DRAFT FEASIBILITY REPORT
FEASIBILITY ANALYSIS OF WATER SUPPLY FOR SMALL PUBLIC WATER SYSTEMS

CRYSTAL LAKE ESTATES WATER SYSTEM
PWS ID# 1870044, CCN# 10147

Prepared for:

THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Prepared by:

THE UNIVERSITY OF TEXAS BUREAU OF ECONOMIC GEOLOGY

AND

PARSONS

Preparation of this report was financed by the Texas Commission on Environmental Quality through the Drinking Water State Revolving Fund Small Systems Assistance Program

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August 2006

EXECUTIVE SUMMARY

INTRODUCTION

The University of Texas Bureau of Economic Geology (BEG) and its subcontractor, Parsons Infrastructure and Technology Group Inc. (Parsons), was contracted by the Texas Commission on Environmental Quality (TCEQ) to conduct a study to assist with identifying and analyzing alternatives for use by Public Water Systems (PWS) to meet and maintain Texas drinking water standards.

The overall goal of this project was to promote compliance using sound engineering and financial methods and data for PWSs that had recently recorded sample results exceeding maximum contaminant levels (MCL). The primary objectives of this project were to provide feasibility studies for PWSs and the TCEQ Water Supply Division that evaluate water supply compliance options, and to suggest a list of compliance alternatives that may be further investigated by the subject PWS for future implementation.

The method for this project follows that of a pilot study performed in 2004 and 2005 by TCEQ, BEG, and Parsons. The pilot study evaluated compliance alternatives for three PWSs that had elevated concentrations of nitrate. The pilot project developed a method (a decision tree approach) for identifying and analyzing compliance options.

This feasibility report provides an evaluation of water supply alternatives for the Crystal Lake Estates Water System, PWS ID# 1870044, Certificate of Convenience and Necessity (CCN) # 10147 located in Polk County (the Crystal Lake PWS). The Crystal Lake PWS is the water system for Crystal Lake Estates, a 91-lot rural subdivision, located outside of Livingston, Texas. It consists of one 540-foot well, one 36,000-gallon ground storage tank, one 350-gallon hydropneumatic tank, one pump control shed, one treatment shed and a distribution system. There are three service pumps: 70 gallons per minute (gpm), 125 gpm, and 150 gpm at the plant. Although not connected to the system, there is an inactive well surrounded by a fence located approximately 300 feet to the north of the facility.

Total combined radium-226 and radium-228 has been detected between 6.9 picoCurie per liter (pCi/L) to 10.7 pCi/L since 2004, which exceeds the MCL of 5 pCi/L. Gross alpha particle activity has been detected between 23.7 pCi/L to 36.2 pCi/L, which exceeds the MCL of 15 pCi/L. The Crystal Lake PWS has not encountered any other water quality issues.

Recent sample results from the Crystal Lake PWS exceeded the MCL for combined radium 226 and 228 of 5 pCi/L and the MCL for gross alpha particle activity of 15 pCi/L (USEPA 2005; TCEQ 2004).

Basic system information for the Crystal Lake PWS is shown in Table ES.1.

Table ES.1
Crystal Lake PWS
Basic System Information

Parameter	Result
Population served	282 current, 600 at full build out
Connections	93 current, 200 at full build out
Average daily flow rate	0.021 million gallons per day (mgd)
Peak demand flow rate	45 gallons per minute estimated
Water system peak capacity	0.083 mgd
Typical total combined radium 226 & 228 range	6.9 – 10.7 pCi/L
Typical gross alpha particle activity range	23.7 - 36.2 pCi/L

STUDY METHOD

The method used for this study was based on a pilot study performed in 2004 and 2005 by TCEQ, BEG, and Parsons. The method for identifying and analyzing compliance options were developed in the pilot study (a decision tree approach).

The process for developing the feasibility study used the following general steps:

1. Gather data from the TCEQ and Texas Water Development Board databases, from TCEQ files, and from information maintained by the PWS;
2. Conduct financial, managerial, and technical (FMT) evaluations of the PWS;
3. Perform a geologic and hydrogeologic assessment of the study area;
4. Develop treatment and non-treatment compliance alternatives which, in general, consist of the following possible options:
    a. Connecting to neighboring PWSs via new pipeline or by pumping water from a newly installed well or an available surface water supply within the jurisdiction of the neighboring PWS;
    b. Installing new wells within the vicinity of the PWS into other aquifers with confirmed water quality standards meeting the MCLs;
    c. Installing a new intake system within the vicinity of the PWS to obtain water from a surface water supply with confirmed water quality standards meeting the MCLs;
    d. Treating the existing non-compliant water supply by various methods depending on the type of contaminant; and

   e. Delivering potable water by way of a bottled water program or a treated water dispenser as an interim measure only.

5. Assess each of the potential alternatives with respect to economic and non-economic criteria;
6. Prepare a feasibility report and present the results to the PWS.

This basic approach is summarized in Figure ES-1.

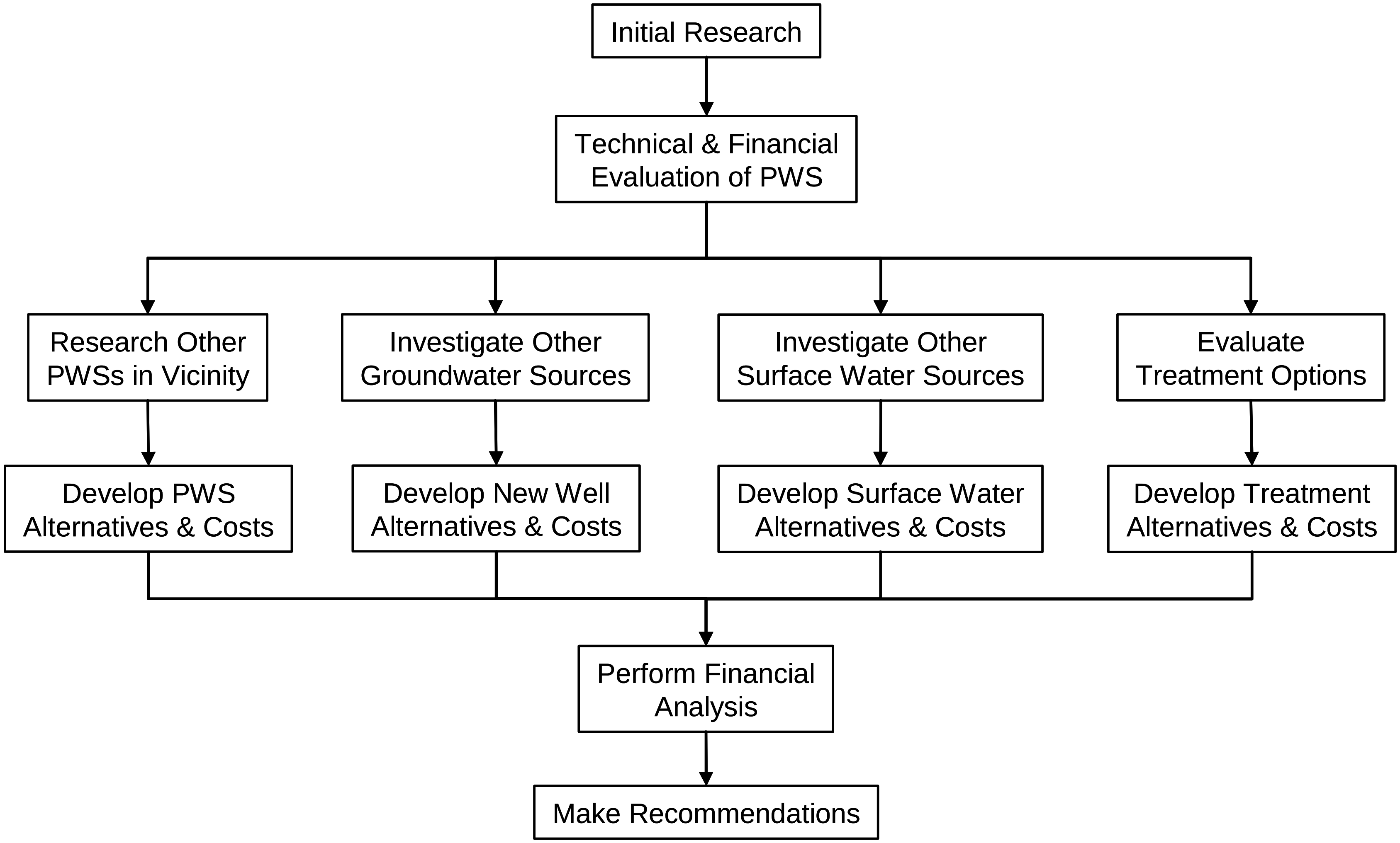
HYDROGEOLOGICAL ANALYSIS

The Crystal Lake PWS obtains groundwater from the Evangeline subunit of the Gulf Coast Aquifer. Radium and gross alpha particle are not commonly found in area wells at concentrations greater than the MCL. The Evangeline and Jasper subunit aquifers are known to be very productive in the area. Other nearby PWS well screens are generally set either shallower or deeper than the well screen of the Crystal Lake PWS. It is likely there could be good quality groundwater nearby. However, the variability of radium and gross alpha particle concentrations makes it difficult to determine where wells can be located to produce acceptable water. It may be possible to do down-hole testing on the Crystal Lake PWS well to determine the source of the contaminants. If the contaminants derive primarily from a single part of the formation, that part could be excluded by modifying the existing well, or avoided altogether by completing a new well.

COMPLIANCE ALTERNATIVES

Crystal Lake PWS is owned by the Lake Livingston Water Supply & Sewer Service Corporation (WSSSC), which provides water to 52 other public water systems in the greater Lake Livingston area and serves 6,894 customers. The General Manager is Mr. Scott Baker, and system operations are managed by Mr. Phillip Everett and Mr. Boyd McDaniel. Overall, the system does have an adequate level of financial, managerial, and technical capacity. The system does have positive aspects, including a knowledgeable and dedicated staff, benefits from economies of scale, communication with customers, and a cross-connection control program. Capacity deficiencies are reflected in lack of compliance with radionuclides standard and water losses. Areas of concern for the system included rates and frequency of rate evaluation, lack of written long-term capital improvements plan, preventative maintenance program and an emergency plan.

Figure ES-1 Summary of Project Methods



There are several PWSs within a few miles of the Crystal Lake PWS, and most of the nearby systems have good quality water. In general, feasibility alternatives were developed based on obtaining water from the nearest PWSs, either by directly purchasing water, or by expanding the existing well field. Another alternative considered is modifying the existing well or installing a new well at the Crystal Lake PWS. There is a minimum of surface water sources available in the area.

A number of centralized treatment alternatives for radium and alpha particle removal have been developed and were considered for this report, for example, ion exchange, WRT Z-88 adsorption, and $KMnO_4$ greensand filtration. Point-of-use (POU) and point-of-entry treatment alternatives were also considered. Temporary solutions such as providing bottled water or providing a centralized dispenser for treated or trucked-in water, were also considered as alternatives.

Developing a new well at or near the Crystal Lake PWS is likely to be an attractive solution if compliant groundwater can be found. Having a new well at or near the Crystal Lake PWS is likely to be one of the lower cost alternatives since the PWS already possesses the technical and managerial expertise needed to implement this option. The cost of new well alternatives quickly increases with pipeline length, making proximity of the alternate source a key concern. Additionally, there are a number of large water supplier that would be willing to sell water within a short distance from the Crystal Lake PWS. Purchasing water or joining one of the larger water systems may also be an attractive option for the Crystal Lake PWS. A new compliant well or obtaining water from a neighboring compliant PWS has the advantage of providing compliant water to all taps in the system.

Central treatment can be cost-competitive with the alternative of new nearby wells, but would require significant institutional changes to manage and operate. Similar to obtaining an alternate compliant water source, central treatment would provide compliant water to all water taps.

POU treatment can be cost competitive, but does not supply compliant water to all taps. Additionally, significant efforts would be required for maintenance and monitoring of the POU treatment units.

Providing compliant water through a central dispenser is significantly less expensive than providing bottled water to 100 percent of the population, but a significant effort is required for clients to fill their containers at the central dispenser.

FINANCIAL ANALYSIS

Financial analysis of the Crystal Lake PWS indicated that current water rates are adequately funding operations, and a rate increase would not be necessary to meet operating expenses. The current average water bill of $909 represents approximately 2.9 percent of the median household income (MHI). Table ES.2 provides a summary of the financial impact of implementing selected compliance alternatives, including the rate increase necessary to meet current operating expenses. The alternatives were selected to highlight results for the best alternatives from each different type or category.

Some of the compliance alternatives offer potential for shared or regional solutions. A group of PWSs could work together to implement alternatives for developing a new groundwater source or expanding an existing source, obtaining compliant water from a large regional provider, or for central treatment. Sharing the cost for implementation of these alternatives could reduce the cost on a per user basis. Additionally, merging PWSs or management of several PWSs by a single entity offers the potential for reduction in administrative costs.

Table ES.2 Selected Financial Analysis Results

Alternative	Funding Option	Average Annual Water Bill	Percent of MHI
Current	NA	$909	2.9
Nearby well within approximately 1 mile	100% Grant	$684	2.2
	Loan/Bond	$733	2.3
Central treatment	100% Grant	$896	2.8
	Loan/Bond	$1,256	4.0
Point-of-use	100% Grant	$1,072	3.4
	Loan/Bond	$1,332	4.2
Public dispenser	100% Grant	$1,301	4.1
	Loan/Bond	$1,356	4.3

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

µ/L	micrograms per liter
AFY	acre-feet per year
BAT	best available technology
BEG	Bureau of Economic Geology
BV	bed volume
CA	chemical analysis
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
CL	Crystal Lake
CO	correspondence
ED	electrodialysis
EDR	electrodialysis reversal
FMT	financial, managerial, and technical
ft^2	square foot
GAM	Groundwater Availability Model
gpm	gallons per minute
IX	Ion exchange
$KMnO_4$	hydrous manganese oxide
MCL	Maximum contaminant level
mg/L	milligrams per Liter
mgd	million gallons per day
MHI	median household income
MnO_2	Manganese dioxide
MOR	monthly operating report
NMEFC	New Mexico Environmental Financial Center
NURE	National Uranium Resource Evaluation
O&M	operation and maintenance
Parsons	Parsons Infrastructure and Technology Group Inc.
pCi/L	picoCuries per liter
POE	Point-of-entry
POU	Point-of-use
PWS	public water system
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TSS	Total suspended solids
TWDB	Texas Water Development Board
USEPA	United States Environmental Protection Agency
WAM	Water Availability Model
WRT	Water Remediation Technologies, Inc.
WSSSC	Water Supply & Sewer Service Corporation

SECTION 1
INTRODUCTION

The University of Texas Bureau of Economic Geology (BEG) and its subcontractor, Parsons Infrastructure and Technology Group Inc. (Parsons), have been contracted by the Texas Commission on Environmental Quality (TCEQ) to assist with identifying and analyzing compliance alternatives for use by Public Water Systems (PWS) to meet and maintain Texas drinking water standards.

The overall goal of this project is to promote compliance using sound engineering and financial methods and data for PWSs that have recently had sample results that exceed maximum contaminant levels (MCL). The primary objectives of this project are to provide feasibility studies for PWSs and the TCEQ Water Supply Division that evaluate water supply compliance options, and to suggest a list of compliance alternatives that may be further investigated by the subject PWS with regard to future implementation. The feasibility studies identify a range of potential compliance alternatives, and present basic data that can be used for evaluating feasibility. The compliance alternatives addressed include a description of what would be required for implementation, conceptual cost estimates for implementation, and non-cost factors that could be used to differentiate between alternatives. The cost estimates are intended for comparing compliance alternatives, and to give a preliminary indication of potential impacts on water rates resulting from implementation.

It is anticipated the PWS will review the compliance alternatives in this report to determine if there are promising alternatives, and then select the most attractive alternative(s) for more detailed evaluation and possible subsequent implementation. This report contains a decision tree approach that guided the efforts for this study, and also contains steps to guide a PWS through the subsequent evaluation, selection, and implementation of a compliance alternative.

This feasibility report provides an evaluation of water supply compliance options for the Crystal Lake Estates Water System, PWS ID# 1870044, Certificate of Convenience and Necessity (CCN) #10147, located in Polk County (the Crystal Lake PWS). Recent sample results from the Crystal Lake PWS exceeded the MCL for combined radium-226 and radium-228 of 5 picoCuries per liter (pCi/L) and the MCL for gross alpha particle activity at 15 pCi/L. (USEPA 2005; TCEQ 2004). The location of the Crystal Lake PWS, also referred to as the "study area" in this report, is shown on Figure 1.1. Various water supply and planning jurisdictions are shown on Figure 1.2. These water supply and planning jurisdictions are used in the evaluation of alternate water supplies that may be available in the area.

1.1 PUBLIC HEALTH AND COMPLIANCE WITH MCLS

The goal of this project is to promote compliance for PWSs that supply drinking water exceeding regulatory MCLs. This project only addresses those contaminants and does not address any other violations that may exist for a PWS. As mentioned above, the Crystal Lake PWS had recent sample results exceeding the MCL for combined radium 226 & radium 228 and gross alpha particles. In general, contaminant(s) in drinking water above the MCL(s) can have both short-term (acute) and long-term or lifetime (chronic) effects. Long-term ingestion of drinking water with radium 226 and/or radium 228 and/or gross alpha particles above the MCL may increase the risk of cancer (USEPA 2005).

1.2 METHOD

The method for this project follows that of the pilot study performed in 2004 and 2005 by TCEQ, BEG, and Parsons. The pilot study evaluated water supply alternatives for PWSs that supply drinking water with nitrate concentrations above U.S. Environmental Protection Agency (USEPA) and Texas drinking water standards. Three PWSs were evaluated in the pilot study to develop the method (*i.e.*, decision tree approach) for analyzing options for provision of compliant drinking water. This project is performed using the decision tree approach developed in the pilot study.

Other tasks of the feasibility study are as follows:

- Identifying available data sources;
- Gathering and compiling data;
- Conducting financial, managerial, and technical (FMT) evaluations of the selected PWSs;
- Performing a geologic and hydrogeologic assessment of the study area;
- Developing treatment and non-treatment compliance alternatives;
- Assessing potential alternatives with respect to economic and non-economic criteria;
- Preparing a feasibility report; and
- Suggesting refinements to the approach for future studies.

The remainder of Section 1 of this report addresses the regulatory background, and provides a summary of radium abatement options. Section 2 describes the method used to develop and assess compliance alternatives. The groundwater sources of radium 226 & 228 and gross alpha particles are addressed in Section 3. Findings for the Crystal Lake PWS, along with compliance alternatives development and evaluation, can be found in Section 4. Section 5 references the sources used in this report.

1.3 REGULATORY PERSPECTIVE

The Utilities & Districts and Public Drinking Water Sections of the TCEQ Water Supply Division are responsible for implementing requirements of the Federal Safe Drinking Water Act (SDWA) which include oversight of PWSs and water utilities. These responsibilities include:

- Monitoring public drinking water quality;
- Processing enforcement referrals for MCL violators;

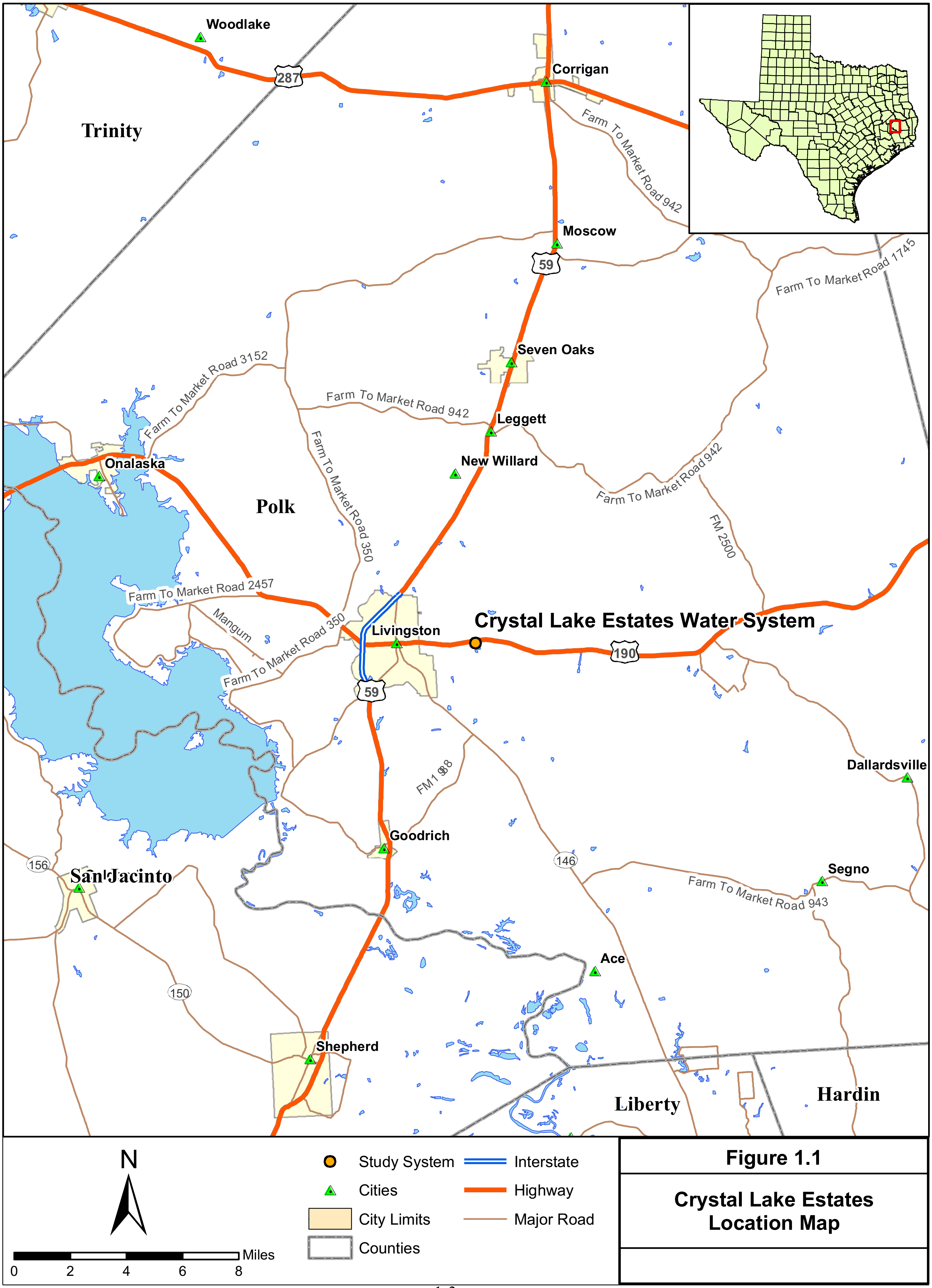


Figure 1.1

Crystal Lake Estates Location Map

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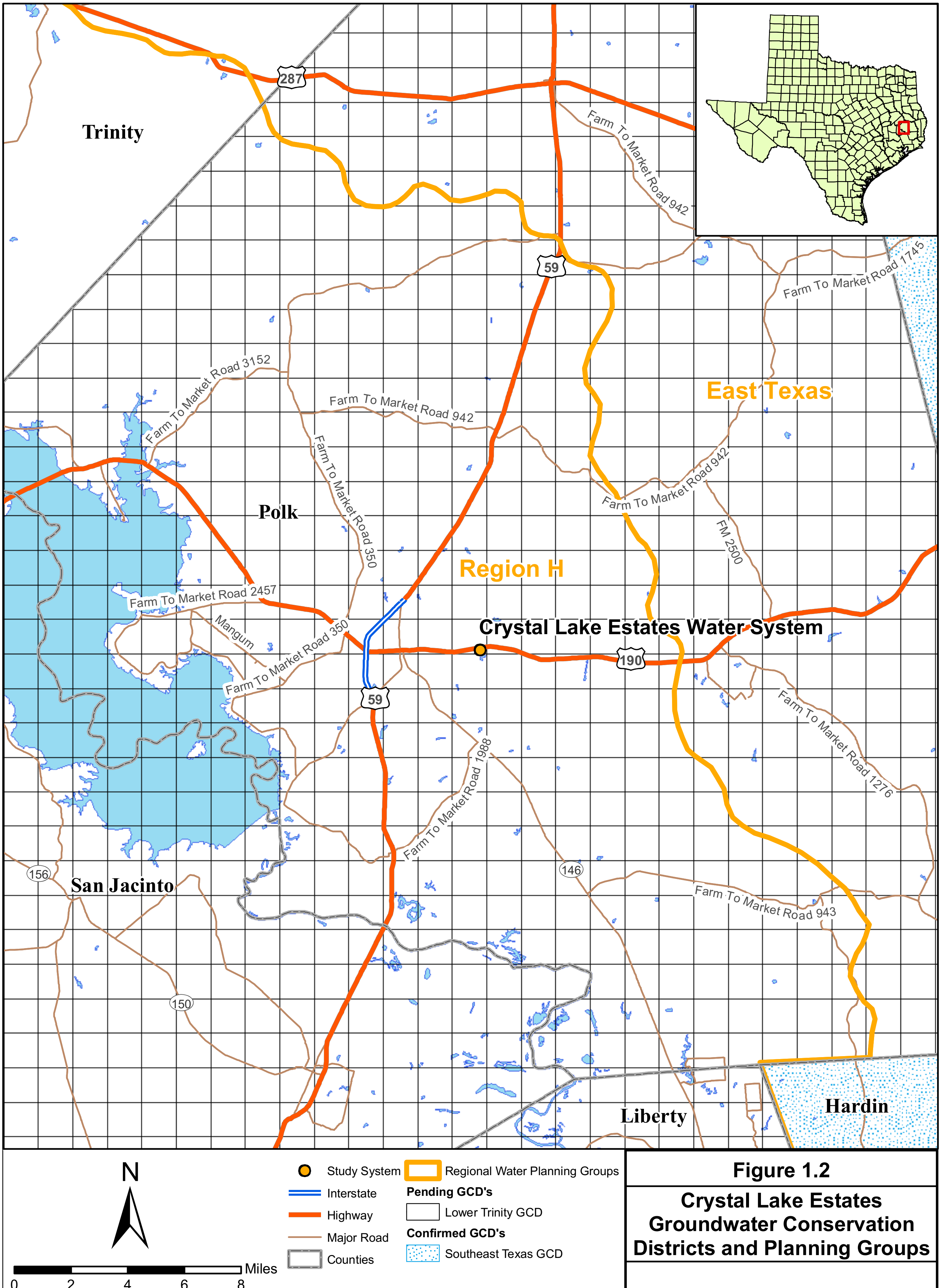

Figure 1.2

Crystal Lake Estates Groundwater Conservation Districts and Planning Groups

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- Tracking and analyzing compliance options for MCL violators;
- Providing FMT assessment and assistance to PWSs;
- Participating in the Drinking Water State Revolving Fund program to assist PWSs in achieving regulatory compliance; and
- Setting rates for privately-owned water utilities.

This project was conducted to assist in achieving these responsibilities.

1.4 ABATEMENT OPTIONS

When a PWS exceeds a regulatory MCL, the PWS must take action to correct the violation. The MCL exceedances at the Crystal Lake PWS involve radium-226 and radium-228 and alpha particle activity. The following subsections explore alternatives considered as potential options for obtain/providing compliant drinking water.

1.4.1 Existing Public Water Supply Systems

A common approach to achieving compliance is for the PWS to make arrangements with a neighboring PWS for water supply. For this arrangement to work, the PWS from which water is being purchased (supplier PWS) must have water in sufficient quantity and quality, the political will must exist, and it must be economically feasible.

1.4.1.1 Quantity

For purposes of this report, quantity refers to water volume, flowrate, and pressure. Before approaching a potential supplier PWS, the non-compliant PWS should determine its water demand on the basis of average day and maximum day. Peak instantaneous demands can be met through proper sizing of storage facilities. Further, the potential for obtaining the appropriate quantity of water to blend to achieve compliance should be considered. The concept of blending involves combining water with low levels of contaminants with non-compliant water in sufficient quantity so the resulting blended water is compliant. The exact blend ratio would depend on the quality of the water a potential supplier PWS can provide, and would likely vary over time. . If high quality water is purchased, produced or otherwise obtained, blending can reduce the amount of high quality water required. Implementation of blending will require a control system to ensure the blended water is compliant.

If the supplier PWS does not have sufficient quantity, the non-compliant community could pay for the facilities necessary to increase the quantity to the extent necessary to supply the needs of the non-compliant PWS. Potential improvements might include, but are not limited to:

- Additional wells;
- Developing a new surface water supply,
- Additional or larger-diameter piping;
- Increasing water treatment plant capacity

- Additional storage tank volume;
- Reduction of system losses,
- Higher-pressure pumps; or
- Upsized, or additional, disinfection equipment.

In addition to the necessary improvements, a transmission pipeline would need to be constructed to tie the two PWSs together. The pipeline must tie-in at a point in the supplier PWS where all the upstream pipes and appurtenances are of sufficient capacity to handle the new demand. In the non-compliant PWS, the pipeline must tie in at a point where no down stream bottlenecks are present. If blending is the selected method of operation, the tie-in point must be at the proper point of the existing non-compliant PWS to ensure that all the water in the system is blended to achieve regulatory compliance.

1.4.1.2 Quality

If a potential supplier PWS obtains its water from the same aquifer (or same portion of the aquifer) as the non-compliant PWS, the quality of water may not be significantly better. However, water quality can vary significantly due to well location, even within the same aquifer. If localized areas with good water quality cannot be identified, the non-compliant PWS would need to find a potential supplier PWS that obtains its water from a different aquifer or from a surface water source. Additionally, a potential supplier PWS may treat non-compliant raw water to an acceptable level.

Surface water sources may offer a potential higher-quality source. Since there are significant treatment requirements, utilization of surface water for drinking water is typically most feasible for larger local or regional authorities or other entities that may provide water to several PWSs. Where PWSs that obtain surface water are neighbors, the non-compliant PWS may need to deal with those systems as well as with the water authorities that supply the surface water.

1.4.2 Potential for New Groundwater Sources

1.4.2.1 Existing Non-Public Supply Wells

Often there are wells not associated with PWSs that are located in the vicinity of the non-compliant PWS . The current use of these wells may be for irrigation, industrial purposes, domestic supply, stock watering, and other purposes. The process for investigating existing wells is as follows:

- Use existing data sources (see below) to identify wells in the areas that have satisfactory quality. For the Crystal Lake PWS, the following standards could be used in a rough screening to identify compliant groundwater in surrounding systems:
    - Radium (total radium for radium-226 and radium-228) less than 4 pCi/L (below the MCL of 5 pCi/L); and

  - Gross alpha particle activity less than 12 pCi/L (below the MCL of 15 pCi/L).

- Review the recorded well information to eliminate those wells that appear to be unsuitable for the application. Often, the "Remarks" column in the Texas Water Development Board (TWDB) hard-copy database provides helpful information. Wells eliminated from consideration generally include domestic and stock wells, dug wells, test holes, observation wells, seeps and springs, destroyed wells, wells used by other communities, *etc*.
- Identify wells of sufficient size which have been used for industrial or irrigation purposes. Often the TWDB database will include well yields, which may indicate the likelihood that a particular well is a satisfactory source.
- At this point in the process, the local groundwater control district (if one exists) should be contacted to obtain information about pumping restrictions. Also, preliminary cost estimates should be made to establish the feasibility of pursuing further well development options.
- If particular wells appear to be acceptable, the owner(s) should be contacted to ascertain their willingness to work with the PWS. Once the owner agrees to participate in the program, questions should be asked about the wells. Many owners have more than one well, and would probably be the best source of information regarding the latest test dates, who tested the water, flowrates, and other well characteristics.
- After collecting as much information as possible from cooperative owners, the PWS would then narrow the selection of wells and sample and analyze them for quality. Wells with good quality would then be potential candidates for test pumping. In some cases, a particular well may need to be refurbished before test pumping. Information obtained from test pumping would then be used in combination with information about the general characteristics of the aquifer to determine whether a well at this location would be suitable as a supply source.
- It is recommended that new wells be installed instead of using existing wells to ensure the well characteristics are known and the well meets construction standards.
- Permit(s) would then be obtained from the groundwater control district or other regulatory authority, and an agreement with the owner (purchase or lease, access easements, *etc*.) would then be negotiated.

1.4.2.2 Develop New Wells

If no existing wells are available for development, the PWS or group of PWSs has an option of developing new wells. Records of existing wells, along with other hydrogeologic information and modern geophysical techniques, should be used to identify potential locations for new wells. In some areas, the TWDB's Groundwater Availability Model (GAM) may be applied to indicate potential sources. Once a general area has been identified, land owners and regulatory agencies should be contacted to determine an exact location for a new well or well field. Pump tests and water quality tests would be required to determine if a new well will produce an adequate quantity of good quality water. Permits from the local groundwater control district or other regulatory authority could also be required for a new well.

