Application for a WaterSMART Water Reclamation Research Grant under the Title XVI Water Reclamation and Reuse Program

for the

City of San Angelo Potable Water Reuse Research Pilot Study

April 19, 2016

Research Study Name:	City of San Angelo Potable Water Reuse Research Pilot Study
Applicant:	City of San Angelo, Texas
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1 Technical Proposal

1.1 EXECUTIVE SUMMARY

Date:	March 30, 2016
Applicant Name:	City of San Angelo
Service Area:	City of San Angelo and wholesale customers
County:	Tom Green
State:	Texas

The City of San Angelo (City) provides water and wastewater service to customers within the City. The City also supplies water to wholesale customers including the U.S. Air Force (Goodfellow Air Force Base), the City of Miles, Concho Rural Water Corporation, and Millersview Doole Water Supply Corporation. The City is located in West Central Texas in the Region F water planning area. The 2016 Region F Water Plan recommends implementation of a reuse project for the City by 2020.[1] The recommended strategy was tentatively identified as a direct reuse project, pending the outcome of a feasibility study which has since been completed.

The City has conducted two studies (described in Section 1.2.1) to evaluate potential reuse alternatives, and the recommended alternative is direct potable reuse[2] (DPR). The City proposes to use funding from a WaterSMART Water Reclamation Research Grant to perform bench scale testing, pilot scale testing, and a deep well feasibility study for the DPR project. The purpose of the proposed research is to enable full-scale implementation of DPR by evaluating approaches to maximize water recovery; verify the performance of advanced treatment processes; and assess the viability of reverse osmosis (RO) concentrate disposal using deep injection wells at an inland location. The associated bench scale and pilot scale testing are also necessary to gain Texas Commission on Environmental Quality (TCEQ) approval for the full-scale project and demonstrate that the treatment scheme is protective of public health. In addition to regulatory and standard operational pilot study goals, the research will advance the industry knowledge related to implementation of DPR projects with a focus on three specific issues: 1) evaluation of the benefit of including biological nutrient removal upstream of membrane treatment to improve RO recovery; 2) evaluation of pretreatment processes and/or concentrate treatment to improve RO recovery and concentrate water quality and 3) evaluation of the impacts of increasing RO recovery on concentrate quality and disposal options. The proposed research represents the first step toward full-scale implementation of the recommended DPR project. A description and discussion of the proposed research study are presented in the following sections.

[1] Freese and Nichols, Inc. and LBG-Guyton Associates, Inc: 2016 Region F Water Plan, prepared for the Region F Water Planning Group, November 2015.

[2] Direct potable reuse is the introduction of reclaimed water either directly into the potable water system or into the raw water supply entering a drinking water treatment plant, without the use of an environmental buffer.

1.2 TECHNICAL RESEARCH STUDY DESCRIPTION

1.2.1 Background

The City of San Angelo is located in Tom Green County at the junction of the North and South Concho Rivers in West Central Texas. The City is located at the southwestern edge of the Edwards Plateau and the northeastern edge of the Chihuahuan Desert and has a semi-arid climate. San Angelo's current water supply comes from the following surface water and groundwater sources (Figure 1):

- Surface water: O.H. Ivie Reservoir; Twin Buttes Reservoir (a Bureau of Reclamation project); Lake Nasworthy; E.V. Spence Reservoir; O.C. Fisher Lake (a U.S. Army Corps of Engineers project); South Concho River
- Groundwater: Hickory Aquifer in McCulloch, Concho, and Menard Counties

The City's surface water supplies have been in an extended hydrological drought since at least 1998, the last time O.H. Ivie Reservoir was full (Figure 2), and the total water volume stored in these surface water supplies is very low. In addition, the firm yield of the City's existing water supplies is not sufficient to meet the City's future water demands under drought-of-record conditions (see discussion on page 9).

The treated wastewater effluent (reclaimed water) produced at the City's Water Reclamation Facility (WRF) is another resource available to the City for municipal water supply. The reclaimed water supply is local, sustainable, and reliable, and the City has direct control of this supply without the need for additional water rights. The 2016 Region F Water Plan recommends that San Angelo implement a reuse project by 2020. The recommended strategy was tentatively identified as a direct reuse project, pending the outcome of the 2015 Reclaimed Water Alternatives Evaluation,[3] which has since been completed.

In two studies, the 2006 Feasibility Study[4] and the 2015 Reclaimed Water Alternatives Evaluation, the City has evaluated the feasibility of various reuse alternatives. The 2006 Feasibility Study considered direct non-potable reuse and indirect potable reuse (IPR) through augmentation of O.C. Fisher Lake and Twin Buttes Reservoir with reclaimed water, recommending that the City pursue augmentation of Twin Buttes Reservoir with reclaimed water.

Since the 2006 Feasibility Study, a substantial amount of research has been carried out related to the water quality characteristics, treatability, and public perception issues associated with potable reuse. Furthermore, in the past 6 years, DPR has become a focus of ongoing research and has been implemented by two utilities in Texas. These advancements in research and experience provided the opportunity to evaluate additional potable reuse alternatives.

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[3] Alan Plummer Associates, Inc.: Reclaimed Water Alternatives Evaluation, prepared for the City of San Angelo, June 2015.

[4] Alan Plummer Associates, Inc. in association with SKG Engineering, LLC and LBG-Guyton Associates: City of San Angelo Reclaimed Water Feasibility Study, prepared for the City of San Angelo, February 2006.

