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

OLSEN ESTATES WATER SYSTEM
PWS ID# 0360065, CCN# A1538

Prepared for:

THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Prepared by:

THE UNIVERSITY OF TEXAS BUREAU OF ECONOMIC GEOLOGY

AND

PARSONS

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

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AUGUST 2006

EXECUTIVE SUMMARY

INTRODUCTION

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

The overall goal of this project was to promote compliance with Texas water quality standards 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 Olsen Estates PWS, a residential subdivision located in Chambers County, Texas, northeast of the City of Baytown. The Olsen Estates PWS recorded arsenic concentrations greater than 20 micrograms per liter (µg/L). These results exceed the 10 µg/L MCL for arsenic that went into effect on January 23, 2006 (USEPA 2005; TCEQ 2004). Therefore, it is likely the Olsen Estates PWS faces potential compliance issues under the new standard.

Basic system information for the Olsen Estates PWS is shown in Table ES.1.

Table ES.1
Olsen Estates
Basic System Information

Population served	180
Connections	60
Average daily flow rate	.023 million gallons per day (mgd)
Peak demand flow rate	0.092 mgd
Water system peak capacity	1.5 mgd
Typical arsenic range	0.0238 to 0.0302 mg/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:

- Gather data from the TCEQ and Texas Water Development Board databases, from TCEQ files, and from information maintained by the PWS;
- Conduct financial, managerial, and technical (FMT) evaluations of the PWS;
- Perform a geologic and hydrogeologic assessment of the study area;
- 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.
- Assess each potential alternatives with respect to economic and non-economic criteria;
- Prepare a feasibility report and present the results to the PWS.

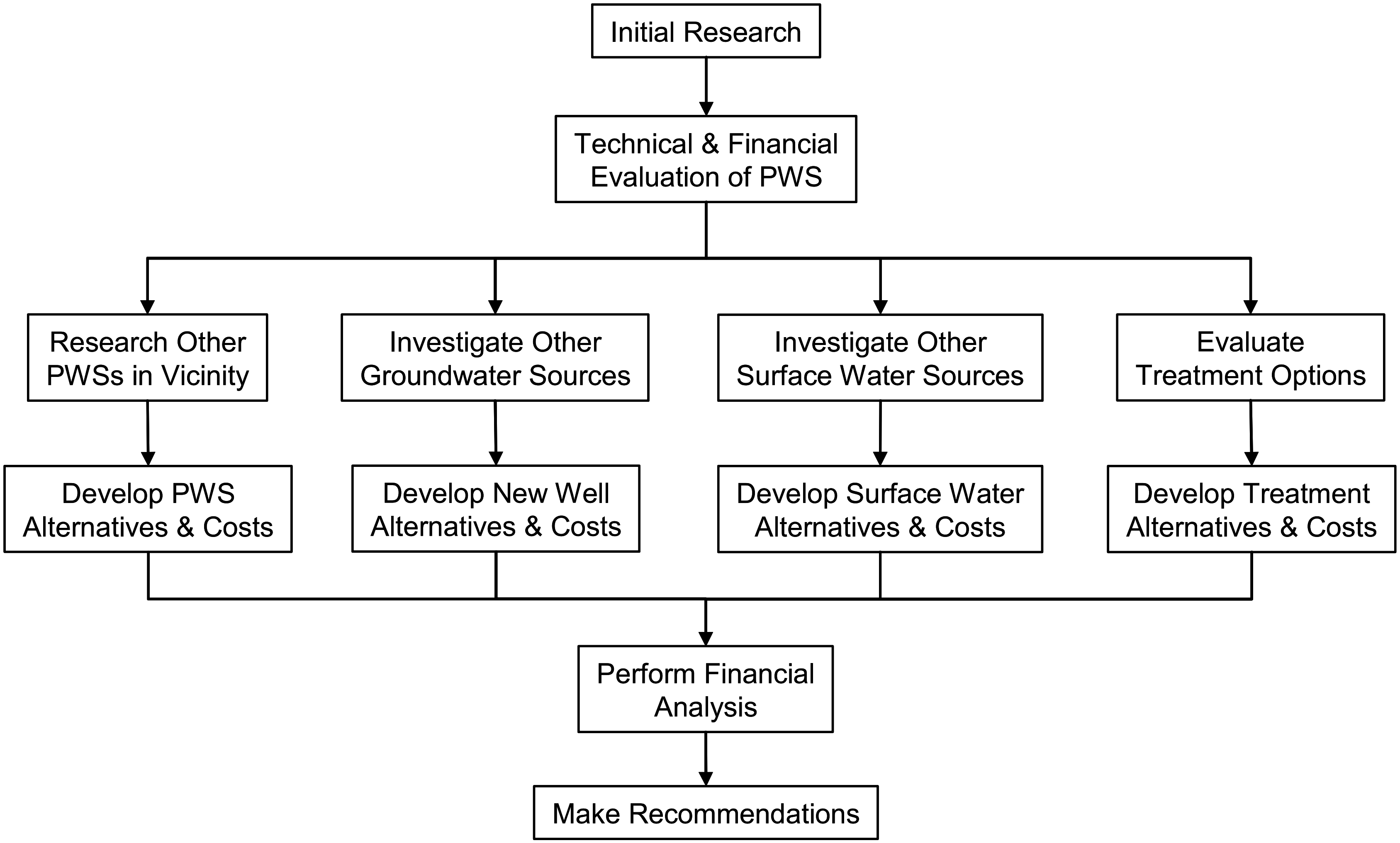
This basic approach is summarized in Figure ES-1.

HYDROGEOLOGICAL ANALYSIS

The Olsen Estates PWS obtains groundwater from the Chicot subunit of the Gulf Coast aquifer. Arsenic is commonly found in area wells at concentrations greater than the MCL. Volcanic ash incorporated into the aquifer material may be the source of arsenic. Arsenic concentrations can vary significantly over relatively short distances; as a result, there could be good quality groundwater nearby. However, the variability of arsenic concentrations makes it difficult to determine where wells can be located to produce acceptable water.

Additionally, since the Olsen Estates PWS has two wells, the water quality of each well should be characterized. If one of the wells is found to produce compliant water, as much production as possible should be shifted to that well as a method of achieving compliance. It may also be possible to do down-hole testing on non-compliant wells 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 Olsen Estates Property Owners is a homeowners association governed by a three-member board of directors. Overall, the system had an inadequate level of FMT capacity. The system had some areas that needed improvement to be able to address future compliance issues; however, the system does have many positive aspects, including enforcement of shut-off policy for delinquent bills. Areas of concern for the system included lack of financial accounting, inadequate record keeping, lack or written long-term capital improvements plan, and failure to prepare and distribute consumer confidence reports.

There are many PWSs within 10 miles of Olsen Estates. Several of these nearby systems also have problems with arsenic, but there are also 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. Another alternative considered is modifying the existing well or installing a new well at the Olsen Estates PWS. 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 the Baytown Area Water Authority.

A number of centralized treatment alternatives for arsenic removal have been developed and were considered for this report, including RO, EDR, iron-based adsorption and coagulation/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.

If compliant groundwater can be found, developing a new well at or near to the Olsen Estates PWS is likely to be an attractive solution. Having a new well at or near to the Olsen Estates 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 preliminary cost estimates also indicate that pursuing a regional solution may be economically feasible. 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. Similar to obtaining an alternate compliant water source, central treatment would provide compliant water to all water taps.

Point-of-use 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 Olsen Estates PWS indicated that current water rates are under funding operations, and a rate increase of 12 percent would be necessary to meet operating expenses. This increase would result in an average water bill of $538. The current average water bill of $480 represents approximately 1.2 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	$480	1.2
To meet current expenses	NA	$538	1.4
New well at Olsen Estates	100% Grant	$743	1.9
	Loan/Bond	$978	2.5
Purchase water from Mont Belvieu	100% Grant	$1,500	3.8
	Loan/Bond	$2,406	6.1
Central treatment - adsorption	100% Grant	$1,368	3.4
	Loan/Bond	$1,864	4.7
Point-of-use	100% Grant	$1,407	3.5
	Loan/Bond	$1,464	3.7

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ACRONYMS AND ABBREVIATIONS

AA	activated alumina
AFY	acre-feet per year
APU	arsenic package unit
BAWA	Bay Area Water Authority
BEG	Bureau of Economic Geology
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
CO	Correspondence
EDR	Electrodialysis reversal
EP	entry point
FM	farm to market
FMT	Financial, managerial, and technical
GAM	Groundwater Availability Model
gpm	Gallons per minute
HGCSD	Harris-Galveston Coastal Subsidence District
IX	Ion exchange
MCL	Maximum contaminant level
mg/L	milligrams per Liter
mgd	Million gallons per day
MF	microfiltration
MG	Million gallons
MHI	median household income
MOR	Monthly operating report
NMEFC	New Mexico Environmental Financial Center
NURE	National Uranium Resource Evaluation
O&M	Operation and Maintenance
OE	Olsen Estates
Parsons	Parsons Infrastructure and Technology Group Inc.
POC	point of collection
POE	Point-of-entry
POU	Point-of-use
ppb	parts per billion
psi	pounds per square inch
PSOC	potential sources of contamination
PWS	public water system
RO	Reverse osmosis
SDWA	Safe Drinking Water Act

SWAP	Source Water Assessment Program
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
USGS	U.S. Geological Survey
WAM	Water Availability Model
ft^2	square foot
µg/L	microgram per liter
ºF	degrees Fahrenheit
kWH	kiloWatt hour

SECTION 1
INTRODUCTION

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

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

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

This feasibility report provides an evaluation of water supply compliance options for the Olsen Estates Water System, PWS ID# 0360065, located in Chambers County (hereinafter referred to as the Olsen Estates PWS). Recent sample results from the Olsen Estates PWS exceeded the MCL for arsenic of 10 micrograms per liter (µg/L) that went into effect January 23, 2006 (USEPA 2005; TCEQ 2004).

The location of the Olsen Estates PWS is shown on Figure 1.1. Various water supply and planning jurisdictions are shown on Figure 1.2. These water supply and planning jurisdictions are used in the evaluation of alternate water supplies that may be available in the area.

1.1 PUBLIC HEALTH AND COMPLIANCE WITH MCLS

The goal of this project is to promote compliance for PWSs that supply drinking water containing contaminants that exceed regulatory MCLs. This project only addresses those contaminants and does not address any other violations that may exist for a PWS. As mentioned above, Olsen Estates PWS had recent sample results exceeding the MCL for arsenic. Health concerns related to drinking water above the MCL for this chemical are briefly described below.

In general, contaminant(s) in drinking water above the MCL(s) can have both short-term (acute) and long-term or lifetime (chronic) effects. Potential health effects from long-term ingestion of water with levels of arsenic above the MCL (0.01 mg/L) include non-cancerous effects, such as cardiovascular, pulmonary, immunological, neurological and endocrine effects, and cancerous effects, including skin, bladder, lung, kidney, nasal passage, liver and prostate 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 methodology (*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 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 arsenic abatement options. Section 2 describes the method used to develop and assess compliance alternatives. The groundwater sources of arsenic are addressed in Section 3. Findings for the Olsen Estates PWS, along with development and evaluation of the compliance alternatives, can be found in Section 4. Section 5 references the sources used in this report.

Figure 1.1

Olsen Estates Water System Location Map

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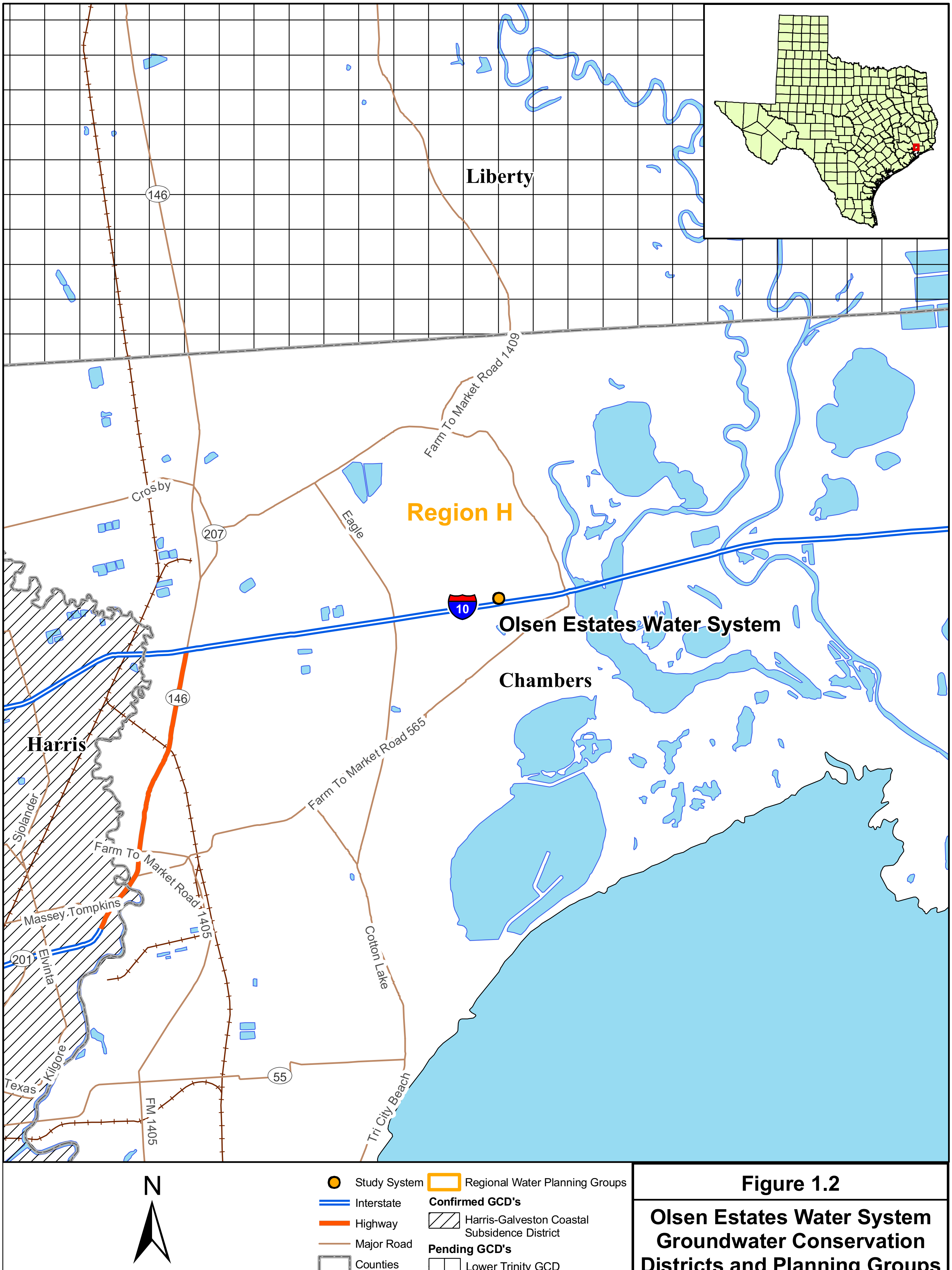

Figure 1.2

Olsen Estates Water System Groundwater Conservation Districts and Planning Groups

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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) including 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;
- 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 Olsen Estates PWS involve arsenic. The following subsections explore alternatives considered as potential options for obtain/providing compliant drinking water.

1.4.1 Existing Public Water Supply Systems

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

1.4.1.1 Quantity

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

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

- Additional wells;
- Developing a new surface water supply,
- Additional or larger-diameter piping;
- Increasing water treatment plant capacity;
- Additional storage tank volume;
- Reduction of system losses;
- Higher-pressure pumps; or
- Upsized, or additional, disinfection equipment.

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

1.4.1.2 Quality

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

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

1.4.2 Potential for New Groundwater Sources

1.4.2.1 Existing Non-Public Supply Wells

Often there are wells not associated with PWSs 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 Olsen Estates PWS, the following standards could be used in a rough screening to identify compliant groundwater in surrounding systems:
  - Arsenic concentrations less than 0.008 mg/L (below the MCL of 0.01 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 that 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 that 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" refers to municipal water authorities and cities that obtain water from surface water sources. The process of obtaining water from such a source is generally less time consuming and less costly than the process of developing a new source; therefore, it should be a primary course of investigation. An existing source would be limited by its water rights, the safe yield of a reservoir or river, or by its water treatment or water conveyance capability. The source must be able to meet the current demand and honor contracts with communities it currently supplies. In many cases, the contract amounts reflect projected future water demand based on population or industrial growth.

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

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

1.4.3.2 New Surface Water Sources

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

- Discussions with TCEQ to indicate the likelihood of obtaining those rights. The TCEQ may use the Water Availability Model (WAM) to assist in the determination.
- Discussions with land owners to indicate potential treatment plant locations.
- Coordination with U.S. Army Corps of Engineers and local river authorities.
- Preliminary engineering design to determine the feasibility, costs, and environmental issues of a new treatment plant.

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

1.4.4 Identification of Treatment Technologies

Various treatment technologies were also investigated as compliance alternatives for treatment of arsenic to regulatory levels (*i.e.*, MCL). According to a recent USEPA report for small water systems with less than 10,000 customers (EPA/600/R-05/001) a number of drinking water treatment technologies are available to reduce arsenic concentrations in source water to below the new MCL of 10 μg/L, including:

- Ion exchange (IX);
- Reverse osmosis (RO);
- Electrodialysis reversal (EDR);
- Adsorption; and
- Coagulation/filtration.

1.4.5 Treatment Technologies Description

Many of the most effective arsenic removal processes available are iron-based treatment technologies such as chemical coagulation/filtration with iron salts, and adsorptive media with iron-based products. These processes are particularly effective at removing arsenic from aqueous systems because iron surfaces have a strong affinity for adsorbing arsenic. Other arsenic removal processes such as activated alumina and enhanced lime softening are more applicable to larger water systems because of their operational complexity and cost. A description and discussion of arsenic removal technologies applicable to smaller systems follow.

1.4.5.1 Ion Exchange

<u>Process</u> – In solution, salts separate into positively-charged cations and negatively charged anions. Ion exchange is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in 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 bed, displacing the contaminant 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 resin 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. For arsenic removal, an anion exchange resin in the chloride form is used to remove arsenate [As(V)]. Because arsenite [As(III)] occurs in water below pH 9 with no ionic charge, As(III) is not consistently removed by the anionic exchange process.

<u>Pretreatment</u> – 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. In addition, chlorination or oxidation may be required to convert As(III) to As(V) for effective removal.

<u>Maintenance</u> – The IX resin requires regular on-site regeneration, the frequency of which depends on raw water characteristics, 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.

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

Advantages (IX)

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

Disadvantages (IX)

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

In considering application of IX for inorganics removal, it is important to understand what the effect of competing ions will be, and to what extent the brine can be recycled.

Similar to activated alumina, IX exhibits a selectivity sequence, which refers to an order in which ions are preferred. Sulfate competes with both nitrate and arsenic, but more aggressive with arsenic in anion exchange. Source waters with TDS levels above 500 mg/L or 120 mg/L sulfate are not amenable to IX treatment for arsenic removal. Spent regenerant is produced during IX bed regeneration, and this spent regenerant may have high concentrations of sorbed contaminants which can be expensive to treat and/or dispose. Research has been conducted to minimize this effect; recent research on arsenic removal shows that the brine can be reduced as many as 25 times.

1.4.5.2 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 hollow fine fiber but most of 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 valves 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 97 percent removal of As(V) and 92 percent removal of As(III). The treatment process is relatively insensitive to pH. Water recovery is typically 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 of bisulfite feed to dechlorinate, and cartridge filters to removing 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 require approved disposal methods.

Advantages (RO)

- Can remove both As(III) and As(V) effectively; and
- Can remove other undesirable dissolved constituents and excessive TDS, if required.

Disadvantages (RO)

- Relatively expensive to install and operate.
- Need sophisticated monitoring systems.
- Need to handle multiple chemicals.
- Waste of water because of the significant concentrate flows
- High silica concentration limits water recovery rate
- Concentrate disposal required.

RO is an expensive alternative to remove arsenic 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 arsenic is the waste of water through concentrate disposal which is also difficult or expensive because of the volume involved.

1.4.5.3 Electrodialysis Reversal

Process. EDR is an electrochemical process in which ions migrate through ion-selective semi-permeable membranes as a result of their attraction to two electrically charged electrodes. A typical EDR system includes a membrane stack with a number of cell pairs, each consisting of a cation transfer membrane, a demineralized 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 the concentrated reject flow in parallel across the membranes and through the demineralized and concentrate flow spaces, 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 arsenic and TDS. Additional stages are required to achieve higher removal efficiency if necessary. EDR uses the technique of regularly reversing the polarity of the electrodes, thereby freeing accumulated ions on the membrane surface. This process requires additional plumbing and electrical controls, but it increases membrane life, may require less added chemicals, and eases cleaning. The conventional EDR treatment train typically includes EDR membranes, chlorine disinfection, and clearwell storage. Treatment of surface water may also require pretreatment steps such as raw water pumps, debris screens, rapid mix with addition of a coagulant, slow mix flocculator, sedimentation basin or clarifier, and gravity filters. Microfiltration (MF) could be used in placement of flocculation, sedimentation and filtration. Additional treatment or management of the concentrate and the removed solids would be necessary prior to disposal.

Pretreatment. There are pretreatment requirements for pH, organics, turbidity, and other raw water characteristics. EDR typically requires chemical feed to prevent scaling, acid addition for pH adjustment, and a cartridge filter for prefiltration.

Maintenance. EDR membranes are durable, can tolerate a pH range from 1 to 10, and temperatures to 115 degrees Fahrenheit (ºF) for cleaning. They 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 space. If the chlorine is not removed, toxic chlorine gas may form. Depending on raw water characteristics, the membranes would require regular maintenance or replacement. EDR requires reversing the polarity. Flushing at high volume/low pressure continuously is required to clean electrodes. If used, pretreatment filter replacement and backwashing would 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 processes and spent materials also require approved disposal methods.

Advantages (EDR)

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

Disadvantages (EDR)

- Not suitable for high levels of iron, manganese, and hydrogen sulfide.
- High energy usage at higher TDS water.

EDR can be quite expensive to run because of the energy it uses. However, because it is generally automated and allows for small systems. It can be used to simultaneously reduce arsenic and TDS.

1.4.5.4 Adsorption

Process – The adsorptive media process is a fixed-bed process by which ions in solution, such as arsenic, are removed by available adsorptive sites on an adsorptive media. When the available adsorptive sites are filled, spent media may be regenerated or simply thrown away and replaced with new media. Granular activated alumina (AA) was the first adsorptive media successfully applied for the removal of arsenic from water supplies. More recently, other adsorptive media (mostly iron-based) have been developed and marketed for arsenic removal. Recent USEPA studies demonstrated that iron-based adsorption media typically have higher arsenic removal capacities compared to alumina-based media. In the USEPAsponsored Round 1 full-scale demonstration of arsenic removal technologies for small water systems program, the selected arsenic treatment technologies included nine adsorptive media systems, one IX system, one coagulation/filtration system, and one process modification.

The selected adsorptive media systems used four different adsorptive media, including three iron-based media (*e.g.*, ADI's G2, Severn Trent and AdEdge's E33, and U.S. Filter's GFH), and one iron-modified AA media (*e.g.*, Kinetico's AAFS50, a product of Alcan). The G2 media is a dry powder of diatomaceous earth impregnated with a coating of ferric hydroxide, developed by ADI specifically for arsenic adsorption. ADI markets G2 for both As(V) and As(III) removal, but it preferentially removes As(V). G2 media adsorbs arsenic most effectively at pH values within the 5.5 to 7.5 range, and less effectively at a higher pH value.

The Bayoxide® E33 media was developed by Bayer AG for the removal of arsenic from drinking water supplies. It is a dry granular iron oxide media designed to remove dissolved arsenic via adsorption onto its ferric oxide surface. Severn Trent markets the media in the U.S. for As(III) and As(V) removal as Sorb-33, and offers several arsenic package units (APU) with flowrates ranging from 150 to 300 gallons per minute (gpm). Another company, AdEdge, provides similar systems using the same media (marketed as AD-33) with flowrates ranging from 5 to 150 gpm. E33 adsorbs arsenic and other ions, such as antimony, cadmium, chromate, lead, molybdenum, selenium and vanadium. The adsorption is effective at pH values ranging between 6.0 and 9.0. At greater than 8.0 to 8.5, pH adjustment is recommended to maintain its adsorption capacity. Two competing ions that can reduce the adsorption capacity are silica (at levels greater than 40 mg/L) and phosphate (at levels greater than 1 mg/L).

GFH is a moist granular ferric hydroxide media produced by GEH Wasserchemie GmbH of Germany and marketed by US Filter under an exclusive marketing agreement. GFH is capable of adsorbing both As(V) and As(III). GFH media adsorb arsenic with a pH range of 5.5 to 9.0, but less effectively at the upper end of this range. Competing ions such as silica and phosphate in source water can adsorb onto GFH media, thus reducing the arsenic removal capacity of the media.

The AAFS50 is a dry granular media of 83% alumina and a proprietary iron-based additive to enhance the arsenic adsorption performance. Standard AA was the first adsorptive media successfully applied for the removal of arsenic from water supplies. However, it often requires pH adjustment to 5.5 to achieve optimum arsenic removal. The AAFS50 product is modified with an iron-based additive to improve its performance and increase the pH range within which it can achieve effective removal. Optimum arsenic removal efficiency is achieved with a pH of the feed water less than 7.7. Competing ions such as fluoride, sulfate, silica, and phosphate can adsorb onto AAFS50 media, and potentially reduce its arsenic removal capacity. The adsorption capacity of AAFS50 can be impacted by both high levels of silica (>40 mg/L) and phosphate (>1 mg/L). The vendor recommended that the system be operated in a series configuration to minimize the chance for arsenic breakthrough to impact drinking water quality.

All iron-based or iron-modified adsorptive media are of the throwaway type after exhaustion. The operations of these adsorption systems are quite similar and simple. Some of the technologies such as the E33 and GFH media have been operated successfully on large scale plants in Europe for several years.

Pretreatment – The adsorptive media are primarily used to remove dissolved arsenic and not for suspended solids removal. Pretreatment to remove TSS may be required if raw water turbidity is >0.3 NTU. However, most well waters are low in turbidity and hence pre-filtration is usually not required. Pre-chlorination may be required to oxidize As(III) to As(V) if the proportion of As(III) is high. No pH adjustment is required unless pH is relatively high.

Maintenance – Maintenance for the adsorption media system is minimal if no pretreatment is required. Backwash is required infrequently (monthly) and replacement and disposal of the exhausted media occurs between one to 3 years, depending on average water consumption, the concentrations of arsenic and competing ions in the raw water, and the media bed volume.

Waste Disposal – If no pretreatment is required there is minimal waste disposal involved with the adsorptive media system. Disposal of backwash wastewater is required especially during startup. Regular backwash is infrequent and disposal of the exhausted media occurs once every one to three years, depending on operating conditions. The exhausted media are usually considered non-hazardous wastes.

Advantages (Adsorption)

- Some adsorbents can remove both As(III) and As(V); and
- Very simple to operate.

Disadvantages (Adsorption)

- Relatively new technology;
- Need replacement of adsorption media when exhausted.

The adsorption media process is the most simple and requires minimal operator attention, compared to other arsenic removal processes. The process is most applicable to small wellhead systems with low or moderate arsenic concentrations with no treatment process in place (*e.g.,* iron and manganese removal; if treatment facilities for iron and/or manganese removal are already in place, incorporating ferric chloride coagulation in the existing system would be a more cost-effective alternative for arsenic removal). The choice of media will depend on raw water characteristics, life cycle cost, and experience of the vendor. Many of the adsorption media are at the field-trial stage, but others are already being used in full-scale applications throughout Europe and the United States. Pilot testing may or may not be necessary prior to implementation depending on the experience of the vendor with similar water characteristics.

1.4.5.5 Coagulation/Filtration and Iron Removal Technologies

Process – Iron removal processes can be used to removal arsenic from drinking water supplies. Iron removal processes involved the oxidation of soluble iron and As(III), adsorption and/or co-precipitation of As(V) onto iron hydroxides, and filtration. The filtration can be accomplished with granular media filter or microfilter. When iron in the raw water is inadequate to accomplish arsenic removal an iron salt such as ferric chloride is added to the water to form ferric hydroxide. The iron removal process is commonly called coagulation/filtration because iron in the form of ferric chloride is a common coagulant. The actual capacity to remove arsenic during iron removal depends on a number of factors, including the amount of arsenic present, arsenic speciation, pH, amount and form of iron present, and existence of competing ions, such as phosphate, silicate, and natural organic matter. The filters used in groundwater treatment are usually pressure filters feeding directly by the well pumps. The filter media can be regular dual media filters or proprietary media such as the engineered ceramic filtration media, Macrolite®, developed by Kinetico. Macrolite® is a low-density, spherical media designed to allow for filtration rates up to 10 gpm/ft^2, which is a higher loading rate than commonly used for conventional filtration media.

Pretreatment – Pre-chlorination to oxidize As(III) to As(V) is usually required for most groundwater sources. The adjustment of pH is required only for relatively high pH value. Coagulation with the feed of ferric chloride is required for this process. Sometimes a 5-minute contact tank is required ahead the filters if the pH is high.

Maintenance – Maintenance is mainly to handle ferric chloride chemical and feed system, and for regular backwash of the filters. No filter replacement is required for this process.

Waste Disposal – The waste from the coagulation/filtration process is mainly the iron hydroxide sludge with adsorbed arsenic in the backwash water. The backwash water can be discharged to a public sewer if it is available. If a sewer is not available, the backwash water can be discharged to a storage and settling tank from where the supernatant is recycled in a controlled rate to the front of the treatment system and the settled sludge can be disposed of periodically to a landfill. The iron hydroxide sludge is usually not classified as hazardous waste.

Advantages (Coagulation/Filtration)

- Very established technology for arsenic removal; and
- Most economical process for arsenic removal.

Disadvantages (Coagulation/Filtration)

- Need to handle chemical;
- Need to dispose of regular backwash wastewater; and
- Need to dispose of sludge.

The coagulation/filtration process is usually the most economical arsenic removal alternative, especially if a public sewer is available for accepting the discharge of the backwash water. However, because of the regular filter backwash requirements, more operation and maintenance attention is required from the utilities. Because of potential interference by competing ions bench-scale or pilot scaling testing may be required to ensure that the arsenic MCL can be met with this process alternative.

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 arsenic removal, these systems typically use small RO 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 POE. 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 primarily 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 include:

- 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 operation and maintenance (O&M) and compliance with MCLs. The water system must retain unit ownership and oversight of unit installation, maintenance and sampling; the utility is ultimately the responsible party when it comes to 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 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 the 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 will alert users when their unit is no longer adequately treating their water. As an alternative, units may be equipped with an automatic shut-off mechanism to meet this requirement.