1.4.3 Potential for Surface Water Sources

Water rights law dominates the acquisition of water from surface water sources. For a PWS, 100 percent availability of water is required, except where a back-up source is available. For PWSs with an existing water source, although it may be non-compliant because of elevated concentrations of one or more parameters, water rights may not need to be 100 percent available.

1.4.3.1 Existing Surface Water Sources

"Existing surface water sources" of water refers to municipal water authorities and cities that obtain water from surface water sources. The process of obtaining water from such a source is generally less time consuming and less costly than the process of developing a new source; therefore, it should be a primary course of investigation. An existing source would be limited by its water rights, the safe yield of a reservoir or river, or by its water treatment or water conveyance capability. The source must be able to meet the current demand and honor contracts with communities it currently supplies. In many cases, the contract amounts reflect projected future water demand based on population or industrial growth.

A non-compliant PWS would look for a source with sufficient spare capacity. Where no such capacity exists, the non-compliant PWS could offer to fund the improvements necessary to obtain the capacity. This approach would work only where the safe yield could be increased (perhaps by enlarging a reservoir) or where treatment capacity could be increased. In some instances water rights, where they are available, could possibly be purchased.

In addition to securing the water supply from an existing source, the non-compliant PWS would need to arrange for transmission of the water to the PWS. In some cases, that could require negotiations with, contracts with, and payments to an intermediate PWS (an intermediate PWS is one where the infrastructure is used to transmit water from a "supplier" PWS to a "supplied" PWS, but does not provide any additional treatment to the supplied water). The non-compliant PWS could be faced with having to fund improvements to the intermediate PWS in addition to constructing its own necessary transmission facilities.

1.4.3.2 New Surface Water Sources

Communication with the TCEQ and relevant planning groups from the beginning is essential in the process of obtaining a new surface water source. Preliminary assessment of the potential for acquiring new rights may be based on surface water availability maps located on the TWDB website. Where water rights appear to be available, the following activities need to occur:

- Discussions with TCEQ to indicate the likelihood of obtaining those rights. The TCEQ may use the Water Availability Model (WAM) to assist in the determination.

- Discussions with land owners to indicate potential treatment plant locations.
- Coordination with U.S. Army Corps of Engineers and local river authorities.
- Preliminary engineering design to determine the feasibility, costs, and environmental issues of a new treatment plant.

Should these discussions indicate that a new surface water source is the best option, the community would proceed with more intensive planning (initially obtaining funding), permitting, land acquisition, and detailed designs.

1.4.4 Identification of Treatment Technologies for Radionuclides

Various treatment technologies were also investigated as compliance alternatives for treatment of radium to regulatory level (*i.e*., MCL). The removal of radium would also remove gross alpha activity as the radium appears to be responsible for most of the gross alpha activity of the groundwater. Radium-226 and radium-228 are cations (Ra^{2+}) dissolved in water and are not easily removed by particle filtration. A 2002 USEPA document (*Radionuclides in Drinking Water: A Small Entity Compliance Guide*, EPA 815-R-02-001) lists a number of small system compliance technologies that can remove radium (combined radium-226 and radium-228) from water. These technologies include ion exchange (IX), reverse osmosis (RO), electrodialysis/electrodialysis reversal (ED/EDR), lime softening, greensand filtration, re-formed hydrous manganese oxide filtration ($KMnO_4$-filtration), and co-precipitation with barium sulfate. A relatively new process using the WRT Z-88™ media that is specific for radium adsorption has been demonstrated to be an effective radium technology. Lime softening and co-precipitation with barium sulfate are technologies that are relatively complex and require chemistry skills that are not practical for small systems with limited resources and hence they are not evaluated further.

1.4.5 Description of Treatment Technologies

The application radium removal treatment technologies include IX, WRT-Z88™ media adsorption, RO, ED/EDR, and $KMnO_4$-greensand filtration. A description of these technologies follows.

1.4.5.1 Ion Exchange

Process – In solution, salts separate into positively-charged cations and negatively-charged anions. Ion exchange is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in the water. The process relies on the fact that certain ions are preferentially adsorbed on the ion exchange resin. Operation begins with a fully charged cation or anion bed, having enough positively or negatively charged ions to carry out the cation or anion exchange. Usually a polymeric resin bed is composed of millions of spherical beads about the size of medium sand grains. As water passes the resin bed, the charged ions are released into the water, being substituted or replaced with the contaminants in the water (ion exchange). When the resin becomes exhausted of positively or negatively charged ions, the bed must be regenerated by passing a strong, sodium chloride, solution over the resin, displacing the contaminants ions with sodium ions for cation exchange and chloride ion for anion exchange. Many different types of resins can be used to reduce dissolved contaminant concentrations. The IX treatment train for groundwater typically includes cation or anion resins beds with a regeneration system, chlorine disinfection, and clear well storage. Treatment trains for surface water may also include raw water pumps, debris screens, and filters for pre-treatment. Additional treatment or management of the concentrate and the removed solids will be necessary prior to disposal, especially for radium removal resins which have elevated radioactivity.

For radium removal, a strong acid cation exchange resin in the sodium form can remove 99 percent of the radium. The strong acid resin has less capacity for radium on water with high hardness and it has the following adsorption preference: $Ra^{2+} > Ba^{2+} > Ca^{2+} > Mg^{2+} > Na^{+}$. Because of the selectivity, radium and barium are much more difficult to remove from the resin during regeneration than calcium and magnesium. Economical regeneration removes most of the hardness ions, but radium and barium buildup on the resin after repeated cycles to the point where equilibrium is reached and then radium and barium will begin to breakthrough shortly after hardness. Regeneration of the sodium form strong acid resin for water with 200 milligrams per liter (mg/L) of hardness with application of 6.5-pound $NaCl/ft^3$ resin would produce 2.4 bed volumes (BV) of 16,400 mg/L total dissolved solids (TDS) brine per 100 BV of product water (2.4%). The radium concentration in the regeneration waste would be approximately 40 times the influent radium concentration in groundwater.

Pretreatment – Pretreatment guidelines are available on accepted limits for pH, organics, turbidity, and other raw water characteristics. Pretreatment may be required to reduce excessive amounts of total suspended solids (TSS), iron, and manganese, which could plug the resin bed, and typically includes media or carbon filtration.

Maintenance – The IX resin requires regular on-site regeneration, the frequency of which depends on raw water characteristics (especially hardness), the contaminant concentration, and the size and number of IX vessels. Many systems have undersized the IX vessels only to realize higher than necessary operating costs. Preparation of the sodium chloride solution is required. If used, filter replacement and backwashing will be required.

Waste Disposal – Approval from local authorities is usually required for disposal of concentrate from the regeneration cycle (highly concentrated salt solution with radioactivity); occasional solids wastes (in the form of broken resin beads) which are backwashed during regeneration; and if used, spent filters and backwash wastewater.

Advantages

- Well established process for radium removal.
- Fully automated and highly reliable process.
- Suitable for small and large installations.

Disadvantages

- Requires salt storage; regular regeneration.
- Concentrate disposal.
- Resins are sensitive to the presence of competing ions such as calcium and magnesium.

In considering application of IX for inorganics, it is important to understand what the effect of competing ions will be, and to what extent the brine can be recycled. Conventional IX cationic resin removes calcium and magnesium in addition to radium and thus the capacity for radium removal and frequency of regeneration depend on the hardness of the water to be treated. Spent regenerant is produced during IX bed regeneration, and it may have concentrations of the sorbed contaminants which will be expensive to treat and/or dispose because of hazardous waste regulations.

1.4.5.2 WRT Z-88™ Media

Process – The Water Remediation Technologies, Inc. (WRT) Z-88 radium treatment process is a proprietary process using a radium specific adsorption resin or zeolite supplied by WRT. The Z-88 process is similar to IX except that no regeneration of the resin is conducted and the resin is disposed of upon exhaustion. The Z-88 does not remove calcium and magnesium and thus it can last for a long time (2-4 years, according to WRT) before replacement is necessary. The process is operated in an upflow, fluidized mode with a surface loading rate of 10.5 gpm/ft^2. Pilot testing of this technology has been conducted successfully for radium removal in many locations including in the State of Texas. Seven full-scale systems with capacities of 750 to 1,200 gpm have been constructed in the Village of Oswego, Illinois since July 2005. The treatment equipment is owned by WRT and the ownership of spent media would be transferred to an approved disposal site. The customer pays WRT based on an agreed upon treated water unit cost (*e.g.*, $3.00/thousand gallons for small systems).

Pretreatment – Pretreatment may be required to reduce excess amounts of TSS, iron, and manganese, which could plug the resin bed, and typically includes media or carbon filtration. No chemical addition is required for radium removal.

Maintenance – Maintenance is relatively low for this technology as no regeneration or chemical handling is required. Periodical water quality monitoring and inspection of mechanical equipment are required.

Waste Disposal – The Z-88 media would be disposed of in an approved low level radioactive waste landfill by WRT once every 2-4 years. No liquid waste is generated for this process. However, if pretreatment filters are used then spent filters and backwash wastewater disposal is required.

Advantages

- Simple and fully automated process.
- No liquid waste disposal.

- No chemical handling, storage, or feed systems.
- No change in water quality except radium reduction.
- Low capital cost as WRT owns the equipment.

Disadvantages

- Relatively new technology.
- Proprietary technology without direct competition.
- Long term contract with WRT required.

From a small utilities point of view the Z-88 process is a desirable technology for radium removal as operation and maintenance (O&M) effort is minimal and no regular liquid waste is generated. However, this technology is very new and without long-term full-scale operating experience. But since the equipment is owned by WRT and the performance is guaranteed by WRT the risk to the utilities is minimized.

1.4.5.3 Reverse Osmosis

Process – RO is a pressure-driven membrane separation process capable of removing dissolved solutes from water by means of particle size and electrical charge. The raw water is typically called feed; the product water is called permeate, and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate and polyamide thin film composite. Common RO membrane configurations include spiral wound and hollow fine fiber but most RO systems to date are of the spiral wound type. A typical RO installation includes a high pressure feed pump with chemical feed, parallel first and second stage membrane elements in pressure vessels, and valving and piping for feed, permeate, and concentrate streams. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, and regular monitoring and maintenance. RO is capable of achieving over 95% removal of radium. The treatment process is relatively insensitive to pH. Water recovery is 60-80 percent, depending on the raw water characteristics. The concentrate volume for disposal can be significant.

Pretreatment – RO requires careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling or other membrane degradation. Removal or sequestering of suspended and colloidal solids is necessary to prevent fouling, and removal of sparingly soluble constituents such as calcium, magnesium, silica, sulfate, barium, *etc*. may be required to prevent scaling. Pretreatment can include media filters, ion exchange softening, acid and antiscalant feed, activated carbon or bisulfite feed to dechlorinate, and cartridge filters to remove any remaining suspended solids to protect membranes from upsets.

Maintenance – Monitoring rejection percentage is required to ensure contaminant removal below MCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove foulants and scalants. Frequency of membrane replacement is dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal – Pretreatment waste streams, concentrate flows, spent filters and membrane elements all required approved disposal methods. The disposal of the significant volume of the concentrate stream is a problem for many utilities.

Advantages

- Can remove radium effectively.
- Can remove other undesirable dissolved constituents.

Disadvantages

- Relatively expensive to install and operate.
- Needs sophisticated monitoring systems.
- Concentrate requires disposal
- Needs to handle multiple chemicals.
- Waste of water because of the significant concentrate flows.
- Reject requires disposal

RO is an expensive alternative to remove radium and is usually not economically competitive with other processes unless nitrate and/or TDS removal is also required. The biggest drawback for using RO to remove radium is the waste of water through concentrate disposal which is also difficult or expensive because of the volume involved.

1.4.5.4 Electrodialysis/Electrodialysis Reversal

Process – ED is an electrochemical separation process in which ions migrate through ion-selective semi-permeable membranes as a result of their attraction to two electrically charged electrodes. The driving force for ion transfer is direct electric current. ED is different from RO in that it removes only dissolved inorganics but not particulates, organics, and silica. EDR is an improved form of ED in which the polarity of the direct current is changed approximately every 15 minutes. The change of polarity helps to reduce the formation of scale and fouling films and thus a higher water recovery can be achieved. EDR has been the dominant form of ED system used for the past 25-30 years. A typical EDR system includes a membrane stack with a number of cell pairs, each consisting of a cation transfer membrane, a demineralized water flow spacer, an anion transfer membrane, and a concentrate flow spacer. Electrode compartments are at opposite ends of the stack. The influent feed water (chemically treated to prevent precipitation) and concentrate reject flow in parallel across the membranes and through the demineralized water and concentrate flow spacers, respectively. The electrodes are continually flushed to reduce fouling or scaling. Careful consideration of flush feed water is required. Typically, the membranes are cation or anion exchange resins cast in sheet form; the spacers are high density polyethylene; and the electrodes are inert metal. EDR stacks are tank-contained and often staged. Membrane selection is based on review of raw water characteristics. A single-stage EDR system usually removes 40-50 percent of the dissolved salts including radium, and multiple stages may be required to meet the MCL if radium concentration is high. The conventional EDR treatment train typically includes EDR membranes, chlorine disinfection, and clear well storage.

Pretreatment – Guidelines are available on acceptable limits on pH, organics, turbidity, and other raw water characteristics. EDR typically requires acid and antiscalant feed to prevent scaling and a cartridge filter for prefiltration. Treatment of surface water may also require pretreatment steps such as raw water pumps, debris screens, rapid mix with addition of a coagulant, flocculation basin, sedimentation basin or clarifier, and gravity filters. MF could be used in place of flocculation, sedimentation, and filtration.

Maintenance – EDR membranes are durable, can tolerate pH from 1-10, and temperatures to 115°F for cleaning. The can be removed from the unit and scrubbed. Solids can be washed off by turning the power off and letting water circulate through the stack. Electrode washes flush out byproducts of electrode reaction. The byproducts are hydrogen, formed in the cathode space, and oxygen and chlorine gas, formed in the anode spacer. If the chlorine is not removed, toxic chlorine gas may form. Depending on raw water characteristics, the membranes will require regular maintenance or replacement. If used, pretreatment filter replacement and backwashing will be required. The EDR stack must be disassembled, mechanically cleaned, and reassembled at regular intervals.

Waste Disposal – Highly concentrated reject flows, electrode cleaning flows, and spent membranes require approved disposal methods. Pretreatment process residuals and spent materials also require approved disposal methods.

Advantages

- EDR can operate with minimal fouling, scaling, or chemical addition.
- Low pressure requirements; typically quieter than RO.
- Long membrane life expectancy.
- More flexible than RO in tailoring treated water quality requirements.

Disadvantages

- Not suitable for high levels of iron, manganese, hydrogen sulfide, and hardness.
- Relatively expensive process and high energy consumption.
- Does not remove particulates, organics, or silica.
- Reject requires disposal

EDR can be quite expensive to run because of the energy it uses. If radium removal is the only purpose it is probably more expensive than other technologies. However, if nitrate and/or TDS removal is also required, then EDR is a competitive process.

1.4.5.5 Potassium Permanganate Greensand Filtration

<u>Process</u> – Manganese dioxide (MnO_2) is known to have capacity to adsorb radium from water. MnO_2 can be formed by oxidation of Mn^{2+} occurring in natural waters and/or reduction of $KMnO_4$ added to the water. The MnO_2 is in the form of colloidal MnO_2 which has a large surface area for adsorption. The MnO_2 does not adsorb calcium and magnesium so hardness is not a factor but iron and manganese and other heavy metal cations can compete strongly with radium adsorption. If these cations are present it would be necessary to install a good iron and manganese removal process before the MnO_2- filtration process or making sure that some MnO_2 is still available for radium sorption. The $KMnO_4$-greensand filtration process can accomplish this purpose as the greensand is coated with MnO2 which is regenerated by the continuous feeding of $KMnO_4$. Many operating treatment systems utilizing continuous feed $KMnO_4$, 30-minute contact time, and manganese greensand remove radium to concentrations below the MCL. The treatment system equipment includes a $KMnO_4$ feed system, a pressurized reaction tank, and a manganese greensand filter. Backwashing of the greensand filter is usually required but periodic regeneration is not required.

<u>Pretreatment</u> – The $KMnO_4$-greensand filtration process usually does not require pretreatment except if the turbidity is very high. The greensand filter usually has an anthracite layer to filter larger particles while the greensand adsorbs dissolved cations such as radium.

<u>Maintenance</u> – The greensand requires periodic backwashing to rid of suspended materials and metal oxides. $KMnO_4$ is usually supplied in the powder form and preparation of $KMnO_4$ solution is required. Occasional monitoring to ensure no overfeeding of $KMNO_4$ (pink water) is important to avoid problems in distribution system and household fixtures.

<u>Waste Disposal</u> – Approval from local authorities is usually required for the backwash wastewater. If local sewer is not available a backwash water storage and settling tank would be required to recycle settled water to the process and disposed of the settled solids periodically.

Advantages

- Well established process for radium removal.
- No regeneration waste generated.
- Low pressure operation and no repumping required.
- No additional process for iron and manganese removal.

Disadvantages

- Need to handle powdered $KMnO_4$, which is an oxidant.
- Need to monitor and backwash regularly.

The $KMnO_4$-greensand filtration is a well established iron and manganese removal process and is effective for radium removal. It is suitable for small and large systems and is cost competitive with other alternative technologies.

1.4.6 Point-of-Entry and Point-of-Use Treatment Systems

Point-of-entry (POE) and point-of-use (POU) treatment systems can be used to provide compliant drinking water. For radium and gross alpha particle removal, these systems typically use small adsorption or reverse osmosis treatment units that are installed "under the sink" in the case of point-of-use, and where water enters a house or building in the case of point-of-entry. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets to meet regulatory requirements, making purchase and installation more expensive. Point-of-entry and point-of-use treatment units would be purchased and owned by the PWS. These solutions are decentralized in nature, and require utility personnel entry into houses or at least onto private property for installation, maintenance, and testing. Due to the large number of treatment units that would be employed and would be largely out of the control of the PWS, it is very difficult to ensure 100 percent compliance. Prior to selection of a point-of-entry or point-of-use program for implementation, consultation with TCEQ would be required to address measurement and determination of level of compliance.

The SDWA [§1412(b)(4)(E)(ii)] regulates the design, management and operation of POU and POE treatment units used to achieve compliance with an MCL. These restrictions, relevant to radium and gross alpha particles are:

- POU and POE treatment units must be owned, controlled, and maintained by the water system, although the utility may hire a contractor to ensure proper O&M and MCL compliance. The water system must retain unit ownership and oversight of unit installation, maintenance and sampling; the utility ultimately is the responsible party for regulatory compliance. The water system staff need not perform all installation, maintenance, or management functions, as these tasks may be contracted to a third party-but the final responsibility for the quality and quantity of the water supplied to the community resides with the water system, and the utility must monitor all contractors closely. Responsibility for O&M of POU or POE devices installed for SDWA compliance may not be delegated to homeowners.
- POU and POE units must have mechanical warning systems to automatically notify customers of operational problems. Each POU or POE treatment device must be equipped with a warning device (*e.g.,* alarm, light) that would alert users when their unit is no longer adequately treating their water. As an alternative, units may be equipped with an automatic shut-off mechanism to meet this requirement.
- If the American National Standards Institute has issued product standards for a specific type of POU or POE treatment unit, only those units that have been independently certified according to those standards may be used as part of a compliance strategy.

The following observations with regard to using POE and POU devices for SDWA compliance were made by Raucher, *et al.* (2004):

- If POU devices are used as an SDWA compliance strategy, certain consumer behavioral changes will be necessary (*e.g.*, encouraging people to drink water only from certain treated taps) to ensure comprehensive consumer health protection.
- Although not explicitly prohibited in the SDWA, USEPA indicates that POU treatment devices should not be used to treat for radon or for most volatile organic contaminants to achieve compliance, because POU devices do not provide 100 percent protection against inhalation or contact exposure to those contaminants at untreated taps (*e.g.*, shower heads).
- Liability – PWSs considering unconventional treatment options (POU, POE, or bottled water) must address liability issues. These could be meeting drinking water standards, property entry and ensuing liabilities, and damage arising from improper installation or improper function of the POU and POE devices.

1.4.7 Water Delivery or Central Drinking Water Dispensers

Current USEPA regulations (40 Code of Federal Regulations [CFR] 141.101) prohibit the use of bottled water to achieve compliance with an MCL, except on a temporary basis. State regulations do not directly address the use of bottled water. Use of bottled water at a non-compliant PWS would be on a temporary basis. Every 3 years, the PWSs that employ interim measures are required to present the TCEQ with estimates of costs for piping compliant water to their systems. As long as the projected costs remain prohibitively high, the bottled water interim measure is extended. Until USEPA amends the noted regulation, the TCEQ is unable to accept water delivery or central drinking water dispensers as compliance solutions.

Central provision of compliant drinking water would consist of having one or more dispensers of compliant water where customers could come to fill containers with drinking water. The centralized water source could be from small to medium-sized treatment units or could be compliant water delivered to the central point by truck.

Water delivery is an interim measure for providing compliant water. As an interim measure for a small impacted population, providing delivered drinking water may be cost effective. If the susceptible population is large, the cost of water delivery would increase significantly.

Water delivery programs require consumer participation to a varying degree. Ideally, consumers would have to do no more than they currently do for a piped-water delivery system. Least desirable are those systems that require maximum effort on the part of the customer (*e.g.*, customer has to travel to get the water, transport the water, and physically handle the bottles). Such a system may appear to be lowest-cost to the utility; however, should a consumer experience ill effects from contaminated water and take legal action, the ultimate cost could increase significantly.

The ideal system would:

- Completely identify the susceptible population. If bottled water is only provided to customers who are part of the susceptible population, the utility should have an active means of identifying the susceptible population. Problems with illiteracy, language fluency, fear of legal authority, desire for privacy, and apathy may be reasons that some members of the susceptible population do not become known to the utility, and do not take part in the water delivery program.

- Maintain customer privacy by eliminating the need for utility personnel to enter the home.
- Have buffer capacity (*e.g.*, two bottles in service, so when one is empty, the other is being used over a time period sufficient to allow the utility to change out the empty bottle).
- Provide for regularly scheduled delivery so the customer would not have to notify the utility when the supply is low.
- Use utility personnel and equipment to handle water containers, without requiring customers to lift or handle bottles with water in them.
- Be sanitary (*e.g.*, where an outside connection is made, contaminants from the environment must be eliminated).
- Be vandal-resistant.
- Avoid heating the water due to exterior temperatures and solar radiation.
- Avoid freezing the water.

SECTION 2
EVALUATION METHOD

2.1 DECISION TREE

The decision tree is a flow chart for conducting feasibility studies for a non-compliant PWS. The decision tree is shown in Figures 2.1 through 2.4. The tree guides the user through a series of phases in the design process. Figure 2.1 shows Tree 1, which outlines the process for defining the existing system parameters, followed by optimizing the existing treatment system operation. If optimizing the existing system does not correct the deficiency, the tree leads to six alternative preliminary branches for investigation. The groundwater branch leads through investigating existing wells to developing a new well field. The treatment alternatives address centralized and on-site treatment. The objective of this phase is to develop conceptual designs and cost estimates for the six types of alternatives. The work done for this report follows through Tree 1 and Tree 2, as well as a preliminary pass through Tree 4.

Tree 3, which begins at the conclusion of the work for this report, starts with a comparison of the conceptual designs, selecting the two or three alternatives that appear to be most promising, and eliminating those alternatives which are obviously infeasible. It is envisaged that a process similar to this would be used by the study PWS to refine the list of viable alternatives. The selected alternatives are then subjected to intensive investigation, and highlighted by an investigation into the socio-political aspects of implementation. Designs are further refined and compared, resulting in the selection of a preferred alternative. The steps for assessing the financial and economic aspects of the alternatives (one of the steps in Tree 3) are given in Tree 4 in Figure 2.4.

2.2 DATA SOURCES AND DATA COLLECTION

2.2.1 Data Search

2.2.1.1 Water Supply Systems

The TCEQ maintains a set of files on public water systems, utilities, and districts at its headquarters in Austin, Texas. The files are organized under two identifiers: a PWS identification number and a CCN number. The PWS identification number is used to retrieve four types of files:

- CO – Correspondence,
- CA – Chemical analysis,
- MOR – Monthly operating reports (quality/quantity), and
- FMT – Financial, managerial and technical issues.

