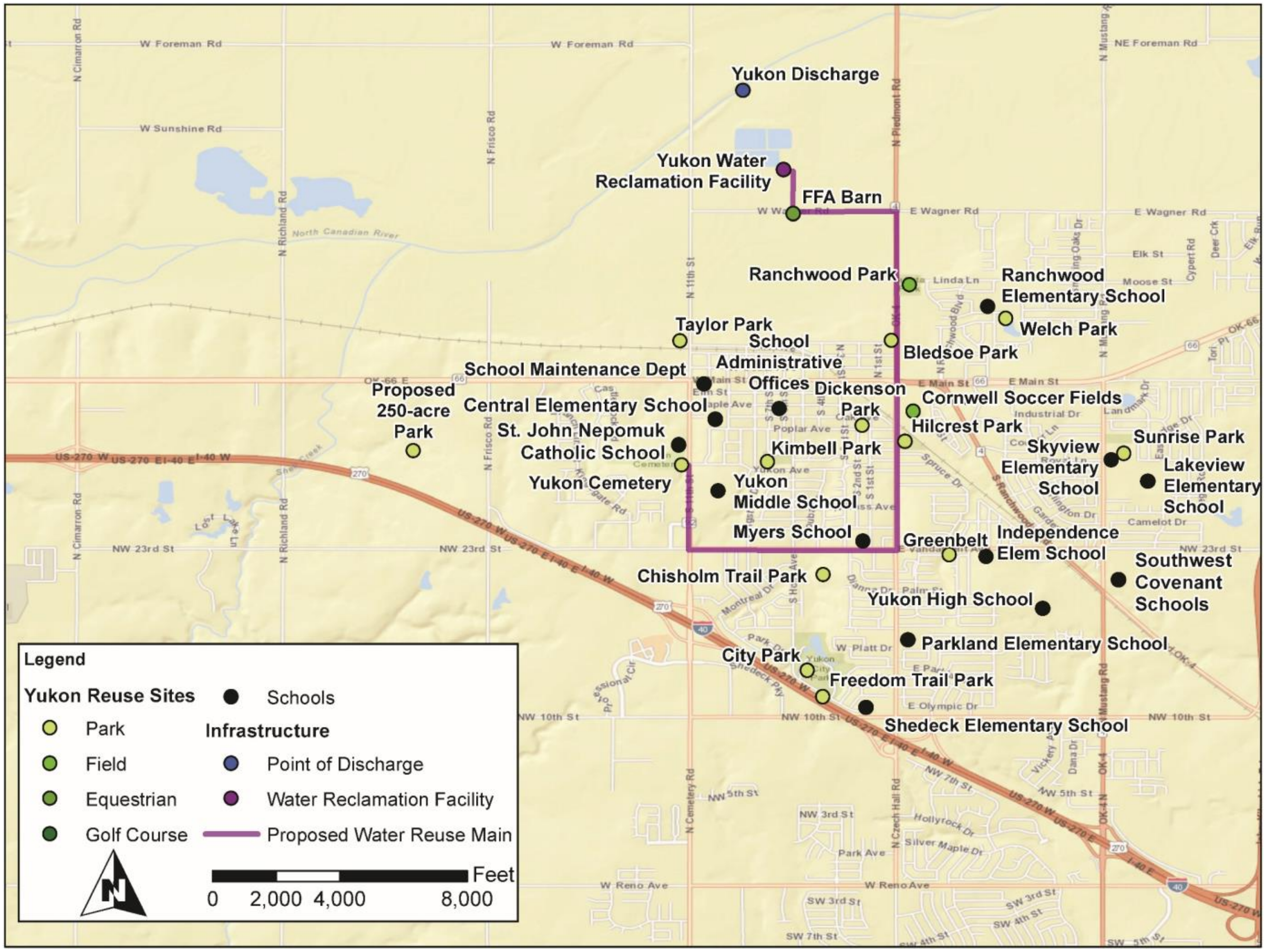
Notes:
(1) Based on 2010-2013 historical annual totals and monthly distribution of flows based on monthly historical data from Yukon.