- If the American National Standards Institute has issued product standards for a specific type of POU or POE treatment unit, only those units that have been independently certified according to those standards may be used as part of a compliance strategy.

With regard to using POE and POU devices for SDWA compliance, the following observations were made (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 SDWA, USEPA indicates that POU treatment devices should not be used to treat for radon or for most volatile organic contaminants to achieve compliance, because POU devices do not provide 100 percent protection against inhalation or contact exposure to those contaminants at untreated taps (*e.g*., shower heads).
- Liability – PWSs considering unconventional treatment options (POU, POE, or bottled water) must address liability issues. These could be meeting the drinking water standards, property entry and ensuing liabilities, and damage arising from improper installation or improper function of the POU and POE devices.

1.4.7 Water Delivery or Central Drinking Water Dispensers

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

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

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

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

The ideal system would:

- Completely identify the susceptible population. If bottled water is only provided to customers who are part of the susceptible population, the utility should have an active means of identifying the susceptible population. Problems with illiteracy, language fluency, fear of legal authority, desire for privacy, and apathy may be reasons that some members of the susceptible population do not become known to the utility, and do not take part in the water delivery program.
- Maintain customer privacy by eliminating the need for utility personnel to enter the home.
- Have buffer capacity (*e.g.,* two bottles in service, so when one is empty, the other is being used over a time period sufficient to allow the utility to change out the empty bottle).
- Provide for regularly scheduled delivery so the customer would not have to notify the utility when the supply is low.
- Use utility personnel and equipment to handle water containers, without requiring customers to lift or handle bottles with water in them.
- Be sanitary (*e.g.*, where an outside connection is made, contaminants from the environment must be eliminated).
- Be vandal-resistant.
- Avoid heating the water due to exterior temperatures and solar radiation.
- Avoid freezing the water.

SECTION 2
EVALUATION 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 Tree 2, as well as a preliminary pass through Tree 4.

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

Figure 2.1
TREE 1 – EXISTING FACILITY ANALYSIS

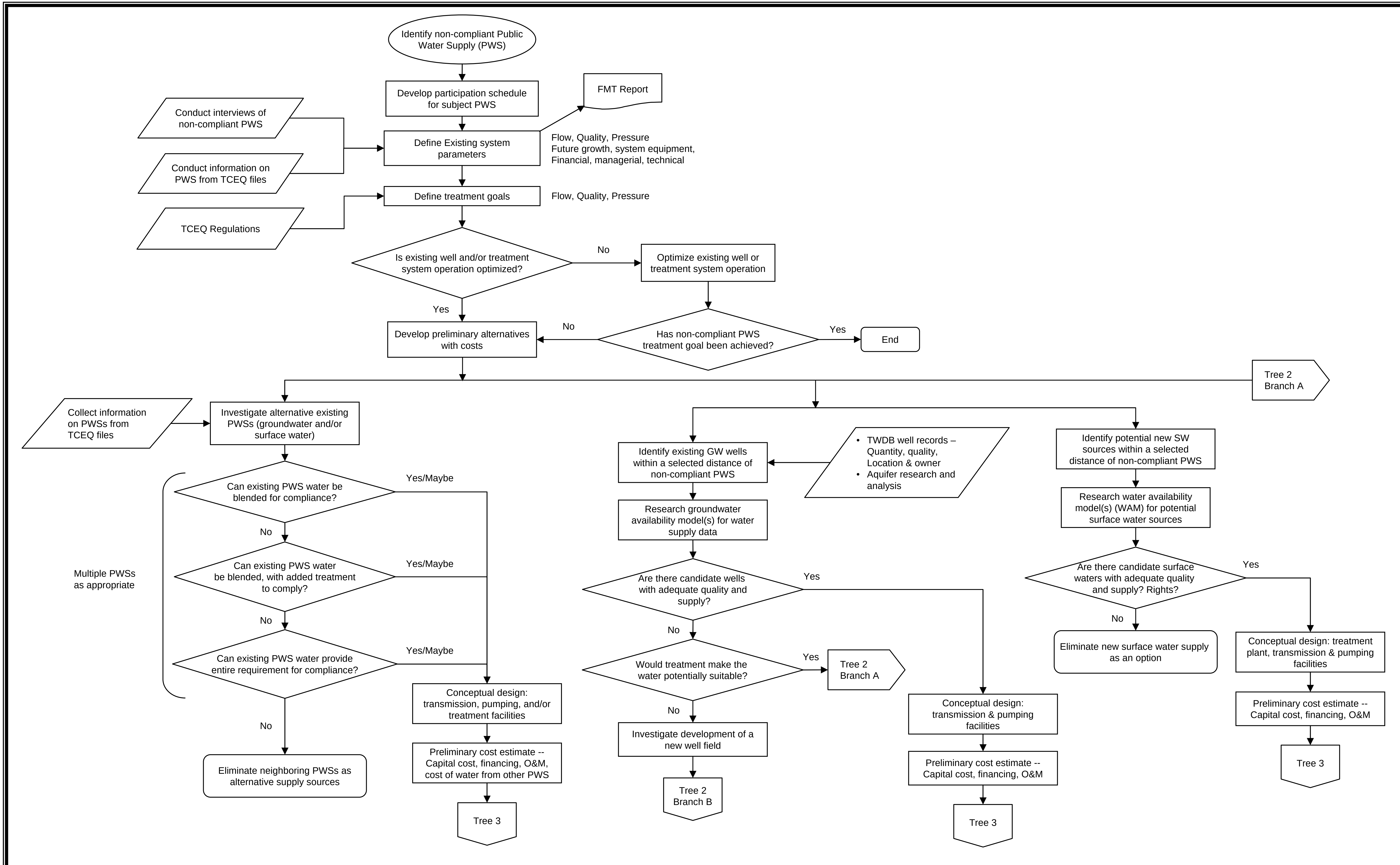
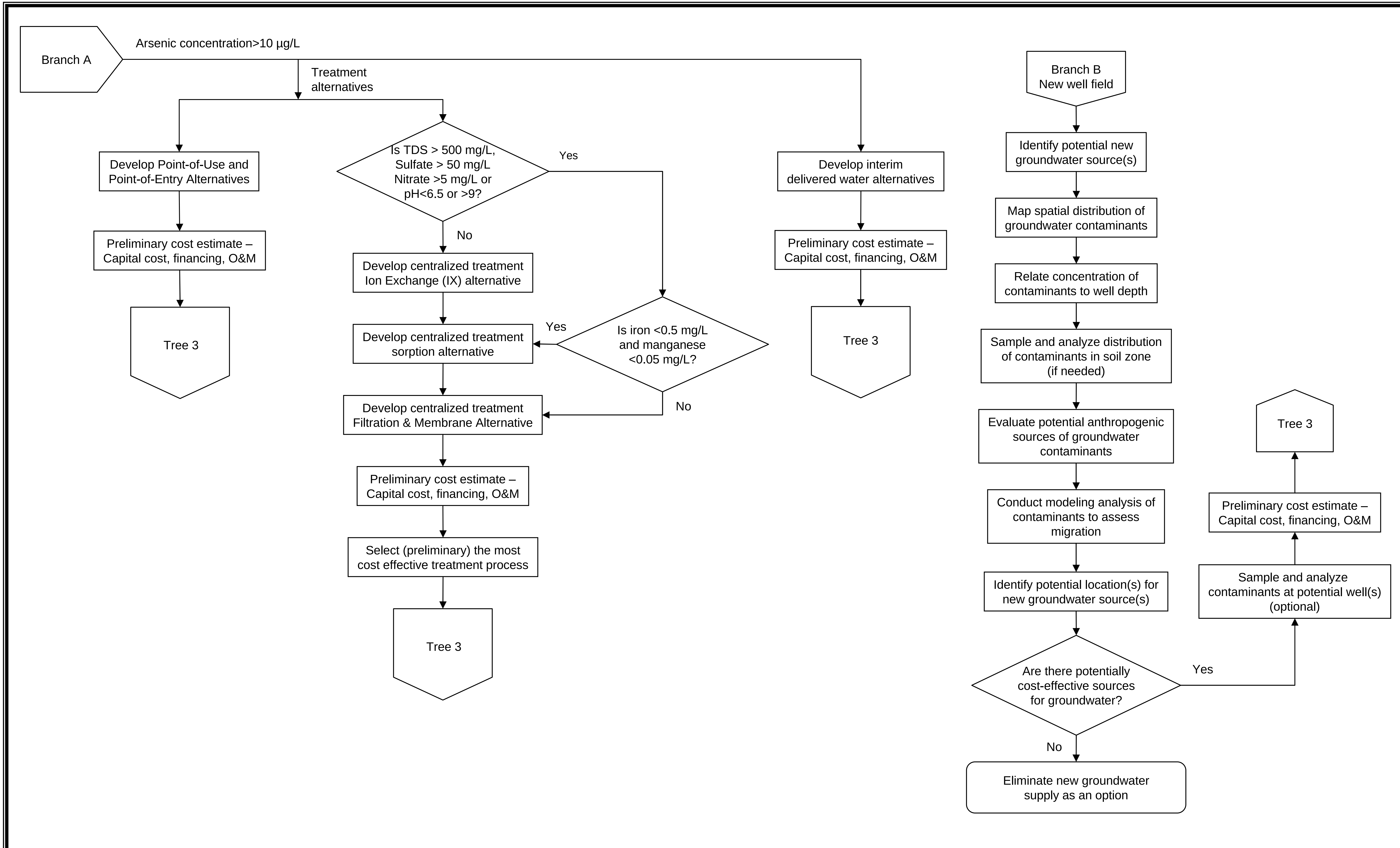


Figure 2.2
TREE 2 – DEVELOP TREATMENT ALTERNATIVES



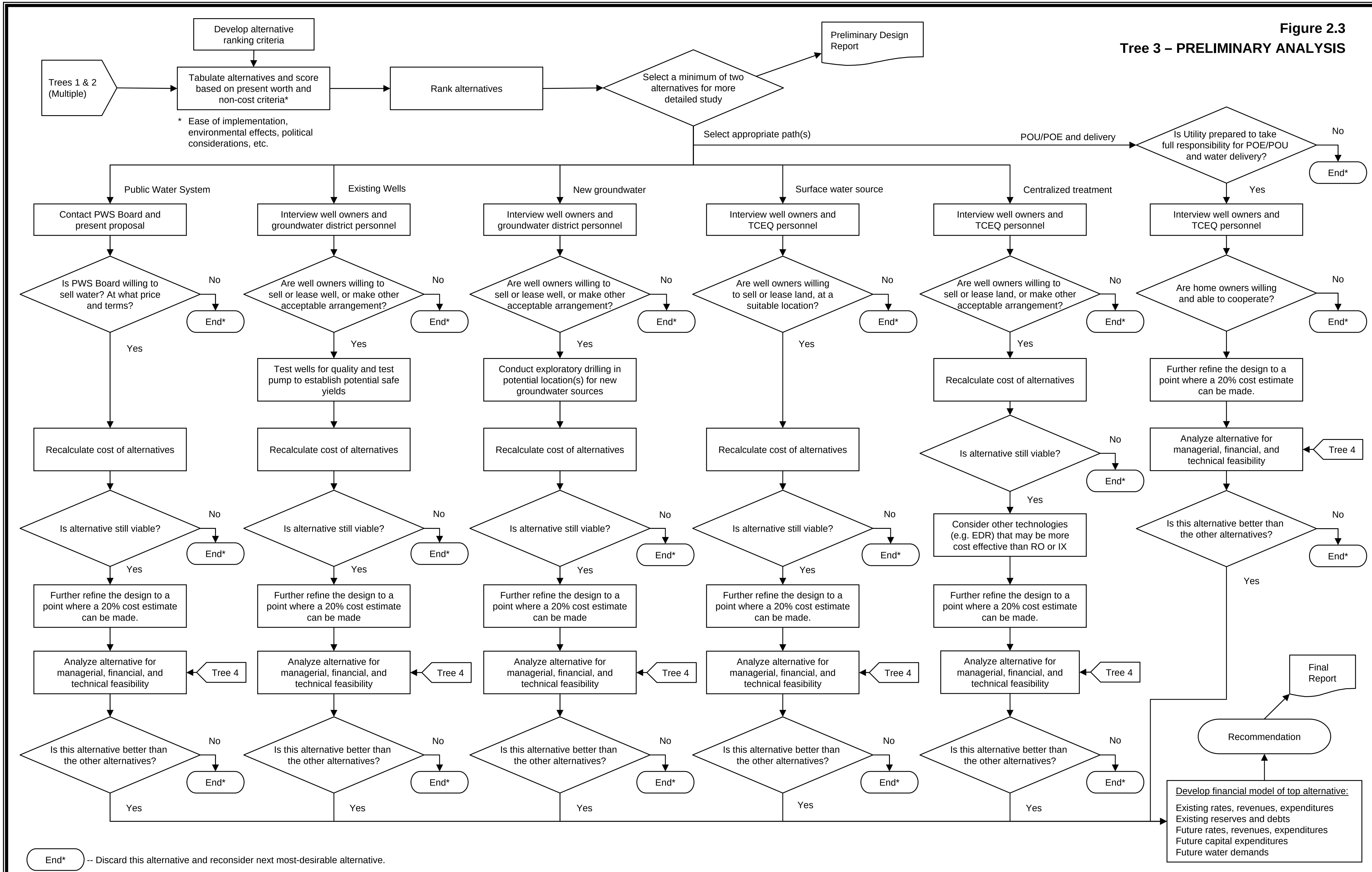
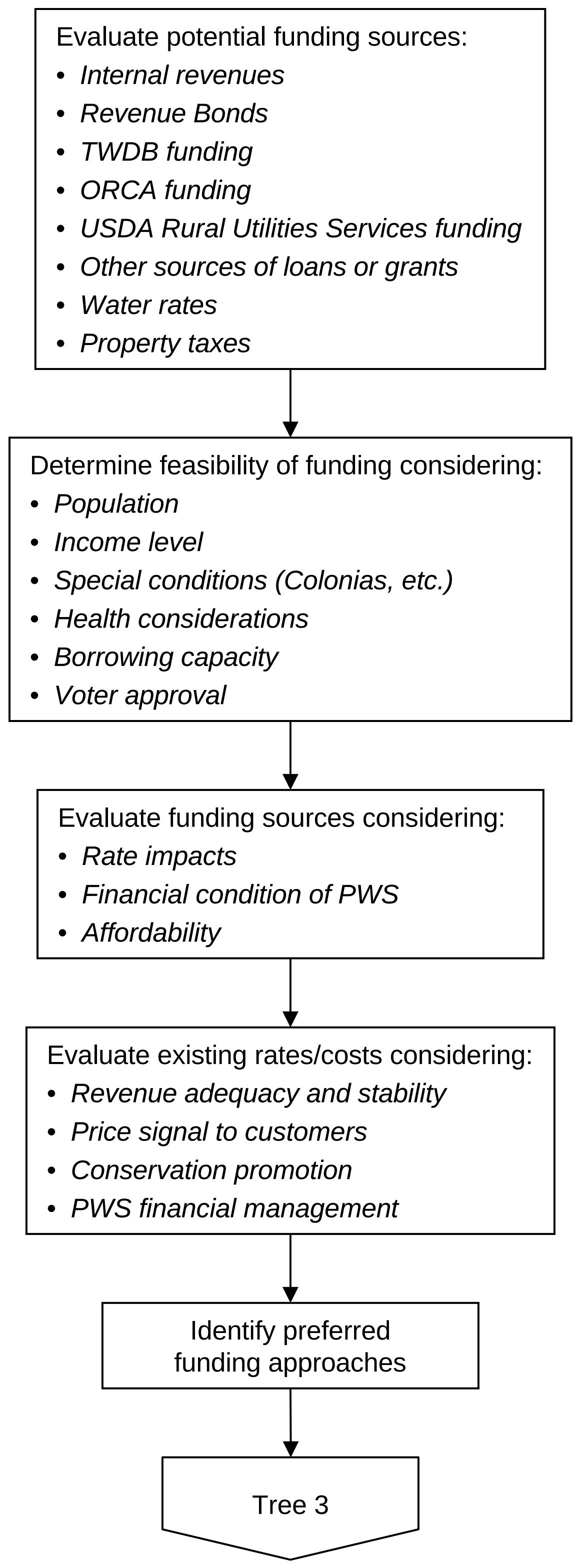


Figure 2.3
Tree 3 – PRELIMINARY ANALYSIS

Figure 2.4
TREE 4 – FINANCIAL



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

These files were reviewed for the PWS and surrounding systems.

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

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

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

2.2.1.2 Existing Wells

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

2.2.1.3 Surface Water Sources

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

2.2.1.4 Groundwater Availability Model

GAMs, developed by the TWDB, are planning tools and should be consulted as part of a search for new or supplementary water sources. The GAM for the northern part of the Gulf Coast 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 and 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 U.S. 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 FMT 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 O&M of the system.

FMT 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 FMT.

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

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

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

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

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

2.2.2.2 Interview Process

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

2.3 ALTERNATIVE DEVELOPMENT AND ANALYSIS

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

2.3.1 Existing PWS

The neighboring PWSs were identified, and the extents of their systems were investigated. PWSs farther than 5 miles from the non-compliant PWSs were not considered because the length of the pipeline required would make the alternative cost prohibitive. The quality of water provided was also investigated. For neighboring PWSs with compliant water, options for water purchase and/or expansion of existing well fields were considered. The neighboring PWSs with non-compliant water were considered as possible partners in sharing the cost for obtaining compliant water either through treatment or developing an alternate source.

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

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

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

2.3.2 New Groundwater Source

It was not possible in the scope of this study to determine conclusively whether new wells could be installed to provide compliant drinking water. To evaluate potential new groundwater source alternatives, three test cases were developed based on distance from the PWS intake point. The test cases were based on distances of 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 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 arsenic removal are IX, RO, EDR, adsorption, and coagulation/filtration. However, because of the high TDS in the well water (>1,000 mg/L), IX is not economically feasible. RO and EDR can also reduce TDS higher than the state secondary MCL of 1,000 mg/L. Adsorption and coagulation/filtration processes remove arsenic only without significantly affecting TDS. RO treatment is considered for central treatment alternatives, as well as POU and POE alternatives. EDR, adsorption and coagulation/filtration are considered for central treatment alternatives only. Both RO and EDR treatment produce a 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. Partial treatment and blending treated and untreated water to meet the arsenic MCL would reduce the amount of raw water used. Adsorption and coagulation filtration treatment produce periodic backwash wastewater for disposal. The treatment units were sized based on flow rates, and capital and annual O&M cost estimates were made based on the size of the treatment equipment required. Neighboring non-compliant PWSs were identified to look for opportunities where the costs and benefits of central treatment could be shared between systems.

Non-economic factors were also identified. Ease of implementation was considered, as well as reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant increases 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. 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 annual MHI 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 is greater than 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 a 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:

- TWDB;
- 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 ARSENIC IN THE GULF COAST AQUIFER

The Gulf Coast aquifer parallels the Texas Gulf Coast and extends from the Texas-Louisiana border to the Rio Grande. Subunits of the Gulf Coast aquifer are from oldest to youngest, the Jasper, Evangeline, and Chicot aquifers. The aquifer is a leaky artesian system composed of middle to late Tertiary and younger interbedded and hydrologically connected layers of clay, silt, sand, and gravel (Ashworth and Hopkins 1995). The PWS wells of concern in Brazoria and Chambers counties are completed in the Chicot aquifer. Groundwater arsenic concentrations in the Gulf Coast aquifer are based on the TWDB database (Figure 3.1) and the National Geochemical Database, also known as the National Uranium Resource Evaluation (NURE) database (Figure 3.2).

Figure 3.1 Most Recent Arsenic Concentrations in Groundwater of the Gulf Coast Aquifer (TWDB Database, 1,095 Samples from 1987 to 2005)

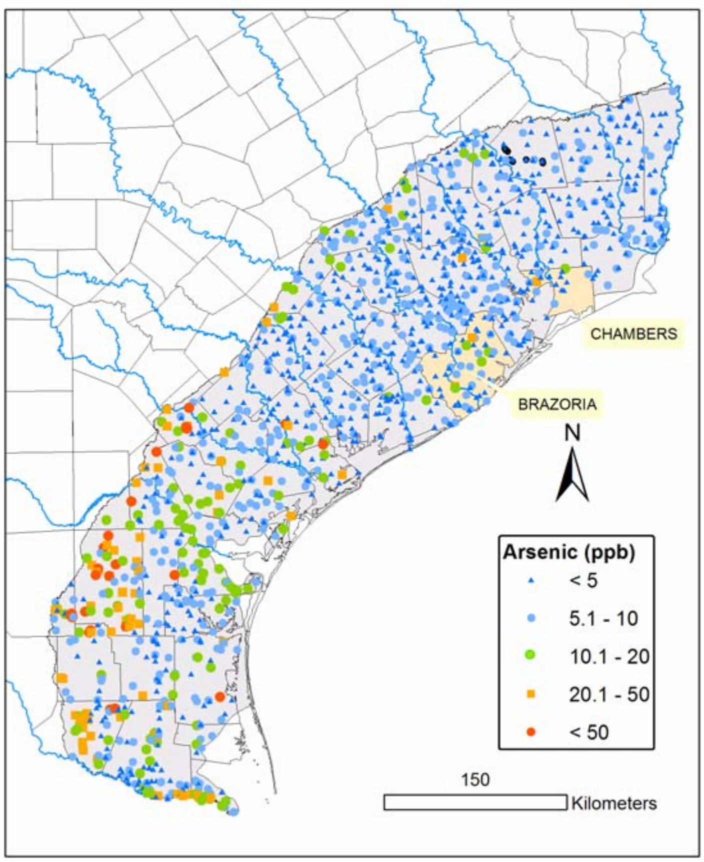
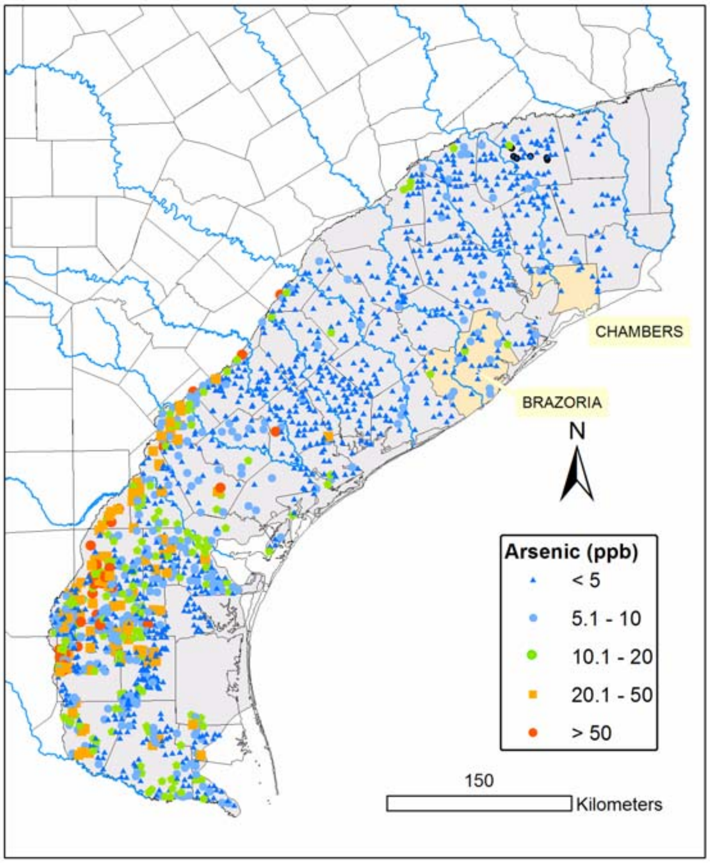


Figure 3.2 Detectable Arsenic Concentrations in Groundwater (NURE Database, 3,467 Samples from 1976 to 1980)



Both databases show higher arsenic concentrations in the south western part of the aquifer. East of the Colorado River wells with arsenic levels higher then the 10 parts per billion (ppb) (≡ 10 µg/L), the new MCL for arsenic, are relatively rare. Within this region wells in the northern part of the aquifer, completed in the Jasper subunit are more likely to have higher arsenic levels (Figures 3.1 and 3.2). The distribution of high levels of arsenic in the Chicot subunit in the central and northern Gulf Coast aquifer is spatially variable. Within this region the number of wells where arsenic ≥10 ppb in Brazoria County is relatively high.

3.2 GEOLOGY OF BRAZORIA, CHAMBERS, AND GALVESTON COUNTIES

Subsurface geologic deposits in Brazoria and Chambers Counties and Galveston County in between, consist mainly of sediments of Tertiary (Pliocene) and Quaternary (Pleistocene) age making up the last progradation wedges in the Gulf Coast. Gulf Coast sediments consist of several progradation wedges of Tertiary and Quaternary age composed of alternating sandstone and clay corresponding to variations in sea level and in inland sediment input as well as in other factors. Those wedges are approximately parallel to the current shoreline, and the deposition process is still active today (*e.g.*, Mississippi River and delta). In the Gulf Coast lowlands, these deposits are generally divided into six or more operational units: the

Fleming formation of Miocene age whose base includes the Oakville Sandstones, the Goliad/Willis formations of Pliocene age, and the Lissie and Beaumont Formations of Pleistocene age. The Willis Sand is more or less equivalent to the Alta Loma Sand (Kreitler, *et al*. 1977, p. 73). The Lissie formation is sometimes divided into a lower unit (Lissie sandstone or Bentley) and an upper unit, the Montgomery formation. The general dip of the formations toward the Gulf is 0.01 foot/foot, or less on average, and increases with depth because wedge thicknesses increase toward the Gulf of Mexico. Several salt domes pierce through the Pliocene formations (Mace, *et al*. 2006), do not seem to alter the regional structure of the Upper Tertiary formations but have the ability to locally degrade water quality. The Beaumont formation and more recent Holocene units (alluvium, barrier-island deposits) are exposed in and cover all of Brazoria, Galveston, and Chambers Counties.

The Gulf Coast aquifer is recognized as a major aquifer in the State of Texas (Ashworth and Hopkins 1995; Mace, *et al.* 2006). In the Tertiary Gulf Coast system, the general flow system consists of water infiltrating in the outcrop areas of the more permeable formations, some of it discharging into rivers and springs along short flow paths, and some of it flowing downdip into the deeper sections of the aquifers. The fate of that slowly moving water is to percolate up by cross-formational flow and discharge into the ocean. This process is necessary to maintain mass balance in the regional flow system although, because of heavy pumping in some areas, the natural upward flow has been locally reversed. The Catahoula formation of mostly Oligocene age is generally recognized as the low-permeability unit marking the base of the Gulf Coast aquifer, although it can locally produce water and thus be part of the Gulf Coast aquifer. Hydrostratigraphic units, solely concerned with permeability and connectivity of permeable bodies, do not always coincide with stratigraphic units defined by age and depositional environments. The other hydrostratigraphic units of the Coastal Plain, from deeper to shallower, are the Jasper aquifer, the Burkeville confining system, and the Evangeline and Chicot aquifers (Baker 1979). The Jasper aquifer is composed of the base of the Fleming formation, that is, the Oakville Sandstone, as well as the Catahoula Sandstone hydraulically connected to them. The upper part of the Fleming formation makes up the Burkeville confining system. The Evangeline aquifer includes mostly the Goliad Sand but also the upper sections of the Fleming formation when permeable. The remainder and younger formations of the section (Willis Sand, Lissie and Beaumont formations) make up the Chicot aquifer (Kasmarek and Robinson 2004).

In the Brazoria-Chambers County area, the base of the Jasper aquifer is at a depth of 4,000 to >6,000 feet below ground surface. The Oakville formation, forming the bulk of the Jasper aquifer, consists of fluvial fine- to coarse-grained, partially consolidated sand with silt and clay intercalations becoming volumetrically important downdip. Its thickness ranges from 1,200 to >3,000 feet (increasing downdip) in the Brazoria-Chambers County area (Baker 1979). The net sand thickness varies in the 400- 700-foot range with a sand fraction in the 15 -30 percent range (Galloway, *et al.* 1986). The Goliad formation, approximately equivalent to the Evangeline aquifer, unconformably overlies the top of the Fleming formation which comprises mostly clay with some calcareous sand. This formation acts as a leaky confining layer between the Jasper and the Evangeline aquifers ("Burkeville confining system") and has an approximate thickness of 600 feet in the Brazoria-Chambers County area.

Goliad sand is medium- to coarse-grained and unconsolidated with intercalations of calcareous clay and marl. The fluvial and deltaic sand of the Goliad formation suggest another small retreat of the shoreline toward the Gulf. Their thickness is in the 2,000-3,500-foot range. Goliad Sand grades into the generally coarse-grained Willis Sand whose depositional system arrangement is similar to that of the Goliad Sand. The Willis Sand makes up the Chicot aquifer with the overlying fine- to coarse-grained Lissie Sand. The top of the Lissie formation, with a higher clay content, and the Beaumont Clay generally pressurize the more permeable sand of the Willis and Bentley formations, confining the Chicot aquifer. The base of the Chicot aquifer is in the 800-1,200-foot depth range and the thickness of the sand-rich lower section is approximately 400-800 feet.

Well yield is generally high in the Gulf Coast aquifer in northeast Texas, including in Brazoria and Chambers counties; however, water quality is variable because of sea water intrusion and presence of shallow salt domes. Groundwater in the Chicot and upper section of the Evangeline aquifers is mostly fresh in Brazoria County, but contains several areas with brackish water in Chambers County (Aronow 1971). The lower section of the Evangeline aquifer could also be brackish in both counties. The Jasper aquifer is mostly slightly brackish in the study area, just northwest of Brazoria, Galveston, and Chambers Counties. Major cones of depression centered on and due to urbanization in neighboring Harris and Galveston Counties and heavy groundwater pumping from the Chicot and Evangeline aquifers extend into Chambers and Brazoria Counties despite their predominantly rural nature.

3.3 GENERAL TRENDS IN ARSENIC CONCENTRATIONS

The geochemistry of arsenic is described in Appendix E. A general analysis of arsenic trends in the vicinity of Brazoria and Chambers Counties was conducted to assess spatial trends as well as correlations with other water quality parameters. Arsenic measurements from the TWDB database (Figure 3.3), the TCEQ database, and from a subset of the NURE database (Figure 3.4), were used to assess the spatial distribution of arsenic.