Figure 2.1
TREE 1 – EXISTING FACILITY ANALYSIS

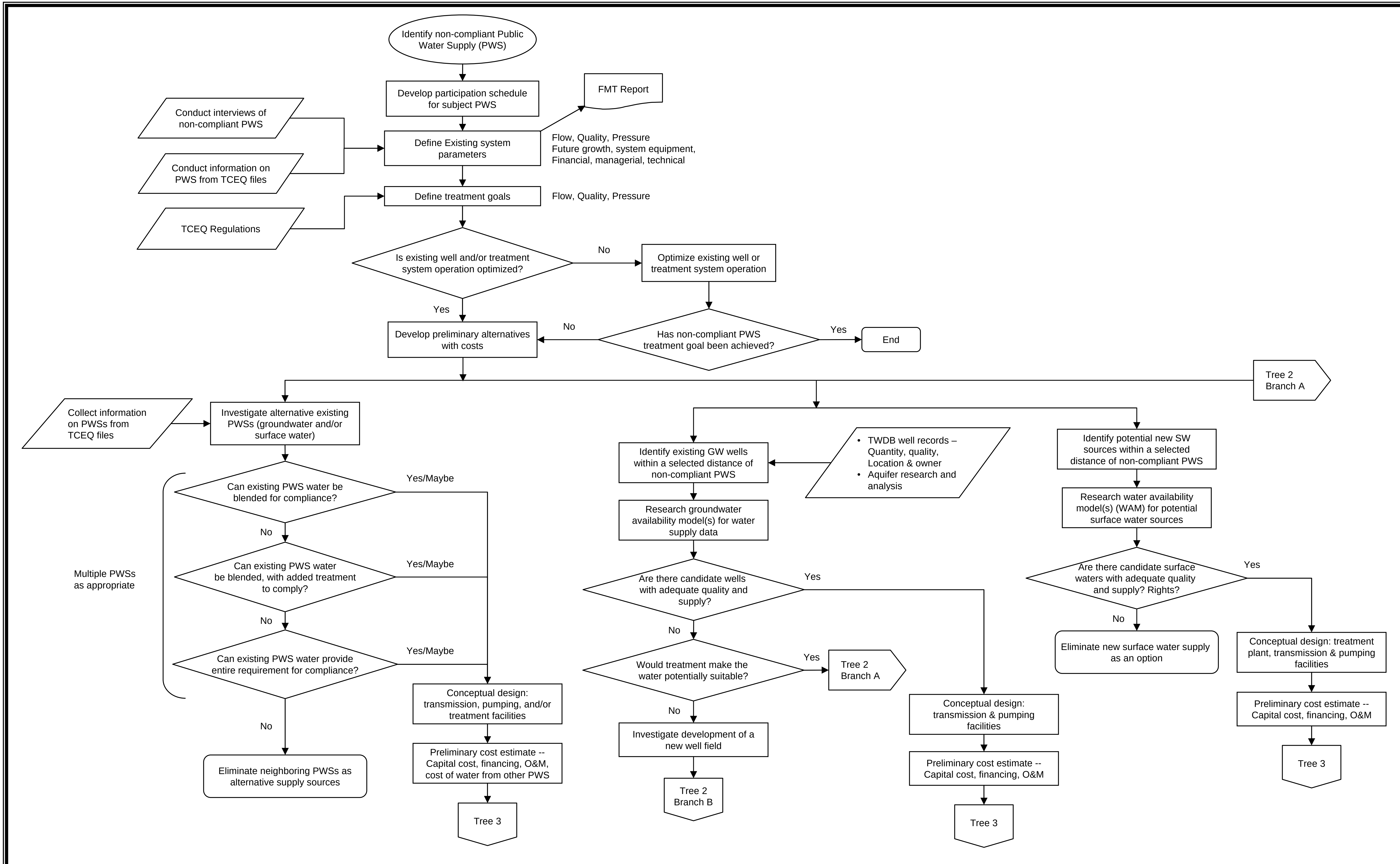


Figure 2.2
TREE 2 – DEVELOP TREATMENT ALTERNATIVES

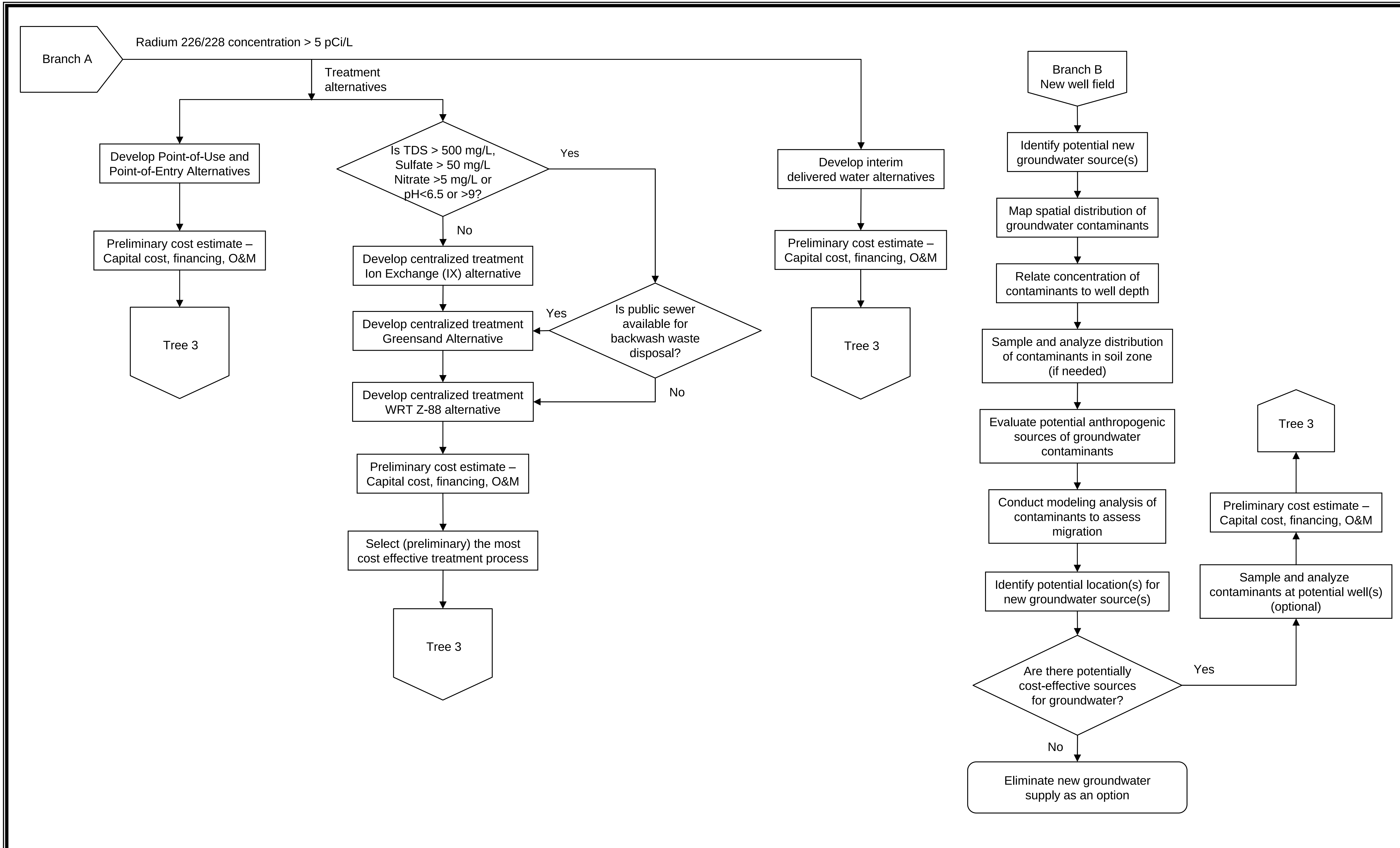


Figure 2.3

Tree 3 – PRELIMINARY ANALYSIS

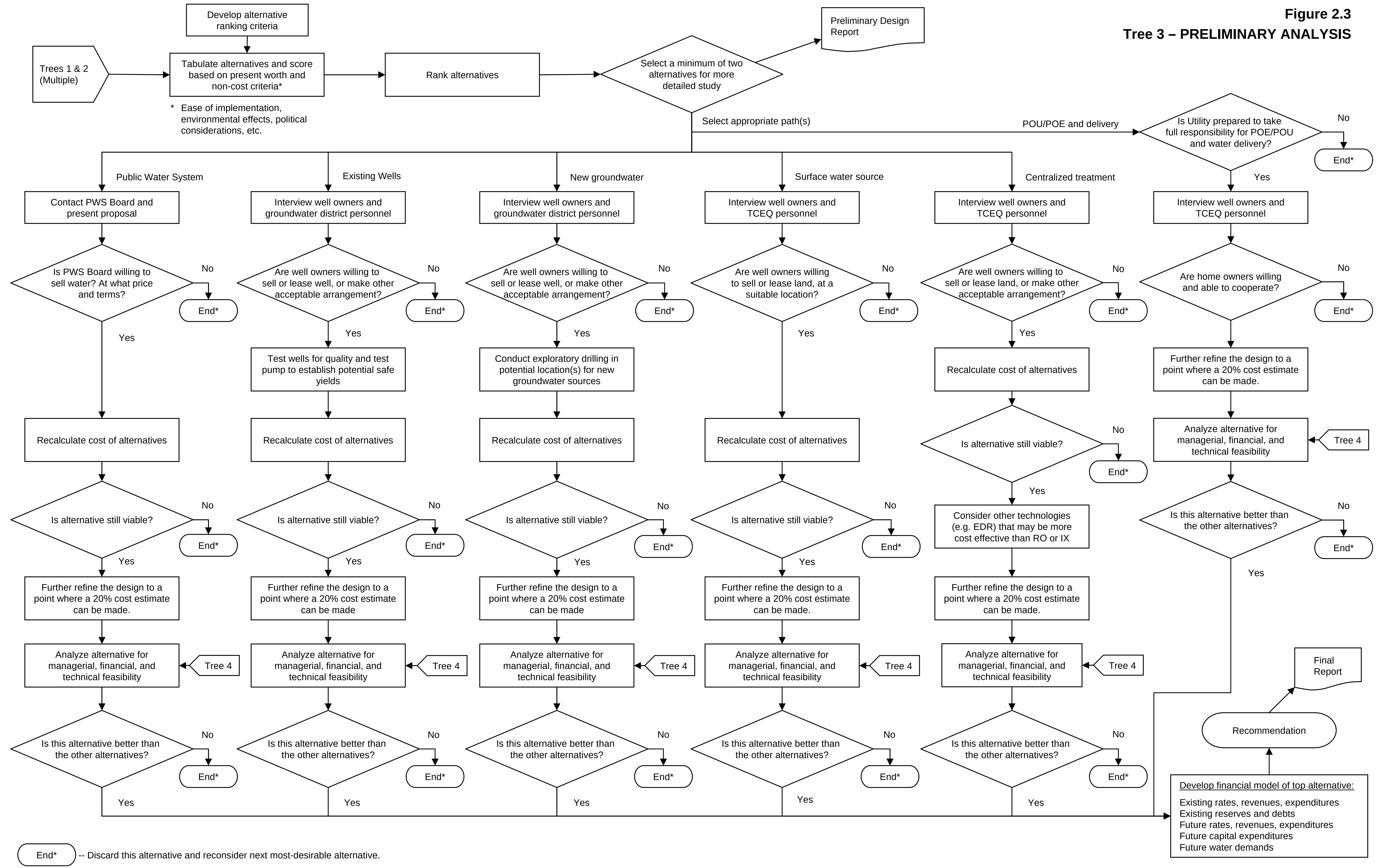
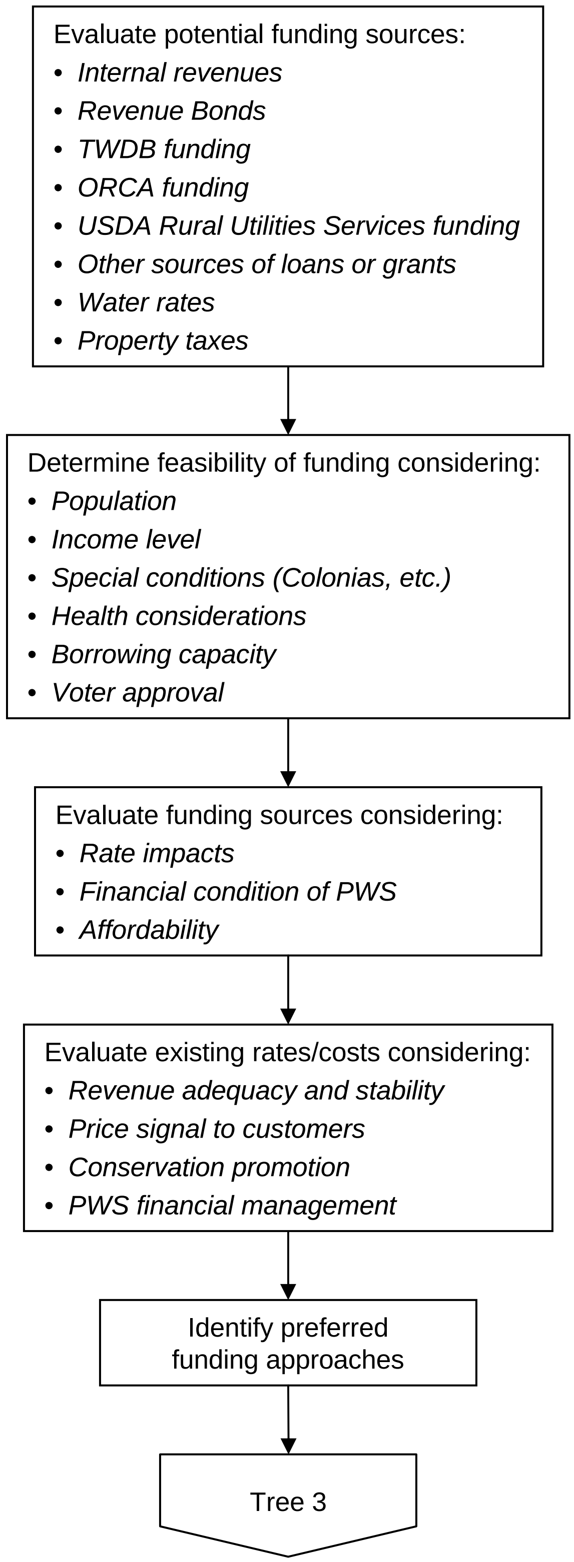


Figure 2.4
TREE 4 – FINANCIAL



The CCN files generally contain a copy of the system's Certificate of Convenience and Necessity, along with maps and other technical data.

These files were reviewed for the PWS and surrounding systems.

The following websites were consulted to identify the water supply systems in the study area:

- Texas Commission on Environmental Quality www3.tnrcc.state.tx.us/iwud/pws/index.cfm? Under "Advanced Search", type in the name(s) of the county(ies) in the study area to get a listing of the public water supply systems.
- USEPA Safe Drinking Water Information System www.epa.gov/safewater/data/getdata.html

Groundwater Control Districts were identified on the TWDB web site, which has a series of maps covering various groundwater and surface water subjects. One of those maps shows groundwater control districts in the State of Texas.

2.2.1.2 Existing Wells

The TWDB maintains a groundwater database available at www.twdb.state.tx.us that has two tables with helpful information. The "Well Data Table" provides a physical description of the well, owner, location in terms of latitude and longitude, current use, and for some wells, items such as flowrate, and nature of the surrounding formation. The "Water Quality Table" provides information on the aquifer and the various chemical concentrations in the water.

2.2.1.3 Surface Water Sources

Regional planning documents were consulted for lists of surface water sources.

2.2.1.4 Groundwater Availability Model

GAMs, developed by the TWDB, are planning tools and should be consulted as part of a search for new or supplementary water sources. The GAM for the Gulf Coast aquifer (northern part) which includes the Evangeline and Jasper aquifers, was investigated as a potential tool for identifying available and suitable groundwater resources.

2.2.1.5 Water Availability Model

The WAM is a computer-based simulation predicting the amount of water that would be in a river or stream under a specified set of conditions. WAMs are used to determine whether water would be available for a newly requested water right or amendment. If water is available, these models estimate how often the applicant could count on water under various conditions (*e.g.,* whether water would be available only 1 month out of the year, half the year, or all year, and whether that water would be available in a repeat of the drought of record).

WAMs provide information that assist TCEQ staff in determining whether to recommend the granting or denial of an application.

2.2.1.6 Financial Data

Financial data were collected through a site visit. Data sought included:

- Annual Budget
- Audited Financial Statements
  - Balance Sheet
  - Income & Expense Statement
  - Cash Flow Statement
  - Debt Schedule
- Water Rate Structure
- Water Use Data
  - Production
  - Billing
  - Customer Counts

2.2.1.7 Demographic Data

Basic demographic data were collected from the 2000 Census to establish incomes and eligibility for potential low cost funding for capital improvements. Median household income (MHI) and number of families below poverty level were the primary data points of significance. If available, MHI for the customers of the PWS should be used. In addition, unemployment data were collected from current U.S. Bureau of Labor Statistics. These data were collected for the following levels: national, state, and county.

2.2.2 PWS Interviews

2.2.2.1 PWS Capacity Assessment Process

A capacity assessment is the industry standard term for an evaluation of a water system's financial, managerial, and technical capacity to effectively deliver safe drinking water to its customers now and in the future at a reasonable cost, and to achieve, maintain and plan for compliance with applicable regulations. The assessment process involves interviews with staff and management who have a responsibility in the operations and management of the system.

Financial, managerial, and technical capacity are individual yet highly interrelated components of a system's capacity. A system cannot sustain capacity without maintaining adequate capability in all three components.

Financial capacity is a water system's ability to acquire and manage sufficient financial resources to allow the system to achieve and maintain compliance with SDWA regulations.

Financial capacity refers to the financial resources of the water system, including but not limited to revenue sufficiency, credit worthiness, and fiscal controls.

Managerial capacity is the ability of a water system to conduct its affairs so the system is able to achieve and maintain compliance with SDWA requirements. Managerial capacity refers to the management structure of the water system, including but not limited to ownership accountability, staffing and organization, and effective relationships to customers and regulatory agencies.

Technical capacity is the physical and operational ability of a water system to achieve and maintain compliance with the SDWA regulations. It refers to the physical infrastructure of the water system, including the adequacy of the source water, treatment, storage and distribution infrastructure. It also refers to the ability of system personnel to effectively operate and maintain the system and to otherwise implement essential technical knowledge.

Many aspects of water system operations involve more than one component of capacity. Infrastructure replacement or improvement, for example, requires financial resources, management planning and oversight, and technical knowledge. A deficiency in any one area could disrupt the entire effort. A system that is able to meet both its immediate and long-term challenges demonstrates that it has sufficient financial, managerial, and technical capacity.

Assessment of the FMT capacity of the PWS was based on an approach developed by the New Mexico Environmental Finance Center (NMEFC), which is consistent with TCEQ FMT assessment process. This method was developed from work the NMEFC did while assisting USEPA Region 6 in developing and piloting groundwater comprehensive performance evaluations. The NMEFC developed a standard list of questions that could be asked of water system personnel. The list was then tailored slightly to have two sets of questions – one for managerial and financial personnel, and one for operations personnel (the questions are included in Appendix A). Each person with a role in the FMT capacity of the system was asked the applicable standard set of questions individually. The interviewees were not given the questions in advance and were not told the answers others provided. Also, most of the questions are open ended type questions so they were not asked in a fashion to indicate what would be the “right” or “wrong” answer. The interviews lasted between 45 minutes to 75 minutes depending on the individual’s role in the system and the length of the individual’s answers.

In addition to the interview process, visual observations of the physical components of the system were made. A technical information form was created to capture this information. This form is also contained in Appendix A. This information was considered supplemental to the interviews because it served as a check on information provided in the interviews. For example, if an interviewee stated he or she had an excellent preventative maintenance schedule and the visit to the facility indicated a significant amount of deterioration (more than would be expected for the age of the facility) then the preventative maintenance program could be further investigated or the assessor could decide that the preventative maintenance program was inadequate.

Following interviews and observations of the facility, answers that all personnel provided were compared and contrasted to provide a clearer picture of the true operations at the water system. The intent was to go beyond simply asking the question, "Do you have a budget?" to actually finding out if the budget was developed and being used appropriately. For example, if a water system manager was asked the question, "Do you have a budget?" he or she may say, "yes" and the capacity assessor would be left with the impression that the system is doing well in this area. However, if several different people are asked about the budget in more detail, the assessor may find that although a budget is present, operations personnel do not have input into the budget, the budget is not used by the financial personnel, the budget is not updated regularly, or the budget is not used in setting or evaluating rates. With this approach, the inadequacy of the budget would be discovered and the capacity deficiency in this area would be noted.

Following the comparison of answers, the next step was to determine which items noted as a potential deficiency truly had a negative effect on the system's operations. If a system had what appeared to be a deficiency, but this deficiency was not creating a problem in terms of the operations or management of the system, it was not considered critical and may not have needed to be addressed as a high priority. As an example, the assessment may have revealed an insufficient number of staff members to operate the facility. However, it may also have been revealed that the system was able to work around that problem by receiving assistance from a neighboring system, so no severe problems resulted from the number of staff members. Although staffing may not be ideal, the system does not need to focus on this particular issue. The system needs to focus on items that are truly affecting operations. As an example of this type of deficiency, a system may lack a reserve account which can then lead the system to delay much-needed maintenance or repair on its storage tank. In this case, the system needs to address the reserve account issue so that proper maintenance can be completed.

The intent was to develop a list of capacity deficiencies with the greatest impact on the system's overall capacity. Those were the most critical items to address through follow-up technical assistance or by the system itself.

2.2.2.2 Interview Process

PWS personnel were interviewed by the project team, and each was interviewed separately. Interview forms were completed during each interview.

2.3 ALTERNATIVE DEVELOPMENT AND ANALYSIS

The initial objective for developing alternatives to address compliance issues is to identify a comprehensive range of possible options that can be evaluated to determine which are the most promising for implementation. Once the possible alternatives are identified, they must be defined in sufficient detail so a conceptual cost estimate (capital and O&M costs) can be developed. These conceptual cost estimates are used to compare the affordability of compliance alternatives, and to give a preliminary indication of rate impacts. Consequently, these costs are pre-planning level and should not be viewed as final estimated costs for alternative implementation. The basis for the unit costs used for the compliance alternative cost estimates is summarized in Appendix B. Other non-economic factors for the alternatives, such as reliability and ease of implementation, are also addressed.

2.3.1 Existing PWS

The neighboring PWSs were identified, and the extents of their systems were investigated. PWSs farther than 10 miles from the non-compliant PWSs were not considered because the length of the pipeline required would make the alternative cost prohibitive. The quality of water provided was also investigated. For neighboring PWSs with compliant water, options for water purchase and/or expansion of existing well fields were considered. The neighboring PWSs with non-compliant water were considered as possible partners in sharing the cost for obtaining compliant water either through treatment or developing an alternate source.

The neighboring PWSs were investigated to get an idea of the water sources in use and the quantity of water that might be available for sale. They were contacted to identify key locations in their systems where a connection might be made to obtain water, and to explore on a preliminary basis their willingness to partner or sell water. Then, the major system components that would be required to provide compliant water were identified. The major system components included treatment units, wells, storage tanks, pump stations, and pipelines.

Once the major components were identified, a preliminary design was developed to identify sizing requirements and routings. A capital cost estimate was then developed based on the preliminary design of the required system components. An annual O&M cost was also estimated to reflect the change in O&M expenditures that would be needed if the alternative was implemented.

Non-economic factors were also identified. Ease of implementation was considered, as well as the reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant increase in the management or technical capability of the PWS, and whether the alternative had the potential for regionalization.

2.3.2 New Groundwater Source

It was not possible in the scope of this study to determine conclusively whether new wells could be installed to provide compliant drinking water. To evaluate potential new groundwater source alternatives, three test cases were developed based on distance from the PWS intake point. The test cases were based on distances of 5 miles, 1 mile, and installing a well on-site. It was assumed that a pipeline would be required for all three test cases, and a storage tank and pump station would be required for the 5-mile alternative. It was also assumed that new wells would be installed, and that their depths would be similar to the depths of the existing wells, or other existing drinking water wells in the area.

A preliminary design was developed to identify sizing requirements for the required system components. A capital cost estimate was then developed based on the preliminary design of the required system components. An annual O&M cost was also estimated to reflect the change (*i.e.*, from current expenditures) in O&M expenditures that would be needed if the alternative was implemented.

Non-economic factors were also identified. Ease of implementation was considered, as well as the reliability for providing adequate quantities of compliant water. Additional factors were; whether implementation of an alternative would require significant increase in the management or technical capability of the PWS, and whether the alternative had the potential for regionalization.

2.3.3 New Surface Water Source

New surface water sources were investigated. Availability of adequate quality water was investigated for the main rivers in the study area, as well as the major reservoirs. TCEQ WAMs were inspected, and the WAM was run, where appropriate.

2.3.4 Treatment

Treatment technologies considered potentially applicable to radium and gross alpha particle removal are IX, WRT Z-88™ media, RO, EDR, and $KMnO_4$-greensand filtration. RO and EDR are membrane processes that produce a considerable amount of liquid waste: a reject stream from RO treatment and a concentrate stream from EDR treatment. As a result, the treated volume of water is less than the volume of raw water that enters the treatment system. The amount of raw water used increases to produce the same amount of treated water if RO or EDR treatment is implemented. Because the TDS is not high the use of RO or EDR would be considerably more expensive than the other potential technologies. Hence, RO and EDR are not considered further. However, RO is considered for POU and POE alternatives. IX, WRT Z-88™ media, and $KMnO_4$-greensand filtration are considered as alternative central treatment technologies. The treatment units were sized based on flow rates, and capital and annual O&M cost estimates were made based on the size of the treatment equipment required. Neighboring non-compliant PWSs were identified to look for opportunities where the costs and benefits of central treatment could be shared between systems.

Non-economic factors were also identified. Ease of implementation was considered, as well as reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant increase in the management or technical capability of the PWS, and whether the alternative had the potential for regionalization.

2.4 COST OF SERVICE AND FUNDING ANALYSIS

The primary purpose of the cost of service and funding analysis is to determine the financial impact of implementing compliance alternatives, primarily by examining the required rate increases, and also the fraction of household income that water bills represent. The current financial situation is also reviewed to determine what rate increases are necessary for the PWS to achieve or maintain financial viability.

2.4.1 Financial Feasibility

A key financial metric is the comparison of average annual household water bill for a PWS customer to the MHI for the area. MHI data from the 2000 Census are used, at the most detailed level available for the community. Typically, county level data are used for small rural water utilities due to small population sizes. Annual water bills are determined for existing, base conditions, including consideration of additional rate increases needed under current conditions. Annual water bills are also calculated after adding incremental capital and operating costs for each of the alternatives to determine feasibility under several potential funding sources.

Additionally, the use of standard ratios provides insight into the financial condition of any business. Three ratios are particularly significant for water utilities:

- Current Ratio = current assets divided by current liabilities provides insight into the ability to meet short-term payments. For a healthy utility, the value should be greater than 1.0.
- Debt to Net Worth Ratio = total debt divided by net worth shows to what degree assets of the company have been funded through borrowing. A lower ratio indicates a healthier condition.
- Operating Ratio = total operating revenues divided by total operating expenses show the degree to which revenues cover ongoing expenses. The value is greater than 1.0 if the utility is covering its expenses.

2.4.2 Median Household Income

The 2000 U.S. Census is used as the basis for MHI. In addition to consideration of affordability, the annual MHI may also be an important factor for sources of funds for capital programs needed to resolve water quality issues. Many grant and loan programs are available to lower income rural areas, based on comparisons of local income to statewide incomes. In the 2000 Census, MHI for the State of Texas was $39,927, compared to the U.S. level of $41,994.

2.4.3 Annual Average Water Bill

The annual average household water bill was calculated for existing conditions and for future conditions incorporating the alternative solutions. Average residential consumption is estimated and applied to the existing rate structure to estimate the annual water bill. The estimates are generated from a long-term financial planning model that details annual revenue, expenditure, and cash reserve requirements over a 30-year period.

2.4.4 Financial Plan Development

The financial planning model uses available data to establish base conditions under which the system operates. The model includes, as available:

- Accounts and consumption data
- Water tariff structure
- Beginning available cash balance
- Sources of receipts:
  - Customer billings
  - Membership fees
  - Capital Funding receipts from:
    - Grants
    - Proceeds from borrowing
- Operating expenditures:
  - Water purchases
  - Utilities
  - Administrative costs
  - Salaries
- Capital expenditures
- Debt service:
  - Existing principal and interest payments
  - Future principal and interest necessary to fund viable operations
- Net cash flow
- Restricted or desired cash balances:
  - Working capital reserve (based on 1-4 months of operating expenses)
  - Replacement reserves to provide funding for planned and unplanned repairs and replacements

From the model, changes in water rates are determined for existing conditions and for implementing the compliance alternatives.

2.4.5 Financial Plan Results

Results from the financial planning model are summarized in two areas: percentage of household income and total water rate increase necessary to implement the alternatives and maintain financial viability.

2.4.5.1 Funding Options

Results are summarized in a table that shows the following according to alternative and funding source:

- Percentage of the annual MHI the average annual residential water bill represents.
- The first year in which a water rate increase would be required
- The total increase in water rates required, compared to current rates

Water rates resulting from the incremental capital costs of the alternative solutions are examined under a number of funding options. The first alternative examined is always funding from existing reserves plus future rate increases. Several funding options were analyzed to frame a range of possible outcomes.

- Grant funds for 100 percent of required capital. In this case, the PWS is only responsible for the associated O&M costs.
- Grant funds for 75 percent of required capital, with the balance treated as if revenue bond funded.
- Grant funds for 50 percent of required capital, with the balance treated as if revenue bond funded.
- State revolving fund loan at the most favorable available rates and terms applicable to the communities.
- If local MHI > 75 percent of state MHI, standard terms, currently at 3.8 percent interest for non-rated entities. Additionally:
  - If local MHI = 70-75 percent of state MHI, 1 percent interest rate on loan.
  - If local MHI = 60-70 percent of state MHI, 0 percent interest rate on loan.
  - If local MHI = 50-60 percent of state MHI, 0 percent interest and 15 percent forgiveness of principal.
  - If local MHI less than 50 percent of state MHI, 0 percent interest and 35 percent forgiveness of principal.
- Terms of revenue bonds assumed to be 25-year term at 6.0 percent interest rate.

2.4.5.2 General Assumptions Embodied in Financial Plan Results

The basis used to project future financial performance for the financial plan model includes:

- No account growth (either positive or negative).
- No change in estimate of uncollectible revenues over time.
- Average consumption per account unchanged over time.

- No change in unaccounted for water as percentage of total (more efficient water use would lower total water requirements and costs).
- No inflation included in the analyses (although the model has provisions to add escalation of O&M costs, doing so would mix water rate impacts from inflation with the impacts from the alternatives being examined).
- Minimum working capital fund established for each district, based on specified months of O&M expenditures.
- O&M for alternatives begins 1 year after capital implementation.
- Balance of capital expenditures not funded from primary grant program is funded through debt (bond equivalent).
- Cash balance drives rate increases, unless provision chosen to override where current net cash flow is positive.

2.4.5.3 Interpretation of Financial Plan Results

Results from the financial plan model for each alternative are presented in Table 4.5 in Section 4 of this report. The model used six funding alternatives: paying cash up front (all revenue); 100 percent grant; 75 percent grant; 50 percent grant, State Revolving Fund (SRF); and obtaining a Loan/Bond. Table 4.5 shows the projected average annual water bill, the maximum percent of household income, and the percentage rate increase over current rates.

2.4.5.4 Potential Funding Sources

A number of potential funding sources exist for rural utilities. Both state and federal agencies offer grant and loan programs to assist rural communities in meeting their infrastructure needs.

Within Texas, the following state agencies offer financial assistance if needed:

- Texas Water Development Board,
- Office of Rural Community Affairs, and
- Texas Department of Health (Texas Small Towns Environment Program).

Small rural communities can also get assistance from the federal government. The primary agencies providing aid are:

- United States Department of Agriculture, Rural Utilities Service, and
- United States Housing and Urban Development.

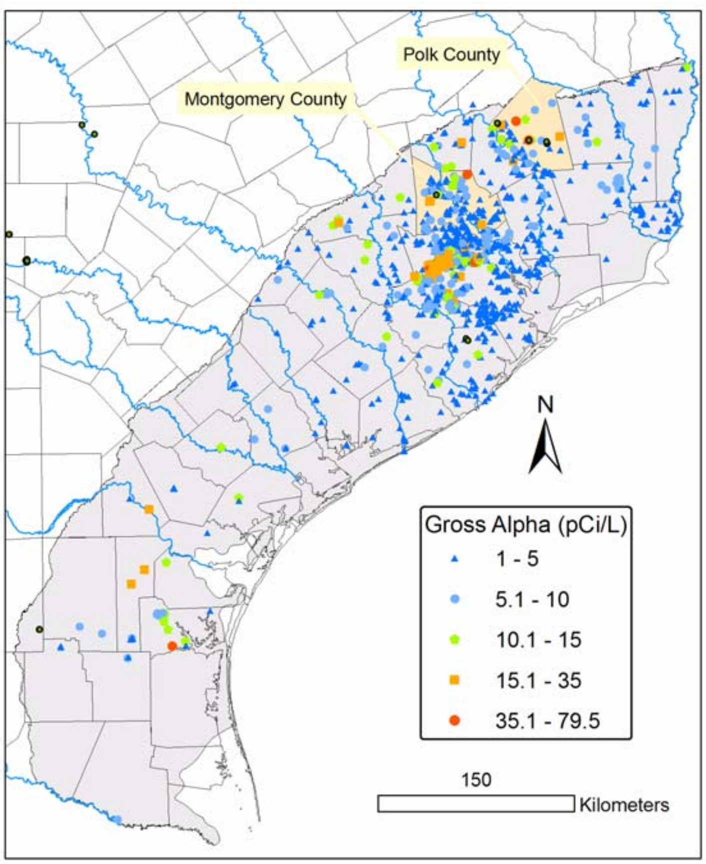
SECTION 3
UNDERSTANDING SOURCES OF CONTAMINANTS

3.1 GROSS ALPHA AND RADIUM IN THE GULF COAST AQUIFER

The Gulf Coast aquifer parallels the Texas Gulf Coast and extends from the Texas-Louisiana border to the Rio Grande. Subunits of the Gulf Coast aquifer are from oldest to youngest, the Jasper, Evangeline, and Chicot aquifers. The aquifer is a leaky artesian system composed of middle to late Tertiary and younger interbedded and hydrologically connected layers of clay, silt, sand, and gravel (Baker 1979, Ashworth and Hopkins 1992). Most PWS wells of concern in Polk and Montgomery counties are completed in the Jasper aquifer.

The most recent gross alpha data from the TCEQ database (contaminants ID 4109 - gross alpha particle activity) were plotted to assess the spatial distribution of alpha radiation in the aquifer (Figure 3.1). Only one well with gross alpha was found for this aquifer in the TWDB database (storet code 80045); therefore, these data were not included in the analysis.

Figure 3.1 Gross Alpha in Groundwater of the Gulf Coast Aquifer (TCEQ Database, 1095 Datapoints from 2001 to 2005)



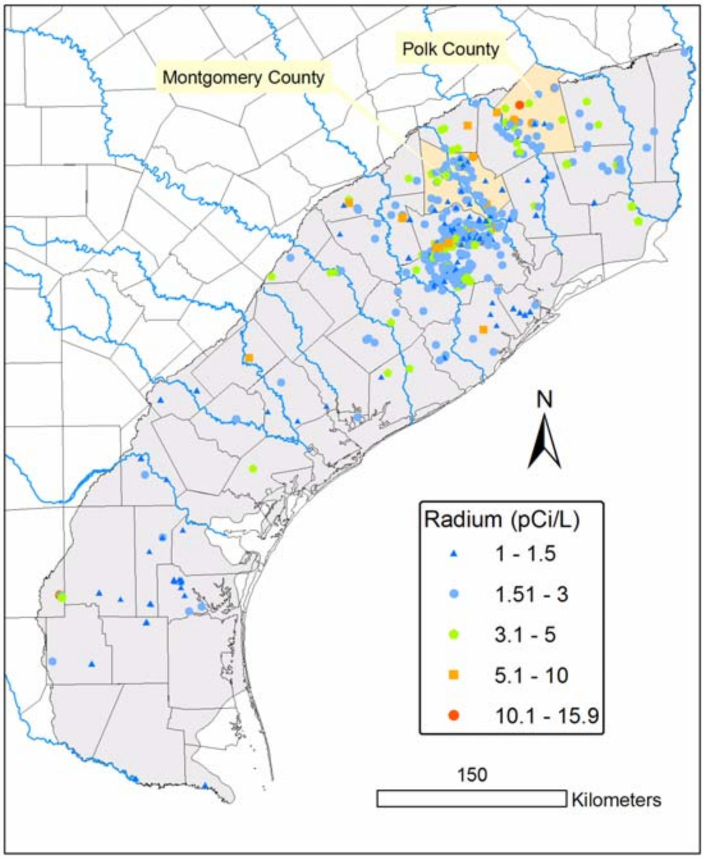
Uranium concentrations were evaluated only in wells where gross alpha exceeds 15 pCi/L. The MCL for uranium is 30 µg/L which is equivalent to 20 pCi/L (using a conservative factor of 0.67 pCi/µg for converting mass concentration to radiation concentration). Therefore, a gross alpha level of 35 pCi/L in a well reflects a level from which the well fails to comply with either the MCL for gross alpha minus alpha radiation due to uranium which is 15 pCi/L, or with the uranium MCL (neglecting the activity due to radon which is rarely measured in PWS wells). Gross alpha >5 pCi/L requires analysis of radium 226. Radium-228 testing must be done regardless of gross alpha results (TCEQ 2004). The symbology for gross alpha levels in Figure 3.1 takes these threshold levels into account.

Relatively high gross alpha levels are common in Polk and Harris counties and to a lesser extent in Montgomery and Walker counties. High levels of gross alpha are found also in the southern part of the aquifer (Jim Wells and Kleberg Counties).

The most recent radium measurements from the TWDB and TCEQ databases were analyzed to assess the overall occurrence of this contaminant in the aquifer (Figure 3.2). In this study the terms *radium* or *radium combined* are generally used to refer to radium-226 + radium-228. Otherwise, radium-226 or radium-228 is specified. The values shown in Figure 3.2 generally represent the upper limit of the radium measurements, because radium-228 was below its detection limit of 1 pCi/L for more than 75 percent of the data and the detection limit was used when summing with radium-226 for the radium combined values. Radium-228 can have negative values in the TWDB database when radiation of the sample is lower than background radiation at the laboratory, in these cases zero was used for the sum. Although TCEQ allows PWSs to subtract the reported error from the radium concentrations to assess compliance, the following analysis of general trends used the most recent radium concentration and did not subtract the reported error. This approach is considered more conservative.

The most recent values for wells from which both isotopes of radium were analyzed are shown in Figure 3.2 (number of samples shown is 526; 432 from TCEQ database and 94 from TWDB database). The codes for the contaminants are: TWDB - Storet code 09503 and 81366; and TCEQ databases - Contaminant ID 4020 and 4030, for radium 226 and 228, respectively. Radium-226 and radium-228 were combined and the combined value for each well is shown. Only measurements from a single entry point that can be related to a specific well were used from the TCEQ database.

Figure 3.2 Radium in Groundwater of the Gulf Coast Aquifer (TCEQ Database, Data from 1998 to 2005, and TWDB Database, Data from 1988 to 1990)

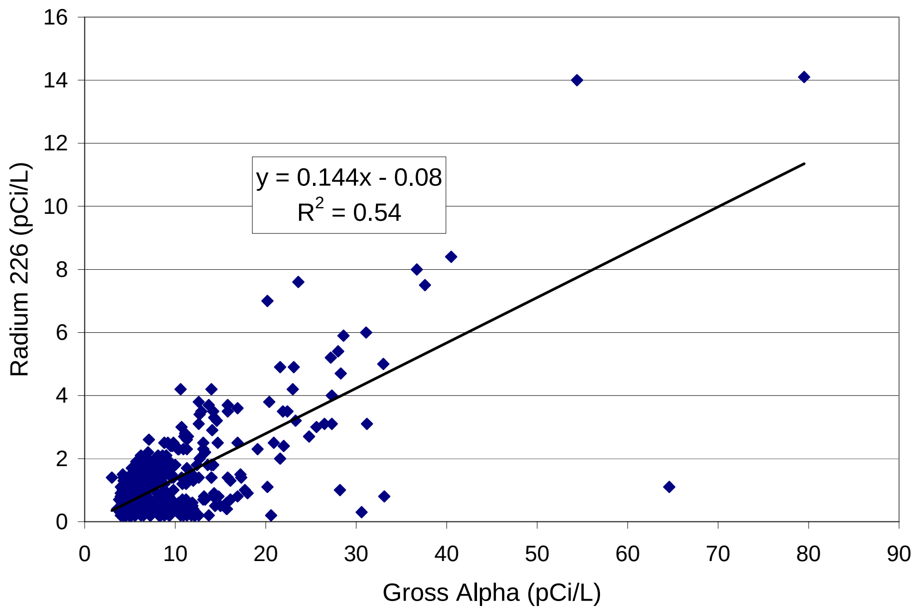


Radium levels exceeding the 5 pCi/L MCL seem more likely to be found in the central to northern parts of the aquifer; however, this distribution may be an artifact of the higher density of measurements toward the northern part of the aquifer (Figure 3.2). Relatively high levels of radium are found in the area of Polk County and the neighboring counties to the west (San Jacinto, Walker, and Montgomery Counties) in wells open to the Jasper aquifer.

