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

BIROME WSC
PWS ID# 1090017, CCN# 10013

Prepared for:

THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Prepared by:

THE UNIVERSITY OF TEXAS BUREAU OF ECONOMIC GEOLOGY

AND

PARSONS

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

AUGUST 2006

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AUGUST 2006

EXECUTIVE SUMMARY

INTRODUCTION

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

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

This feasibility report provides an evaluation of water supply alternatives for the Birome Water Supply Corporation (WSC) PWS. The Birome WSC supplies water to a population of 1,356 people and is located east of Waco, Texas (the Birome PWS). The Birome PWS recorded arsenic concentrations of 9.1 micrograms per liter (μg/L) to 15.3 μg/L since 1997. These results were above the 10 μg/L MCL for arsenic that went into effect on January 23, 2006 (USEPA 2005a; TCEQ 2004a). Therefore, it is likely the Birome PWS faces potential compliance issues under the new standard.

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

Table ES.1
Birome PWS
Basic System Information

Population served	1,356
Connections	463
Average daily flow rate	0.15 million gallons per day (mgd)
Water system peak capacity	0.76 mgd
Typical arsenic range	9.1 – 15.3 μg/L

STUDY METHODS

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

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

1. Gather data from the TCEQ and Texas Water Development Board databases, from TCEQ files, and from information maintained by the PWS;
2. Conduct financial, managerial, and technical (FMT) evaluations of the PWS;
3. Perform a geologic and hydrogeologic assessment of the study area;
4. Develop treatment and non-treatment compliance alternatives which, in general, consist of the following possible options:
    - Connecting to neighboring PWSs via new pipeline or by pumping water from a newly installed well or an available surface water supply within the jurisdiction of the neighboring PWS;
    - Installing new wells within the vicinity of the PWS into other aquifers with confirmed water quality standards meeting the MCLs;
    - Installing a new intake system within the vicinity of the PWS to obtain water from a surface water supply with confirmed water quality standards meeting the MCLs;
    - Treating the existing non-compliant water supply by various methods depending on the type of contaminant; and
    - Delivering potable water by way of a bottled water program or a treated water dispenser as an interim measure only.
5. Assess each of the potential alternatives with respect to economic and non-economic criteria;
6. Prepare a feasibility report and present the results to the PWS.

This basic approach is summarized in Figure ES-1.

HYDROGEOLOGICAL ANALYSIS

The Birome PWS obtains groundwater from the Twin Mountain formation of the Trinity aquifer. Arsenic is commonly found in area wells at concentrations greater than the MCL. 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. Since Birome 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.

COMPLIANCE ALTERNATIVES

The Birome PWS is governed by a nine-member board of directors. The Birome PWS has a very good level of 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 knowledgeable and dedicated staff and board of directors, successful annual membership meetings, spare part inventory, customer relations, water loss control, and regional cooperation. Areas of concern for the system included lack of an emergency plan, and lack of written operational procedures.

There are several PWSs within 15 miles of Birome PWS. Many of these nearby systems also have problems with arsenic, but there are several with good quality water. In general, feasible alternatives were developed based on obtaining water from the nearest PWSs, either by directly purchasing water, or by expanding the existing well field. There is a minimum of surface water available in the area, and obtaining a new surface water source is considered through an alternative where treated surface water is obtained from the City of Waco.

Developing a new well near the Birome PWS is likely to be an attractive solution if compliant groundwater can be found. Having a new well near the Birome PWS is likely to be one of the lower cost alternatives since the PWS already possesses the technical and managerial expertise needed to implement this option. The cost of new well alternatives quickly increases with pipeline length, making proximity of the alternate source a key concern. A new compliant well or obtaining water from a neighboring compliant PWS has the advantage of providing compliant water to all taps in the system.

A number of centralized treatment alternatives for arsenic removal have been developed and were considered for this report, including reverse osmosis, electrodialysis reversal, 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.