Figure 3.3 Spatial Distribution of Arsenic Concentrations (TWDB Database)

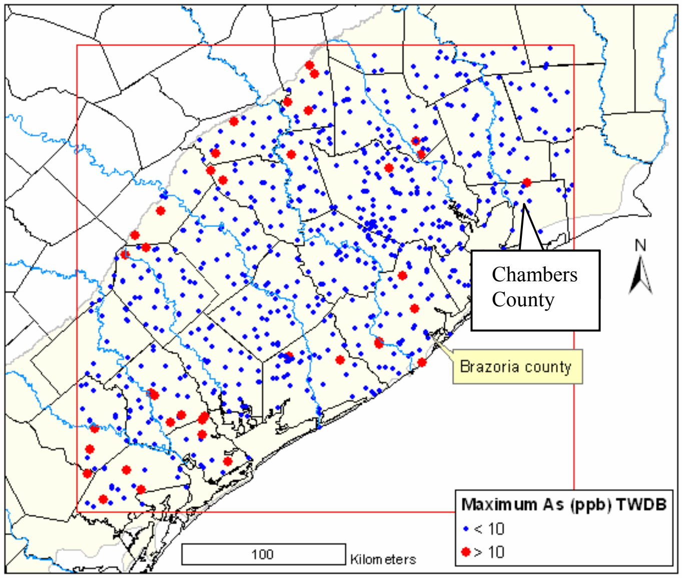
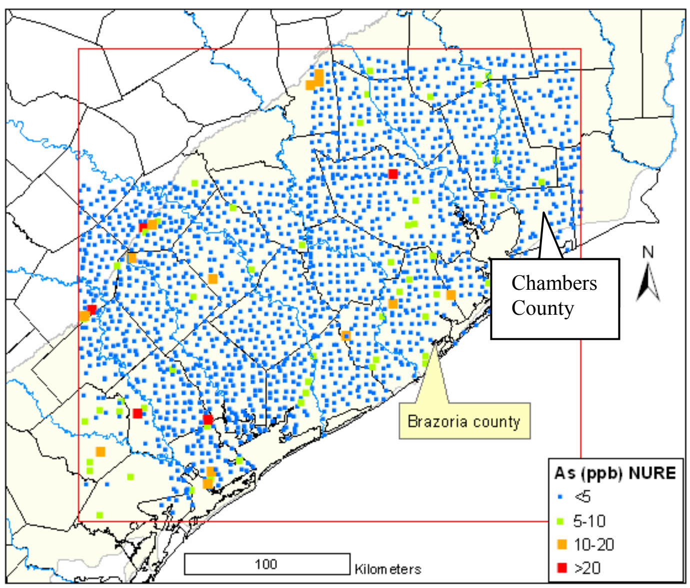


Figure 3.4 Spatial Distribution of Arsenic Concentrations (NURE Database)



The databases were queried in an area delineated by the following coordinates (bottom left: -97.45, 28.18; top right: -94.30, 30.64). From the TWDB database, 730 measurements were extracted, representing the most recent arsenic measurement taken at a specific well. Wells not in the Gulf Coast aquifer were excluded. The NURE database contained 2118 groundwater (sample type 03) arsenic measurements within the defined boundary. The wells do not have an aquifer identifier; therefore, no measurements were excluded.

Relationships between arsenic and well depth, pH, sulfate, fluoride, chloride, total dissolved solids (TDS), dissolved oxygen, phosphorus, iron, selenium, boron, vanadium, uranium, and molybdenum were evaluated using data from the NURE database and from the TWDB database separately. Correlations between arsenic concentrations and these parameters were weak (r^2 values ≤ 0.1); nevertheless, a trend of increasing probability for finding high arsenic concentrations in wells that show high molybdenum concentrations was found (Figures 3.5 and 3.6). The relationship between the probability of arsenic >10 µg/L and molybdenum concentrations are shown for the NURE (Figure 3.5) and TWDB (Figure 3.6) databases.

Figure 3.5 Relationship Between Arsenic and Molybdenum (NURE Database)

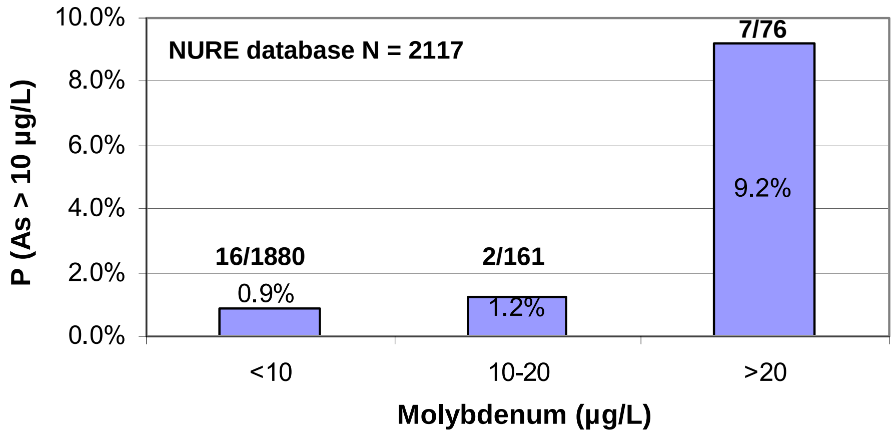
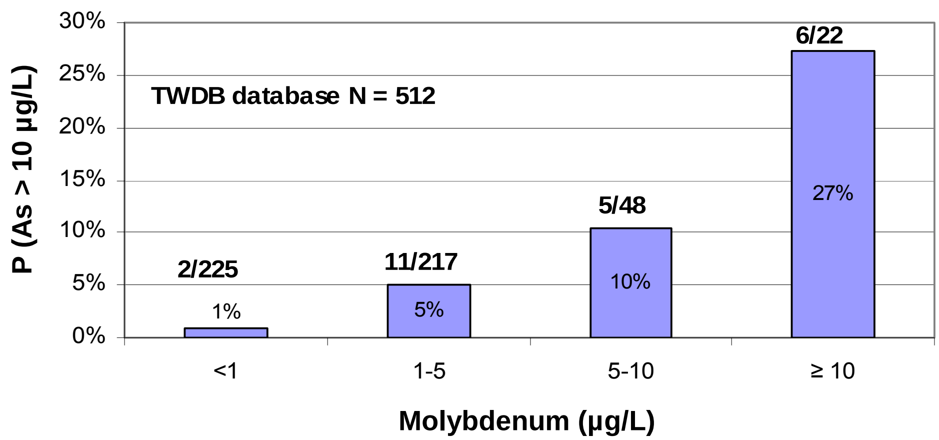


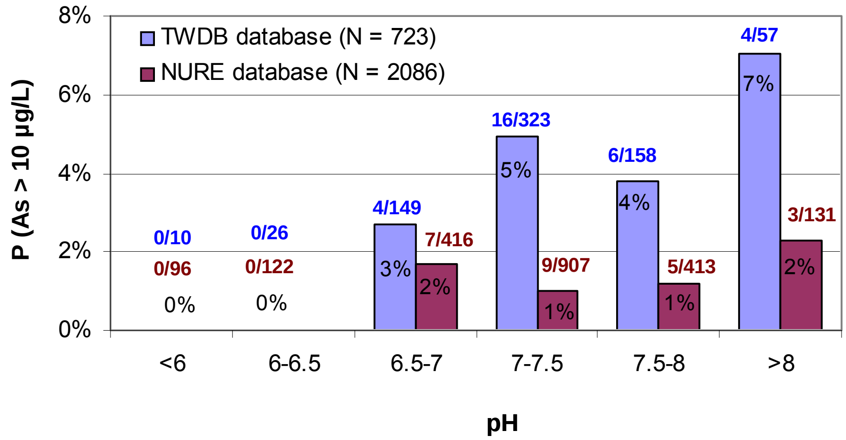
Figure 3.6 Relationship Between Arsenic and Molybdenum (TWDB Database)



N represents number of measurements used from each database. Numbers on top of the graph columns show number of arsenic measurements >10 µg/L and total number of measurements in each bin. For example "7/76" in the bin for molybdenum >20 ppb means that seven out of 76 arsenic measurements were greater than 10 µg/L.

Elevated arsenic concentrations and pH are also related (Figure 3.7). The absence of high arsenic concentrations (>10 μg/L) at pH less than 6.5 is notable.

Figure 3.7 Relationship Between High Arsenic Concentrations and pH



The relation between high arsenic concentrations and high molybdenum concentration and pH (similar relations exist between arsenic and TDS – not shown) suggest natural sources of elevated arsenic in Brazoria and Chambers Counties; however, there are insufficient data to make this conclusion definitive, and anthropogenic sources should be explored as well.

3.3.1 Arsenic and Point Sources of Contamination

Information regarding location of Potential Sources of Contamination (PSOC) was collected as part of the TCEQ Source Water Assessment Program (SWAP). Arsenic concentrations from TWDB (Figure 3.8) and NURE (Figure 3.9) databases were compared to the PSOC coverage. A density map of the PSOCs was generated (number of PSOCs per km^2) and the PSOC density values were compared with arsenic concentrations from the NURE database.

Figure 3.8 Potential Sources of Arsenic Contamination and Arsenic Concentrations from the TWDB Database

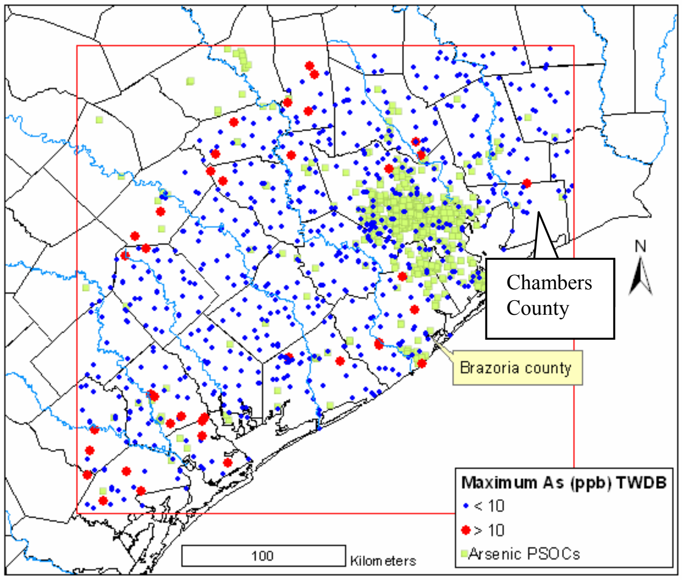
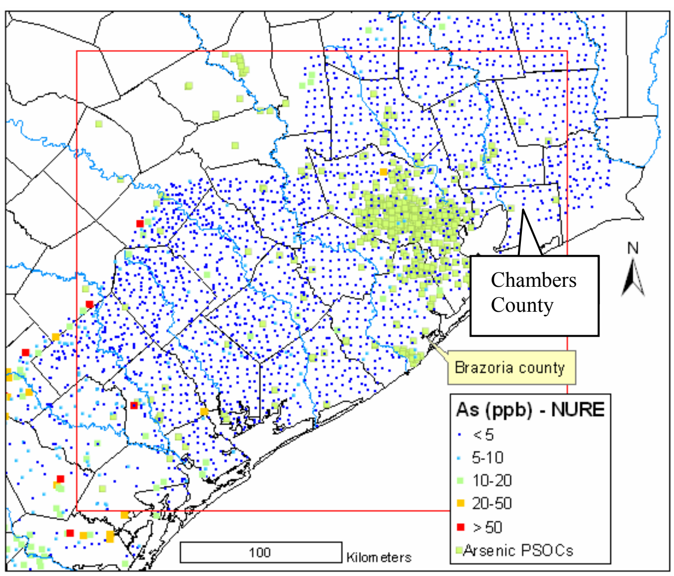


Figure 3.9 Potential Sources of Arsenic Contamination and Arsenic Concentrations from the NURE Database

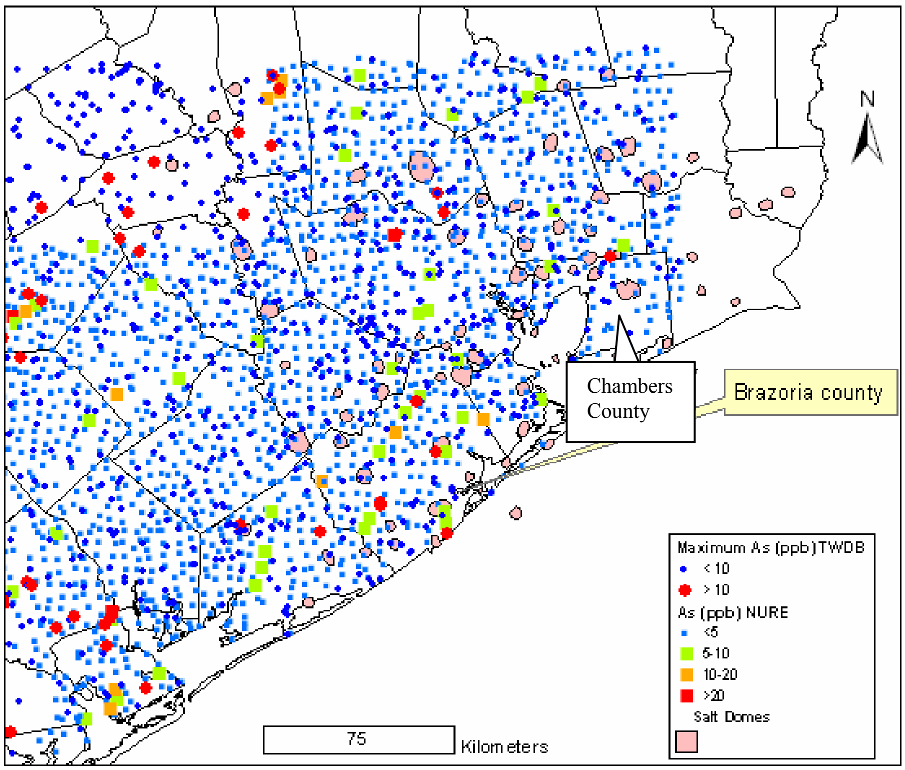


No general correlation was found between high arsenic concentrations and density of potential sources of contamination. This strengthens the conclusion that the majority of arsenic sources in this area are natural. Specific PSOCs near the PWS systems will be analyzed in more detail in Subsection 3.4.

3.3.2 Salt domes

Elevated arsenic concentrations were not correlated with salt dome locations (Figure 3.10).

Figure 3.10 Salt Dome Locations and Arsenic Concentrations from TWDB and NURE Databases

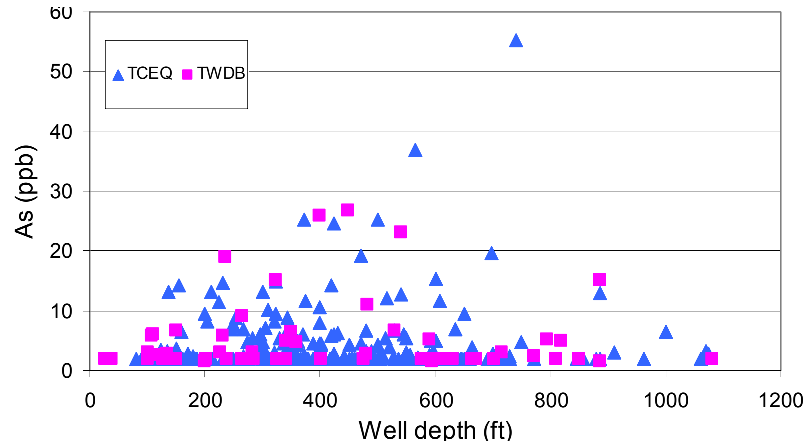


3.3.3 Arsenic Levels and Correlation With Well Depth In Brazoria, Galveston and Chambers Counties

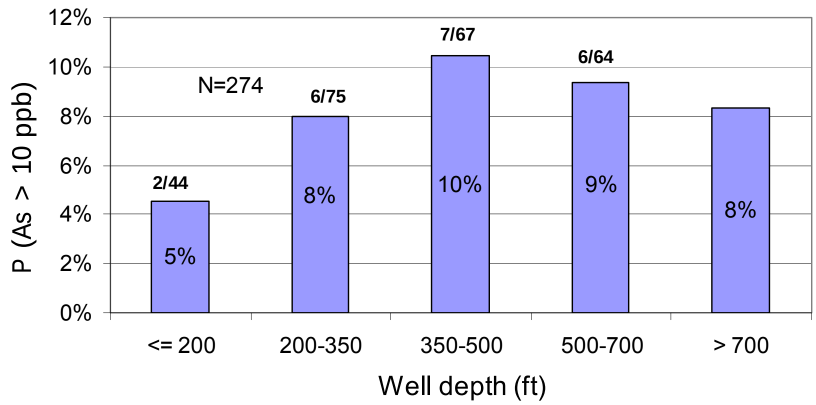
Arsenic concentrations were compared to well depth in a smaller region which includes only Brazoria, Galveston, and Chambers Counties to infer more representative statistics for the PWSs being analyzed. Well depth was used in this area instead of absolute altitude (surface elevation – well depth) because the surface elevation data were not complete and contained more errors; and the variability in these three counties was relatively small (0-60 feet). Sixty two of the most recent samples from the TWDB data set were taken after March 1997 because the arsenic detection limit from earlier samples was commonly 10 µg/L while the median arsenic concentration in this area was less than 2 µg/L. Two hundred seventy-four most recent arsenic samples from the three counties (1996-2005) from the TCEQ database that can be related to a single well were used for this analysis (Figure 3.11). The TCEQ database designates 271 out of the 274 wells to the Chicot aquifer without further details, whereas the TWDB database has further classifications within the Chicot (*e.g.*, 112CHCTU – Chicot Upper Sand, 112CHCTL – Chicot Lower Sand).

Figure 3.11 Relationship Between Arsenic Concentrations and Well Depth in Wells from Brazoria, Galveston, and Chambers Counties

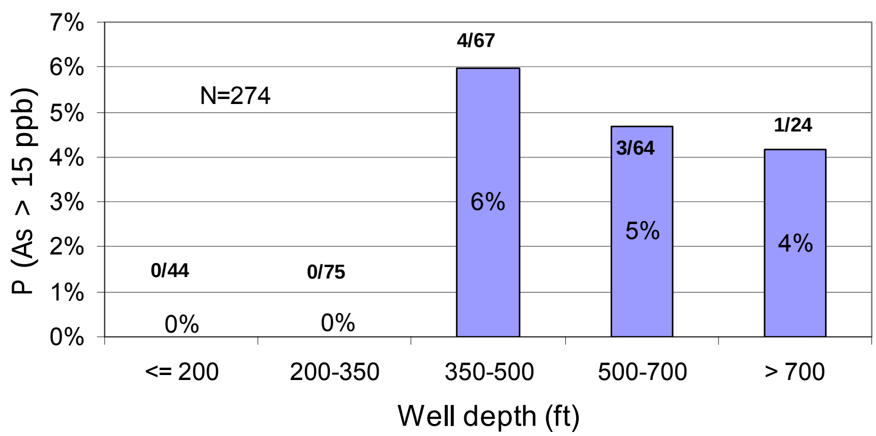
a)



b)



c)



In Figures 3.11b and c, N represents the total number of samples in the analysis (274 - TCEQ database), and the numbers above each column represent the number of arsenic measurements >10 µg/L (11b) or >15 µg/L (11c) relative to the total number of analyses in the bin. For example, 4/67 in Figure 3.11c represents four samples where arsenic was >15 µg/L out of 67 samples taken from wells with depths between 350-500 feet.

Groundwater arsenic levels in this area are low, with an average of 4.2 µg/L in the TCEQ wells and 4.8 µg/L in the TWDB wells (concentrations of 2 µg/L in TCEQ and 2.04 in the TWDB databases were assigned for samples <2 µg/L and <2.04 µg/L, so these averages are an upper boundary for the real averages). The median for the three counties in both data sets are below the aforementioned detection-limits, *i.e.,* <2 µg/L.

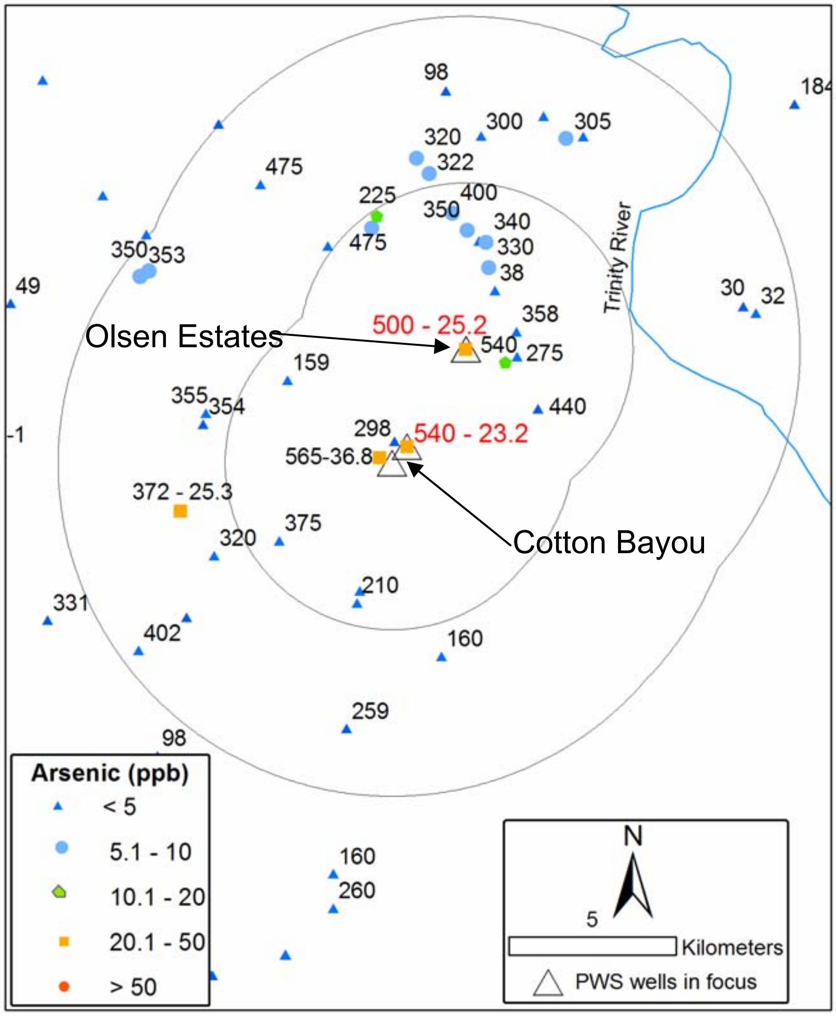
There is a tendency toward higher densities of elevated arsenic concentrations at depths between 300 and 700 feet relative to shallower and deeper wells (Figure 3.11a). The probability analyses of As >10 and As >15 in Figures 3.11b and 3.11c confirm this tendency (only TCEQ data). The medium range wells 350-500 feet deep are the most likely to have high arsenic concentration. In this area where most wells have very low arsenic concentrations, the option of blending high and low arsenic water is more feasible; therefore, recognizing the very low probability of As >15 in wells shallower than 350 feet is significant (Figure 3.11c).

3.4 DETAILED ASSESSMENT FOR OLSEN ESTATES PWS

The Olsen Estates PWS has two wells with a lateral separation of 5 meters (this is shown as one triangle in Figure 3.12) but with different depths, G0360065A (350 feet deep) G0360065B (500 feet deep). The TCEQ database lists only one entry point (EP) (EP 1) for this system, which is connected only to the deeper well G0360065B. Nevertheless, the table of inorganic contaminant levels in the TCEQ database shows that the point of collection (POC) for samples from this PWS until 2001 was EP 2 and in 2004 changed to EP 1. Either EP 2 relates to the shallower well G0360065A and is not in use today or it is an older EP related to well G0360065B, or to both wells. The arsenic concentrations in samples from both POCs are between 24- 30 µg/L. If EP 2 is not related to G0360065A, water from this well should be analyzed to determine if high arsenic concentrations are restricted to depths greater than 350 feet, which is common in Chambers, Galveston, and Brazoria Counties (Figure 3.11c).

This analysis was prepared for reports that address the Olsen Estates PWS and the Cotton Bayou Manor Mobile Home Park PWS (Cotton Bayou PWS) and, consequently, both appear in the text, tables, and figures in this section.

Figure 3.12 Most Recent Arsenic Concentrations in Wells within 5-km and 10-km Buffers of the Cotton Bayou and Olsen Estates PWS Wells



Labels are depth in feet, for higher than 20 ppb wells depth – arsenic (ppb); PWS labels are in red

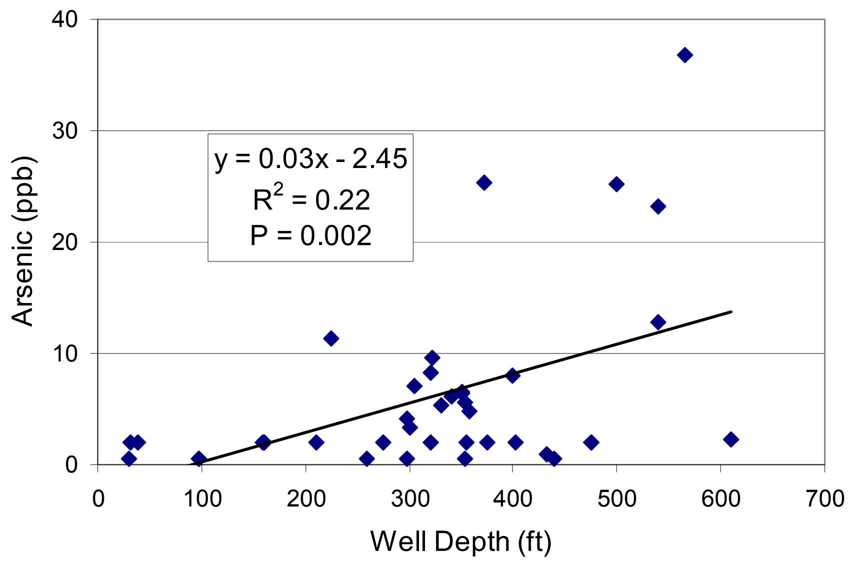
There is a positive significant correlation between arsenic levels and well depths within the 10-km buffer drawn in Figure 3.12 (R^2 =0.22, P value = 0.002) (Table 3.1, Figure 3.13). This means the probability of finding low arsenic concentrations in shallow wells in this area is high. There are no wells shallower than 200 feet with arsenic >10 ppb, no well shallower than 370 feet with arsenic >20 ppb, and in four out of five wells deeper than 500 feet, arsenic >10 ppb (Figure 3.13).

Table 3.1 Arsenic Levels and Hydrogeologic Well Data from a 10-km Buffer Around Cotton Bayou and Olsen Estates Wells (in red)

Database	State well number	Aquifer	Well depth (ft)	Opening top (ft)	Opening bottom (ft)	Sampling date	Arsenic (µg/L)
TWDB	6401905	112CHCTU	475			7/25/2005	<2.04
TWDB	6409811	112CHCTL	402			7/26/2005	<2.04
TWDB	6410211	112CHCTU	38			5/2/2001	<2
TWDB	6410214	112CHCTL	350			7/27/2005	6.5
TWDB	***6410416***	***112CHCTU***	***540***			***7/26/2005***	***23.2***
TWDB	6410519	112CHCT	358			8/16/2005	4.8
TWDB	6411107	112CHCTU	32			7/27/2005	<2.04
	Well id						
TCEQ	G0360081A	112CHCT	305	285	305	6/27/2001	7.1
TCEQ	G0360094A	112CHCT	159			4/10/2002	<2.0
TCEQ	G0360079A	112CHCT	320	220	230	4/10/2002	<2.0
TCEQ	G0360075A	112CHCT	355			8/5/2002	<2.0
TCEQ	G0360059A	112CHCT	160			8/5/2002	<2.0
TCEQ	G0360061A	112CHCT	275			8/5/2002	<2.0
TCEQ	G0360024A	112CHCT	372	344	364	1/27/2003	25.3
TCEQ	G0360085A	112CHCT	350	340	350	3/10/2004	6.4
TCEQ	G0360085B	112CHCT	353	343	353	3/10/2004	5.6
TCEQ	G0360049A	112CHCT	300			7/19/2004	3.3
TCEQ	G0360093A	112CHCT	400			7/19/2004	8.0
TCEQ	G0360100A	112CHCT	565			7/19/2004	36.8
TCEQ	G0360069A	112CHCT	375			10/26/2004	<2.0
TCEQ	G0360090A	112CHCT	330			10/26/2004	5.3
TCEQ	G0360108A	112CHCT	340			11/11/2004	6.2
TCEQ	G0360042A	112CHCT	210	200	210	12/9/2004	<2.0
TCEQ	G0360027B	112CHCT	322	312	322	1/6/2005	9.6
TCEQ	G0360017F	112CHCT	475			1/6/2005	<2.0
TCEQ	***G0360065B***	***112CHCT***	***500***			***3/1/2005***	***25.2***
TCEQ	G0360060A	112CHCT	225			4/4/2005	11.4
TCEQ	G0360095A	112CHCT	540			4/4/2005	12.8
TCEQ	G0360027A	112CHCT	320	300	320	4/19/2005	8.3
	Record number	**Sgeounit**					
NURE	1148508	QPB	433	413		1978/01/12	1
NURE	1148586	QPB	298			1978/02/24	<0.5
NURE	1148587	QPB	298	289		1978/02/27	4.2
NURE	1148680	QPB	259			1978/01/23	<0.5
NURE	1148681	QPB	98			1978/01/23	<0.5
NURE	1148780	QPB				1978/02/07	<0.5
NURE	1148783	QPB	354			1978/02/08	<0.5
NURE	1148784	QPB	440			1978/02/09	<0.5
NURE	1148786	QPB				1978/02/24	<0.5
NURE	1148788	QPB				1978/02/24	9.6

Database	State well number	Aquifer	Well depth (ft)	Opening top (ft)	Opening bottom (ft)	Sampling date	Arsenic (µg/L)
NURE	1148789	QPB				1978/02/24	2.4
NURE	1148790	QPB	610			1978/02/24	2.3
NURE	1148796	QPB	98			1978/02/28	<0.5
NURE	1148797	QD				1978/02/28	2.2
NURE	1149015	QD	30	30		1978/03/07	<0.5

Figure 3.13 Arsenic Versus Well Depth in 10-km Buffer around Cotton Bayou and Olsen Estates PWS Wells



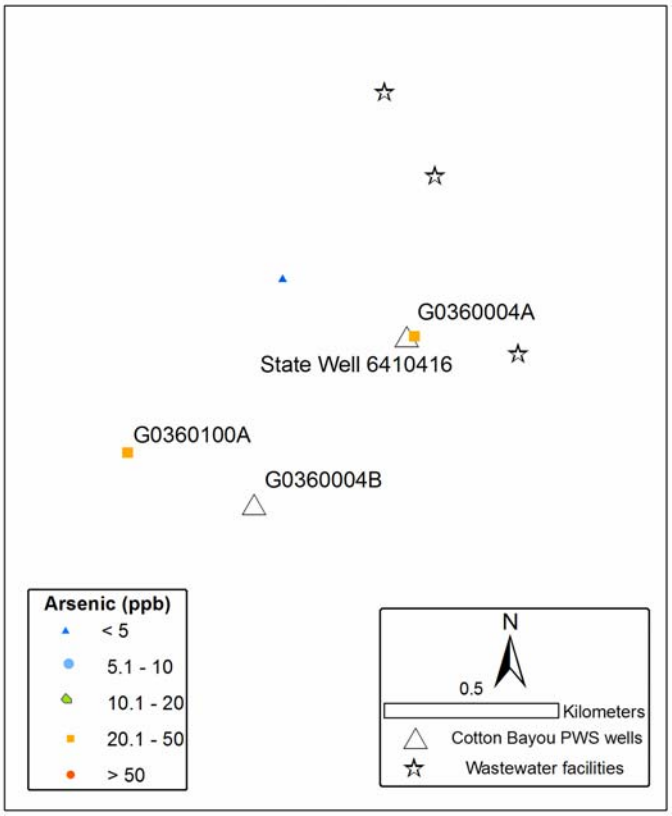
There is no trend in arsenic concentrations with time in both PWS systems (Table 3.2).