3.1.1 Gross Alpha and Radium Trends

Gross alpha and radium trends were calculated with data from the TCEQ PWS database (Figures 3.3, 3.4, and 3.5). Only the most recent analyses with both parameters analyzed from a single entry point that can be related to a specific well are included in the analysis.

Figure 3.3 Radium-226 vs. Gross Alpha in Groundwater of the Gulf Coast Aquifer (TCEQ Database from 2001 to 2005, 434 Samples)



The average contribution of radium-226 to the Gross alpha count is 14.4 percent (based on the slope in Figure 3.3). All samples of radium 226 >4 pCi/L are above the regression line, which means that in wells with high levels of radium the contribution of radium to gross alpha counts is higher (~15-20%). In five out of six wells in which gross alpha is >35 pCi/L radium-226 >7 pCi/L. Therefore, non compliance with radium MCL is strongly related with non compliance with gross alpha MCL in the Gulf Coast aquifer.

Gross alpha and radium are highest in the Jasper aquifer, while the Evangeline and Chicot aquifers have radium exceeding MCL in only in 3.8 and 1.7 percent of their wells, respectively (Table 3.1). Gross alpha levels are relatively high both in the Jasper and the Evangeline aquifers and low in the Chicot aquifer. Higher levels of gross alpha (>35 pCi/L) are more frequently found in the Jasper aquifer (specifically in Polk County) whereas gross alpha levels in the Evangeline aquifer are more commonly in the medium (>5pCi/L) and high (>15pCi/L) levels (Table 3.1).

Table 3.1 Distribution of Gross Alpha and Radium within the Gulf Coast Aquifers (Most Recent Data for Wells in the TCEQ Database)

	Radium				Gross Alpha				
Aquifer	Number of wells with radium samples	Average radium (pCi/L)	Median radium (pCi/L)	% of wells with radium > 5 pCi/L	Wells with gross alpha samples	Median gross alpha (PCi/L)	% of wells with gross alpha > 5 pCi/L	% of wells with gross alpha > 15 pCi/L	% of wells with gross alpha > 35 pCi/L
Chicot	121	1.7	1.4	1.7	406	<2	22.4	1.2	0.2
Evangeline	261	1.9	1.6	3.8	573	3.5	36.8	7.0	0.5
Jasper	49	3.2	2.6	10.2	142	2.5	30.3	4.9	1.4

Samples of radium 228 with concentrations equal to the detection limit of 1 pCi/L were assigned a value of 0.5 in the calculation of combined radium.

No correlation between radium and well depth was found for the combined three aquifers (Figure 3.4) nor when separately plotted (not shown). Correlation between gross alpha and well depth (plot not shown) is slightly higher (R^2=0.019) but still low. Correlations of radium with general water quality parameters such as chloride and TDS are very small as well (Figure 3.5).

Figure 3.4 Radium Concentrations vs. Well Depth (434 Wells in the Chicot, Evangeline and Jasper Aquifers)

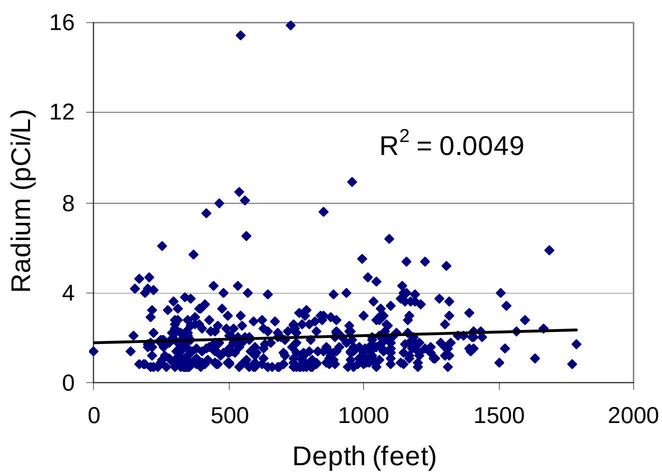
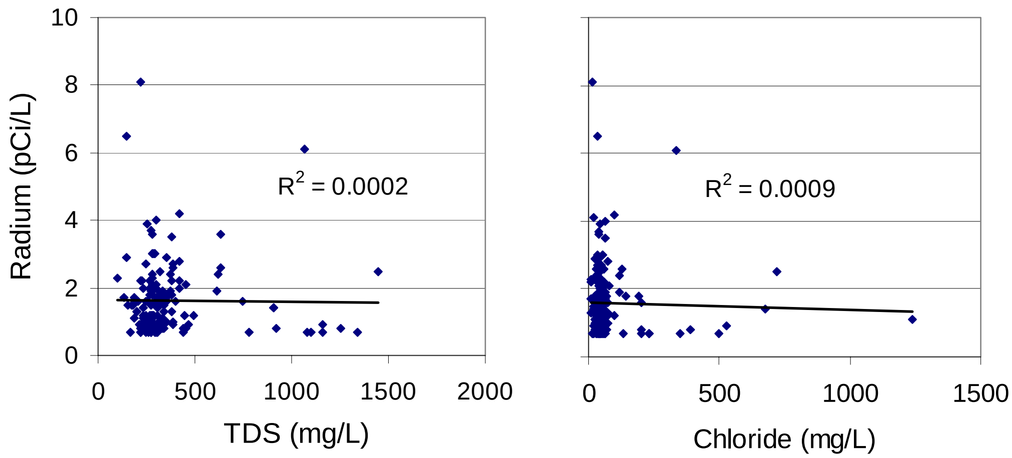


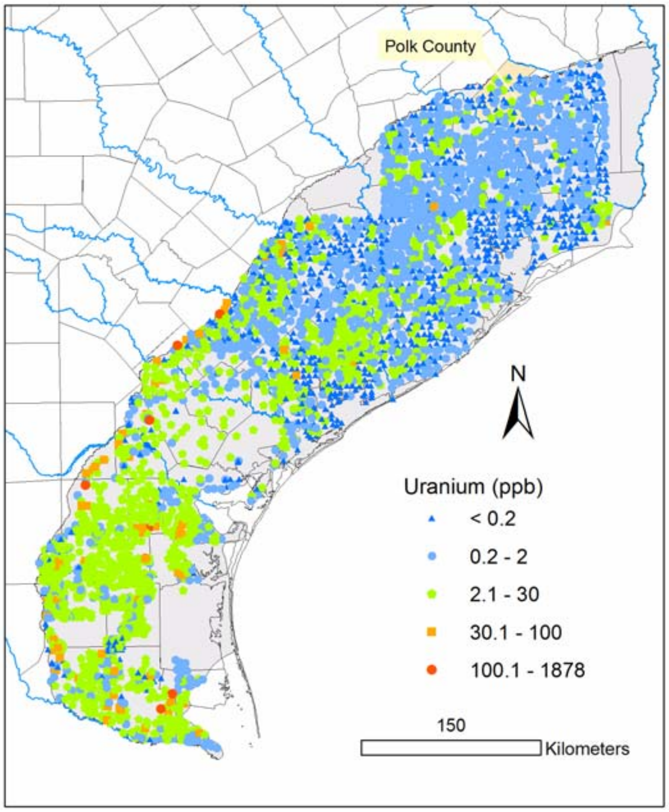
Figure 3.5 Relationship between Radium and Chloride Concentrations (186 Wells) and Radium and TDS Concentrations (163 wells) in the Chicot, Evangeline, and Jasper Aquifers



3.1.2 Uranium in the Gulf Coast Aquifer

The National Uranium Resource Evaluation (NURE) database contains many uranium analyses from the Gulf Coast aquifer; therefore, it was used to assess the spatial distribution of uranium at the basin scale. The southern part of the aquifer has higher uranium levels than the northern part (Figure 3.6). A narrow strip of high uranium concentrations is found near the northwestern boundary of the aquifer where wells are open to the Jasper aquifer. High levels of uranium in the south and along the Jasper aquifer correspond to high levels of arsenic in these regions also. Another area with relatively high uranium levels is between the Colorado and San Antonio rivers (Wharton, Jackson, and Victoria Counties). Most wells in this area obtain water from the Chicot aquifer. Water from wells in Polk County do not exceed the uranium MCL of 30 µg/L. The relatively high gross alpha found in this county (Figure 3.1) is probably not related to uranium, but this is discussed in more detail in Subsection 3.3 where individual wells are evaluated.

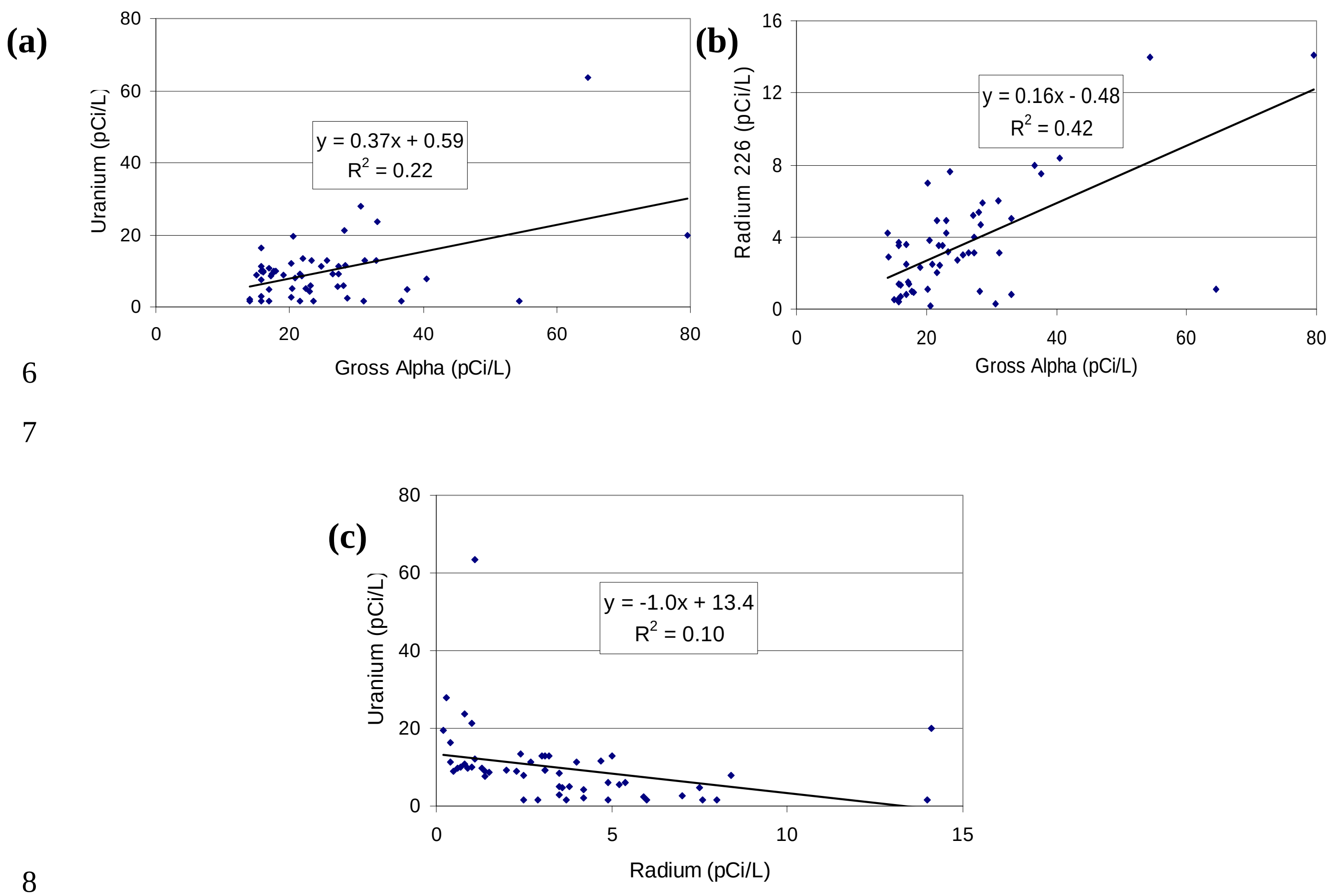
Figure 3.6 Uranium Concentrations in Groundwater of the Gulf Coast Aquifer



Note: (NURE database, analyses from 1976 to 1980). In *the NURE database there is one sample per well (number of samples shown is 2802).*

The TCEQ database contains only 62 single well source measurements of uranium in the Gulf Coast aquifer (uranium 234, uranium 235, and uranium 238 are measured separately). Uranium in pCi/L is referred to as total uranium (*i.e.*, the sum of the three isotopes). A total of 55 out of these 62 most recent samples that have measurements of radium 226 and gross alpha in the same sample were used in Figure 3.7 to describe the relationship between uranium, radium, and gross alpha.

Figure 3.7 Relationships between Uranium, Radium 226, and Gross Alpha in Groundwater of the Gulf Coast Aquifer (Data from the TCEQ Database from 2001 to 2005, total of 55 Samples)



The correlation between uranium and gross alpha concentrations (Figure 3.7a) is not as strong as the correlation of gross alpha and radium (Figure 3.7b). Uranium contributes about 37 percent of the alpha radiation on average (based on slope in Figure 3.7a), but variability is high. The slope in Figure 3.7b is slightly larger than in Figure 3.3 where all pairs of radium and gross alpha were included. In Figure 3.7 only wells in which gross alpha >15 pCi/L are included because this is the level from which an analysis for uranium is required. The low negative correlation between radium and uranium (Figure 3.7c) implies that high gross alpha in the aquifer are due to either high uranium or high radium but most probably not high concentrations of both. Most of the samples in Figure 3.7c where uranium exceeds 20 pCi/L have low levels of radium.

3.2 HYDROGEOLOGY OF POLK, SAN JACINTO AND MONTGOMERY COUNTIES

Subsurface deposits in Polk, Montgomery and San Jacinto Counties consist mainly of sediments of Pliocene and Pleistocene age making up the last progradation wedges in the Gulf Coast. Gulf Coast sediments consist of several progradation wedges of Tertiary age composed of alternating sandstone and clay corresponding to variations in sea level and in inland sediment input as well as in other factors. Those wedges are approximately parallel to the current shoreline and the deposition process is still active today (*e.g.*, Mississippi River and delta). In the Gulf Coast lowlands, those deposits are generally divided into six or more operational units: the Fleming formation of Miocene age whose base includes the Oakville Sandstone, the Goliad/Willis formations of Pliocene age, and the Lissie and Beaumont formations of Pleistocene age. The Lissie formation is sometimes divided into a lower unit (Lissie s.s. or Bentley) and an upper unit, the Montgomery formation. The general dip of the formations toward the Gulf is 0.01 feet/feet or less on average. Some salt domes exist at depth in the south of Polk and Montgomery counties but they do not seem to alter the general structure of the Upper Tertiary formations.

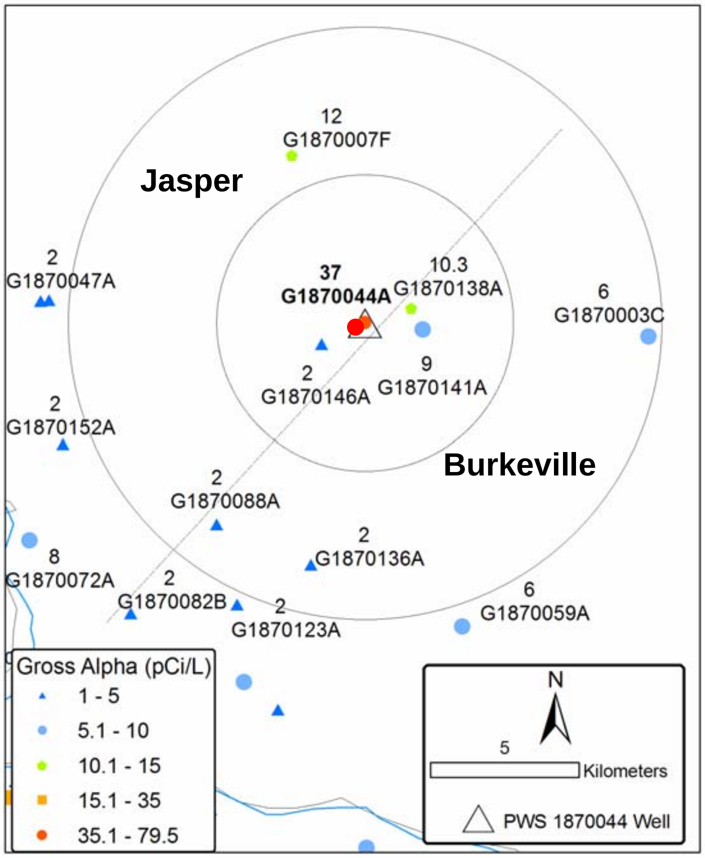
The Gulf Coast aquifer is recognized as a major aquifer in the State of Texas (Ashworth and Hopkins 1995; Mace, *et al*. 2006). In the Tertiary Gulf Coast system, the general flow system consists in water infiltrating in the outcrop areas of the more permeable formations, some of it discharging into rivers and springs along short flow paths, and some of it flowing downdip into the deeper sections of the aquifers. The fate of that slowly moving water is to slowly percolate up by cross-formational flow and discharge into the ocean. This process is necessary to maintain mass balance in the regional flow system although, because of heavy pumping in some areas, the natural upward flow has been locally reversed. The northern confines of Polk County include the upper formations of the Jackson Group of Eocene age and the Catahoula formation of mostly Oligocene age. The Catahoula formation is generally recognized as the low-permeability base of the Gulf Coast aquifer, although it can locally produce water. The other hydrostratigraphic units of the Coastal Plain are the Jasper aquifer, the Burkeville confining system, and the Evangeline and Chicot aquifers (Baker 1979). The Jasper aquifer is composed of the base of the Fleming formation, that is, the Oakville Sandstone, as well as the Catahoula sandstone hydraulically connected to them. The upper part of the Fleming formation makes up the Burkeville confining system. The Evangeline aquifer includes mostly the Goliad Sand but also the upper sections of the Fleming formation when permeable. The remainder and younger formations of the section (Willis Sand, Lissie and Beaumont formations) make up the Chicot aquifer (Kasmarek and Robinson 2004). Polk and Montgomery counties present a similar stratigraphy, only slightly shifted toward more recent sediments in Montgomery County; there, the oldest sediments at the surface are from the Fleming formation and they crop out in the extreme northwest area of the county. The succession is then the same in both counties with the addition of a large section of Beaumont Clay of Pleistocene age south of Lake Conroe along the West Fork San Jacinto River. Some Beaumont Clay also exists in southwest Polk County along Lake Livingstone and the Trinity River.

The base of the Jasper aquifer is at a depth of 0 (outcrop area) to 3,000 feet below ground surface. The Oakville formation, forming the bulk of the Jasper aquifer, consists of fluvial fine- to coarse-grained partially consolidated sand with silt and clay intercalations. Its thickness ranges from 700 to 1,200 feet (increasing downdip) in the Polk and Montgomery County area with a high net sand thickness (Kasmarek and Robinson 2004). The net sand thickness varies from <400 feet to >600 feet with a sand fraction >40 percent (Galloway, *et al*. 1986). The net thickness of sand within the aquifer varies according to the geological conditions in which the sediments were deposited. The Goliad formation, approximately equivalent to the Evangeline aquifer, unconformably overlies the top of the Fleming formation which is composed of mostly clay with some calcareous sand. The Upper Fleming formation depositional systems indicate an environment near the shoreline with fluvial sediments transitioning into fluvial, deltaic, and lagoonal sediments outside of the study area toward the Gulf. This formation acts as a leaky confining layer between the Jasper and the Evangeline aquifers ("Burkeville confining system") and has an approximate thickness of 300 feet. Goliad sand is medium- to coarse-grained and unconsolidated with intercalations of calcareous clay and marl whose base is located at approximately 1,000 feet below ground surface. The fluvial and deltaic sand of the Goliad formation suggest another small retreat of the shoreline toward the Gulf. Their thickness is in the range from 0 in the outcrop area to a consistent 800-foot downdip to more than 1,000 feet in Southern Montgomery County. Goliad Sand grades into the generally coarse-grained Willis Sand whose depositional system arrangement is similar to that of the Goliad Sand. The Willis Sand makes up the Chicot aquifer with the overlying fine- to coarse-grained Lissie Sand. The top of the Lissie formation, with a higher clay content, and the Beaumont Clay generally pressurize the more permeable sans of the Willis and Bentley formations confining the Chicot aquifer. The Chicot aquifer is not well-expressed in Polk County but its thickness can reach 200 feet in southern Montgomery County. Water quality and well yield are generally good in the Gulf Coast aquifer in northeast Texas including in Polk, San Jacinto and Montgomery counties.

3.3 Detailed Assessment for Crystal Lake PWS

Well G1870044A is the single source for this system; it draws water from the Jasper aquifer, and shows high levels of gross alpha (36.7 pCi/L) and radium (9 pCi/L). Figure 3.8 shows that in this area there is no hydrostratigraphic control on the gross alpha, and high and low levels can be found both in the Jasper aquifer and the Burkeville confining unit (Table 3.2). The variability within the Jasper aquifer is high, well G1870146A, that is only 1.6 km west-south-west of the PWS well, shows gross alpha less than the detection limit of 2 pCi/L (Figure 3.8, Table 3.2). The spatial distribution of gross alpha shown in Figure 3.8 suggests that low levels of this contaminant can be found in the section spanning from west to south of well G1870044A.

Figure 3.8 Gross Alpha (pCi/L) in 5 and 10-km Buffers of the Crystal Lake PWS Well



Wells south east of the diagonal line drawn on the map withdraw water from the Burkeville confining unit while the wells northwest of it withdraw from the Jasper aquifer (the first number near each well represents the most recent gross alpha concentration in pCi/L, the second is the well identifier in the TCEQ database.

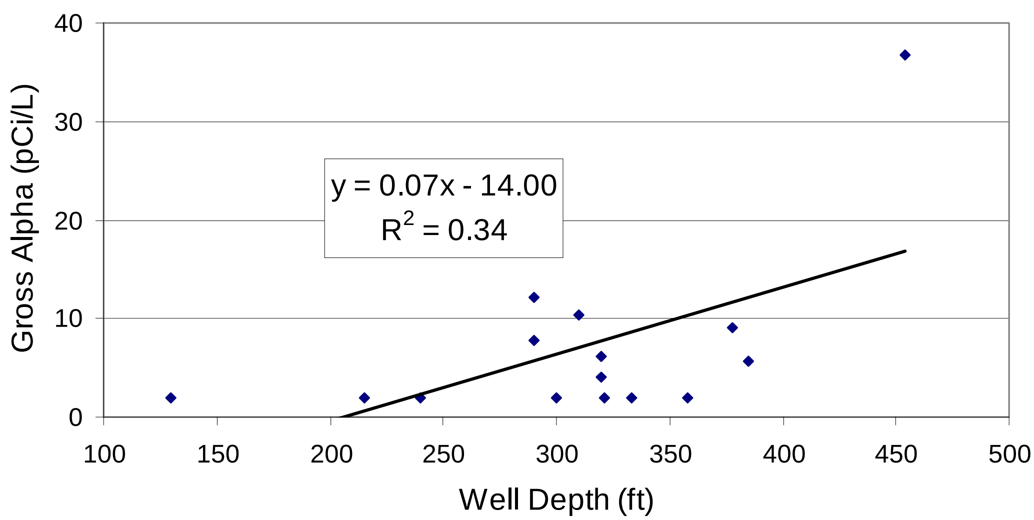
Table 3.2 Gross Alpha Levels and Aquifer Units in the Crystal Lake PWS and Nearby Wells

Well ID	Well Depth (ft)	Aquifer unit	Screen Top (ft)	Screen Bottom (ft)	Sampling Date	Gross Alpha (pCi/L)
G1870123A	333	122BKVL	303	323	3/29/2001	<2
G1870136A	300	122BKVL			3/29/2001	<2
G1870082B	240	122BKVL	210	240	5/29/2001	<2
G1870088A	215	122BKVL			6/25/2001	<2
G1870059A	320	122BKVL			2/18/2003	6.2
G1870003C	385	122BKVL			3/18/2003	5.7
G1870141A	378	122BKVL	310, 360	320, 378	9/16/2003	9.1
G1870138A	310	122BKVL	287	307	7/13/2004	10.3

Well ID	Well Depth (ft)	Aquifer unit	Screen Top (ft)	Screen Bottom (ft)	Sampling Date	Gross Alpha (pCi/L)
G1870152A	130	122JSPR			6/25/2001	<2
G1870146A	358	122JSPR			6/25/2001	<2
G1870047A	321	122JSPR			2/12/2003	<2
G1870007F	290	122JSPR			10/16/2003	12.1
G1870072A	290	122JSPR			6/9/2004	7.7
G1870047B	320	122JSPR			11/2/2004	4
G1870044A	**454**	**122JSPR**	**429**	**454**	**11/2/2004**	**36.7**

There is a low, yet significant, correlation (P value = 0.02) between gross alpha and well depth in this area (Figure). This suggests that shallower wells may be considered for improving water quality relative to gross alpha.

Figure 3.9 Relationship Between Gross Alpha and Well Depth in Wells of the Crystal Lake Area



The spatial distribution of radium is similar to the distribution of gross alpha, though the fact that the wells with very low gross alpha were not sampled for radium makes the relationship between the two less clear in Figure 3.10 than that in Figure 3.8. A slight trend toward higher values of radium in the Jasper wells may be inferred from Figure 3.10. No temporal trends in radionuclides levels in the Crystal Lake PWS were observed (Table 3.3).

Figure 3.10 Combined Radium (pCi/L) in 5 and 10-km Buffers of the Crystal Lake PWS Wells (Data from the TCEQ Database)

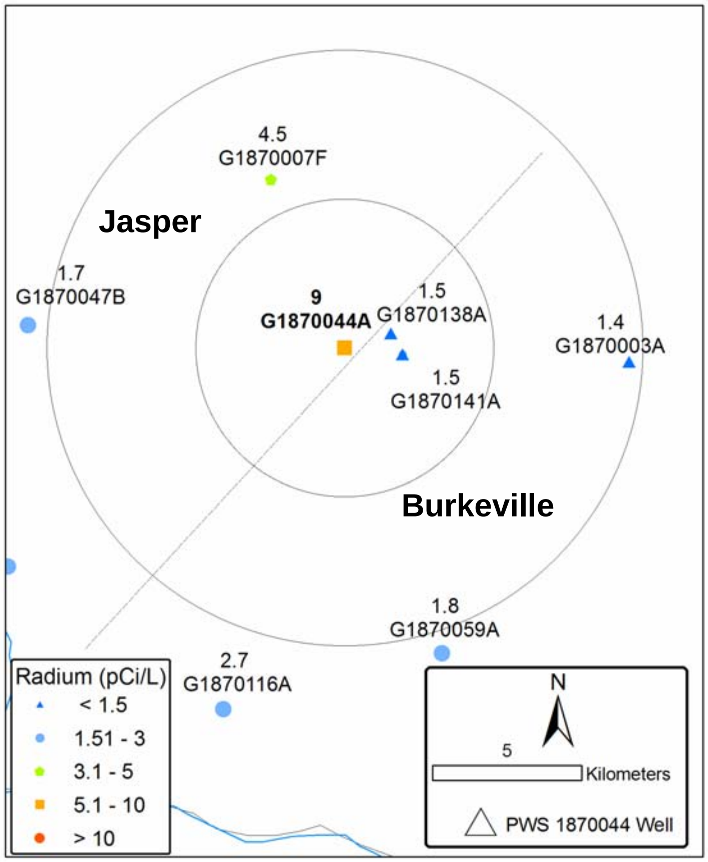


Table 3.3 History of Gross alpha, Combined Radium and Combined Uranium in Crystal Lake PWS

Sampling Date	Gross Alpha (pCi/L)	Radium (pCi/L)	Uranium (pCi/L)
12/11/97		7.67	
3/29/01	41.2	10.1	<2
10/21/03	38.9	9.1	<1.5
7/14/04	31.2	10.9	<1.5
11/2/04	36.7	9	<1.6

3.4 Summary of Alternative Groundwater Sources for the Crystal Lake PWS

Low levels of gross alpha and radium can be found in a quarter-circle section spanning from west to south of Crystal Lake's well (G1870044A). The nearest well with low levels of these contaminants is well G1870146A located 1.6 km southwest of the Crystal Lake PWS well. This well is 358 feet deep and withdraws water from the Jasper aquifer. There is some correlation between contaminant levels and well depth in this area. It may be that shallower intervals in the Jasper aquifer or even in the Burkeville confining system can be screened in the Crystal Lake PWS well and dilute the deep screened interval (425–429 feet). Drilling a new shallower well in the aforementioned quarter-circle section is also a possibility; however, more detailed hydrogeologic data are required for positioning such a new well.

SECTION 4
ANALYSIS OF THE CRYSTAL LAKE ESTATES PWS

4.1 DESCRIPTION OF EXISTING SYSTEM

4.1.1. Existing System

The Crystal Lake PWS is shown in Figure 4.1. The Crystal Lake PWS is owned and operated by Lake Livingston WSSSC. Crystal Lake PWS is a water system that supplies Crystal Lake Estates subdivision. Crystal Lake is a small residential subdivision with 93 current connections and 200 connections at full build out. It is located off Highway 190 East, approximately 4.5 miles east of the City of Livingston, Texas.

The water source for this PWS is one well, which is completed in the Jasper aquifer. The well is located in Polk County and is 454 feet in depth. The well has one 58 gpm pump. The water system's total production is 0.083 million gallons per day (mgd). Disinfection with gaseous chlorine and sequestration with polyphosphate for high iron levels is performed at the wellhead before water is pumped into the distribution system. There is one 3,500-gallon hydro-pneumatic tank in the system and one 36,000 ground storage tank. There are three service pumps: 70 gpm, 125 gpm, and 150 gpm at the plant. Although not connected to the system, there is an inactive well surrounded by a fence located approximately 300 feet to the north of the plant.

Total combined radium 226 and 228 has been detected between 6.9 pCi/L to 10.7 pCi/L since 2004, which exceeds the MCL of 5 pCi/L. Gross alpha particle activity has been detected between 23.7 pCi/L to 36.2 pCi/L, which exceeds the MCL of 15 pCi/L. The Crystal Lake PWS has not encountered any other water quality issues.

The treatment employed for disinfection is not appropriate or effective for removal of combined radium or alpha particles, so optimization is not expected to be effective for increasing removal of this contaminant. Attractive options might be finding a new nearby water source, either groundwater at a different depth, or acceptable water from an adjacent system.

It may also be possible to identify radium-producing strata through comparison of well logs or through sampling of water produced by various strata intercepted by the well screen.

