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

LIVE OAKS MOBILE HOME PARK
PWS ID# 0860090

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

AUGUST 2006

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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.

This feasibility report provides an evaluation of water supply alternatives for the Live Oaks Mobile Home Park (MHP) PWS, a mobile home park located southwest of Fredericksburg in Gillespie County, Texas (Live Oaks MHP PWS). The Live Oaks MHP PWS recorded combined radium concentrations that exceed the MCL of 5 picoCuries per liter (pCi/L). Therefore, it is likely the Live Oaks MHP PWS faces radium compliance issues.

Basic system information for the Live Oaks MHP PWS is shown in Table ES.1.

Table ES.1
Live Oaks MHP PWS
Basic System Information

Population served	264 at full build out
Connections	132 at full build out
Average daily demand	0.026 million gallons per day (mgd)
Peak demand flow rate	0.103 mgd
Water system peak capacity	0.120 mgd
Typical combined radium range	4.9 – 9.9 pCi/L

STUDY METHODS

The methods used for this study were based on a pilot study performed in 2004 and 2005 by TCEQ, BEG, and Parsons. Methods 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;

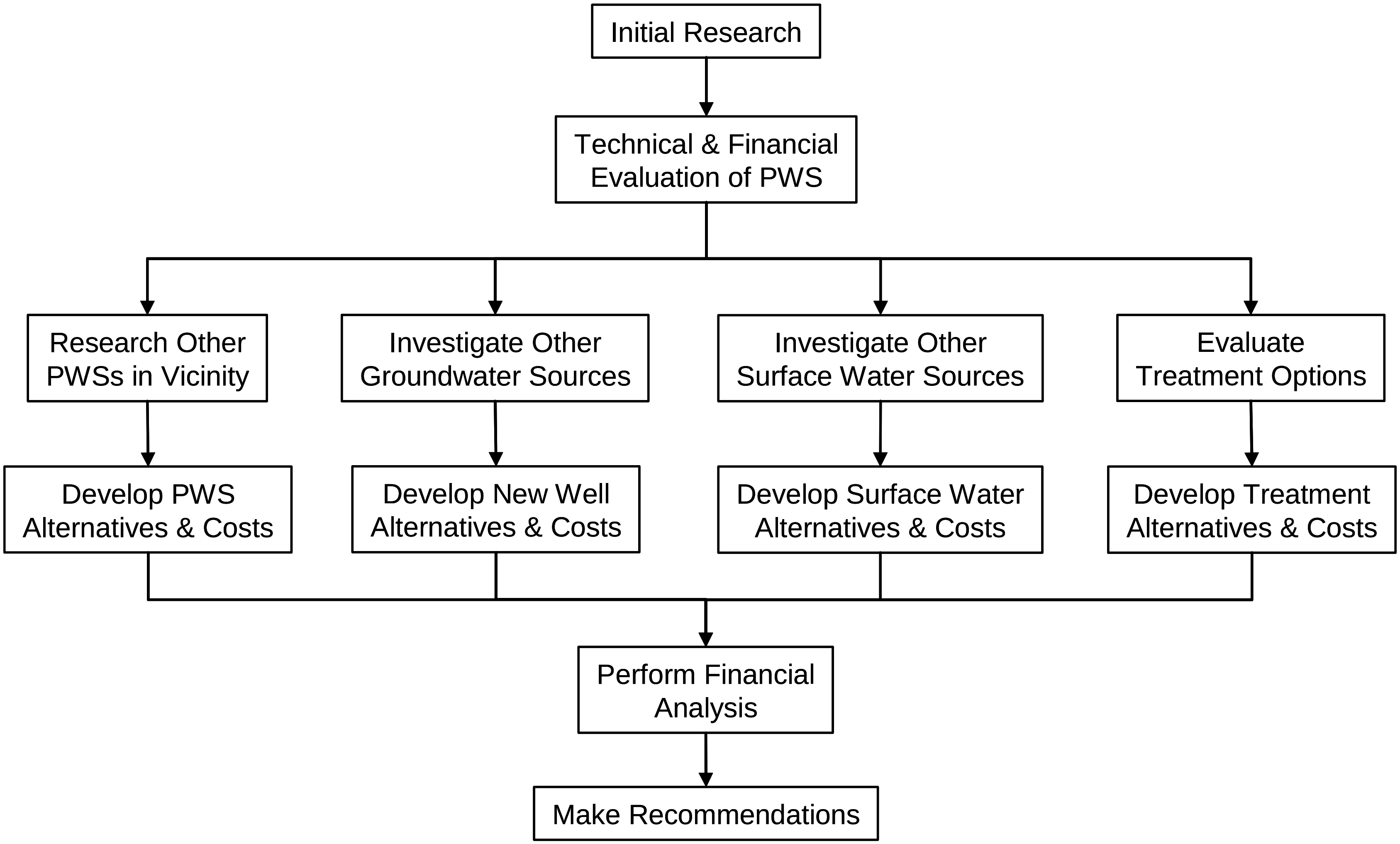
3) Perform a geologic and hydrogeologic assessment of the study area;
4) Develop treatment and non-treatment compliance alternatives which, in general, consist of the following possible options:
   - Connecting to neighboring PWSs via new pipeline or by pumping water from a newly installed well or an available surface water supply within the jurisdiction of the neighboring PWS;
   - Installing new wells within the vicinity of the PWS into other aquifers with confirmed water quality standards meeting the MCLs;
   - 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;
   - Treating the existing non-compliant water supply by various methods depending on the type of contaminant; and
   - 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 Live Oaks MHP PWS obtains groundwater from the Hensell Sand member in the middle Trinity aquifer. The higher radium concentrations tend to occur in the western part of the aquifer in Gillespie, Kendall, and Kerr Counties. Radium concentrations can vary significantly over relatively short distances; as a result, there could be good quality groundwater nearby. However, the variability of radium concentrations makes it difficult to determine where wells can be located to produce acceptable water. The radium concentration for Well 2 is consistently less than the concentration for Well 1, but may not be below the MCL. As much production as possible should be shifted to Well 2 as possible to reduce the radium concentration in the drinking water It may also be possible to do down-hole testing 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.

Figure ES-1
Summary of Project Methods



COMPLIANCE ALTERNATIVES

The Live Oaks MHP PWS is located on 650 acres between Kerrville and Fredericksburg. The MHP is family owned. Overall, the Live Oaks MHP PWS had a very good level of FMT capacity, and there are several positive aspects of FMT capacity, including knowledgeable and dedicated staff, adequate financial resources for the water system, and preventive maintenance program. Areas of concern for the system included lack of reserve account, lack of written contract for water operations, lack of cross connection control, and lack of emergency plan.

There are several PWSs within 10 miles of Live Oaks MHP PWS. A few of these nearby systems also have problems with radium, but there are several with 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. There is a minimum of surface water available in the area, and obtaining a new surface water source is considered through an alternative where treated surface water is obtained from a large supplier.

A number of centralized treatment alternatives for arsenic removal have been developed and were considered for this report, including ion exchange, WRT Z-88 adsorption, and KMnO4-green sand 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 near the Live Oaks MHP PWS is likely to be an attractive solution if compliant groundwater can be found. Having a new well near the Live Oaks MHP 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. 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. Like 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 Live Oaks MHP PWS indicated that current water rates are funding operations, and a rate increase would not be necessary to meet estimated operating expenses. The current average water bill of $300 represents approximately 1.1 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	$300	1.1
Purchase water from the City of Kerrville	100% Grant	$472	1.7
	Loan/Bond	$1,769	6.4
Central treatment - IX	100% Grant	$746	2.7
	Loan/Bond	$1,129	4.1
Point-of-use	100% Grant	$980	3.5
	Loan/Bond	$1035	3.7

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ACRONYMS AND ABBREVIATIONS

AFY	acre-feet per year
ANSI	American National Standards Institute
BEG	Bureau of Economic Geology
BV	bed volume
CA	chemical analysis
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
CO	correspondence
ED	electrodialysis
EDR	electrodialysis reversal
EP	entry point
FMT	financial, managerial technical
ft^2	square foot
GAM	Groundwater Availability Model
gpm	gallons per minute
gpm/ft^2	gpm per square foot
IX	Ion exchange
LOM	Live Oaks Mobile Home Park PWS
MCL	Maximum contaminant level
mg/L	milligrams per Liter
mgd	million gallons per day
MHI	median household income
MHP	mobile home park
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
ppb	parts per billion
PWS	public water system
$KMnO_4$-filtration	re-formed hydrous manganese oxide filtration
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
SRF	State Revolving Fund
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
UGRA	Upper Guadalupe River Authority
VOC	volatile organic contaminant
WAM	Water Availability Model
WRT	Water Remediation Technologies, Inc.

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 that 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 Live Oaks Mobile Home Park (MHP) PWS, ID# 0860090, located in Gillespie County (Live Oaks MHP PWS). Recent sample results from the Live Oaks MHP PWS exceeded the MCL for radium of 5 picoCuries per liter (pCi/L) (USEPA 2005; TCEQ 2004). The location of the Live Oaks MHP PWS is shown in 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 Live Oaks MHP PWS had recent sample results exceeding the MCL for radium. 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 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 methods used to develop and assess compliance alternatives. The groundwater sources of radium are addressed in Section 3. Findings for the Live Oaks MHP 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;
- Tracking and analyzing compliance options for MCL violators;
- Providing FMT assessment and assistance to PWSs;

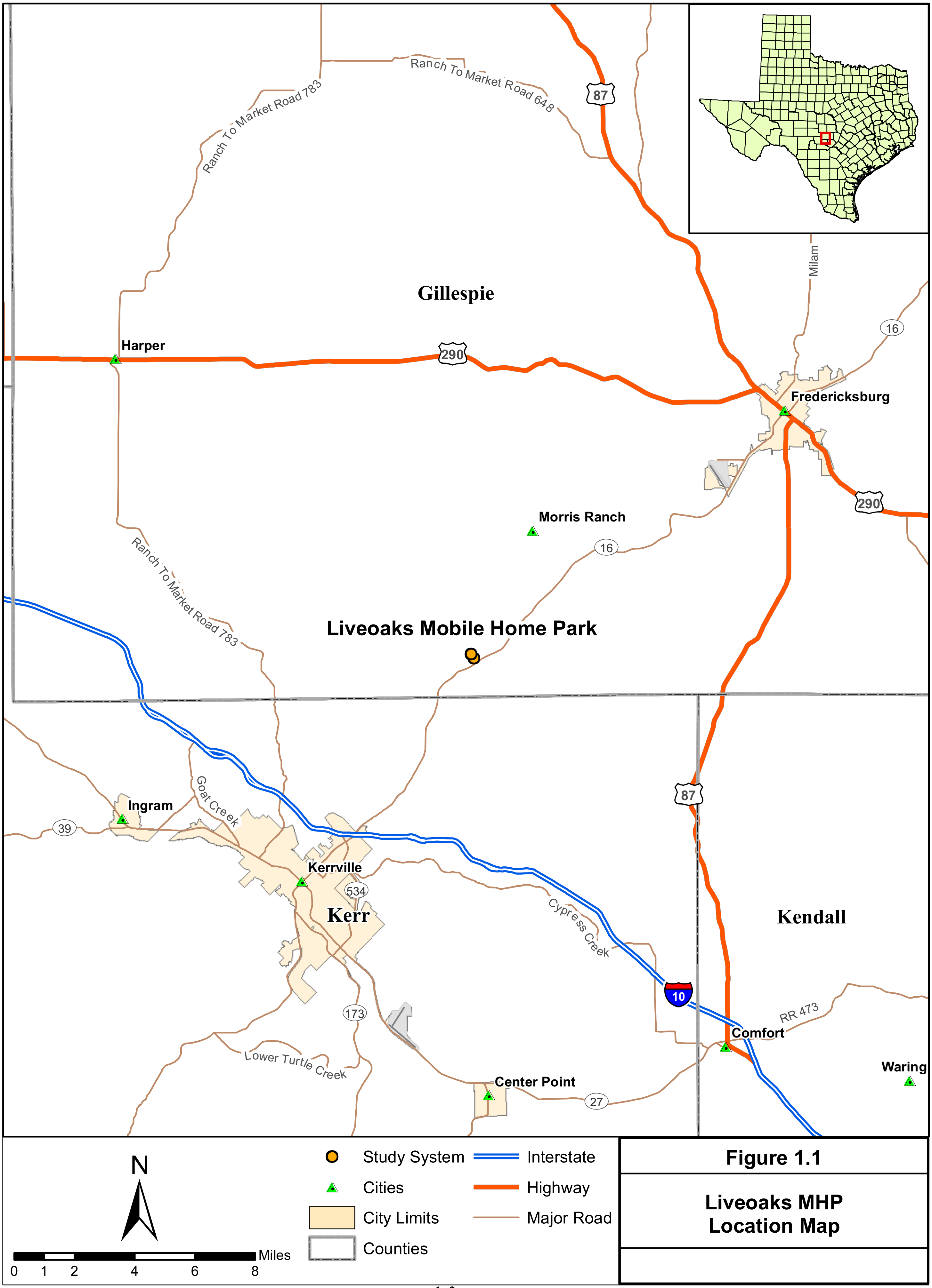

Figure 1.1

Liveoaks MHP Location Map

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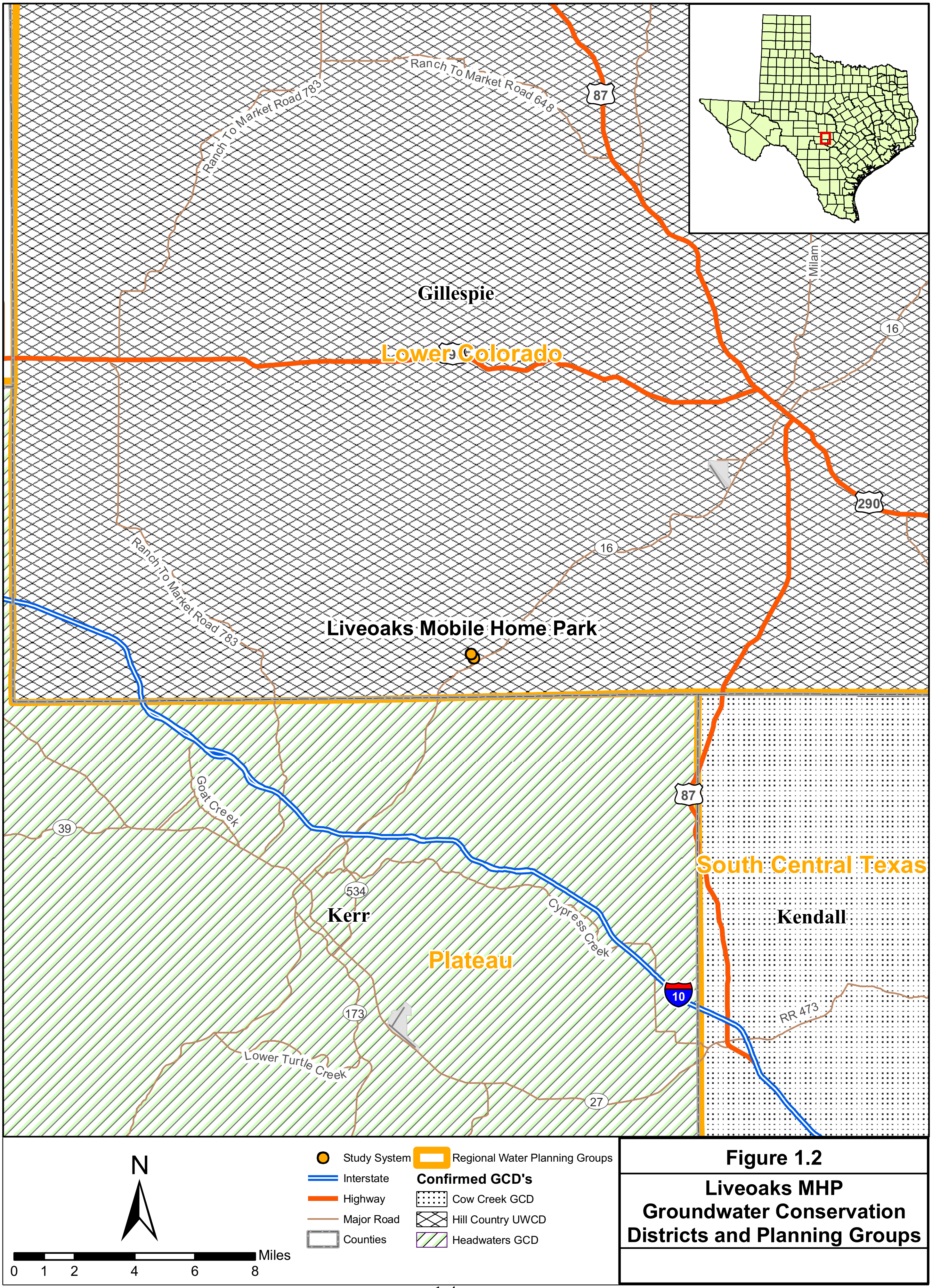


Figure 1.2

Liveoaks MHP Groundwater Conservation Districts and Planning Groups

- 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 Live Oaks MHP PWS involve radium. 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 that 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 Live Oaks MHP PWS, the following standards could be used in a rough screening to identify compliant groundwater in surrounding systems:
    - Total Radium (radium-226 and radium-228) less than 4 pCi/L (below the MCL of 5 pCi/L); and
    - TDS concentrations less than 1,000 milligrams per liter (mg/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.
- 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

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 a major part 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, 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

<u>Process</u> – In solution, salts separate into positively-charged cations and negatively-charged anions. Ion exchange (IX) 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 mg/L of hardness with application of 6.5 lb NaCl/ft^3 resin would produce 2.4 bed volumes (BV) of 16,400 mg/L 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 inorganic, 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 WRT Z-88 radium treatment process is a proprietary process using a radium specific adsorption resin or zeolite supplied by Water Remediation Technologies, Inc. (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 (2-3 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 gallons per minute per square foot (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.*, $1.00-6.70/kgal, depending on water characteristics, flow capacity and annual production for the water 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 2-3 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 an 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 percent 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.
- Needs to handle multiple chemicals.
- Concentrate disposal.
- Waste of water because of the significant concentrate flows.

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 – Electrodialysis (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. Electrodialysis reversal (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 clearwell 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^{o}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.

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

Process – 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.

Pretreatment – 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.

Maintenance – 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.