Table 3.2 History of Arsenic in Cotton Bayou and Olsen Estates PWS Wells

PWS	Database	Sampling date	Arsenic (ppb)
Cotton Bayou	TCEQ	8/26/1998	28.5
Cotton Bayou	TCEQ	6/11/2001	25.9
Cotton Bayou	TCEQ	10/26/2004	25.7
Cotton Bayou	TCEQ	1/3/2005	24.9
Cotton Bayou	TWDB	7/26/2005	23.2
Olsen Estates	TCEQ	3/10/1998	23.8
Olsen Estates	TCEQ	4/16/2001	30.2
Olsen Estates	TCEQ	5/26/2004	24.1
Olsen Estates	TCEQ	3/1/2005	25.2

Three wastewater facilities are listed in the PSOC for arsenic in the vicinity of the Cotton Bayou wells (Figure 3.14).

Figure 3.14 Arsenic Potential Sources of Contamination and Arsenic Concentrations in the Cotton Bayou PWS



There were no arsenic PSOCs near the Olsen Estates PWS wells listed. The head gradient in the Cotton Bayou area is westward toward the Houston depression (based on the GAM report see Figure 55 in Kasmarek and Robinson 2004). Therefore, these wastewater facilities could contaminate the wells, if they leak (Figure 3.14). The well with low levels of arsenic in Figure 3.14 is from the NURE database (298 feet deep) sampled in 1978; therefore, it does not prove that contamination in these wells is not from the surface. Nevertheless, it is most probable that these surface sources are not the primary source of arsenic in these wells.

3.4.1. Summary of Alternative Groundwater Sources for Olsen Estates PWS

There is a high probability of finding wells with low arsenic concentrations in wells less than 200-feet deep in the Olsen Estates PWS area. Sampling well G0360065A (350 feet deep) is essential for assessing arsenic concentrations in this depth interval. It may be that low arsenic levels in this area can be found only in shallower wells. Well 60360061A 1,600 meters west of the Olsen Estates PWS wells is 275 feet deep with arsenic concentrations less than the detection limit of 2 ppb, whereas a nearby well that is 540 feet deep well had arsenic concentrations above 10 ppb (Figure 3.12). New shallow wells (<250 feet) drilled east of the existing wells may also provide an alternative groundwater source, but more hydrogeologic evidence is needed to confirm this.

SECTION 4
ANALYSIS OF THE OLSEN ESTATES WATER SYSTEM PWS

4.1 DESCRIPTION OF EXISTING SYSTEM

4.1.1. Existing System

The Olsen Estates (OE) PWS location is shown in Figure 4.1. Olsen Estates PWS serves a residential subdivision of 60 connections and 180 people at full build out. The current number of connections is 52, with a population of 144.

The water sources for this PWS are two wells, both of which are completed in the Chicot aquifer (Code 112CHCT). G0360065A is 350 feet deep with a tested capacity of 43 gpm (0.06 mgd), while Well G0360065B is 500 feet deep with a tested capacity of 65 gpm (0.09 mgd). The total production of the two wells is 108 gpm (1.5 mgd). Disinfection with hypochlorite is performed near the wellheads before the water enters the pressure tank and subsequently enters the distribution system.

The treatment employed for disinfection is not appropriate or effective for removal of arsenic, so optimization is not expected to be effective in increasing removal of this contaminant. There is, however, a potential opportunity for system optimization to reduce arsenic concentration. The system has two wells close together but at different depths. Since arsenic concentrations can vary significantly between wells, arsenic concentrations should be determined for each well. If one of the wells produces water with acceptable arsenic levels, as much production as possible should be shifted to that well. It may also be possible to identify arsenic-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: 144 current, 180 at full build out
- Connections: 52 current, 60 at full build out
- Average daily flow: 0.023 mgd
- Total production capacity: 1.5 mgd

Basic system raw water quality data is as follows:

- Typical total arsenic range: 0.0238 to 0.0302 mg/L
- Typical total dissolved solids range: 1,231 to 1,234 mg/L
- Typical pH range: 7.4 to 7.9
- Typical calcium range: 17.0 to 17.1 mg/L
- Typical magnesium range: 5.7 to 6.14 mg/L
- Typical sodium range: 431 to 458 mg/L

Figure 4.1

Olsen Estates Water System Pipeline Alternatives

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- Typical chloride range: 454 to 476 mg/L
- Typical bicarbonate (HCO_3) range: 538 to 542 mg/L
- Typical fluoride range: 0.1 to 1.5 mg/L
- Typical iron range: 0.140 to 0.155 mg/L

4.1.2 Capacity Assessment for Olsen Estates PWS

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

The project team interviewed the following individuals.

- Philip Beam – Secretary/Treasurer, Board of Directors
- Roger Durgas – Board Member

4.1.2.1 General Structure

Olsen Estates Property Owners is a homeowners' association governed by a three-member board of directors. The association contracts with a certified operator to operate the water system. The vice-president of the association also acts as the manager of the PWS and does some O&M on the system. He is currently in the process of becoming certified as an operator. The water system currently serves 144 people at 52 connections. The system consists of two wells and a 5,000-gallon pressure tank. The board meets annually, and all property owners are invited but there are no monthly meetings. The board members speak to each other informally throughout the year, but do not formally vote on procedures or activities except at the annual meeting. The association has recently changed its policies on late payments and has instituted a policy on termination of service and disconnection.

4.1.2.2 General Assessment of Capacity

The system has an inadequate level of capacity. Although there are some positive managerial and technical aspects of the water system, there are some capacity deficiencies and concerns.

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 Olsen Estates are listed below.

- **Enforcement of Shut-off Policy for Delinquent Bills –** At the last annual meeting, it was decided that because some customers were not paying their bills, the system would shut off a customer after the bill was 60 days past due. In addition, the system would charge a $200 deposit fee, which is returned to the customer if they are current with their bills for one year or if they discontinue service and are current with their bill. They also charge a $100 lock-out fee if they system has to disconnect service for non-payment. Because the operator received threats when he attempted to disconnect service, two people are needed to disconnect or turn on service. The system indicated that the collection rate has increased since they instituted these new policies. Also, the system previously charged a one-time fee of $5 for late bills. They recently changed to policy to a fee of $5 per month for each month the bill is late.

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 Financial Accounting** – Without tracking expenses and revenues for the water system, it is not possible to know if the revenue collected through user charges is sufficient to cover the cost of current operation, repair, and replacement, compliance with the arsenic regulations, and provide a reserve fund. The lack of a method to track revenues and expenses could negatively impact the system's ability to develop a budget and associated rate structure that will provide for the system's long term needs. While the system expressed the goal to have a reserve account, they also stated that they charge what they think will cover the expenses and have a reserve. There does not appear to be a way to check expenses against revenues. Also, a rate increase is determined when they do not have sufficient revenue to pay bills. The last rate increase was 5 years ago and the rate increased from a flat rate of $20 to $40. The current rate is $40 a month or $100 a quarter. The system does not read the meters because they stated that there was no one available to take that responsibility. With sufficient revenues, the system could pay for meter reading service.
- **Inadequate Recordkeeping -** The system does not receive the results of their compliance sampling and did not understand that it was their responsibility to keep a record of the results. They were not sure if the contract operator received the results. The system has received monitoring violations from TCEQ, but is unsure whether the problem was a lack of testing, or simply the result of the laboratory not sending the results to TCEQ. Without the laboratory reports, the system cannot resolve this issue.

Furthermore, without the sampling results, the system cannot follow water quality trends over time.

- **Lack of Written Long-Term Capital Improvements Plan –** The system does not have a process for long-term planning and there is no written plan. The lack of a long-term written plan could negatively impact the system's ability to develop a budget and associated rate structure that will provide for the system's long term needs and for compliance with the arsenic standard.
- **Failure to Prepare and Distribute Consumer Confidence Report –** The board members stated that they do not prepare a Consumer Confidence Report as required under the SDWA.

4.1.2.5 Potential Capacity Concerns

The following items were concerns regarding capacity but there are no particular FMT problems that can be attributed to these items. The system should focus on the deficiencies noted above in the capacity deficiency section. Addressing the items listed below will help in further improving technical, managerial, and financial capabilities.

- **Lack of Written Contract for Water Operations –** Olsen Estates does not have a written agreement with the water operator for water operations services. There is only a verbal agreement. It is always better to have the 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 Knowledge of SDWA Regulations** – The board members indicated that they are not familiar with the SDWA regulations, and that they rely on the operator to operate the system in compliance with TCEQ regulations. Water system management should be familiar with the SDWA requirements that apply to their system. They should learn about system needs through site visits and frequent discussions with operators. Lack of first-hand knowledge may result in poor decision-making.
- **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, the residents would run out of water in a very short time, because the system has limited storage capacity. The system should have an emergency or contingency plan that outlines what actions will be taken and by whom. The emergency plan should meet the needs of the facility, the geographical area, and the nature of the likely emergencies. Conditions such as storms, floods, major line breaks, electrical failure, drought, system contamination or equipment failure should be considered. The emergency plan should be updated annually, and larger facilities should practice implementation of the plan annually. This system did experience an emergency during Hurricane Rita when the power was out for 3 days and the system could not supply water to its customers.
- **Lack of Customer Support –** The board members indicated that some of them had received threats from customers who were delinquent in their bills. In addition, there is a problem recruiting members to serve on the board of directors.

- **Infrequent Board Meeting** – The board of directors meets as needed, rather than on a regular schedule, although there appears to be a significant amount of informal communication. There are some procedures in place, such as requiring two signatures of board members on all checks. However, to prevent future problems, a more formal board meetings in which decisions are recorded should be considered.

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

Table 4.1 is a list of the existing PWSs within approximately 8 miles of the Olsen Estates PWS. Five miles was selected as the radius for the evaluation owing to the large number of PWSs with compliant water in proximity to the Olsen Estates PWS.

Based on the initial screening summarized in Table 4.1, several alternatives for obtaining water from a neighboring PWS were selected for further evaluation. These alternatives were selected based on factors such as water quality, distance from the OE PWS, sufficient total production capacity for selling or sharing water, and willingness of the system to sell or share water or drill a new well. These are summarized in Table 4.2.

After the PWSs in Table 4.1 with water quality problems were eliminated from further consideration, the remaining PWSs were screened by proximity to Olsen Estates PWS and water production capacity. Since there are a large number of PWSs relatively close to Olsen Estates PWS, some of the larger, more distant PWSs were included instead of some of the small but closer PWSs.

Table 4.1 Existing Public Water Systems within 8 miles of Olsen Estates Water System

System Name	Distance From Olsen Estates PWS (Miles)	Comments/ Other Issues
Chambers Cnty New Cove Blding	0.8	Small system. WQ issues: As
Chambers Cnty Old Cove Building	1.0	Small system. No WQ issues..
River Oaks Subdivision	1.6	Small system. No WQ issues..
Lost Lakes	2.0	Small system. No WQ issues..
Plantation On Cotton Bayou	2.2	Small system. No WQ issues.
Grays Trailer Court	2.4	Small system. WQ issues: As
Cotton Bayou Manor Mobile Home Pk	2.5	Small GW system. WQ issues: As
Hackberry Creek Subdivision	2.7	Small system. WQ issues: As
Woodland Acres Subdivision	2.9	Small system. WQ issues: As
Chambers Cnty Old River Building	2.9	Small system. WQ issues: As
City Of Mont Belvieu	3.1	Large system. No WQ issues. ***Evaluate further.***
Trinity Cove Subdivision	3.5	Small system. No WQ issues.
KOA Campground	3.6	Small system. No WQ issues..
Carriage Trail Subdivision	4.7	Small system. WQ issues: As
Tower Terrace	5.0	Large system. No WQ issues. ***Evaluate further.***
Cedar Bayou Community Building	5.0	Small system. No WQ issues..
Beach Haven Subdivision	5.1	Small system. No WQ issues..
Villa Utilities	5.4	Small system. No As data.
Engineered Carbons Inc	5.9	Large system. No WQ issues. ***Evaluate further.***
Cedar Bayou Estates	6.1	Small system. No WQ issues..
Snappy Mart	6.1	Small system. No WQ issues..
Cedar Bayou Mobile Home Park	6.1	Small system. WQ issues: As
Gulf Coast Fractionator	6.1	Small system. WQ issues: marginal As
Tall Pine Mobile Home Park (Country Living Mobile Home Park)	7.0	Small system. No WQ issues..
Mcgee Place	7.1	Small system. No WQ issues..
Delynn Water System	7.1	Small system. No WQ issues..
Convenient Supermarket	7.2	Small system. No As data.
J & L Terry Lane	7.7	Small system. No As data.
City of Baytown	8.0	Large system. No WQ issues. ***Evaluate further***

Table 4.2 Public Water Systems within 8 miles of Olsen Estates Water System Selected for further Evaluation

System Name	Pop	Conn	Total Production (mgd)	Ave Daily Usage (mgd)	Approx. Dist. from Olsen Estates PWS	Comments/Other Issues
City Of Mont Belvieu	3,100	1,257	2.808	0.715	3.1	Probable excess capacity, may not be interesting in selling water.
Tower Terrace	756	253	0.266	0.086	5.0	Sufficient excess capacity.
Engineered Carbons Inc	60	11	0.676		5.9	Probable excess capacity, may not be interested in selling water.
City of Baytown	70,850	18,029	26	14	8.0	Sufficient excess capacity and willing to sell water.

4.2.1.1 City Of Mont Belvieu

The City of Mont Belvieu is located is located 3.1 miles northwest of the Olsen Estates PWS. The Mont Belvieu PWS is operated by the city, and serves a population of 3,100 with 1,257 connections, 1,059 of which are metered. The PWS is supplied by three local groundwater wells. Well G0360017C was completed in the Chicot aquifer and drilled to a depth of 405 feet. The second well, G0360017D, was completed in the Evangeline aquifer and drilled to a depth of 982 feet. The third well, G0360017F, was drilled to a depth of 475 feet. The tested flow rates of the wells are 370, 1,000 gpm and 580 gpm, respectively, for a total system production of 2.808 mgd. The average daily consumption is 0.715 mgd which means the City of Mont Belvieu PWS is utilizing approximately 25 percent of total system capacity. The water is used primarily for residential purposes. The water is chlorinated for disinfection before distribution. The system has total tank storage of 0.561 million gallons (MG), elevated storage of 0.350 MG, and a total booster pump capacity of 1.44 mgd. Two more wells are being installed to meet the increased demand for planned new subdivisions currently under construction within the city.

The Mont Belvieu PWS may have excess capacity that could be used to supplement the Olsen Estates PWS; however, it has expressed doubt about possessing enough excess capacity to allow it to sell water. No water quality issues are reported for the City of Mont Belvieu PWS in the TCEQ database.

4.2.1.2 Tower Terrace

The Tower Terrace PWS, formerly known as Tecon Water Company PWS, is located approximately 5 miles southwest of Olsen Estates PWS. This PWS is operated by Monarch Utilities 1 LP, and serves a population of 756 with 253 metered connections. The Tower Terrace PWS is supplied by two local groundwater wells completed in the Lower Chicot aquifer. The wells, G0360069A and G0360069B, were drilled to depths of 390 feet and 379 feet, respectively. The rated flow rates of each well are 195 and 200 gpm for a total system production of 0.266 mgd. The average daily consumption is 0.086 mgd which means that the Tower Terrace PWS is utilizing approximately 32 percent of total system capacity. The water is used primarily for residential purposes. The water is chlorinated for disinfection before distribution. The system has total tank storage of 0.06 MG, pressure tank capacity of 0.007 MG, and a total booster pump capacity of 3.024 mgd.

This water supply system has excess capacity that could be used to supplement the Olsen Estates PWS, and would consider providing a portion of its excess water supply. The current rate schedule for the residences is a flat fee of $31.45/month and $3.80 per every 1,000 gallons. No water quality issues are reported for the Tower Terrace PWS in the TCEQ database.

4.2.1.3 Engineered Carbons Inc.

The Engineered Carbons Inc. Water System is located 5.9 miles southwest of the Olsen Estates PWS. This PWS is operated by Degussa Engineered Carbons LP, and serves an industrial facility with 60 people. The PWS is supplied by two local groundwater wells. The wells, G1011038A and G1011038B, were drilled to depths of 365 feet and 373 feet, respectively. A third well, G1011038C, drilled to a depth of 365 feet, is for emergency use. The total water production is 0.676 mgd. The water is used primarily for industrial and agricultural purposes. The water is hypochlorinated for disinfection before distribution. The system has one 75,000-gallon elevated tank. There is no information on the capacity of the booster pumps.

This PWS likely has excess capacity that could be used to supplement the Olsen Estates PWS. However, the system has indicated an initial unwillingness to sell excess water. No water quality issues are reported for the Engineered Carbons Inc. system in the TCEQ database.

4.2.1.4 City of Baytown

The City of Baytown water distribution system extends to within 8 miles southwest of the Olsen Estates PWS. The City of Baytown PWS serves a population of 70,850 with 18,029 connections. The City of Baytown obtains treated surface water from the Baytown Area Water Authority (BAWA). BAWA obtains Trinity River water via the Coastal Industrial Water Authority canal, and treats it to provide water on a wholesale basis to the following entities:

- The City of Baytown;
- Harris County Water Control & Improvement District #1 (Highlands);
- Harris County Fresh Water Supply District #1A (McNair) ;
- Harris County Fresh Water Supply District #1B (Highlands);
- Harris County Fresh Water Supply District #27 (Coady);
- Lake Municipal Utility District (Meadowlake and Toyota of Baytown);

- C & R Water Supply (Cedar Bayou); and
- Country Terrace Water Supply (Wallisville Road).

The City of Baytown lies between the BAWA system and Olsen Estates, so the Olsen Estates PWS would obtain BAWA water that would be passed through the City of Baytown transmission/distribution system. The City of Baytown has the ability to produce up to 26 mgd, which is significantly more than the average water usage of approximately 14 mgd. The City of Baytown PWS has excess capacity that could be used to supplement the Olsen Estates PWS, and would consider selling a portion of its excess water supply, as it currently provides drinking water to several small PWSs in the area. The current water rate for residents is $3.60 per 1,000 gallons. No water quality issues are reported for the City of Baytown PWS in the TCEQ database.

4.2.2 Potential for New Groundwater Sources

4.2.2.1 Installing New Compliant Wells

Developing new wells or well fields is likely to be an attractive alternative, provided good quality groundwater in sufficient quantity can be identified. Since a number of water systems in the area also have problems with arsenic, it should be possible to share in the cost and effort of identifying compliant groundwater and constructing well fields. Additionally, the assessment in Section 3 indicates there is a possibility for finding compliant water at the Olsen Estates PWS location by installing shallower wells.

Installation of a new well in the vicinity of the system intake point is likely to be an attractive option provided compliant groundwater can be found, since the personnel of the PWS are already familiar with operation of water wells. 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 will ensure the well characteristics are known and that well construction meets 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

Regional groundwater withdrawal in the PWS area is extensive and is likely to steadily increase over the next decades. Within 10 miles of the Olsen Estates PWS, and throughout Chambers County, the Chicot aquifer is the primary groundwater source for public supplies. This aquifer is the upper unit of the Gulf Coast aquifer system that extends along the entire Texas coastal region. Throughout the northern part of the Gulf Coast aquifer system, large groundwater withdrawals since the 1900s have resulted in declines in the aquifer's potentiometric surface from tens to hundreds of feet. The largest declines have occurred in the Harris-Galveston Coastal Subsidence District (HGCSD), around the Houston metropolitan area, whose area of influence encompasses the entire Chambers County.

A GAM for northern part of the Gulf Coast aquifer was recently developed by the TWDB. Modeling was performed by the U.S. Geological Survey (USGS) to simulate historical conditions (Kasmerek and Robinson 2004), and to develop long-term groundwater projections (Kasmerek, Reece and Houston 2005). Two projections were evaluated, a TWDB scenario based on 50-year regional projections by regional user groups, and an HGCSD scenario that incorporates 30-year projections by the HGCSD for the Houston Metropolitan area. Modeling of both projections anticipates extensive groundwater use and a drop in aquifer levels, with far more critical groundwater availability conditions anticipated under the 30-year HGCSD scenario.

Under the more conservative HGCSD scenario, withdrawals from the Chicot aquifer and underlying Evangeline aquifer would increase by 2030 to an estimated 1,520 million gallons per day (mgd), a 74 percent increase relative to 1995 conditions. Modeling of these projections indicates a significant increase in the aquifer's cone of depression by 2030, with depth increases of over 200 feet relative to current conditions (Kasmerek, Reece and Houston 2005). The percent of withdrawals supplied by net aquifer recharges would also steadily decrease, from an estimated 72 percent in 1995 to 43 percent projected in 2030 (Kasmerek, Reece and Houston 2005). In western Chambers County, the projected 30-year drop in water level ranges from 50 to 100 feet.

Under the TWDB scenario, long-term withdrawals from the Chicot aquifer and underlying Evangeline aquifer would moderately increase or remain level over the 50-year simulation period; the largest increase in withdrawal would occur between 2000 and 2010, with an 8 percent increase from 850 to 920 mgd (Kasmerek, Reece and Houston 2005). Modeling of the TWDB scenario showed relatively little change in elevation of the Chicot aquifer's potentiometric surface. In Matagorda County, however, an elevation drop from 50 to 100 feet would occur under 2010 withdrawal conditions. The simulated net recharge of the aquifer, in contrast with the HGCSD scenario, would moderately increase under the TWDB scenario (Kasmerek, Reece and Houston 2005).

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

4.2.3 Potential for New Surface Water Sources

The Olsen Estates PWS is located at the boundary of the Trinity Basin and Trinity-San Jacinto Basin. For the Trinity Basin, the 2002 Texas Water Plan anticipates an 11 percent reduction in water availability from 2000 (1,912,777 acre-feet per year [AFY]) to 2050 (1,709,838 AFY). For the Trinity-San Jacinto Basin, a steady water supply is expected over the next 50 years (approximately 30,100 AFY).

There is a limited potential for development of new surface water sources for the system from the Trinity-San Jacinto Basin as indicated by the 2002 TCEQ water availability maps. For the Trinity Basin, however, unappropriated flows for new uses within a 20-mile radius of the system are typically available less than 75 percent of the time. This supply is inadequate as the TCEQ requires 100 percent supply availability for a PWS.

While the Trinity-San Jacinto Basin in the site vicinity has a year-round availability of surface water for new applications (new perpetual rights), development of a new surface water source is not considered feasible for a small water system due to the permitting required, and the cost and complexity associated with construction and operation of intake works, treatment plant, and water conveyance. Development of a new surface water source is considered more appropriate as a regional solution to be undertaken by a group of small PWSs or by a regional water supply organization such as BAWA. For this study, surface water source development alternatives are limited to obtaining water from existing water providers utilizing surface water.

4.2.4 New Water Source Options for Detailed Consideration

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

1. Installing a new, shallower well at Olsen Estates PWS that would produce compliant water in place of the water produced by the existing active well (Alternative OE-1).

2. City of Mont Belvieu. Purchase groundwater from the City of Mont Belvieu PWS. A pipeline and pump station would be constructed to transfer the water to the Olsen Estates PWS (Alternative OE-2). This alternative would have pipeline costs almost identical to similar alternatives involving two other nearby PWSs (Chambers County Old Cove Building and KOA Campground). These two nearby systems are small, so installation of a new well would probably be necessary.

3. Tower Terrace. Purchase groundwater from the Tower Terrace PWS. A pipeline and pump station would be constructed to transfer the water to the Olsen Estates PWS (Alternative OE-3). This alternative would have pipeline costs almost

identical to similar alternatives involving two other nearby PWSs (Beach Haven Subdivision and Snappy Mart). These two nearby systems are small, so installation of a new well would probably be necessary.

4. Engineered Carbons Inc. Purchase groundwater from the Engineered Carbons Inc. PWS. A pipeline and pump station would be constructed to transfer the water to the Olsen Estates PWS (Alternative OE-4). This alternative would have pipeline costs almost identical to similar alternatives involving two other nearby PWSs (Cedar Bayou Community Building and Tall Pine Mobile Home Park (Country Living Mobile Home Park). These two nearby systems are small, so installation of a new well would probably be necessary.

5. City of Baytown. Purchase treated surface water from the City of Baytown PWS. A pipeline and pump station would be constructed to transfer the water to the Olsen Estates PWS (Alternative OE-5).

6. Installing a new well within 10, 5, or 1 mile of Olsen Estates PWS that would produce compliant water in place of the water produced by the existing wells (Alternatives OE-6, OE-7, and OE-8).

4.3 TREATMENT OPTIONS

4.3.1 Centralized Treatment Systems

Centralized treatment of the well field water is identified as a potential alternative for Olsen Estates PWS. RO, EDR, iron-based adsorption, and coagulation/filtration treatments are potential applicable processes. RO and EDR treatment technologies can remove TDS in addition to arsenic to produce compliant water. The central RO treatment alternative is Alternative OE-9, the central EDR treatment alternative is Alternative OE-10, the central iron-based adsorption treatment is Alternative OE-11, and the central coagulation/filtration treatment is Alternative OE-12.

4.3.2 Point-of-Use Systems

POU treatment using RO technology is valid for arsenic removal. The POU treatment alternative is OE-13.

4.3.3 Point-of-Entry Systems

POE treatment using RO technology is valid for arsenic removal. The POE treatment alternative is OE-14.

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 a bottled water program. An alternative to providing bottled water is to provide a central, publicly accessible dispenser for treated drinking water. Alternatives addressing bottled water are OE-15, OE-16, and OE-17.

4.5 ALTERNATIVE DEVELOPMENT AND ANALYSIS

A number of potential alternatives for compliance with the MCL for arsenic 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 a 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 OE-1: New Well at the Current Olsen Estates Location

This alternative involves completing a new, shallower well at the current Olsen Estates PWS site, and tying it into the existing water system. The new well would be 250 feet deep. The water quality data in the TCEQ database indicates there is a possibility for finding compliant water at shallower depths than the existing wells.

The estimated capital cost for this alternative includes completing the new well, constructing the connection piping, and a new storage tank and feed pump set to supply water to the existing system. The estimated capital cost for this alternative is $161,929, and the estimated O&M cost for this is $11,099.

The reliability of adequate amounts of compliant water under this alternative should be good. From the perspective of Olsen Estates PWS, this alternative would be characterized as easy to operate and repair, since O&M and repair of the current system is well understood, and Olsen Estates PWS personnel currently operate it. If the decision were made to perform blending, then the operational complexity would increase.

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

4.5.2 Alternative OE-2: Purchase Water from the City Of Mont Belvieu

This alternative involves purchasing compliant water from the City of Mont Belvieu. The City of Mont Belvieu may have sufficient excess capacity, but has expressed doubts about having enough excess capacity to allow the sale of water.

This alternative would require constructing a pipeline from a City of Mont Belvieu water main to Olsen Estates, and a new storage tank and feed pump set at Olsen Estates. A pump station would also be required to overcome pipe friction and the elevation differences between the City of Mont Belvieu and Olsen Estates. The 4-inch pipeline would primarily follow I-10 and Eagle Drive. The pipeline would be approximately 1.92 miles long. The required pump horsepower is 2.5 hp.

The pump station would include two pumps, including one standby, and would be housed in a building. A tank would also be constructed for the pumps to draw from. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Olsen Estates 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 Olsen Estates would be obtaining drinking water from an existing larger supplier. It is possible Olsen Estates could turn over provision of drinking water to the City of Mont Belvieu instead of purchasing water. Also, other PWSs near the Olsen Estates PWS are in need of compliant drinking water and could share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and a new storage tank and feed pump set at Olsen Estates. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the Olsen Estates wells, 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 $625,441, and the alternative's estimated annual O&M cost is $51,967.

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

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

4.5.3 Alternative OE-3: Purchase Water from Tower Terrace

This alternative involves purchasing compliant water from the Tower Terrace PWS, which will be used to supply the Olsen Estates PWS. The Tower Terrace PWS currently has sufficient excess capacity for this alternative to be feasible and may be willing to sell water.

This alternative would require constructing a pipeline from the Tower Terrace PWS to the Olsen Estates PWS, and a new storage tank and feed pump set at Olsen Estates. A pump station would also be required to overcome pipe friction and the elevation differences between Tower Terrace PWS and Olsen Estates. The 4-inch pipeline would primarily follow I-10, farm-to-market road (FM) 3180, and FM 565. The pipeline would be approximately 5.80 miles long. The required pump horsepower is 4 hp.

The pump station would include two pumps, including one standby, and would be housed in a building. A tank would also be constructed for the pumps to draw from. It is assumed the pumps and piping would be installed with capacity to meet all water demand for Olsen Estates 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 OE would be obtaining drinking water from an existing larger supplier. It is possible OE could turn over provision of drinking water to the Tower Terrace PWS instead of purchasing water. Also, other PWSs near Olsen Estates are in need of compliant drinking water and could share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and a new storage tank and feed pump set at OE. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the OE wells, plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $1.5 million, and the alternative's estimated annual O&M cost is $53,085.

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

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

There are several small PWSs relatively close to Olsen Estates that have water quality problems that would be good candidates for sharing the cost for obtaining water from Tower Terrace PWS. The cost to the Olsen Estates PWS for this alternative could be reduced if the other PWSs would be willing to share the costs. The analysis for a shared solution is presented in Appendix F. This analysis shows that the Olsen Estates PWS could expect to save from $378,419 to $926,673 on the capital cost for this alternative, which is a saving of between 26 and 63 percent.

4.5.4 Alternative OE-4: Purchase Water from Engineered Carbons Inc.

This alternative involves purchasing compliant water from the Engineered Carbons Inc. PWS, which will be used to supply the Olsen Estates PWS. The Engineered Carbons PWS may have sufficient excess capacity for this alternative to be feasible, but has not expressed an interest in selling water.