Thirty-two sites were identified as potentially suitable candidates for using reclaimed water for non-potable irrigation. No candidates for commercial or industrial non-potable water use were identified in the community. The non-potable irrigation sites are illustrated on Figure 3.4. Table 3.14 summarizes site characteristics and water demands.

Table 3.14 Yukon Candidate Water Reuse Sites				
Potential Site	Served in Phase 1 Project?	ODEQ Reclaimed Water Category	Annual Demand (AFY)	Peak Day Demand (mgd)
Proposed 250 Acre Park	No	2	118.3	1.16
Chisholm Trail Park	Yes	3	51	0.50
Yukon Cemetery	Yes	3	37	0.36
FFA Barn	Yes	3	36.6	0.36
Shedeck Elementary School	No	3	21.3	0.21
Greenbelt	Yes	3	8.8	0.09
Kimbell Park	No	3	8.1	0.08
Central Elementary School	No	3	7.7	0.07
City Park	No	3	6.4	0.06
Sunrise Park	No	3	3.5	0.03
Bledsoe Park	Yes	3	2.8	0.03
St John Nepomuk Catholic School	Yes	3	2.4	0.02
Skyview Elementary School	No	3	2.1	0.02
School Administrative Offices	No	3	0.3	0.003
School Maintenance Department	No	3	0.1	0.001
Yukon High School	No	2	102	1.0
Taylor Park	No	2	101	0.99
Southwest Covenant Schools	No	2	64.3	0.63
City Park	No	2	36.7	0.36
Lakeview Elementary School	No(1)	2	32.9	0.32
Yukon Middle School	No(1)	2	20.1	0.20
Cornwell Soccer Fields	No	2	18.1	0.18
Independence Elementary School	No	2	15	0.15
Welch Park	No	2	12.5	0.12
Ranchwood Park	No(1)	2	12	0.12
Freedom Trail Park	No	2	11.1	0.11
Ranchwood Elementary School	No	2	6.9	0.07
Myers Elementary School	No(1)	2	6.8	0.07
Sunrise Park	No	2	6.2	0.06
Hillcrest Park	No(1)	2	6.1	0.06
Dickenson Park	No(1)	2	5.8	0.06
Parkland Elementary School	No	2	4.3	0.04

Notes:

(1) Site is located in close proximity to Phase 1 pipeline alignment. To serve this site, treatment improvements are necessary. However, the Phase 1 pipeline was sized with sufficient capacity to serve this site.



SITES CONSIDERED FOR USING RECLAIMED WATER AND PROPOSED REUSE PIPELINE IN YUKON

FIGURE 3.4

OWRB/USACE TULSA DISTRICT
WATER FOR 2060 HOT SPOT BASIN MARGINAL QUALITY WATER ANALYSES

carollo

pw:\\Carollo/Documents\Client/OK/CH2M Hill Inc/9093B00/Deliverables/TM03 MQW\Fig03_04.docx (Final)

Planning level costs for the Phase 1 pipeline include a 4.3-mile pipeline that would be used to convey recycled water generally south then west to Phase 1 reuse sites. Costs were developed based on the conceptually-identified route for the new pipeline segment and demands served along the existing pipeline, excluding costs for onsite piping, connections, and irrigation systems.

Six of the identified sites are served in the proposed Phase 1 project. By serving these sites with reclaimed water, Yukon can avoid the use of approximately 139 AFY of fresh water. Table 3.15 presents the capital cost associated with the proposed Phase 1 project, which includes a new pipeline, pump station, and reclaimed water storage.

Table 3.15 Yukon Phase 1 Water Reuse Project Costs

Description	Costing Factors	Cost
Pipeline[(2)]	18-inch diameter, 4.3 miles	$3,480,000
Pump Station[(3)]	60 hp	$280,000
Reclaimed Water Storage[(4)]	500,000 gallons	$500,000
	Subtotal	**$4,460,000**
Engineering, Legal, and Administration	20%	$890,000
Contingency	30%	$1,340,000
	Total Capital Cost	**$6,690,000**
Estimated Annual Power	8,000 kWh	$700

Notes:
(1) All costs in 2015 dollars. Sums may differ slightly from totals due to rounding.
(2) Sized to accommodate initial Category 3 flows and future Category 2 flows.
(3) Sized to accommodate initial Category 3 flows. Assumed that design of pump station would facilitate replacement of pumps with larger ones sized to meet Categories 2 and 3 demands in the future.
(4) Sized to meet peak day demand in 100,000 gallon increments.