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

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

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

FINANCIAL ANALYSIS

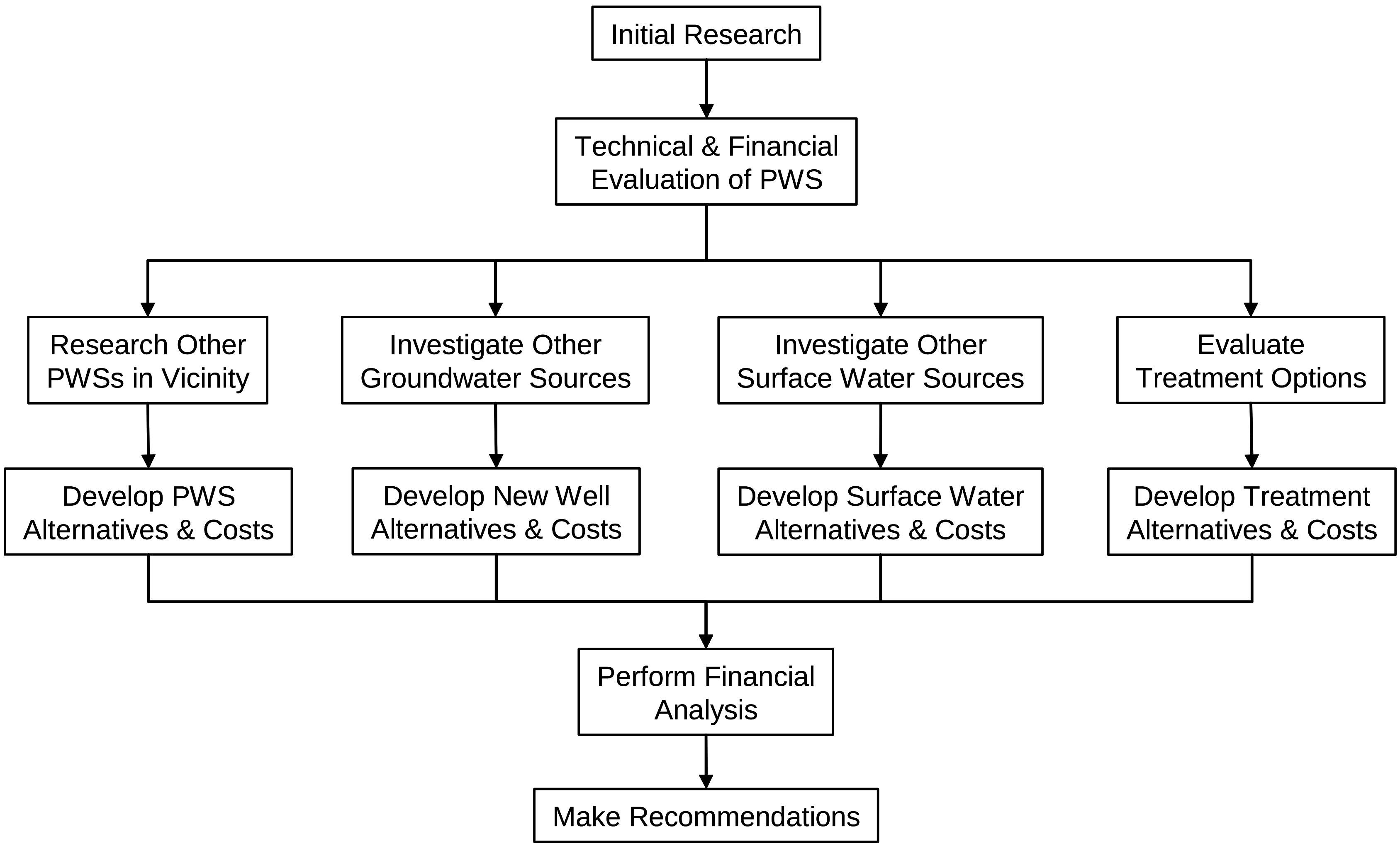
Financial analysis of the Birome PWS indicated that current water rates are funding operations, and a rate increase would not be necessary to meet operating expenses. The current average water bill of $482 represents approximately 1.5 percent of the median household income (MHI). Table ES.2 provides 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	1.5
Purchase water from Post Oak WSC	100% Grant	$619	1.9
	Loan/Bond	$837	2.6
New well at Penelope	100% Grant	$541	1.7
	Loan/Bond	$976	3.0
Central treatment - adsorption	100% Grant	$618	1.9
	Loan/Bond	$753	2.3
Point-of-use	100% Grant	$1,153	3.6
	Loan/Bond	$1,203	3.7