This alternative would require constructing a pipeline from the Engineered Carbons PWS to the Olsen Estate PWS, and a new storage tank and feed pump set at Olsen Estates. A pump station would also be required to overcome pipe friction and the elevation differences between the Engineered Carbons PWS and the Olsen Estates PWS. The 4-inch pipeline would primarily follow I-10 and the Union Pacific Railway. The pipeline would be approximately 6.62 miles long. The required pump horsepower is 4 hp.

The pump station would include two pumps, including one standby, and would be housed in a building. A tank would also be constructed for the pumps to draw from. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Olsen Estates 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 the Olsen Estates PWS would be obtaining drinking water from an existing larger supplier. Also, other PWSs near Olsen Estates are in need of compliant drinking water and could share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and storage tank and feed pump set at OE. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the OE wells, plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $1.69 million, and the alternative's estimated annual O&M cost is $53,324.

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

The feasibility of this alternative is dependent on an agreement being reached with the Engineered Carbons Inc. PWS to purchase water.

4.5.5 Alternative OE-5: Purchase Water from the City of Baytown

This alternative involves purchasing compliant water from the City of Baytown, which will be used to supply the Olsen Estates PWS. The City of Baytown currently has sufficient excess capacity for this alternative to be feasible and is willing to sell water.

This alternative would require constructing a pipeline from a City of Baytown water main to Olsen Estates, and a new storage tank and feed pump set at Olsen Estates. A pump station would also be required to overcome pipe friction and the elevation differences between the City of Baytown and Olsen Estates. The 4-inch pipeline would primarily follow I-10, FM 3180, FM 565, State Highway 146, and Massey Tompkins Road. The pipeline would be approximately 9.40 miles long. The required pump horsepower is 5 hp.

The pump station would include two pumps, including one standby, and would be housed in a building. A tank would also be constructed for the pumps to draw from. It is assumed the pumps and piping would be installed with capacity to meet all water demand for Olsen Estates 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 OE would be obtaining drinking water from an existing larger supplier. It is possible the Olsen Estates PWS could turn over provision of drinking water to the City of Baytown instead of purchasing water. Also, other PWSs near Olsen Estates are in need of compliant drinking water and could share in implementation of this alternative.

The estimated capital cost for this alternative includes constructing the pipeline, pump station, and a new storage tank and feed pump set at Olsen Estates. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost related to current operation of the Olsen Estates wells, 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 $2.3 million, and the alternative's estimated annual O&M cost is $54,126.

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

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

There are several small PWSs relatively close to Olsen Estates that have water quality problems that would be good candidates for sharing the cost for obtaining water from the City of Baytown. The cost to the Olsen Estates PWS for this alternative could be reduced if the other PWSs would be willing to share the costs. The analysis for a shared solution is presented in Appendix F. This analysis shows that Olsen Estates could expect to save from $824,692 to $1,526,182 on the capital cost for this alternative, which is a saving of between 37 and 69 percent.

4.5.6 Alternative OE-6: New Well at 10 miles

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

This alternative would require constructing a new 300-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the Olsen Estates PWS, and a new storage tank and feed pump set at Olsen Estates. 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 a

4-inch line. The pump station would include two pumps, including one standby, and would be housed in a building.

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

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 $2.44 million, and the estimated annual O&M cost for this alternative is $34,984.

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 Olsen Estates PWS, this alternative would be similar to the existing system in terms of operation. Olsen Estates PWS has experience with O&M of wells and pumps.

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 Olsen Estates PWS, so landowner cooperation would be required.

4.5.7 Alternative OE-7: New Well at 5 miles

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

This alternative would require constructing a new 300-foot well, a new pump station with storage tank near the new well, a pipeline from the new well/tank to the Olsen Estates PWS, and a new storage tank and feed pump set at Olsen Estates. 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 a 4-inch line. The pump station would include two pumps, including one standby, and would be housed in a building.

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

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 $1.44 million, and the estimated annual O&M cost for this alternative is $33,273.

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 Olsen Estates PWS, this alternative would be similar in terms of operation as the existing system. Olsen Estates PWS has experience with O&M of wells and pumps.

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 Olsen Estates PWS, so landowner cooperation would be required.

4.5.8 Alternative OE-8: New Well at 1 mile

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

This alternative would require constructing a new 300-foot well, a pipeline from the new well to the Olsen Estates PWS, and a new storage tank and feed pump set at OE. For this alternative, the pipeline is assumed to be approximately 1 mile long, and would be a 4-inch line.

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

The estimated capital cost for this alternative includes cost to install the well, and construct the pipeline. The estimated O&M cost for this alternative includes the cost for O&M for the pipeline. The estimated capital cost for this alternative is $346,934, and the estimated annual O&M cost for this alternative is $11,258.

The reliability of adequate amounts of compliant water under this alternative should be good, since water wells and pipelines are commonly employed. From the perspective of Olsen Estates PWS, this alternative would be similar in terms of operation compared to the existing system. Olsen Estates PWS has experience with O&M of wells.

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

4.5.9 Alternative OE-9: Central RO Treatment

This system would continue to pump water from the existing Olsen Estates PWS wells, and would treat the water through an RO system prior to distribution. For this option, the full flow of the raw water would be treated to obtain overall compliant water. The RO process concentrates impurities in the reject stream which would require disposal. It is estimated the RO reject generation would be approximately 3,300 gpd when the system is operated at full flow.

This alternative consists of constructing the RO treatment plant near the existing Olsen Estates PWS wells. The plant is composed of a 500 square foot (ft^2) building with a paved driveway; a skid with the pre-constructed RO plant; two transfer pumps, a 10,000-gallon tank for storing the treated water, and a 50,000-gallon pond for storing reject water. The treated water would be chlorinated and stored in the new treated water tank prior to being pumped into the distribution system. The entire facility is fenced. The capital cost includes purchase of a water truck-trailer to periodically haul reject water for disposal.

The estimated capital cost for this alternative is $560,484, and the estimated annual O&M cost is $49,716.

The reliability of adequate amount of compliant water under this alternative is good, since RO treatment is a common and well-understood treatment technology. However, O&M efforts required for the central RO treatment plant may be significant, and O&M personnel would require training with RO. The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.10 Alternative OE-10: Central EDR Treatment

The system would continue to pump water from the existing Olsen Estates PWS wells, and would treat the water through an EDR system prior to distribution. For this option the EDR unit would treat the full flow without bypass as the EDR operation can be tailored for desired removal efficiency. It is estimated the EDR reject generation would be approximately 2,600 gpd when the system is operated at full flow.

This alternative consists of constructing the EDR treatment plant near the existing Olsen Estates PWS well site. The plant is composed of a 500 ft^2 building with a paved driveway; a skid with the pre-constructed EDR system; two transfer pumps; a 10,000-gallon tank for storing the treated water, and a 40,000-gallon pond for storing concentrated water. The treated water would be chlorinated and stored in the new treated water tank prior to being pumped into the distribution system. The entire facility is fenced. The capital cost includes purchase of a water truck-trailer to periodically haul concentrated water for disposal.

The estimated capital cost for this alternative is $708,384, and the estimated annual O&M cost is $48,226.

The reliability of adequate amounts of compliant water under this alternative is good, since EDR treatment is a common and well-understood treatment technology. However, O&M efforts required for the central EDR treatment plant may be significant, and O&M personnel would require training with EDR. The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.11 Alternative OE-11: Central Iron-Based Adsorption Treatment

The system would treat groundwater from the existing well using an iron-based adsorption system prior to distribution. This alternative consists of constructing the adsorption treatment plant at well site. The plant comprises a 500 ft^2 building with a paved driveway, the pre-constructed adsorption system on a skid (*e.g.,* one AdEdge APU-100 package units), a 15,000-gallon backwash wastewater equalization tank, and a 15,000-gallon treated water storage tank and booster pump set. The entire facility would be fenced. The water would be pre-chlorinated to oxide AS(III) to AS(V) and post chlorinated for disinfection prior to flowing to the distribution system. Backwash would be required monthly with raw well water supplied directly by the well pump. The backwash would be equalized in the 15,000-gallon tank and recycled to the APU-100 system at a very low rate. Accumulated sludge would be trucked off-site periodically for disposal. The adsorption media are expected to last approximately 2 years before replacement and disposal. The media replacement cost would be approximately $18,000.

The estimated capital cost for this alternative is $342,490, and the estimated annual O&M cost is $44,850 which includes the annualized media replacement cost of $6,000. Reliability of supply of adequate amounts of compliant water under this alternative is good as the adsorption technology has been demonstrated effective in full-scale and pilot-scale facilities. The technology is simple and requires minimal O&M effort.

4.5.12 Alternative OE-12: Central Coagulation/Filtration Treatment

The system would treatment groundwater from the existing wells using a coagulation/filtration system prior to distribution. This alternative consists of constructing the coagulation/filtration plant at or near the well site. The plant comprises a 500 ft^2 building with a paved driveway, the pre-constructed coagulation/filtration system on a skid (*e.g.*, two Macrolite filters from Kinetico), a ferric chloride feed and storage system, a 15,000-gallon backwash wastewater equalization tank, and a treated water storage tank and booster pump set. The entire facility would be fenced. The water would be pre-chlorinated to oxidize As(III) to As(V) and post-chlorinated for disinfection prior to flowing to the distribution system. Ferric chloride solution would be fed to the well water after pre-chlorination and before entering the filters. The filters would be backwashed every one to two days by well water directly from the well pump. The backwash wastewater would be equalized in the 15,000-gal tank and recycled to the treatment system at a controlled rate. Accumulated sludge would be trucked off-site for disposal. The Macrolite media do not need replacement.

The estimated capital cost for this alternative is $343,360, and the estimated annual O&M cost is $47,906. This alternative requires more O&M labor cost and sludge disposal than the adsorption alternative. Reliability of supply of adequate amounts of compliant water under this alternative is good as the coagulation/filtration process is a well-established technology for arsenic removal. The technology is simple but requires significant effort for chemical handling and backwash monitoring. The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.13 Alternative OE-13: Point-of-Use Treatment

This alternative consists of the continued operation of the existing Olsen Estates PWS wells, plus treatment of water to be used for drinking or food preparation at the point of use to remove arsenic. 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. Reverse osmosis POU treatment units would also be effective for reducing other potential contaminants such as TDSs and sulfate.

This alternative would require installing the POU treatment units in dwellings and other buildings that provide drinking or cooking water. Olsen Estates Water System would be responsible for purchasing and maintaining the treatment units, including membrane and filter replacement, periodic sampling, and necessary repairs. In residences, the most convenient point for installing 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 Olsen Estates Water System or contract personnel into residences 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 access could be made without entry into the residence, which would complicate the installation and increase costs.

POU RO treatment processes typically produce liquid waste streams equal in volume to the treated water and require disposal. These waste streams result in an increased overall volume of water used. POU systems have the advantage that only a minimum volume of water is treated (only that 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 that the increase in water consumption is insignificant in terms of supply cost and that the waste stream can be recovered for reuse or discharged to the house sewer or septic 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 membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $39,600, and the estimated annual O&M cost for this alternative is $46,950. For the cost estimate, it is assumed that one POU treatment unit would be required for each of the 60 connections to the Olsen Estates Water System. 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 will be significant, and Olsen Estates Water System personnel are inexperienced in this type of work. From the perspective of Olsen

Estates Water System, this alternative would be characterized as more difficult to operate due to the in-home requirements.

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

4.5.14 Alternative OE-14: Point-of-Entry Treatment

This alternative consists of the continued operation of the existing Olsen Estates PWS wells, plus treatment of water to remove arsenic as it enters the residence. The purchase, installation, and maintenance of the treatment systems at the POE would be necessary for this alternative. Blending is not an option in this case. Reverse osmosis POE treatment units would also be effective for reducing other potential contaminants such as TDSs and sulfate.

This alternative would require installing the POE treatment units at dwellings and other buildings that provide water for drinking or cooking. Olsen Estates PWS would be responsible for purchasing and maintaining the treatment units, including membrane and filter replacement, periodic sampling, and necessary repairs. The plumbing in houses should be investigated to ensure that the aggressive water that would result from RO treatment would not cause damage. It may also be desirable to modify piping so that water for non-consumptive uses could be withdrawn upstream of the treatment unit. The POE treatment units would be installed outside the residence, so entry would not be necessary for O&M. Some cooperation from customers would be necessary for installation and maintenance of the treatment systems.

POE RO treatment processes typically produce liquid waste streams that are equal in volume to the treated water and require disposal. These waste streams result in an increased overall volume of water used. Point-of-entry systems treat a greater volume of water than POU systems. For this alternative, it is assumed that the increase in water consumption is insignificant in terms of supply cost and that the waste stream can be recovered for reuse or discharged to the house sewer or septic 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 membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $693,000, and the estimated annual O&M cost for this alternative is $93,450. For the cost estimate, it is assumed that one POE treatment unit would be required for each of the 60 existing connections to the Olsen Estates PWS.

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

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

4.5.15 Alternative OE-15: Public Dispenser for Treated Drinking Water

This alternative consists of the continued operation of the existing two active Olsen Estates 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 fill their own containers. This alternative also includes notifying customers of the importance of obtaining drinking water from the dispenser. In this way, only a relatively small volume of water requires treatment, but customers would be required to pick up and deliver their own water. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

Olsen Estates PWS would be responsible for maintenance of the treatment unit, including membrane and filter replacement, periodic sampling, and necessary repairs. A method for disposal of the reject waste stream produced by the treatment system will have to be found. This alternative relies on a great deal of cooperation and action from the customers to be effective.

This alternative does not present options for a regional solution.

The estimated capital cost for this alternative includes purchasing and installing the treatment system to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes purchasing and replacing filters and 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 $22,399.

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. Olsen Estates PWS has not provided this type of service in the past. From the perspective of the Olsen Estates 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.

4.5.16 Alternative OE-16: 100 Percent Bottled Water Delivery

This alternative consists of the continued operation of the existing two active Olsen Estates PWS wells, but compliant drinking water will be delivered to customers in containers.

This alternative involves setting up and operating a bottled water delivery program to serve all the customers in the system. It is expected that Olsen Estates PWS would find it convenient and economical to contract a bottled water service. The bottle delivery program would have to be flexible enough to allow for delivery of smaller containers should customers be incapable of lifting and manipulating 5-gallon bottles. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

This alternative does not involve capital cost for construction, but would require some initial costs for system setup, and then ongoing costs to have the bottled water furnished. It is assumed for this alternative that bottled water is provided to 100 percent of the Olsen Estates 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 initial cost for this alternative is $36,509, and the estimated annual O&M cost for this alternative is $138,597. For the cost estimate, it is assumed that 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 will require attention from Olsen Estates PWS.

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

4.5.17 Alternative OE-17: Public Dispenser for Trucked Drinking Water

This alternative consists of continued operation of the existing two active Olsen Estates PWS wells, plus dispensing compliant water for drinking and cooking at a publicly accessible location. The compliant water would be purchased from a nearby system with compliant drinking water, and delivered by truck to a tank at a central location where customers would be able to fill their own containers. This alternative also includes notifying customers of the importance of obtaining drinking water from the dispenser. In this way, only a relatively small volume of compliant water is required, 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 Olsen Estates PWS would purchase a truck that would be suitable for hauling potable water, and install a storage tank. It is assumed the storage tank would be filled once a week, and that the chlorine residual would be tested for each truckload. This alternative relies on cooperation and action from the customers for it to be effective.

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

The estimated capital cost for this alternative includes constructing the storage tank to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes the contract water delivery service, maintenance for the tank, water quality testing, and record keeping. The estimated capital cost for this alternative is $102,986, and the estimated annual O&M cost for this alternative is $19,817.

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 Olsen Estates PWS has not provided this type of service in the past. From the perspective of Olsen Estates 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.

4.5.18 Summary of Alternatives

Table 4.3 provides a summary of the key features of each alternative for Olsen Estates PWS.

Table 4.3 Summary of compliance Alternative for Olsen Estates PWS

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
OE-1	Drill new, shallower well at OE	- New well (250 ft) - Ground storage tank - Pump station	$161,929	$11,099	$25,216	Good	N	New, shallower well on-site. Sharing cost with neighboring systems may be possible.
OE-2	Purchase water from the City Of Mont Belvieu	Storage Tank - Pump station - 1.9-mile pipeline	$625,441	$51,967	$106,496	Good	N	Agreement must be successfully negotiated with the City of Mont Belvieu. Blending may be possible. Costs could be shared with other nearby small PWSs.
OE-3	Purchase water from the Tower Terrace PWS	- Storage Tank - Pump station - 5.8-mile pipeline	$1,503,912	$53,085	$184,203	Good	N	Agreement must be successfully negotiated with the Tower Terrace PWS. Blending may be possible. Costs could be shared with other nearby small PWSs.
OE-4	Purchase water from Engineered Carbons Inc	- Storage Tank - Pump station - 6.6-mile pipeline	$1,693,600	$53,324	$200,980	Good	N	Agreement must be successfully negotiated with the Engineered Carbon, Inc. Blending may be possible. Costs could be shared with other nearby small PWSs
OE-5	Purchase water from the City of Baytown	- Storage Tank - Pump station - 9.4-mile pipeline	$2,297,184	$54,126	$254,405	Good	N	Agreement must be successfully negotiated with The City of Baytown. Blending may be possible. Costs could be shared with other nearby small PWSs.
OE-6	Install new compliant well within 10 miles	- New well - Storage tank - Pump station - 10-mile pipeline	$2,435,322	$34,984	$247,306	Good	N	May be difficult to find well with good water quality. Costs could be shared with other nearby small systems.
OE-7	Install new compliant well within 5 miles	- New well - Storage tank - Pump station - 5-mile pipeline	$1,439,645	$33,273	$158,788	Good	N	May be difficult to find well with good water quality. Costs could be shared with other nearby small systems.
OE-8	Install new compliant well within 1 mile	- New well - Storage tank - Pump station - 1-mile pipeline	$346,934	$11,258	$41,506	Good	N	May be difficult to find well with good water quality. Costs could be shared with other nearby small systems.
OE-9	Continue operation of Olsen Estates well field with central RO treatment	- Central RO treatment plant	$560,484	$49,716	$98,582	Good	T	Costs could possibly be shared with nearby small systems.
OE-10	Continue operation of Olsen Estates well field with central EDR treatment	- Central EDR treatment plant	$708,384	$48,226	$109,986	Good	T	Costs could possibly be shared with nearby small systems.

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
OE-11	Continue operation of Olsen Estates well field with central iron based adsorption treatment	- Central IBAT treatment plant	$342,490	$44,850	$74,710	Good	T	Costs could possibly be shared with nearby small systems.
OE-12	Continue operation of Olsen Estates well field with Coag./Filtr. treatment	- Central C/F treatment plant	$343,360	$47,906	$77,841	Good	T	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.
OE-13	Continue operation of current well field, with POU treatment	- POU treatment units	$39,600	$46,950	$50,403	Fair	T, M	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.
OE-14	Continue operation of current well field, with POE treatment	- POE treatment units	$693,000	$93,450	$153,869	Fair (*better than POU*)	T, M	All home taps compliant and less resident cooperation required.
OE-15	Continue operation of current well field, but furnish public dispenser for treated drinking water	- Water treatment and dispenser unit	$11,600	$22,399	$23,410	Fair/interim measure	T	Does not provide compliant water to all taps, and requires a lot of effort by customers.
OE-16	Continue operation of current well field, but furnish bottled drinking water for all customers	- Set up bottled water system	$36,509	$138,597	$141,780	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.
OE-17	Continue operation of current well field, but furnish public dispenser for trucked drinking water.	- Construct storage tank and dispenser - Purchase potable water truck	$102,986	$19,817	$28,796	Fair/interim measure	M	Does not provide compliant water to all taps, and requires a lot of effort by customers.

Notes: *N – No significant increase required in technical or management capability*
T – Implementation of alternative will require increase in technical capability
M – Implementation of alternative will require increase in management capability
1 – See cost breakdown in Appendix C
2 – 20-year return period and 6 percent interest

4.6 COST OF SERVICE AND FUNDING ANALYSIS

4.6.1 Olsen Estates PWS Financial Data

No separate financial data are maintained by the system operator for the Olsen Estates 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 $40/month. 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 Olsen Estates 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 Olsen Estates PWS is estimated to be $480, or less than 1.2 percent of the annual household income of $39,735 for the Census Zip code Tract that includes the Olsen Estates PWS. Because of the lack of separate financial data exclusively for the water system, it is difficult to determine exact cash flow needs. Water usage revenues may fall short of expenditures with the system being subsidized by other revenues.

4.6.2.2 Ratio Analysis

Current Ratio

The Current Ratio for the Olsen Estates 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 Olsen Estates 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 $29,026 were more than the operating revenues, with a resulting operating ratio of less than 1.0, indicating revenues are not keeping pace with expenses for the system.

4.6.3 Financial Plan Results

Each compliance alternative for Olsen Estates 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 Section 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 Olsen Estates PWS was not available, Census Zip code Tract data were used. The Census Zip code Tract for the Olsen Estates PWS is located had an estimated annual household income of $39,735 according to the 2000 U.S. Census compared to a statewide average of $39,927, or approximately 100 percent of the statewide average. Since the MHI for Census Zip code Tract is greater than 75 percent of the statewide average, Olsen Estates MHP may qualify for an interest rate of 3.8 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 (11,500 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 for Olsen Estates PWS

Alternative	Description		All Revenue	100% Grant	75% Grant	50% Grant	SRF	Bond
1	New Well at Olsen Estates	Max % of HH Income	11%	3%	4%	4%	4%	4%
		Max % Rate Increase Compared to Current	1310%	333%	372%	412%	471%	490%
		Average Water Bill Required by Alternative	$ 3,974	$ 1,229	$ 1,337	$ 1,445	$ 1,609	$ 1,661
2	Purchase Water from City of Mont Belvieu	Max % of HH Income	34%	8%	9%	10%	12%	12%
		Max % Rate Increase Compared to Current	4465%	922%	1073%	1224%	1453%	1526%
		Average Water Bill Required by Alternative	$ 12,801	$ 2,796	$ 3,212	$ 3,629	$ 4,261	$ 4,462
3	Purchase Water From Tower Terrace	Max % of HH Income	75%	8%	11%	13%	17%	19%
		Max % Rate Increase Compared to Current	9896%	938%	1301%	1664%	2215%	2391%
		Average Water Bill Required by Alternative	$ 28,042	$ 2,839	$ 3,840	$ 4,842	$ 6,361	$ 6,845
4	Purchase Water from Engineered Carbons Inc.	Max % of HH Income	84%	8%	11%	14%	19%	20%
		Max % Rate Increase Compared to Current	11069%	942%	1350%	1759%	2380%	2577%
		Average Water Bill Required by Alternative	$ 31,332	$ 2,848	$ 3,976	$ 5,104	$ 6,814	$ 7,359
5	Purchase Water From the City of Baytown	Max % of HH Income	112%	8%	12%	16%	23%	25%
		Max % Rate Increase Compared to Current	14800%	953%	1508%	2062%	2904%	3172%
		Average Water Bill Required by Alternative	$ 41,804	$ 2,879	$ 4,408	$ 5,938	$ 8,259	$ 8,998
6	New Well at 10 Miles	Max % of HH Income	118%	6%	10%	15%	21%	24%
		Max % Rate Increase Compared to Current	15515%	677%	1265%	1853%	2745%	3029%
		Average Water Bill Required by Alternative	$ 43,824	$ 2,145	$ 3,767	$ 5,388	$ 7,848	$ 8,632
7	New Well at 5 Miles	Max % of HH Income	71%	6%	8%	11%	15%	16%
		Max % Rate Increase Compared to Current	9357%	653%	1000%	1348%	1875%	2043%
		Average Water Bill Required by Alternative	$ 26,542	$ 2,079	$ 3,038	$ 3,997	$ 5,451	$ 5,914
8	New Well at 1 Mile	Max % of HH Income	19%	3%	4%	5%	6%	6%
		Max % Rate Increase Compared to Current	2453%	336%	419%	503%	630%	671%
		Average Water Bill Required by Alternative	$ 7,182	$ 1,236	$ 1,467	$ 1,698	$ 2,048	$ 2,160
9	Central Treatment - RO	Max % of HH Income	31%	7%	8%	10%	11%	12%
		Max % Rate Increase Compared to Current	4048%	890%	1025%	1160%	1365%	1431%
		Average Water Bill Required by Alternative	$ 11,632	$ 2,710	$ 3,083	$ 3,456	$ 4,022	$ 4,203
10	Central Treatment - EDR	Max % of HH Income	38%	7%	9%	10%	12%	12%
		Max % Rate Increase Compared to Current	4950%	868%	1039%	1210%	1470%	1552%
		Average Water Bill Required by Alternative	$ 14,165	$ 2,653	$ 3,124	$ 3,596	$ 4,312	$ 4,539
11	Central Treatment -Adsorption	Max % of HH Income	21%	7%	8%	8%	9%	9%
		Max % Rate Increase Compared to Current	2667%	819%	902%	985%	1110%	1150%
		Average Water Bill Required by Alternative	$ 7,761	$ 2,523	$ 2,751	$ 2,979	$ 3,325	$ 3,435
12	Central Treatment- Coag-Filt	Max % of HH Income	21%	7%	8%	9%	9%	10%
		Max % Rate Increase Compared to Current	2695%	864%	946%	1029%	1155%	1195%
		Average Water Bill Required by Alternative	$ 7,835	$ 2,640	$ 2,869	$ 3,098	$ 3,444	$ 3,555
13	Point-of-Use Treatment	Max % of HH Income	7%	7%	7%	7%	7%	7%
		Max % Rate Increase Compared to Current	850%	850%	859%	869%	883%	888%
		Average Water Bill Required by Alternative	$ 2,651	$ 2,604	$ 2,630	$ 2,656	$ 2,696	$ 2,709
14	Point-of-Entry Treatment	Max % of HH Income	40%	12%	13%	15%	17%	17%
		Max % Rate Increase Compared to Current	5181%	1519%	1687%	1854%	2108%	2189%
		Average Water Bill Required by Alternative	$ 14,781	$ 4,386	$ 4,848	$ 5,309	$ 6,009	$ 6,232
15	Public Dispenser for Treated Drinking Water	Max % of HH Income	5%	5%	5%	5%	5%	5%
		Max % Rate Increase Compared to Current	496%	496%	499%	502%	506%	507%
		Average Water Bill Required by Alternative	$ 1,676	$ 1,663	$ 1,670	$ 1,678	$ 1,690	$ 1,694
16	Supply Bottled Water to 100% of Population	Max % of HH Income	17%	17%	17%	17%	17%	17%
		Max % Rate Increase Compared to Current	2170%	2170%	2179%	2187%	2201%	2205%
		Average Water Bill Required by Alternative	$ 6,160	$ 6,117	$ 6,141	$ 6,165	$ 6,202	$ 6,214
17	Central Trucked Drinking Water	Max % of HH Income	8%	4%	4%	5%	5%	5%
		Max % Rate Increase Compared to Current	1009%	459%	484%	509%	546%	558%
		Average Water Bill Required by Alternative	$ 3,123	$ 1,564	$ 1,632	$ 1,701	$ 1,805	$ 1,838

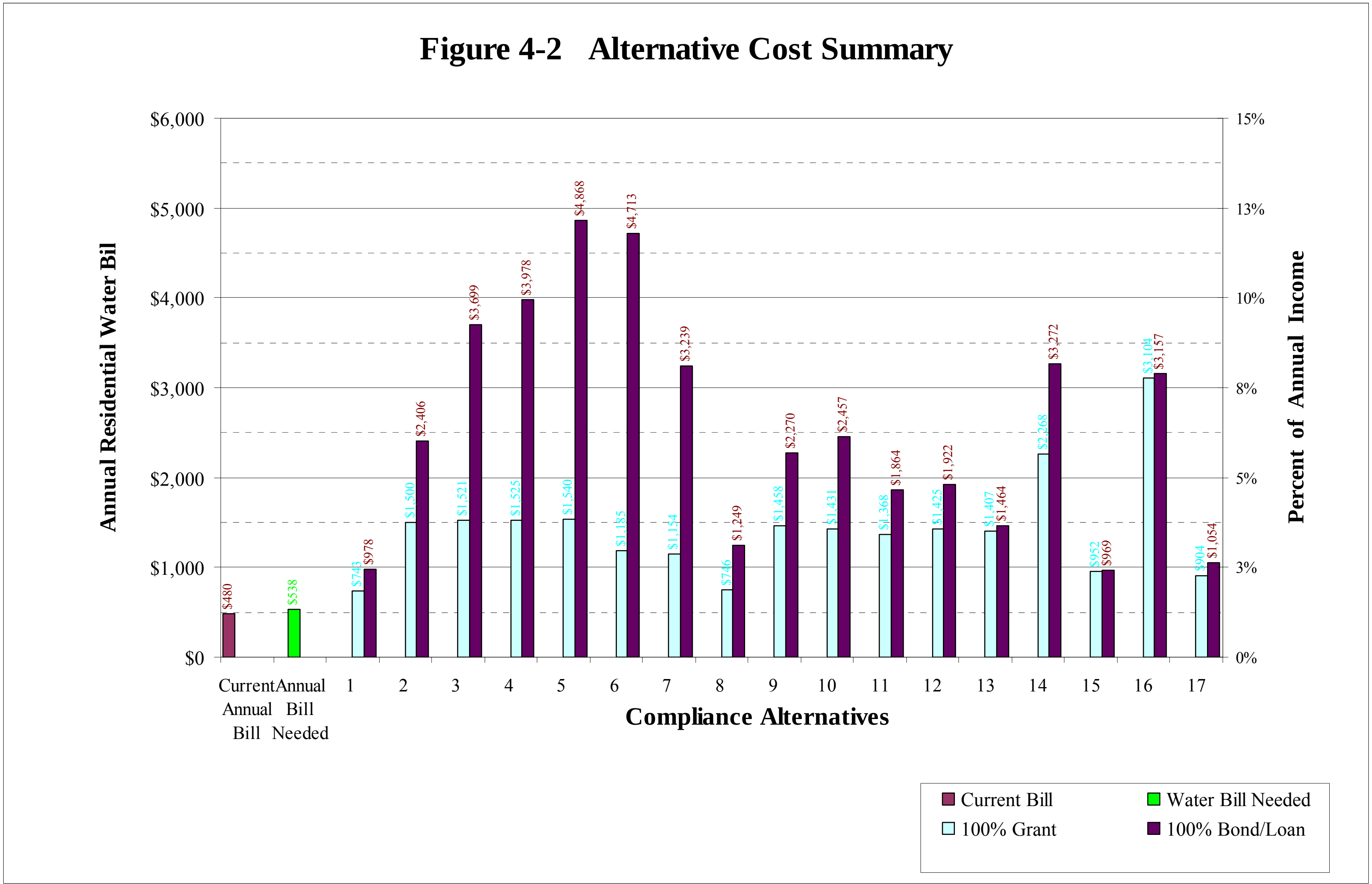
Figure 4-2 Alternative Cost Summary
Annual Residential Water Bil
Percent of Annual Income
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
15%
13%
10%
8%
5%
3%
0%
$480
$538
$743 $978
$1,500 $2,406
$1,521 $3,699
$1,525 $3,978
$1,540 $4,868
$1,185 $4,713
$1,154 $3,239
$746 $1,249
$1,458 $2,270
$1,431 $2,457
$1,368 $1,864
$1,425 $1,922
$1,407 $1,464
$2,268 $3,272
$952 $969
$3,104 $3,157
$904 $1,054
Current Annual Bill
Annual Bill Needed
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Compliance Alternatives
Current Bill
Water Bill Needed
100% Grant
100% Bond/Loan

1

SECTION 5
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APPENDIX A
PWS INTERVIEW FORM

CAPACITY DEVELOPMENT ASSESSMENT FORM

*Prepared By*___________________________________ *Date*___________________________

Section 1. Public Water System Information

1. PWS ID # [ ] 2. Water System Name [ ]

3. County [ ]

4. Owner [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]

5. Admin [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]

6. Operator [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]

7. Population Served [ ] 8. No. of Service Connections [ ]

9. Ownership Type [ ] 10. Metered (Yes or No) [ ]

11. Source Type [ ]

12. Total PWS Annual Water Used [ ]

13. Number of Water Quality Violations (Prior 36 months)

    Total Coliform [ ] Chemical/Radiological [ ]

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

A. Basic Information

1. Name of Water System:

2. Name of Person Interviewed:

3. Position:

4. Number of years at job:

5. Number of years experience with drinking water systems:

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

7. Certified Water Operator (Yes or No):

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

   7b. How long have you been certified?