Applying recycled water to the Category 2 sites along the proposed Phase 1 pipeline route (Lakeview Elementary School, Yukon Middle School, Myers Elementary School, Ranchwood, Hillcrest, and Dickenson parks, and future Yukon Athletic Complex [250-acre park]) would require the addition of coagulation and filtration at the WRF due to the elevated potential for public contact with recycled water at these sites, as defined in the ODEQ regulations. These treatment upgrades (sized to meet 1.1 mgd for the Phase 1 pipeline Categories 2 and 3 demands) would have an estimated capital cost of $1,180,000, which in turn would allow the City to avoid an additional 83.7 AFY of fresh water use. Larger pumps (260 hp) also would be required.

Significant additional sites could be irrigated using available recycled water supplies by adding additional distribution infrastructure. Routing and costs for subsequent pipeline phases were not developed for this analysis. Similarly, costs for treatment upgrades associated with these additional sites – which would be necessary for the entire reuse system delivery capacity if the City served one or more Category 2 sites anywhere in the reclaimed water distribution system – were not estimated in this analysis.

4.4 Statewide Applicability

The demonstration of potential non-potable water reuse systems in Basin 51 shows the value of using water quality that is suited to the type of water use. High quality drinking water is not needed for landscape irrigation; a lower quality, but still safe, reclaimed water supply is well-suited for irrigation. Table 3.16 quantifies the amount of fresh water use avoided if the proposed "Phase 1" MQW projects are implemented. Additional avoidance of fresh water use could be achieved through extension of additional reclaimed water piping in El Reno and Yukon, and treatment improvements in all three communities would allow irrigation of sites with higher potential for human contact that require Category 2 water quality.

Table 3.16 MQW Demonstration Project Summary

With Phase 1 Non-Potable Water Reuse Projects In:	Avoided Fresh Water Use
Watonga	67 AFY
El Reno	76 AFY
Yukon	139 AFY

Communities across Oklahoma that have mechanical wastewater treatment facilities could implement similar water reuse projects. The WRF offers a centralized and drought-proof "supply" of water that can offset the need to use fresh water supplies. Additional treatment processes (i.e., coagulation and filtration) can be added to expand opportunities for non-potable water reuse to sites with high potential for human contact with recycled water, further extending the efficient use of available local supplies.

A water reuse system for non-potable uses (like irrigation) requires separate piping, which can drive significant construction costs in rights-of-way already populated with existing infrastructure. However, costs for new fresh water sources vary significantly, depending on what is needed to develop supplies (new reservoir, new pipe from existing reservoir, new groundwater wells, new or expanded treatment facilities, etc.). As fresh water supplies are increasingly stressed and local sources become fully utilized, using reclaimed water appropriately may be the lowest cost alternative. Additionally, because wastewater flows are driven by a community's indoor water use, they are a reliable source of flow under virtually all conditions, and can be an energy- and water-efficient means of providing the right water for the right use in the community.

5.0 OTHER KEY OPPORTUNITIES FOR MARGINAL QUALITY WATER USE IN BASIN 51

In addition to non-potable water reuse, other uses of MQW to offset fresh water use may become increasingly attractive over time in Basin 51. This is a function of:

- The types of MQW sources available in the basin;
- The types of demand, including both potable-quality needs and opportunities for non-potable water use in the basin;
- Evolving technologies and reductions in the capital and operating costs to treat MQWs as those technologies evolve over time; and
- Increasing competition for local water supplies and the corresponding need to consider local MQW sources as potentially cost-effective alternatives to importing traditional supplies from more distant sources.

The most promising MQW sources available in the basin identified in this analysis include:

- Brackish groundwater,
- Alluvial groundwater with elevated levels of nitrate, and
- Potable water reuse.