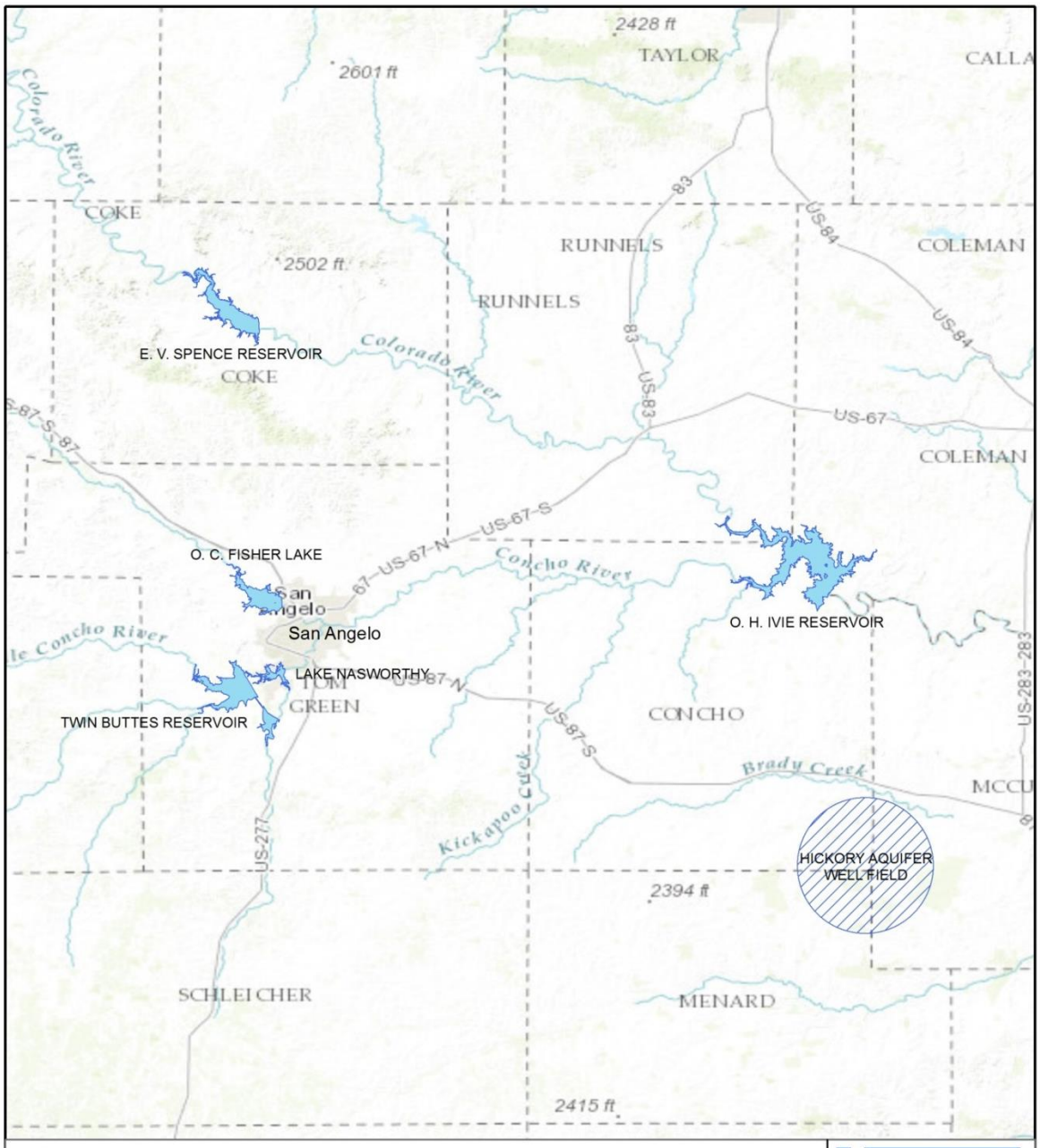
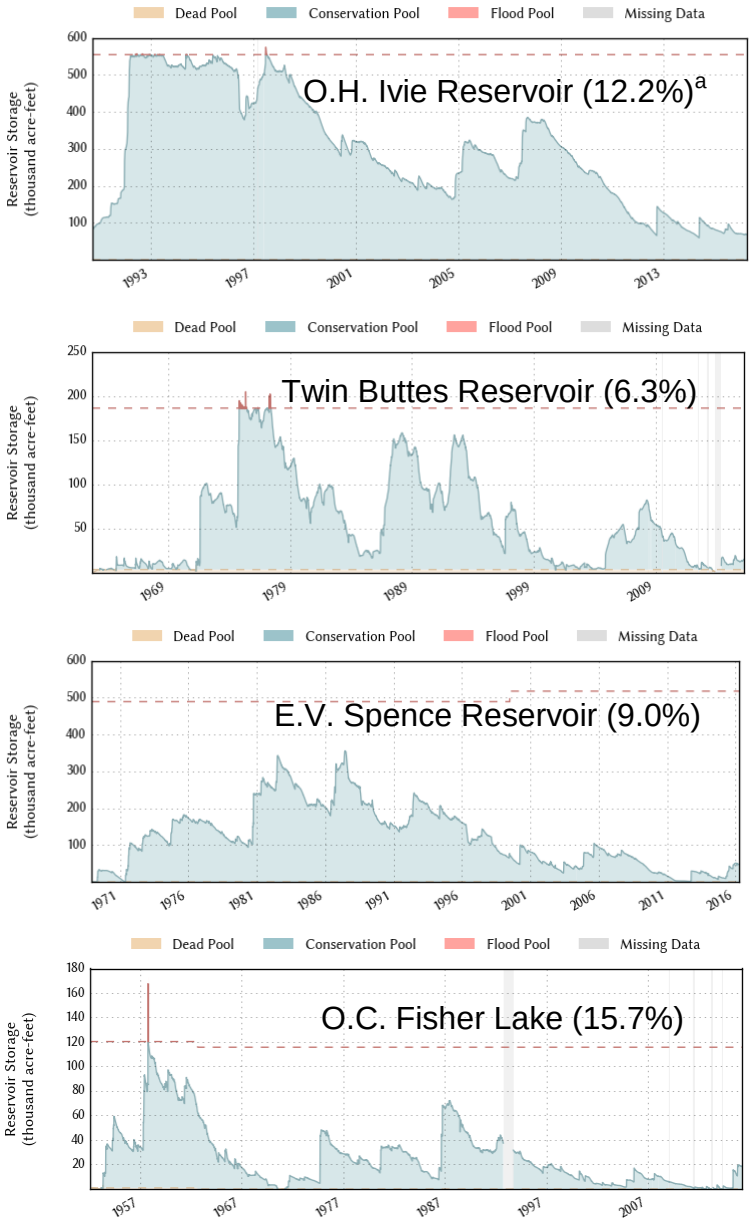


Figure 1
San Angelo Existing Water Supplies

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS
1320 S. University Drive
Suite 300
Fort Worth, Texas 76107
(817) 806-1700
www.apaienv.com

F:\projects\0858\003-01\2-0 Wrk Prod\2-9 GIS\MXD\Figure 1 Water Supplies.mxd 4/6/2016

Figure 2: Historical Storage in Selected San Angelo Water Supplies



[a] Quantity in parentheses is the percent full as of April 3, 2016. Graphs and information from http://waterdatafortexas.org.

After consideration of DPR and augmentation of Twin Buttes Reservoir and Lake Nasworthy with reclaimed water, the 2015 Reclaimed Water Alternatives Evaluation recommended that the City pursue DPR. Although the DPR scenarios generally had higher unit costs than the IPR scenarios, the challenges associated with securing water rights for the IPR scenarios were considered to be a significant hurdle to implementing a reclaimed water project within the next 5 years. In addition, the improved drinking water quality obtained through full treatment with RO for the DPR scenarios adds significant value.

The City proposes to use funding from the Water Reclamation Research grant program, supported by matching funds, to perform bench scale testing, pilot scale testing, and a deep well feasibility study for the recommended DPR project. The bench scale testing and pilot

scale testing includes extensive water quality and equipment performance evaluations required by the TCEQ. The testing also provides process design information for the proposed advanced treatment facility and upgrades to the City's existing Water Reclamation Facility (WRF). The deep well feasibility study will identify potential locations, strata, and water quality limitations for deep well injection of RO concentrate. Bench scale testing, pilot scale testing, and a deep well feasibility study will be performed by completing the tasks described in the following sections.

1.2.2 Overview

The purpose of the proposed research is to enable full-scale implementation of DPR by evaluating approaches to maximize water recovery, verifying the performance of advanced treatment processes, and assessing the viability of reverse osmosis (RO) concentrate disposal using deep injection wells at an inland location. The associated bench scale and pilot scale testing are also necessary to gain Texas Commission on Environmental Quality (TCEQ) approval for the full-scale project and demonstrate that the treatment scheme is protective of public health.

The overall DPR project is anticipated to include the following elements:

1. Improvements to San Angelo's existing WRF to remove nutrients from the WRF effluent;
2. A new advanced treatment system that integrates multiple treatment processes to provide reliability and robustness and to further remove contaminants from the treated wastewater effluent;
3. Conveyance facilities for transferring the advanced treated water to the water treatment plant for raw water augmentation at the City's existing water treatment plant (WTP);
4. Improvements to the City's WTP for raw water augmentation and blending, water treatment, and water storage; and
5. RO concentrate reduction, conveyance and disposal facilities.

The research project is based on the following assumptions:

1. The phase I design WRF and reclaimed water flowrate is 9 MGD (initial design).
2. The phase II design WRF and reclaimed water flowrate is 12 MGD (future expansion).
3. The bench and pilot testing scope addresses the following components:
    i. WRF biological nutrient removal
    ii. Cloth media disk filter
    iii. Hollow fiber membrane filtration
    iv. Reverse osmosis
    v. UV advanced oxidation process (UV/AOP)
    vi. Alternatives to further enhance the RO recovery such as lime or caustic softening, enhanced coagulation, solids recirculation processes to reduce organics and hardness, and concentrate treatment.
    vii. RO concentrate disposal using turbo mist evaporators in conjunction with evaporation ponds
    viii. RO concentrate disposal using deep wells
    ix. Post stabilization of the advanced treated water will be addressed by bench top blending and computer modeling.
4. One goal of this research is to simulate the future WRF effluent quality to be treated by the planned advanced treatment system. Since the existing WRF is not a BNR process,

the pilot study includes a pilot scale biological nutrient removal system that provides nitrification, partial denitrification, and phosphorus removal. The target effluent phosphorus goal for the BNR portion of the pilot study is less than 1 mg/L total phosphorus.