Figure ES-1
Summary of Project Methods



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ACRONYMS AND ABBREVIATIONS

µg/L	microgram per liter
AA	activated alumina
AFY	acre-feet per year
APU	arsenic package unit
BEG	Bureau of Economic Geology
BR	Birome PWS
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
CO	Correspondence
EDR	Electrodialysis reversal
EP	entry point
ETJ	extraterritorial jurisdiction
FHLM	Fall, Hill, Limestone and McLennan regional water planning group
FMT	Financial, managerial, and technical
ft^2	square foot
GAM	Groundwater Availability Model
gpm	gallons per minute
IX	Ion exchange
MCL	Maximum contaminant level
MF	microfiltration
mg/L	milligrams per Liter
mgd	Million gallons per day
MHI	median household income
MOR	Monthly operating report
NMEFC	New Mexico Environmental Financial Center
O&M	Operation and Maintenance
ºF	degrees Fahrenheit
Parsons	Parsons Infrastructure and Technology Group Inc.
POE	Point-of-entry
POU	Point-of-use
ppb	parts per billion
PSOC	potential sources of contamination
PWS	public water system
RO	reverse osmosis
RWHA	R.W. Harden & Associates, Inc.
SDWA	Safe Drinking Water Act
SF	Sanderson Farms

TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TSS	Total suspended solids
TWDB	Texas Water Development Board
USEPA	United States Environmental Protection Agency
WAM	Water Availability Model
WSC	water supply corporation

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SECTION 1
INTRODUCTION

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

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

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

This feasibility report provides an evaluation of water supply compliance options for the Birome Water Supply Corporation (WSC) PWS, ID# 1090017, Certificate of Convenience and Necessity (CCN) #10013, located in Hill County, Texas (hereinafter the Birome PWS). Recent sample results from the Birome 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 Birome 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. It should be noted that the Birome PWS is not a member of a ground water control district, but instead is a member of the Falls, Hill, Limestone and McLennan Regional Water Planning Group (FHLM). This group was formed to allow for small PWSs east of Waco and within Falls, Hill, Limestone, and McLennan Counties to address ground water compliance issues and share technologies for running each PWS more efficiently. The Birome PWS lies within the TWDB's Regional Water Planning Group G (one of 16 regional areas) and is also within

Groundwater Management Area 8 of the Texas Water Development Board (TWDB), which is one of 16 regional areas designated across Texas in 2005 via Texas House Bill 1763.

1.1 PUBLIC HEALTH AND COMPLIANCE WITH MCLS

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

In general, contaminant(s) in drinking water above the MCL(s) can have long-term or lifetime (chronic) effects. Potential health effects from long-term ingestion of water with levels of arsenic above the MCL (0.01 µg/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 method (*i.e.*, decision tree approach) for analyzing options for provision of compliant drinking water. This project is performed using the decision tree approach developed in the pilot study.

Other tasks of the feasibility study are as follows:

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

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

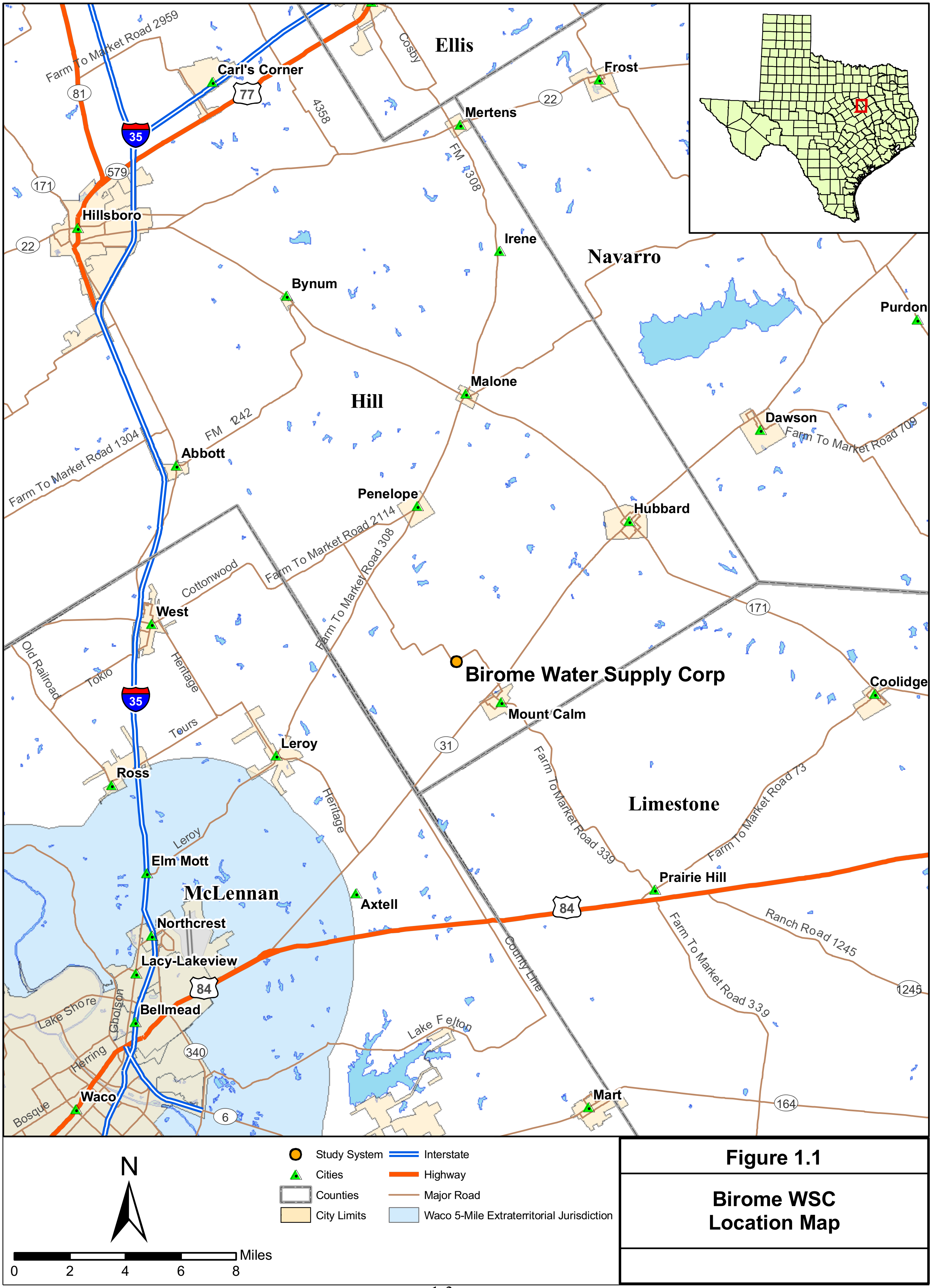

Figure 1.1

Birome WSC Location Map

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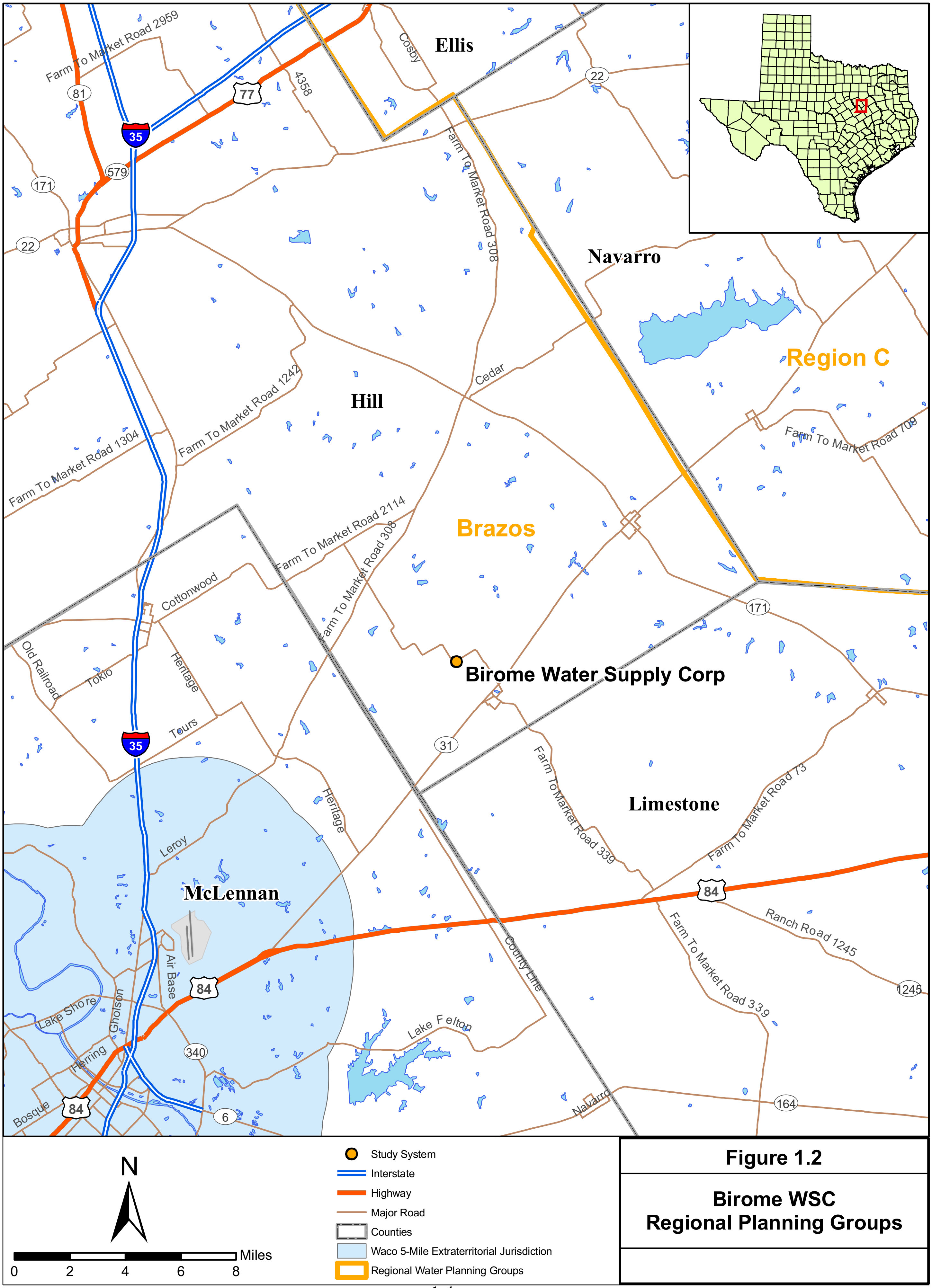


Figure 1.2

Birome WSC Regional Planning Groups

1.3 REGULATORY PERSPECTIVE

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

- Monitoring public drinking water quality;
- Processing enforcement referrals for MCL violators;
- Tracking and analyzing compliance options for MCL violators;
- Providing FMT assessment and assistance to PWSs;
- 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 Birome PWS involve arsenic. The following subsections explore alternatives considered as potential options for obtaining/providing compliant drinking water.