Waste Disposal – 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 KMnO4, which is an oxidant.
- Need to monitor and backwash regularly.
- Need to disposal of settled solids.

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 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 in order 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 which 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 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 (ANSI) 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 (VOC) 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 that 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 METHODS

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 Tree2, 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 Certificate of Convenience and Necessity (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.

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

Figure 2.1
TREE 1 – EXISTING FACILITY ANALYSIS

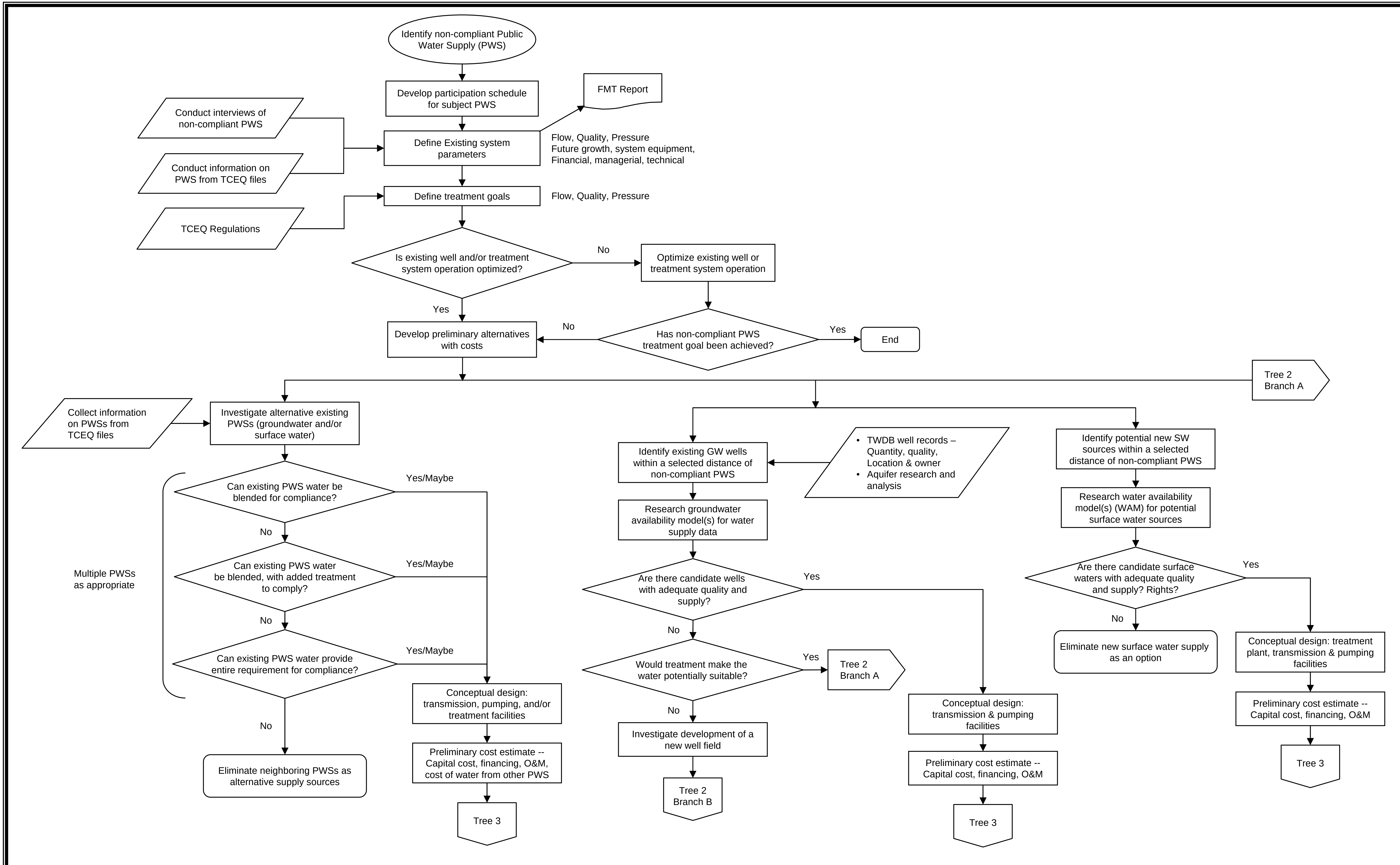
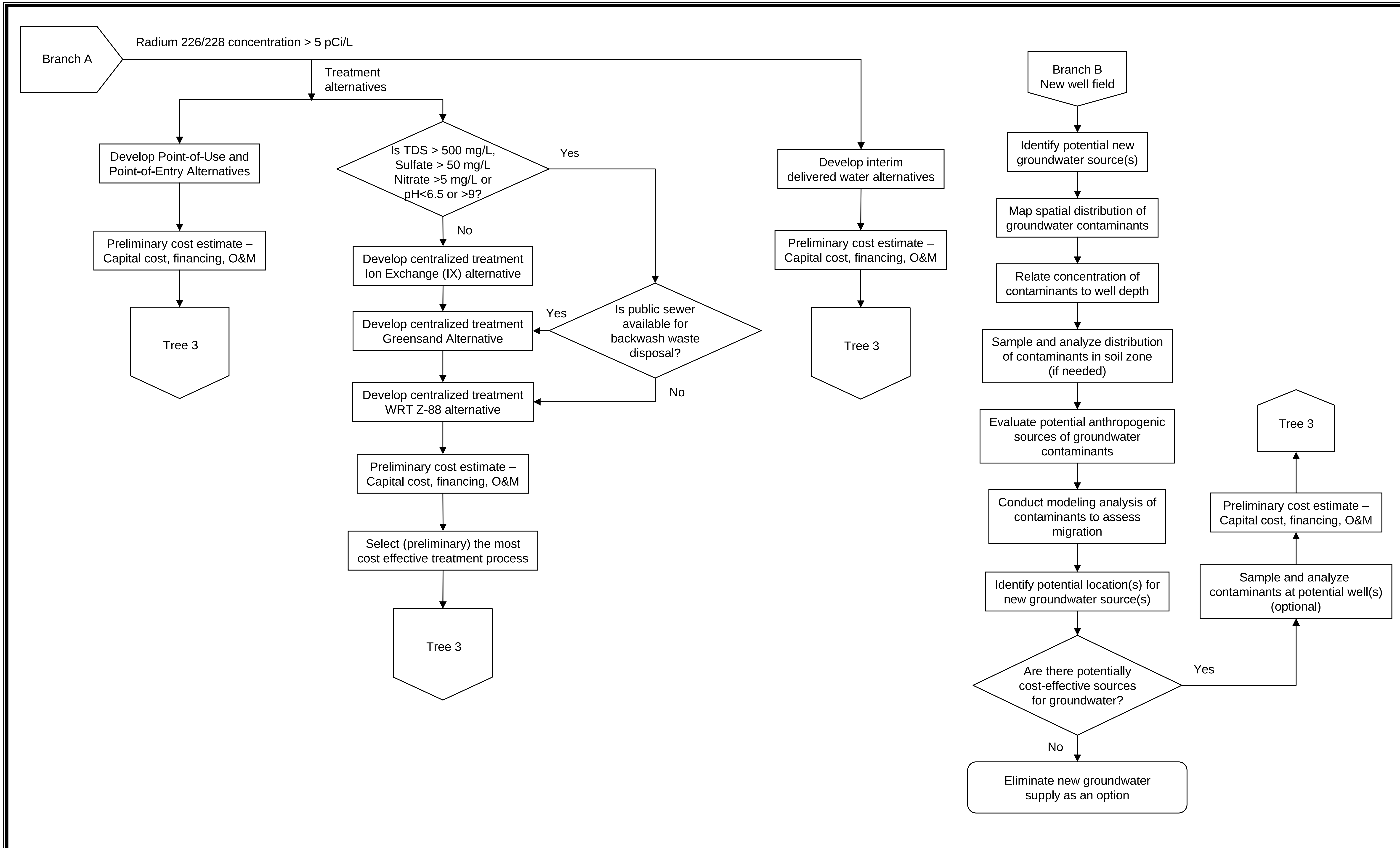


Figure 2.2
TREE 2 – DEVELOP TREATMENT ALTERNATIVES



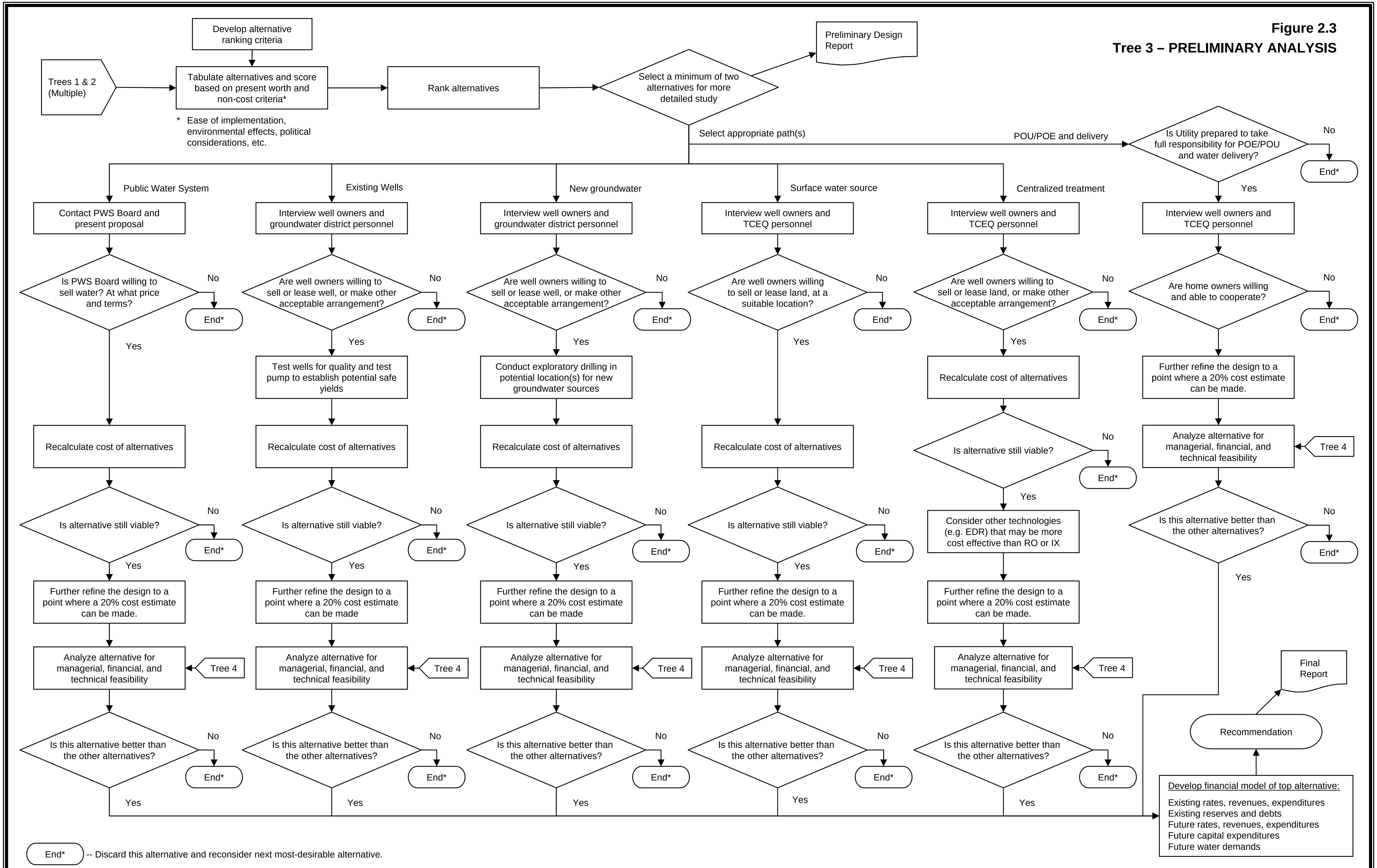
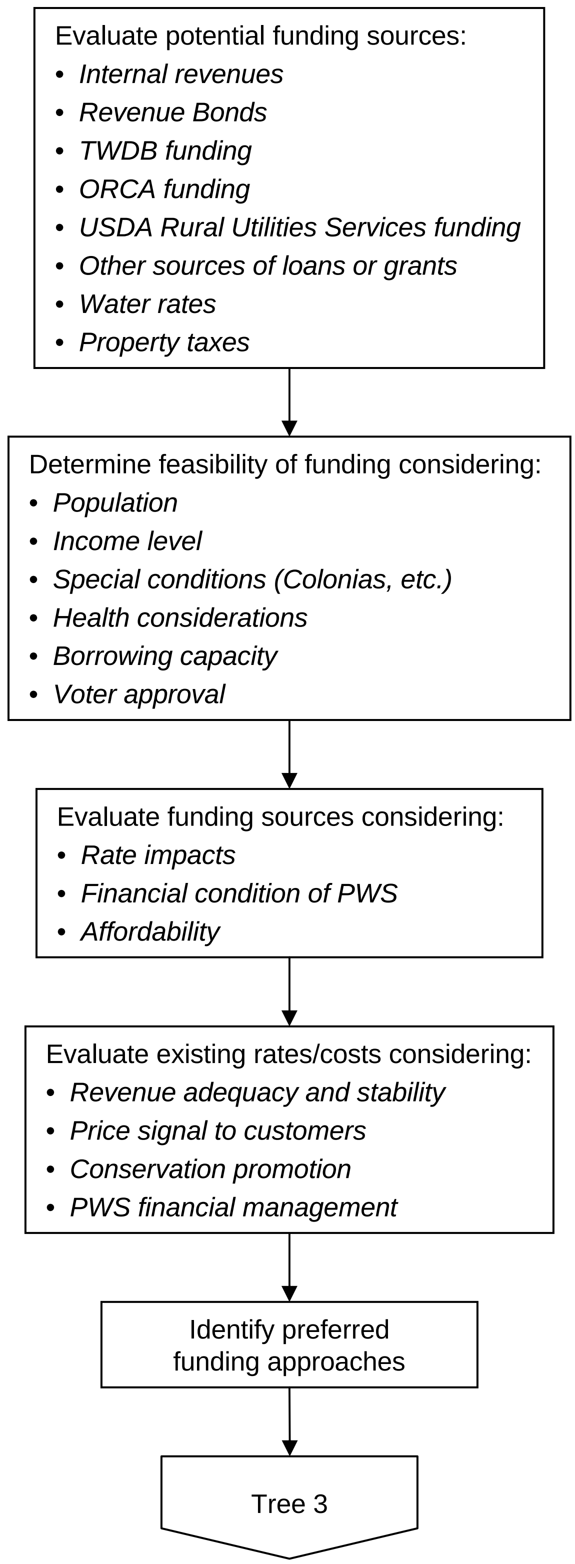


Figure 2.3
Tree 3 – PRELIMINARY ANALYSIS

Figure 2.4
TREE 4 – FINANCIAL



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:

- TCEQ Water Utility Database: www.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 SDWIS: 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 Edwards-Trinity Plateau aquifer 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 that 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 preliminary 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. In order 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 10 miles, 5 miles, and 1 mile. 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 10-mile and 5-mile alternatives. 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 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. And thus 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-economical 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.

2.4 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. For service areas with a sparse population base, county data may be the most reliable, and for many rural areas corresponds to census tract data. The census broke down MHIs geographically by block group and ZIP code. The MHIs can vary significantly for the same location, depending on the geographic subdivision chosen. The MHI for each PWS was estimated by selecting the most appropriate value based on block group or ZIP code based on results of the site interview and a comparison with the surrounding area.

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 median annual household income that 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 4.4 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; and obtaining a Loan/Bond. Table 4.4 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:

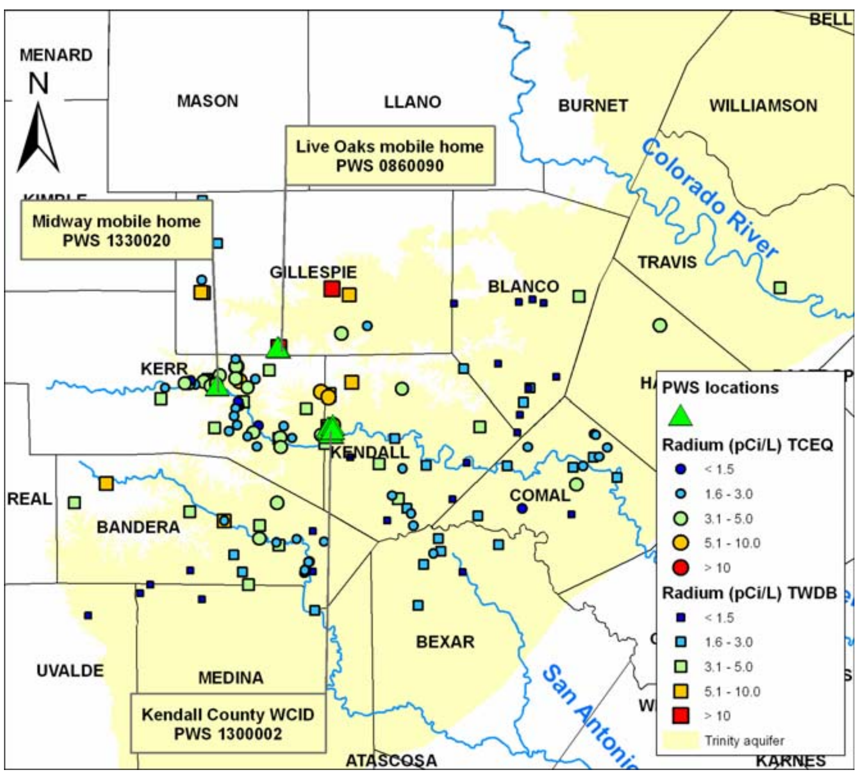
- United States Department of Agriculture, Rural Utilities Service, and
- United States Housing and Urban Development.