5. Project schedule and pilot study design are based on using a sequenced approach to pilot testing (as opposed to pilot testing multiple process alternatives in parallel) and conducting process evaluations and selections as piloting progresses.
6. Coordination with the TCEQ for approval of the pilot study protocol and submittal of a pilot report is included in the scope.

1.2.3 Task 1 – Bench Scale Testing

The tasks associated with bench scale testing are described below.

A. Identify processes that can be bench scale tested either at City facilities or by sending water samples to offsite locations. Determine the volume and nature of the samples necessary, the water quality parameters to be tested, and the process parameters such as chemical dosages to be tested.
B. Coordinate with equipment suppliers, the City, and testing labs to accomplish the bench scale testing. Bench scale testing is anticipated for the processes listed below.
    1. Onsite coagulant jar testing, softening jar testing, and acid feed requirements
    2. UV/AOP
    3. Chlorine disinfection
    4. Raw water blending and stabilization
C. Prepare test protocols and test result summaries of the bench scale testing. Based on the results, adjust pilot test protocol and processes.

1.2.4 Task 2 – Pilot Testing

The majority of work for this research study is associated with the advanced treatment pilot study. The purpose of the pilot study is to conduct research on the treatment capabilities, process loading rates, and operational aspects for the advanced treatment equipment proposed for the full scale DPR facility and for the proposed WRF upgrades. These parameters include detention times, recycle rates, chemical dosages, membrane flux rates, backwash intervals, cleaning requirements, and others. Additionally, the pilot study fulfills regulatory requirements from the TCEQ for the membrane filtration and RO components. The tasks associated with the field pilot testing are described below.

A. Select up to one conventional filter technology, up to four membrane filtration technologies, and one RO process configuration to evaluate during pilot testing. Design a pilot-scale biological nutrient removal (BNR) secondary treatment system in the unused, existing WRF chlorine contact basin. Develop testing sequences for the pilot study. Feed water for the advanced treatment pilot study will be effluent from the BNR system or the “reclaimed water”. [Completed.]
B. Develop a pilot test protocol for the above listed processes. Include flowrates, process loading rates, chemical dosages, cleaning requirements, sampling locations and associated constituents to be tested, sampling and testing frequency, test durations and sequences, online instrumentation with PLC and data storage and transmission, schedule, tanks, piping, and pumps required. Develop pilot test process schematics with piping sizes, valves, pumps and tanks needed. Develop a pilot test process and instrumentation diagram

(P&ID). Submit the protocol to the City for review and to the TCEQ for approval. Incorporate comments. [Completed.]

C. Obtain electrical requirements for components and develop a summary table showing loads, voltages, and power requirements. Coordinate with the City for power availability and locations. [Completed.]
D. Routinely monitor pilot study and obtain selected water quality data. This task is a joint effort between WRF staff, Alan Plummer Associates, Inc. (APAI), and subconsultants. Operators at the WRF are responsible for daily water quality sampling by collecting grab samples from specific locations and testing for parameters such as temperature, pH, turbidity, conductivity, hardness, total alkalinity, chorine residual, orthophosphate, and others. WRF staff also manually waste sludge from the BNR system at routine intervals and complete field logs of the advanced treatment equipment during each shift. APAI and/or a subconsultant will visit the pilot study site an average of two times per week during the pilot test to assist with operator training, monitor pilot study progress, review pilot study records, assist with pilot study process adjustments, and assist with equipment troubleshooting. [In progress.]
E. Prepare a table that summarizes the sampling and testing plan, including the number of and type of tests and the opinion of cost for testing. [Completed.]
F. Summarize pilot study results on a monthly basis over the duration of the pilot study. Review pilot study data weekly to determine if manufacturers are following the schedule detailed in the pilot study protocol and that pilot units are operating satisfactorily and as anticipated. Investigate deviations from anticipated results. [In progress.]
G. Perform an autopsy of up to four (4) membrane filtration modules and up to four (4) RO elements to assess the condition of the membranes and identify foulants.
H. Prepare a pilot study report consisting of a summary of water quality data, pilot process data, and an evaluation of the pilot study results.

1.2.5 Task 3 – Deep Well Disposal Feasibility Study

The purpose of this task is to evaluate the feasibility of deep well injection for RO concentrate to determine if the groundwater and geologic strata are compatible with the concentrate and regeneration waste water qualities and quantities, to determine treatment needs, and to determine the opinion of probable construction costs and other costs for deep well injection. Specific tasks associated with this scope item are described below.

A. Provide water quality assessment support. This will include potential water quality concentrations, solids loading, scaling, filtration requirements, etc.

B. Evaluate tradeoff between increasing RO recovery and disposal challenges related to increasing the scale forming tendency of the concentrate. Parameters of concern in the concentrate include sulfates, silica and hardness, among others. Determine if RO concentrate water quality will be compatible with the geologic strata at different RO process recoveries. Determine the maximum acceptable RO recovery that will allow deep well injection and the number of wells necessary.
C. Review data collected to date to assess potential injection intervals and ability to permit those injection intervals.
D. Provide refined cost estimate to construct the injection wells for the previously selected injection interval.
E. If required, provide cost estimates to install injection wells in alternate injection intervals.

1.2.6 Task 4 – Project Management, Meetings, and Site Visits

As discussed in Section 1.2.4, oversite of the pilot study will be a collaborative effort between San Angelo city staff, APAI, and subconsultants. Coordination meetings and site visits will be critical to the success of the research study.

A. Provide project management services to properly plan the work, sequence, manage, coordinate, schedule, and monitor the scope tasks and completion of the tasks.
B. Prepare a project management plan including scope, budget, schedule, communication, project team, and file organization.
C. Conduct internal team coordination meetings as required to accomplish the work.
D. Provide monthly status updates showing the percent complete for scope tasks and the issues, budget status, and schedule.
E. Conduct project site visits and review meetings.

1.2.7 Schedule

The schedule for the research study is as follows:

A. Contract with APAI signed on September 15th, 2015 and work began immediately;
B. Submission of the Pilot Study Protocol to TCEQ occurred on November 10, 2015;
C. Bench and Pilot Testing: Phase 1 began on March 9th, 2016 and is anticipated to end June 8th, 2016. Pilot Testing may be extended to allow for additional testing in Phases 2 and 3.
D. Pilot Study Report Submittal to San Angelo: within two months of completion of testing. The research will be completed by September 1, 2016, unless pilot testing is extended.

1.3 EVALUATION CRITERIA

Evaluation Criterion 1: Statement of Problems and Needs – 10 Points

Points will be awarded based on the presence of watershed-based water resource management problems and needs for which water reclamation and reuse may provide a solution.

(1) If the proposed research study aims to address the needs of a specific applicant or locale, describe in detail the water resource management problems and needs in the local area and explain how water reclamation and reuse may address those problems and needs.

(2) Identify the water supply imbalance that the research study will address for the area of responsibility of the applicant. Additional consideration will be given to proposals that explain how water supply imbalances in the area may be impacted by climate change, and/or if the research study will attempt to address projected climate change impacts in the area.