1.4.1 Existing Public Water Supply Systems

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

1.4.1.1 Quantity

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

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

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

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

1.4.1.2 Quality

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

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

1.4.2 Potential for New Groundwater Sources

1.4.2.1 Existing Non-Public Supply Wells

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

- Use existing data sources (see below) to identify wells in the areas that have satisfactory quality. For the Birome PWS, the following standards could be used in a rough screening to identify compliant groundwater in surrounding systems:
  - Arsenic concentrations less than 0.008 milligrams per liter (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 TWDB hard-copy database provides helpful information. Wells eliminated from consideration generally include domestic and stock wells, dug wells, test holes, observation wells, seeps and springs, destroyed wells, wells used by other communities, *etc*.
- Identify wells of sufficient size which have been used for industrial or irrigation purposes. Often the TWDB database will include well yields, which may indicate the likelihood that a particular well is a satisfactory source.
- At this point in the process, the local groundwater control district (if one exists) should be contacted to obtain information about pumping restrictions. Also, preliminary cost estimates should be made to establish the feasibility of pursuing further well development options.
- If particular wells appear to be acceptable, the owner(s) should be contacted to ascertain their willingness to work with the PWS. Once the owner agrees to participate in the program, questions should be asked about the wells. Many owners have more than one well, and would probably be the best source of information regarding the latest test dates, who tested the water, flowrates, and other well characteristics.
- After collecting as much information as possible from cooperative owners, the PWS would then narrow the selection of wells and sample and analyze them for quality. Wells with good quality would then be potential candidates for test pumping. In some cases, a particular well may need to be refurbished before test pumping. Information obtained from test pumping would then be used in combination with information about the general characteristics of the aquifer to determine whether a well at this location would be suitable as a supply source.
- It is recommended that new wells be installed instead of using existing wells to ensure the well characteristics are known and the well meets construction standards.

- Permit(s) would then be obtained from the groundwater control district or other regulatory authority, and an agreement with the owner (purchase or lease, access easements, *etc*.) would then be negotiated.

1.4.2.2 Develop New Wells

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

1.4.3 Potential for Surface Water Sources

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

1.4.3.1 Existing Surface Water Sources

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

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

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

1.4.3.2 New Surface Water Sources

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

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

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

1.4.4 Identification of Treatment Technologies

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 <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 Description of Treatment Technologies

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 system 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

Process – In solution, salts separate into positively-charged cations and negatively charged anions. Ion exchange is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in 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.

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

Maintenance – 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.

Waste Disposal – 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; and
- Suitable for small and large installations.

Disadvantages (IX)

- Requires salt storage; regular regeneration;
- Concentrate disposal; and
- 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 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 total dissolved solids (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;
- Concentrate disposal; and
- High silica concentration limits water recovery rate.

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/Electrodialysis Reversal

Pro 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 required approved disposal methods. Pretreatment processes and spent materials also required approved disposal methods.

Advantages (EDR)

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

Disadvantages (EDR)

- Not suitable for high levels of iron, manganese, and hydrogen sulfide; and
- 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 have demonstrated that iron-based adsorption media typically have higher arsenic removal capacities compared to alumina-based media. In the USEPA-sponsored 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 U.S. 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 percent 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 to 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 can 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 the system be operated in a series configuration to minimize the chance for arsenic breakthrough to impact drinking water quality.

All of the 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 operation 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; and
- 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 and is 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; and
- Need to dispose of regular backwash wastewater.

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 (O&M) attention is required from the utilities. Because of potential interference by competing ions bench-scale or pilot scaling testing may be required to ensure 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 adsorption or reverse osmosis treatment units that are installed “under the sink” in the case of point-of-use, and where water enters a house or building in the case of point-of-entry. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets to meet regulatory requirements, making purchase and installation more expensive. Point-of-entry and point-of-use treatment units would be purchased and owned by the PWS. These solutions are decentralized in nature, and require utility personnel entry into houses or at least onto private property for installation, maintenance, and testing. Due to the large number of treatment units that would be employed and would be 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, relevant to arsenic are:

- POU and POE treatment units must be owned, controlled, and maintained by the water system, although the utility may hire a contractor to ensure proper O&M and MCL compliance. The water system must retain unit ownership and oversight of unit installation, maintenance and sampling; the utility ultimately is the responsible party for regulatory compliance. The water system staff need not perform all installation, maintenance, or management functions, as these tasks may be contracted to a third party-but the final responsibility for the quality and quantity of the water supplied to the community resides with the water system, and the utility must monitor all contractors closely. Responsibility for O&M of POU or POE devices installed for SDWA compliance may not be delegated to homeowners.

- POU and POE units must have mechanical warning systems to automatically notify customers of operational problems. Each POU or POE treatment device must be equipped with a warning device (*e.g.*, alarm, light) that would alert users when their unit is no longer adequately treating their water. As an alternative, units may be equipped with an automatic shut-off mechanism to meet this requirement.
- If the American National Standards Institute has issued product standards for a specific type of POU or POE treatment unit, only those units that have been independently certified according to those standards may be used as part of a compliance strategy.