SECTION 3
UNDERSTANDING SOURCES OF CONTAMINANTS

3.1 RADIUM, GROSS ALPHA, AND URANIUM IN THE SOUTHERN PART OF THE TRINITY AQUIFER

The Hill Country of Central Texas includes aquifers of Cretaceous age (mainly within the Trinity Group) but also of Paleozoic age (Hickory and Ellenburger - San Saba aquifers) as a result of the presence of the nearby Llano uplift whose southern confines crop out in northern Gillespie County (Bluntzer 1992). The PWS wells of concern are located in Gillespie, Kendall, and Kerr counties and are completed in the southern part of the Trinity aquifer (south of the Colorado River). Most of the wells are designated as in the Trinity Group (aquifer code 218TRNT), and a few are designated specifically in the Hensell Sand and Cow Creek Limestone formations (218HNSL and 218HSCC) which are part of the middle Trinity aquifer. In general, radium concentrations in the southern part of the Trinity aquifer are low and most samples are below the radium MCL of 5 pCi/L (Figure 3.1). Radium concentrations >5 pCi/L are found in the western part of the aquifer outcrop in Gillespie, Kendall, and Kerr Counties.

Figure 3.1 Radium Concentrations in Groundwater of Southern part of the Trinity Aquifer



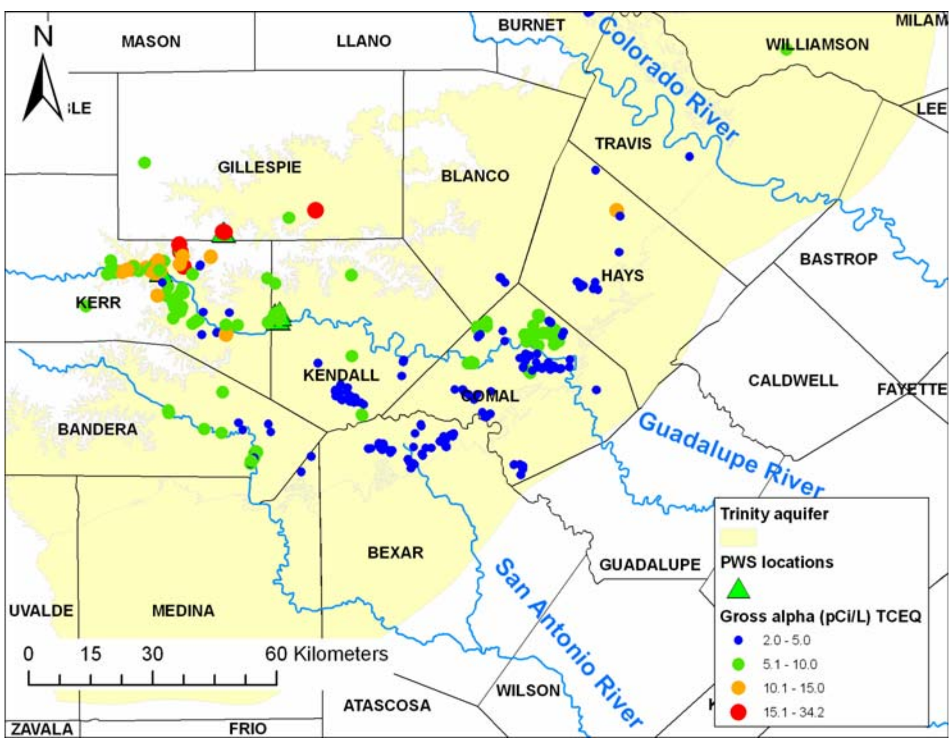
Data in Figure 3.1 are from the TWDB groundwater database (storet codes 09503 and 81366) and TCEQ public water supply database (contaminant id 4020 and 4030). Figure 3.1 is based on the most recent values for wells from which both isotopes of radium were analyzed.

The data include raw samples from wells and samples from entry points which are connected to a single well.

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 3.1 generally represent the upper limit of the radium measurements because the detection limit was used for samples that are below the detection limit. Although TCEQ allows public water systems 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.

Gross alpha concentrations follow a trend similar to radium. Concentrations of gross alpha are generally <15 pCi/L throughout most of the aquifer. Concentrations >15 pCi/L are generally restricted to the western part of the aquifer in Gillespie and Kerr counties (Figure 3.2). The MCL for uranium is 30 parts per billion (ppb), 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).

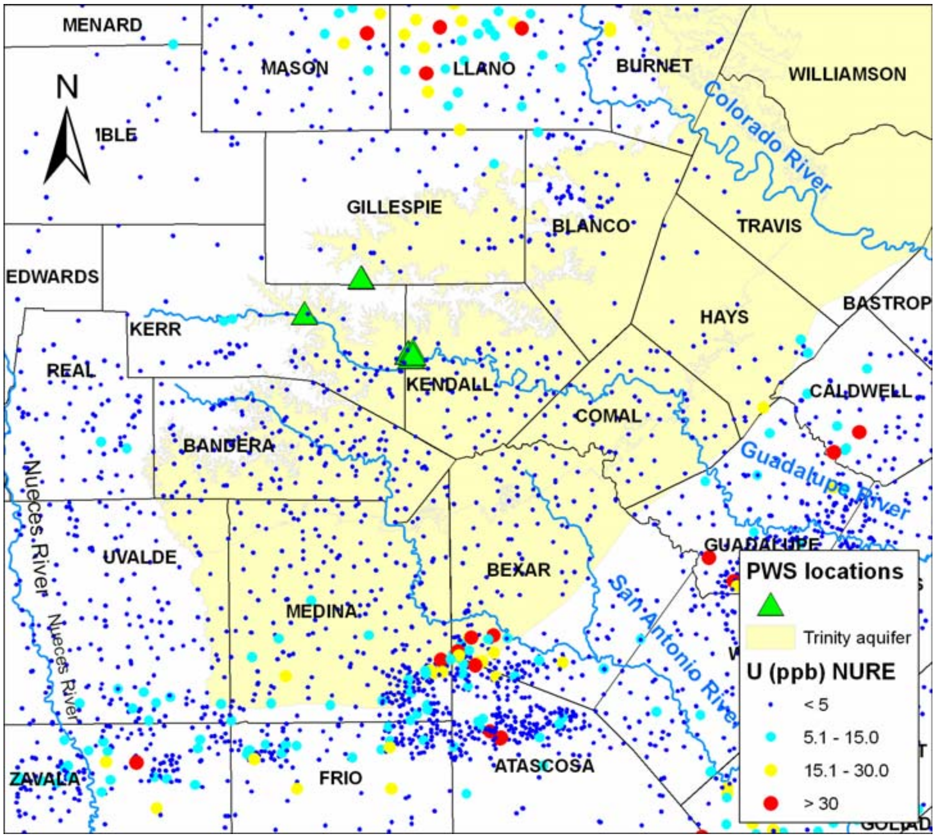
Figure 3.2 Gross Alpha in Groundwater in the Southern Part of the Trinity Aquifer



Data in Figure 3.2 are from the TCEQ public water supply database (contaminant ID 4109). The most recent sample is shown for each well.

Data from the National Uranium Resource Evaluation (NURE) database were used to evaluate uranium concentrations in the study area (Figure 3.3). Uranium concentrations were below the MCL of 30 ppb and samples in the southern area of the Trinity aquifer were <5 ppb (the NURE database does not include aquifer information).

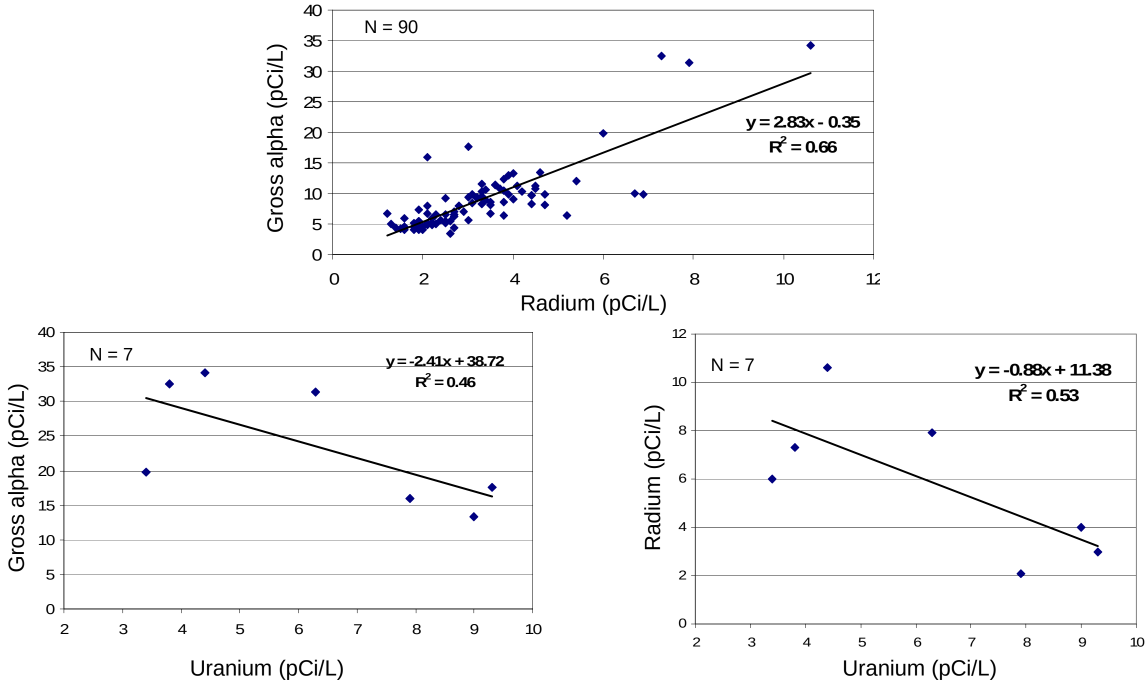
Figure 3.3 Uranium in Groundwater of the Southern Trinity Aquifer



A total of 11 wells in the Trinity aquifer (not shown in Figure 3.3) have uranium analyses, and these show uranium concentrations <10 pCi/L (equivalent to 15 ppb).

The correlation between radium and gross alpha is strong (r^2 = 0.66) and positive, while correlations of gross alpha and radium with uranium are negative (Figure 3.4). Although the number of uranium analyses is small (only seven samples with radium and gross alpha), these trends suggest that gross alpha count is mostly from radium in the groundwater.

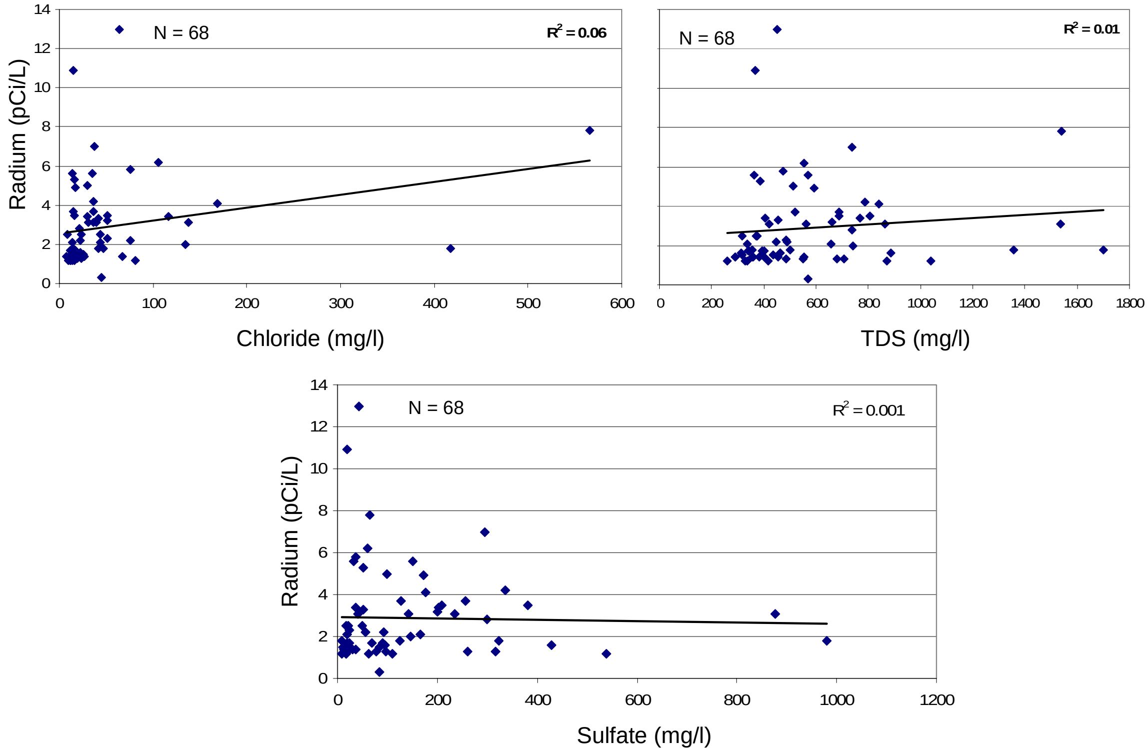
Figure 3.4 Relationships Between Radium, Gross Alpha, and Uranium in Groundwater in the Southern Part of the Trinity Aquifer



Data shown in Figure 3.4 are from the TCEQ public water supply database and include samples from entry points which are connected to a single well. For each well the most recent sample is used in the analysis (data include only samples where both parameters were analyzed on the same day). N represents the number of samples used in the analysis.

Correlations between gross alpha and radium concentrations and well depth in the southern part of the Trinity aquifer are weak (r^2 <0.1), and correlations with other general parameters such as chloride, Total Dissolved Solids (TDS), and sulfate are also weak (Figure 3.5).

Figure 3.5 Relationships Between Radium Concentrations and Chloride, TDS, and Sulfate in the Southern Trinity Aquifer



Data in Figure 3.5 are from the TWDB groundwater database. Samples of radium, chloride, TDS, and sulfate were taken on the same day. N represents the number of samples in the analysis.

3.2 REGIONAL GEOLOGY

Subsurface deposits of Cretaceous age in Gillespie, Kendall, and Kerr counties overlie a Paleozoic basement. The Precambrian Llano uplift with its ring of Paleozoic formations crops out in northern Gillespie County (Bluntzer 1992). Although Kerr and Kendall Counties have access to Paleozoic aquifers, this supply is tapped mostly by Gillespie County operators. Water resources in this three-county area are relatively well known (Anaya and Jones 2004; Mace, *et al*. 2000; Preston, *et al*. 1996; Bluntzer 1992; Ashworth 1983; Walker 1979; Reeves 1969; and Reeves 1967).

Cretaceous sediments were deposited on a mostly flat stable platform and transitions between different depositional facies and rock type (sand, shale, carbonate) are generally laterally smooth. Sandy units suggest proximity to the continent when the sediments were deposited while shaley units reflect a greater distance from the continent. The development of important carbonate accumulations imply periodic limited clastic input. The Cretaceous sediments consist of a basal conglomerate grading into sandy material (Hosston Sand) overlain by mostly calcareous rocks (Sligo Member). This marks the beginning of a more shaley and calcareous series of sediments until the deposition of another continuous sand unit (Hensell Sand). The formation between Hosston Sand and Hensell Sand is known as the Pearsall formation and is composed of a shaley member overlain by the Cow Creek Limestone Member. The previously described formations have been traditionally called the Travis Peak formation in Central Texas. The Travis Peak is overlain by the thick accumulation of the Glen Rose formation. Formations from the Hosston Sand to the Glen Rose Limestone make up the Trinity Group. The Paluxy Sand, prevalent farther north, does not exist in the three-county study area. The mostly calcareous accumulations of the Fredericksburg and Washita Groups (including the Comanche Peak, Edwards, and Buda Limestone) that top the Lower Cretaceous close the local stratigraphic column. Pertinent Paleozoic formations are the Hickory Member (mainly sand), first formation of Cambrian age covering the Precambrian basement and the Ellenburger Group (mostly carbonates) of Ordovician age. The dip of Cretaceous layers is generally toward the south and less than 0.3 percent (15 feet per mile) but can be higher and over 1 percent, especially near the Balcones Fault zone, just south of Kendall County. Paleozoic layers, which dip away from the Llano Uplift located just north of Gillespie County, display a higher dip of 7 percent to 17 percent (400 to 900 feet per mile, Bluntzer 1992). Paleozoic layers are also compartmentalized by faults that became inactive before the deposition of Cretaceous sediments. Because the Llano Uplift has been a structural high since at least the beginning of the Cretaceous, some layers thin or pinch out when approaching the uplift (*e.g.,* Hosston Sand; Bluntzer 1992, Figure 5).

Major water-bearing formations are the Hosston Sand (Lower Trinity aquifer), the Hensell Sand forming the Middle Trinity aquifer to which is added the Cow Creek Limestone. Some Glen Rose beds can also locally produce some poor quality water; they are then collectively called the Upper Trinity aquifer. The uppermost water-bearing formation is the Edwards limestone under water-table conditions, unlike the other aquifers which are mostly confined. The State of Texas has recognized the Trinity Aquifer as a major aquifer while the Hickory and Ellenburger / San Saba aquifers (mainly in Gillespie County) are considered minor aquifers (Ashworth and Hopkins 1995). Hydraulic connection between Cretaceous and Paleozoic aquifers is common (Bluntzer 1992). For example, in Gillespie County, the Hensell Sand was directly deposited on top of the Hickory Member.

Thickness of the entire Hickory Member is up to ~500 feet (McBride, *et al*. 2002). Black (1988) states that lower portions of the Hickory aquifer are nearly stagnant and have minimal interaction with outcrop portions of the aquifer. In Gillespie County, depth to the top of Hickory aquifer is variable from shallow water-table conditions to more than 2,500 feet (Preston *et al*. 1996, Figure 5). The Ellenburger/San Saba aquifer, composed of over 2,000 feet of sediments, is located ~700 - 1,000 feet above the Hickory aquifer and follows its structural vagaries. Depth to the Hensell Sand and Hosston Sand is generally less than 600 feet and 1,000 feet, respectively (Mace, *et al*. 2000, Figure 9). The average thickness of the Hosston Sand can reach more than 250 feet, but it pinches out in Gillespie County. The thickness of the Hensell Sand ranges from 150 to 300 feet. The Cow Creek Limestone is no more than 100 feet thick and pinches out along with the Hosston Sand.

The Paleozoic aquifers yield small to large quantities of fresh (mostly in Gillespie County) to slightly saline water (Ashworth 1983; LBG-Guyton Associates 2003). The Trinity Group aquifers can produce mostly fresh water often with high hardness (Anaya and Jones 2004) at highly variable yields.

3.3 DETAILED ASSESSMENT FOR LIVE OAKS MOBILE HOME PARK PWS

There are two wells in the Live Oaks MHP PWS: G0860090A and G0860090B. The wells are designated as within the Hensell Sand member, in the middle Trinity aquifer, and have depths of 341 and 498 feet (Table 3.1). Each well is connected to a different entry point in the water supply system (Well A is connected to EP1 and Well B to EP2), thus samples taken at entry points can be related to a single well.