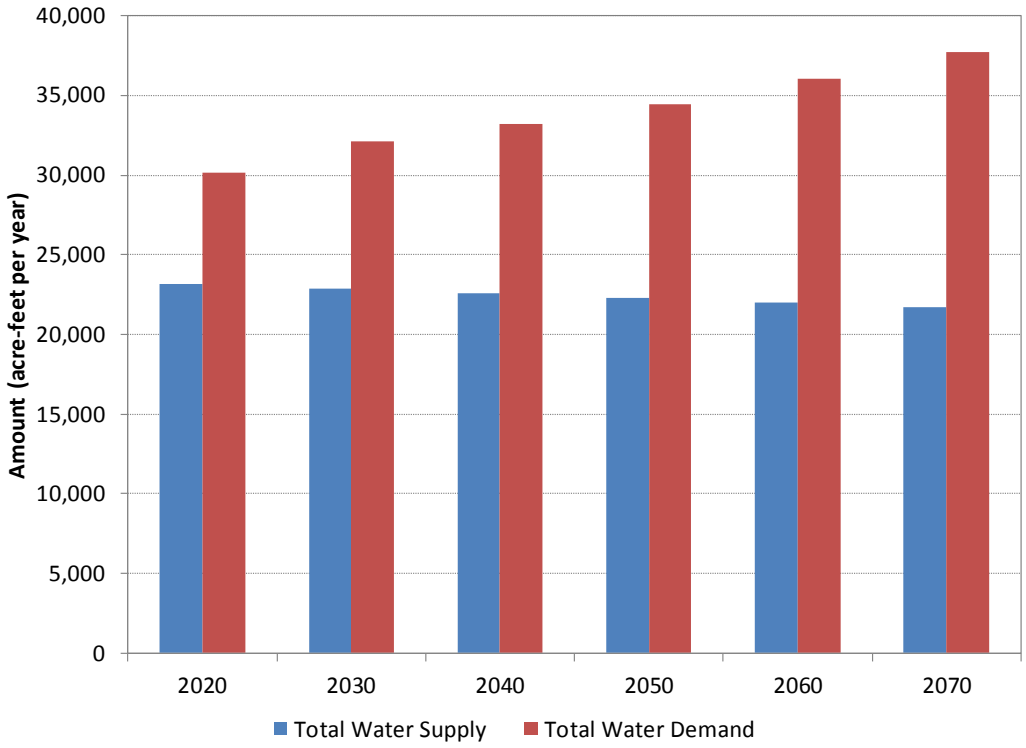
The City of San Angelo is located in West Central Texas in a semi-arid region. The City and its wholesale customers currently rely on both surface water and groundwater sources (Figure 1):

- Surface water: O.H. Ivie Reservoir; Twin Buttes Reservoir (a Bureau of Reclamation project); Lake Nasworthy; E.V. Spence Reservoir; O.C. Fisher Lake (a U.S. Army Corps of Engineers project); South Concho River
- Groundwater: Hickory Aquifer in McCulloch, Concho, and Menard Counties

The City's surface water supplies have been in an extended hydrological drought since at least 1998, the last time O.H. Ivie Reservoir was full (Figure 2), and the total water volume stored in these surface water supplies is very low. For each of the City's surface water supplies, the current drought represents a new and ongoing drought of record. As a result, the estimated firm yields for these supplies have been revised steadily downward since the late 1990s.

Considering the water supplies currently available to the City and the water demands (including wholesale customers), the 2016 Region F Water Plan projects that the City will experience a shortage under drought of record conditions of 6,769 acre-feet per year (ac-ft/yr) by 2020, increasing to 15,794 ac-ft/yr by 2070 (Figure 3).

Figure 3: Comparison of Water Supply and Demand for San Angelo



From the 2016 Region F Water Plan.

The reclaimed water produced at the City's Water Reclamation Facility (WRF) is a resource available to the City for municipal water supply. The reclaimed water supply is local, sustainable, and reliable, and the City has direct control of this supply without the need for additional water rights. Using the reclaimed water for a direct potable reuse project would help to address the projected shortage. Phase 1 of the proposed DPR project would provide up to 7.2 MGD (8,070 ac-ft/yr) of treated drinking water, and Phase 2 would provide up to an additional 2.4 MGD (2,690 ac-ft/yr).

The steady decline in storage in the City's surface water supplies since the late 1990s has called attention to the impact that changing climate conditions may have on surface water supplies. While climate change has not been explicitly accounted for in the 2016 Region F Water Plan, the Plan accounts for the inherent uncertainty in the predictability of both supply and demand by recommending multiple water management strategies that would result in a surplus of water supply for the City. The recommended DPR project is part of the set of recommended water management strategies that implicitly addresses the impact of climate change on the City's water supplies.

(3) If the proposed research study aims to address broader needs of the industry in terms of technology or practices, describe these needs as they occur on a watershed, regional, and/or national scale.

Previous DPR projects in Texas (Big Spring and Wichita Falls, Texas) have relied on the discharge of RO concentrate into a nearby saline stream for concentrate disposal. The preliminary feasibility study for San Angelo concluded that surface discharge of RO concentrate is unlikely to be feasible due to the absence of a nearby saline stream. The feasibility study identified deep injection wells as a possible method of concentrate disposal for the City. Deep well injection is used by some RO facilities treating groundwater supplies; however, reclaimed effluent water quality often differs significantly from groundwater quality. For example, reclaimed water in West Texas can contain elevated concentrations of organics, hardness, silica, and sulfates that may not be present in traditional brackish groundwater supplies. The effects of injecting RO concentrate from a facility treating municipal effluent are not well understood. Accordingly, the research team, which includes a deep well injection consulting firm, will assess the feasibility of injecting RO concentrate from a DPR process into a deep well. The results from this research study will advance the understanding of deep well injection as a concentrate disposal option for DPR projects. The researchers anticipate that the study results will provide valuable information for future DPR projects nationwide.

Another knowledge gap that this research study will address is optimizing advanced treatment processes to minimize RO concentrate. As discussed previously, surface discharge of RO concentrate in San Angelo is not a viable option, so an alternative disposal method must be used such as deep well injection or surface evaporation. These disposal methods can be costly, so one goal of this research study is to minimize the volume of concentrate from the RO process. This will be investigated during the research study using two strategies. The first strategy uses pretreatment to increase RO recovery. The RO pilot unit is currently operating at a recovery of 88 percent. The RO pretreatment strategy includes a pilot scale biological nutrient removal (BNR) system at the water reclamation facility. One of the primary functions of the BNR step is to decrease the phosphorus concentration in the RO feed. Phosphorus is one of the limiting factors for RO system recovery for this water source. The full-scale implementation of BNR would provide the first known DPR treatment system to incorporate a biological phosphorus removal treatment step upstream of the advanced treatment processes. Additional pretreatment processes, such as coagulation and lime soda softening, may also be investigated to assess impacts on water quality and membrane process performance.

Secondly, this research study will evaluate the feasibility of further reducing the volume of RO concentrate by treating the RO concentrate stream with a process such as lime softening. The treated concentrate could then go through an additional volume reduction step using a brine concentrator. The study will also evaluate the need for concentrate treatment to provide a water quality suitable for deep well injection. The results of the research will enable a comparison of the tradeoff between reducing the volume of RO concentrate and increasing the overall cost of treatment. The results from these two evaluations will be valuable for future municipalities interested in DPR who have to weigh capital cost against the volume of water produced in the advanced treatment process and concentrate disposal considerations.

Evaluation Criterion 2: Water Reclamation and Reuse Opportunities – 15 points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will explore opportunities for water reclamation and reuse within and outside the research study area.

(1) Describe the source(s) of water that will be investigated for potential reclamation, including impaired surface or ground waters.