Basic system information is as follows:

- Population served: 282 current, 600 at full build out
- Connections: 93 current, 200 at full build out
- Estimated average daily flow: 0.021 mgd
- Total production capacity: 0.083 mgd

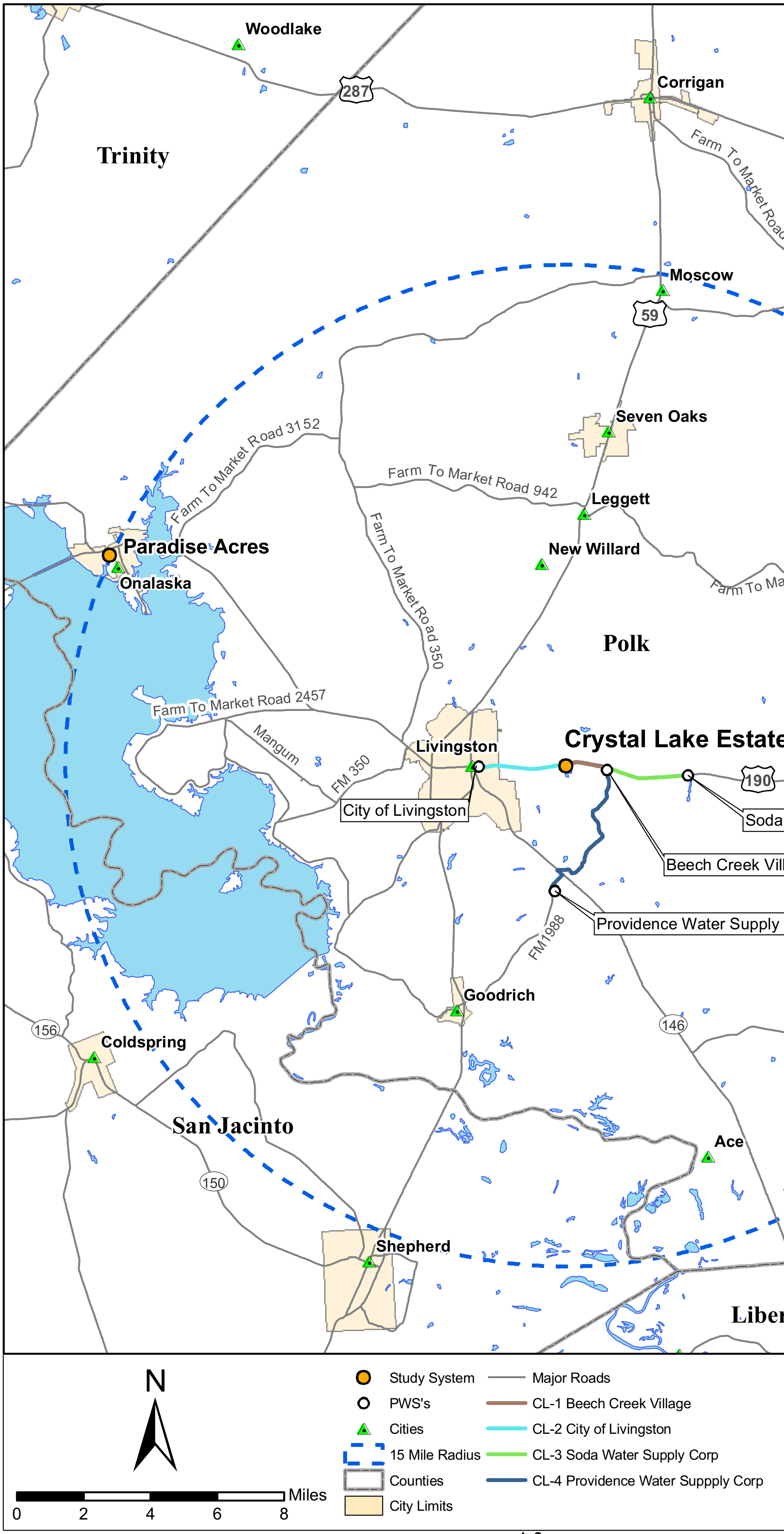


Figure 4.1

Crystal Lake Estates Pipeline Alternatives

Raw water quality is summarized as follows:

- Typical total combined radium range: 6.9 pCi/L to 10.7 pCi/L
- Typical total alpha particle range: 23.7 pCi/L to 36.2 pCi/L
- Total dissolved solids: 306 mg/L (average result)
- pH : 7.4 s.u. (average result)
- Calcium: 48.8 mg/L (average result)
- Magnesium: 4.03 mg/L (average result)
- Sodium: 51.3 mg/L (average result)
- Chloride: 67.1 mg/L (average result)
- Bicarbonate (HCO_3): 274.5 mg/L (average result)
- Iron: 0.13 mg/L (average result)
- Fluoride: 0.1 mg/L (average result)
- Typical manganese range: 0.036 mg/L (average result)

The Crystal Lake PWS has already investigated possible solutions to its combined radium and alpha particle issues, including a new groundwater well. An alternative examined was the drilling of a new groundwater well that would be completed to an undetermined depth. Drilling a new well was expected to avoid the radium problem. It was noted during the interview that the estimated capital cost of completing the new well several years ago was approximately $40,000 for a new 300 foot well. That cost is likely to have risen in the intervening years and is likely between $50,000 and $100,000.

4.1.2 Capacity Assessment for the Crystal Lake PWS

The project team conducted a capacity assessment of the Lake Livingston WSSSC – Crystal Lake Estates water system. The results of this evaluation are separated into four categories: general assessment of capacity, positive aspects of capacity, capacity deficiencies, and capacity concerns. The general assessment of capacity describes the overall impression of FMT capability of the water system. The positive aspects of capacity describe those factors the system is doing well. These factors should provide opportunities for the system to build upon to improve capacity deficiencies. The capacity deficiencies noted are those aspects that are creating a particular problem for the system related to long-term sustainability. Primarily, these problems are related to the system's ability to meet current or future compliance, ensure proper revenue to pay the expenses of running the system, and to ensure the proper operation of the system. The last category is titled capacity concerns. These are items that in general are not causing significant problems for the system at this time. However, the system may want to address them before these issues have the opportunity to cause problems.

The project team interviewed the following individuals:

- Scott Baker – General Manager

- John Ganzer – Financial Manager
- Phillip Everett – Supervisor, System Operations
- Boyd McDaniel – Supervisor, System Reports

4.1.2.1 General Structure of the Water System

Lake Livingston WSSSC is a public utility corporation that provides water services to 52 public water systems in the greater Livingston area and serves a total of 6,894 customers. It is governed by a 7-member board of directors and is financed through water fees and equity buy-in fees. The WSSSC purchased the Crystal Lake PWS along with several others in April 1997 when the previous owner declared bankruptcy. The WSSSC borrowed $1.9 million from CoBank to upgrade the water systems, and then received a loan from the U.S. Department of Agriculture for $7 million for additional improvements. Their total operations staff consists of a general manager, field supervisor, eight certified operators, and a construction/general labor crew.

The Crystal Lake PWS has 93 connections and serves approximately 282 people. The system has one active well, one storage tank, one pressure tank, and disinfects using gas chlorine. It also injects phosphates for corrosion control. One certified operator is responsible for O&M activities at Crystal Lake. The well has exceeded the maximum contaminant levels for both gross alpha and combined radium (radionuclides).

4.1.2.2 General Assessment of Capacity

Based on the team's assessment, this system has a very good level of capacity. There are several positive managerial, financial and technical aspects of the water system, but there are also some areas that need improvement.

4.1.2.3 Positive Aspects of Capacity

In assessing a system's overall capacity, it is important to look at all aspects – positive and negative. It is important for systems to understand those characteristics that are working well, so that those activities can be continued or strengthened. In addition, these positive aspects can assist the system in addressing the capacity deficiencies or concerns. The factors that were particularly important for the Crystal Lake PWS are listed below.

- **Knowledgeable and Dedicated Staff** – While the general manager has only worked for the Crystal Lake PWS for about 1 year, he is certified and has over 30 years experience in the water industry. The field supervisor is certified and has been working for the Crystal Lake PWS for 24 years. The other supervisor is also certified and has 26 years with the company. All positions have written job descriptions. The operations staff meets every morning to receive work orders for the day. The water operators rotate being on-call, so the system is covered 24-hours per day. The Board of Directors is composed of individuals who live in the various communities served by the Lake Livingston WSSSC and are familiar with their own water systems.

- **Benefits from Economies of Scale –** The Crystal Lake PWS is one of 52 systems operated by the Lake Livingston WSSSC. This structure allows a very small water system to benefit from the pool of operators and a central construction/general maintenance crew. They are able to maintain a large inventory of spare parts in their warehouse. All of the systems owned and operated by the Lake Livingston WSSSC have a single rate structure. As new compliance rules and regulations are introduced that will require more complex and expensive treatment, or as system upgrades and improvements are needed, the ability to take advantage of the economies of scale offered by a single rate structure is critical to maintaining affordability for the small systems. To ensure the system's finances are adequate, the board reviews the operating budget every month, and compares it with the previous year's expenditures. They have an emergency fund to cover shortfalls, and maintain a reserve account. The WSSSC tracks the expenses related to electricity, meter reading, and chemicals separately for each water system. Finally, due to their prudent financial practices, the WSSSC was able to build their existing office/warehouse complex without incurring any debt.
- **Communication with Customers** – The WSSSC works hard to keep their customers informed about the water system. They issue a quarterly Public Notice and an annual consumer confidence report as required by TCEQ. And because the residents have been extremely vocal about the radionuclides problem, they have invited TCEQ to attend public meetings to reassure their customers.
- They respond to and document all customer complaints in a timely manner. If a water line break will take more than a couple of hours to repair, they post a sign at the entrance to the subdivision. They also issue a "Boil Order" until they are sure the water is free of Total Coliform bacteria. Finally, they are in the process of developing a website that will enable their customers to view information about their accounts and the activities of the WSSSC.
- **Cross-Connection Control Program –** The Crystal Lake PWS has an active program for preventing cross connections in the distribution system. This program includes customer agreements, service inspections on all new taps, and hose-bib vacuum breakers at all new homes. This program provides an increased level of public health protection.

4.1.2.4 Capacity Deficiencies

The following capacity deficiencies were noted in conducting the assessment and could impact the ability of the PWS to meet compliance with current and future regulations and to ensure long-term sustainability.

- **Lack of Compliance with Radionuclides Standard –** The Lake Livingston WSSSC is under a Compliance Order for the Crystal Lake PWS, which outlines the steps the system needs to take to return to compliance. The WSSSC has been working to address the compliance issue by hiring a geological company who is searching for areas in the aquifer that can meet the radionuclides regulations. As part of this project, they are updating maps of the WSSSC's water systems.

However, the WSSSC told the project team they have purchased arsenic removal treatment systems for three of their other water systems. While it is positive that the WSSSC is taking a proactive approach to complying with the arsenic standard, it is unclear why the WSSSC is not concentrating its efforts on the systems that are under a Compliance Order. The WSSSC needs to be working toward compliance to avoid further escalation in enforcement actions.

- **Water Losses –** A water audit conducted in 2005, estimated a 25 percent water loss at the Crystal Lake PWS. A reduction in water loss would reduce the amount of water that must be pumped and/or treated. Reducing water losses could result in a cost savings depending on the compliance alternative implemented. In addition, there is no water conservation program. This is especially critical due to the significant amount of water loss that this system sustains. Conservation reduces the demand on the source, reduces chemical and electrical costs, and minimizes wear and tear on equipment such as pumps.

4.1.2.5 Potential Capacity Concerns

The following items were concerns regarding capacity but no specific operational, managerial, or financial problems can be attributed to these items at this time. The PWS should address the items listed below to further improve FMT capabilities and to improve the system's long-term sustainability.

- **Rates and Frequency of Rate Evaluation –** The Lake Livingston WSSSC water rates are based on recommendations by the staff and reviewed by the board. The last rate increase was in June 2004. Although current rates fully cover the costs of service, they are not sufficient to allow for future growth or if the system incurs additional debt. In addition, it does not appear the rates are evaluated on a regular basis.
- **Lack of Written Long-Term Capital Improvements Plan –** While there appears to be some process in place to plan for future improvements and there is a Capital Budget, there is no formal written plan. The lack of a long-term written plan could negatively impact the system's ability to develop a budget and associated rate structure that will provide for the system's long term needs.
- The general manager indicated they are in the process of applying for a planning loan/grant with the Texas Water Development Board which will address growth and compliance concerns. Specific projects will improve capacity, pressure and water quality compliance. The planning grant should be used to develop a written long-term Capital Improvement Plan to address this concern.
- **Preventative Maintenance Program –** It doesn't appear there is any preventative maintenance program, and in general, they make repairs on a reactive basis instead of a proactive one. There is no scheduled maintenance for line flushing or valve exercising. Routine flushing clears sediment in the lines and routine valve exercising identifies valves that need replacement, and ensures proper operation

during the next line repair. However, they do have a written O&M manual, which is located in the pumphouse and referred to as necessary.

- **Emergency Plan –** The Lake Livingston WSSSC does not have a written emergency plan, nor does it have enough emergency equipment such as generators. In the event of a power outage, they would have to rely only on the water in the storage tanks. In 2005, Hurricane Rita struck the Lake Livingston area, and several of the Lake Livingston WSSSC water systems were without water for 6-7 days. As a result of the storm, a statewide program known as "TxWARN" was developed and implemented by the State of Texas. The WSSSC is now a member of this program that will enable water facilities to help each other and share resources.
- The system should have an emergency or contingency plan that outlines what actions will be taken and by whom. The emergency plan should meet the needs of the facility, the geographical area, and the nature of the likely emergencies. Conditions such as storms, floods, major line breaks, electrical failure, drought, system contamination or equipment failure should be considered. The emergency plan should be updated annually, and larger facilities should practice implementation of the plan annually.

4.2 ALTERNATIVE WATER SOURCE DEVELOPMENT

4.2.1 Identification of Alternative Existing Public Water Supply Sources

Using data drawn from the TCEQ drinking water and TWDB groundwater well databases, the PWSs surrounding the Crystal Lake PWS were reviewed with regard to their reported drinking water quality and production capacity. PWSs that appeared to have water supplies with water quality issues were ruled out from evaluation as alternative sources, while those without identified water quality issues were investigated further. If it was determined these PWSs had excess supply capacity and might be willing to sell the excess, or might be a suitable location for a new groundwater well, the system was taken forward for further consideration.

Table 4.1 is a list of the selected PWSs within 11.5 miles of the Crystal Lake PWS. From these PWSs, four were selected for further evaluation based on factors such as water quality, distance from the Crystal Lake PWS, sufficient total production capacity for selling or sharing water, and willingness of the system to sell or share water or drill a new well. The PWSs selected for further evaluation are shown in Table 4.2.

The PWSs in Table 4.1 were screened by proximity to Crystal Lake PWS and water production capacity. The nearest PWSs with acceptable water quality and adequate capacity were selected for further consideration. Additional PWSs were also selected for further consideration if they were large water suppliers in the area.

Table 4.1 Selected Public Water Systems within 11.5 Miles of Crystal Lake PWS

PWS ID	PWS Name	Distance from Crystal Lakes	Comments/Other Issues
1870138	Country Wood Water System	1 mile	Small system (0.56 mgd) with no WQ issues.
1870141	Beech Creek Village LL	1.2 miles	Small system (0.048 mgd) with no WQ issues.
1870146	Phillips Acres	1.2 miles	Small system (0.68 mgd) with no WQ issues.
1870129	City of Livingston	2 miles	Large (>5 mgd) system with no WQ issues
1870003	Soda Water Supply Company	3.1 miles	Large system (>1 mgd) with no WQ issues
1870095	Providence Water Supply Company	4.1 miles	Large system (>1 mgd) with no WQ issues
1870095	Lakeside Village Water Corp.	4.3 miles	Small system (0.126 mgd) with no WQ issues.
1870088	Chesswood Water System	5.2 miles	Small system (0.85 mgd) with no WQ issues.
1870123	Goodrich North Water System	6.1 miles	Small system (0.08 mgd) with no WQ issues
1870059	Forest Springs Water System	6.7 miles	Small system (0.156 mgd) with no WQ issues
1870047	Wiggins Village 1 LL	6.7 miles	Small system (0.104 mgd) with no WQ issues
1870030	Memorial Point Utilities District	11.5 miles	Small system (0.711 mgd) with no WQ issues

Table 4.2 Public Water Systems Within the Vicinity of the Crystal Lake PWS Selected for Further Evaluation

PWS ID	PWS Name	Pop	Conn	Total Production (mgd)	Ave Daily Usage (mgd)	Approx. Dist. from Crystal Lakes	Comments/Other Issues
1870141	Beech Creek Village LL	339	113	0.048 mgd	0.023 mgd	1.2 miles	Does not have excess capacity, but it owned by Lake Livingston WSSSC and may be a new well site.
1870129	City of Livingston	8700	1	5.184 mgd	1.617 mgd	2 miles	Has excess capacity and only sells water retail. Purchase would be from the City of Livingston that owns the water.
1870003	Soda Water Supply Company	1788	596	1.05 mgd	0.17 mgd	3.1 miles	Has excess capacity. Currently sell retail, but may consider selling wholesale or annexing an area to sell retail.
1870095	Providence Water Supply Company	1770	665	0.777 mgd	0.169 mgd	4.1 miles	Has excess capacity. Additionally, based on WQ data, this PWS may provide a suitable location for a new well.

4.2.1.1 Beech Creek Village LL

Beech Creek Village LL PWS (Beech Creek PWS) water system is located east of the City of Livingston, 1.2 miles from Crystal Lake PWS. The PWS is owned and operated by Livingston Water Supply & Sewer Service Corporation. Beech Creek PWS is supplied by one groundwater well completed in the Burkeville Aquiclude of the Gulf Coast aquifer. The well is 378 feet deep and has a steady-state pumping capacity of 65-70 gpm. The water system has a total production of 0.048 mgd. Water is disinfected with gaseous chlorine and treated with an orthophosphate rust inhibitor before being sent to a 19,000 gallon ground storage tank. The water system uses a 500 gallon pressure tank. Montgomery County Utility District 3 Water System serves a population of 3,492 through 1,164 metered connections.

Beech Creek does not currently have sufficient excess capacity to supplement the Crystal Lake PWS existing supply. Nevertheless, the area may be a good site to install a separate well to supply the Crystal Lake PWS. Since Beech Creek PWS and the Crystal Lake PWS are owned by the same corporation, contracting costs would be minimal.

Soda Water Supply Corporation

The Soda WSC PWS is located approximately 2 miles east of Crystal Lake Estates along Highway 190. TCEQ data indicate the distribution system of the Soda PWS comes within 0.25 miles of the Crystal Lake PWS distribution system. Soda PWS's main water supply line passes east of Crystal Lakes Estates along Highway 190 to the approximate city limits of Livingston. The PWS is owned and operated by Soda Water Supply Corporation and is supplied by three groundwater treatment plants.

Plants 1 and 2 have two groundwater wells each. Plant 3 is supplied by one groundwater well. The two groundwater wells supplying Plant 1 are completed in the Burkeville Aquiclude of the Gulf Coast aquifer. The wells are 356 feet deep and 375 feet deep and have pumping capacities of 157 gpm and 72 gpm, respectively. Plant 2 is also supplied by two groundwater wells completed in the Jasper aquifer (Code 122JSPR). One well is 500 feet deep and the other is 610 feet deep with pumping capacities of 158 gpm and 219 gpm, respectively. Plant 3's well is completed in the Burkeville Aquiclude of the Gulf Coast aquifer. The well is 320 feet deep with pumping capacity of 96 gpm. The combined production capacity of the 5-well system is approximately 1.0 mgd. Water is disinfected with hypochlorite and treated with an orthophosphate rust inhibitor before being sent to the storage tanks and distribution system.

The Soda PWS has 152,000 gallons in storage capacity, 1,900 gallons of hydropneumatic storage, and 3.384 mgd in service pumping capacity. Soda WSC serves a population of 1,788 and has approximately 596 metered connections.

Management of the Crystal Lake PWS has communicated with Soda PWS in the past. The possibility of Soda PWS providing finished groundwater to the Crystal Lake PWS for the purpose of blending with their current supply was discussed.

4.2.1.3 Providence Water Supply Corporation

The Providence Water Supply Corporation PWS is located southeast of the City of Livingston, 4.1 miles to the south of the Crystal Lake PWS on farm-to-market road (FM) 1988. The PWS is owned and operated by Providence Water Supply Corporation, and is supplied by two water plants with one groundwater well each. There are also three inactive wells associated with the system. The well for Plant 1 is likely completed in the Burkeville Aquiclude of the Gulf Coast aquifer. The well is 270 feet deep and has a pumping capacity of 240 gpm. The well for Plant 2 is completed in the Burkeville Aquiclude of the Gulf Coast aquifer and is 229 feet deep and has a pumping capacity of 300 gpm. Water from the well are disinfected with hypochlorite and treated with an orthophosphate rust inhibitor and adjusted for pH before being sent to ground storage tanks. The ground storage tanks have a total capacity of 290,000 gallons. The hydropneumatic tanks have a capacity of 11,400 gallons. Providence Water Supply Company Water System serves a population of 1770 through 665 metered connections.

Providence Water Supply Company Water System has sufficient excess capacity to supplement the Crystal Lake PWS existing supply. The District board of directors has not considered selling water wholesale in the past, but may consider it in the future.

4.2.1.4 Livingston Regional Water Supply

Livingston Regional Water Supply is owned and operated by the Trinity River Authority. The Trinity River is their water source. The City of Livingston contracts with Livingston Regional Water Supply to provide treated water to the municipality. It is Livingston Regional's only customer. The water is treated in a state of the art water treatment facility and piped to the City of Livingston, which distributes the water through its own storage and distribution system. Although Livingston Regional Water Supply produces the water, actual purchase agreements would need to be procured from the City of Livingston to supply water to the Crystal Lake PWS.

Livingston Regional Water Supply's production capacity is up to 5.18 mgd. The current average daily production is 1.8 mgd, with a past peak daily use of 2.5 mgd. The City of Livingston does not sell water wholesale, but may be willing to annex the area and provide retail water service to the area users. City of Livingston Water System is operated by City Council, City Manager and the Water & Wastewater Superintendent.

4.2.2 Potential for New Groundwater Sources

4.2.2.1 Installing New Compliant Wells

Developing new wells or well fields is likely to be an attractive solution, provided good quality groundwater available in sufficient quantity can be identified. Since a number of water systems in the area do not have water quality problems, it is likely that compliant groundwater can be found.

Installation of a new well within in the vicinity of the system intake point is likely to be an attractive option for obtaining compliant water since the PWS is already familiar with operation of a water well. As a result, existing wells with good water quality should be investigated. Re-sampling and test pumping would be required to verify and determine the quality and quantity of water at those wells.

Installation of a new well to the Burkeville Aquiclude of the Gulf Coast aquifer or Jasper aquifers is a possibility for the Crystal Lake PWS. Additionally, PWSs located within 2 miles of the Crystal Lake PWS have wells drilled to a depth of 229-378 feet and produce sufficient quantities of compliant water.

The Crystal Lake PWS well is set at 540 feet deep apparently too deep for these two productive aquifers. It may be possible to adjust the screen depth of the existing well to access the compliant water in these water-bearing sand, although further study would be required to make that determination.

Some of the alternatives suggest new wells be drilled in areas where existing wells produce compliant water with levels of combined radium 226 and 228 below the MCL of 5 pCi/L and levels of gross alpha particles below the MCL of 15 pCi/L. In developing the cost estimates, Parsons assumed the aquifer in these areas would produce the required amount of water with only one well. Site investigations and geological research, which are beyond the scope of this study, could indicate whether the aquifer at a particular site and depth would provide the amount of water needed or if more than one well would need to be drilled in separate areas.

4.2.2.2 Results of Groundwater Availability Modeling

The Gulf Coast aquifer system that extends along the entire Texas coastal region is the groundwater source for the PWS. Five hydrogeologic units comprise the aquifer system, from land surface downward, the Chicot aquifer, the Evangeline aquifer, the Burkeville confining unit, the Jasper aquifer, and the Catahoula confining unit. For the Crystal Lake PWS, both the Burkeville Aquiclude and the Jasper aquifer are the primary groundwater sources reported in the TCEQ database. This unit of the northern Gulf Coast aquifer, along with the Burkeville confining unit, are the primary source for wells located within 10 miles of the PWS, and throughout southeast Polk County.

Regional groundwater withdrawal throughout the northern part of the Gulf Coast aquifer system is extensive and likely to steadily increase over the next decades. Since the 1900s, large groundwater withdrawals have resulted in declines in the aquifer's potentiometric surface from tens to hundreds of feet conditions (Mace, *et al*. 2006). A groundwater availability model (GAM) for northern part of the Gulf Coast aquifer was recently developed by the TWDB. Modeling was performed by the U.S. Geological Survey to simulate historical conditions (Kasmerek and Robinson 2004), and to develop long-term groundwater projections (Kasmerek, Reece and Houston 2005). Modeling of a TWDB scenario based on 50-year regional projections by regional user groups anticipate extensive groundwater use and drop in aquifer levels, with the largest declines around the Houston metropolitan area.

GAM simulation data reported by Kasmerek, Reece and Houston (2005) indicate that over a 50-year simulation withdrawals for the entire Gulf Coast aquifer are expected to peak at 920 mgd in 2020, and subsequently decrease to 850 mgd. Withdrawals from the Evangeline aquifer represent nearly half of that value, estimated at 420 mgd in 2000. This rate would steadily decrease to 315 mgd in 2020, and remain within 4 percent of this value for the remaining simulation period. Withdrawals from the Jasper aquifer represent only a fraction of those values, with an estimated 36 mgd withdrawal in 2000. The rate is projected to increase to 51 mgd by 2010, approximately 42 percent, and stabilize within 6 percent of that value through 2050. A minimum increase in water elevation of the Evangeline aquifer is anticipated throughout Montgomery County during the 50-year simulation period. For the Jasper aquifer, however, a depression cone centered in Montgomery and Jackson counties is anticipated. A water level reduction from 50 to 100 feet. is projected for 2050 in north central Montgomery County where the PWS is located.

The GAM of the northern part of the Gulf Coast aquifer was not run for the PWS as groundwater availability would reflect regional conditions primarily driven by groundwater withdrawal from the Houston area. Water use by the small PWS would represent a minor addition to the regional water use, making potential changes in aquifer levels well beyond the spatial resolution of the regional GAM model.

4.2.3 Potential for New Surface Water Sources

There is a minimum potential for development of new surface water sources for the system as indicated by limited water availability over the entire river basin, and within the site vicinity.

The Crystal Lake PWS is located in lower Trinity Basin, where the 2002 Texas Water anticipates an 11 percent reduction in water availability from 2000 (1,912,777 acre-feet per year [AFY]) to 2050 (1,709,838 AFY).

The vicinity of the Crystal Lake PWS has a minimum availability of surface water for new uses. The TCEQ availability map for the Trinity Basin indicates that, over a 20-mile radius of the site, unappropriated flows for new uses are typically available up to 75 percent of the time. This supply is inadequate as the TCEQ requires 100 percent supply availability for a PWS.

4.2.4 Alternative Water Source Options for Detailed Consideration

The initial review of alternative sources of water results in the following options for more-detailed consideration:

1. Crystal Lake PWS (Alternative CL-1). A new groundwater well would be completed at a different depth (300-400 feet) in the vicinity of the existing well.

2. Beech Creek PWS (Alternative CL-2). This alternative involves installing a new well at the Beech Creek PWS (300-400 feet), and constructing a pump station and pipeline to transfer the water to the Crystal Lake PWS. Based on the water quality data in the TCEQ database, it is expected that groundwater from this well field would be compliant

with drinking water MCLs, though there may be a minor issue with iron. An agreement would need to be negotiated with Beech Creek Village LL or land would have to be purchased to implement this alternative.

3. City of Livingston PWS (Alternative CL -3). This alternative involves purchasing finished drinking water from City of Livingston and constructing a pump station and pipeline to transfer the pumped water to the Crystal Lake PWS. Based on the water quality data in the TCEQ database, it is expected that finished water from this system would be compliant with drinking water MCLs, though there may be a minor issue with iron. An agreement would need to be negotiated with City of Livingston to provide this water.

4. Soda PWS (Alternative CL-4). This alternative involves purchasing finished drinking water from Soda WSC, and constructing a pump station and pipeline to transfer the pumped water to the Crystal Lake PWS. Based on the water quality data in the TCEQ database, it is expected that finished water from this system would be compliant with drinking water MCLs, though there may be a minor issue with iron. An agreement would need to be negotiated with Soda WSC to provide this water.

5. Providence PWS(Alternative CL-5). This alternative involves purchasing finished drinking water from the Providence PWS, and constructing a pump station and pipeline to transfer the pumped water to the Crystal Lake PWS. Based on the water quality data in the TCEQ database, it is expected that finished water from this system would be compliant with drinking water MCLs, though there may be a minor issue with iron. An agreement would need to be negotiated with the Providence Water Supply Corporation to provide this water.

6. Alternatives CL-6, CL-7 and CL-8 provides the estimated costs to install wells 10-, 5-miles, and 1-mile from Crystal Lake PWS.

4.3 TREATMENT OPTIONS

4.3.1 Centralized Treatment Systems

Centralized treatment of the well water is identified as a potential option. Ion exchange, WRT Z-88, and $KMnO_4$ treatment could all be potentially applicable. The central IX treatment alternative is CL-9, the central WRT Z-88 treatment alternative is CL-10, and the central $KMnO_4$ treatment alternative is CL-11.

4.3.2 Point-of-Use Systems

POU treatment using resin-based adsorption technology or RO is valid for total radium removal. The POU treatment alternative is CL-12.

4.3.3 Point-of-Entry Systems

POE treatment using resin based adsorption technology or RO is valid for total radium removal. The POE treatment alternative is CL-13.

4.4. BOTTLED WATER

Providing bottled water is considered an interim measure to be used until a compliance alternative is implemented. Even though the community is small and people know each other; it would be reasonable to require a quarterly communication advising customers of the need to take advantage of the bottled water program. An alternative to providing delivered bottled water is to provide a central, publicly accessible dispenser for treated drinking water. Alternatives addressing bottled water are CL-14, CL-15, and CL-16.

4.5 ALTERNATIVE DEVELOPMENT AND ANALYSIS

A number of potential alternatives for compliance with the MCLs for combined radium-226 and radium-228 and gross alpha particles have been identified. Each of the potential alternatives is described in the following subsections. It should be noted that the cost information given is the capital cost and change in O&M costs associated with implementing the particular alternative. Appendix C contains cost estimates for the compliance alternatives. These compliance alternatives represent a range of possibilities, and a number of them are likely not feasible. However, all have been presented to provide a complete picture of the range of alternatives considered. It is anticipated that a PWS will be able to use the information contained herein to select the most attractive alternative(s) for more detailed evaluation and possible subsequent implementation.

4.5.1 Alternative CL-1: New Well at the Current Crystal Lake PWS Location

This alternative involves completing a new shallower well at the current Crystal Lake PWS site, and tying it into an existing water system. The new well would be between 300 and 400 feet deep. Based on the water quality data in the TCEQ database, it is expected that groundwater from this location at a different depth may be compliant with drinking water MCLs.

The estimated capital cost for this alternative includes completing the new well, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $55,086, and the alternative’s estimated annual O&M savings is $34. The O&M savings is due to lower pumping costs with a shallower well.

The reliability of adequate amounts of compliant water under this alternative should be good. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as easy to operate and repair, since O&M and repair of a well system understood. The Lake Livingston WSSSC personnel currently operate other well systems. Lake Livingston

WSSSC personnel have experience with O&M of wells, pipelines, and pump stations. If the decision were made to perform blending, then the operational complexity would increase.

Obtaining agreements is not necessary for implementing this option, and should not impact the feasibility of this alternative.

4.5.2 Alternative CL-2: New Well at Water from Beech Creek Village PWS

This alternative would require constructing a pipeline from Beech Creek Village PWS to the Crystal Lake PWS. A pump station would be required to overcome pipe friction and the elevation differences between Beech Creek PWS and the Crystal Lake PWS. A storage tank and feed pump set would also be required at the Beech Creek PWS site. The required pipeline would be constructed of 4-inch pipe and would follow Tom Cummings Rd. .Hwy 190, and Carolyn Dr. Using this route, shown in Figure 4.1, the pipeline required would be 1.4 miles in length.

The pump station would include two pumps (minimum of 2 hp each), one of the pumps is a standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Crystal Lake Estates Subdivision, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative has limited opportunity for regionalization in that the Crystal Lake PWS could possibly turn over provision of drinking water to the Beech Creek Village LL Water System instead of installing its own new well. Other non-compliant systems have not been identified near Crystal Lake PWS or along the pipeline route, so there is little chance to share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and storage tank and feed pump set. The estimated O&M cost for this alternative are related to maintenance cost for the pipeline, and power and O&M labor and materials for the pump station, storage, and feed pumps. The estimated capital cost for this alternative is $406,277, and the alternatives' estimated annual O&M cost is $20,576.

The reliability of adequate amounts of compliant water under this alternative should be good. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pumps stations is well understood. Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines and pump stations. The feasibility of this alternative is dependent on an agreement being reached with the Beech Creek PWS to install a well in its well field.

4.5.3 Alternative CL-3: Purchase Water from City of Livingston

This alternative would require constructing a pipeline from City of Livingston to the Crystal Lake PWS. A pump station would be required to overcome pipe friction and the elevation differences between City of Livingston and Crystal Lake PWS, and a storage tank and feed pumps would also be required at the City of Livingston site. The required pipeline would be constructed of 4-inch pipe and would follow U.S. Highway 190 and Carolyn Dr. Using this route, shown in Figure 4.1, the pipeline required would be 2.7 miles in length.

The pump station would include two pumps (minimum of 3 hp each), one of the pumps is a standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Crystal Lake Estates Subdivision, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative involves regionalization by definition, since the Crystal Lake PWS would obtain drinking water from an existing larger supplier. It is possible the Crystal Lake PWS could turn over provision of drinking water to the City of Livingston instead of purchasing water. Other non-compliant systems have not been identified near Crystal Lake PWS or along the pipeline route, so there is little chance to share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and storage tank. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the Crystal Lake PWS well, plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $712,072, and the alternatives' estimated annual O&M cost is $20,576.