Radium concentrations measured at the two entry points of the PWS are above the 5 pCi/L MCL (Table 3.2). Samples taken at entry point (EP) 1 are somewhat higher than those taken at EP 2. Concentrations sampled at EP1 (connected with well A) are between 6.3 and 13.1 with an average of 10.1 pCi/L, while samples from EP2 (connected with Well B) range from 6 to 7 pCi/L, with an average value of 6.3 pCi/L. Gross alpha concentrations are <4 pCi/L for both entry points (Table 3.3) and total uranium sampled at the PWS is below the MCL of 20 pCi/L and generally below 3 pCi/L at both entry points (Table 3.4).

Table 3.1 Well Depth and Screen Interval Depths for Wells in the Live Oaks MHP PWS

Water source	Depth (ft)	Screen depth (ft)	Aquifer
G0860090A	341	253-341	Trinity (code 218 HNSL Hensell sand member of the Travis Peak formation)
G0860090B	498	458-498	Trinity (code 218 HNSL Hensell sand member of the Travis Peak formation)

Table 3.2 Radium Concentrations at Live Oaks MHP PWS

Date	Source	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Radium total (pCi/L)
8/27/1996	Domestic	2.9	1.3	4.2
11/17/1997	Raw	4.6	2.9	7.5
11/2/2000	Domestic	4.7	2.4	7.1
2/7/2001	EP1	10.4	2.7	13.1
2/7/2001	EP2	5	2	7
11/5/2002	EP1	3.9	2.4	6.3
11/5/2002	EP2	4.2	2.1	6.3
10/13/2003	EP1	8.8	1.8	10.6
10/13/2003	EP2	4	2	6
10/7/2004	EP1	8.6	2	10.6
10/7/2004	EP2	4.5	1.5	6

Table 3.3 Gross Alpha Concentrations at Live Oaks MHP PWS

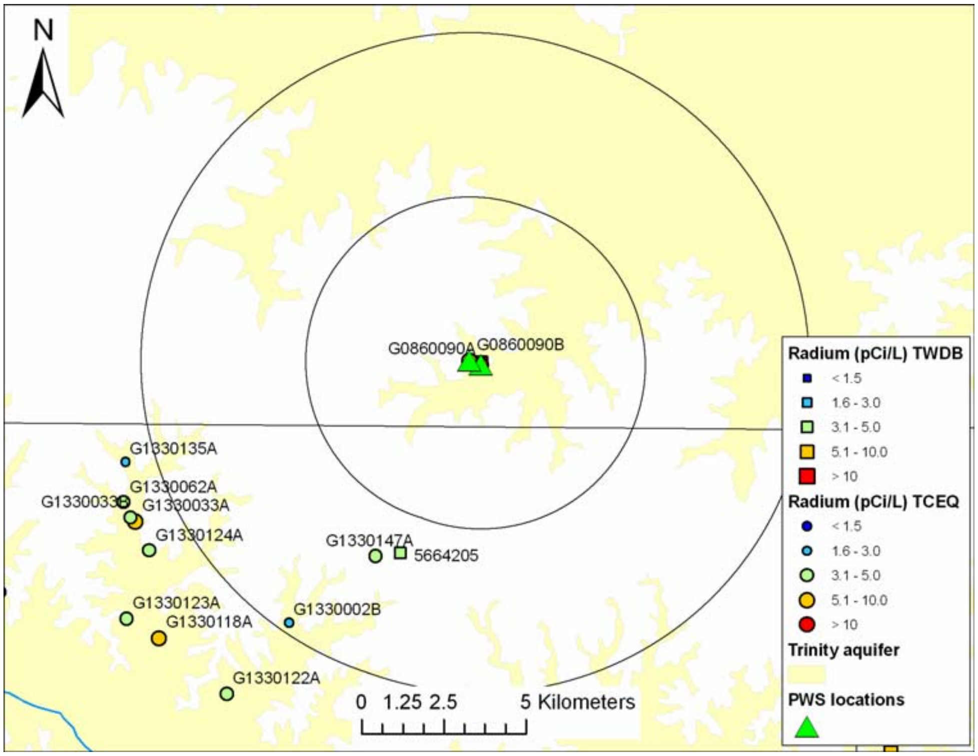
Date	Source	Gross alpha (pCi/L)
8/27/1996	D	3
11/17/1997	R	2.7
11/2/2000	D	2.5
2/7/2001	EP2	2.6
2/7/2001	EP1	4
11/5/2002	EP1	2.9
11/5/2002	EP2	2.8
10/13/2003	EP2	2.6
10/13/2003	EP1	3.7
10/7/2004	EP2	2.6
10/7/2004	EP1	3.4

Table 3.4 Uranium Concentrations at Live Oaks MHP PWS

Date	Source	Total Uranium (pCi/L)
11/5/2002	EP2	2.53
11/5/2002	EP1	2.33
10/13/2003	EP1	2.8
10/13/2003	EP1	1.93
10/7/2004	EP1	3.33
10/7/2004	EP2	2.67

Data from the TWDB and TCEQ databases show a number of wells with radium <5 pCi/L in the vicinity of the Live Oaks MHP PWS (Figure 3.6). Southwest of the Live Oaks MHP PWS there are a number of wells with radium <5 pCi/L. The nearest well is well 5664205 screened in the lower Glen Rose Limestone formation (218GLRSL) at depths of 600 to 750 feet. Two public water supply wells also have radium <5 pCi/L: well G1330002B is 400 ft deep screened from 300 to 377 feet and categorized as in the middle Trinity aquifer (code 218TRNT), and well G1330147A is 620 feet deep screened from 510 to 620 feet, and categorized as in the Hensel Sand formation.

Figure 3.6 Radium in the 5- and 10-km Buffers of the Live Oaks MHP PWS Wells



Potential Sources of Contamination (PSOC) are identified as part of TCEQ's Source Water Assessment Program. There are no PSOC sites identified in the vicinity of the Live Oaks MHP PWS, thus point sources are not expected to influence radium concentrations at the Live Oaks MHP PWS.

3.3.2 Summary of Alternative Groundwater Sources for the Live Oaks PWS

Data in Figure 3.6 suggest that possible alternative sources can be found southwest of the Live Oaks MHP PWS, although the data are limited due to lack of samples east and north of the PWS. No trend is found between radium and specific formations; therefore, it is impossible with the current data to identify specific well intervals containing groundwater with low radium.

SECTION 4
ANALYSIS OF THE LIVE OAKS MHP PWS

4.1 DESCRIPTION OF EXISTING SYSTEM

4.1.1. Existing System

The location of the Live Oaks MHP PWS is shown in Figure 4.1. The system has two active wells. Well A is 340 feet deep, and has a tested capacity of 42 gpm (0.060 million gallons per day [mgd]). Well B is 498 feet deep, and has a tested capacity of 42 gpm (0.060 mgd). Each of the wells feed into storage tanks, and the storage tanks feed booster pumps that pump into pressure tanks, which in turn feed the distribution system. The water is chlorinated before flowing into the pressure tanks. Combined radium concentration of the combined flow from the two wells has exceeded the MCL of 5 pCi/L. A phosphate inhibitor is added to Well B water to control high iron concentrations.

The treatment employed is not appropriate or effective for removal of radium, so optimization is not expected to be effective increasing removal of this contaminant. However, there is a potential opportunity for system optimization to reduce radium concentration. The system has two wells, which pump to separate entry points to the distribution system. Since both entry points are monitored for radium, it is possible to determine the radium concentrations in each well. The combined radium concentration in Well B is consistently less than the combined radium concentration in the Well A water.

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: 234 current, 264 at full build out
- Connections: 117 current, and 132 at full build out
- Average daily flow at full build out: 0.026 million gallons per day (mgd)
- Maximum daily flow: 0.103 mgd
- Total production capacity: 0.120 mgd

Raw water characteristics:

- Typical combined radium range: 4.9 pCi/L to 9.9 pCi/L
- Typical total dissolved solids range: 396 to 449 mg/L
- Typical pH range: 7.5 to 7.6
- Typical calcium range: 54.6 to 64.1 mg/L
- Typical magnesium range: 51.4 to 60.5 mg/L

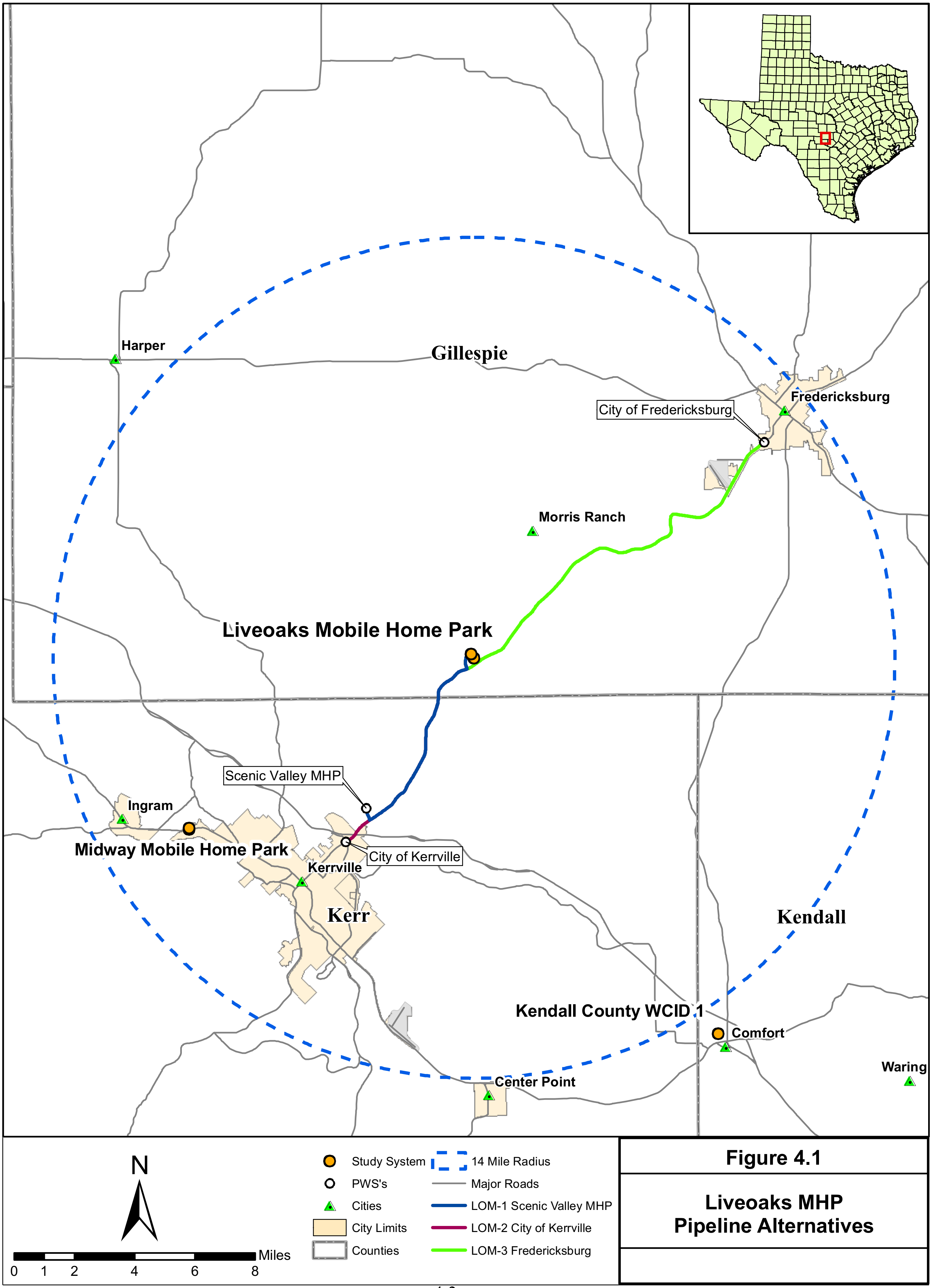


Figure 4.1

Liveoaks MHP Pipeline Alternatives

J:\744\744655_BEG_2006\GIS_06\mxd\Fig4-1\liveoaks4-1.mxd - 8/29/2006 @ 9:45:17 AM

- Typical sodium range: 15.9 to 23.4 mg/L
- Typical chloride range: 60.0 to 60.7 mg/L
- Typical bicarbonate (HCO3) range: 367 mg/L (one result)
- Typical fluoride range: 0.449 to 0.500 mg/L
- Typical iron range: Well A 0.61 to 0.69 mg/L; Well B 0.277 to 0.291 mg/L
- Typical manganese range: 0.0053 to 0.0110 mg/L

4.1.2 Capacity Assessment for the Live Oaks MHP PWS

The project team conducted a capacity assessment of the Live Oaks MHP PWS. 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 technical, managerial, and financial capability of the water system. The positive aspects of capacity describe those factors that the system is doing well. These factors should provide opportunities for the system to build upon in order 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, capacity concerns, includes items that are not currently associated with a significant problem for the system. However, the system should consider addressing these items so that they do not have the opportunity to cause problems in the future.

The following personnel were interviewed:

- Brad Kott – Owner/Manager
- Jerry Hefley – Contract Water Operator
- Ernie and Ruth Kott, Owner

All interviews were conducted in person.

4.1.2.1 General Structure

The Live Oaks Mobile Home Park is located on 650 acres between Kerrville and Fredericksburg. The mobile home park is family owned, and the business is known as Kott Live Oaks, Inc. The owners provide managerial and financial oversight of the water system. They contract with a certified operator who works full-time for the City of Kerrville as an Engineering Inspector. He checks the water system about two times a week, and reports directly to the owners. In addition, there is a maintenance person who lives on-site and checks the system on a daily basis, but is not certified.

The mobile home park provides housing to residents in the mid-to-upper income bracket, and is well maintained. The water system has 117 connections, and serves a population of about 234 people. The monthly lot rent includes water service, garbage collection and septic tank maintenance. The water system is not metered.

The system has two active wells that are each chlorinated, and serve different parts of the distribution system.

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.

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 Live Oaks MHP PWS are listed below.

- **Knowledgeable and Dedicated Staff –** The owner/manager of the water system is also the Finance Director for the City of Fredericksburg. He has been responsible for managing this water system for the past 6 years, and was previously the certified water operator for the system. The current certified water operator has been on contract with the Live Oaks MHP PWS for about 3 years, and due to his position with the City of Kerrville, has received extensive training in the water operations field. He has over 23 years experience in the water industry. Therefore, he has access to many resources in the industry. In addition, the manager's parents and the maintenance staff live on the property and are available to respond to customer requests in a timely manner. In addition, the maintenance person checks the pumps and chlorinators on a daily basis. This is important since the operator only checks the system twice a week. The phone numbers for all water system contacts are posted on a sign at the mobile home park.
- **Adequate Financial Resources for the Water System –** The manager indicated that the revenues from the rental fee more than covers the costs of water services. The rental fee ranges from $185-250 for 117 lots, and most of the lots are leased. There are only 10-15 spaces available. Since they have a high collection rate, they have never had to implement a policy for non-payment. There is an operating budget, however, the project team never received it. The only financial concern is a lack of a reserve account, which is discussed in the section on "Capacity Concerns."
- **Preventative Maintenance Program –** The operator has a preventative maintenance program that includes: flushing the lines, maintaining the chlorinator, cleaning the pumphouse, and inspecting the storage and pressure tanks. He also maintains an inventory of spare parts and has access to additional parts if needed, through his connections with the City of Kerrville.

4.1.2.4 Capacity Deficiencies

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

- **Lack of Compliance with Radium Standard –** The system is under a Compliance Agreement with TCEQ which outlines the steps the system needs to take to return to compliance with the radium standard. The system manager indicated that they have been working to address the radium problem. Thus far, they have already consulted with a local engineering company, obtained information on the costs associated with drilling a new well, and are exploring the possibility of using a nearby surface water source. They own 650 acres, so there may be an area where a shallower or deeper well might produce water that meets the radium standard. Finally, they indicated that the nearest PWS is 5-6 miles away and does not have the capacity to assist the Live Oaks MHP PWS. The system needs to continue working toward compliance to avoid further escalation in enforcement actions.

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 system should address the items listed below to further improve technical, managerial, and financial capabilities and to improve the system's long-term sustainability.

- **No Reserve Account** – The owner/manager indicated that there is no specific water system reserve account. However, thus far their revenues have been sufficient to fund emergencies and other capital items. It does not appear that funds have been specifically set-aside specifically to address the current radium compliance issue.

- **Lack of Written Contract for Water Operations –** The Live Oaks MHP PWS. does not have a written agreement with the water operator for water operations services. There is only a verbal agreement and the operator knows what needs to be done, and does it. It is always better to have the operator's responsibilities in writing, in the event there are ever disagreements about what was expected or what was actually done. In addition, it is a good idea to clearly define expectations for both parties.

- **Lack of Emergency Plan –** The system does not have a written emergency plan, nor does it have emergency equipment such as generators. In the event of a power outage, they would have to rely solely on the storage facilities to provide water. The utility 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, PWSs surrounding the Live Oaks MHP PWS were reviewed with regard to reported drinking water quality and production capacity. PWSs that appeared to have water supplies with water quality issues were ruled out from consideration as alternative sources, while those without identified water quality issues were investigated further. If it was determined those 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 existing PWSs within approximately 10 miles of the Live Oaks MHP PWS. This distance was selected as the radius for the evaluation owing to the relatively large number of PWSs in proximity to the Live Oaks MHP PWS.

Based on the initial screening summarized in Table 4.1, several alternatives were selected for further evaluation. These alternatives were selected based on factors such as water quality, distance from the Live Oaks MHP PWS, sufficient total production capacity for selling or sharing water, and willingness of the PWS to sell or share water or drill a new well. A number of small systems with good water quality were not carried forward for further evaluation since a pipeline to them would have to pass through Kerrville, a large water provider with good water quality. The City of Fredericksburg was added to the alternative for further evaluation despite being farther than 12 miles from Live Oaks MHP PWS because it is a large water provider. These alternatives are summarized in Table 4.2.