The source of water to be investigated for potential reclamation is treated effluent from the City's WRF. The WRF is a conventional activated sludge plant that uses primary clarifiers, aeration basins, and secondary clarifiers to accomplish treatment for land application of the effluent. As part of the recommended DPR project, the WRF will be upgraded to improve effluent water quality. The 2015 Reclaimed Water Alternatives Evaluation recommended upgrading the WRF to a biological nutrient removal process and adding tertiary treatment with cloth media filters.

Effluent from the WRF typically has a high concentration of total dissolved solids (TDS). Sampling during the first stages of the pilot study showed an average TDS concentration of 976 mg/L; however, historical TDS concentrations in the effluent have been greater than 2,000 mg/L. As the concentration of TDS increases, the pressure required to treat water through RO also increases. The variability of the effluent quality increases the need for operational flexibility at the full scale. The pilot study will assess water quality over time and correlate the water quality to system performance. The results of this investigation will have relevance for other areas of the western US with similar water quality characteristics and variability.

(2) Describe how the research study will help to eliminate obstacles for using reclaimed water as a supply within and/or outside the area of responsibility of the applicant.

Initial obstacles to incorporating DPR into the City's potable water supply include verifying the performance of advanced treatment processes and identifying viable options for RO concentrate disposal. These items, in conjunction with completing TCEQ testing requirements, are obstacles that represent opportunities for advancing the knowledge base relative to DPR. The proposed research study will provide data to achieve the pilot study objectives by incorporating a combination of bench scale testing, pilot scale testing, and a deep well injection feasibility study. Public acceptance of DPR is also an obstacle for DPR projects. The research results can be used to demonstrate that the advanced treatment process produces water that meets or exceeds current drinking water standards and improves the overall water quality relative to parameters such as TDS.

(3) Describe how the research study will expand a water market and promote implementation of new uses or expand existing uses for reclaimed water (e.g., environmental restoration, fish and wildlife, groundwater recharge, municipal, domestic, industrial, agricultural, power generation, and recreation).

The proposed research study will expand the water market for reclaimed water and help promote a new municipal use of reclaimed water (DPR) by removing the initial obstacles to DPR described in the previous section.

(4) Describe how the research study will help establish or expand a water market to use reclaimed water outside your specific locale, including providing regional or West-wide benefits.

The research study will help to establish the reclaimed water market for potable purposes outside of San Angelo, Texas by expanding the knowledge of treatment technologies used in the DPR process. This research study incorporates extensive water quality sampling to demonstrate the robustness of the treatment processes in removing specific constituents. Another goal for this research study is to involve the community of San Angelo in the pilot study in order to improve the public perception of reclaimed water. Historically, the general

public opinion of potable reclaimed water has been negative. This perception is beginning to change, however, and this research study aims to further reduce these social barriers to implementing DPR at a national level.

Evaluation Criterion 3: Description of Potential Alternatives – 15 points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will evaluate water supply alternatives or technology implementation options that support water reclamation and reuse of non-traditional water supplies.

(1) Describe objectives of the proposed research study and how the proposed research is innovative in advancing water reclamation knowledge and/or practices relative to existing knowledge and/or standard practices. References and literature citations should be provided, as applicable.

The City proposes to use funding from a WaterSMART Water Reclamation Research Grant to perform bench scale testing, pilot scale testing, and a deep well feasibility study for the recommended DPR project. The purpose of the proposed research is to enable full-scale implementation of DPR by evaluating approaches to maximize water recovery, verifying the performance of advanced treatment processes, and assessing the viability of reverse osmosis (RO) concentrate disposal using deep injection wells at an inland location. The proposed research is part of a detailed evaluation of the recommended DPR water supply alternative and will identify technology implementation options for DPR in San Angelo.

As discussed above in Evaluation Criterion 1.3, DPR has been implemented at the full scale in a few locations; however, additional research is needed to further the knowledge base. For example, the concentrate from the aforementioned facilities is discharged into a nearby saline stream. This option is not available to San Angelo. Ocean discharge is another common method for concentrate disposal, but due to the location of San Angelo, this is not possible either. This research study is innovative because deep well injection of reclaimed water concentrate is not well understood. Additionally, the Bureau of Reclamation is currently working with the North Texas Municipal Water District and APAI to develop a concentrate disposal toolbox. The research is anticipated to benefit the toolbox development effort by providing additional information relative to concentrate injection at inland locations.

Additionally, this research study is innovative due to the assessment of pretreatment approaches upstream of the advanced treatment processes. A small portion (~120 gpm) of raw wastewater from the San Angelo collection system passes through the influent screens at the Water Reclamation Facility (WRF) headworks and is then diverted to a pilot scale biological nutrient removal (BNR) system. The BNR system is specifically targeting biological removal of phosphorus, which can limit the recovery in an RO system, as well as partial denitrification, among other benefits. Following treatment in the BNR system and chlorine addition, effluent is pumped to the advanced treatment pilot building where the water is further pretreated by a cloth media disk filter pilot unit before proceeding into the ultrafiltration pilot units. The research will help demonstrate the value of pretreatment in improving performance and recovery of the downstream RO treatment process. Additional testing may evaluate further pretreatment for the removal of organics and hardness upstream of the RO process.

(2) If applicable, describe alternative water reclamation measures or technologies that will be investigated as part of the research study.

Alternative water reclamation technologies investigated during this research study include: coagulation, chloramination, biological nutrient removal, cloth media filtration, polymeric ultrafiltration membranes, reverse osmosis, ultraviolet light disinfection with advanced oxidation processes, caustic softening, ion exchange softening, lime softening, and deep well injection. Four different ultrafiltration membranes are being tested to determine the membrane performance for this application. Three membranes are pressure type and one is a submerged vacuum membrane. The UV/AOP study includes the evaluation of both chlorine and hydrogen peroxide as oxidants. The other DPR facilities in Texas do not currently use chlorine in the full-scale UV/AOP reactors. Accordingly, the bench scale evaluation will provide valuable information on the viability of substituting chlorine for hydrogen peroxide as the UV/AOP oxidant in reuse applications.

(3) Describe any collaborators involved with the research and their respective roles.

A number of collaborators are involved in this research project. Enprotec / Hibbs & Todd, Inc. (eHT), an engineering firm with headquarters in Abilene, Texas, is a contributing partner on the project team. Dr. Steven Duranceau, PhD, P.E. from the University of Central Florida and James Vickers, P.E. with SPI Engineering both provided input during the formation of the pilot study protocol and the RO element preselection process. Avista Technologies will be performing autopsies on the RO elements at the conclusion of the pilot study to investigate fouling in the membranes. PB Energy Storage Services, Inc. is providing consultation for the deep well injection portion of the research study. Much of the water quality sampling will be performed by Eurofins and BioVir Laboratories in California. The pilot units for the research study were rented from Wigen Water Technologies, Evoqua Water Technologies, Aqua-Aerobic Systems, Inc, and Harn R/O Systems, Inc.

(4) Please describe the credentials, experience, and past performance of the research team. Alternatively, describe the process and criteria that will be used to select an appropriate, experienced research team.

David Gudal, P.E. is a principal and Water Treatment/Reuse Treatment group leader at Alan Plummer Associates, Inc (APAI) with more than 30 years of design experience. He specializes in water and wastewater infrastructure, as well as treatment facility design. David has served as the technical leader, project manager, or project engineer for numerous water treatment and wastewater treatment plant projects that have included analysis, detailed design, and construction services. He has been involved in six prior membrane pilot projects and the full scale design of multiple membrane treatment plants. David received his Bachelor's and Master's degrees in civil engineering from the University of Texas at Arlington.