Each of these MQW sources is discussed below.

5.1 Brackish Groundwater

Brackish water was defined in the OCWP as surface and groundwater sources that have higher salinity than freshwater, but salinity lower than seawater. For purposes of the OCWP MQW analyses, brackish water was considered to be waters with total dissolved solids (TDS) concentrations between 1,000 mg/L and 35,000 mg/L. Brackish groundwater sources have been identified in portions of Basin 51.

Communities in the southern portion of Basin 51 are evaluating the use of brackish groundwater for potable supply through work currently underway by COWRA. This initiative is consistent with the state's efforts to promote the use of MQW, as brackish groundwater was identified in the OCWP as one potential source of MQW that could be more widely utilized to offset the use of fresh water supplies in support of meeting the state's Water for 2060 goals.

The COWRA effort is being implemented in a phased effort, starting with an evaluation of existing water supplies and records of supplies. The group has sited and initiated development of test wells, which will be used to analyze yields and water quality prevalent in the brackish groundwater formation in the area. Subsequent phases of the program may include pilot testing of membrane-based treatment systems for the water produced from the test wells or evaluation of other groundwater alternatives.

5.2 Nitrates in Groundwater

Water resources are very limited in Basin 51, as evidenced by the OCWP projection of surface water gaps and groundwater depletions. Its projected physical water shortages led it to be designated in the OCWP as one of the state's 12 water supply hot spots. However, physical supply is not the basin's only challenge. The water quality of in-basin supplies can exhibit localized issues, as well, as seen in Watonga's wells (elevated levels of nitrates) and Yukon's observation of some wells with elevated arsenic concentrations.

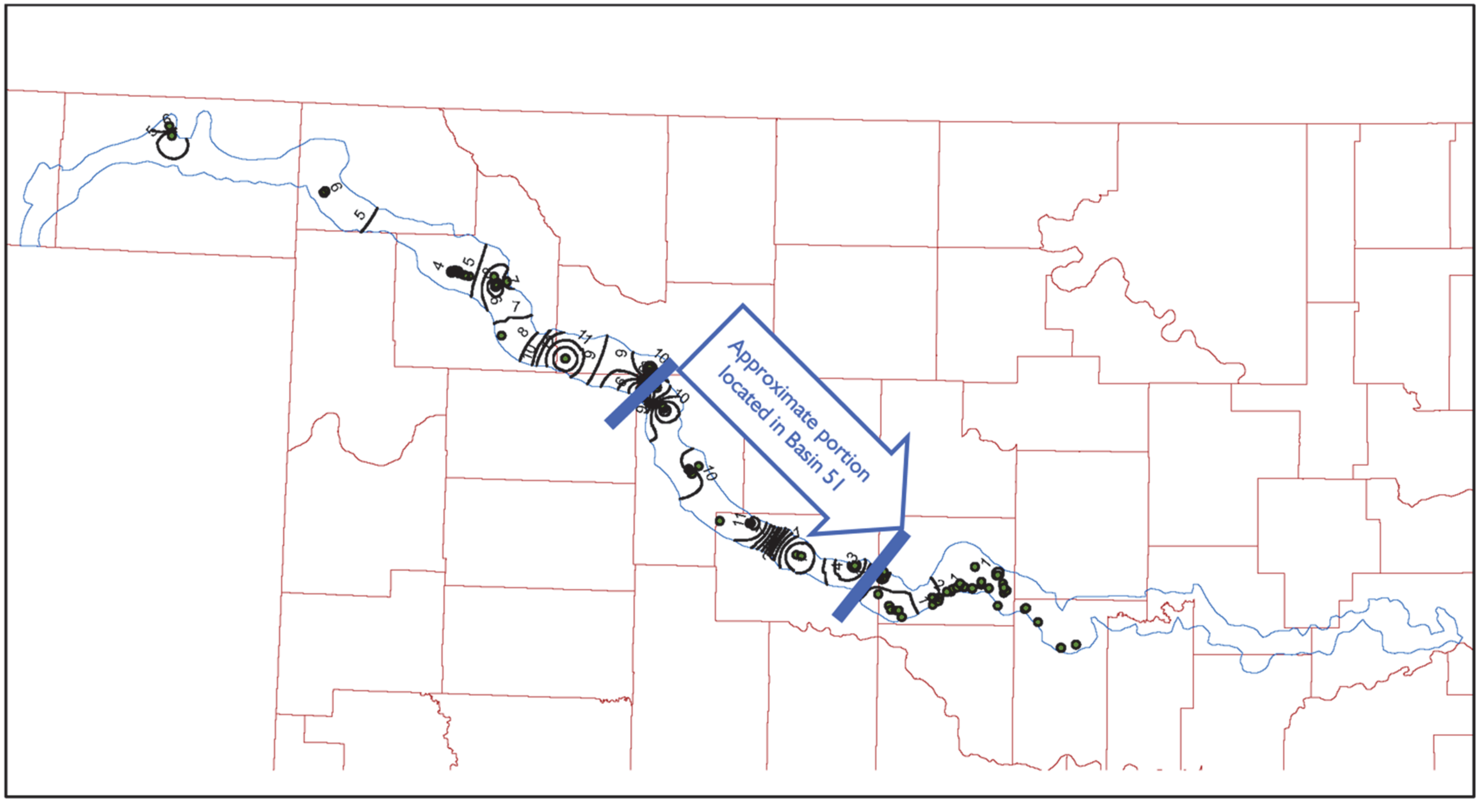
Perhaps the most prevalent of these water quality challenges in the basin is nitrates in the North Canadian River alluvial aquifer. ODEQ nitrate data for the aquifer are shown in Figure 3.5, along with an approximate indication of the upstream and downstream boundaries of Basin 51. Nitrates can be naturally occurring and/or can be introduced from non-point sources in other sources in the watershed.