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

B. Organization and Structure

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

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

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

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

    3b. May we see a copy?

C. Personnel

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

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

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

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

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

D. Communication

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

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

3. How are your work priorities set?

4. How are work tasks delegated to staff?

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

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

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

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

9. Describe communication between utility and customers.

E. Planning and Funding

1. Describe the rate structure for the utility.

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

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

3. How often are the rates reviewed?

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

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

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

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

8. How is the budget approved or adopted?

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

    9a. How are budget shortfalls handled?

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

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

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

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

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

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

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

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

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

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

F. Policies, Procedures, and Programs

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

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

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

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

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

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

7. Approximately how many complaints are there per month?

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

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

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

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

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

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

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

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

G. Operations and Maintenance

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

    a. Process Control

    b. Purchases of supplies or small equipment

    c. Compliance sampling/reporting

    d. Staff scheduling

2. Describe your utility's preventative maintenance program.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

H. SDWA Compliance

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

2. How were the violations handled?

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

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

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

I. Emergency Planning

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

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

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

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

Attachment A

A. Technical Capacity Assessment Questions

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

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

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

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

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

   YES ☐ NO ☐

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

   _____NM Small System _____Class 2

   _____NM Small System Advanced _____Class 3

   _____Class 1 _____Class 4

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

   YES ☐ NO ☐ No Deficiencies ☐

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

   Source ☐ Storage ☐

   Treatment ☐ Distribution ☐

   Other _____

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

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

   Radionuclides YES ☐ NO ☐ Doesn't Apply ☐

   Arsenic YES ☐ NO ☐ Doesn't Apply ☐

   Stage 1 Disinfectants and Disinfection By-Product (DBP)

   YES ☐ NO ☐ Doesn't Apply ☐

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

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

   YES ☐ NO ☐

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

YES ☐ NO ☐

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

Drought _____ Limited Supply _____

System Failure _____ Other _____

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

YES ☐ NO ☐ Don't Know ☐

If YES, please complete the following table.

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

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

YES ☐ NO ☐

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

Source ☐ Storage ☐

Treatment ☐ Distribution ☐

Other ☐ _____

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

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

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

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

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

13. Are there any dead end lines in the system?

YES ☐ NO ☐

14. Does the system have a flushing program?

YES ☐ NO ☐

If YES, please describe.

15. Are there any pressure problems within the system?

YES ☐ NO ☐

If YES, please describe.

16. Does the system disinfect the finished water?

YES ☐ NO ☐

If yes, which disinfectant product is used? ______

Interviewer Comments on Technical Capacity:

B. Managerial Capacity Assessment Questions

17. Has the system completed a 5-year Infrastructure Capital Improvement Plan (ICIP) plan?

YES ☐ NO ☐

If YES, has the plan been submitted to Local Government Division?

YES ☐ NO ☐

18. Does the system have written operating procedures?

YES ☐ NO ☐

19. Does the system have written job descriptions for all staff?

YES ☐ NO ☐

20. Does the system have:

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

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

Water quality violations
YES ☐ NO ☐

Public notification
YES ☐ NO ☐

Sampling exemptions
YES ☐ NO ☐

22. Please describe how the above records are maintained:

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

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

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

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

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

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

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

If yes, from which agency and how much?

Describe the project?

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

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

YES ☐ NO ☐

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

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

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

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

Interviewer Comments on Managerial Capacity:

C. Financial Capacity Assessment

30. Does the system have a budget?

YES ☐ NO ☐

If YES, what type of budget?

Operating Budget ☐

Capital Budget ☐

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

YES ☐ NO ☐

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

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

YES ☐ NO ☐

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

34. Are rates reviewed annually?

YES ☐ NO ☐

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

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

Operation & Maintenance ☐

Infrastructure Repair & replacement ☐

Staffing ☐

Emergency/Reserve fund ☐

Debt payment ☐

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

YES ☐ NO ☐

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

YES ☐ NO ☐

If yes, is this policy implemented?

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

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

[Convert to % of active connections

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

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

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

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

YES ☐ NO ☐

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

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

YES ☐ NO ☐

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

YES ☐ NO ☐

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

YES ☐ NO ☐

If yes, please describe.

41. Has the system ever had a financial audit?

YES ☐ NO ☐

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

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

Interviewer Comments on Financial Assessment:

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

APPENDIX B
COST BASIS

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

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

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

Unit costs for pipeline components are based on 2006 R.S. 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 polyvinyl 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 R.S. Means Building Construction Data specific to each region.

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

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

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

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

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

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

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

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

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

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

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

Table B.1
Summary of General Data
Olsen Estates Water System
PWS #0360065
General PWS Information

Service Population	180	**Number of Connections**	60
Total PWS Daily Water Usage	0.023 (mgd)	**Source**	Calculated using assumed 130 gpcd

Unit Cost Data
East Texas

General Items	**Unit**	**Unit Cost**
Treated water purchase cost	*See alternative*	
Water purchase cost (trucked)	$/1,000 gals	$ 3.40
Contingency	20%	n/a
Engineering & Constr. Management	25%	n/a
Procurement/admin (POU/POE)	20%	n/a
Pipeline Unit Costs	**Unit**	**Unit Cost**
PVC water line, Class 200, 04"	LF	$ 27
Bore and encasement, 10"	LF	$ 60
Open cut and encasement, 10"	LF	$ 35
Gate valve and box, 04"	EA	$ 370
Air valve	EA	$ 1,000
Flush valve	EA	$ 750
Metal detectable tape	LF	$ 0.15
Bore and encasement, length	Feet	200
Open cut and encasement, length	Feet	50
Pump Station Unit Costs	**Unit**	**Unit Cost**
Pump	EA	$ 7,500
Pump Station Piping, 04"	EA	$ 4,000
Gate valve, 04"	EA	$ 405
Check valve, 04"	EA	$ 595
Electrical/Instrumentation	EA	$ 10,000
Site work	EA	$ 2,000
Building pad	EA	$ 4,000
Pump Building	EA	$ 10,000
Fence	EA	$ 5,870
Tools	EA	$ 1,000
Well Installation Unit Costs	**Unit**	**Unit Cost**
Well installation	*See alternative*	
Water quality testing	EA	$ 1,500
Well pump	EA	$ 7,500
Well electrical/instrumentation	EA	$ 5,000
Well cover and base	EA	$ 3,000
Piping	EA	$ 2,500
Storage Tank - 15,000 gals	EA	$ 21,600
Electrical Power	$/kWH	$ 0.136
Building Power	kWH	11,800
Labor	$/hr	$ 46
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	$ 46
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	$ 61
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
Reject pond, excavation	CYD	$ 3
Reject pond, compacted fill	CYD	$ 7
Reject pond, lining	SF	$ 0.50
Reject pond, vegetation	SY	$ 1
Reject pond, access road	LF	$ 30
Reject water haulage truck	EA	$ 100,000
Chlorination point	EA	$ 2,000
Building power	kwh/yr	$ 0.136
Equipment power	kwh/yr	$ 0.136
Labor, O&M	hr	$ 46
Analyses	test	$ 200
Reverse Osmosis		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
RO package plant	UNIT	$ 88,000
Transfer pumps (5 hp)	EA	$ 5,000
Permeate tank	gal	$ 3
RO materials	year	$ 3,000
RO chemicals	year	$ 1,500
Backwash disposal mileage cost	miles	$ 1.00
Backwash disposal fee	1,000 gal/yr	$ 5.00
EDR		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
Product storage tank	gal	$ 3.00
EDR package plant	UNIT	$ 200,000
EDR materials	year	$ 3,000
EDR chemicals	year	$ 2,000
Backwash disposal mileage cost	miles	$ 1.00
Backwash disposal fee	1,000 gal/yr	$ 5.00
Blending pumps	EA	$ 7,500
Blending control system	EA	$ 10,000
Materials (filter cartridges)	year	$ 17,000
Chemicals (calibration)	year	$ 400
Analyses	test	$ 50
Adsorption		
Electrical	JOB	$ 45,000
Piping	JOB	$ 15,000
Adsorption package plant	UNIT	$ 80,000
Backwash tank	GAL	$ 2.00
Sewer connection fee	EA	$ 15,000
Spent media disposal	CY	$ 20
Adsorption materials	year	$ 9,000
Backwash discharge to sewer	MG/year	$ 5,000
Coagulation/filtration		
Electrical	JOB	$ 45,000
Piping	JOB	$ 15,000
Coagulation package plant	UNIT	$ 80,000
Backwash tank	GAL	$ 2.00
Coagulant tank	GAL	$ 3.00
Sewer connection fee	EA	$ 15,000
Coagulation/Filtration Materials	year	$ 2,000
Chemicals, Coagulation	year	$ 2,000
Backwash discharge to sewer	kgal/year	$ 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.17. 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	***Olsen Estates Water System***
Alternative Name	***New Well at Olsen Estates***
Alternative Number	***OE-1***

Distance from PWS to new well location	0.06	miles
Estimated well depth	250	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	0	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	300	LF	$ 27.00	$ 8,100
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	-	EA	$ 370.00	$ -
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	-	EA	$ 750.00	$ -
Metal detectable tape	300	LF	$ 0.15	$ 45
Subtotal				**$ 8,145**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 15,000 gals	1	EA	$ 21,600	$ 21,600
Subtotal				**$ 76,280**
Well Installation				
Well installation	250	LF	$ 25	$ 6,250
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				**$ 27,250**
Subtotal of Component Costs				**$ 111,675**
Contingency	20%			$ 22,335
Design & Constr Management	25%			$ 27,919
TOTAL CAPITAL COSTS				**$ 161,929**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	0.1	mile	$ 200	$ 11
Subtotal				**$ 11**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	-	kWH	$ 0.136	$ -
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 46	$ 16,699
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 20,504**
Well O&M				
Pump power	736	kWH	$ 0.136	$ 100
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 46	$ 8,235
Subtotal				**$ 9,535**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 11,099**

Table C.2

PWS Name ***Olsen Estates Water System***
Alternative Name ***Purchase Water from City of Mont Belvieu***
Alternative Number ***OE-2***

Distance from Alternative to PWS (along pipe)	1.9	miles
Total PWS annual water usage	8.541	MG
Treated water purchase cost	$ 3.40	per 1,000 gals
Number of Pump Stations Needed	1	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	10,111	LF	$ 27.00	$ 272,997
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	2	EA	$ 370.00	$ 748
Air valve	2	EA	$ 1,000.00	$ 2,000
Flush valve	2	EA	$ 750.00	$ 1,517
Metal detectable tape	10,111	LF	$ 0.15	$ 1,517
Subtotal				**$ 278,779**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 15,000 gals	2	EA	$ 21,600	$ 43,200
Subtotal				**$ 152,560**
Subtotal of Component Costs				**$ 431,339**
Contingency	20%			$ 86,268
Design & Constr Management	25%			$ 107,835
TOTAL CAPITAL COSTS				**$ 625,441**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	1.9	mile	$ 200	$ 383
Subtotal				**$ 383**
Water Purchase Cost				
From Source	8,541	1,000 gal	$ 3.40	$ 29,039
Subtotal				**$ 29,039**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	3,595	kWH	$ 0.136	$ 489
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 46	$ 33,398
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 41,496**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 51,967**

Table C.3

PWS Name	***Olsen Estates Water System***
Alternative Name	***Purchase Water from Tower Terrace***
Alternative Number	***OE-3***

Distance from Alternative to PWS (along pipe)	5.8	miles
Total PWS annual water usage	8.541	MG
Treated water purchase cost	$ 3.40	per 1,000 gals
Number of Pump Stations Needed	1	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	3	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 04"	30,590	LF	$ 27.00	$ 825,930
Bore and encasement, 10"	600	LF	$ 60.00	$ 36,000
Open cut and encasement, 10"	150	LF	$ 35.00	$ 5,250
Gate valve and box, 04"	6	EA	$ 370.00	$ 2,264
Air valve	6	EA	$ 1,000.00	$ 6,000
Flush valve	6	EA	$ 750.00	$ 4,589
Metal detectable tape	30,590	LF	$ 0.15	$ 4,589
Subtotal				**$ 884,621**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 15,000 gals	2	EA	$ 21,600	$ 43,200
Subtotal				**$ 152,560**
Subtotal of Component Costs				**$ 1,037,181**
Contingency	20%			$ 207,436
Design & Constr Management	25%			$ 259,295
TOTAL CAPITAL COSTS				**$ 1,503,912**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	5.8	mile	$ 200	$ 1,159
Subtotal				**$ 1,159**
Water Purchase Cost				
From Source	8,541	1,000 gal	$ 3.40	$ 29,039
Subtotal				**$ 29,039**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	6,113	kWH	$ 0.136	$ 831
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 46	$ 33,398
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 41,838**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 53,085**

Table C.4

PWS Name ***Olsen Estates Water System***
Alternative Name ***Purchase Water from Engineered Carbons Inc.***
Alternative Number ***OE-4***

Distance from Alternative to PWS (along pipe)	6.6	miles
Total PWS annual water usage	8.541	MG
Treated water purchase cost	$ 3.40	per 1,000 gals
Number of Pump Stations Needed	1	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	4	n/a	n/a	n/a
Number of Crossings, open cut	2	n/a	n/a	n/a
PVC water line, Class 200, 04"	34,958	LF	$ 27.00	$ 943,866
Bore and encasement, 10"	800	LF	$ 60.00	$ 48,000
Open cut and encasement, 10"	100	LF	$ 35.00	$ 3,500
Gate valve and box, 04"	7	EA	$ 370.00	$ 2,587
Air valve	7	EA	$ 1,000.00	$ 7,000
Flush valve	7	EA	$ 750.00	$ 5,244
Metal detectable tape	34,958	LF	$ 0.15	$ 5,244
Subtotal				**$ 1,015,440**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 15,000 gals	2	EA	$ 21,600	$ 43,200
Subtotal				**$ 152,560**
Subtotal of Component Costs				**$ 1,168,000**
Contingency	20%			$ 233,600
Design & Constr Management	25%			$ 292,000
TOTAL CAPITAL COSTS				**$ 1,693,600**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	6.6	mile	$ 200	$ 1,324
Subtotal				**$ 1,324**
Water Purchase Cost				
From Source	8,541	1,000 gal	$ 3.40	$ 29,039
Subtotal				**$ 29,039**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	6,651	kWH	$ 0.136	$ 905
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 46	$ 33,398
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 41,912**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 53,324**

Table C.5

PWS Name ***Olsen Estates Water System***
Alternative Name ***Purchase Water from the City of Baytown***
Alternative Number ***OE-5***

Distance from Alternative to PWS (along pipe)	9.4	miles
Total PWS annual water usage	8.541	MG
Treated water purchase cost	$ 3.40	per 1,000 gals
Number of Pump Stations Needed	1	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	4	n/a	n/a	n/a
Number of Crossings, open cut	9	n/a	n/a	n/a
PVC water line, Class 200, 04"	49,644	LF	$ 27.00	$ 1,340,388
Bore and encasement, 10"	800	LF	$ 60.00	$ 48,000
Open cut and encasement, 10"	450	LF	$ 35.00	$ 15,750
Gate valve and box, 04"	10	EA	$ 370.00	$ 3,674
Air valve	9	EA	$ 1,000.00	$ 9,000
Flush valve	10	EA	$ 750.00	$ 7,447
Metal detectable tape	49,644	LF	$ 0.15	$ 7,447
Subtotal				**$ 1,431,705**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 15,000 gals	2	EA	$ 21,600	$ 43,200
Subtotal				**$ 152,560**
Subtotal of Component Costs				**$ 1,584,265**
Contingency	20%			$ 316,853
Design & Constr Management	25%			$ 396,066
TOTAL CAPITAL COSTS				**$ 2,297,184**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	9.4	mile	$ 200	$ 1,880
Subtotal				**$ 1,880**
Water Purchase Cost				
From Source	8,541	1,000 gal	$ 3.40	$ 29,039
Subtotal				**$ 29,039**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	8,457	kWH	$ 0.136	$ 1,150
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 46	$ 33,398
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 42,157**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 54,126**

Table C.9

PWS Name *Olsen Estates Water System*
Alternative Name *New Well at 10 Miles*
Alternative Number *OE-9*

Distance from PWS to new well location	10.0	miles
Estimated well depth	371	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	5	n/a	n/a	n/a
Number of Crossings, open cut	6	n/a	n/a	n/a
PVC water line, Class 200, 04"	52,800	LF	$ 27.00	$ 1,425,600
Bore and encasement, 10"	1,000	LF	$ 60.00	$ 60,000
Open cut and encasement, 10"	300	LF	$ 35.00	$ 10,500
Gate valve and box, 04"	11	EA	$ 370.00	$ 3,907
Air valve	10	EA	$ 1,000.00	$ 10,000
Flush valve	11	EA	$ 750.00	$ 7,920
Metal detectable tape	52,800	LF	$ 0.15	$ 7,920
Subtotal				**$ 1,525,847**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 15,000 gals	2	EA	$ 7,025	$ 14,050
Subtotal				**$ 123,410**
Well Installation				
Well installation	371	LF	$ 25	$ 9,275
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				**$ 30,275**
Subtotal of Component Costs				**$ 1,679,532**
Contingency	20%			$ 335,906
Design & Constr Management	25%			$ 419,883
TOTAL CAPITAL COSTS				**$ 2,435,322**

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	23,600	kWH	$ 0.136	$ 3,210
Pump Power	10,457	kWH	$ 0.136	$ 1,422
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 46	$ 33,398
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 42,429**
Well O&M				
Pump power	523	kWH	$ 0.136	$ 71
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 46	$ 8,235
Subtotal				**$ 9,506**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 34,984**

Table C.10

PWS Name	***Olsen Estates Water System***
Alternative Name	***New Well at 5 Miles***
Alternative Number	***OE-10***

Distance from PWS to new well location	5.0	miles
Estimated well depth	371	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	2	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 04"	26,400	LF	$ 27.00	$ 712,800
Bore and encasement, 10"	1,800	LF	$ 60.00	$ 108,000
Open cut and encasement, 10"	100	LF	$ 35.00	$ 3,500
Gate valve and box, 04"	5	EA	$ 370.00	$ 1,954
Air valve	5	EA	$ 1,000.00	$ 5,000
Flush valve	5	EA	$ 750.00	$ 3,960
Metal detectable tape	26,400	LF	$ 0.15	$ 3,960
Subtotal				**$ 839,174**
Pump Station(s) Installation				
Pump	4	EA	$ 7,500	$ 30,000
Pump Station Piping, 04"	2	EA	$ 4,000	$ 8,000
Gate valve, 04"	8	EA	$ 405	$ 3,240
Check valve, 04"	4	EA	$ 595	$ 2,380
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 15,000 gals	2	EA	$ 7,025	$ 14,050
Subtotal				**$ 123,410**
Well Installation				
Well installation	371	LF	$ 25	$ 9,275
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				**$ 30,275**
Subtotal of Component Costs				**$ 992,859**
Contingency	20%			$ 198,572
Design & Constr Management	25%			$ 248,215
TOTAL CAPITAL COSTS				**$ 1,439,645**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	5.0	mile	$ 200	$ 1,000
Subtotal				**$ 1,000**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	5,228	kWH	$ 0.136	$ 711
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 46	$ 33,398
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 41,718**
Well O&M				
Pump power	523	kWH	$ 0.136	$ 71
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 46	$ 8,235
Subtotal				**$ 9,506**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 33,273**

Table C.11

PWS Name ***Olsen Estates Water System***
Alternative Name ***New Well at 1 Mile***
Alternative Number ***OE-11***

Distance from PWS to new well location	1.0	miles
Estimated well depth	371	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	0	
Number of feed tanks/pump sets needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	5,280	LF	$ 27.00	$ 142,560
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	1	EA	$ 370.00	$ 391
Air valve	1	EA	$ 1,000.00	$ 1,000
Flush valve	1	EA	$ 750.00	$ 792
Metal detectable tape	5,280	LF	$ 0.15	$ 792
Subtotal				**$ 147,285**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 15,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 61,705**
Well Installation				
Well installation	371	LF	$ 25	$ 9,275
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				**$ 30,275**
Subtotal of Component Costs				**$ 239,265**
Contingency	20%			$ 47,853
Design & Constr Management	25%			$ 59,816
TOTAL CAPITAL COSTS				**$ 346,934**

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	11,800	kWH	$ 0.136	$ 1,605
Pump Power	-	kWH	$ 0.136	$ -
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 46	$ 16,699
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 20,504**
Well O&M				
Pump power	523	kWH	$ 0.136	$ 71
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 46	$ 8,235
Subtotal				**$ 9,506**
O&M Credit for Existing Well Closure				
Pump power	598	kWH	$ 0.136	$ (81)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 46	$ (16,470)
Subtotal				**$ (18,951)**
TOTAL ANNUAL O&M COSTS				**$ 11,258**

Table C.9

PWS Name *Olsen Estates Water System*
Alternative Name *Central Treatment - RO*
Alternative Number *OE-9*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Reverse Osmosis Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	15	CY	$ 1,000	$ 15,000
Building	500	SF	$ 60	$ 30,000
Building electrical	500	SF	$ 8	$ 4,000
Building plumbing	500	SF	$ 8	$ 4,000
Heating and ventilation	500	SF	$ 7	$ 3,500
Fence	700	LF	$ 15	$ 10,500
Paving	2,600	SF	$ 2	$ 5,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Reverse osmosis package including:				
High pressure pumps - 15hp				
Cartridge filters and vessels				
RO membranes and vessels				
Control system				
Chemical feed systems				
Freight cost				
Vendor start-up services	1	UNIT	$ 88,000	$ 88,000
Transfer pumps	2	EA	$ 5,000	$ 10,000
Permeate tank	10,000	gal	$ 3	$ 30,000
Reject pond:				
Excavation	1,500	CYD	$ 3.00	$ 4,500
Compacted fill	1,250	CYD	$ 7.00	$ 8,750
Lining	21,750	SF	$ 0.50	$ 10,875
Vegetation	2,500	SY	$ 1.00	$ 2,500
Access road	625	LF	$ 30.00	$ 18,750
Subtotal of Design/Construction Costs				**$ 317,575**
Contingency	20%			$ 63,515
Design & Constr Management	25%			$ 79,394
Reject water haulage truck	1	EA	$ 100,000	$ 100,000
TOTAL CAPITAL COSTS				**$ 560,484**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Reverse Osmosis Unit O&M				
Building Power	9,000	kwh/yr	$ 0.136	$ 1,224
Equipment power	15,000	kwh/yr	$ 0.136	$ 2,040
Labor	600	hrs/yr	$ 46	$ 27,600
Materials	1	year	$ 3,000	$ 3,000
Chemicals	1	year	$ 1,500	$ 1,500
Analyses	24	test	$ 200	$ 4,800
Subtotal				**$ 40,164**
Backwash Disposal				
Disposal truck mileage	552	miles	$ 1.00	$ 552
Backwash disposal fee	1,200	kgal/yr	$ 7.50	$ 9,000
Subtotal				**$ 9,552**
TOTAL ANNUAL O&M COSTS				**$ 49,716**

Table C.10

PWS Name *Olsen Estates Water System*
Alternative Name *Central Treatment - EDR*
Alternative Number *OE-10*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
EDR Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	15	CY	$ 1,000	$ 15,000
Building	500	SF	$ 60	$ 30,000
Building electrical	500	SF	$ 8	$ 4,000
Building plumbing	500	SF	$ 8	$ 4,000
Heating and ventilation	500	SF	$ 7	$ 3,500
Fence	700	LF	$ 15	$ 10,500
Paving	2,600	SF	$ 2	$ 5,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Product storage tank	10,000	gal	$ 3.00	$ 30,000
EDR package including:				
Feed and concentrate pumps				
Cartridge filters and vessels				
EDR membrane stacks				
Electrical module				
Chemical feed systems				
Freight cost				
Vendor start-up services	1	UNIT	$ 200,000	$ 200,000
Reject pond:				
Excavation	1,500	CYD	$ 3.00	$ 4,500
Compacted fill	1,250	CYD	$ 7.00	$ 8,750
Lining	21,750	SF	$ 0.50	$ 10,875
Vegetation	2,500	SY	$ 1.00	$ 2,500
Access road	625	LF	$ 30.00	$ 18,750
Subtotal of Design/Construction Costs				**$ 419,575**
Contingency	20%			$ 83,915
Design & Constr Management	25%			$ 104,894
Reject water haulage truck	1	EA	$ 100,000	$ 100,000
TOTAL CAPITAL COSTS				**$ 708,384**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
EDR Unit O&M				
Building Power	9,000	kwh/yr	$ 0.136	$ 1,224
Equipment power	15,000	kwh/yr	$ 0.136	$ 2,040
Labor	600	hrs/yr	$ 46	$ 27,600
Materials	1	year	$ 3,000	$ 3,000
Chemicals	1	year	$ 2,000	$ 2,000
Analyses	24	test	$ 200	$ 4,800
Subtotal				**$ 40,664**
Backwash Disposal				
Disposal truck mileage	437	miles	$ 1.00	$ 437
Backwash disposal fee	950	kgal/yr	$ 7.50	$ 7,125
Subtotal				**$ 7,562**
TOTAL ANNUAL O&M COSTS				**$ 48,226**

Table C.11

PWS Name	***Olsen Estates Water System***
Alternative Name	***Central Treatment -Adsorption***
Alternative Number	***OE-11***

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Adsorption Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	15	CY	$ 1,000	$ 15,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	600	LF	$ 15	$ 9,000
Paving	2,500	SF	$ 2	$ 5,000
Electrical	1	JOB	$ 45,000	$ 45,000
Piping	1	JOB	$ 15,000	$ 15,000
Adsorption package including:				
4 Adsorption vessels				
E33 Iron oxide media				
Controls & instruments	1	UNIT	$ 80,000	$ 80,000
Backwash Tank	15,000	GAL	$ 2	$ 30,000
Sewer Connection Fee	-	EA	$ 15,000	$ -
Chlorination Point	1	EA	$ 2,000	$ 2,000
Subtotal of Component Costs				**$ 236,200**
Contingency	20%			$ 47,240
Design & Constr Management	25%			$ 59,050
TOTAL CAPITAL COSTS				**$ 342,490**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Adsorption Unit O&M				
Building Power	9,000	kwh/yr	$ 0.136	$ 1,224
Equipment power	5,000	kwh/yr	$ 0.136	$ 680
Labor	400	hrs/yr	$ 46	$ 18,400
Materials	1	year	$ 9,000	$ 9,000
Analyses	24	test	$ 200	$ 4,800
Sludge disposal	30	kgal/yr	$ 200	$ 6,000
Spent Media Disposal	18	CY	$ 30	$ 540
Subtotal				**$ 40,644**
Haul Regenerant Waste and Brine				
Waste haulage truck rental	6	days	$ 700	$ 4,200
Mileage charge	6	miles	$ 1.00	$ 6
Subtotal				**$ 4,206**
TOTAL ANNUAL O&M COSTS				**$ 44,850**

Table C.12

PWS Name *Olsen Estates Water System*
Alternative Name *Central Treatment- Coag-Filt*
Alternative Number *OE-12*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	15	CY	$ 1,000	$ 15,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	600	LF	$ 15	$ 9,000
Paving	2,500	SF	$ 2	$ 5,000
Electrical	1	JOB	$ 45,000	$ 45,000
Piping	1	JOB	$ 15,000	$ 15,000
Coagulant/filter package including:				
Chemical feed system				
Pressure ceramic filters				
Controls & Instruments	1	UNIT	$ 80,000	$ 80,000
Backwash Tank	15,000	GAL	$ 2	$ 30,000
Coagulant Tank	200	GAL	$ 3	$ 600
Sewer Connection Fee	-	EA	$ 15,000	$ -
Chlorination Point	1	EA	$ 2,000	$ 2,000
Subtotal of Component Costs				**$ 236,800**
Contingency	20%			$ 47,360
Design & Constr Management	25%			$ 59,200
TOTAL CAPITAL COSTS				**$ 343,360**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	9,000	kwh/yr	$ 0.136	$ 1,224
Equipment power	500	kwh/yr	$ 0.136	$ 68
Labor	600	hrs/yr	$ 46	$ 27,600
Materials	1	year	$ 2,000	$ 2,000
Chemicals	1	year	$ 2,000	$ 2,000
Analyses	24	test	$ 200	$ 4,800
Sludge disposal	30	kgal/yr	$ 200	$ 6,000
Subtotal				**$ 43,692**
Haul Regenerant Waste and Brine				
Waste haulage truck rental	6	days	$ 700	$ 4,200
Mileage charge	14	miles	$ 1.00	$ 14
Subtotal				**$ 4,214**
TOTAL ANNUAL O&M COSTS				**$ 47,906**

Table C.13

PWS Name *Olsen Estates Water System*
Alternative Name *Point-of-Use Treatment*
Alternative Number *OE-13*

Number of Connections for POU Unit Installation 60

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POU-Treatment - Purchase/Installation				
POU treatment unit purchase	60	EA	$ 250	$ 15,000
POU treatment unit installation	60	EA	$ 150	$ 9,000
Subtotal				**$ 24,000**
Subtotal of Component Costs				**$ 24,000**
Contingency	20%			$ 4,800
Design & Constr Management	25%			$ 6,000
Procurement & Administration	20%			$ 4,800
TOTAL CAPITAL COSTS				**$ 39,600**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POU materials, per unit	60	EA	$ 225	$ 13,500
Contaminant analysis, 1/yr per unit	60	EA	$ 100	$ 6,000
Program labor, 10 hrs/unit	600	hrs	$ 46	$ 27,450
Subtotal				**$ 46,950**
TOTAL ANNUAL O&M COSTS				**$ 46,950**