Ellen McDonald, PhD, P.E. is a principal at APAI where she leads APAI's water resources group. Ellen has more than 25 years of experience in the areas of water resources planning, water reuse, water quality modeling and water and wastewater system modeling and planning. Ellen recently led a project funded by the Texas Water Development Board and 11 water utility sponsors to develop a Direct Potable Reuse Resource Document that provides state of the art information related to implementation of DPR projects. In addition, Ellen was a member of the expert panel tasked with developing a national framework for direct potable reuse through the WateReuse Association and the National Water Research Institute. Ellen is recognized

nationally as a leading expert in water reuse and currently serves as president of WateReuse Texas. She also serves on the board of directors of the WateReuse Association. Ellen received her Bachelor of Science in civil engineering from Bucknell University, and her Master of Science and Doctorate in water resources engineering from Stanford University.

Alan Davis, P.E. leads APAI's water reuse treatment team and has professional engineering experience in the planning, process design, detailed design, and construction administration of water and wastewater treatment facilities. His water treatment design projects have included hydraulic analysis, conventional and high-rate clarification, low-pressure membrane design, ion exchange, UV advanced oxidation, conventional disinfection, hypochlorite generation, and taste and odor design. Alan received a Bachelor of Science in civil engineering from the University of Texas at Austin and his Master of Science in engineering at the University of Iowa.

Christopher Boyd, PhD, P.E. is a project engineer at Alan Plummer Associates, Inc. in Fort Worth, Texas. Dr. Boyd has worked on a variety of water treatment and reuse projects and currently serves on the Board of Directors for the South Central Membrane Association (SCMA) and the American Membrane Technology Association as the SCMA Liaison. He has also served as a technical peer reviewer for the Journal of Membrane Science and the journal Desalination and Water Treatment. Dr. Boyd received his Bachelor's, Master's and Doctoral degrees in Environmental Engineering from the University of Central Florida in Orlando, FL.

Scott Hibbs, P.E., President of eHT, has over 30 years of experience as a water resources consultant for many private, public and governmental entities in Texas. He has extensive experience analyzing and developing resource alternatives for vital water supply, treatment and storage projects. He directs multi-discipline and multi-organizational teams for regional water and wastewater projects, in addition to overseeing construction management and providing hands on training for operations and maintenance personnel. Scott received his Bachelor's in civil engineering from Texas Tech University.

Josh Berryhill, P.E., project manager at eHT, has considerable experience in the design, operation, and analysis of water and wastewater treatment systems. He has experience in the piloting, design, construction, and operation of water treatment plants, including reverse osmosis systems for groundwater and seawater, chemical feed systems, sedimentation, microfiltration, dual- and tri-media filtration, clear wells and plant water and high service pumping systems. He also has experience in the design, construction and operation of wastewater treatment plants, including pump stations, preliminary screening, extended aeration basins, activated sludge aeration basins, biological nutrient removal systems, sequencing batch reactors, clarification, tertiary filtration, chemical and UV disinfection, anaerobic digestion systems, plant water and reuse systems. Josh obtained his Bachelor's and Master's degrees in environmental engineering from Texas Tech University.

Jordan Hibbs, P.E., project manager at eHT, has eight years of experience in the design and management of water, wastewater, drainage, and site development projects for municipal clients. He has experience designing and evaluating water treatment plants, water distribution systems, wastewater treatment plants, wastewater collection systems and storm drainage systems. Jordan regularly coordinates with state and federal agencies for various projects. He received his Bachelor's in civil engineering and Master's in engineering and technology management from Colorado School of Mines.

James Vickers, P.E. has over thirty years of experience in the planning, design, construction and implementation of membrane treatment processes for water and wastewater. His main area of emphasis has been membrane filtration. He is a primary author of the AWWA MF and UF Manual of Practice (MOP) chapters on Design of MF/UF Systems and Costs of MF/UF Systems and was a primary contributor for the development of the USEPA Membrane Filtration Guidance Manual. James holds a Bachelor of Science Degree in Chemical Engineering from Youngstown State University and a Master's Degree in Engineering Management from George Washington University.

Steven Duranceau, PhD, P.E. is Associate Professor of Environmental Engineering in the Civil, Environmental and Construction Engineering Department at the University of Central Florida (UCF) in Orlando, Florida. For the 16-year period prior to joining UCF, he worked for a national design engineering corporation. He directed and served as engineer-of-record for the preliminary design, design, permitting, and construction observation services for the construction and operation of advanced water treatment plants for drinking water purposes.

Evaluation Criterion 4: Stretching Water Supplies – 15 points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will address activities that will help to secure and stretch water supplies.

(1) At your specific locale and/or on a regional or West-wide scale, if applicable, describe how the research study could promote the establishment or expansion of a market for water reclamation and reuse that will reduce, postpone, or eliminate the development of new or expanded water supplies.

The proposed research study is the first step in implementation of the recommended DPR project in San Angelo. As shown in Figure 3, the City faces a near-term shortage during drought of record conditions. Development of a DPR project will help to address the projected shortage by maximizing the efficiency of the existing water supplies and deferring the need to develop additional groundwater and surface water resources. Phase 1 of the proposed DPR project would provide up to 7.2 MGD (8,070 ac-ft/yr) of treated drinking water, and Phase 2 would provide up to an additional 2.4 MGD (2,690 ac-ft/yr).

The proposed research study will expand the water market for reclaimed water and help promote a new municipal use of reclaimed water (DPR) by removing the initial obstacles to DPR implementation, as described in a previous section.

(2) Describe how the research study could or will streamline the implementation of a project that will reduce or eliminate the use of existing diversions from natural watercourses or withdrawals from aquifers and improve available supplies during droughts.

Without additional runoff into the City's surface water supplies, the City is projected to exhaust its surface water supplies in about 26 months at the current rate of water usage. In this case, the City would be totally reliant on the groundwater supply from the Hickory Aquifer. The proposed research study will help remove initial obstacles to implementation of the recommended DPR project, which would maximize the efficient use of existing water supplies, improve available supplies during droughts, reduce diversions from existing surface water and groundwater supplies, and defer the need to develop additional groundwater and surface water resources.

(3) Describe how the research study could or will streamline the implementation of a project that will reduce the demand on existing Federal water supply facilities.

Two of the City's surface water supplies are Federal water supply facilities: Twin Buttes Reservoir, which is Federally-owned and operated by the Bureau of Reclamation, and O.C. Fisher Lake, which is Federally-owned and operated by the U.S. Army Corps of Engineers. As described in the previous sections, the proposed research study will remove the initial obstacles for implementation of a DPR project for San Angelo. The recommended DPR project would reduce demand on the City's surface water supplies, including the Federal water supply facilities Twin Buttes Reservoir and O.C. Fisher Lake.

Evaluation Criterion 5: Environment and Water Quality – 15 points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will address the potential or provide results that improve surface, ground water, or effluent discharge quality; restore or enhance habitat for nonlisted species; or provide water or critical habitat for federally listed threatened or endangered species.

(1) Describe the potential for the research study to identify methods or produce results that improve the quality of surface or groundwater, including description of any specific issues that will be investigated or information that will be developed as part of the research study.

The proposed research study will remove the initial obstacles for implementation of a DPR project for San Angelo. Implementation of the recommended DPR project would reduce diversions from the City's surface water supplies, leading to higher water levels in these supplies. Modeling conducted during the 2015 Reclaimed Water Alternatives Evaluation indicated that the total dissolved solids (TDS) in the Twin Buttes Reservoir[5]/Lake Nasworthy system increase as water levels decrease. Therefore, higher water levels are projected to result in better water quality (lower TDS concentrations) in these water supplies.

(2) Describe the potential for the research study to identify methods or produce results that improve flow conditions in a natural stream channel that benefit the environment, including a description of any specific issues that will be investigated or information that will be developed as part of the research study.