Table 4.1 Existing Public Water Systems within 15 miles of Live Oaks MHP PWS

System Name	Dist. From Live Oaks MHP (Miles)	Comments/Other Issues
The Wilderness	3.8	Small system. No WQ issues. **Evaluate Further.**
Cherry Ridge Water Co	4.3	Small system. No WQ issues. **Evaluate Further.**
Scenic Valley MHP	6.2	Small system. No WQ issues. **Evaluate Further.**
Kamira Water System	6.9	Small system. No WQ issues. Pipeline would pass through Kerrville.
USDA Livestock Insect Research Lab	7.0	Small system. No radium data.
Hill Country Camp	7.1	Small system with WQ issues: marginal radium.
Northwest Hills Subdivision	7.1	Small system. No WQ issues. Pipeline would pass through Kerrville.
Aqua Vista Utilities Co.	7.2	Small system. No WQ issues. Pipeline would pass through Kerrville
TDH & Pt Comfort Station I-10	7.3	Small system. No radium data.
James Avery Craftsman, Inc.	7.3	Small system. No radium data.

System Name	Dist. From Live Oaks MHP (Miles)	Comments/Other Issues
Hill Country Ranch Estates	7.5	Small system with WQ issues: sulfate.
Cherokee MHP	7.8	Small system. No WQ issues. Pipeline would pass through Kerrville.
City of Kerrville	8.0	Large system. No WQ issues. **Evaluate further.**
Horseshoe Oaks Subd Water System	8.1	Small system with WQ issues: radium and gross alpha.
Kerr Villa MHP	8.2	Small system. No WQ issues. Pipeline would pass through Kerrville.
Hillcrest Inn	8.3	Small system. No radium data.
Wood Trail Water Supply	9.3	Small system. No WQ issues. Pipeline would pass through Kerrville.
Falling Water Subdivision	9.6	Small system with WQ issues: radium.
Buckhorn Lake Resort	9.6	Small system. No radium data.
Whispering Oaks	9.9	Small system with WQ issues: marginal gross alpha.
El Gallo Mexican Restaurant	10.0	Small system. No radium data.
Sleepy Hollow	10.0	Small system. No WQ issues. Pipeline would pass through Kerrville.
City of Fredericksburg	15	Large system. No WQ issues. **Evaluate further.**

Table 4.2 Public Water Systems within the Vicinity of Live Oaks MHP Selected for Further Evaluation

System Name	Pop	Conn	Total Production (mgd)	Ave Daily Usage (mgd)	Approx. Dist. from Live Oaks MHP	Comments/Other Issues
The Wilderness	300	100	0.201	0.015	3.8 miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well.
Cherry Ridge Water Co	72	24	0.036	0.009	4.3 miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well.
Scenic Valley MHP	270	90	0.176	0.075	6.2 miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well.
City of Kerrville	21,653	11,534	10.4	3.76	8.0 miles	Have excess capacity and are willing to discuss selling water.
City of Fredericksburg	11,966	4,986	8.89	2.09	15 miles	Have excess capacity and are willing to discuss selling water. Already blends water to address radium issues.

4.2.1.1 The Wilderness

The Wilderness PWS is located northeast of Kerrville, approximately 4 miles southwest of Live Oaks MHP PWS. The Wilderness PWS is supplied by a single groundwater well completed in the Glen Rose Limestone formation (Code 218GLRS). This well is 750 feet deep and has a total production of 0.201 mgd. Water is disinfected using hypochlorination before being distributed. The Wilderness serves a population of 300, has 100 metered connections, and has an approximate average daily usage of 0.015 mgd.

The Wilderness PWS does not have sufficient excess capacity to supplement Live Oaks MHP PWS's existing supply; however, based on the available water quality data, the location may be a suitable point for a new groundwater well.

4.2.1.2 Cherry Ridge Water Company

Cherry Ridge Water Company serves a mobile home park located northeast of Kerrville, approximately 4 miles to the southwest of Live Oaks MHP PWS. The PWS is owned and operated by Aqua Texas, and is supplied by a single groundwater well completed in the Hensell Sand Member of the Travis Peak formation (Code 218HNSL). This well is 620 feet deep and has a total production of 0.036 mgd. Water is treated with a polyphosphate inhibitor and disinfected using hypochlorite before being distributed. Cherry Ridge Water Company serves a population of 72 and has 24 metered connections.

Cherry Ridge Water Company does not have sufficient excess capacity to supplement Live Oaks MHP PWS's existing supply; however, based on the available water quality data, the location may be a suitable point for a new groundwater well.

4.2.1.3 Scenic Valley Mobile Home Park

Scenic Valley Mobile Home Park is located northeast of Kerrville, approximately 6 miles southwest of Live Oaks MHP PWS. The PWS is supplied by two groundwater wells that are both completed in the Hensell Sand Member of the Travis Peak formation (Code 218HNSL). These wells are 370 and 400 feet deep, respectively, and have a total production of 0.176 mgd. Water is disinfected with hypochlorite before being distributed. Scenic Valley Mobile Home Park serves a population of 270, has 90 connections, and has an approximate average daily usage of 0.075 mgd.

Scenic Valley Mobile Home Park does not have sufficient excess capacity to supplement Live Oaks MHP PWS's existing supply; however, based on the available water quality data, the location may be a suitable point for a new groundwater well.

4.2.1.4 City of Kerrville

The City of Kerrville is located approximately 12 miles southwest of Live Oaks MHP PWS. The water supply for the City of Kerrville consists of a series of ground water wells and a surface water plant that treats water from the headwaters of the Guadalupe River. There are five groundwater extraction wells located throughout the City of Kerrville, all of which are completed in the Hosston formation (Code 217HSTN). These wells range from 600 to 638 feet in depth and do not have any water quality issues. The current production rates are 6,625 acre-feet/year, or 5.91 mgd and 4.25 mgd for the well field and surface water plant, respectively. The City has a population of approximately 21,650 people and a total of 11,534 connections. The average annual usage for the city of Kerrville is between 3.4 and 3.8 mgd.

The water and waste water systems at the City of Kerrville consist of a staff of 42 personnel who run the day-to-day operations, maintain a small in-house testing lab, and handle small construction and maintenance activities. Until several years ago, the Upper Guadalupe River Authority (UGRA) was involved with a portion of the operations of the Kerrville water system. UGRA is still in existence, but has no means of conveying the water via pipeline or tanker. It has access to 2,000 acre-feet/year or 1.79 mgd from the Upper Guadalupe River until its permit expires in 2010.

Water treatment facility personnel make the day-to-day technical decisions. However, the five-member City Council makes the decisions regarding major changes proposed by the public works staff, such as the current expansion to the surface water plant, which has an anticipated completion date of summer 2006. The sale of treated water to a system such as the Live Oaks MHP PWS must be also approved by the five-member City Council. Future changes planned for the water system include modifying the surface water intake from a standard stream intake system to a river bank extraction system where the stream sediments between the extraction wells and the streambed serve as a filtration system.

To be prepared for any future drought conditions, the City of Kerrville evaluated the feasibility of aquifer storage and recovery in the Kerrville area. Based on the study, it was determined that the Lower Trinity below the Hammond Shale would serve as an excellent rock formation or aquifer for storing approximately 1.5 billion gallons of water (approximate volume of water usage per year). A portion of the water recovered from both the surface water supply and groundwater is chlorinated and then pumped through two injection wells into the Lower Trinity at a depth of about 600 feet. As of July 2005, approximately 485 million gallons of water have been pumped into the Lower Trinity. The first injection well was installed in 1998 followed by a second in 2003. A third injection well is currently being proposed.

The City of Kerrville has sufficient excess capacity to supplement Live Oaks MHP PWS's existing supply. If an agreement could be negotiated with the City Council, the City of Kerrville could be a viable alternative source of water.

4.2.1.5 City of Fredericksburg

The City of Fredericksburg is located approximately 15 miles northeast of Live Oaks MHP PWS. The water for Fredericksburg is collected from two wells in the Hickory formation (Code 371HCKR), which are at a depths of 332 and 370 feet, and seven wells in the Ellenburger formation (Code 367ELBG) at depths between 216 and 500 feet. The maximum production from the nine wells is rated at 8.9 mgd; however, the current production rate is 4.3 mgd and the average usage is 2.1 mgd. The City of Fredericksburg serves a population of approximately 12,000 and has almost 5,000 connections.

Groundwater from the two deeper wells is stored in a 1-million gallon tank, and groundwater from the seven shallow wells is stored in a second 1-million gallon tank. Analytical results for water samples from the two deeper wells indicate elevated levels of radium at 10 pCi/L, whereas radium has not been detected in the seven shallower wells. For this reason, the City of Fredericksburg has a verbal agreement with the TCEQ to blend the water from the two tanks to achieve compliance with the MCL for total radium (5 pCi/L).

According to the Utility Manager for the City of Fredericksburg, Mr. Gerry Banks, the City of Fredericksburg considered a water supply option in the early 1990s to transport water from Lake Buchanan to the City of Fredericksburg. The cost was estimated by the Lower Colorado River Authority to be approximately $20 million. Mr. Banks also indicated that LBG Guyton from Austin is currently in the process of developing a Groundwater Availability Evaluation for the Ellenburger formation in the Fredericksburg area. Preliminary discussions between LBG and Mr. Banks indicate that the Ellenburger formation is very capable of serving as a suitable ground water source for Fredericksburg.

Future plans for the water system at the City of Fredericksburg include supplementing the current system with a third million gallon storage tank. A majority of the costs for the tank would be handled by the private funds being used to construct a golf course 3 miles from the City of Fredericksburg. Two more wells would be installed and would not be connected to the system, but would be available for future use. The golf course development would use well water for drinking water use, but plan to use surface water for maintaining the grounds.

All decisions relating to water treatment and distribution are made by the five-person City Council. The City does have excess capacity and could be a viable alternative source of water, assuming a suitable agreement could be negotiated.

4.2.2 Potential for New Groundwater Sources

4.2.2.1 Installing New Compliant Wells

Developing new wells or well fields is recommended, provided good quality groundwater available in sufficient quantity can be identified. Since a number of water systems in the area have problems with radium, it should be possible to share in the cost and effort of identifying compliant groundwater and constructing well fields.

Installation of new wells in the vicinity of the system intake point is likely to be an attractive option provided compliant groundwater can be found, since the PWS is already familiar with operation of a water well.. As a result, existing nearby 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.

The use of existing wells should probably be limited to use as indicators of groundwater quality and availability. If a new groundwater source is to be developed, it is recommended that a new well or wells be installed instead of using existing wells. This would ensure well characteristics are known and meet standards for drinking water wells.

Some of the alternatives suggest new wells be drilled in areas where existing wells are compliant. In developing the cost estimates, it is assumed that 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. Two wells are used in cases where the PWS is large enough that two wells are required by TCEQ rules.

4.2.2.2 Results of Groundwater Availability Modeling

The PWS is located in the southeast edge of the Edwards-Trinity Plateau aquifer that extends along central and west Texas. According to TCEQ records, the Live Oaks MHP PWS groundwater supply is the Hensell Sand formation of the Edwards-Trinity Plateau aquifer. The 2002 Texas Water Plan indicates that the overall groundwater supply from the aquifer is likely to remain at nearly current levels over the next 50 years. The anticipated aquifer supply in the year 2050 is 220,374 acre-feet per year (AFY), representing a 3 percent decline relative to 2000 conditions.

In September 2004 the TWDB published results of the GAM for the Edwards-Trinity Plateau aquifer (Anaya and Jones 2004). The Live Oaks MHP PWS is located within the Southeastern Edwards Plateau segment of the aquifer. Over this segment, groundwater pumping represents approximately 25 percent of the aquifer discharge. GAM data indicate that the rate of total withdrawal from the Edwards-Trinity Plateau aquifer in Gillespie County would increase moderately over the next decades, from an estimated 1,994 AFY in 2000, to 2,175 AFY by the year 2050. The Edwards-Trinity Plateau aquifer GAM was not run for the Live Oaks MHP PWS. Potential groundwater usage by the system would be a small addition to the regional withdrawal, making potential changes in aquifer levels by the PWS beyond the spatial resolution of the regional GAM model.

The Live Oaks MHP PWS overlays a second groundwater source, the outcrop of the Trinity aquifer present along the upper half of Kendall County; in some areas water-bearing rock formations are located below the Edwards-Trinity aquifer. The outcrop of the Trinity aquifer is present along southeast Gillespie County, and in some areas water-bearing rock formations are located below the Edwards-Trinity aquifer. The Trinity aquifer runs along central and north Texas, and its water supply is expected to moderately decrease over the next 50 years. The 2002 Texas Water Plan anticipates a supply of 150,317 acre-feet by the year 2050, a 4 percent decline in supply relative to value estimated for the year 2000. A GAM model for the Hill Country area of the Trinity aquifer was completed by the TWDB in September 2000. Long-term numerical simulation of future water levels for drought-of-record conditions indicated that water levels in the aquifer may decline up to 100 feet by 2050. The largest water level decline is anticipated in the Cibolo Creek area in northern Bexar, western Comal, and southern Kendall counties. For south Gillespie County, where Live Oaks MHP PWS is located, the anticipated decline by the year 2050 is moderate, within the 10 to 25-foot range (Mace, *et al*. 2000).

An additional groundwater source, the downdip of the Hickory aquifer, extends through the entire Gillespie County. Currently there is a minimum utilization of the Hickory aquifer by PWS in the Live Oaks MHP PWS vicinity. The 2002 Texas Water Plan indicates that water supply from this aquifer, considered minor on the basis of potential water production, will steadily decline over several decades from 50,699 AFY in 2000 to 46,133 AFY in 2050.

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 Live Oaks MHP is located in the central Colorado Basin, few miles from the upper Guadalupe Basin. Current surface water availability in the Colorado Basin is expected to steadily decrease as a result of the increased water demand. The Texas Water Development Board's 2002 Water Plan anticipates a 11 percent reduction in surface water availability in the Colorado River basin over the next 50 years, from 879,400 AFY in 2000 to 783,641 AFY in 2050. The west boundary of the Guadalupe basin is located approximately 6 miles from the Live Oaks MHP. Current surface water availability in the Guadalupe Basin is expected to decrease 5 percent as a result of the increased water demand (2002 Texas Water Plan).

The vicinity of the Live Oaks MHP system has a minimum availability of surface water for new uses as indicated by the TCEQ's availability maps for the Colorado and Guadalupe Basins. In the site vicinity, and over the entire Gillespie County, unappropriated flows for new uses are available at most 25 percent of the time in both basins. This supply is inadequate as the TCEQ requires 100 percent supply availability for a PWS.

4.2.4 Options for Detailed Consideration

The initial review of alternative sources of water for the Live Oaks MHP PWS (LOM) results in the following options for more-detailed consideration:

1. Scenic Valley MHP. A new groundwater well would be completed in the vicinity of the well at the Scenic Valley Mobile Home Park. A pipeline would be constructed and the water would be piped to Live Oaks MHP PWS (Alternative LOM-1). *This alternative would have almost identical costs to a similar alternative involving the nearby Cherry Ridge Water Company and the Wilderness, so these alternatives will be considered to be identical for purposes of this report.*

2. City of Kerrville. Water would be purchased from the City of Kerrville to be used by the Live Oaks MHP PWS. A pipeline would be constructed to convey water from a City of Kerrville water main to Live Oaks MHP PWS (Alternative LOM-2).

3. City of Fredericksburg. Water would be purchased from the City of Fredericksburg to be used by the Live Oaks MHP PWS. A pipeline would be constructed to convey water from a City of Fredericksburg water main to Live Oaks MHP PWS (Alternative LOM-3).

4. Installing a new well within 10, 5, or 1 mile of Live Oaks MHP PWS that would produce compliant water in place of the water produced by the existing wells (Alternatives LOM-4, LOM-5, and LOM-6).

4.3 TREATMENT OPTIONS

4.3.1 Centralized Treatment Systems

Centralized treatment of well field water is identified as a potential for the Live Oaks MHP PWS. IX, WRT Z-88 adsorption, and $KMnO_4$-greensand filtration are potential applicable processes. The central IX treatment alternative is Alternative LOM-7, the central Z-88 treatment process alternative is Alternative LOM-8, and the central $KMnO_4$-greensand treatment alternative is Alternative LOM-9.

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 LOM-10.

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 LOM-11.

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 LOM-12, LOM-13, and LOM-14.

4.5 ALTERNATIVE DEVELOPMENT AND ANALYSIS

A number of potential alternatives for compliance with the MCL for total radium have been identified. Each potential alternative 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 LOM-1: New Well at Scenic Valley MHP

This alternative involves completing a new well in the vicinity of Scenic Valley Mobile Home Park, and constructing a pump station and pipeline to transfer the pumped groundwater to the Live Oaks MHP PWS. Based on the water quality data in the TCEQ database, it is expected that groundwater from this well would be compliant with drinking water MCLs, though there may be a minor issue with iron to take into consideration. An agreement would need to be negotiated with Scenic Valley Mobile Home Park to expand its well field.

This alternative would require completing a new 385-foot well and storage tank at the Scenic Valley Mobile Home Park, and constructing a pipeline from that well to the existing intake points for the Live Oaks MHP PWS. A pump station would also be required to overcome pipe friction and the elevation differences between Scenic Valley Mobile Home Park and Live Oaks MHP PWS. The required pipeline would be constructed of 4-inch pipe and would follow Scenic Valley Park, Scenic Valley Rd., Hwy 16, Oak Ridge Rd., and Blue Stem Circle to Live Oaks MHP. Using this route, the pipeline required would be 7.7 miles in length. The pipeline would terminate at the existing Live Oaks MHP PWS storage tanks. The required pump horsepower would be 8 hp.

The pump station would include two pumps, including one 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 Live Oaks MHP PWS even if blending is planned, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative presents a limited regional solution since Scenic Valley MHP and Live Oaks MHP PWS would be working together. There are not other PWSs located near Live Oaks MHP PWS that would be good candidates for sharing the cost of this alternative.

The estimated capital cost for this alternative includes the cost to complete the new well, and construct 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 $1.92 million, and the alternative's estimated annual O&M cost is $11,686. If the purchased water was used for blending rather than for the full water supply, the annual O&M cost for this alternative could be reduced because of reduced pumping costs and reduced water purchase costs. However, additional costs would be incurred for equipment to ensure proper blending, and additional monitoring to ensure the finished water is compliant.

The reliability of adequate amounts of compliant water under this alternative should be good. From the Live Oaks MHP PWS' perspective, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood, and Live Oaks MHP PWS personnel currently operate pipelines and a pump station. If the decision were made to perform blending, then the operational complexity would increase.

The feasibility of this alternative would be dependent on Live Oaks MHP PWS being able to reach an agreement with the Scenic Valley Mobile Home Park to install a new groundwater well.