The reliability of adequate amounts of compliant water under this alternative should be good. City of Livingston provides treated surface water on a large scale, facilitating adequate O&M resources. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood. Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines, and pump stations. If the decision were made to perform blending, then the operational complexity would increase.

The feasibility of this alternative is dependent on an agreement being reached with the City of Livingston to purchase treated drinking water.

4.5.4 Alternative CL-4: Purchase Water from Soda PWS

This alternative would require constructing a pipeline from the Soda PWS to the Crystal Lake PWS. A pump station would be required to overcome pipe friction and elevation differences between Soda WSC's well and the Crystal Lake PWS storage tank. The required pipeline would be constructed of 4-inch pipe and would follow State Highway 190 and Carolyn Dr. to the Crystal Lake PWS. Using this route, shown in Figure 4.1, the pipeline required would be 3.8 miles long.

The pump station would include two 4-hp pumps, one of the pumps is a standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Crystal Lake Estates Subdivision, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative involves regionalization by definition, since Crystal Lake PWS would obtain drinking water from an existing larger supplier. It is possible the Crystal Lake PWS could turn over provision of drinking water to the Soda WSC instead of purchasing water. Other non-compliant systems have not been identified near Crystal Lake PWS or along the pipeline route, so there is little chance to share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and storage tank. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the Crystal Lake PWS well, plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $953,097, and the alternatives' estimated annual O&M cost is $21,111.

The reliability of adequate amounts of compliant water under this alternative should be good. Soda Water Supply Company provides treated groundwater on a large scale, facilitating adequate O&M resources. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood. Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines, and pump stations. If the decision were made to perform blending, then the operational complexity would increase.

The feasibility of this alternative is dependent on an agreement being reached with the Soda Water Supply Company to purchase treated drinking water.

4.5.5 Alternative CL-5: Purchase Water from Providence PWS

This alternative would require constructing a pipeline from the Providence PWS to the Crystal Lake PWS. A pump station would be required to overcome pipe friction and the elevation differences between Providence PWS and Crystal Lake PWS, and a storage tank and feed pump set would also be required at the Providence PWS site. The required pipeline would be constructed of 4-inch pipe and would follow FM 1988, Hwy 146 Mill gate Rd. and Tom Cummings Rd. to the Crystal Lake PWS. Using this route, shown in Figure 4.1, the pipeline required would be 6.6 miles in length.

The pump station would include two pumps (minimum of 5 hp each), one of the pumps is a standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Crystal Lake Estates Subdivision, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative involves regionalization by definition, since the Crystal Lake PWS would obtain drinking water from an existing larger supplier. It is possible the Crystal Lake PWS could turn over provision of drinking water to the Providence Water Supply Company Water System instead of purchasing water. Other non-compliant systems have not been identified near the Crystal Lake PWS or along the pipeline route, so there is little chance to share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and storage tank and feed pumps. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the Crystal Lake PWS well, plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $1,54 million, and the alternatives' estimated annual O&M cost is $21,850.

The reliability of adequate amounts of compliant water under this alternative should be good. Providence PWS provides treated groundwater on a large scale, facilitating adequate O&M resources. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood. The Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines, and pump stations. If the decision were made to perform blending, then the operational complexity would increase.

The feasibility of this alternative is dependent on an agreement being reached with the Providence PWS to purchase treated drinking water.

4.5.6 Alternative CL-6: New Well at 10 miles

This alternative consists of installing one new well within 10 miles of the Crystal Lake PWS that would produce compliant water in place of the water produced by the existing wells. At this level of study, it is not possible to positively identify an existing well or the location where a new well could be installed.

This alternative would require constructing one new 309-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the Crystal Lake PWS. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be 10 miles long, and would be a 4-inch line that discharges to the existing storage tank at the Crystal Lake PWS. The pump station would include two pumps, including one standby, and would be housed in a building.

Depending on well location and capacity, this alternative could present some options for a more regional solution. It may be possible to share water and costs with another nearby system.

The estimated capital cost for this alternative includes installing the well, and constructing the pipeline, pump station, and storage tank. The estimated O&M cost for this alternative includes O&M for the pipeline and pump station. The estimated capital cost for this alternative is $2.34 million, and the estimated annual O&M cost for this alternative is $17,302.

The reliability of adequate amounts of compliant water under this alternative should be good, since water wells, pump stations and pipelines are commonly employed. From the perspective of the Lake Livingston WSSSC, this alternative would be similar to operate as the existing system. Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines, and pump stations.

The feasibility of this alternative is dependent on the ability to find an adequate existing well or success in installing a well that produces an adequate supply of compliant water. It is possible an alternate groundwater source could not be found on land owned by the Lake Livingston WSSSC, so landowner cooperation would likely be required at the new location.

4.5.7 Alternative CL-7: New Well at 5 miles

This alternative consists of installing one new well within 5 miles of the Crystal Lake PWS that would produce compliant water in place of the water produced by the existing wells. At this level of study, it is not possible to positively identify an existing well or the location where a new well could be installed.

This alternative would require constructing one new 309-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to a new storage tank and feed pump set for the Crystal Lake PWS. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be 5 miles long, and would be a 4-inch line that discharges to the existing storage tank at the Crystal Lake PWS. The pump station would include two pumps, including one standby, and would be housed in a building.

Depending on well location and capacity, this alternative could present some options for a more regional solution. It may be possible to share water and costs with another nearby system.

The estimated capital cost for this alternative includes installing the well, and constructing the pipeline, pump station, and storage tank. The estimated O&M cost for this alternative includes O&M for the pipeline and pump station. The estimated capital cost for this alternative is $1,44 million, and the estimated annual O&M cost for this alternative is $28,631.

The reliability of adequate amounts of compliant water under this alternative should be good, since water wells, pump stations and pipelines are commonly employed. From the perspective of the Lake Livingston WSSSC, this alternative would be similar to operate as the existing system. Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines, and pump stations.

The feasibility of this alternative is dependent on the ability to find an adequate existing well or success in installing a well that produces an adequate supply of compliant water. It is possible an alternate groundwater source could not be found on land owned by the Lake Livingston WSSSC, so landowner cooperation would likely be required at the new location.

4.5.8 Alternative CL-8: New Well at 1 mile

This alternative consists of installing one new well within 1 mile of the Crystal Lake PWS that would produce compliant water in place of the water produced by the existing wells. At this level of study, it is not possible to positively identify an existing well or the location where a new well could be installed.

This alternative would require constructing one new 309 foot well, a pipeline from the new well to a new storage tank and pump set for the Crystal Lake PWS. For this alternative, the pipeline is assumed to be 1 mile long, and would be a 4-inch line that discharges to the new storage tank at the Crystal Lake PWS.

Depending on well location and capacity, this alternative could present some options for a more regional solution. It may be possible to share water and costs with another nearby system.

The estimated capital cost for this alternative includes installing the well, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes O&M for the pipeline and pump station. The estimated capital cost for this alternative is $260,289, and the estimated annual O&M cost for this alternative is $155.

The reliability of adequate amounts of compliant water under this alternative should be good, since water wells, pump stations and pipelines are commonly employed. From the perspective of the Lake Livingston WSSSC, this alternative would be similar to operate as the existing system. Lake Livingston WSSSC personnel have experience with O&M of wells, pipelines, and pump stations.

The feasibility of this alternative is dependent on the ability to find an adequate existing well or success in installing a well that produces an adequate supply of compliant water. It is possible an alternate groundwater source would not be found on land owned by the Lake Livingston WSSSC, so landowner cooperation may be required.

4.5.9 Alternative CL-9: Central IX Treatment

The system would continue to pump water from the Crystal Lake PWS well , and would treat the water through an IX system prior to distribution. For this option, the entire flow of the raw water will be treated to obtain compliant water as the radium concentration is relatively high. Water in excess of that currently produced would be required for backwashing and regeneration of the resin beds.

The IX treatment plant, located at the Crystal Lake PWS well site, features a 400 square foot (ft^2) building with a paved driveway; the pre-constructed IX equipment on a skid, a 24”x50” commercial brine drum with regeneration equipment, two transfer pumps, a 5,000-gallon tank for storing the treated water, a 6,000-gallon tank for storing spent backwash water, and a 2,000 gallon tank for storing regenerant waste. The spent backwash water and regenerant waste would be trucked off-site for disposal. The treated water would be chlorinated and stored in the new treated water tank prior to being pumped into the distribution system. The entire facility is fenced.

The estimated capital cost for this alternative is $293,770, and the estimated annual O&M cost is $34,292.

Reliability of supply of adequate amounts of compliant water under this alternative is good, since IX treatment is a common and well-understood treatment technology. IX treatment does not require high pressure, but can be affected by interfering constituents in the water. The O&M efforts required for the central IX treatment plant may be significant, and operating personnel would require training with ion exchange.

4.5.10 Alternative CL-10: WRT Z-88 Treatment

The system would continue to pump water from the Crystal Lake PWS well, and would treat the water through the Z-88 adsorption system prior to distribution. The full flow of raw water would be treated by the Z-88 system as the media specifically adsorb radium and do not affect other constituents. There is no liquid waste generated in this process. The Z-88 media would be replaced and disposed of by WRT in an approved low-level radioactive waste landfill after 1-2 years of operation.

This alternative consists of constructing the Z-88™ treatment system at the existing Crystal Lake PWS well site. WRT owns the Z-88™ equipment and the water company pays for the installation of the system and auxiliary facilities and an initial setup fee of $58,000 to WRT. The plant comprises a 400 ft^2 building with a paved driveway; the pre-constructed Z-88 adsorption system (2- 26” diameter x 115” tall vessels) owned by WRT; the piping system, and a water storage tank and feed pumps. The entire facility is fenced. The treated water will be chlorinated prior to distribution.

The estimated capital cost for this alternative is $286,230 and the annual O&M cost is estimated to be $40,629.

Based on many pilot testing results and some full-scale plant data this technology appears to be reliable. It is very simple to operate and the media replacement and disposal would be handled by WRT. Because WRT owns the equipment the capital cost is relatively low. The main operating cost is the treated water fee charged by WRT. One concern with this technology is the potential health effect of the level of radioactivity accumulated in the Z-88™ vessel on O&M personnel when the media have been operating for a long time.

4.5.11 Alternative CL-11: KMnO4-Greensand Filtration

The system would continue to pump water from the Crystal Lake PWS well, and would treat the water through a greensand filter system prior to distribution. For this option, the entire flow of the raw water will be treated and the flow will be decreased when one of the two 50 percent filters is being backwashed by raw water.

The greensand plant, located at the Crystal Lake PWS well site, features a 400 ft^2 building with a paved driveway; the pre-constructed filters and a KMnO4 solution tank on a skid; a 3,000 gallon spent backwash tank, piping systems, and a storage tank and feed pumps for treated water. The spent backwash will be allowed to settle in the spent backwash tank, and the water will be recycled to the head of the plant, and there will be periodic disposal of accumulated sludge. The entire facility is fenced.

The estimated capital cost for this alternative is $342,780 and the annual O&M is estimated to be $47,232.

Reliability of supply of adequate amounts of compliant water under this alternative is good, since KMnO4-greensand is an established treatment technology for radium removal. The O&M efforts required is moderate and the operating personnel needs to ensure that KMnO4 is not overfed. The spent backwash water contains MnO2 particles with sorbed radium and the level of radioactivity in the backwash is relatively low.

4.5.12 Alternative CL-12: Point-of-Use Treatment

This alternative consists of the continued operation of the Crystal Lake PWS well, plus treatment of water to be used for drinking or food preparation at the point of use (POU) to remove radium and alpha particle activity. The purchase, installation, and maintenance of POU treatment systems to be installed "under the sink" would be necessary for this alternative. Blending is not an option in this case.

This alternative would require installing the POU treatment units in residences and other buildings that provide drinking or cooking water. Lake Livingston WSSSC staff would be responsible for purchase and maintenance of the treatment units, including media or membrane and filter replacement, periodic sampling, and necessary repairs. In houses, the most convenient point for installation of the treatment units is typically under the kitchen sink, with a separate tap installed for dispensing treated water. Installation of the treatment units in kitchens would require entry by Lake Livingston WSSSC staff or contract personnel into the houses of customers. As a result, cooperation of customers would be important for success implementing this alternative. The treatment units could be installed so they could be accessed without house entry, but that would complicate the installation and increase costs.

For the cost estimate, it is assumed the POU radium and alpha particle activity treatment would involve RO. RO treatment processes typically produce a reject water stream that requires disposal. The reject stream results in an increase in the overall volume of water used. POU systems have the advantage of using only a minimum volume of treated water for human consumption. This minimizes the size of the treatment units, the water required for treatment, and the quantity of waste for disposal. For this alternative, it is assumed the increase in water consumption is insignificant in terms of supply cost, and that the reject waste stream could be discharged to the house septic or sewer system.

This alternative does not present options for a shared solution.

The estimated capital cost for this alternative includes the cost to purchase and install the POU treatment systems. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $61,380, and the estimated annual O&M cost for this alternative is $54,507. For the cost estimate, it is assumed that one POU treatment unit will be required for each of the existing 93 connections. Costs are not calculated for the Crystal Lake PWS at full-build-out.

The reliability of adequate amounts of compliant water under this alternative is fair, since it relies on the active cooperation of the customers for system installation, use, and maintenance, and only provides compliant water to single tap within a house. Additionally, the O&M efforts required for the POU systems will be significant, and the current personnel are inexperienced in this type of work. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as more difficult to operate owing to the in-home requirements and the large number of individual units. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets to meet regulatory requirements, making purchase and installation more expensive.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.13 Alternative CL-13: Point-of-Entry Treatment

This alternative consists of the continued operation of the Crystal Lake PWS well, plus treatment of water as it enters residences to remove radium and gross alpha particle activity. The purchase, installation, and maintenance of the treatment systems at the point of entry to a household would be necessary for this alternative. Blending is not an option in this case.

This alternative would require the installation of the POE treatment units at houses and other buildings that provide drinking or cooking water. Lake Livingston WSSSC would be responsible for purchasing and maintaining the treatment units, including media or membrane and filter replacement, periodic sampling, and necessary repairs. It may also be desirable to modify piping so water for non-consumptive uses can be withdrawn upstream of the treatment unit. The POE treatment units would be installed outside the residences, so entry would not be necessary for O&M. Some cooperation from customers would be necessary for installation and maintenance of the treatment systems.

For the cost estimate, it is assumed the POE radium and alpha particle activity treatment would involve RO. RO treatment processes typically produce a reject water stream that requires disposal. The waste streams result in an increased overall volume of water used. POE systems treat a greater volume of water than POU systems. For this alternative, it is assumed the increase in water consumption is insignificant in terms of supply cost, and that the reject waste stream could be discharged to the house septic or sewer system.

This alternative does not present options for a shared solution.

The estimated capital cost for this alternative includes cost to purchase and install the POE treatment systems. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $1.07 million, and the estimated annual O&M cost for this alternative is $126,582. For the cost estimate, it is assumed that one POU treatment unit will be required for each of the 93 existing connections. Costs are not calculated for the Crystal Lake PWS at full-build-out.

The reliability of adequate amounts of compliant water under this alternative are fair, but better than POU systems since it relies less on the active cooperation of the customers for system installation, use, and maintenance, and compliant water is supplied to all taps within a house. Additionally, the O&M efforts required for the POE systems will be significant, and the current personnel are inexperienced in this type of work. From the perspective of the Crystal Lake PWS, this alternative would be characterized as more difficult to operate owing to the on-property requirements and the large number of individual units.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.14 Alternative CL-14: Public Dispenser for Treated Drinking Water

This alternative consists of the continued operation of the Crystal Lake PWS well, plus dispensing treated water for drinking and cooking at a publicly accessible location. Implementing this alternative would require purchasing and installing a treatment unit where customers would be able to come and fill their own containers. This alternative also includes notifying customers of the importance of obtaining drinking water from the dispenser. In this way, only a relatively small volume of water requires treatment, but customers would be required to pick up and deliver their own water. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

Lake Livingston WSSSC personnel would be responsible for maintenance of the treatment unit, including media or membrane replacement, periodic sampling, and necessary repairs. The spent media or membranes will require disposal. This alternative relies on a great deal of cooperation and action from the customers to be effective.

This alternative does not present options for a regional solution.

The estimated capital cost for this alternative includes purchasing and installing the treatment system to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes purchasing and replacing filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $11,600, and the estimated annual O&M cost for this alternative is $15,230.

The reliability of adequate amounts of compliant water under this alternative is fair, because of the large amount of effort required from the customers and the associated inconvenience. Lake Livingston WSSSC has not provided this type of service in the past. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as relatively easy to operate, since these types of treatment units are highly automated, and there is only one unit.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.15 Alternative CL-15: 100 Percent Bottled Water Delivery

This alternative consists of the continued operation of the Crystal Lake PWS well, but compliant drinking water will be delivered to customers in containers. This alternative involves setting up and operating a bottled water delivery program to serve all of the customers in the system. It is expected that Lake Livingston WSSSC would find it most convenient and economical to contract a bottled water service. The bottle delivery program would have to be flexible enough to allow the delivery of smaller containers should customers be incapable of lifting and manipulating 5-gallon bottles. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

This alternative does not involve capital cost for construction, but would require some initial costs for system setup, and then ongoing costs to have the bottled water furnished. It is assumed for this alternative that bottled water is provided to 100 percent of the Crystal Lake PWS customers.

This alternative does not present options for a regional solution.

The estimated initial capital cost is for setting up the program. The estimated O&M cost for this alternative includes program administration and purchase of the bottled water. The estimated capital cost for this alternative is $20,836, and the estimated annual O&M cost for this alternative is $2,185,940. For the cost estimate, it is assumed that each person requires one gallon of bottled water per day.

The reliability of adequate amounts of compliant water under this alternative is fair, since it relies on the active cooperation of customers to order and utilize the water. Management and administration of the bottled water delivery program will require attention from the Lake Livingston WSSSC.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.16 Alternative CL-16: Public Dispenser for Trucked Drinking Water

This alternative consists of continued operation of the Crystal Lake PWS well, plus dispensing compliant water for drinking and cooking at a publicly accessible location. The compliant water would be purchased from the City of Livingston, and delivered by truck to a tank at a central location where customers would be able to fill their own containers. This alternative also includes notifying customers of the importance of obtaining drinking water from the dispenser. In this way, only a relatively small volume of water requires treatment, but customers are required to pick up and deliver their own water. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

Lake Livingston WSSSC would purchase a truck that would be suitable for hauling potable water, and install a storage tank. It is assumed the storage tank would be filled once a week, and that the chlorine residual would be tested for each truckload. The truck would have to meet requirements for potable water, and each load would be treated with bleach. This alternative relies on a great deal of cooperation and action from the customers for it to be effective.

This alternative presents limited options for a regional solution if two or more systems share the purchase and operation of the water truck.

The estimated capital cost for this alternative includes purchasing a water truck and construction of the storage tank to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes O&M for the truck, maintenance for the tank, water quality testing, record keeping, and water purchase, The estimated capital cost for this alternative is $102,986, and the estimated annual O&M cost for this alternative is $14,020.

The reliability of adequate amounts of compliant water under this alternative is fair because of the large amount of effort required from the customers and the associated inconvenience. Current personnel have not provided this type of service in the past. From the perspective of the Lake Livingston WSSSC, this alternative would be characterized as relatively easy to operate, but the water hauling and storage would have to be done with care to ensure sanitary conditions.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.17 Summary of Alternatives

Table 4.3 provides a summary of the key features of each alternative for the Crystal Lake PWS.

Table 4.3 Summary of Compliance Alternatives for Crystal Lake PWS

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
CL -1	New well at Crystal Lake PWS	- New well	$55086	$(34)	$4,769	Good	N	New, deeper well at the same location. Sharing cost with neighboring systems may be possible. Blending may be possible.
CL -2	New Well Beech Creek Village LL PWS	- Pump station - 1.4-mile pipeline	$406,277	$20,453	$55,874	Good	N	Agreement must be successfully negotiated with Beech Creek Village LL PWS. Blending may be possible.
CL -3	Purchase water from City of Livingston	- Pump station - 2.7-mile pipeline	$712,072	$20,576	$82,658	Good	N	Agreement must be successfully negotiated with City of Livingston. Blending may be possible.
CL -4	Purchase water from Soda Water Supply Company	- Pump station - 3.8-mile pipeline	$953,097	$21,111	$104,206	Good	N	Agreement must be successfully negotiated with Soda Water Supply Company. Sharing cost with neighboring systems may be possible. Blending may be possible.
CL -5	Purchase water from Providence Water Supply Company	- Pump station - 6.6-mile pipeline	$1,540,765	$21,850	$156,181	Good	N	Agreement must be successfully negotiated with Providence Water Supply Company. Sharing cost with neighboring systems may be possible. Blending may be possible.
CL -6	Install new compliant well within 10 miles	- New well - Storage tank - Pump station - 10-mile pipeline	$2,342,152	$17,302	$221,502	Good	N	There is good probability for finding good quality groundwater. Costs could possibly be shared with small systems along pipeline route.
CL -7	Install new compliant well within 5 miles	- New well - Storage tank - Pump station - 5-mile pipeline	$1,437,397	$28,631	$153,950	Good	N	There is good probability for finding good quality groundwater. Costs could possibly be shared with small systems along pipeline route.
CL -8	Install new compliant well within 1 mile	- New well - Storage tank - 1-mile pipeline	$260,289	$155	$22,848	Good	N	There is good probability for finding good quality groundwater.
CL -9	Continue operation of the Crystal Lake PWS well field with central IX treatment	- Central IX treatment plant	$293,770	$34,292	$59,904	Good	T	Costs could possibly be shared with nearby small systems.
CL -10	Continue operation of Crystal Lake PWS well field with central WRT Z-88 treatment	- Central WRT Z-88 treatment plant	$286,230	$40,629	$65,584	Good	T	Costs could possibly be shared with nearby small systems.
CL -11	Continue operation of Crystal Lake PWS well field with central $KMnO_4$ treatment	- Central $KMnO_4$ treatment plant	$342,780	$47,232	$77,177	Good	T	Costs could possibly be shared with nearby small systems.

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
CL -12	Continue operation of Crystal Lake PWS well field, and POU treatment	- POU treatment units.	$61,380	$54,507	$59,859	Fair	T, M	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.
CL -13	Continue operation of Crystal Lake PWS well field, and POE treatment	- POE treatment units.	$1,074,150	$126,582	$220,232	Fair (*better than POU*)	T, M	All home taps compliant and less resident cooperation required.
CL -14	Continue operation of Crystal Lake PWS well field, but furnish public dispenser for treated drinking water	- Water treatment and dispenser unit	$11,600	$15,230	$16,241	Fair/interim measure	T	Does not provide compliant water to all taps, and requires a lot of effort by customers.
CL -15	Continue operation of Crystal Lake PWS well field, but furnish bottled drinking water for all customers	- Set up bottled water system	$20,836	$185,940	$187,756	Fair/interim measure	M	Does not provide compliant water to all taps, and requires customers to order and use. Management of program may be significant.
CL -16	Continue operation of Crystal Lake PWS well field, but furnish public dispenser for trucked drinking water.	- Construct storage tank and dispenser - Purchase potable water truck	$102,986	$14,020	$22,998	Fair/interim measure	M	Does not provide compliant water to all taps, and requires a lot of effort by customers.

Notes: N – No significant increase required in technical or management capability
T – Implementation of alternative will require increase in technical capability
M – Implementation of alternative will require increase in management capability

1 – See cost breakdown in Appendix C

2 – 20-year return period and 6 percent interest

4.6 COST OF SERVICE AND FUNDING ANALYSIS

To evaluate the financial impact of implementing the compliance alternatives, a 30-year financial planning model was developed. This model can be found in Appendix D. The financial model is based on estimated cash flows, with and without implementation of the compliance alternatives. Data for such models are typically derived from established budgets, audited financial reports, published water tariffs, and consumption data. Information available to complete the financial analysis on the Crystal Lake PWS (Crystal Lake) included the 2005 Consolidated Financial Statement for the parent company, Lake Livingston WSSSC, with combined revenues and expenses for all 52 PWSs it manages. Also evaluated were the "Capacity Assessment" document prepared after conducting interviews with Crystal Lake personnel and the Water Usage Rates provided by the Lake Livingston WSSSC. Crystal Lake customers use an average of 232 gpd per connection.

This analysis will need to be performed in a more detailed fashion and applied to alternatives deemed attractive and worthy of more detailed evaluation. A more detailed analysis should include additional factors such as:

- Cost escalation,
- Price elasticity effects where increased rates may result in lower water consumption,
- Costs for other system upgrades and rehabilitation needed to maintain compliant operation.

4.6.1 Financial Plan Development

Since Lake Livingston WSSSC does not keep separate financial records for each of the 52 PWSs it manages, the revenues and expenses for Crystal Lake had to be estimated. Total revenues and expenses for the Lake Livingston WSSSC systems were obtained from a consolidated 2005 Income and Expense statement. The annual revenue for the Crystal Lake PWS was estimated based on its percentage water usage of 2.5 percent as shown in Table 4.4. The resultant 2005 annual revenue of $84,533 was entered into the financial model and is presented in Table 4.4 for comparison with other Lake Livingston WSSSC systems.

Table 4.4 Summary of Lake Livingston WSSSC 2005 Estimated Water Revenues

PWS Name	2005 Water Usage	% of Total Water Usage	No. Connections	2005 Water Revenues
Crystal Lake Estates	7,719,750	2.5 %	93	$84,533
Indian Springs Lake Estates	43,304,000	15.5 %	360	$517,990
Paradise Acres	21,626,250	7.1 %	395	$236,812
Other Water Systems	232,308,000	74.9 %	6052	2,500,021
Total	304,958,000	100 %	6900	$3,339,356

Annual expenses for the Crystal Lake PWS were estimated based on its percentage water usage of 2.5 percent as shown in Table 4.4. In 2005, the consolidated financial statement provided by Lake Livingston WSSSC lists the total operating expenses as $2,418,031. The resultant total expenses for the Crystal Lake PWS amount to $60,450, leaving a surplus of $24,083 after expenses.

4.6.2 Current Financial Condition

4.6.2.1 Cash Flow Needs

Using the estimated water usage rates as noted above, the current average annual water bill for Crystal Lake PWS customers is estimated at $929 or about 2.9 percent of the Zip Code 77351 Tract MHI of $31,671.

The 2005 estimated annual water sales revenues for the Crystal Lake PWS are greater than the operating expenses. Lake Livingston WSSSC's 2005 consolidated financial report also indicates that it has a cash reserve of $1,434,450, which based on current expenditures, is sufficient to maintain operations for 7 months for all of the 52 PWSs. However, in an effort to maintain its reserve fund, Lake Livingston WSSSC may elect to raise rates to offset the expenditures for any capital improvements necessary to address the water quality issues concerning arsenic.

4.6.2.2 Ratio Analysis

Current Ratio= 2.28

The Current Ratio is a measure of liquidity. A Current Ratio of 2.28 indicates that the Lake Livingston WSSSC would be able to meet all of its current obligations, with total current assets of $1,188,583 exceeding total current liabilities of $520,782.

Debt to Net Worth Ratio=1.43

A Debt to Net Worth ratio is another measure of financial liquidity and stability. Lake Livingston WSSSC has a Net Worth of $4,741,473 and a debt total of $6,803,965 resulting in a Debt to Net Worth ratio of 1.43. Ratios less than 1.25 are indicative of financial stability, with lower ratios indicating greater financial stability and better credit risks for future borrowings. Based on the present ratio, Lake Livingston WSSSC could be perceived as a slight credit risk which may make it difficult to obtain financing for water improvement projects at competitive interest rates.

Operating Ratio = 1.38

In 2005 Lake Livingston WSSSC had operating revenues of $3,339,356 and operating expenses of $2,418,031 resulting in an Operating Ratio equal to 1.38. Thus, in fiscal year 2005 the operating revenues were more than sufficient to cover the operating expenses, and resulted in a surplus income of $921,325.

4.6.3 Financial Plan Results

Each of the compliance alternatives for the Crystal Lake Estates PWS was evaluated using the financial model to determine the overall increase in water rates that would be necessary to pay for the improvements. Each alternative was examined under the various funding options described in Subsection 2.4.

For State Revolving Fund (SRF) funding options, customer MHI compared to the state average determines the availability of subsidized loans. According the 2000 U.S. Census data, the Zip Code MHI for customers of the Crystal Lake PWS was $31,671, which is 79 percent of the statewide income average of $39,927. As a result, Lake Livingston WSSSC would qualify for a loan at an interest rate of 3.8 percent from the SRF. In the event SRF funds would be unavailable, Lake Livingston WSSSC would need to rely on revenue bonds as a funding alternative.

Results of the financial impact analysis are provided in Table 4.5and Figure 4.2. Table 4.5 presents rate impacts assuming that any deficiencies in reserve accounts are funded immediately in the year following the occurrence of the deficiency, which would cause the first few years' water rates to be higher than they would be if the reserve account was built-up over a longer period of time. Figure 4.2 provides a bar chart that, in terms of the yearly billing to an average customer, shows the following:

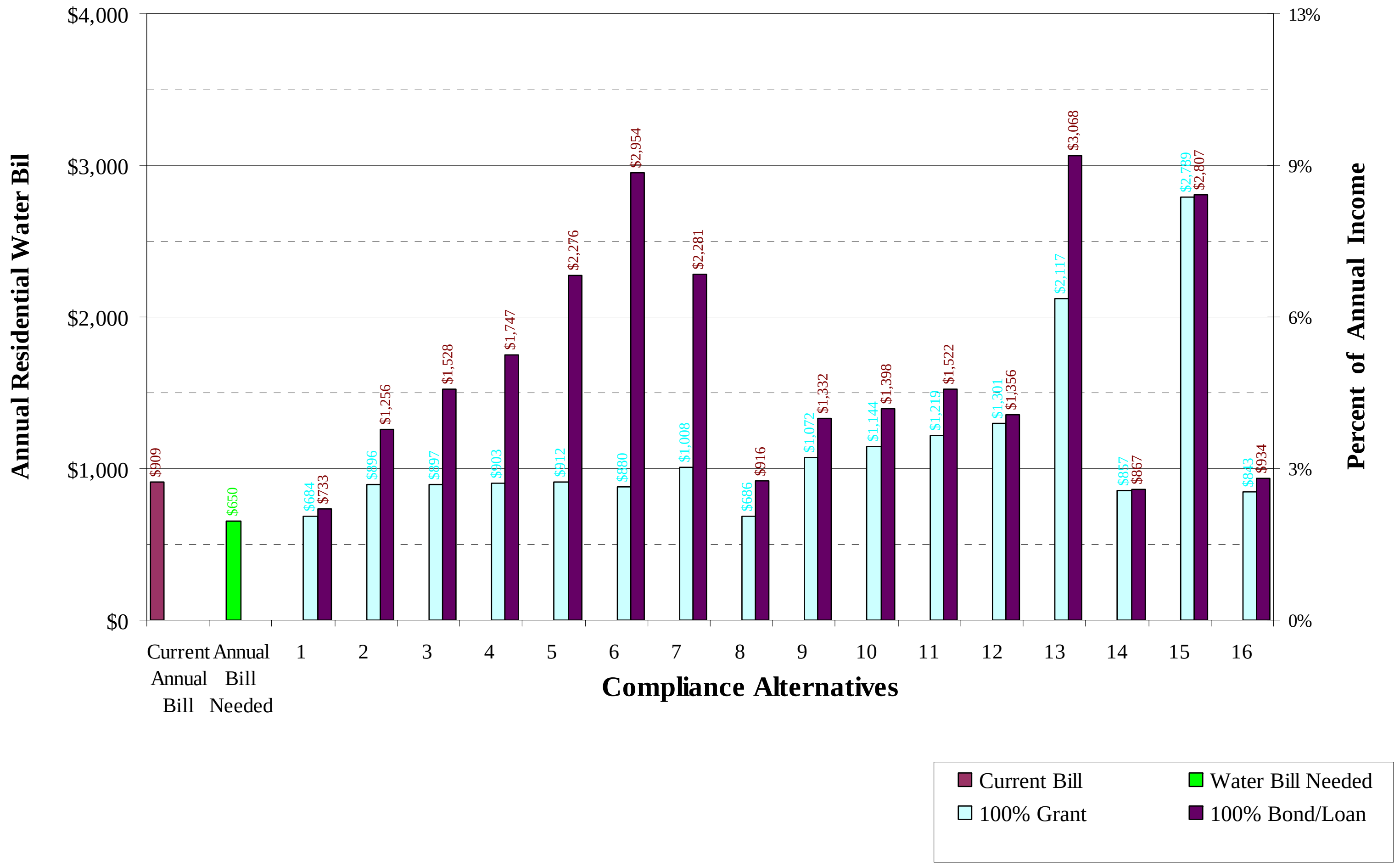
- Current annual average bill,
- Projected annual average bill including rate increase, if needed, to match existing expenditures, and
- Projected annual bill including rate increases needed to fund implementation of a compliance alternative (this does not include funding for reserve accounts).