Table C.14

PWS Name ***Olsen Estates Water System***
Alternative Name ***Point-of-Entry Treatment***
Alternative Number ***OE-14***

Number of Connections for POE Unit Installation 60

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POE-Treatment - Purchase/Installation				
POE treatment unit purchase	60	EA	$ 3,000	$ 180,000
Pad and shed, per unit	60	EA	$ 2,000	$ 120,000
Piping connection, per unit	60	EA	$ 1,000	$ 60,000
Electrical hook-up, per unit	60	EA	$ 1,000	$ 60,000
Subtotal				**$ 420,000**
Subtotal of Component Costs				**$ 420,000**
Contingency	20%			$ 84,000
Design & Constr Management	25%			$ 105,000
Procurement & Administration	20%			$ 84,000
TOTAL CAPITAL COSTS				**$ 693,000**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POE materials, per unit	60	EA	$ 1,000	$ 60,000
Contaminant analysis, 1/yr per unit	60	EA	$ 100	$ 6,000
Program labor, 10 hrs/unit	600	hrs	$ 46	$ 27,450
Subtotal				**$ 93,450**
TOTAL ANNUAL O&M COSTS				**$ 93,450**

Table C.15

PWS Name ***Olsen Estates Water System***
Alternative Name ***Public Dispenser for Treated Drinking Water***
Alternative Number ***OE-15***

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 u	52	EA	$ 100	$ 5,200
Sampling/reporting, 1 hr/day	365	HRS	$ 46	$ 16,699
Subtotal				**$ 22,399**
TOTAL ANNUAL O&M COSTS				**$ 22,399**

Table C.16

PWS Name ***Olsen Estates Water System***
Alternative Name ***Supply Bottled Water to Population***
Alternative Number ***OE-16***

Service Population	180	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	65,700	gallons

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Implementation				
Initial program set-up	500	hours	$ 61	$ 30,424
Subtotal				**$ 30,424**
Subtotal of Component Costs				**$ 30,424**
Contingency	20%			$ 6,085
TOTAL CAPITAL COSTS				**$ 36,509**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water purchase costs	65,700	gals	$ 1.60	$ 105,120
Program admin, 9 hrs/wk	468	hours	$ 61	$ 28,477
Program materials	1	EA	$ 5,000	$ 5,000
Subtotal				**$ 138,597**
TOTAL ANNUAL O&M COSTS				**$ 138,597**

Table C.17

PWS Name	***Olsen Estates Water System***
Alternative Name	***Central Trucked Drinking Water***
Alternative Number	***OE-17***

Service Population	180	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	65,700	gallons
Travel distance to compliant water source (roundtrip)	2	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	$ 46	$ 9,516
Truck operation, 1 round trip/wk	120	miles	$ 1.00	$ 120
Water purchase	66	1,000 gals	$ 3.40	$ 223
Water testing, 1 test/wk	52	EA	$ 100	$ 5,200
Sampling/reporting, 2 hrs/wk	104	hrs	$ 46	$ 4,758
Subtotal				**$ 19,817**
TOTAL ANNUAL O&M COSTS				**$ 19,817**

APPENDIX D
EXAMPLE FINANCIAL MODEL

Table D.1 Example Financial Model

Water System	Olsen Estates
Funding Alternative	Bond
Alternative Description	Purchase Water from City of Mont Belvieu

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 Bonds	$ -	$ -	$ -	$ 625,441	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Grants	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Revenue/R	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ -	$ -	$ 625,441	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds				$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926
	State Revolving Funds				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service Sum					$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926	$ 48,926
Operating Expenditures	Administrative Expenses			$ 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
	Chemicals, Treatment			$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 1,500
	Contract Labor			$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715	$ 715
	Insurance			$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417	$ 417
	Other Operating Expenditures 1			$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479	$ 479
	Other Operating Expenditures 2			$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000
	Repairs			$ 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
	Salaries & Benefits			$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880	$ 5,880
	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			$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000
	O&M Associated with Alternative					$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967	$ 51,967
	Maintenance			$ 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
	Accounting and Legal Fees			$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35	$ 35
Operating Expenditures Sum				$ 29,026	$ 29,026	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993	$ 80,993
Residential Operating Revenues	Residential Base Monthly Rate			$ 25,920	$ 25,920	$ 93,234	$ 211,982	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416
	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				$ 25,920	$ 25,920	$ 93,234	$ 211,982	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416

Location_Name	Olsen Estates
Alt_Desc	Purchase Water from City of Mont Belvieu

		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	$ -	$ (9,194)	$ (67,314)	$ (118,748)	$ (51,435)	$ 67,314	$ 186,062	$ 304,810	$ 423,558	$ 542,306	$ 661,054	$ 779,802	$ 898,550	$ 1,017,299	$ 1,136,047	$ 1,254,795	$ 1,373,543	$ 1,492,291	$ 1,611,039	$ 1,729,787	$ 1,848,535	$ 1,967,284
	Sum of Total_Expenditures	$ 29,026	$ 703,393	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919	$ 129,919
	Sum of Total_Receipts	$ 25,920	$ 651,361	$ 93,234	$ 211,982	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416	$ 263,416
	Sum of Net_Cash_Flow	$ (3,106)	$ (52,032)	$ (36,686)	$ 82,062	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497	$ 133,497
	Sum of Ending_Cash_Bal	$ (3,106)	$ (61,226)	$ (103,999)	$ (36,686)	$ 82,062	$ 200,811	$ 319,559	$ 438,307	$ 557,055	$ 675,803	$ 794,551	$ 913,299	$ 1,032,047	$ 1,150,796	$ 1,269,544	$ 1,388,292	$ 1,507,040	$ 1,625,788	$ 1,744,536	$ 1,863,284	$ 1,982,032	$ 2,100,781
	Sum of Working_Cap	$ 4,838	$ 4,838	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499	$ 13,499
	Sum of Repl_Resv	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250	$ 1,250
	Sum of Total_Reqd_Resv	$ 6,088	$ 6,088	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749	$ 14,749
	Sum of Net_Avail_Bal	$ (9,194)	$ (67,314)	$ (118,748)	$ (51,435)	$ 67,314	$ 186,062	$ 304,810	$ 423,558	$ 542,306	$ 661,054	$ 779,802	$ 898,550	$ 1,017,299	$ 1,136,047	$ 1,254,795	$ 1,373,543	$ 1,492,291	$ 1,611,039	$ 1,729,787	$ 1,848,535	$ 1,967,284	$ 2,086,032
	Sum of Add_Resv_Needed	$ (9,194)	$ (67,314)	$ (118,748)	$ (51,435)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	260%	127%	24%	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%	260%	718%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%	916%

APPENDIX E
GENERAL ARSENIC GEOCHEMISTRY

Geochemistry of arsenic is complex because of the possible coexistence of two or even three redox states, because of the complex chemistry of organo-arsenicals, and because of the strong interaction of most arsenic compounds with soil particles, particularly iron oxides (and to a lesser degree aluminum and manganese oxides). The fully deprotonated arsenate AsO_4^{-3} is the expected form of arsenic in most soils under aerobic conditions only at high pH (Figure E.1). At more neutral and acid pH's, the $HAsO_4^{-2}$ and $H_2AsO_4^{-1}$ forms, respectively, are dominant. The general understanding of arsenic mobility in soil and aquifers is that it will increase with increasing pH and phosphate concentration and with decreasing clay and iron oxide content. As pH increases, the negative charge of the arsenate ion increases making it less likely to sorb on negatively charged soil particles. Phosphates have a chemical structure very similar to arsenates and sorb to soils preferentially to them in some conditions. Nitrogen also belongs to the same group in the periodic table but does not show the same competing behavior as phosphate. Other structurally similar oxyanions, sulfate and selenate, are also weak sorbers. Under less oxidizing conditions, the arsenite ion H_3AsO_3 is most stable. The lack of charge renders the ion more mobile and less likely to sorb to soil particles. Its pH stability spread ranges from acid to alkaline. The first deprotonated form $H_2AsO_3^{-1}$ exists at significant concentrations only above a pH of approximately 9. The redox processes seem to be mediated by microorganisms (Welch, *et al.* 2000) and to take place next to mineral surfaces.

Under even more reducing conditions, arsenide is the stable ionic form of arsenic. Arsenic has a complex geochemistry with sulfur both in solution where several thioarsenic ions can form and in the associated minerals. Arsenic metal –As(0)- rarely occurs. Methylated arsenic compounds are generally present at low aqueous concentrations (<1ppb), if at all, except maybe when there is an abundance of organic matter (Welch, *et al*. 2000).

As(V) and As(III) minerals are fairly soluble and do not control arsenic solubility in oxidizing and mildly reducing conditions except maybe if barium is present (Henry, *et al*. 1982, p.21). This is in contrast to other companion oxyanions which are not as mobile under reducing conditions, except vanadium. In reducing conditions, arsenic precipitates as arsenopyrite (FeAsS) but more commonly in solid solution with pyrite. Realgar (AsS) and orpiment (As_2S_3) require a high sulfur activity and are unlikely in the southern Gulf Coast.

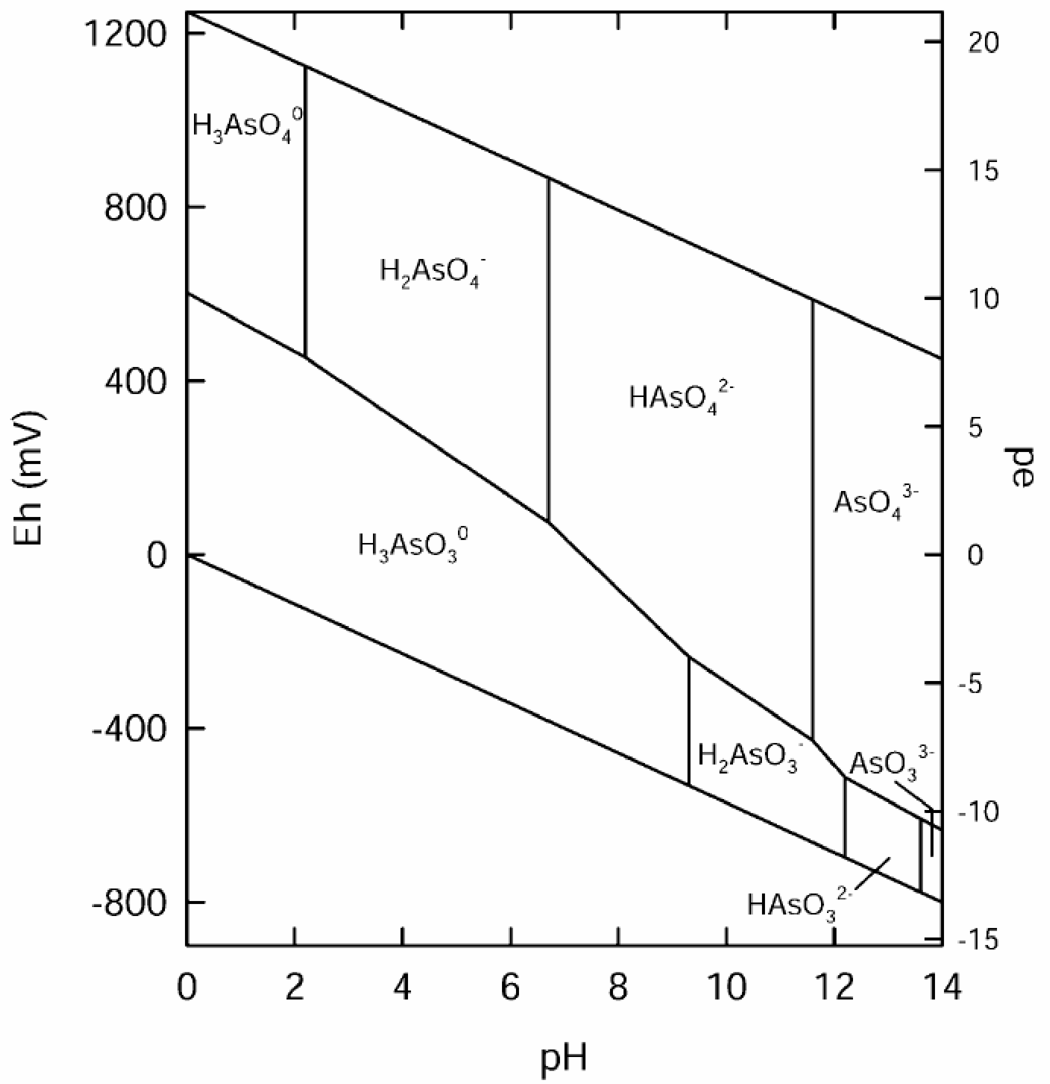

Figure E.1 Eh-pH Diagram for Arsenic Aqueous Species in the As-O_2-H_2O System at 25°C and 1 Bar (from Smedley and Kinniburgh 2002)

APPENDIX F
ANALYSIS OF SHARED SOLUTIONS FOR OBTAINING WATER FROM TOWER TERRACE, AND THE CITY OF BAYTOWN

F.1 Overview of Method Used

There are a number of small PWSs with water quality problems located in the vicinity of Olsen Estates that could benefit from joining together and cooperating to share the cost for obtaining compliant drinking water. This cooperation could involve creating a formal organization of individual PWSs to address obtaining compliant drinking water, consolidating to form a single PWS, or having the individual PWSs be taken over or bought out by a larger regional entity.

The small PWSs with water quality problems near the Olsen Estates PWS are listed in Table F.1, along with their average water consumption and estimates of the capital cost for each PWS to construct an individual pipeline. It is assumed for this analysis that all the systems would participate in a shared solution.

This analysis focuses on compliance alternatives related to obtaining water from large water providers interested in providing water outside their current area, either by wholesaling to PWSs, or by expanding their service areas. This type of solution is most likely to have the best prospects for sustainability, and a reliable provision of compliant drinking water.

The purpose of this analysis is to approximate the level of capital cost savings that could be expected from pursuing a shared solution versus a solution where the study PWS obtains compliant drinking water on its own. Regardless of the form a group solution would take, water consumers would have to pay for the infrastructure needed for obtaining compliant water. To keep this analysis as straightforward and realistic as possible, it is assumed the individual PWSs would remain independent, and would share the capital cost for the infrastructure required. Also, to maintain simplicity, this analysis is limited to estimating capital cost savings related to pipeline construction, which is likely to be by far the largest component of the overall capital cost. A shared solution could also produce savings in O&M expenses as a result of reduction in redundant facilities and the potential for shared O&M resources, and these savings would have to be evaluated if the PWSs are interested in implementing a shared solution.

There are many ways pipeline capital costs could be divided between participating PWSs, and the final apportioning of costs would likely be based on negotiation between the participating entities. At this preliminary stage of analysis it is not possible to project results from negotiations regarding cost sharing. For this reason, three methods are used to allocate cost between PWSs in an effort to give an approximation of the range of savings that might be attainable for an individual PWS.

Method A is based on allocating capital cost of the shared pipeline solution proportionate to the amount of water used by each PWS. In this case, the capital cost for the shared pipeline and the necessary pump stations is estimated, and then this total capital cost is allocated based on the fraction of the total water used by each PWS. For example, PWS#1 has an average daily water use of 0.1 mgd and PWS#2 has an average daily use of 0.3 mgd. Using this method, PWS#1 would be allocated 25 percent of the capital cost of the shared solution. This method is a reasonable method for allocating cost when all of the PWSs are different in size but are relatively equidistant from the shared water source.

Method B is also based on allocating capital cost of the shared pipeline solution proportionate to the amount of water used by the PWSs. However, rather than allocating the *total* capital cost of the shared solution between each participating PWS, this approach splits the shared pipeline into segments and allocates flow-proportional costs to the PWSs using each segment. Costs for a pipeline segment are not shared by a PWS if the PWS does not use that particular segment. For example, PWS#1 has an average daily water use of 0.3 mgd and PWS#2 has an average daily use of 0.2 mgd. A 3-mile long pipeline segment is common to both PWSs, while PWS#2 requires an additional 4-mile segment. Using this method, PWS#2 would be allocated 40 percent of the cost of the 3-mile segment and 100 percent of the cost of the 4-mile segment. This method is a reasonable method for allocating cost when all of the PWSs are different in size and are located at different distances from the shared water source.

Method C is based on allocating capital cost of the shared pipeline solution proportionate to the cost each PWS would have to pay to obtain compliant water if it were to implement an individual solution. In this case, the total capital cost for the shared pipeline and the necessary pump stations is estimated as well as the capital cost each PWS would have for obtaining its own pipeline. The total capital cost for the shared solution is then allocated between the participating PWSs based on what each PWS would have to pay to construct its own pipeline. For example, the individual solution cost for PWS#1 is $4 million and the individual solution cost for PWS#2 is $1 million. Using this method, PWS#1 would be allocated 80 percent of the cost of the shared solution. This method is a reasonable method for allocating cost when the PWS are located at different distances from the water source.

For any given PWS, all three of these methods should generate costs for the shared solution that produce savings for the PWS over an individual solution. However, for different PWSs participating in a shared solution, each of these three methods can produce savings of varying magnitudes: for one PWS, Method A might show the best cost savings while for another Method C might provide the best savings. For this reason, this range is considered to be representative of possible savings that could result from an agreement that should be fair and equitable to all parties involved.

F.2 Shared Solution for Obtaining Water from Tower Terrace PWS

This alternative would consist of constructing a 4-inch main pipeline from the Tower Terrace PWS that would run northeast along FM 565 to the Olsen Estates PWS. Each PWS would connect directly to this main or with a spur line. Spur lines would convey the water from the main line to the storage tanks of each PWS. All of the spur pipelines are 4 inches in diameter. It is assumed one pump station would be required to transfer the water from the Tower Terrace PWS to the end of the pipeline. The pipeline routing is shown in Figure F.1.

The capital costs for each pipe segment and the total capital cost for the shared pipeline are summarized in Table F.2. Table F.3 shows the capital costs allocated to each PWS using Method A. Table F.4 shows the capital costs allocated to each PWS using Method B. Table F.5 shows the allocation of pipeline capital costs to each of the PWSs using Method C, as described above, and Table F.6 provides a summary of the pipeline capital costs estimated for each PWS, and the savings that could be realized compared to developing individual pipelines. More detailed cost estimates for the pipe segments are shown at the end of this appendix in Tables F.7 through F.16.

Based on these estimates, the range of pipeline capital cost savings to Olsen Estates PWS could be between $380,000 and $927,000 if they were to implement a shared solution like this, which would be a savings of 26 to 63 percent. These estimates are hypothetical and are only provided to approximate the magnitude of potential savings if this shared solution is implemented as described.

F.3 Group Solution for Obtaining Water from the City of Baytown

This alternative would consist of constructing a 4-inch main pipeline from the City of Baytown that would run northeast along FM 565 to the Olsen Estates PWS. Each PWS would connect directly to this main or with a spur line. Spur lines would convey the water from the main line to the storage tanks of each PWS. All of the spur pipelines are 4 inches in diameter. It is assumed one pump station would be required to transfer the water from the City of Baytown to the end of the pipeline. The pipeline routing is shown in Figure F.2.

The capital costs for each pipe segment and the total capital cost for the shared pipeline are summarized in Table F.7. Table F.8 shows the capital costs allocated to each PWS using Method A. Table F.9 shows the capital cost allocated to each PWS using Method B. Table F.10 shows the allocation of pipeline capital costs to each of the PWSs using Method C, as described above and Table F.11 provides a summary of the pipeline capital costs estimated for each PWS, and the savings that could be realized compared to developing individual pipelines. More detailed cost estimates for the pipe segments are shown at the end of this appendix in Tables F.27 through F.36.

Based on these estimates, the range of capital cost savings to Olsen Estates PWS could be between $825,000 and $1.5 million if they were to implement a shared solution like this, which would be savings of 37 to 69 percent. These estimates are hypothetical and are only provided to approximate the magnitude of potential savings if this shared solution is implemented as described.

Figures F.1 and F.2 are in J:\744\744655_BEG_2006\GIS_06\figures\reports

Tables F.1 through F.16 are in J:\744\744655_BEG_2006\Cost Estimates\OLD Cost Estimates\ChambersCounty\Chambers Area\APPENDIX_F\CostcalculationChamber.xls

Tables F.17 through F.21 are in J:\744\744655_BEG_2006\Cost Estimates\OLD Cost Estimates\ChambersCounty\Chambers Area\APPENDIX_F\BEG Cost Estimate from Tecon.xls

Tables F.22 through F.26 are in J:\744\744655_BEG_2006\Cost Estimates\OLD Cost Estimates\ChambersCounty\Chambers Area\APPENDIX_F\BEG Cost Estimate from Tecon to each PWS.xls

Tables F.27 through F.31 are in J:\744\744655_BEG_2006\Cost Estimates\OLD Cost Estimates\ChambersCounty\Chambers Area\APPENDIX_F\BEG Cost Estimate from Baytown.xls

Tables F.32 through F.36 are in J:\744\744655_BEG_2006\Cost Estimates\OLD Cost Estimates\ChambersCounty\Chambers Area\APPENDIX_F\BEG Cost Estimate from Baytown to each PWS.xls

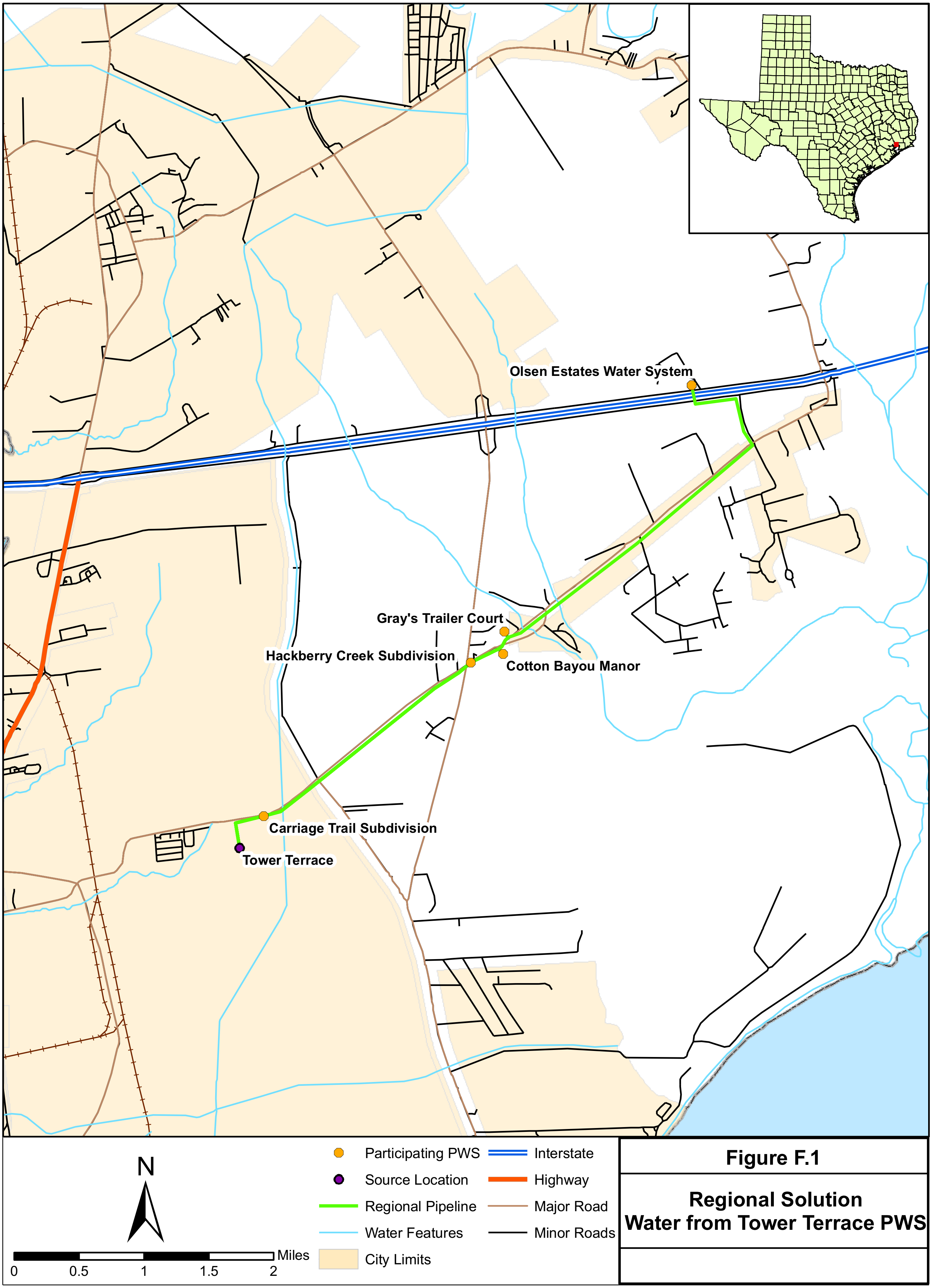

Figure F.1

Regional Solution
Water from Tower Terrace PWS

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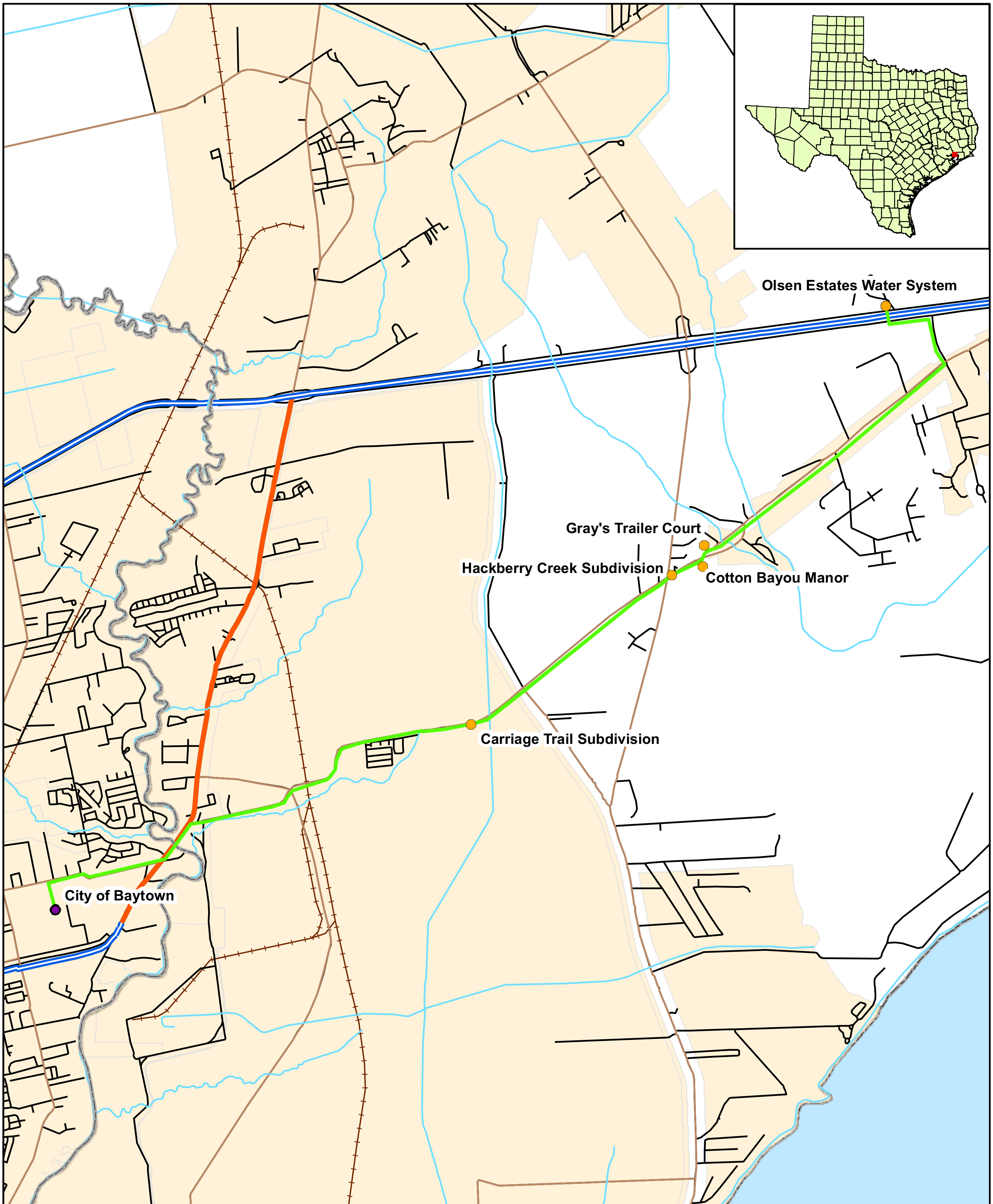

N

0 0.5 1 1.5 2 Miles

Participating PWS
Source Location
Regional Pipeline
Water Features
City Limits
Interstate
Highway
Major Road
Minor Roads

Figure F.2

Regional Solution
Water from City of Baytown

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Table F.1
Summary Information for PWSs Participating in Shared Solution

PWS Names	PWS #	Average Water Demand, mgd	Water Demand as Percent of Total Demand	Pipeline Capital Cost for Individual Solutions from Tower Terrace	Percent of sum of capital costs for individual solutions from Tower Terrace	Pipeline Capital Cost for Individual Solutions from Plantation	Percent of sum of capital costs for individual solutions from Plantation	Pipeline Capital Cost for Individual Solutions from Baytown	Percent of sum of capital costs for individual solutions from Baytown
Olsen Estates	0360065	16	36%	$ 1,468,939	41%	$ 818,516	20%	$ 2,208,527	30%
Grays Trailer Court	0360005	2	5%	$ 697,711	19%	$ 654,492	16%	$ 1,470,648	20%
Cotton Bayou	0360004	6	13%	$ 669,175	19%	$ 675,129	17%	$ 1,442,112	19%
Hackberry Creek Subd	0360100	14	30%	$ 607,591	17%	$ 714,504	18%	$ 1,381,979	19%
Carriage Trail Subd	0360093	7	16%	$ 166,039	5%	$ 1,158,593	29%	$ 957,827	13%
Totals		**45**	**100%**	**$ 3,609,455**	**100%**	**$ 4,021,234**	**100%**	**$ 7,461,093**	**100%**

Table F.2
Capital Cost for Shared Pipeline from Tower Terrace PWS

Pipe Segment	Capital Cost
Pipe 1	$ 166,039
Pipe 2	$ 441,552
Pipe 3	$ 49,734
Pipe 4	$ 27,266
Pipe 5	$ 782,898
Pipe A	$ 18,097
Pipe B	$ 10,399
Total	**1,495,985**