4.5.2 Alternative LOM-2: Purchase Water from the City of Kerrville

This alternative involves purchasing compliant water from the City of Kerrville, which would be used to supply the Live Oaks MHP PWS. The City has indicated it does have excess production capacity and would be willing to consider selling water to PWSs within Kerr County, assuming a suitable agreement could be negotiated.

This alternative would require construction of a storage tank at a point adjacent to the City of Kerrville's water system, and a pipeline from the tank to the existing intake points for the Live Oaks MHP PWS. A pump station would also be required to overcome pipe friction and the elevation differences between Kerrville and the Live Oaks MHP PWS. The required pipeline would be constructed of 4-inch pipe and would follow State Highway 16 from Kerrville to the Live Oaks MHP PWS. Using this route, the length of pipe required would be 8.4 miles. The pipeline would terminate at the existing storage tanks at the Live Oaks MHP PWS. The required pump horsepower is 8 hp.

The pump station would include two pumps, including one 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 Live Oaks MHP PWS even if blending is planned, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative involves regionalization by definition, since Live Oaks MHP PWS would be obtaining drinking water from an existing larger supplier. It is possible that the Live Oaks MHP PWS could turn over provision of drinking water to the City of Kerrville instead of purchasing water.

The estimated capital cost for this alternative includes constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost that Live Oaks MHP PWS currently pays to operate its well field, 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 $2.06 million, and the alternative's estimated annual O&M cost is $20,121. If the purchased water was used for blending rather than for the full water supply, the annual O&M cost for this alternative could be reduced because of reduced pumping costs and reduced water purchase costs. However, additional costs would be incurred for equipment to ensure proper blending, and additional monitoring to ensure the finished water is compliant.

The reliability of adequate amounts of compliant water under this alternative should be good. The City of Kerrville has adequate O&M resources. From Live Oaks MHP PWS' perspective, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood, and Live Oaks MHP PWS personnel currently operate pipelines and pump stations. If the decision were made to perform blending, then the operational complexity would increase.

This alternative has the potential to provide a regional solution, as there are several PWSs in the vicinity that have a need for compliant water. PWSs located near the proposed pipeline route could share the cost of pipeline construction.

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

4.5.3 Alternative LOM-3: Purchase Water from the City of Fredericksburg

This alternative involves purchasing compliant water from the City of Fredericksburg, which would be used to supply the Live Oaks MHP PWS. The City currently has sufficient excess capacity to sell additional water outside their community, assuming that an agreement could be negotiated.

This alternative would require construction of a storage tank at a point adjacent to the City of Fredericksburg's water system, and a pipeline from the tank to the existing intake points for the Live Oaks MHP PWS. A pump station would also be required to overcome pipe friction and the elevation differences between Fredericksburg and the Live Oaks MHP PWS. The required pipeline would be constructed of 4-inch pipe and would follow State Highway 16 from Fredericksburg to the Live Oaks MHP PWS. Using this route, the length of pipe required would be approximately 14.5 miles. The pipeline would terminate at the existing storage tanks at the Live Oaks MHP PWS. The pump station would include two pumps, including one standby, and would be housed in a building. The required pump horsepower is 7 hp.

This alternative involves regionalization by definition, since Live Oaks MHP PWS would be obtaining drinking water from an existing larger supplier. It is possible that the Live Oaks MHP PWS could turn over provision of drinking water to the City of Fredericksburg instead of purchasing water.

The estimated capital cost for this alternative includes constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost that Live Oaks MHP PWS currently pays to operate its well field, 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 $3.46 million, and the alternative's estimated annual O&M cost is $22,148. Using the purchased water for blending would not be an option in this case, because the City of Fredericksburg already blends its drinking water to achieve compliance for radium.

The reliability of adequate amounts of compliant water under this alternative should be good. The City of Fredericksburg has adequate O&M resources. From Live Oaks MHP PWS' perspective, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood, and Live Oaks MHP PWS personnel currently operate pipelines and pump stations.

This alternative has the potential to provide a regional solution, as there are several PWSs in the vicinity that have a need for compliant water. PWSs located near the proposed pipeline route could share the cost of pipeline construction.

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

4.5.4 Alternative LOM-4: New Well at 10 miles

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

This alternative would require construction of a new 385-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the existing intake points for the Live Oaks MHP 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 approximately 10 miles long, and would be an 4-inch pipe that discharges to the existing storage tanks at the Live Oaks MHP PWS. The pump station would include two pumps, including one standby, and would be housed in a building.

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 $2.46 million, and the estimated annual O&M cost for this alternative is $12,260.

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 Live Oaks MHP PWS, this alternative would be similar to operate as the existing system. The Live Oaks MHP PWS has 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 likely the alternate groundwater source would not be found on land controlled by the Live Oaks MHP PWS, so landowner cooperation would likely be required.

4.5.5 Alternative LOM-5: New Well at 5 miles

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

This alternative would require constructing a new 385-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the existing intake point for the Live Oaks MHP PWS system. 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 approximately 5 miles long, and would be an 4-inch line that discharges to the existing storage tank at the Live Oaks MHP PWS. The pump station would include two pumps, including one standby, and would be housed in a building.

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 the cost for O&M for the pipeline and pump station. The estimated capital cost for this alternative is $1.33 million, and the estimated annual O&M cost for this alternative is $10,292.

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 Live Oaks MHP PWS, this alternative would be similar to operate as the existing system. The Live Oaks MHP PWS has 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 likely the alternate groundwater source would not be found on land controlled by the Live Oaks MHP PWS, so landowner cooperation would likely be required.

4.5.6 Alternative LOM-6: New Well at 1 mile

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

This alternative would require construction of a new 385-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the existing intake points for the Live Oaks MHP 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 approximately 1 mile long, and would be an 4-inch pipe that discharges to the existing storage tanks at the Live Oaks MHP PWS. The pump station would include two pumps, including one standby, and would be housed in a building.

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 the cost for O&M for the pipeline and pump station. The estimated capital cost for this alternative is $269,042 and the estimated annual O&M cost for this alternative is $6,596 less what is being spent to operate 2 wells..

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 Live Oaks MHP PWS, this alternative would be similar to operate as the existing system. The Live Oaks MHP PWS has 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 likely an alternate groundwater source would not be found on land controlled by the Live Oaks MHP PWS, so landowner cooperation would likely be required.

4.5.7 Alternative LOM-7: Central IX Treatment

Two individual central treatment plants would be required for the Live Oaks MHP PWS. The No. 1 system would continue to pump water from the Live Oaks MHP PWS Well No. 1, and would treat the water through an IX system prior to distribution to the lower distribution system. The No. 2 system would continue to pump water from Well No. 2, and would treat the water through an IX system prior to distribution to the upper distribution. For this option, the entire flow of the raw water will be treated to obtain compliant water. Water in excess of that currently produced would be required for backwashing and regeneration of the resin beds.

The two IX treatment plants would be located at the Live Oaks MHP PWS well sites, and each 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 12,000-gallon tank for storing spent backwash water, and a 4,000 gallon tank for storing regenerant waste. The spent backwash would be allowed to settle in the spent backwash tank, and the water would be recycled to the head of the plant, and there would be periodic disposal of accumulated sludge. The regenerant waste would be trucked off-site for disposal. The treated water would be chlorinated prior to being pumped into the distribution system.

The estimated total capital cost for this alternative is $613,640, and the estimated total annual O&M cost is $54,484.

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.

4.5.8 Alternative LOM-8: Central WRT Z-88 Treatment

Two individual WRT Z-88™ systems would be required for this alternative. The systems would continue to pump water from the Live Oaks MHP PWS Well 1 and Well 2, and would treat the water through the Z-88™ adsorption systems 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 two Z-88™ treatment systems at the existing Live Oaks MHP PWS well sites. 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 for each system. Each plant comprises a 400 ft^2 building with a paved driveway; the pre-constructed Z-88™ adsorption system (2- 32" diameter x 115" tall vessels) owned by WRT; and piping system. The entire facility is fenced. The treated water will be chlorinated prior to distribution. It is assumed that the well pumps have adequate pressure to pump the water through the Z-88™ system and to the existing storage tanks without requiring new pumps.

The estimated capital cost for this alternative is $598,560 and the annual O&M cost is estimated to be $68,873.

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.

4.5.9 Alternative LOM -9: Central $KMnO_4$ Treatment

This alternative includes installing two individual KMnO4-green sand filtration systems. The systems would continue to pump water from Live Oaks MHP PWS Well 1 and Well 2, and would treat the water through two individual greensand filter systems prior to distribution. For this option, the entire flow of 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. It is assumed that the existing well pumps have adequate pressure to pump the water through the greensand filters and to the existing storage tanks.

The two greensand plants, located at Live Oaks MHP PWS well sites, each features a 400 ft^2 building with a paved driveway; the pre-constructed filters and a $KMnO_4$ solution tank on a skid; a 18,000 gallon spent backwash tank, and piping systems. The spent backwash would be allowed to settle in the spent backwash tank, and the water would be recycled to the head of the plant, and there would be periodic disposal of accumulated sludge. The entire facility is fenced.

The estimated total capital cost for this alternative is $640,610 and the total annual O&M is estimated to be $60,148.

Reliability of supply of adequate amounts of compliant water under this alternative is good, since $KMnO_4$-greensand is an established treatment technology for radium removal. The O&M efforts required is moderate and the operating personnel needs to ensure that $KMnO_4$ is not overfed. The spent backwash water contains MnO_2 particles with sorbed radium and the level of radioactivity in the backwash is relatively low.

4.5.10 Alternative LOM -10: Point-of-Use Treatment

This alternative consists of the continued operation of the Live Oaks MHP PWS wells, plus treatment of water to be used for drinking or food preparation at the point of use to remove radium. 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 installation of the POU treatment units in residences and other buildings that provide drinking or cooking water The Live Oaks MHP PWS would be responsible for purchasing and maintaining 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 Live Oaks MHP PWS or contract personnel into the houses of customers. As a result, the cooperation of customers would be important for success in 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 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 increase in water required, and the 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 regional solution.

The estimated capital cost for this alternative includes purchasing and installing the POU treatment systems. 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 $87,120, and the estimated annual O&M cost for this alternative is $83,820. For the cost estimate, it is assumed that one POU treatment unit would be required for each of the 132 connections to the Live Oaks MHP PWS. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets in order to meet regulatory requirements, making purchase and installation more expensive.

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 would be significant, and the Live Oaks MHP PWS personnel are inexperienced in this type of work. From the perspective of the Live Oaks MHP PWS, this alternative would be characterized as more difficult to operate due to the in-home requirements and large number of individual units.

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

4.5.11 Alternative LOM -11: Point-of-Entry Treatment

This alternative consists of the continued operation of the Live Oaks MHP PWS wells, plus treatment of water as it enters residences to remove radium. The purchase, installation, and maintenance of the treatment systems at the POE to a household would be necessary for this alternative. Blending is not an option in this case.

This alternative would require installation of the POE treatment units at residences and other buildings that provide drinking or cooking water. The Live Oaks MHP PWS 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 total radium 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 regional solution.

The estimated capital cost for this alternative includes purchasing and installing the POE treatment systems. 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 $1.52 million, and the estimated annual O&M cost for this alternative is $186,120. For the cost estimate, it is assumed that one POE treatment unit would be required for each of the 132 connections to the Live Oaks MHP PWS .

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

4.5.12 Alternative LOM -12: Public Dispenser for Treated Drinking Water

This alternative consists of the continued operation of the Live Oaks MHP PWS wells, 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 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.

The Live Oaks MHP PWS would be responsible for maintaining the treatment units, including media or membrane replacement, periodic sampling, and necessary repairs. The spent media or membranes would require disposal. This alternative relies on a great deal of cooperation and action from the customers in order 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. 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 $17,015.

The reliability of adequate amounts of compliant water under this alternative is fair, because of the large amount of effort required from customers and the associated inconvenience. The Live Oaks MHP PWS has not provided this type of service in the past. From the perspective of the Live Oaks MHP PWS, 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.

4.5.13 Alternative LOM -13: 100 Percent Bottled Water Delivery

This alternative consists of the continued operation of the Live Oaks MHP PWS wells, but compliant drinking water would be delivered in containers to customers. This alternative involves setting up and operating a bottled water delivery program to serve all customers in the system. It is expected the Live Oaks MHP PWS 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 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 would be provided to 100 percent of the Live Oaks MHP 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 $24,738, and the estimated annual O&M cost for this alternative is $178,472. For the cost estimate, it is assumed each person requires 1 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 would require attention from the Live Oaks MHP PWS.

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

4.5.14 Alternative LOM -14: Public Dispenser for Trucked Drinking Water

This alternative consists of continued operation of the Live Oaks MHP PWS wells, plus dispensing compliant water for drinking and cooking at a publicly accessible location. The compliant water would be purchased from the City of Kerrville, and would be 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.

The Live Oaks MHP PWS would purchase a truck 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 does not present options for a regional solution.

The estimated capital cost for this alternative includes purchasing a water truck, and constructing 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 $15,877.

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. The Live Oaks MHP PWS has not provided this type of service in the past. From the perspective of the Live Oaks MHP PWS, 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.

4.5.15 Summary of Alternatives

Table 4.3 provides a summary of the key features of each alternative for the Live Oaks MHP PWS.

1 **Table 4.3 Summary of Compliance Alternatives for the Live Oaks MHP PWS**

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
LOM-1	New well at Scenic Valley MHP	- New well - Pump station - 7.7-mile pipeline	$ 1,915,459	$ 11,686	$ 178,685	Good	N	Agreement must be successfully negotiated with Scenic Valley MHP, or land must be purchased. Blending may be possible. Costs could possibly be shared with small systems along pipeline route.
LOM-2	Purchase treated water from City of Kerrville	- Storage Tank - Pump station - 8.4-mile pipeline	$ 2,058,187	$ 20,121	$ 199,563	Good	N	Agreement must be successfully negotiated with Kerrville, or land must be purchased. Blending may be possible. Costs could possibly be shared with small systems along pipeline route.
LOM-3	Purchase treated water from City of Fredericksburg	- Storage Tank - Pump station - 14.5-mile pipeline	$ 3,457,559	$ 22,148	$ 323,593	Good	N	Agreement must be successfully negotiated with Fredericksburg. Blending may be possible. Costs could possibly be shared with small systems along pipeline route.
LOM-4	Install new compliant well within 10 miles	- New well - Storage tank - Pump station - 10-mile pipeline	$ 2,457,607	$ 12,260	$ 226,525	Good	N	May be difficult to find well with good water quality. Costs could possibly be shared with small systems along pipeline route.
LOM-5	Install new compliant well within 5 miles	- New well - Storage tank - Pump station - 5-mile pipeline	$ 1,331,891	$ 10,292	$ 126,412	Good	N	May be difficult to find well with good water quality. Costs could possibly be shared with small systems along pipeline route.
LOM-6	Install new compliant well within 1 mile	- New well - Storage tank - Pump station - 1-mile pipeline	$ 269,042	($6,596)	$ 16,860	Good	N	May be difficult to find well with good water quality.
LOM-7	Continue operation of Live Oaks PWS well field with central IX treatment	- Central IX treatment plant	$ 613,640	$ 54,484	$ 107,984	Good	T	Costs could possibly be shared with nearby small systems.
LOM-8	Continue operation of Live Oaks PWS well field with central WRT Z-88 treatment	- Central WRT Z-88 treatment plant	$ 598,560	$ 68,873	$ 121,058	Good	T	Costs could possibly be shared with nearby small systems.
LOM-9	Continue operation of Live Oaks PWS well field with central KMnO4 treatment	- Central KMnO4 treatment plant	$ 640,610	$ 60,148	$ 115,999	Good	T	Costs could possibly be shared with nearby small systems.
LOM-10	Continue operation of Live Oaks PWS well field, and POU treatment	- POU treatment units.	$ 87,120	$ 83,820	$ 91,416	Fair	T, M	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
LOM-11	Continue operation of Live Oaks PWS well field, and POE treatment	- POE treatment units.	$ 1,524,600	$ 186,120	$ 319,042	Fair (*better than POU*)	T, M	All home taps compliant and less resident cooperation required.
LOM-12	Continue operation of Live Oaks PWS well field, but furnish public dispenser for treated drinking water	- Water treatment and dispenser unit	$ 11,600	$ 17,015	$ 18,026	Fair/interim measure	T	Does not provide compliant water to all taps, and requires a lot of effort by customers.
LOM-13	Continue operation of Live Oaks PWS well field, but furnish bottled drinking water for all customers	- Set up bottled water system	$ 24,738	$ 178,472	$ 180,628	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.
LOM-14	Continue operation of Live Oaks PWS well field, but furnish public dispenser for trucked drinking water.	- Construct storage tank and dispenser - Purchase potable water truck	$ 102,986	$ 15,877	$ 24,856	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 would require increase in technical capability
M – Implementation of alternative would 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

4.6.1 Live Oaks MHP PWS Financial Data

No separate financial data are maintained by the system operator for the Live Oaks MHP PWS. Financial information on the water system is included in the consolidated financial data for the overall business. Water usage does not constitute a separate monthly billing, but is included in the monthly rent for the mobile home pads. The estimated water usage per connection is approximately $25/month, or approximately 10 percent of monthly pad rental. This value was used in the financial model as the basic monthly charge for unlimited water usage with no additional rate structure tiers. Financial data for system expenditures for Live Oaks MHP PWS were based on estimates and pro-rating of expenses based on documented expenses of similar systems.

This analysis will need to be performed in a more detailed fashion and applied to alternatives that are 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.

4.6.2 Current Financial Condition

4.6.2.1 Cash Flow Needs

Based on estimates for the system, the current average annual water use by residential customers of Live Oaks MHP PWS is estimated to be $300, or approximately 1.1 percent of the annual household income of $27,621 for the Census Block Group that includes the Midway MHP PWS. Because of the lack of separate financial data exclusively for the water system, it is difficult to determine exact cash flow needs. The owner believes water usage revenues are sufficient to cover of expenditures so the water system is not subsidized by other revenues.

4.6.2.2 Ratio Analysis

Current Ratio

The Current Ratio for the Live Oaks MHP PWS could not be determined due to lack of necessary financial data to determine this ratio.

Debt to Net Worth Ratio

A Debt-to-Net-Worth Ratio also could not be determined owing to lack of the necessary financial data to determine this ratio.