The two bars shown for each compliance alternative represent the rate changes necessary for revenues to match total expenditures assuming 100 percent grant funding and 100 percent loan/bond funding. Most funding options will fall between 100 percent grant and 100 percent loan/bond funding, with the exception of 100 percent revenue financing. Establishing or increasing reserve accounts would require an increase in rates. If existing reserves are insufficient to fund a compliance alternative, rates would need to be raised before implementing the compliance alternative. This would allow for accumulation of sufficient reserves to avoid larger but temporary rate increases during the years the compliance alternative was being implemented.

Table 4.5 Financial Impact on Households

Alternative	Description		All Revenue	100% Grant	75% Grant	50% Grant	SRF	Bond
1	New Well at Crystal Lakes	Max % of HH Income	3%	3%	3%	3%	3%	3%
		Max % Rate Increase Compared to Current	8%	0%	0%	0%	0%	0%
		Average Water Bill Required by Alternative	$ 981	$ 909	$ 909	$ 909	$ 909	$ 909
2	Purchase Water from Beech Creek Village	Max % of HH Income	16%	4%	5%	5%	6%	6%
		Max % Rate Increase Compared to Current	465%	39%	59%	78%	108%	118%
		Average Water Bill Required by Alternative	$ 4,859	$ 1,187	$ 1,353	$ 1,518	$ 1,769	$ 1,849
3	Purchase Water from City of Livingston	Max % of HH Income	27%	4%	5%	6%	7%	8%
		Max % Rate Increase Compared to Current	846%	39%	74%	109%	161%	178%
		Average Water Bill Required by Alternative	$ 8,099	$ 1,190	$ 1,480	$ 1,770	$ 2,209	$ 2,350
4	Purchase Water from Soda Water Supply Corp.	Max % of HH Income	36%	4%	5%	7%	9%	9%
		Max % Rate Increase Compared to Current	1147%	41%	87%	134%	204%	226%
		Average Water Bill Required by Alternative	$ 10,657	$ 1,203	$ 1,591	$ 1,979	$ 2,567	$ 2,754
5	Purchase Water from Providence WSC	Max % of HH Income	57%	4%	6%	8%	12%	13%
		Max % Rate Increase Compared to Current	1880%	43%	118%	193%	307%	343%
		Average Water Bill Required by Alternative	$ 16,888	$ 1,220	$ 1,847	$ 2,474	$ 3,426	$ 3,728
6	New Well at 10 Miles	Max % of HH Income	85%	4%	7%	10%	15%	17%
		Max % Rate Increase Compared to Current	2874%	35%	149%	263%	436%	491%
		Average Water Bill Required by Alternative	$ 25,341	$ 1,155	$ 2,108	$ 3,061	$ 4,507	$ 4,968
7	New Well at 5 Miles	Max % of HH Income	53%	5%	7%	9%	12%	13%
		Max % Rate Increase Compared to Current	1764%	68%	138%	208%	314%	348%
		Average Water Bill Required by Alternative	$ 15,896	$ 1,420	$ 2,005	$ 2,590	$ 3,477	$ 3,760
8	New Well at 1 Mile	Max % of HH Income	10%	3%	3%	3%	4%	4%
		Max % Rate Increase Compared to Current	264%	0%	0%	10%	30%	36%
		Average Water Bill Required by Alternative	$ 3,154	$ 909	$ 909	$ 965	$ 1,125	$ 1,177
9	Central Treatment - IX	Max % of HH Income	13%	5%	6%	6%	7%	7%
		Max % Rate Increase Compared to Current	348%	84%	98%	113%	135%	141%
		Average Water Bill Required by Alternative	$ 3,854	$ 1,553	$ 1,672	$ 1,792	$ 1,973	$ 2,031
10	Central Treatment - WRT Z-88	Max % of HH Income	13%	6%	6%	7%	7%	7%
		Max % Rate Increase Compared to Current	348%	103%	117%	130%	152%	158%
		Average Water Bill Required by Alternative	$ 3,850	$ 1,701	$ 1,818	$ 1,934	$ 2,111	$ 2,167
11	Central Treatment - KMnO4	Max % of HH Income	15%	6%	7%	7%	8%	8%
		Max % Rate Increase Compared to Current	428%	122%	138%	155%	180%	189%
		Average Water Bill Required by Alternative	$ 4,527	$ 1,856	$ 1,995	$ 2,135	$ 2,346	$ 2,414
12	Point-of-Use Treatment	Max % of HH Income	7%	7%	7%	7%	7%	7%
		Max % Rate Increase Compared to Current	143%	143%	146%	149%	153%	155%
		Average Water Bill Required by Alternative	$ 2,071	$ 2,026	$ 2,051	$ 2,076	$ 2,114	$ 2,126
13	Point-of-Entry Treatment	Max % of HH Income	45%	13%	14%	16%	18%	19%
		Max % Rate Increase Compared to Current	1454%	352%	405%	457%	536%	562%
		Average Water Bill Required by Alternative	$ 13,218	$ 3,715	$ 4,152	$ 4,589	$ 5,252	$ 5,464
14	Public Dispenser for Treated Drinking Water	Max % of HH Income	4%	4%	4%	4%	4%	4%
		Max % Rate Increase Compared to Current	29%	29%	29%	30%	31%	31%
		Average Water Bill Required by Alternative	$ 1,114	$ 1,106	$ 1,111	$ 1,115	$ 1,123	$ 1,125
15	Supply Bottled Water to 100% of Population	Max % of HH Income	18%	18%	18%	18%	18%	18%
		Max % Rate Increase Compared to Current	525%	525%	526%	527%	528%	529%
		Average Water Bill Required by Alternative	$ 5,121	$ 5,105	$ 5,114	$ 5,122	$ 5,135	$ 5,139
16	Central Trucked Drinking Water	Max % of HH Income	5%	4%	4%	4%	4%	4%
		Max % Rate Increase Compared to Current	81%	25%	30%	35%	43%	45%
		Average Water Bill Required by Alternative	$ 1,592	$ 1,078	$ 1,120	$ 1,162	$ 1,225	$ 1,245

Figure 4-2 Alternative Cost Summary



SECTION 5
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APPENDIX A
PWS INTERVIEW FORM

CAPACITY DEVELOPMENT ASSESSMENT FORM

*Prepared By*___________________________________ *Date*___________________________

Section 1. Public Water System Information

1. PWS ID # [ ]
2. Water System Name [ ]
3. County [ ]
4. Owner [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]
5. Admin [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]
6. Operator [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]
7. Population Served [ ]
8. No. of Service Connections [ ]
9. Ownership Type [ ]
10. Metered (Yes or No) [ ]
11. Source Type [ ]
12. Total PWS Annual Water Used [ ]
13. Number of Water Quality Violations (Prior 36 months)

    Total Coliform [ ] Chemical/Radiological [ ]

    Monitoring (CCR, Public Notification, etc.) [ ] Treatment Technique, D/DBP [ ]

A. Basic Information

1. Name of Water System:

2. Name of Person Interviewed:

3. Position:

4. Number of years at job:

5. Number of years experience with drinking water systems:

6. Percent of time (day or week) on drinking water system activities, with current position (how much time is dedicated exclusively to the water system, not wastewater, solid waste or other activities):

7. Certified Water Operator (Yes or No):

   If Yes,
   7a. Certification Level (water):

   7b. How long have you been certified?

8. Describe your water system related duties on a typical day.

B. Organization and Structure

1. Describe the organizational structure of the Utility. Please provide an organizational chart. (Looking to find out the governance structure (who reports to whom), whether or not there is a utility board, if the water system answers to public works or city council, etc.)

2. If not already covered in Question 1, to whom do you report?

3. Do all of the positions have a written job description?

   3a. If yes, is it available to employees?

   3b. May we see a copy?

C. Personnel

1. What is the current staffing level (include all personnel who spend more than 10% of their time working on the water system)?

2. Are there any vacant positions? How long have the positions been vacant?

3. In your opinion, is the current staffing level adequate? If not adequate, what are the issues or staffing needs (how many and what positions)?

4. What is the rate of employee turnover for management and operators? What are the major issues involved in the turnover (e.g., operator pay, working conditions, hours)?

5. Is the system staffed 24 hours a day? How is this handled (on-site or on-call)? Is there an alarm system to call an operator if an emergency occurs after hours?

D. Communication

1. Does the utility have a mission statement? If yes, what is it?

2. Does the utility have water quality goals? What are they?

3. How are your work priorities set?

4. How are work tasks delegated to staff?

5. Does the utility have regular staff meetings? How often? Who attends?

6. Are there separate management meetings? If so, describe.

7. Do management personnel ever visit the treatment facility? If yes, how often?

8. Is there effective communication between utility management and state regulators (e.g., NMED)?

9. Describe communication between utility and customers.

E. Planning and Funding

1. Describe the rate structure for the utility.

2. Is there a written rate structure, such as a rate ordinance? May we see it?

    2a. What is the average rate for 6,000 gallons of water?

3. How often are the rates reviewed?

4. What process is used to set or revise the rates?

5. In general, how often are the new rates set?

6. Is there an operating budget for the water utility? Is it separate from other activities, such as wastewater, other utilities, or general city funds?

7. Who develops the budget, how is it developed and how often is a new budget created or the old budget updated?

8. How is the budget approved or adopted?

9. In the last 5 years, how many budget shortfalls have there been (i.e., didn't collect enough money to cover expenses)? What caused the shortfall (e.g., unpaid bills, an emergency repair, weather conditions)?

    9a. How are budget shortfalls handled?

10. In the last 5 years how many years have there been budget surpluses (i.e., collected revenues exceeded expenses?

    10a. How are budget surpluses handled (i.e., what is done with the money)?

11. Does the utility have a line-item in the budget for emergencies or some kind of emergency reserve account?

12. How do you plan and pay for short-term system needs?

13. How do you plan and pay for long- term system needs?

14. How are major water system capital improvements funded? Does the utility have a written capital improvements plan?

15. How is the facility planning for future growth (either new hook-ups or expansion into new areas)?

16. Does the utility have and maintain an annual financial report? Is it presented to policy makers?

17. Has an independent financial audit been conducted of the utility finances? If so, how often? When was the last one?

18. Will the system consider any type of regionalization with any other PWS, such as system interconnection, purchasing water, sharing operator, emergency water connection, sharing bookkeeper/billing or other?

F. Policies, Procedures, and Programs

1. Are there written operational procedures? Do the employees use them?

2. Who in the utility department has spending authorization? What is the process for obtaining needed equipment or supplies, including who approves expenditures?

3. Does the utility have a source water protection program? What are the major components of the program?

4. Are managers and operators familiar with current SDWA regulations?

5. How do the managers and operators hear about new or proposed regulations, such as arsenic, DBP, Groundwater Rule? Are there any new regulations that will be of particular concern to the utility?

6. What are the typical customer complaints that the utility receives?

7. Approximately how many complaints are there per month?

8. How are customer complaints handled? Are they recorded?

9. (If not specifically addressed in Question 7) If the complaint is of a water quality nature, how are these types of complaints handled?

10. Does the utility maintain an updated list of critical customers?

11. Is there a cross-connection control plan for the utility? Is it written? Who enforces the plan's requirements?

12. Does the utility have a written water conservation plan?

13. Has there been a water audit of the system? If yes, what were the results?

14. (If not specifically answered in 11 above) What is the estimated percentage for loss to leakage for the system?

15. Are you, or is the utility itself, a member of any trade organizations, such as AWWA or Rural Water Association? Are you an active member (i.e., attend regular meetings or participate in a leadership role)? Do you find this membership helpful? If yes, in what ways does it help you?

G. Operations and Maintenance

1. How is decision-making authority split between operations and management for the following items:

    a. Process Control

    b. Purchases of supplies or small equipment

    c. Compliance sampling/reporting

    d. Staff scheduling

2. Describe your utility's preventative maintenance program.

3. Do the operators have the ability to make changes or modify the preventative maintenance program?

4. How does management prioritize the repair or replacement of utility assets? Do the operators play a role in this prioritization process?

5. Does the utility keep an inventory of spare parts?

6. Where does staff have to go to buy supplies/minor equipment? How often?

    6a. How do you handle supplies that are critical, but not in close proximity (for example if chlorine is not available in the immediate area or if the components for a critical pump are not in the area)

7. Describe the system's disinfection process. Have you had any problems in the last few years with the disinfection system?

   7a. Who has the ability to adjust the disinfection process?

8. How often is the disinfectant residual checked and where is it checked?

   8a. Is there an official policy on checking residuals or is it up to the operators?

9. Does the utility have an O & M manual? Does the staff use it?

10. Are the operators trained on safety issues? How are they trained and how often?

11. Describe how on-going training is handled for operators and other staff. How do you hear about appropriate trainings? Who suggests the trainings – the managers or the operators? How often do operators, managers, or other staff go to training? Who are the typical trainers used and where are the trainings usually held?

12. In your opinion is the level of your on-going training adequate?

13. In your opinion is the level of on-going training for other staff members, particularly the operators, adequate?

14. Does the facility have mapping of the water utility components? Is it used on any routine basis by the operators or management? If so, how is it used? If not, what is the process used for locating utility components?

15. In the last sanitary survey, were any deficiencies noted? If yes, were they corrected?

16. How often are storage tanks inspected? Who does the inspection?

    16a. Have you experienced any problems with the storage tanks?

H. SDWA Compliance

1. Has the system had any violations (monitoring or MCL) in the past 3 years? If so, describe.

2. How were the violations handled?

3. Does the system properly publish public notifications when notified of a violation?

4. Is the system currently in violation of any SDWA or state regulatory requirements, including failure to pay fees, fines, or other administrative type requirements?

5. Does the utility prepare and distribute a Consumer Confidence Report (CCR)? Is it done every year? What type of response does the utility get to the CCR from customers?

I. Emergency Planning

1. Does the system have a written emergency plan to handle emergencies such as water outages, weather issues, loss of power, loss of major equipment, etc?

2. When was the last time the plan was updated?

3. Do all employees know where the plan is? Do they follow it?

4. Describe the last emergency the facility faced and how it was handled.

Attachment A

A. Technical Capacity Assessment Questions

1. Based on available information of water rights on record and water pumped has the system exceeded its water rights in the past year? YES ☐ NO ☐

   In any of the past 5 years? YES ☐ NO ☐ How many times? _____

2. Does the system have the proper level of certified operator? *(Use questions a – c to answer.)*
   YES ☐ NO ☐

   a. What is the Classification Level of the system by NMED? _____

   b. Does the system have one or more certified operator(s)? [20 NMAC 7.4.20]

   YES ☐ NO ☐

   c. If YES, provide the number of operators at each New Mexico Certification Level. [20 NMAC 7.4.12]

   _____NM Small System _____Class 2

   _____NM Small System Advanced _____Class 3

   _____Class 1 _____Class 4

3. Did the system correct any sanitary deficiency noted on the most recent sanitary survey within 6 months of receiving that information? [20 NMAC 7.20.504]

   YES ☐ NO ☐ No Deficiencies ☐

   What was the type of deficiency? *(Check all that are applicable.)*

   Source ☐ Storage ☐

   Treatment ☐ Distribution ☐

   Other _____

   From the system's perspective, were there any other deficiencies that were not noted on the sanitary survey? Please describe.

4. Will the system's current treatment process meet known future regulations?

   Radionuclides YES ☐ NO ☐ Doesn't Apply ☐

   Arsenic YES ☐ NO ☐ Doesn't Apply ☐

   Stage 1 Disinfectants and Disinfection By-Product (DBP)

   YES ☐ NO ☐ Doesn't Apply ☐

   Surface Water Treatment Rule YES ☐ NO ☐ Doesn't Apply ☐

5. Does the system have a current site plan/map? [20 NMAC 7.10.302 A.1.]

   YES ☐ NO ☐

6. Has the system had a water supply outage in the prior 24 months?

YES ☐ NO ☐

What were the causes of the outage(s)? *(Include number of outages for each cause.)*

Drought _____ Limited Supply _____

System Failure _____ Other _____

7. Has the system ever had a water audit or a leak evaluation?

YES ☐ NO ☐ Don't Know ☐

If YES, please complete the following table.

Type of Investigation	Date Done	Water Loss (%)	What approach or technology was used to complete the investigation?	Was any follow-up done? If so, describe

8. Have all drinking water projects received NMED review and approval? [20 NMAC 7.10.201]

YES ☐ NO ☐

If NO, what types of projects have not received NMED review and approval.

Source ☐ Storage ☐

Treatment ☐ Distribution ☐

Other ☐ _____

9. What are the typical customer complaints that the utility receives?

10. Approximately how many complaints are there per month? _____

11. How are customer complaints handled? Are they recorded?

12. What is the age and composition of the distribution system? ***(Collect this information from the Sanitary Survey)***

Pipe Material	Approximate Age	Percentage of the system	Comments
			Sanitary Survey Distribution System Records Attached

13. Are there any dead end lines in the system?
YES ☐ NO ☐

14. Does the system have a flushing program?
YES ☐ NO ☐
If YES, please describe.

15. Are there any pressure problems within the system?
YES ☐ NO ☐
If YES, please describe.

16. Does the system disinfect the finished water?
YES ☐ NO ☐
If yes, which disinfectant product is used? ______

Interviewer Comments on Technical Capacity:

B. Managerial Capacity Assessment Questions

17. Has the system completed a 5-year Infrastructure Capital Improvement Plan (ICIP) plan?
YES ☐ NO ☐
If YES, has the plan been submitted to Local Government Division?
YES ☐ NO ☐

18. Does the system have written operating procedures?
YES ☐ NO ☐

19. Does the system have written job descriptions for all staff?
YES ☐ NO ☐

20. Does the system have:

A preventative maintenance plan?
YES ☐ NO ☐
A source water protection plan?
YES ☐ NO ☐ N/A ☐
An emergency plan?
YES ☐ NO ☐
A cross-connection control program?
YES ☐ NO ☐
An emergency source?
YES ☐ NO ☐
System security measures?
YES ☐ NO ☐

21. Does the system report and maintain records in accordance with the drinking water regulations concerning:

Water quality violations
YES ☐ NO ☐

Public notification
YES ☐ NO ☐

Sampling exemptions
YES ☐ NO ☐

22. Please describe how the above records are maintained:

23. Describe the management structure for the water system, including board and operations staff. Please include examples of duties, if possible.

24. Please describe type and quantity of training or continuing education for staff identified above.

25. Describe last major project undertaken by the water system, including the following: project in detail, positive aspects, negative aspects, the way in which the project was funded, any necessary rate increases, the public response to the project, whether the project is complete or not, and any other pertinent information.

26. Does the system have any debt? YES ☐ NO ☐

If yes, is the system current with all debt payments?
YES ☐ NO ☐

If no, describe the applicable funding agency and the default.

27. Is the system currently contemplating or actively seeking funding for any project?
YES ☐ NO ☐

If yes, from which agency and how much?

Describe the project?

Is the system receiving assistance from any agency or organization in its efforts?

28. Will the system consider any type of regionalization with other PWS? *(Check YES if the system has already regionalized.)*

YES ☐ NO ☐

If YES, what type of regionalization has been implemented/considered/discussed? *(Check all that apply.)*

System interconnection ☐
Sharing operator ☐
Sharing bookkeeper ☐
Purchasing water ☐
Emergency water connection ☐
Other: _____

29. Does the system have any of the following? *(Check all that apply.)*

Water Conservation Policy/Ordinance ☐ Current Drought Plan ☐
Water Use Restrictions ☐ Water Supply Emergency Plan ☐

Interviewer Comments on Managerial Capacity:

C. Financial Capacity Assessment

30. Does the system have a budget?

YES ☐ NO ☐

If YES, what type of budget?

Operating Budget ☐

Capital Budget ☐

31. Have the system revenues covered expenses and debt service for the past 5 years?

YES ☐ NO ☐

If NO, how many years has the system had a shortfall? _____

32. Does the system have a written/adopted rate structure?

YES ☐ NO ☐

33. What was the date of the last rate increase? _____

34. Are rates reviewed annually?

YES ☐ NO ☐

IF YES, what was the date of the last review? _____

35. Did the rate review show that the rates covered the following expenses? *(Check all that apply.)*

Operation & Maintenance ☐

Infrastructure Repair & replacement ☐

Staffing ☐

Emergency/Reserve fund ☐

Debt payment ☐

36. Is the rate collection above 90% of the customers?

YES ☐ NO ☐

37. Is there a cut-off policy for customers who are in arrears with their bill or for illegal connections?

YES ☐ NO ☐

If yes, is this policy implemented?

38. What is the residential water rate for 6,000 gallons of usage in one month. _____

39. In the past 12 months, how many customers have had accounts frozen or dropped for non-payment? _____

[Convert to % of active connections

Less than 1% ☐ 1% - 3% ☐ 4% - 5% ☐ 6% - 10% ☐

11% - 20% ☐ 21% - 50% ☐ Greater than 50% ☐]

40. The following questions refer to the process of obtaining needed equipment and supplies.

a. Can the water system operator buy or obtain supplies or equipment when they are needed?

YES ☐ NO ☐

b. Is the process simple or burdensome to the employees?

c. Can supplies or equipment be obtained quickly during an emergency?

YES ☐ NO ☐

d. Has the water system operator ever experienced a situation in which he/she couldn't purchase the needed supplies?

YES ☐ NO ☐

e. Does the system maintain some type of spare parts inventory?

YES ☐ NO ☐

If yes, please describe.

41. Has the system ever had a financial audit?

YES ☐ NO ☐

If YES, what is the date of the most recent audit? ______

42. Has the system ever had its electricity or phone turned off due to non-payment? Please describe.

Interviewer Comments on Financial Assessment:

43. What do you think the system capabilities are now and what are the issues you feel your system will be facing in the future? In addition, are there any specific needs, such as types of training that you would like to see addressed by NMED or its contractors?

APPENDIX B
COST BASIS

This section presents the basis for unit costs used to develop the conceptual cost estimates for the compliance alternatives. Cost estimates are conceptual in nature (+50%/-30%), and are intended to make comparisons between compliance options and to provide a preliminary indication of possible rate impacts. Consequently, these costs are pre-planning level and should not be viewed as final estimated costs for alternative implementation. Capital cost includes an allowance for engineering and construction management. It is assumed that adequate electrical power is available near the site. The cost estimates specifically do not include costs for the following:

- Obtaining land or easements.
- Surveying.
- Mobilization/demobilization for construction.
- Insurance and bonds

In general, unit costs are based on recent construction bids for similar work in the area; when possible, consultations with vendors or other suppliers; published construction and O&M cost data; and USEPA cost guidance. Unit costs used for the cost estimates are summarized in Table B.1.

Unit costs for pipeline components are based on 2006 RS Means Building Construction Cost Data.. The number of borings and encasements, and open cuts and encasements is estimated by counting the road, highway, railroad, stream, and river crossings for a conceptual routing of the pipeline. The number of air release valves is estimated by examining the land surface profile along the conceptual pipeline route. It is assumed gate valves and flush valves would be installed on average every 5,000 feet along the pipeline. Pipeline cost estimates are based on use of C-900 PVC pipe. Other pipe materials could be considered for more detailed development of attractive alternatives.

Pump station unit costs are based on experience with similar installations. The cost estimate for the pump stations include two pumps, station piping and valves, station electrical and instrumentation, minor site improvement, installation of a concrete pad, fence, building, and tools. Construction cost of a storage tank is based on RS Means Building Construction Data.

Labor costs are estimated based on RS Means Building Construction Data specific to each geographic area.

Electrical power cost is estimated to be $0.136 per kWH. The annual cost for power to a pump station is calculated based on the pumping head and volume, and includes 11,800 kWH for pump building heating, cooling, and lighting, as recommended in USEPA publication, *Standardized Costs for Water Supply Distribution Systems* (1992).

In addition to the cost of electricity, pump stations have other maintenance costs. These costs cover: materials for minor repairs to keep the pumps operating; purchase of a maintenance vehicle, fuel costs, and vehicle maintenance costs; utilities; office supplies, small tools and equipment; and miscellaneous materials such as safety, clothing, chemicals, and paint. The non-power O&M costs are estimated based on the USEPA publication, *Standardized Costs for Water Supply Distribution Systems* (1992), which provides cost curves for O&M components. Costs from the 1992 report are adjusted to 2006 dollars based on the ENR construction cost index.

Pipeline maintenance costs include routine cleaning and flushing, as well as minor repairs to lines. The unit rate for pipeline maintenance is calculated based on the USEPA technical report, *Innovative and Alternate Technology Assessment Manual MCD 53* (1978). Costs from the 1978 report are adjusted to 2006 dollars based on the ENR construction cost index.

Storage tank maintenance costs include cleaning and renewal of interior lining and exterior coating. Unit costs for storage tank O&M are based on USEPA publication *Standardized Costs for Water Supply Distribution Systems* (1992). Costs from the 1992 report are adjusted to 2006 dollars based on the ENR construction cost index.

The purchase price for POU water treatment units is based on vendor price lists for treatment units, plus installation. O&M costs for POU treatment units are also based on vendor price lists. It is assumed that a yearly water sample would be analyzed for the contaminant of concern.

The purchase price for POE water treatment units is based on vendor price lists for treatment units, plus an allowance for installation, including a concrete pad and shed, piping modifications, and electrical connection. O&M costs for POE treatment units are also based on vendor price lists. It is assumed that a yearly water sample would be analyzed for the contaminant of concern.

Central treatment plant costs, for both adsorption and coagulation/filtration, include pricing for buildings, utilities, and site work. Costs are based on pricing given in the various R.S. Means Construction Cost Data References, as well as prices obtained from similar work on other projects. Pricing for treatment equipment was obtained from vendors.

Well installation costs are based on quotations from drillers for installation of similar depth wells in the area. Well installation costs include drilling, a well pump, electrical and instrumentation installation, well finishing, piping, and water quality testing. O&M costs for water wells include power, materials, and labor. It is assumed that new wells located more than 1 mile from the intake point of an existing system would require at least one storage tank and pump station.

Purchase price for the treatment unit dispenser is based on vendor price lists, plus an allowance for installation at a centralized public location. The O&M costs are also based on vendor price lists. It is assumed that weekly water samples would be analyzed for the contaminant of concern.

Costs for bottled water delivery alternatives are based on consultation with vendors that deliver residential bottled water. The cost estimate includes an initial allowance for set-up of the program, and a yearly allowance for program administration.

The cost estimate for a public dispenser for trucked water includes the purchase price for a water truck and construction of a storage tank. Annual costs include labor for purchasing the water, picking up and delivering the water, truck maintenance, and water sampling and testing. It is assumed the water truck would be required to make one trip per dispenser each week, and that chlorine residual would be determined for each truck load.

Table B.1
Summary of General Data
Crystal Lake Estates Water System
PWS #1870044
General PWS Information

Service Population	282	**Number of Connections**	93
Total PWS Daily Water Usage	0.021 (mgd)	**Source**	TCEQ website

Unit Cost Data
East Texas

General Items	**Unit**	**Unit Cost**
Treated water purchase cost	*See alternative*	
Water purchase cost (trucked)	$/1,000 gals	$ 2.50
Contingency	20%	n/a
Engineering & Constr. Management	25%	n/a
Procurement/admin (POU/POE)	20%	n/a

Pipeline Unit Costs	**Unit**	**Unit Cost**
PVC water line, Class 200, 04"	LF	$ 27
Bore and encasement, 10"	LF	$ 60
Open cut and encasement, 10"	LF	$ 35
Gate valve and box, 04"	EA	$ 370
Air valve	EA	$ 1,000
Flush valve	EA	$ 750
Metal detectable tape	LF	$ 0.15
Bore and encasement, length	Feet	200
Open cut and encasement, length	Feet	50

Pump Station Unit Costs	**Unit**	**Unit Cost**
Pump	EA	$ 7,500
Pump Station Piping, 04"	EA	$ 4,000
Gate valve, 04"	EA	$ 405
Check valve, 04"	EA	$ 595
Electrical/Instrumentation	EA	$ 10,000
Site work	EA	$ 2,000
Building pad	EA	$ 4,000
Pump Building	EA	$ 10,000
Fence	EA	$ 5,870
Tools	EA	$ 1,000

Well Installation Unit Costs	**Unit**	**Unit Cost**
Well installation	*See alternative*	
Water quality testing	EA	$ 1,500
Well pump	EA	$ 7,500
Well electrical/instrumentation	EA	$ 5,000
Well cover and base	EA	$ 3,000
Piping	EA	$ 2,500
Storage Tank - 10,000 gals	EA	$ 19,900
Electrical Power	$/kWH	$ 0.136
Building Power	kWH	11,800
Labor	$/hr	$ 26
Materials	EA	$ 1,200
Transmission main O&M	$/mile	$ 200
Tank O&M	EA	$ 1,000

POU/POE Unit Costs		
POU treatment unit purchase	EA	$ 250
POU treatment unit installation	EA	$ 150
POE treatment unit purchase	EA	$ 3,000
POE - pad and shed, per unit	EA	$ 2,000
POE - piping connection, per unit	EA	$ 1,000
POE - electrical hook-up, per unit	EA	$ 1,000
POU treatment O&M, per unit	$/year	$ 225
POE treatment O&M, per unit	$/year	$ 1,000
Contaminant analysis	$/year	$ 100
POU/POE labor support	$/hr	$ 26

Dispenser/Bottled Water Unit Costs		
Treatment unit purchase	EA	$ 3,000
Treatment unit installation	EA	$ 5,000
Treatment unit O&M	EA	$ 500
Administrative labor	hr	$ 35
Bottled water cost (inc. delivery)	gallon	$ 1.60
Water use, per capita per day	gpcd	1.0
Bottled water program materials	EA	$ 5,000
Storage Tank - 5,000 gals	EA	$ 7,025
Site improvements	EA	$ 4,000
Potable water truck	EA	$ 60,000
Water analysis, per sample	EA	$ 100
Potable water truck O&M costs	$/mile	$ 1.00

Central Treatment Unit Costs	**Unit**	**Unit Cost**
General		
Site preparation	acre	$ 4,000
Slab	CY	$ 1,000
Building	SF	$ 60
Building electrical	SF	$ 8.00
Building plumbing	SF	$ 8.00
Heating and ventilation	SF	$ 7.00
Fence	LF	$ 15
Paving	SF	$ 2.00
Chlorination point	EA	$ 2,000
Building power	kwh/yr	$ 0.136
Equipment power	kwh/yr	$ 0.136
Labor, O&M	hr	$ 40
Analyses	test	$ 200
Ion exchange		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
Ion exchange package plant	UNIT	$ 30,000
Transfer pumps (10 hp)	EA	$ 5,000
Clean water tank	gal	$ 1.00
Regenerant tank	gal	$ 1.50
Backwash tank	gal	$ 2.00
Sewer connection fee	EA	$ 15,000
Ion exchange materials	year	$ 1,500
Ion exchange chemicals	year	$ 1,500
Backwash discharge to sewer	kgal/year	$ 5.00
Waste haulage truck rental	days	$ 700
Mileage charge	mile	$ 1.00
Waste disposal fee	kgal/yr	$ 200
WRT Z-88 package		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
WRT Z-88 package plant	UNIT	$ 58,000
(Initial setup *cost for WRT Z-88 package*)		
WRT treated water charge	1,000 gal/yr	$ 2.70
KMnO4-greensand package		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
KMnO4-greensand package plant	UNIT	$ 80,000
Backwash tank	gal	$ 2.00
Sewer connection fee	EA	$ 15,000
KMnO4-greensand materials	year	$ 3,000
KMnO4-greensand chemicals	year	$ 3,000
Backwash discharge to sewer	1,000 gal/yr	$ 5.00
Sludge truck rental	days	$ 700
Sludge truck mileage fee	miles	$ 1.00
Sludge disposal fee	1,000 gal/yr	$ 200.00

APPENDIX C
COMPLIANCE ALTERNATIVE CONCEPTUAL COST ESTIMATES

This appendix presents the conceptual cost estimates developed for the compliance alternatives. The conceptual cost estimates are given in Tables C.1 through C.16. The cost estimates are conceptual in nature (+50%/-30%), and are intended for making comparisons between compliance options and to provide a preliminary indication of possible water rate impacts. Consequently, these costs are pre-planning level and should not be viewed as final estimated costs for alternative implementation.