The federal maximum contaminant level for nitrate in drinking water, per the Safe Drinking Water Act, is 10 mg/L as N. Oftentimes, as has been observed in Watonga, wells within a single well field will have a range of nitrate concentrations, and concentrations can vary seasonally or from year to year. Watonga has found that prolonged use of a well can sometimes result in increased nitrate levels, but rotating and resting individual wells and blending several wells has proven to be a successful management strategy without treating for nitrate removal.

As demands increase, utilities using the North Canadian alluvial aquifer could potentially see nitrate levels continue to rise, and may have fewer options to rotate wells or blend water produced from these wells with other sources. At that point, the water provider could face a decision between seeking out new fresh water supplies from alternate sources or finding a way to utilize the "MQW" source with elevated levels of nitrates. Options could include finding non-potable uses for the water (i.e., uses that do not require low levels of nitrates), or treating for nitrates to comply with federal drinking water quality requirements.

Treatment technologies are rapidly evolving to better facilitate the use of MQWs with elevated levels of nitrates. Historically, ion exchange or reverse osmosis (RO) systems have been available for nitrate removal – physically separating the nitrate contaminant from the water. For example, the City of Brighton, Colorado installed an RO-based treatment system to treat source waters impacted by nonpoint source contributions of nitrates in the early 1990s. However, these traditional methods come with significant capital and operating costs, generate a waste stream that can be problematic and costly to dispose, and in the case of RO, the process can be energy-intensive and complex to operate.

Newer technologies are focusing on the use of biologically active treatment reactors to convert nitrates to nitrogen gas, much like a biological process is used at a WRF to change nitrate to nitrogen gas. As a result, operating costs can be significantly lower, and there is no concentrated waste stream or "brine" to dispose. Biological treatment technologies have started to be adopted in parts of central California where nitrates in source waters, coupled with limited alternatives for sources of supply and the region's extended severe drought, have made it even more attractive relative to traditional technologies.