The proposed research study will remove the initial obstacles for implementation of a DPR project for San Angelo. The recommended DPR project would defer the need to develop additional groundwater and surface water resources. Development of additional groundwater resources has the potential to reduce spring flows, and development of additional surface water resources could reduce and/or change flow conditions in natural stream channels. Therefore, deferral of the development of additional groundwater and surface water resources provides a positive environmental benefit.

(3) Describe the potential for the research study to identify methods or produce results that provide water or habitat for non-listed, sensitive, or federally-listed threatened or endangered species, including description of any specific issues that will be investigated or information that will be developed as part of the research study.

One federally listed endangered species, one state listed threatened species, and one non-listed rare species have the potential to occur within or migrate across the study area: the

[5] A Bureau of Reclamation project.

Whooping Crane, the Bald Eagle, and the Guadalupe Bass. The proposed project should not impact the whooping crane or the bald eagle, which are migrants through the area. There is no designated critical habitat for any of these species in the research study activity area.

If the DPR option is employed as a result of the research study, the amount of water diverted from the surrounding surface water resources would be reduced. This would alleviate stress on surface water levels for these resources, providing more habitat for the above species to utilize. Implementing the DPR option would be beneficial to the Guadalupe Bass, which occurs in perennial streams in the Edwards Plateau region.

The research study and implementation of the DPR treatment option should not adversely impact any rare, threatened or endangered species.

Evaluation Criterion 6: Legal and Institutional Requirements – 10 Points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will address legal or institutional requirements or barriers to implementing a project, including water rights issues and any unresolved issues associated with implementation of a water reclamation and reuse project.

(1) For planning related research, describe how the research study will identify methods or produce results that help to eliminate obstacles for using reclaimed water as a supply in the research study area.

The deep well feasibility study is the planning element in the proposed research study. The proposed DPR project is anticipated to include RO treatment, which generates a waste stream of concentrate. Currently, identifying a feasible means of concentrate disposal and obtaining a permit for the concentrate disposal are obstacles to DPR in San Angelo. The 2015 Reclaimed Water Alternatives Evaluation identified deep well injection as a potentially feasible disposal method and recommended an investigation of local geology to identify potential locations and strata for deep injection wells for RO concentrate disposal.

The deep well feasibility study will assess the groundwater and geologic strata compatibility with the concentrate water quality and quantity and will determine an opinion of probable construction costs and other costs for deep well injection. Tasks associated with the proposed deep well feasibility study are described in Section 1.2.5. Determination of a feasible means of concentrate disposal will remove one of the legal/institutional barriers to implementation of the recommended DPR project.

Recent rule changes have provided a regulatory pathway for the disposal of RO concentrate into Class II injection wells. If deep well disposal is demonstrated to be viable, the deep well feasibility study will support the City's application for an injection well permit. The injection well permit would remove another of the legal/institutional barriers to implementation of the recommended DPR project.

(2) For field research studies focused on state of the art technology deployment describe the readiness to proceed in terms of:

(a) The type and level of preliminary research investigations that have been completed.

(b) The type and level of preliminary research plans or testing designs that have completed.

(c) Uncertainties that could affect the timing of research completion associated with environmental compliance, permitting, etc. as applicable to the research study?

(d) How will the testing of new state of the art technology aid in producing results that help address institutional requirements to implement a project?

Work on the research study began on September 15th, 2015. The initial plans and designs for the pilot study were completed in the first several months and the pilot study protocol was submitted to the TCEQ on November 10th, 2015. The pilot study officially began in early March 2016 and is currently underway. The TCEQ requires that membrane pilot studies be conducted in three stages for a total period of at least 90 days. Stage 1 for the first phase of this research study is scheduled to conclude on April 15, 2016. Stage 2 is scheduled to begin on April 19th, 2016 and last for at least 30 days. Stage 3 will begin following a mandatory chemical clean in place (CIP) event and last a minimum of ten days. The water quality sampling that accompanies the pilot study has also started and will be an ongoing process throughout the pilot study. The deep well injection feasibility study is also in progress.

Items that could delay completion of the research include unscheduled downtime for equipment maintenance or a request by the TCEQ to extend testing time to collect additional data for the pilot study review.

The pilot study is an important step in the City's efforts to obtain an exception from the TCEQ to implement DPR for augmenting their potable water supply. When a new source of water is proposed, the TCEQ requires that the source water be characterized to determine the minimum treatment requirements with respect to pathogens and other regulated constituents. The treatment requirements include the required log removal of pathogens that must be achieved by the overall treatment scheme. In addition to an overall exception to implement DPR, TCEQ approval of innovative technologies, such as ultrafiltration will also be required. The TCEQ requires that innovative technologies be pilot tested prior to full-scale implementation. Accordingly, the TCEQ will review the pilot study results and then make a determination as to whether to grant approval for the tested ultrafiltration products to be used in the full-scale system. The concentrate disposal portion of the project will also require regulatory approval in the form on an injection permit. The deep well injection evaluation included within the scope of this study is a critical step in receiving regulatory approval for injection of the concentrate.

Evaluation Criterion 7: Renewable Energy and Energy Efficiency – 10 points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will evaluate methods to incorporate the use of renewable energy or will otherwise address energy efficiency aspects of the water reclamation and reuse project being investigated.

(1) For research studies that include evaluation or incorporation of renewable energy, please describe the proposed or existing renewable energy system and the research objectives proposed to evaluate the integration of renewable energy into the research study area or project.

(2) For research studies focused on improving energy efficiency, describe the full scale plant energy requirements, if applicable, proposed efficiency improvements, and reduced carbon footprint. Provide calculations and describe assumptions and methodology.

(3) Please quantify the energy savings that are expected to be identified in the research study through renewable energy or improved facility efficiencies. Include support for how energy savings were calculated.

There are two main ways in which this research study improves energy efficiency. The first is by incorporating pretreatment upstream of the RO system in order to optimize RO recovery and decrease the volume of concentrate for disposal. As discussed previously, it is assumed that concentrate will be disposed through deep well injection. Any incremental increases in RO recovery will yield a corresponding decrease in concentrate volume resulting in reduced energy consumption for concentrate disposal. Secondly, the project could result in energy savings by deferring the need to deliver water from supplies further away from the City, such as O.H. Ivie or groundwater from the Hickory Aquifer. The O.H. Ivie reservoir is approximately 44 miles from the San Angelo WTP and is approximately 300 ft. lower than the WTP. For purposes of comparison, e the WRF is approximately 6 miles from the WTP and is approximately 50 ft. lower than the WTP.

Evaluation Criterion 8: Watershed Perspective – 10 points

Points will be awarded based on the extent to which the proposal demonstrates that the research study will promote and apply a regional or watershed perspective to water resource management.

(1) Describe whether or the extent to which the research study is based off of recommendations from an existing plan that is sponsored or otherwise recommends research needs on a regional or national scale.

San Angelo is located in West Central Texas in the Region F water planning area. The 2016 Region F Water Plan recommends implementation of a reuse project for the City and its wholesale customers by 2020.[6] The recommended strategy was tentatively identified as a direct reuse project, pending the outcome of the 2015 Reclaimed Water Alternatives Evaluation, which has since been completed. The 2015 Reclaimed Water Alternatives Evaluation did recommend that San Angelo pursue a DPR project by conducting the proposed research.

(2) Explain any additional benefits of, or specific need for, the proposed research study within the sponsors watershed, regional area, and nationally.

There is a strong need for the recommended DPR project in San Angelo, because:

- The City's surface water supplies have been in an extended hydrological drought since at least 1998, and the total water volume stored in these supplies is very low (Figure 2).
- The estimated firm yields for these supplies have been revised steadily downward since the late 1990s.
- The 2016 Region F Water Plan projects that the City will experience shortages under drought of record conditions (Figure 3).