Table C.1

PWS Name	***Crystal Lake Estates Water System***
Alternative Name	***New Well at Crystal Lakes***
Alternative Number	***CL-1***

Distance from PWS to new well location	0.06	miles
Estimated well depth	309	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	0	
Number of feed tanks/pump sets needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	300	LF	$ 27.00	$ 8,100
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	1	EA	$ 370.00	$ 370
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	1	EA	$ 750.00	$ 750
Metal detectable tape	300	LF	$ 0.15	$ 45
Subtotal				**$ 9,265**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 10,000 gals	-	EA	$ 19,900	$ -
Subtotal				**$ -**
Well Installation				
Well installation	309	LF	$ 25	$ 7,725
Water quality testing	2	EA	$ 1,500	$ 3,000
Well pump	1	EA	$ 7,500	$ 7,500
Well electrical/instrumentation	1	EA	$ 5,000	$ 5,000
Well cover and base	1	EA	$ 3,000	$ 3,000
Piping	1	EA	$ 2,500	$ 2,500
Subtotal				**$ 28,725**
Subtotal of Component Costs				**$ 37,990**
Contingency	20%			$ 7,598
Design & Constr Management	25%			$ 9,498
TOTAL CAPITAL COSTS				**$ 55,086**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	0.1	mile	$ 200	$ 11
Subtotal				**$ 11**
Pump Station(s) O&M				
Building Power	-	kWH	$ 0.136	$ -
Pump Power	-	kWH	$ 0.136	$ -
Materials	-	EA	$ 1,200	$ -
Labor	-	Hrs	$ 26	$ -
Tank O&M	-	EA	$ 1,000	$ -
Subtotal				**$ -**
Well O&M				
Pump power	712	kWH	$ 0.136	$ 97
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 26	$ 4,700
Subtotal				**$ 5,997**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ (34)**

Table C.2

PWS Name *Crystal Lake Estates Water System*
Alternative Name *Purchase Water from Beech Creek Village*
Alternative Number *CL-2*

Distance from Alternative to PWS (along pipe)	1.4	miles
Total PWS annual water usage	7.665	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	5	n/a	n/a	n/a
PVC water line, Class 200, 04"	7,155	LF	$ 27	$ 193,185
Bore and encasement, 10"	-	LF	$ 60	$ -
Open cut and encasement, 10"	250	LF	$ 35	$ 8,750
Gate valve and box, 04"	1	EA	$ 370	$ 529
Air valve	1	EA	$ 1,000	$ 1,000
Flush valve	1	EA	$ 750	$ 1,073
Metal detectable tape	7,155	LF	$ 0.15	$ 1,073
Subtotal				**$ 205,611**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 10,000 gals	1	EA	$ 19,900	$ 19,900
Subtotal				**$ 74,580**
Subtotal of Component Costs				**$ 280,191**
Contingency	20%			$ 56,038
Design & Constr Management	25%			$ 70,048
TOTAL CAPITAL COSTS				**$ 406,277**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	1.4	mile	$ 200	$ 271
Subtotal				**$ 271**
Water Purchase Cost				
From BWA	7,665	1,000 gal	$ 1.60	$ 12,264
Subtotal				**$ 12,264**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	4,593	kWH	$ 0.136	$ 625
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 26	$ 9,530
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 13,960**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ 20,453**

Table C.3

PWS Name	***Crystal Lake Estates Water System***
Alternative Name	***Purchase Water from City of Livingston***
Alternative Number	***CL-3***

Distance from Alternative to PWS (along pipe)	2.7	miles
Total PWS annual water usage	7.665	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	9	n/a	n/a	n/a
PVC water line, Class 200, 04"	14,092	LF	$ 27	$ 380,484
Bore and encasement, 10"	200	LF	$ 60	$ 12,000
Open cut and encasement, 10"	450	LF	$ 35	$ 15,750
Gate valve and box, 04"	3	EA	$ 370	$ 1,043
Air valve	3	EA	$ 1,000	$ 3,000
Flush valve	3	EA	$ 750	$ 2,114
Metal detectable tape	14,092	LF	$ 0.15	$ 2,114
Subtotal				**$ 416,504**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 10,000 gals	1	EA	$ 19,900	$ 19,900
Subtotal				**$ 74,580**
Subtotal of Component Costs				**$ 491,084**
Contingency	20%			$ 98,217
Design & Constr Management	25%			$ 122,771
TOTAL CAPITAL COSTS				**$ 712,072**

Annual Operations and Maintenance Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline O&M				
Pipeline O&M	2.7	mile	$ 200	$ 534
Subtotal				**$ 534**
Water Purchase Cost				
From BWA	7,665	1,000 gal	$ 1.60	$ 12,264
Subtotal				**$ 12,264**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	3,567	kWH	$ 0.136	$ 485
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 26	$ 9,530
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 13,820**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ 20,576**

Table C.4

PWS Name ***Crystal Lake Estates Water System***
Alternative Name ***Purchase Water from Soda Water Supply Corp.***
Alternative Number ***CL-4***

Distance from Alternative to PWS (along pipe)	3.8	miles
Total PWS annual water usage	7.665	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	12	n/a	n/a	n/a
PVC water line, Class 200, 04"	19,936	LF	$ 27	$ 538,272
Bore and encasement, 10"	200	LF	$ 60	$ 12,000
Open cut and encasement, 10"	600	LF	$ 35	$ 21,000
Gate valve and box, 04"	4	EA	$ 370	$ 1,475
Air valve	4	EA	$ 1,000	$ 4,000
Flush valve	4	EA	$ 750	$ 2,990
Metal detectable tape	19,936	LF	$ 0.15	$ 2,990
Subtotal				**$ 582,728**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 10,000 gals	1	EA	$ 19,900	$ 19,900
Subtotal				**$ 74,580**
Subtotal of Component Costs				**$ 657,308**
Contingency	20%			$ 131,462
Design & Constr Management	25%			$ 164,327
TOTAL CAPITAL COSTS				**$ 953,097**

Annual Operations and Maintenance Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline O&M				
Pipeline O&M	3.8	mile	$ 200	$ 755
Subtotal				**$ 755**
Water Purchase Cost				
From BWA	7,665	1,000 gal	$ 1.60	$ 12,264
Subtotal				**$ 12,264**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	5,875	kWH	$ 0.136	$ 799
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 26	$ 9,530
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 14,134**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ 21,111**

Table C.5

PWS Name ***Crystal Lake Estates Water System***
Alternative Name ***Purchase Water from Providence WSC***
Alternative Number ***CL-5***

Distance from Alternative to PWS (along pipe)	6.6	miles
Total PWS annual water usage	7.665	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	12	n/a	n/a	n/a
PVC water line, Class 200, 04"	34,632	LF	$ 27	$ 935,064
Bore and encasement, 10"	200	LF	$ 60	$ 12,000
Open cut and encasement, 10"	600	LF	$ 35	$ 21,000
Gate valve and box, 04"	7	EA	$ 370	$ 2,563
Air valve	7	EA	$ 1,000	$ 7,000
Flush valve	7	EA	$ 750	$ 5,195
Metal detectable tape	34,632	LF	$ 0.15	$ 5,195
Subtotal				**$ 988,016**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 10,000 gals	1	EA	$ 19,900	$ 19,900
Subtotal				**$ 74,580**
Subtotal of Component Costs				**$ 1,062,596**
Contingency	20%			$ 212,519
Design & Constr Management	25%			$ 265,649
TOTAL CAPITAL COSTS				**$ 1,540,765**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	6.6	mile	$ 200	$ 1,312
Subtotal				**$ 1,312**
Water Purchase Cost				
From BWA	7,665	1,000 gal	$ 1.60	$ 12,264
Subtotal				**$ 12,264**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	7,213	kWH	$ 0.136	$ 981
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 26	$ 9,530
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 14,316**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ 21,850**

Table C.6

PWS Name *Crystal Lake Estates Water System*
Alternative Name *New Well at 10 Miles*
Alternative Number *CL-6*

Distance from PWS to new well location	10.0	miles
Estimated well depth	309	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	2	n/a	n/a	n/a
Number of Crossings, open cut	26	n/a	n/a	n/a
PVC water line, Class 200, 04"	52,800	LF	$ 27	$ 1,425,600
Bore and encasement, 10"	400	LF	$ 60	$ 24,000
Open cut and encasement, 10"	1,300	LF	$ 35	$ 45,500
Gate valve and box, 04"	11	EA	$ 370	$ 3,907
Air valve	10	EA	$ 1,000	$ 10,000
Flush valve	11	EA	$ 750	$ 7,920
Metal detectable tape	52,800	LF	$ 0.15	$ 7,920
Subtotal				**$ 1,524,847**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 10,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 61,705**
Well Installation				
Well installation	309	LF	$ 25	$ 7,725
Water quality testing	2	EA	$ 1,500	$ 3,000
Well pump	1	EA	$ 7,500	$ 7,500
Well electrical/instrumentation	1	EA	$ 5,000	$ 5,000
Well cover and base	1	EA	$ 3,000	$ 3,000
Piping	1	EA	$ 2,500	$ 2,500
Subtotal				**$ 28,725**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	10.0	mile	$ 200	$ 2,000
Subtotal				**$ 2,000**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	14,798	kWH	$ 0.136	$ 2,012
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 26	$ 9,530
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 15,347**
Well O&M				
Pump power	712	kWH	$ 0.136	$ 97
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 26	$ 4,700
Subtotal				**$ 5,997**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**

Subtotal of Component Costs		**$ 1,615,277**
Contingency	20%	$ 323,055
Design & Constr Management	25%	$ 403,819
TOTAL CAPITAL COSTS		**$ 2,342,152**

TOTAL ANNUAL O&M COSTS **$ 17,302**

Table C.7

PWS Name *Crystal Lake Estates Water System*
Alternative Name *New Well at 5 Miles*
Alternative Number *CL-7*

Distance from PWS to new well location	5.0	miles
Estimated well depth	309	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	2	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	13	n/a	n/a	n/a
PVC water line, Class 200, 04"	26,400	LF	$ 27	$ 712,800
Bore and encasement, 10"	1,800	LF	$ 60	$ 108,000
Open cut and encasement, 10"	100	LF	$ 35	$ 3,500
Gate valve and box, 04"	5	EA	$ 370	$ 1,954
Air valve	5	EA	$ 1,000	$ 5,000
Flush valve	5	EA	$ 750	$ 3,960
Metal detectable tape	26,400	LF	$ 0.15	$ 3,960
Subtotal				**$ 839,174**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 10,000 gals	2	EA	$ 7,025	$ 14,050
Subtotal				**$ 123,410**
Well Installation				
Well installation	309	LF	$ 25	$ 7,725
Water quality testing	2	EA	$ 1,500	$ 3,000
Well pump	1	EA	$ 7,500	$ 7,500
Well electrical/instrumentation	1	EA	$ 5,000	$ 5,000
Well cover and base	1	EA	$ 3,000	$ 3,000
Piping	1	EA	$ 2,500	$ 2,500
Subtotal				**$ 28,725**
Subtotal of Component Costs				**$ 991,309**
Contingency	20%			$ 198,262
Design & Constr Management	25%			$ 247,827
TOTAL CAPITAL COSTS				**$ 1,437,397**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	5.0	mile	$ 200	$ 1,000
Subtotal				**$ 1,000**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	7,399	kWH	$ 0.136	$ 1,006
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 26	$ 19,060
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 27,676**
Well O&M				
Pump power	712	kWH	$ 0.136	$ 97
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 26	$ 4,700
Subtotal				**$ 5,997**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ 28,631**

Table C.8

PWS Name	***Crystal Lake Estates Water System***
Alternative Name	***New Well at 1 Mile***
Alternative Number	***CL-8***

Distance from PWS to new well location	1.0	miles
Estimated well depth	309	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 04"	5,280	LF	$ 27	$ 142,560
Bore and encasement, 10"	-	LF	$ 60	$ -
Open cut and encasement, 10"	150	LF	$ 35	$ 5,250
Gate valve and box, 04"	1	EA	$ 370	$ 391
Air valve	1	EA	$ 1,000	$ 1,000
Flush valve	1	EA	$ 750	$ 792
Metal detectable tape	5,280	LF	$ 0.15	$ 792
Subtotal				**$ 150,785**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 10,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**
Well Installation				
Well installation	309	LF	$ 25	$ 7,725
Water quality testing	2	EA	$ 1,500	$ 3,000
Well pump	1	EA	$ 7,500	$ 7,500
Well electrical/instrumentation	1	EA	$ 5,000	$ 5,000
Well cover and base	1	EA	$ 3,000	$ 3,000
Piping	1	EA	$ 2,500	$ 2,500
Subtotal				**$ 28,725**
Subtotal of Component Costs				**$ 179,510**
Contingency	20%			$ 35,902
Design & Constr Management	25%			$ 44,877
TOTAL CAPITAL COSTS				**$ 260,289**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	1.0	mile	$ 200	$ 200
Subtotal				**$ 200**
Pump Station(s) O&M				
Building Power	-	kWH	$ 0.136	$ -
Pump Power	-	kWH	$ 0.136	$ -
Materials	-	EA	$ 1,200	$ -
Labor	-	Hrs	$ 26	$ -
Tank O&M	-	EA	$ 1,000	$ -
Subtotal				**$ -**
Well O&M				
Pump power	712	kWH	$ 0.136	$ 97
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 26	$ 4,700
Subtotal				**$ 5,997**
O&M Credit for Existing Well Closure				
Pump power	1,046	kWH	$ 0.136	$ (142)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 26	$ (4,700)
Subtotal				**$ (6,042)**
TOTAL ANNUAL O&M COSTS				**$ 155**

Table C.9

PWS Name *Crystal Lake Estates Water System*
Alternative Name *Central Treatment - IX*
Alternative Number *CL-9*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Ion Exchange Unit Purchase/Installation				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	-	LF	$ 15	$ -
Paving	3,200	SF	$ 2	$ 6,400
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Ion exchange package including:				
Regeneration system				
Brine tank				
IX resins & FRP vessels	1	UNIT	$ 30,000	$ 30,000
Transfer pumps (10 hp)	2	EA	$ 5,000	$ 10,000
Clean water tank	5,000	gal	$ 1.00	$ 5,000
Regenerant tank	2,000	gal	$ 1.50	$ 3,000
Backwash Tank	6,000	gal	$ 2.00	$ 12,000
Sewer Connection Fee	-	EA	$ 15,000	$ -
Subtotal of Component Costs				**$ 202,600**
Contingency	20%			$ 40,520
Design & Constr Management	25%			$ 50,650
TOTAL CAPITAL COSTS				**$ 293,770**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Ion Exchange Unit O&M				
Building Power	12,000	kwh/yr	$ 0.136	$ 1,632
Equipment power	10,000	kwh/yr	$ 0.136	$ 1,360
Labor	400	hrs/yr	$ 40	$ 16,000
Materials	1	year	$ 1,500	$ 1,500
Chemicals	1	year	$ 1,500	$ 1,500
Analyses	24	test	$ 200	$ 4,800
Backwash disposal	1.500	kgal/yr	$ 200.00	$ 300
Subtotal				**$ 27,092**
Haul Regenerant Waste and Brine				
Waste haulage truck rental	6	days	$ 700	$ 4,200
Mileage charge	600	miles	$ 1.00	$ 600
Waste disposal	12	kgal/yr	$ 200.00	$ 2,400
Subtotal				**$ 7,200**
TOTAL ANNUAL O&M COSTS				**$ 34,292**

Table C.10

PWS Name — ***Crystal Lake Estates Water System***
Alternative Name — ***Central Treatment - WRT Z-88***
Alternative Number — ***CL-10***

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	-	LF	$ 15	$ -
Paving	1,600	SF	$ 2	$ 3,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
WRT Z-88 package including:				
Z-88 vessels				
Adsorption media	1	UNIT	$ 58,000	$ 58,000
(Initial Setup Cost for WRT Z-88 package plant)				
Subtotal of Component Costs				**$ 197,400**
Contingency	20%			$ 39,480
Design & Constr Management	25%			$ 49,350
TOTAL CAPITAL COSTS				**$ 286,230**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	6,000	kwh/yr	$ 0.136	$ 816
Equipment power	5,000	kwh/yr	$ 0.136	$ 680
Labor	400	hrs/yr	$ 40	$ 16,000
Analyses	24	test	$ 200	$ 4,800
WRT treated water charge	6,790	kgal/yr	$ 2.70	$ 18,333
Subtotal				**$ 40,629**
TOTAL ANNUAL O&M COSTS				**$ 40,629**

Table C.11

PWS Name ***Crystal Lake Estates Water System***
Alternative Name ***Central Treatment - KMnO4***
Alternative Number ***CL-11***

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	30	CY	$ 1,000	$ 30,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	-	LF	$ 15	$ -
Paving	1,600	SF	$ 2	$ 3,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
KMnO4-Greensand package including:				
Greensand filters				
Solution tank	1	UNIT	$ 80,000	$ 80,000
Backwash tank	9,000	gal	$ 2.00	$ 18,000
Sewer connection fee	-	EA	$ 15,000	$ -
Subtotal of Component Costs				**$ 236,400**
Contingency	20%			$ 47,280
Design & Constr Management	25%			$ 59,100
TOTAL CAPITAL COSTS				**$ 342,780**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	6,000	kwh/yr	$ 0.136	$ 816
Equipment power	6,000	kwh/yr	$ 0.136	$ 816
Labor	500	hrs/yr	$ 40	$ 20,000
Materials	1	year	$ 3,000	$ 3,000
Chemicals	1	year	$ 3,000	$ 3,000
Analyses	24	test	$ 200	$ 4,800
Backwash disposal	14	kgal/yr	$ 200.00	$ 2,800
Subtotal				**$ 35,232**
Sludge Disposal				
Truck rental	10.0	days	$ 700	$ 7,000
Mileage	1000	miles	$ 1.00	$ 1,000
Disposal fee	20	kgal/yr	$ 200.00	$ 4,000
Subtotal				**$ 12,000**
TOTAL ANNUAL O&M COSTS				**$ 47,232**

Table C.12

PWS Name ***Crystal Lake Estates Water System***
Alternative Name ***Point-of-Use Treatment***
Alternative Number ***CL-12***

Number of Connections for POU Unit Installation 93

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POU-Treatment - Purchase/Installation				
POU treatment unit purchase	93	EA	$ 250	$ 23,250
POU treatment unit installation	93	EA	$ 150	$ 13,950
Subtotal				**$ 37,200**
Subtotal of Component Costs				**$ 37,200**
Contingency	20%			$ 7,440
Design & Constr Management	25%			$ 9,300
Procurement & Administration	20%			$ 7,440
TOTAL CAPITAL COSTS				**$ 61,380**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POU materials, per unit	93	EA	$ 225	$ 20,925
Contaminant analysis, 1/yr per unit	93	EA	$ 100	$ 9,300
Program labor, 10 hrs/unit	930	hrs	$ 26	$ 24,282
Subtotal				**$ 54,507**
TOTAL ANNUAL O&M COSTS				**$ 54,507**

Table C.13

PWS Name ***Crystal Lake Estates Water System***
Alternative Name ***Point-of-Entry Treatment***
Alternative Number ***CL-13***

Number of Connections for POE Unit Installation 93

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POE-Treatment - Purchase/Installation				
POE treatment unit purchase	93	EA	$ 3,000	$ 279,000
Pad and shed, per unit	93	EA	$ 2,000	$ 186,000
Piping connection, per unit	93	EA	$ 1,000	$ 93,000
Electrical hook-up, per unit	93	EA	$ 1,000	$ 93,000
Subtotal				**$ 651,000**
Subtotal of Component Costs				**$ 651,000**
Contingency	20%			$ 130,200
Design & Constr Management	25%			$ 162,750
Procurement & Administration	20%			$ 130,200
TOTAL CAPITAL COSTS				**$ 1,074,150**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POE materials, per unit	93	EA	$ 1,000	$ 93,000
Contaminant analysis, 1/yr per unit	93	EA	$ 100	$ 9,300
Program labor, 10 hrs/unit	930	hrs	$ 26	$ 24,282
Subtotal				**$ 126,582**
TOTAL ANNUAL O&M COSTS				**$ 126,582**

Table C.14

PWS Name ***Crystal Lake Estates Water System***
Alternative Name ***Public Dispenser for Treated Drinking Water***
Alternative Number ***CL-14***

Number of Treatment Units Recommended 1

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Public Dispenser Unit Installation				
POE-Treatment unit(s)	1	EA	$ 3,000	$ 3,000
Unit installation costs	1	EA	$ 5,000	$ 5,000
Subtotal				**$ 8,000**
Subtotal of Component Costs				**$ 8,000**
Contingency	20%			$ 1,600
Design & Constr Management	25%			$ 2,000
TOTAL CAPITAL COSTS				**11,600**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Treatment unit O&M, 1 per unit	1	EA	$ 500	$ 500
Contaminant analysis, 1/wk per ui	52	EA	$ 100	$ 5,200
Sampling/reporting, 1 hr/day	365	HRS	$ 26	$ 9,530
Subtotal				**$ 15,230**
TOTAL ANNUAL O&M COSTS				**$ 15,230**

Table C.15

PWS Name	***Crystal Lake Estates Water System***
Alternative Name	***Supply Bottled Water to Population***
Alternative Number	***CL-15***

Service Population	282	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	102,930	gallons

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Implementation				
Initial program set-up	500	hours	$ 35	$ 17,363
Subtotal				**$ 17,363**
Subtotal of Component Costs				**$ 17,363**
Contingency	20%			$ 3,473
TOTAL CAPITAL COSTS				**$ 20,836**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water purchase costs	102,930	gals	$ 1.60	$ 164,688
Program admin, 9 hrs/wk	468	hours	$ 35	$ 16,252
Program materials	1	EA	$ 5,000	$ 5,000
Subtotal				**$ 185,940**
TOTAL ANNUAL O&M COSTS				**$ 185,940**

Table C.16

PWS Name	***Crystal Lake Estates Water System***
Alternative Name	***Central Trucked Drinking Water***
Alternative Number	***CL-16***

Service Population	282	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	102,930	gallons
Travel distance to compliant water source (roundtrip)	8	miles

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Storage Tank Installation				
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Site improvements	1	EA	$ 4,000	$ 4,000
Potable water truck	1	EA	$ 60,000	$ 60,000
Subtotal				**$ 71,025**
Subtotal of Component Costs				**$ 71,025**
Contingency	20%			$ 14,205
Design & Constr Management	25%			$ 17,756
TOTAL CAPITAL COSTS				**$ 102,986**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water delivery labor, 4 hrs/wk	208	hrs	$ 26	$ 5,431
Truck operation, 1 round trip/wk	416	miles	$ 1.00	$ 416
Water purchase	103	1,000 gals	$ 2.50	$ 257
Water testing, 1 test/wk	52	EA	$ 100	$ 5,200
Sampling/reporting, 2 hrs/wk	104	hrs	$ 26	$ 2,715
Subtotal				**$ 14,020**
TOTAL ANNUAL O&M COSTS				**$ 14,020**

APPENDIX D
EXAMPLE FINANCIAL MODEL

Water System	Crystal Lakes
Funding Alternative	Bond
Alternative Description	Purchase Water from Providence WSC

Sum of Amount		Year										
Group	Type	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Capital Expenditures	Capital Expenditures-Funded from Bonds	$ -	$ -	$ -	########	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Grants	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Revenue/Reserves	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ -	$ -	########	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds				$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529
	State Revolving Funds				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service Sum					$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529
Operating Expenditures	Other Operating Expenditures 1			$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322
	Professional and Directors Fees			$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660
	Repairs			$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993
	Salaries & Benefits			$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029
	Utilities			$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252
	O&M Associated with Alternative					$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098
	Accounting and Legal Fees			$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196
Operating Expenditures Sum				$ 60,452	$ 60,452	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550
Residential Operating Revenues	Residential Base Monthly Rate			$ 80,310	$ 80,310	$ 152,575	$ 290,349	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860
	Residential Tier 1 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier2 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier3 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier4 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Unmetered Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residential Operating Revenues Sum				$ 80,310	$ 80,310	$ 152,575	$ 290,349	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860

Group	Type	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Capital Expenditures	Capital Expenditures-Funded from Bonds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Grants	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Revenue/Reserves	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529
	State Revolving Funds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service Sum		$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529	$ 120,529
Operating Expenditures	Other Operating Expenditures 1	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322	$ 32,322
	Professional and Directors Fees	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660	$ 660
	Repairs	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993	$ 2,993
	Salaries & Benefits	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029	$ 18,029
	Utilities	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252	$ 4,252
	O&M Associated with Alternative	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098	$ 20,098
	Accounting and Legal Fees	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196	$ 2,196
Operating Expenditures Sum		$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550	$ 80,550
Residential Operating Revenues	Residential Base Monthly Rate	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860
	Residential Tier 1 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier2 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier3 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier4 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Unmetered Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residential Operating Revenues Sum		$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860

Location_Name	Crystal Lakes
Alt_Desc	Purchase Water from Providence WSC

		Current_Year										
Funding_Alt	Data	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bond	Sum of Beginning_Cash_Bal	$ 35,861	$ 42,063	$ (72,264)	$ (137,775)	$ (65,510)	$ 72,264	$ 210,039	$ 347,814	$ 485,589	$ 623,364	$ 761,139
	Sum of Total_Expenditures	$ 60,452	$ 1,721,746	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079
	Sum of Total_Receipts	$ 80,310	$ 1,621,075	$ 152,575	$ 290,349	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860
	Sum of Net_Cash_Flow	$ 19,858	$ (100,671)	$ (48,504)	$ 89,270	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781
	Sum of Ending_Cash_Bal	$ 55,719	$ (58,608)	$ (120,769)	$ (48,504)	$ 89,270	$ 227,045	$ 364,820	$ 502,595	$ 640,370	$ 778,145	$ 915,919
	Sum of Working_Cap	$ 10,075	$ 10,075	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425
	Sum of Repl_Resv	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581
	Sum of Total_Reqd_Resv	$ 13,656	$ 13,656	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006
	Sum of Net_Avail_Bal	$ 42,063	$ (72,264)	$ (137,775)	$ (65,510)	$ 72,264	$ 210,039	$ 347,814	$ 485,589	$ 623,364	$ 761,139	$ 898,913
	Sum of Add_Resv_Needed	$ -	$ (72,264)	$ (137,775)	$ (65,510)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	90%	90%	23%	0%	0%	0%	0%	0%	0%	0%
	Sum of Percent_Rate_Increase	0%	0%	90%	262%	343%	343%	343%	343%	343%	343%	343%

Funding_Alt	Data	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Bond	Sum of Beginning_Cash_Bal	$ 898,913	$ 1,036,688	$ 1,174,463	$ 1,312,238	$ 1,450,013	$ 1,587,788	$ 1,725,562	$ 1,863,337	$ 2,001,112	$ 2,138,887	$ 2,276,662
	Sum of Total_Expenditures	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079	$ 201,079
	Sum of Total_Receipts	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860	$ 355,860
	Sum of Net_Cash_Flow	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781	$ 154,781
	Sum of Ending_Cash_Bal	$ 1,053,694	$ 1,191,469	$ 1,329,244	$ 1,467,019	$ 1,604,794	$ 1,742,568	$ 1,880,343	$ 2,018,118	$ 2,155,893	$ 2,293,668	$ 2,431,443
	Sum of Working_Cap	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425	$ 13,425
	Sum of Repl_Resv	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581	$ 3,581
	Sum of Total_Reqd_Resv	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006	$ 17,006
	Sum of Net_Avail_Bal	$ 1,036,688	$ 1,174,463	$ 1,312,238	$ 1,450,013	$ 1,587,788	$ 1,725,562	$ 1,863,337	$ 2,001,112	$ 2,138,887	$ 2,276,662	$ 2,414,437
	Sum of Add_Resv_Needed	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0
	Sum of Percent_Rate_Increase	343%	343%	343%	343%	343%	343%	343%	343%	343%	343%	343%

APPENDIX E
RADIONUCLIDE GEOCHEMISTRY

Radionuclide impact on water quality is measured according to two scales: intrinsic measurement of radioactivity and impact on human beings. Activity or number of disintegrations per unit time is typically measured in pico Curies (pCi), whereas impact on living organisms is measured in mrem. Radioactive decay can generate alpha or beta particles, as well as gamma rays. Two radioactive elements with the same activity may have vastly different impacts on life, depending on the energy released during decay. Each radionuclide has a conversion factor from pCi to mrem as a function of exposure pathway. Activity is related to contaminant concentration and half-life. A higher concentration and a shorter half-life lead to increased activity. Given the ratio of the half-life of each (Table E.1), it is apparent that radium is approximately 1 million times more radioactive than uranium. Concentrations of gross alpha and beta emitters take into account the whole decay series and not just uranium and radium, as well as other elements such as K 40.

Uranium and thorium (atomic number 92 and 90, respectively), both radium sources, are common trace elements and have a crustal abundance of 2.6 and 10 mg/kg, respectively. They are abundant in acidic rock. Intrusive rock such as granite will partly sequester uranium and thorium in erosion-resistant accessory minerals (*e.g.*, monazite, thorite) while uranium in volcanic rock is much more labile and can be leached by surface water and groundwater. Lattice substitution in minerals (*e.g.*, Ca^{+2} and U^{+4} have almost the same ionic radius) as well as micrograins of uranium and thorium minerals are other possibilities. In sedimentary rock, uranium and thorium aqueous concentrations are controlled mainly by the sorbing potential of the rock (metal oxide, clay, and organic matter).

The geochemistry of uranium is complicated but can be summarized by the following. Uranium (VI) in oxidizing conditions exists as the soluble positively charged uranyl UO_2^{+2}. Solubility is higher at acid pHs, decreases at neutral pHs, and increases at alkaline pHs. The uranyl ion can easily form aqueous complexes, including with hydroxyl, fluoride, carbonate, and phosphate ligands. Hence, in the presence of carbonates, uranium solubility is considerably enhanced in the form of uranyl-carbonate (UO_2CO_3) and other higher order carbonate complexes: uranyl-di-carbonate $(UO_2(CO_3)_2^{-2}$ and uranyl-tri-carbonates $UO_2(CO_3)_3^{-4}$). Adsorption of uranium is inversely related to its solubility and is highest at neutral pH's (De Soto 1978). Uranium sorbs strongly to metal oxides and clay. Uranium(IV) is the other commonly found redox state. In that state, however, uranium is not very soluble and precipitates as uraninite, UO_2, coffinite, $USiO_4.nH_2O$ (if SiO_2 >60 mg/L, Henry, *et al*. 1982, p.18), or related minerals. In most aquifers, no mineral controls uranium solubility in oxidizing conditions. However, uranite and coffinite are the controlling minerals if Eh drops below 0-100 mV.

Thorium exists naturally only in one redox state Th(IV). Th^{+4} forms complexes with most common aqueous anions. However, thorium solubility remains low except perhaps at higher pH when complexed by carbonate ions (USEPA 1999). Thorium sorbs strongly to metal oxides in a way similar to uranium.

Radium has an atomic number of 88. Radium originates from the radioactive decay of uranium and thorium. Radium-226 is an intermediate product of U238 (the most common uranium isotope >99%, Table A-1) decay, whereas radium-228 belongs to the Th232 (~100% of natural thorium) decay series. Both radium isotopes further decay to radon and, ultimately, to lead. Radon is a gas and tends to volatilize from shallower units. Radium-223 and radium-224 isotopes are also naturally present but in minute quantities. Radium-224 belongs to the thorium decay series, whereas radium-223 derives from the much rarer U235 (~0.7%). Radium is an alkaline Earth element and belongs to the same group (2A in periodic table) as magnesium, calcium, strontium, and barium. It most resembles barium chemically, as evidenced by removal technologies such as ion exchange with Na and lime softening. Sorption on iron and manganese oxides is also a common trait of alkaline Earth elements. Radium exists only under one oxidation state, the divalent cation Ra^{+2}, similar to other alkaline Earth elements (Ca^{+2}, Mg^{+2}, Sr^{+2}, and Ba^{+2}). $RaSO_4$ is extremely insoluble (more so than barium sulfate), with a log K solubility product of -10.5, compared to that of barium sulfate at ~-10. Radium solubility is mostly controlled by sulfate activity.

Table E.1 Uranium, thorium, and radium abundance and half-lives

Decay series	Uranium/thorium	Radium	Radon
U238	U238 – ~99.3% (4.47×10^9 yrs)	Ra226 - (1,599 yrs)	Rn222 - (3.8 days)
	U234 – 0.0055% (0.246×10^9 yrs)	Intermediate product of U238 decay	
U235	U235 - ~0.7% (0.72×10^9 yrs)	Ra223 – (11.4 days)	Rn219 - (4 seconds)
Th232	Th232 – ~100% (14.0×10^9 yrs)	Ra228 - (5.76 yrs) Ra224 - (3.7 days)	Rn220 - (~1 min)

NOTE: half-life from Parrington, et al. (1996)

USEPA Maximum Contaminant Levels

- Uranium: 30 ppb
- Gross alpha : 15 pCi/L
- Beta particles and photon emitters: 4 mrem/yr
- Combined Radium 226 and radium 228: 5 pCi/L

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