Legend

- N. Canadian Wells
- N. Canadian Boundary
- County
- N. Canadian NO3 Contours

50 25 0 50 Miles

Map Source: Oklahoma Department of Environmental Quality
http://www.deq.state.ok.us/wqdnew/groundwater/aquifer_maps/current_alluvial_nitrate_maps/n_canadian_no3.pdf

ArcMap generated 1 mg/L contours

NITRATE CONCENTRATIONS IN THE NORTH CANADIAN RIVER WATERSHED

FIGURE 3.5

OWRB/USACE TULSA DISTRICT
WATER FOR 2060 HOT SPOT BASIN MARGINAL QUALITY WATER ANALYSES

In 2011, the American Water Works Association (AWWA) Inorganic Contaminant Research and Inorganic Water Quality Joint Project Committees published a review and comparison of treatment technologies for nitrate treatment ("An Assessment of the State of Nitrate Treatment Alternatives," AWWA, June 2011). The committees' findings on five major categories of nitrate treatment technologies for potable water are summarized below. With the exception of chemical denitrification, all types of treatment were identified as being proven for full-scale implementation.

- Ion exchange: Physical removal of nitrate to waste stream, with rapid startup time and typical water recovery of 97 percent. Potentially capable of multiple contaminant removal, but can have high chemical use, generates waste brine requiring disposal, and has potential for disinfection byproduct (DBP) formation.
- Reverse osmosis: Physical removal of nitrate to waste stream, with rapid startup time and typical water recovery of 85 percent. Capable of multiple contaminant removal and desalination, but can be subject to membrane fouling and scaling, is operationally complex, generates brine requiring disposal, and has high energy demand.
- Electrodialysis: Physical removal of nitrate to waste stream, with rapid startup time and typical water recovery of 95 percent. Capable of multiple contaminant removal and desalination, but has high energy demand, is operationally complex, and requires disposal of waste product.
- Biological denitrification: Biological reduction of nitrate, with days or weeks required for startup and water recovery rates approaching 100 percent. Potentially capable of multiple contaminant removal and avoids brine disposal challenges, but may have higher monitoring needs, may be sensitive to environmental conditions, and may have other implications on drinking water quality.
- Chemical denitrification: Chemical reduction of nitrate, with rapid startup time. Not demonstrated at full-scale. Potentially capable of multiple contaminant removal and avoids brine disposal challenges, but is not proven for consistent performance.

Since the report was published, biological treatment technologies have continued to develop at a fast pace, and have been recognized in particular for their ability to treat for a broad spectrum of contaminants in a single reactor, while offering benefits of lower operating costs and no concentrated waste product.

5.3 Potable Water Reuse

Irrigation and other non-potable applications are often the most feasible water reuse options for initial implementation, due to the relatively low water quality necessary to safely put the locally-available MQW to beneficial use. With irrigation, there is relatively low risk of human ingestion or other significant exposure to recycled water, and proper controls can be put into place to mitigate risks of potential cross-connections with potable water distribution system piping. Accordingly, the water can be treated to standards that are below potable quality. As demonstrated above for communities in Basin 51, non-potable water reuse can offset significant quantities of fresh water use.

However, the seasonality of irrigation-dominated non-potable water reuse systems tends to underutilize the available treated effluent resource. While the resource is available at a nearly constant year-round flow rate (driven by indoor water use), there is little or no irrigation demand in winter months across most of Oklahoma. Seasonal storage sized to store wintertime flows for use in the peak irrigation season is typically impractical from both economic and land use perspectives.

Potable reuse refers to the practice of intentionally augmenting drinking water supplies with recycled water. “De facto” reuse is the unplanned but widely prevalent augmentation of potable water supply sources with recycled water that happens when an upstream community discharges into a receiving water used for potable supply by downstream communities. In fact, the vast majority of surface water and alluvial groundwater resources across Oklahoma today are in effect part of a de facto reuse system. The WateReuse Foundation developed a public outreach video that provides a simple, yet factual and modern view of the urban water cycle, available at https://www.watereuse.org/foundation/ways-of-water.

The intentional, planned augmentation of supplies with recycled water is becoming more widely implemented across the U.S. in three distinct ways:

- Indirect potable reuse (IPR), via surface water augmentation.
- IPR via groundwater augmentation.
- Direct potable reuse (DPR).