The proposed research study will remove the initial obstacles for implementation of a DPR project for San Angelo. The recommended DPR project would maximize the efficiency of the existing water supplies, improving available supplies during droughts, reducing diversions from existing surface water and groundwater supplies, and deferring the need to develop additional groundwater and surface water resources. Improved supplies during droughts would benefit the City and its wholesale customers. Reduced diversions from the City's existing surface

[6] Freese and Nichols, Inc. and LBG-Guyton Associates, Inc: 2016 Region F Water Plan, prepared for the Region F Water Planning Group, November 2015.

water and groundwater supplies would benefit other water users in the region that share these water supplies through better water quality and increased water availability. Deferral of the need to develop additional groundwater and surface water resources would provide positive environmental benefits in the region.

(3) Describe how the research objectives will benefit other locations and the technical, economic, or institutional questions that will be answered by the research study.

The research objectives will not only benefit other West Texas municipalities interested in pursuing DPR, but will also benefit other municipalities nationally. Specifically, the research study will examine deep well injection of reclaimed water concentrate. The research study will also evaluate the tradeoff between improved RO recovery and economic burden. This research study will answer the question: What are the advantages and disadvantages of maximizing RO recovery in terms of economics and treated water quality?

Additionally, this research study will evaluate the benefit of biological nutrient removal upstream of the RO treatment process. This research study will answer the questions: Is phosphorus removal pretreatment for RO recommended in a DPR treatment scheme? Is biological nutrient removal a viable alternative for treating phosphorus in a DPR treatment scheme? The answers to these questions will benefit future municipalities interested in pursuing DPR.

(4) Explain how the research study includes or promotes and encourages collaboration among parties. Identify if there is widespread support for the research study.

This research study encourages and promotes collaboration among multiple parties. The pilot study is located at the City's WRF and uses treatment processes typically used for water treatment. The treatment processes used in this research study bridge the gap between water treatment and wastewater treatment. Operators at the WRF in San Angelo have taken ownership of the pilot study and have exerted a significant amount of effort to perform the on-site work that is required. This has led to close collaboration between the consulting engineers on the project and the group of operators at the WRF and WTP.

Additionally, there is growing public support for this research study. The City of San Angelo recently invited local reporters to tour the pilot study and release a story describing the treatment process in order to inform the public of the current study progress. Furthermore, there is significant technical collaboration for this research study. The research team includes individuals across the United States. The parties involved in the pilot study include engineering firms (APAI, eHT, SPI), equipment vendors (Evoqua Water Technologies; Toray Membrane USA, Dow Water and Process Solutions, Wigen Water Technologies, Harn RO Systems, Aqua-Aerobics, Xylem, Trojan UV), and water quality laboratories (Eurofins Eaton Analytical, IEH BioVir, Abilene Environmental Laboratory). The study also includes academic review (Steven Duranceau, Ph.D., P.E.).

2 Environmental Compliance

(1) Will the research study activities impact the surrounding environment (i.e., soil [dust], air, water [quality and quantity], animal habitat, etc.)?

- *Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the research study area.*

- *Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.*

No earth disturbing work will take place for the research study. No soil, air, water or animal habitat will be impacted by the study activities.

(2) Are you aware of any species listed, or proposed to be listed as a Federal endangered or threatened species, or designated Critical Habitat in the research study area? If so, how would they be affected by activities associated with the proposed research study activities?

There are no listed or proposed to be listed species or designated Critical Habitat in the research study area.

(3) Are there wetlands or other surface waters inside the research study boundaries that potentially fall under Federal Clean Water Act jurisdiction as "waters of the United States?" If so, please describe and estimate any impacts the research study activities may have.

There are no wetlands or surface waters inside the research study boundary that would potentially fall under the Federal Clean Water Act jurisdiction as "waters of the United States".

(4) Are there any known archeological sites in the research study activities area? If so, please describe and estimate any impacts the research study may have.

There are no known archeological sites in the research study area.

(5) Will the proposed research study activities have a disproportionately high and adverse effect on low income or minority populations? If so, please describe and estimate any impacts the research study may have.

The research study activities will not have any disproportionately high or adverse effects on low income or minority populations.

(6) Will the research study activities limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands? If so, please describe and estimate any impacts the research study activities may have.

The research study activities will not limit access to Indian sacred sites or impact tribal lands.

(7) Will the research study activities contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area? If so, please describe and estimate any impacts the research study activities may have.

The research study activities will not contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area.

3 Required Permits and Approvals

No permits are required to perform the feasibility study. TCEQ approval was received for the pilot study protocol.

4 Official Resolution

Will be forwarded within 30 days of application deadline.

5 Research Study Budget

5.1 SUMMARY

The total proposed project budget cost is $1,394,849. The following sections describe details of the budget proposal.

5.2 FUNDING PLAN AND LETTERS OF COMMITMENT

Non-federal funds will be provided by the City of San Angelo from their Type B Sales Tax money.

Table 1: Summary of Non-Federal and Federal Funding Sources

Funding Sources	Funding Amount
Non-Federal Entities	
1.City of San Angelo	$1,094,849
Non-Federal Subtotal:	$1,094,849
Requested Reclamation Funding	$ 300,000
Total Research Study Funding	**$1,394,849**

5.3 BUDGET PROPOSAL

Table 2: Funding Sources

Funding Sources	Percent of Total Research Study Cost	Total Cost by Source
Recipient funding	78%	$1,094,849
Reclamation funding	22%	$300,000
Other Federal funding	0%	$0
Totals	**100%**	**$1,394,849**

Table 3: Budget Proposal

Budget Item Description	Computation		Recipient Funding	Reclamation Funding	Total Cost
	$/Unit	Quantity			
Salaries and Wages					
Employee 1					
Fringe Benefits					
Full-Time Employees					
Part-Time Employees					
Travel					
Trip 1					
Equipment					
Item A					
Supplies/Materials					
Office Supplies					
Construction					
Contractual/Construction					
Alan Plummer Associates, Inc.			$1,094,849	$300,000	$1,394,849
Item 2					
Other					
Final Reporting (Salaries)					
Final Reporting (Fringe Benefits)					
Total Direct Costs			$1,094,849	$300,000	$1,394,849
Indirect Costs - __ %					
Total Project Costs					**$1,394,849**

5.4 BUDGET NARRATIVE

5.4.1 Salaries and Wages

It is estimated that San Angelo city staff contribute approximately 103 hours per week to the research study. This time accounts for WRF staff performing routine water quality testing and oversight of the pilot study as well as attending training and coordination meetings. When these hours are multiplied by staff salaries it results in an in-kind contribution of approximately $11,000 per month to the research study. It was decided to not include these in-kind contributions in the research study budget, however, since they would result in additional reporting requirements for San Angelo.

5.4.2 Fringe Benefits

See above. No in-kind contributions are included in the budget.

5.4.3 Travel

The costs associated with travel are minimal and are not part of this proposal.

5.4.4 Equipment

The costs associated with equipment are minimal and are not part of this proposal. Pilot unit equipment rental costs are included in the contract with APAI.

5.4.5 Materials and Supplies

The costs associated with materials and supplies are minimal and are not part of this proposal.

5.4.6 Contractual/Construction

Alan Plummer Associates, Inc. (APAI) was contracted to provide consulting and engineering work for the project on September 15, 2015. San Angelo's contract with APAI covers engineering labor as well as reimbursable expenses for pilot rental equipment, water quality testing, and subconsultant expenses for various tasks. A breakdown of all tasks to be completed and a detailed budget estimate of labor and rates for each task are provided on the following pages.

5.4.7 Environmental and Regulatory Compliance Costs

The costs associated with environmental and regulatory compliance are minimal and not part of this proposal.

5.4.8 Other Expenses

Not applicable.

5.4.9 Indirect Costs

Not applicable.

5.4.10 Total Costs

The total proposed project budget cost is $1,394,849.