Table F.3
Pipeline Capital Cost Allocation by Method A
Shared Pipeline Assessment for Tower Terrace PWS

PWS	PWS #	Flow Weighted Percent Use	Allocated Capital Cost
Olsen Estates	0360065	36%	$ 542,265
Grays Trailer Court	0360005	5%	$ 67,741
Cotton Bayou	0360004	13%	$ 199,220
Hackberry Creek Subd	0360100	30%	$ 451,832
Carriage Trail Subd	0360093	16%	$ 234,926
	Totals	**100%**	**$ 1,495,985**

Table F.4
Breakdown of Pipline Capital Cost for Each PWS under Method B
Shared Pipeline Assessment for Tower Terrace PWS

Pipeline Segment		Olsen Estates		Grays Trailer Court		Cotton Bayou		Hackberry Creek Subdivision		Carrigae Trail Subdivision	
	Pipe Segment Capital Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost
Pipe 1	$ 166,039	36%	$ 60,186	5%	$ 7,519	13%	$ 22,111	30%	$ 50,149	16%	$ 26,074
Pipe 2	$ 441,552	43%	$ 189,871	5%	$ 23,719	16%	$ 69,756	36%	$ 158,206	0%	$ -
Pipe 3	$ 49,734	67%	$ 33,327	8%	$ 4,163	25%	$ 12,244	0%	$ -	0%	$ -
Pipe 4	$ 27,266	89%	$ 24,238	11%	$ 3,028	0%	$ -	0%	$ -	0%	$ -
Pipe 5	$ 782,898	100%	$ 782,898	0%	$ -	0%	$ -	0%	$ -	0%	$ -
Pipe A	$ 18,097	0%	$ -	100%	$ 18,097	0%	$ -	0%	$ -	0%	$ -
Pipe B	$ 10,399	0%	$ -	0%	$ -	100%	$ 10,399	0%	$ -	0%	$ -
Total	**$ 1,495,985**		$1,090,520		$ 56,526		$114,510		$ 208,355		$ 26,074

Table F.5
Pipeline Capital Cost Allocation by Method C
Shared Pipeline Assessment for Tower Terrace PWS

PWS	PWS #	Cost for Individual Pipelines	Percent of Sum of Capital Costs for Individual Pipelines	Allocated Capital Cost
Olsen Estates	0360065	$ 1,468,939	41%	$ 608,821
Grays Trailer Court	0360005	$ 697,711	19%	$ 289,175
Cotton Bayou	0360004	$ 669,175	19%	$ 277,348
Hackberry Creek Subd	0360100	$ 607,591	17%	$ 251,824
Carriage Trail Subdivision	0360093	$ 166,039	5%	$ 68,817
	Totals	**$ 3,609,455**	**100%**	**$ 1,495,985**

Table F.6
Pipeline Capital Cost Summary
Shared Pipeline Assessment for Tower Terrace PWS

PWS	Individual Pipeline Capital Costs	Shared Solution Capital Cost Allocation			Shared Solution Savings			Shared Solution Percent Savings		
		Method A	Method B	Method C	Method A	Method B	Method C	Method A	Method B	Method C
Olsen Estates	$ 1,468,939	$ 542,265	$ 1,090,520	$ 608,821	$ 926,673	$ 378,419	$ 860,118	63%	26%	59%
Grays Trailer Court	$ 697,711	$ 67,741	$ 56,526	$ 289,175	$ 629,969	$ 641,185	$ 408,536	90%	92%	59%
Cotton Bayou	$ 669,175	$ 199,220	$ 114,510	$ 277,348	$ 469,955	$ 554,665	$ 391,827	70%	83%	59%
Hackberry Creek Subd	$ 607,591	$ 451,832	$ 208,355	$ 251,824	$ 155,759	$ 399,236	$ 355,767	26%	66%	59%
Carriage Trail Subdivision	$ 166,039	$ 234,926	$ 26,074	$ 68,817	$ (68,887)	$ 139,965	$ 97,222	-41%	84%	59%
Totals	**$ 3,609,455**	**$ 1,495,985**	**$ 1,495,985**	**$ 1,495,985**	**$ 2,113,470**	**$ 2,113,470**	**$ 2,113,470**	**59%**	**59%**	**59%**

Table F.7
Capital Cost for Shared Pipeline from Baytown

Pipe Segment	Capital Cost
Pipe 1	$ 975,227
Pipe 2	$ 441,552
Pipe 3	$ 49,734
Pipe 4	$ 27,266
Pipe 5	$ 782,898
Pipe A	$ 18,097
Pipe B	$ 10,399
Total	**2,305,173**

Table F.8
Pipeline Capital Cost Allocation by Method A
Shared Pipeline Assessment for City of Baytown

PWS	PWS #	Flow Weighted Percent Use	Allocated Capital Cost
Olsen Estates	0360065	36%	$ 835,580
Grays Trailer Court	0360005	5%	$ 104,383
Cotton Bayou	0360004	13%	$ 306,979
Hackberry Creek Subd	0360100	30%	$ 696,231
Carriage Trail Subd	0360093	16%	$ 361,999
	Totals	**100%**	**$ 2,305,173**

Table F.9
Breakdown of Pipeline Capital Cost for Each PWS under Method B
Shared Pipeline Assessment for City of Baytown

Pipeline Segment	Pipe Segment Capital Cost	Olsen Estates		Grays Trailer Court		Cotton Bayou		Hackberry Creek Subdivision		Carriage Trail Subdivision	
		Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost
Pipe 1	$ 975,227	36%	$ 353,501	5%	$ 44,160	13%	$ 129,871	30%	$ 294,548	16%	$ 153,147
Pipe 2	$ 441,552	43%	$ 189,871	5%	$ 23,719	16%	$ 69,756	36%	$ 158,206	0%	$ -
Pipe 3	$ 49,734	67%	$ 33,327	8%	$ 4,163	25%	$ 12,244	0%	$ -	0%	$ -
Pipe 4	$ 27,266	89%	$ 24,238	11%	$ 3,028	0%	$ -	0%	$ -	0%	$ -
Pipe 5	$ 782,898	100%	$ 782,898	0%	$ -	0%	$ -	0%	$ -	0%	$ -
Pipe A	$ 18,097	0%	$ -	100%	$ 18,097	0%	$ -	0%	$ -	0%	$ -
Pipe B	$ 10,399	0%	$ -	0%	$ -	100%	$ 10,399	0%	$ -	0%	$ -
Total	**$ 2,305,173**		**$ 1,383,834**		**$ 93,168**		**$ 222,270**		**$ 452,754**		**$ 153,147**

Table F.10
Pipeline Capital Cost Allocation by Method C
Shared Pipeline Assessment for City of Baytown

PWS	PWS #	Cost for Individual Pipelines	Percent of Sum of Capital Costs for Individual Pipelines	Allocated Capital Cost
Olsen Estates	0360065	$ 2,208,527	30%	$ 682,344
Grays Trailer Court	0360005	$ 1,470,648	20%	$ 454,370
Cotton Bayou	0360004	$ 1,442,112	19%	$ 445,554
Hackberry Creek Subd	0360100	$ 1,381,979	19%	$ 426,975
Carriage Creek Subdivisi	0360093	$ 957,827	13%	$ 295,929
	Totals	**$ 7,461,093**	**100%**	**$ 2,305,173**

Table F.11
Pipeline Capital Cost Summary
Shared Pipeline Assessment for City of Baytown

PWS	Individual Pipeline Capital Costs	Shared Solution Capital Cost Allocation			Shared Solution Savings			Shared Solution Percent Savings		
		Method A	Method B	Method C	Method A	Method B	Method C	Method A	Method B	Method C
Olsen Estates	$ 2,208,527	$ 835,580	$ 1,383,834	$ 682,344	$ 1,372,946	$ 824,692	$ 1,526,182	62%	37%	69%
Grays Trailer Court	$ 1,470,648	$ 104,383	$ 93,168	$ 454,370	$ 1,366,265	$ 1,377,481	$ 1,016,278	93%	94%	69%
Cotton Bayou	$ 1,442,112	$ 306,979	$ 222,270	$ 445,554	$ 1,135,133	$ 1,219,843	$ 996,559	79%	85%	69%
Hackberry Creek Subd	$ 1,381,979	$ 696,231	$ 452,754	$ 426,975	$ 685,748	$ 929,225	$ 955,004	50%	67%	69%
Carriage Trail Subdivision	$ 957,827	$ 361,999	$ 153,147	$ 295,929	$ 595,828	$ 804,680	$ 661,898	62%	84%	69%
Totals	**$ 7,461,093**	**$ 2,305,173**	**$ 2,305,173**	**$ 2,305,173**	**$ 5,155,920**	**$ 5,155,920**	**$ 5,155,920**	**69%**	**69%**	**69%**

Table F.12
Capital Cost for Shared Pipeline from Plantation On Cotton Bayou

Pipe Segment	Capital Cost
Pipe 1	$ 338,314
Pipe 2	$ 480,202
Pipe 3	$ 299,145
Pipe 4	$ 25,849
Pipe 5	$ 49,734
Pipe 6	$ 444,049
Pipe A	$ 18,097
Pipe B	$ 10,399
Total	**1,665,790**

Table F.13
Pipeline Capital Cost Allocation by Method A
Shared Pipeline Assessment for Plantation On Cotton Bayou

PWS	PWS #	Flow Weighted Percent Use	Allocated Capital Cost
Olsen Estates	0360065	36%	$ 603,816
Grays Trailer Court	0360005	5%	$ 75,431
Cotton Bayou	0360004	13%	$ 221,833
Hackberry Creek Subd	0360100	30%	$ 503,118
Carriage Trail Subd	0360093	16%	$ 261,592
	Totals	**100%**	**$ 1,665,790**

Table F.14
Breakdown of cost for Each PWS under Method B
Shared Pipeline Assessment for Plantation On Cotton Bayou

Pipeline Segment	Pipe Segment Capital Cost	Olsen Estates		Grays Trailer Court		Cotton Bayou		Hackberry Creek Subdivision		Carriage Creek Subdivision	
		Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost	Cost Allocation Based on Water Use	Allocated Cost
Pipe 1	$ 338,314	36%	$ 122,632	5%	$ 15,320	13%	$ 45,053	30%	$ 102,181	16%	$ 53,128
Pipe 2	$ 480,202	100%	$ 480,202	0%	$ -	0%	$ -	0%	$ -	0%	$ -
Pipe 3	$ 299,145	0%	$ -	7%	$ 21,248	21%	$ 62,488	47%	$ 141,722	25%	$ 73,687
Pipe 4	$ 25,849	0%	$ -	0%	$ -	22%	$ 5,812	51%	$ 13,182	27%	$ 6,854
Pipe 5	$ 49,734	0%	$ -	0%	$ -	0%	$ -	66%	$ 32,721	34%	$ 17,013
Pipe 6	$ 444,049	0%	$ -	0%	$ -	0%	$ -	0%	$ -	100%	$ 444,049
Pipe A	$ 18,097	0%	$ -	100%	$ 18,097	0%	$ -	0%	$ -	0%	$ -
Pipe B	$ 10,399	0%	$ -	0%	$ -	100%	$ 10,399	0%	$ -	0%	$ -
Total Cost	**$ 1,665,790**		**$ 602,834**		**$ 54,664**		**$ 123,753**		**$ 289,807**		**$ 594,732**

Table F.15
Pipeline Capital Cost Allocation by Method C
Shared Pipeline Assessment for Plantation On Cotton Bayou

PWS	PWS #	Cost for Individual Pipelines	Percent of Sum of Capital Costs for Individual Pipelines	Allocated Capital Cost
Olsen Estates	0360065	$ 818,516	20%	$ 339,069
Grays Trailer Court	0360005	$ 654,492	16%	$ 271,122
Cotton Bayou	0360004	$ 675,129	17%	$ 279,671
Hackberry Creek Subd	0360100	$ 714,504	18%	$ 295,982
Carriage Trail Subdivisior	0360093	$ 1,158,593	29%	$ 479,945
	Totals	**$ 4,021,234**	**100%**	**$ 1,665,790**

Table F.16
Pipeline Capital Cost Summary
Shared Pipeline Assessment for Plantation On Cotton Bayou

PWS	Individual Pipeline Capital Costs	Shared Solution Capital Cost Allocation			Shared Solution Savings			Shared Solution Percent Savings		
		Method A	Method B	Method C	Method A	Method B	Method C	Method A	Method B	Method C
Olsen Estates	$ 818,516	$ 603,816	$ 602,834	$ 339,069	$ 214,699	$ 215,682	$ 479,447	26%	26%	59%
Grays Trailer Court	$ 654,492	$ 75,431	$ 54,664	$ 271,122	$ 579,062	$ 599,828	$ 383,370	88%	92%	59%
Cotton Bayou	$ 675,129	$ 221,833	$ 123,753	$ 279,671	$ 453,297	$ 551,377	$ 395,458	67%	82%	59%
Hackberry Creek Subdiv	$ 714,504	$ 503,118	$ 289,807	$ 295,982	$ 211,386	$ 424,697	$ 418,522	30%	59%	59%
Carriage Creek Subdivisic	$ 1,158,593	$ 261,592	$ 594,732	$ 479,945	$ 897,001	$ 563,861	$ 678,648	77%	49%	59%
Totals	**$ 4,021,234**	**$ 1,665,790**	**$ 1,665,790**	**$ 1,665,790**	**$ 2,355,445**	**$ 2,355,445**	**$ 2,355,445**	**59%**	**59%**	**59%**

Table F.17

	Area wide solution
Alternative Name	***Purchase Water from Tower Terrace to Carriage***
Alternative Number	***Pipe 1***

Distance from Alternative to PWS (along pipe)	0.4	miles
Total PWS annual water usage	23.543	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	2,203	LF	$ 27.00	$ 59,481
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	0	EA	$ 370.00	$ 163
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	0	EA	$ 750.00	$ 330
Metal detectable tape	2,203	LF	$ 0.15	$ 330
Subtotal				**$ 60,305**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 114,510**
Contingency	20%	$ 22,902
Design & Constr Management	25%	$ 28,627
TOTAL CAPITAL COSTS		**$ 166,039**

Table F.18

	Area wide solution
Alternative Name	***Purchase Water from Carriage to Hackberry***
Alternative Number	***Pipe 2***

Distance from Alternative to PWS (along pipe)	2.0	miles
Total PWS annual water usage	19.856	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
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	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	10,549	LF	$ 27.00	$ 284,823
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	2	EA	$ 370.00	$ 781
Air valve	2	EA	$ 1,000.00	$ 2,000
Flush valve	2	EA	$ 750.00	$ 1,582
Metal detectable tape	10,549	LF	$ 0.15	$ 1,582
Subtotal				**$ 304,518**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 304,518**
Contingency	20%	$ 60,904
Design & Constr Management	25%	$ 76,130
TOTAL CAPITAL COSTS		**$ 441,552**

Table F.19

	Area wide solution
Alternative Name	***Purchase Water from Hackberry to T2 (Cotton)***
Alternative Number	***Pipe 3***

Distance from Alternative to PWS (along pipe)	0.2	miles
Total PWS annual water usage	12.739	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	1,253	LF	$ 27.00	$ 33,831
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	0	EA	$ 370.00	$ 93
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	0	EA	$ 750.00	$ 188
Metal detectable tape	1,253	LF	$ 0.15	$ 188
Subtotal				**$ 34,300**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 34,300**
Contingency	20%	$ 6,860
Design & Constr Management	25%	$ 8,575
TOTAL CAPITAL COSTS		**$ 49,734**

Table F.20

	Area wide solution
Alternative Name	***Purchase Water from T2(Cotton) to T1(Grays)***
Alternative Number	***Pipe 4***

Distance from Alternative to PWS (along pipe)	0.1	miles
Total PWS annual water usage	9.600	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	0	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	623	LF	$ 27.00	$ 16,821
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	0	EA	$ 370.00	$ 46
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	0	EA	$ 750.00	$ 93
Metal detectable tape	623	LF	$ 0.15	$ 93
Subtotal				**$ 18,804**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 18,804**
Contingency	20%	$ 3,761
Design & Constr Management	25%	$ 4,701
TOTAL CAPITAL COSTS		**$ 27,266**

Table F.21

	Area wide solution
Alternative Name	***Purchase Water from T1(Grays) to Olsen***
Alternative Number	***Pipe 5***

Distance from Alternative to PWS (along pipe)	3.3	miles
Total PWS annual water usage	8.541	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	5	n/a	n/a	n/a
Number of Crossings, open cut	4	n/a	n/a	n/a
PVC water line, Class 200, 04"	17,167	LF	$ 27.00	$ 463,509
Bore and encasement, 10"	1,000	LF	$ 60.00	$ 60,000
Open cut and encasement, 10"	200	LF	$ 35.00	$ 7,000
Gate valve and box, 04"	3	EA	$ 370.00	$ 1,270
Air valve	3	EA	$ 1,000.00	$ 3,000
Flush valve	3	EA	$ 750.00	$ 2,575
Metal detectable tape	17,167	LF	$ 0.15	$ 2,575
Subtotal				**$ 539,929**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 539,929**
Contingency	20%	$ 107,986
Design & Constr Management	25%	$ 134,982
TOTAL CAPITAL COSTS		**$ 782,898**

Table F.22

Alternative Name	***Purchase Water from Tecon to Carriage***
Alternative Number	***Carriage***

Distance from Alternative to PWS (along pipe)	0.4	miles
Total PWS annual water usage	3.687	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	2,203	LF	$ 27.00	$ 59,481
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	0	EA	$ 370.00	$ 163
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	0	EA	$ 750.00	$ 330
Metal detectable tape	2,203	LF	$ 0.15	$ 330
Subtotal				**$ 60,305**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 114,510**
Contingency	20%	$ 22,902
Design & Constr Management	25%	$ 28,627
TOTAL CAPITAL COSTS		**$ 166,039**

Table F.23

Alternative Name	***Purchase Water from Tecon to Hackberry***
Alternative Number	***Hackberry***

Distance from Alternative to PWS (along pipe)	2.4	miles
Total PWS annual water usage	7.118	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	12,752	LF	$ 27.00	$ 344,304
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	3	EA	$ 370.00	$ 944
Air valve	2	EA	$ 1,000.00	$ 2,000
Flush valve	3	EA	$ 750.00	$ 1,913
Metal detectable tape	12,752	LF	$ 0.15	$ 1,913
Subtotal				**$ 364,823**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 419,028**
Contingency	20%	$ 83,806
Design & Constr Management	25%	$ 104,757
TOTAL CAPITAL COSTS		**$ 607,591**

Table F.24

Alternative Name	***Purchase Water from Tecon to Cotton***
Alternative Number	***Cotton***

Distance from Alternative to PWS (along pipe)	2.7	miles
Total PWS annual water usage	3.139	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	14,267	LF	$ 27.00	$ 385,209
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	3	EA	$ 370.00	$ 1,056
Air valve	3	EA	$ 1,000.00	$ 3,000
Flush valve	3	EA	$ 750.00	$ 2,140
Metal detectable tape	14,267	LF	$ 0.15	$ 2,140
Subtotal				**$ 407,295**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 461,500**
Contingency	20%	$ 92,300
Design & Constr Management	25%	$ 115,375
TOTAL CAPITAL COSTS		**$ 669,175**

Table F.25

Alternative Name	***Purchase Water from Tecon to Grays***
Alternative Number	***Grays***

Distance from Alternative to PWS (along pipe)	2.8	miles
Total PWS annual water usage	1.059	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	2	n/a	n/a	n/a
PVC water line, Class 200, 04"	14,922	LF	$ 27.00	$ 402,894
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	100	LF	$ 35.00	$ 3,500
Gate valve and box, 04"	3	EA	$ 370.00	$ 1,104
Air valve	3	EA	$ 1,000.00	$ 3,000
Flush valve	3	EA	$ 750.00	$ 2,238
Metal detectable tape	14,922	LF	$ 0.15	$ 2,238
Subtotal				**$ 426,975**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 481,180**
Contingency	20%	$ 96,236
Design & Constr Management	25%	$ 120,295
TOTAL CAPITAL COSTS		**$ 697,711**

Table F.26

Alternative Name	***Purchase Water from Tecon to Olsen***
Alternative Number	***Olsen***

Distance from Alternative to PWS (along pipe)	6.0	miles
Total PWS annual water usage	8.541	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	6	n/a	n/a	n/a
Number of Crossings, open cut	6	n/a	n/a	n/a
PVC water line, Class 200, 04"	31,795	LF	$ 27.00	$ 858,465
Bore and encasement, 10"	1,200	LF	$ 60.00	$ 72,000
Open cut and encasement, 10"	300	LF	$ 35.00	$ 10,500
Gate valve and box, 04"	6	EA	$ 370.00	$ 2,353
Air valve	6	EA	$ 1,000.00	$ 6,000
Flush valve	6	EA	$ 750.00	$ 4,769
Metal detectable tape	31,795	LF	$ 0.15	$ 4,769
Subtotal				**$ 958,856**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 1,013,061**
Contingency	20%	$ 202,612
Design & Constr Management	25%	$ 253,265
TOTAL CAPITAL COSTS		**$ 1,468,939**

Table F.27

	Area wide solution
Alternative Name	***Purchase Water from Baytown to Carriage***
Alternative Number	***Pipe 1***

Distance from Alternative to PWS (along pipe)	4.0	miles
Total PWS annual water usage	23.543	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	2	n/a	n/a	n/a
Number of Crossings, open cut	5	n/a	n/a	n/a
PVC water line, Class 200, 04"	21,247	LF	$ 27.00	$ 573,669
Bore and encasement, 10"	400	LF	$ 60.00	$ 24,000
Open cut and encasement, 10"	250	LF	$ 35.00	$ 8,750
Gate valve and box, 04"	4	EA	$ 370.00	$ 1,572
Air valve	4	EA	$ 1,000.00	$ 4,000
Flush valve	4	EA	$ 750.00	$ 3,187
Metal detectable tape	21,247	LF	$ 0.15	$ 3,187
Subtotal				**$ 618,365**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 672,570**
Contingency	20%	$ 134,514
Design & Constr Management	25%	$ 168,143
TOTAL CAPITAL COSTS		**$ 975,227**

Table F.28

	Area wide solution
Alternative Name	***Purchase Water from Carriage to Hackberry***
Alternative Number	***Pipe 2***

Distance from Alternative to PWS (along pipe)	2.0	miles
Total PWS annual water usage	19.856	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
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	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	10,549	LF	$ 27.00	$ 284,823
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	2	EA	$ 370.00	$ 781
Air valve	2	EA	$ 1,000.00	$ 2,000
Flush valve	2	EA	$ 750.00	$ 1,582
Metal detectable tape	10,549	LF	$ 0.15	$ 1,582
Subtotal				**$ 304,518**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 304,518**
Contingency	20%	$ 60,904
Design & Constr Management	25%	$ 76,130
TOTAL CAPITAL COSTS		**$ 441,552**

Table F.29

	Area wide solution
Alternative Name	***Purchase Water from Hackberry to T2 (Cotton)***
Alternative Number	***Pipe 3***

Distance from Alternative to PWS (along pipe)	0.2	miles
Total PWS annual water usage	12.739	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	0	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	-	n/a	n/a	n/a
PVC water line, Class 200, 04"	1,253	LF	$ 27.00	$ 33,831
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	-	LF	$ 35.00	$ -
Gate valve and box, 04"	0	EA	$ 370.00	$ 93
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	0	EA	$ 750.00	$ 188
Metal detectable tape	1,253	LF	$ 0.15	$ 188
Subtotal				**$ 34,300**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 34,300**
Contingency	20%	$ 6,860
Design & Constr Management	25%	$ 8,575
TOTAL CAPITAL COSTS		**$ 49,734**

Table F.30

	Area wide solution
Alternative Name	***Purchase Water from T2(Cotton) to T1(Grays)***
Alternative Number	***Pipe 4***

Distance from Alternative to PWS (along pipe)	0.1	miles
Total PWS annual water usage	9.600	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 04"	623	LF	$ 27.00	$ 16,821
Bore and encasement, 10"	-	LF	$ 60.00	$ -
Open cut and encasement, 10"	50	LF	$ 35.00	$ 1,750
Gate valve and box, 04"	0	EA	$ 370.00	$ 46
Air valve	-	EA	$ 1,000.00	$ -
Flush valve	0	EA	$ 750.00	$ 93
Metal detectable tape	623	LF	$ 0.15	$ 93
Subtotal				**$ 18,804**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 18,804**
Contingency	20%	$ 3,761
Design & Constr Management	25%	$ 4,701
TOTAL CAPITAL COSTS		**$ 27,266**

Table F.31

	Area wide solution
Alternative Name	***Purchase Water from T1(Grays) to Olsen***
Alternative Number	***Pipe 5***

Distance from Alternative to PWS (along pipe)	3.3	miles
Total PWS annual water usage	8.541	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	5	n/a	n/a	n/a
Number of Crossings, open cut	4	n/a	n/a	n/a
PVC water line, Class 200, 04"	17,167	LF	$ 27.00	$ 463,509
Bore and encasement, 10"	1,000	LF	$ 60.00	$ 60,000
Open cut and encasement, 10"	200	LF	$ 35.00	$ 7,000
Gate valve and box, 04"	3	EA	$ 370.00	$ 1,270
Air valve	3	EA	$ 1,000.00	$ 3,000
Flush valve	3	EA	$ 750.00	$ 2,575
Metal detectable tape	17,167	LF	$ 0.15	$ 2,575
Subtotal				**$ 539,929**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 04"	-	EA	$ 4,000	$ -
Gate valve, 04"	-	EA	$ 405	$ -
Check valve, 04"	-	EA	$ 595	$ -
Electrical/Instrumentation	-	EA	$ 10,000	$ -
Site work	-	EA	$ 2,000	$ -
Building pad	-	EA	$ 4,000	$ -
Pump Building	-	EA	$ 10,000	$ -
Fence	-	EA	$ 5,870	$ -
Tools	-	EA	$ 1,000	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**

Subtotal of Component Costs		**$ 539,929**
Contingency	20%	$ 107,986
Design & Constr Management	25%	$ 134,982
TOTAL CAPITAL COSTS		**$ 782,898**

Table F.32

Alternative Name	***Purchase Water from Baytown to Carriage***
Alternative Number	***Carriage***

Distance from Alternative to PWS (along pipe)	4.0	miles
Total PWS annual water usage	3.687	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	5	n/a	n/a	n/a
PVC water line, Class 200, 04"	21,247	LF	$ 27.00	$ 573,669
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	250	LF	$ 35.00	$ 8,750
Gate valve and box, 04"	4	EA	$ 370.00	$ 1,572
Air valve	4	EA	$ 1,000.00	$ 4,000
Flush valve	4	EA	$ 750.00	$ 3,187
Metal detectable tape	21,247	LF	$ 0.15	$ 3,187
Subtotal				**$ 606,365**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 660,570**
Contingency	20%	$ 132,114
Design & Constr Management	25%	$ 165,143
TOTAL CAPITAL COSTS		**$ 957,827**

Table F.33

Alternative Name	***Purchase Water from Baytown to Hackberry***
Alternative Number	***Hackberry***

Distance from Alternative to PWS (along pipe)	6.0	miles
Total PWS annual water usage	7.118	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	6	n/a	n/a	n/a
PVC water line, Class 200, 04"	31,796	LF	$ 27.00	$ 858,492
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	300	LF	$ 35.00	$ 10,500
Gate valve and box, 04"	6	EA	$ 370.00	$ 2,353
Air valve	6	EA	$ 1,000.00	$ 6,000
Flush valve	6	EA	$ 750.00	$ 4,769
Metal detectable tape	31,796	LF	$ 0.15	$ 4,769
Subtotal				**$ 898,884**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 953,089**
Contingency	20%	$ 190,618
Design & Constr Management	25%	$ 238,272
TOTAL CAPITAL COSTS		**$ 1,381,979**

Table F.34

Alternative Name	***Purchase Water from Baytown to Cotton***
Alternative Number	***Cotton***

Distance from Alternative to PWS (along pipe)	6.3	miles
Total PWS annual water usage	3.139	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	6	n/a	n/a	n/a
PVC water line, Class 200, 04"	33,311	LF	$ 27.00	$ 899,397
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	300	LF	$ 35.00	$ 10,500
Gate valve and box, 04"	7	EA	$ 370.00	$ 2,465
Air valve	6	EA	$ 1,000.00	$ 6,000
Flush valve	7	EA	$ 750.00	$ 4,997
Metal detectable tape	33,311	LF	$ 0.15	$ 4,997
Subtotal				**$ 940,355**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 994,560**
Contingency	20%	$ 198,912
Design & Constr Management	25%	$ 248,640
TOTAL CAPITAL COSTS		**$ 1,442,112**

Table F.35

Alternative Name	***Purchase Water from Baytown to Grays***	
Alternative Number	***Grays***	

Distance from Alternative to PWS (along pipe)	6.4	miles
Total PWS annual water usage	1.059	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	7	n/a	n/a	n/a
PVC water line, Class 200, 04"	33,966	LF	$ 27.00	$ 917,082
Bore and encasement, 10"	200	LF	$ 60.00	$ 12,000
Open cut and encasement, 10"	350	LF	$ 35.00	$ 12,250
Gate valve and box, 04"	7	EA	$ 370.00	$ 2,513
Air valve	6	EA	$ 1,000.00	$ 6,000
Flush valve	7	EA	$ 750.00	$ 5,095
Metal detectable tape	33,966	LF	$ 0.15	$ 5,095
Subtotal				**$ 960,035**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 1,014,240**
Contingency	20%	$ 202,848
Design & Constr Management	25%	$ 253,560
TOTAL CAPITAL COSTS		**$ 1,470,648**

Table F.36

Alternative Name	***Purchase Water from Baytown to Olsen***
Alternative Number	***Olsen***

Distance from Alternative to PWS (along pipe)	9.6	miles
Total PWS annual water usage	8.541	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	4	n/a	n/a	n/a
Number of Crossings, open cut	11	n/a	n/a	n/a
PVC water line, Class 200, 04"	50,839	LF	$ 27.00	$ 1,372,653
Bore and encasement, 10"	800	LF	$ 60.00	$ 48,000
Open cut and encasement, 10"	550	LF	$ 35.00	$ 19,250
Gate valve and box, 04"	10	EA	$ 370.00	$ 3,762
Air valve	10	EA	$ 1,000.00	$ 10,000
Flush valve	10	EA	$ 750.00	$ 7,626
Metal detectable tape	50,839	LF	$ 0.15	$ 7,626
Subtotal				**$ 1,468,917**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 405	$ 1,620
Check valve, 04"	2	EA	$ 595	$ 1,190
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 54,205**

Subtotal of Component Costs		**$ 1,523,122**
Contingency	20%	$ 304,624
Design & Constr Management	25%	$ 380,780
TOTAL CAPITAL COSTS		**$ 2,208,527**