Operating Ratio = 1.0

Because of the lack of complete separate financial data on expenses specifically related to the Live Oaks MHP PWS, the Operating Ratio could not be accurately determined. However, based on expenditure estimates for the system, the system's estimated operating expenditures of approximately $39,100 were approximately equal to the operating revenues, with a resulting operating ratio of 1.0. Thus, since the operating ratio is equal to 1.0, revenues may cover expenses for the system.

4.6.3 Financial Plan Results

Each compliance alternative for Live Oaks MHP PWS was evaluated, with emphasis on the impact on affordability (expressed as a percentage of household income), and the overall increase in water rates necessary to pay for the improvements. Each alternative was examined under the various funding options described in Subsection 2.4.

For State Revolving Fund funding options, customer MHI compared to the state average determines the availability of subsidized loans. Since the MHI for customers of Live Oaks MHP PWS was not available, Census Block Group data were used. The Census Block Group for the Live Oaks MHP PWS is located had an estimated annual household income of $27,621 according to the 2000 U.S. Census compared to a statewide average of $39,927, or 69 percent of the statewide average. Since the MHI for Census Block Group is greater than 70 percent of the statewide average, Live Oaks MHP may qualify for an interest rate of 0 percent.

Results of the financial impact analysis are provided in Table 4.4 and Figure 4.2. Table 4.4 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 (5,991 gallons/month consumption), 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 4.4 Financial Impact on Households

Alternative	Description		All Revenue	100% Grant	75% Grant	50% Grant	SRF	Bond
1	New Well at Scenic Valley MHP	Max % of HH Income	58%	3%	5%	7%	8%	11%
		Max % Rate Increase Compared to Current	5272%	131%	332%	534%	646%	936%
		Average Water Bill Required by Alternative	$ 15,088	$ 660	$ 1,215	$ 1,770	$ 2,080	$ 2,881
2	Purchase Water from the City of Kerrville	Max % of HH Income	63%	3%	5%	8%	9%	12%
		Max % Rate Increase Compared to Current	5677%	183%	399%	616%	736%	1048%
		Average Water Bill Required by Alternative	$ 16,224	$ 799	$ 1,395	$ 1,992	$ 2,323	$ 3,184
3	Purchase Water from the City of Fredericksberg	Max % of HH Income	103%	3%	7%	11%	13%	19%
		Max % Rate Increase Compared to Current	9403%	196%	558%	919%	1121%	1643%
		Average Water Bill Required by Alternative	$ 26,680	$ 832	$ 1,830	$ 2,828	$ 3,383	$ 4,823
4	New Well at 10 Miles	Max % of HH Income	73%	3%	5%	8%	10%	14%
		Max % Rate Increase Compared to Current	6658%	135%	390%	646%	788%	1157%
		Average Water Bill Required by Alternative	$ 18,980	$ 669	$ 1,374	$ 2,079	$ 2,471	$ 3,488
5	New Well at 5 Miles	Max % of HH Income	41%	2%	4%	5%	6%	8%
		Max % Rate Increase Compared to Current	3660%	122%	261%	399%	476%	676%
		Average Water Bill Required by Alternative	$ 10,566	$ 637	$ 1,019	$ 1,401	$ 1,613	$ 2,164
6	New Well at 1 Mile	Max % of HH Income	10%	2%	2%	2%	3%	3%
		Max % Rate Increase Compared to Current	782%	67%	95%	123%	139%	179%
		Average Water Bill Required by Alternative	$ 2,495	$ 488	$ 565	$ 642	$ 685	$ 796
7	Central Treatment - IX	Max % of HH Income	22%	5%	6%	7%	7%	8%
		Max % Rate Increase Compared to Current	1888%	396%	460%	524%	560%	652%
		Average Water Bill Required by Alternative	$ 5,579	$ 1,366	$ 1,542	$ 1,718	$ 1,816	$ 2,070
8	Central Treatment - WRT Z-88	Max % of HH Income	22%	6%	7%	8%	8%	9%
		Max % Rate Increase Compared to Current	1892%	486%	548%	610%	645%	735%
		Average Water Bill Required by Alternative	$ 5,587	$ 1,604	$ 1,775	$ 1,947	$ 2,043	$ 2,290
9	Central Treatment - KMnO4	Max % of HH Income	23%	6%	6%	7%	8%	9%
		Max % Rate Increase Compared to Current	1977%	432%	498%	565%	602%	698%
		Average Water Bill Required by Alternative	$ 5,828	$ 1,460	$ 1,643	$ 1,827	$ 1,929	$ 2,195
10	Point-of-Use Treatment	Max % of HH Income	7%	7%	7%	8%	8%	8%
		Max % Rate Increase Compared to Current	579%	578%	587%	596%	602%	615%
		Average Water Bill Required by Alternative	$ 1,898	$ 1,850	$ 1,875	$ 1,900	$ 1,914	$ 1,950
11	Point-of-Entry Treatment	Max % of HH Income	52%	14%	16%	18%	19%	21%
		Max % Rate Increase Compared to Current	4718%	1213%	1371%	1530%	1618%	1847%
		Average Water Bill Required by Alternative	$ 13,481	$ 3,539	$ 3,976	$ 4,413	$ 4,657	$ 5,288
12	Public Dispenser for Treated Drinking Water	Max % of HH Income	3%	3%	3%	3%	3%	3%
		Max % Rate Increase Compared to Current	171%	164%	165%	166%	167%	169%
		Average Water Bill Required by Alternative	$ 773	$ 748	$ 751	$ 754	$ 756	$ 761
13	Supply Bottled Water to 100% of Population	Max % of HH Income	14%	14%	14%	14%	14%	14%
		Max % Rate Increase Compared to Current	1165%	1165%	1168%	1171%	1172%	1176%
		Average Water Bill Required by Alternative	$ 3,426	$ 3,413	$ 3,420	$ 3,427	$ 3,431	$ 3,441
14	Central Trucked Drinking Water	Max % of HH Income	6%	3%	3%	3%	3%	3%
		Max % Rate Increase Compared to Current	411%	157%	168%	178%	184%	200%
		Average Water Bill Required by Alternative	$ 1,445	$ 729	$ 759	$ 788	$ 804	$ 847

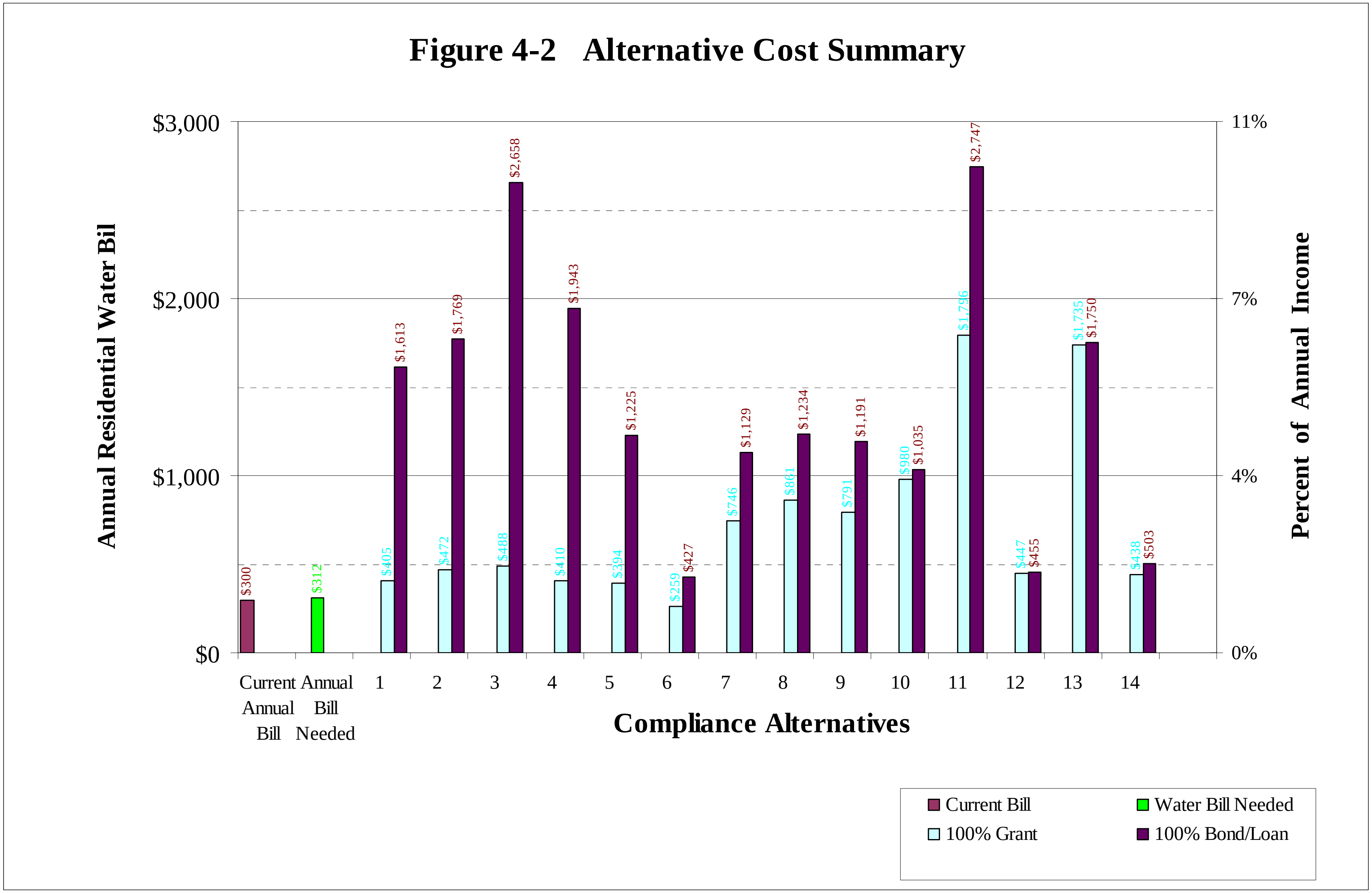


Figure 4-2 Alternative Cost Summary
Annual Residential Water Bil
Percent of Annual Income
$3,000
$2,000
$1,000
$0
11%
7%
4%
0%
$300
$312
$405
$1,613
$472
$1,769
$488
$2,658
$410
$1,943
$394
$1,225
$259
$427
$746
$1,129
$861
$1,234
$791
$1,191
$980
$1,035
$1,796
$2,747
$447
$455
$1,735
$1,750
$438
$503
Current Annual Bill
Annual Bill Needed
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Compliance Alternatives
Current Bill
Water Bill Needed
100% Grant
100% Bond/Loan

1

SECTION 5
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APPENDIX A
PWS INTERVIEW FORMS

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, and building, and tools. Construction cost of a storage tank is based on 2006 RS Means Building Construction Cost Data.

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

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.

Appendix references

USEPA 1978. Technical Report, *Innovative and Alternate Technology Assessment Manual* MCD 53.

USEPA. 1992. Standardized Costs for Water Supply Distribution Systems. EPA/600/R-92/009.

Table B.1
Summary of General Data
Live Oaks Mobile Home Park
PWS # 0860090
General PWS Information

Service Population	264	**Number of Connections**	132
Total PWS Daily Water Usage	0.026 (mgd)	**Source**	TCEQ website

Unit Cost Data
Central Texas

General Items	**Unit**	**Unit Cost**
Treated water purchase cost	*See alternative*	
Water purchase cost (trucked)	$/1,000 gals	$ 1.80
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	$ 395
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	$ 460
Check valve, 04"	EA	$ 540
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 - 15,000 gals	EA	$ 21,600
Electrical Power	$/kWH	$ 0.136
Building Power	kWH	11,800
Labor	$/hr	$ 31
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	$ 31
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	$ 41
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	$ 31
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	$ 1,000
Ion exchange chemicals	year	$ 1,000
Backwash discharge	kgal/year	$ 200
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 Well No.1	1,000 gal/yr	$ 3.75
WRT treated water charge Well No.2	1000 gal/yr	$4.40
KMnO4-greensand package		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
KMnO4-greensand package plant	UNIT	$ 60,000
Backwash tank	gal	$ 2.00
Sewer connection fee	EA	$ 15,000
KMnO4-greensand materials	year	$ 3,000
KMnO4-greensand chemicals	year	$ 2,000
Backwash discharge to sewer	1,000 gal/yr	$ 200
Sludge truck rental	days	$ 700
Sludge truck mileage fee	miles	$ 1.00
Sludge disposal fee	1,000 gal/yr	$ 2,200

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.14. 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	***Live Oaks Mobile Home Park***
Alternative Name	***New Well at Scenic Valley MHP***
Alternative Number	***LOM-1***

Distance from PWS to new well location	7.73	miles
Estimated well depth	385	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	10	n/a	n/a	n/a
Number of Crossings, open cut	2	n/a	n/a	n/a
PVC water line, Class 200, 04"	40,815	LF	$ 27	$ 1,081,598
Bore and encasement, 10"	2,000	LF	$ 60	$ 120,000
Open cut and encasement, 10"	100	LF	$ 35	$ 3,500
Gate valve and box, 04"	8	EA	$ 395	$ 3,224
Air valve	8	EA	$ 1,000	$ 8,000
Flush valve	8	EA	$ 750	$ 6,122
Metal detectable tape	40,815	LF	$ 0.15	$ 6,122
Subtotal				**$ 1,228,566**
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	$ 460	$ 1,840
Check valve, 04"	2	EA	$ 540	$ 1,080
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 - 15,000 gals	1	EA	$ 21,600	$ 21,600
Subtotal				**$ 76,390**
Well Installation				
Well installation	385	LF	$ 25	$ 9,625
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				**$ 30,625**
Subtotal of Component Costs				**$ 1,335,581**
Contingency	20%			$ 267,116
Design & Constr Management	25%			$ 333,895
TOTAL CAPITAL COSTS				**$ 1,936,593**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	7.7	mile	$ 200	$ 1,546
Subtotal				**$ 1,546**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	13,357	kWH	$ 0.136	$ 1,817
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 31	$ 11,315
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 16,936**
Well O&M				
Pump power	1,281	kWH	$ 0.136	$ 174
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 31	$ 5,580
Subtotal				**$ 6,954**
O&M Credit for Existing Well Closure				
Pump power	1,400	kWH	$ 0.136	$ (190)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 31	$ (11,160)
Subtotal				**$ (13,750)**
TOTAL ANNUAL O&M COSTS				**$ 11,686**

Table C.2

PWS Name ***Live Oaks Mobile Home Park***
Alternative Name ***Purchase Water from the City of Kerrville***
Alternative Number ***LOM-2***

Distance from Alternative to PWS (along pipe)	8.4	miles
Total PWS annual water usage	9.490	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	13	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 04"	44,212	LF	$ 27	$ 1,171,618
Bore and encasement, 10"	2,600	LF	$ 60	$ 156,000
Open cut and encasement, 10"	150	LF	$ 35	$ 5,250
Gate valve and box, 04"	9	EA	$ 395	$ 3,493
Air valve	8	EA	$ 1,000	$ 8,000
Flush valve	9	EA	$ 750	$ 6,632
Metal detectable tape	44,212	LF	$ 0.15	$ 6,632
Subtotal				**$ 1,357,624**
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	$ 460	$ 1,840
Check valve, 04"	2	EA	$ 540	$ 1,080
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 - 15,000 gals	1	EA	$ 21,600	$ 21,600
Subtotal				**$ 76,390**
Subtotal of Component Costs				**$ 1,434,014**
Contingency	20%			$ 286,803
Design & Constr Management	25%			$ 358,504
TOTAL CAPITAL COSTS				**$ 2,079,321**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	8.4	mile	$ 200	$ 1,675
Subtotal				**$ 1,675**
Water Purchase Cost				
From Source	9,490	1,000 gal	$ 1.60	$ 15,184
Subtotal				**$ 15,184**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	13,921	kWH	$ 0.136	$ 1,893
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 31	$ 11,315
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 17,013**
O&M Credit for Existing Well Closure				
Pump power	1,400	kWH	$ 0.136	$ (190)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 31	$ (11,160)
Subtotal				**$ (13,750)**
TOTAL ANNUAL O&M COSTS				**$ 20,121**

Table C.3

PWS Name	***Live Oaks Mobile Home Park***
Alternative Name	***Purchase Water from the City of Fredericksberg***
Alternative Number	***LOM-3***

Distance from Alternative to PWS (along pipe)	14.5	miles
Total PWS annual water usage	9.490	MG
Treated water purchase cost	$ 1.65	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	20	n/a	n/a	n/a
Number of Crossings, open cut	5	n/a	n/a	n/a
PVC water line, Class 200, 04"	76,601	LF	$ 27	$ 2,029,927
Bore and encasement, 10"	4,000	LF	$ 60	$ 240,000
Open cut and encasement, 10"	250	LF	$ 35	$ 8,750
Gate valve and box, 04"	15	EA	$ 395	$ 6,051
Air valve	15	EA	$ 1,000	$ 15,000
Flush valve	15	EA	$ 750	$ 11,490
Metal detectable tape	76,601	LF	$ 0.15	$ 11,490
Subtotal				**$ 2,322,708**
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	$ 460	$ 1,840
Check valve, 04"	2	EA	$ 540	$ 1,080
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 - 15,000 gals	1	EA	$ 21,600	$ 21,600
Subtotal				**$ 76,390**
Subtotal of Component Costs				**$ 2,399,098**
Contingency	20%			$ 479,820
Design & Constr Management	25%			$ 599,775
TOTAL CAPITAL COSTS				**$ 3,478,693**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	14.5	mile	$ 200	$ 2,902
Subtotal				**$ 2,902**
Water Purchase Cost				
From Source	9,490	1,000 gal	$ 1.65	$ 15,659
Subtotal				**$ 15,659**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	16,310	kWH	$ 0.136	$ 2,218
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 31	$ 11,315
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 17,338**
O&M Credit for Existing Well Closure				
Pump power	1,400	kWH	$ 0.136	$ (190)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 31	$ (11,160)
Subtotal				**$ (13,750)**
TOTAL ANNUAL O&M COSTS				**$ 22,148**

Table C.4

PWS Name *Live Oaks Mobile Home Park*
Alternative Name *New Well at 10 Miles*
Alternative Number *LOM-4*