Both IPR and DPR systems use a multiple-barrier approach to treatment to reliably assure human health protection. The primary difference between IPR systems and DPR systems is that in an IPR system, recycled water is first discharged to a natural body of water, sometimes referred to as an “environmental buffer,” where it blends with native water before it is diverted and treated to potable standards for distribution to customers. For example, recycled water could be discharged to a river or reservoir, blended with the native surface water supplies, and diverted downstream through a surface diversion or riverbank filtration wells. Alternatively, recycled water could be percolated into the groundwater or directly injected into an aquifer, allowed to travel some time and distance through the aquifer, and recovered for potable supply through wells. The environmental buffer provides storage, transport, and dilution, and may provide an additional treatment barrier for some compounds.

IPR systems have been safely and beneficially used to increase the reliable yield of surface water and groundwater supplies in the U.S. for many years. For example, the Upper Occoquan Service Authority in Centreville, Virginia has supplied highly treated recycled water since 1978 to Occoquan Reservoir, which is used as a drinking water supply source by the Fairfax County Water Authority. California’s Orange County Water District has operated its Groundwater Replenishment System since 2008, billed as the world’s largest water purification system for potable reuse, by treating up to 70 mgd of water to potable quality through advanced treatment processes, then injecting it into the local aquifer to recharge potable water supplies. And in 2010, the City of Aurora, Colorado initiated operations of its Prairie Waters Project, which diverts effluent-dominated supplies from the South Platte River through riverbank filtration wells to an advanced potable water treatment process, after which it is blended with treated water from mountain reservoir supplies. Countless other IPR projects are operating successfully today.

DPR does not include the use of an environmental buffer, instead taking water from a WRF and conveying it directly as source water for further treatment at an advanced water treatment facility where it will be treated to potable standards. Typically, this supply will be blended with other traditional sources of supply either before, during, or after potable treatment. The use of an “engineered storage buffer” in combination with advanced monitoring technologies replaces the environmental buffer inherent to IPR systems. This provides the ability to monitor for, and respond to, process failures to assure that potable standards are being met at all times in water being sent to distribution.

Until only very recently, DPR was not practiced in the U.S. The only globally-operational DPR system until recent years was in Windhoek, Namibia, which started operations in 1968. Extended severe drought, coupled with advances in technology and public perception, drove changes in the DPR landscape in the U.S.

The Colorado River Municipal Water District in Big Spring, Texas initiated operations of the first DPR system in the U.S. in spring 2013. Its Raw Water Production Facility uses a series of advanced treatment processes to treat recycled water for blending with other traditional sources for potable water treatment. The City of Wichita Falls, Texas implemented an interim Emergency DPR Project in July 2014 to mitigate extreme drought conditions, after which it plans to transition to an IPR system. The Village of Cloudcroft, New Mexico is currently constructing a DPR system to increase the reliability of its community’s water supplies. Other DPR systems around the country are in various stages of planning and design.

In Oklahoma, there are no operational IPR or DPR systems, but potable reuse is actively being considered by many communities. Norman’s 2060 Strategic Water Supply Plan calls for the vast majority of its projected growth in water demand to be met with an IPR project. Norman’s plan calls for augmenting Lake Thunderbird with highly-treated effluent from its WRF, then diverting and treating that water from Lake Thunderbird much as it diverts and treats water from Lake Thunderbird today. The plan calls for the addition of ozonation and biologically-active filtration at Norman’s WRF to address trace organics in the recycled water. Edmond’s water and wastewater master plan calls for similar supply augmentation in the long-term, where Arcadia Lake will be augmented with recycled water to increase its reliable yield for water supply. And recently, the City of Oklahoma City announced that it is investigating augmentation of Lake Hefner supplies with recycled water to increase the reliable yield of its North Canadian River source.

OWRB and ODEQ are working together to develop a regulatory structure for surface water IPR in Oklahoma to facilitate projects such as the Norman, Edmond, and Oklahoma City concepts described above. As Oklahoma’s supplies become further stressed by demands placed on them and periodic drought, potable reuse is almost certain to become more prevalent across the state. In the meantime, Basin 51 communities and water providers across the state can initiate water reuse with non-potable uses, and continue to monitor developments in regulations, public perception, and technology that will advance the potential for potable reuse implementation.