Distance from PWS to new well location	10.0	miles
Estimated well depth	385	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	14	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 04"	52,800	LF	$ 27	$ 1,399,200
Bore and encasement, 10"	2,800	LF	$ 60	$ 168,000
Open cut and encasement, 10"	150	LF	$ 35	$ 5,250
Gate valve and box, 04"	11	EA	$ 395	$ 4,171
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				**$ 1,602,461**
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	$ 460	$ 1,840
Check valve, 04"	2	EA	$ 540	$ 1,080
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 - 15,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 61,815**
Well Installation				
Well installation	385	LF	$ 25	$ 9,625
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				**$ 30,625**

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	14,239	kWH	$ 0.136	$ 1,937
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 31	$ 11,315
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 17,056**
Well O&M				
Pump power	1,281	kWH	$ 0.136	$ 174
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 31	$ 5,580
Subtotal				**$ 6,954**
O&M Credit for Existing Well Closure				
Pump power	1,400	kWH	$ 0.136	$ (190)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 31	$ (11,160)
Subtotal				**$ (13,750)**

Table C.5

PWS Name	***Live Oaks Mobile Home Park***
Alternative Name	***New Well at 5 Miles***
Alternative Number	***LOM-5***

Distance from PWS to new well location	5.0	miles
Estimated well depth	385	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	7	n/a	n/a	n/a
Number of Crossings, open cut	2	n/a	n/a	n/a
PVC water line, Class 200, 04"	26,400	LF	$ 27	$ 699,600
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	$ 395	$ 2,086
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				**$ 826,106**
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	$ 460	$ 1,840
Check valve, 04"	2	EA	$ 540	$ 1,080
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 - 15,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 61,815**
Well Installation				
Well installation	385	LF	$ 25	$ 9,625
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				**$ 30,625**

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	11,800	kWH	$ 0.136	$ 1,605
Pump Power	7,120	kWH	$ 0.136	$ 968
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 31	$ 11,315
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 16,088**
Well O&M				
Pump power	1,281	kWH	$ 0.136	$ 174
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 31	$ 5,580
Subtotal				**$ 6,954**
O&M Credit for Existing Well Closure				
Pump power	1,400	kWH	$ 0.136	$ (190)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 31	$ (11,160)
Subtotal				**$ (13,750)**

Table C.6

PWS Name	***Live Oaks Mobile Home Park***
Alternative Name	***New Well at 1 Mile***
Alternative Number	***LOM-6***

Distance from PWS to new well location	1.0	miles
Estimated well depth	385	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	1	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	5,280	LF	$ 27	$ 139,920
Bore and encasement, 10"	200	LF	$ 60	$ 12,000
Open cut and encasement, 10"	-	LF	$ 35	$ -
Gate valve and box, 04"	1	EA	$ 395	$ 417
Air valve	1	EA	$ 1,000	$ 1,000
Flush valve	1	EA	$ 750	$ 792
Metal detectable tape	5,280	LF	$ 0.15	$ 792
Subtotal				**$ 154,921**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 460	$ -
Check valve, 04"	-	EA	$ 540	$ -
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 - 15,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**
Well Installation				
Well installation	385	LF	$ 25	$ 9,625
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				**$ 30,625**

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	$ 31	$ -
Tank O&M	-	EA	$ 1,000	$ -
Subtotal				**$ -**
Well O&M				
Pump power	1,281	kWH	$ 0.136	$ 174
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 31	$ 5,580
Subtotal				**$ 6,954**
O&M Credit for Existing Well Closure				
Pump power	1,400	kWH	$ 0.136	$ (190)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 31	$ (11,160)
Subtotal				**$ (13,750)**

Table C.7

PWS Name *Live Oaks Mobile Home Park*
Alternative Name *Central Treatment - IX*
Alternative Number *LOM-7*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Ion Exchange Unit Purchase/Installation				
Site preparation	1.50	acre	$ 4,000	$ 6,000
Slab	60	CY	$ 1,000	$ 60,000
Building	800	SF	$ 60	$ 48,000
Building electrical	800	SF	$ 8	$ 6,400
Building plumbing	800	SF	$ 8	$ 6,400
Heating and ventilation	800	SF	$ 7	$ 5,600
Fence	1,200	LF	$ 15	$ 18,000
Paving	6,400	SF	$ 2	$ 12,800
Electrical	2	JOB	$ 50,000	$ 100,000
Piping	2	JOB	$ 20,000	$ 40,000
Ion exchange package including:				
Regeneration system				
Brine tank				
IX resins & FRP vessels	2	UNIT	$ 30,000	$ 60,000
Transfer pumps (10 hp)	4	EA	$ 5,000	$ 20,000
Clean water tank	10,000	gal	$ 1.00	$ 10,000
Regenerant tank	4,000	gal	$ 1.50	$ 6,000
Backwash Tank	12,000	gal	$ 2.00	$ 24,000
Sewer Connection Fee	-	EA	$ 15,000	$ -
Subtotal of Component Costs				**$ 423,200**
Contingency	20%			$ 84,640
Design & Constr Management	25%			$ 105,800
TOTAL CAPITAL COSTS				**$ 613,640**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Ion Exchange Unit O&M				
Building Power	24,000	kwh/yr	$ 0.136	$ 3,264
Equipment power	20,000	kwh/yr	$ 0.136	$ 2,720
Labor	800	hrs/yr	$ 31	$ 24,800
Materials	2	year	$ 1,000	$ 2,000
Chemicals	2	year	$ 1,000	$ 2,000
Analyses	48	test	$ 200	$ 9,600
Backwash discharge disposal	2	kgal/yr	$ 200	$ 400
Subtotal				**$ 44,784**
Haul Regenerant Waste and Brine				
Waste haulage truck rental	9	days	$ 700	$ 6,300
Mileage charge	600	miles	$ 1.00	$ 600
Waste disposal	14	kgal/yr	$ 200	$ 2,800
Subtotal				**$ 9,700**
TOTAL ANNUAL O&M COSTS				**$ 54,484**

Table C.8

PWS Name *Live Oaks Mobile Home Park*
Alternative Name *Central Treatment - WRT Z-88*
Alternative Number *LOM-8*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	1.50	acre	$ 4,000	$ 6,000
Slab	60	CY	$ 1,000	$ 60,000
Building	800	SF	$ 60	$ 48,000
Building electrical	800	SF	$ 8	$ 6,400
Building plumbing	800	SF	$ 8	$ 6,400
Heating and ventilation	800	SF	$ 7	$ 5,600
Fence	1,200	LF	$ 15	$ 18,000
Paving	3,200	SF	$ 2	$ 6,400
Electrical	2	JOB	$ 50,000	$ 100,000
Piping	2	JOB	$ 20,000	$ 40,000
WRT Z-88 package including:				
Z-88 vessels				
Adsorption media	2	UNIT	$ 58,000	$ 116,000
(Initial Setup Cost for WRT Z-88 package plant)				
Subtotal of Component Costs				**$ 412,800**
Contingency	20%			$ 82,560
Design & Constr Management	25%			$ 103,200
TOTAL CAPITAL COSTS				**$ 598,560**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	12,000	kwh/yr	$ 0.136	$ 1,632
Equipment power	10,000	kwh/yr	$ 0.136	$ 1,360
Labor	800	hrs/yr	$ 31	$ 24,800
Analyses	48	test	$ 200	$ 9,600
WRT treated water charge	8,395	kgal/yr	$ 3.75	$ 31,481
Subtotal				**$ 68,873**
TOTAL ANNUAL O&M COSTS				**$ 68,873**

Table C.9

PWS Name *Live Oaks Mobile Home Park*
Alternative Name *Central Treatment - KMnO4*
Alternative Number *LOM-9*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	1	acre	$ 4,000	$ 4,000
Slab	60	CY	$ 1,000	$ 60,000
Building	800	SF	$ 60	$ 48,000
Building electrical	800	SF	$ 8	$ 6,400
Building plumbing	800	SF	$ 8	$ 6,400
Heating and ventilation	800	SF	$ 7	$ 5,600
Fence	600	LF	$ 15	$ 9,000
Paving	3,200	SF	$ 2	$ 6,400
Electrical	2	JOB	$ 50,000	$ 100,000
Piping	2	JOB	$ 20,000	$ 40,000
KMnO4-Greensand package including:				
Greensand filters				
Solution tank	2	UNIT	$ 60,000	$ 120,000
Backwash tank	18,000	gal	$ 2.00	$ 36,000
Sewer connection fee	-	EA	$ 15,000	$ -
Subtotal of Component Costs				**$ 441,800**
Contingency	20%			$ 88,360
Design & Constr Management	25%			$ 110,450
TOTAL CAPITAL COSTS				**$ 640,610**

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	12,000	kwh/yr	$ 0.136	$ 1,632
Labor	1,000	hrs/yr	$ 31	$ 31,000
Materials	2	year	$ 3,000	$ 6,000
Chemicals	2	year	$ 2,000	$ 4,000
Analyses	48	test	$ 200	$ 9,600
Backwash discharge disposal	2	kgal/yr	$ 200.00	$ 380
Subtotal				**$ 53,428**
Sludge Disposal				
Truck rental	7	days	$ 700	$ 4,900
Mileage	420	miles	$ 1.00	$ 420
Disposal fee	7	kgal/yr	$ 200.00	$ 1,400
Subtotal				**$ 6,720**
TOTAL ANNUAL O&M COSTS				**$ 60,148**

Table C.10

PWS Name *Live Oaks Mobile Home Park*
Alternative Name *Point-of-Use Treatment*
Alternative Number *LOM-10*

Number of Connections for POU Unit Installation 132

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POU-Treatment - Purchase/Installation				
POU treatment unit purchase	132	EA	$ 250	$ 33,000
POU treatment unit installation	132	EA	$ 150	$ 19,800
Subtotal				**$ 52,800**
Subtotal of Component Costs				**$ 52,800**
Contingency	20%			$ 10,560
Design & Constr Management	25%			$ 13,200
Procurement & Administration	20%			$ 10,560
TOTAL CAPITAL COSTS				**$ 87,120**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POU materials, per unit	132	EA	$ 225	$ 29,700
Contaminant analysis, 1/yr per unit	132	EA	$ 100	$ 13,200
Program labor, 10 hrs/unit	1,320	hrs	$ 31	$ 40,920
Subtotal				**$ 83,820**
TOTAL ANNUAL O&M COSTS				**$ 83,820**

Table C.11

PWS Name ***Live Oaks Mobile Home Park***
Alternative Name ***Point-of-Entry Treatment***
Alternative Number ***LOM-11***

Number of Connections for POE Unit Installation 132

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POE-Treatment - Purchase/Installation				
POE treatment unit purchase	132	EA	$ 3,000	$ 396,000
Pad and shed, per unit	132	EA	$ 2,000	$ 264,000
Piping connection, per unit	132	EA	$ 1,000	$ 132,000
Electrical hook-up, per unit	132	EA	$ 1,000	$ 132,000
Subtotal				**$ 924,000**
Subtotal of Component Costs				**$ 924,000**
Contingency	20%			$ 184,800
Design & Constr Management	25%			$ 231,000
Procurement & Administration	20%			$ 184,800
TOTAL CAPITAL COSTS				**$ 1,524,600**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POE materials, per unit	132	EA	$ 1,000	$ 132,000
Contaminant analysis, 1/yr per unit	132	EA	$ 100	$ 13,200
Program labor, 10 hrs/unit	1,320	hrs	$ 31	$ 40,920
Subtotal				**$ 186,120**
TOTAL ANNUAL O&M COSTS				**$ 186,120**

Table C.12

PWS Name ***Live Oaks Mobile Home Park***
Alternative Name ***Public Dispenser for Treated Drinking Water***
Alternative Number ***LOM-12***

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	$ 31	$ 11,315
Subtotal				**$ 17,015**
TOTAL ANNUAL O&M COSTS				**$ 17,015**

Table C.13

PWS Name ***Live Oaks Mobile Home Park***
Alternative Name ***Supply Bottled Water to Population***
Alternative Number ***LOM-13***

Service Population	264	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	96,360	gallons

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Implementation				
Initial program set-up	500	hours	$ 41	$ 20,615
Subtotal				**$ 20,615**
Subtotal of Component Costs				**$ 20,615**
Contingency	20%			$ 4,123
TOTAL CAPITAL COSTS				**$ 24,738**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water purchase costs	96,360	gals	$ 1.60	$ 154,176
Program admin, 9 hrs/wk	468	hours	$ 41	$ 19,296
Program materials	1	EA	$ 5,000	$ 5,000
Subtotal				**$ 178,472**
TOTAL ANNUAL O&M COSTS				**$ 178,472**

Table C.14

PWS Name ***Live Oaks Mobile Home Park***
Alternative Name ***Central Trucked Drinking Water***
Alternative Number ***LOM-14***

Service Population	264	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	96,360	gallons
Travel distance to compliant water source (roundtrip)	16	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	$ 31	$ 6,448
Truck operation, 1 round trip/wk	832	miles	$ 1.00	$ 832
Water purchase	96	1,000 gals	$ 1.80	$ 173
Water testing, 1 test/wk	52	EA	$ 100	$ 5,200
Sampling/reporting, 2 hrs/wk	104	hrs	$ 31	$ 3,224
Subtotal				**$ 15,877**
TOTAL ANNUAL O&M COSTS				**$ 15,877**

APPENDIX D
EXAMPLE FINANCIAL MODEL

Table D.1 Example Financial Model

Water System	Live Oaks
Funding Alternative	Bond
Alternative Description	New Well at Scenic Valley MHP

Sum of Amount		Year																					
Group	Type	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Capital Expenditures	Capital Expenditures-Funded from B	$ -	$ -	$ -	########	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from G	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from R	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from S	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ -	$ -	########	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds				$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493
	State Revolving Funds				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service Sum					$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493	$ 151,493
Operating Expenditures	Administrative Expenses			$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000
	Chemicals, Treatment			$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
	Contract Labor			$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
	Insurance			$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000
	Repairs			$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000
	Salaries & Benefits			$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000	$ 17,000
	Supplies			$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000
	Utilities			$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000
	O&M Associated with Alternative					$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686	$ 11,686
	Maintenance			$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
	Accounting and Legal Fees			$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100
Operating Expenditures Sum				$ 39,100	$ 39,100	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786	$ 50,786
Residential Operating Revenues	Residential Base Monthly Rate			$ 37,620	$ 37,620	$ 211,107	$ 387,230	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867
	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				$ 37,620	$ 37,620	$ 211,107	$ 387,230	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867

Location_Name	Live Oaks
Alt_Desc	New Well at Scenic Valley MHP

		Current_Year																					
Funding_Alt	Data	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Bond	Sum of Beginning_Cash_Bal	$ -	$ (10,997)	$ (173,487)	$ (176,124)	$ (2,637)	$ 173,487	$ 349,610	$ 525,734	$ 701,858	$ 877,981	$ 1,054,105	$ 1,230,229	$ 1,406,352	$ 1,582,476	$ 1,758,599	$ 1,934,723	$ 2,110,847	$ 2,286,970	$ 2,463,094	$ 2,639,218	$ 2,815,341	$ 2,991,465
	Sum of Total_Expenditures	$ 39,100	$ 2,127,186	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279	$ 202,279
	Sum of Total_Receipts	$ 37,620	$ 1,974,213	$ 211,107	$ 387,230	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867	$ 389,867
	Sum of Net_Cash_Flow	$ (1,480)	$ (152,973)	$ 8,827	$ 184,951	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588	$ 187,588
	Sum of Ending_Cash_Bal	$ (1,480)	$ (163,970)	$ (164,659)	$ 8,827	$ 184,951	$ 361,075	$ 537,198	$ 713,322	$ 889,446	$ 1,065,569	$ 1,241,693	$ 1,417,817	$ 1,593,940	$ 1,770,064	$ 1,946,187	$ 2,122,311	$ 2,298,435	$ 2,474,558	$ 2,650,682	$ 2,826,806	$ 3,002,929	$ 3,179,053
	Sum of Working_Cap	$ 6,517	$ 6,517	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464	$ 8,464
	Sum of Repl_Resv	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000
	Sum of Total_Reqd_Resv	$ 9,517	$ 9,517	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464	$ 11,464
	Sum of Net_Avail_Bal	$ (10,997)	$ (173,487)	$ (176,124)	$ (2,637)	$ 173,487	$ 349,610	$ 525,734	$ 701,858	$ 877,981	$ 1,054,105	$ 1,230,229	$ 1,406,352	$ 1,582,476	$ 1,758,599	$ 1,934,723	$ 2,110,847	$ 2,286,970	$ 2,463,094	$ 2,639,218	$ 2,815,341	$ 2,991,465	$ 3,167,589
	Sum of Add_Resv_Needed	$ (10,997)	$ (173,487)	$ (176,124)	$ (2,637)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	461%	83%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0
	Sum of Percent_Rate_Increase	0%	0%	461%	929%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%	936%

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 pCi while 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 the exposure pathway. Activity is related to contaminant concentration and half-life. A higher concentration and a shorter half-life lead to an increase in activity. Radium is approximately one million times more radioactive than uranium based on the ratio of their half lives (Table E.1). 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 K40.

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 rocks. Intrusive rocks such as granites partially sequester uranium and thorium in erosion-resistant accessory minerals (*e.g.*, monazite, thorite) while uranium in volcanic rocks 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 rocks, uranium and thorium aqueous concentrations are controlled mainly by the sorbing potential of the rocks (metal oxides, 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 ion UO_2^{+2}. Solubility is higher at low pH (acid), decreases at neutral pHs, and increases at high pH (alkaline). The uranyl ion can easily form aqueous complexes, such as 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 pHs (DeSoto 1978, p.11). Uranium sorbs strongly to metal oxides and clay.

Uranium (IV) is the other common redox state. In that state, however, uranium is not very soluble and precipitates as uranite , UO_2, coffinite, $USiO_4.nH_2O$ (if SiO_2>60 mg/L, Henry, *et al.* 1982), or related minerals. In most aquifers, there is no mineral controlling uranium solubility in oxidizing conditions. However, uranite and coffinite are the controlling minerals if the 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 maybe at higher pH when complexed by carbonate ions (USEPA 1999). Similar to uranium, thorium sorbs strongly to metal oxides.

Radium has an atomic number of 88. Radium originates from the radioactive decay of uranium and thorium. Ra226 is an intermediate product of U238 (the most common uranium isotope >99%, Table 1) decay while Ra228 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. Ra223 and Ra224 isotopes are also naturally present but in minute quantities. Ra224 belongs to the thorium decay series while Ra223 is derived 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
- Radium-226 and radium-228: 5 pCi/L

Appendix References

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