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

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

1.4.7 Water Delivery or Central Drinking Water Dispensers

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

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

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

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

The ideal system would:

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

SECTION 2
EVALUATION METHOD

2.1 DECISION TREE

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

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

2.2 DATA SOURCES AND DATA COLLECTION

2.2.1 Data Search

2.2.1.1 Water Supply Systems

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

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

Figure 2.1
TREE 1 – EXISTING FACILITY ANALYSIS

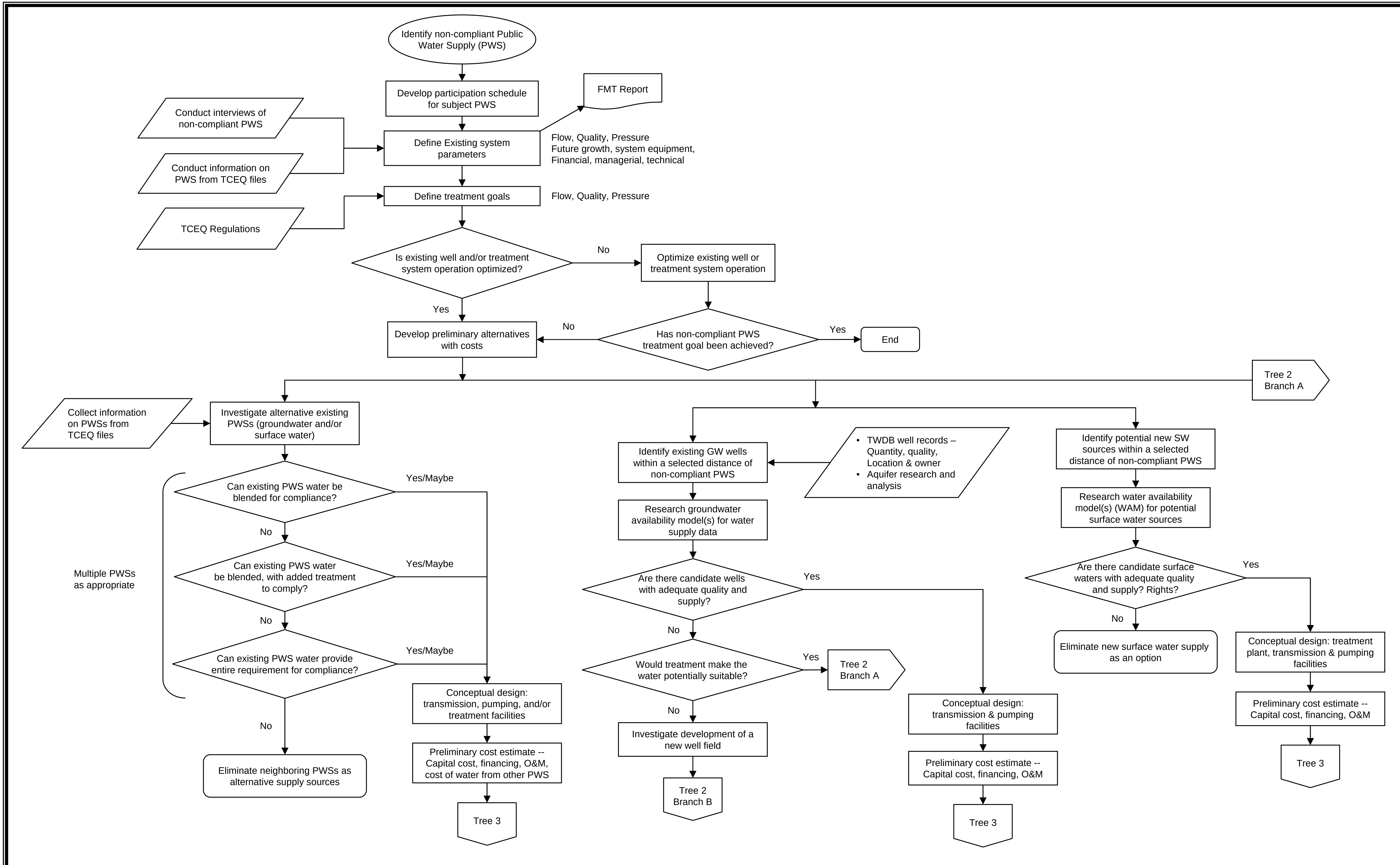
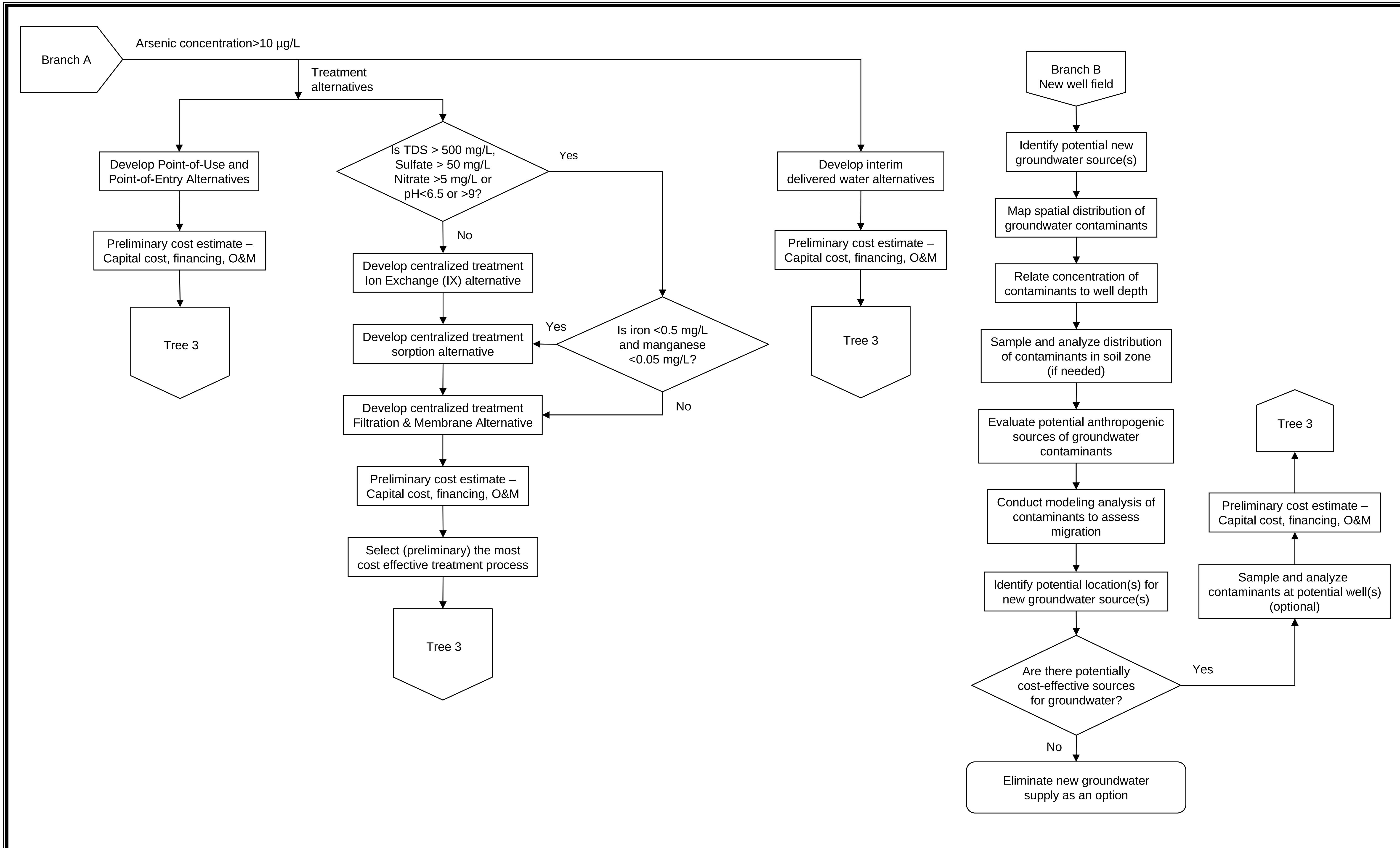


Figure 2.2
TREE 2 – DEVELOP TREATMENT ALTERNATIVES



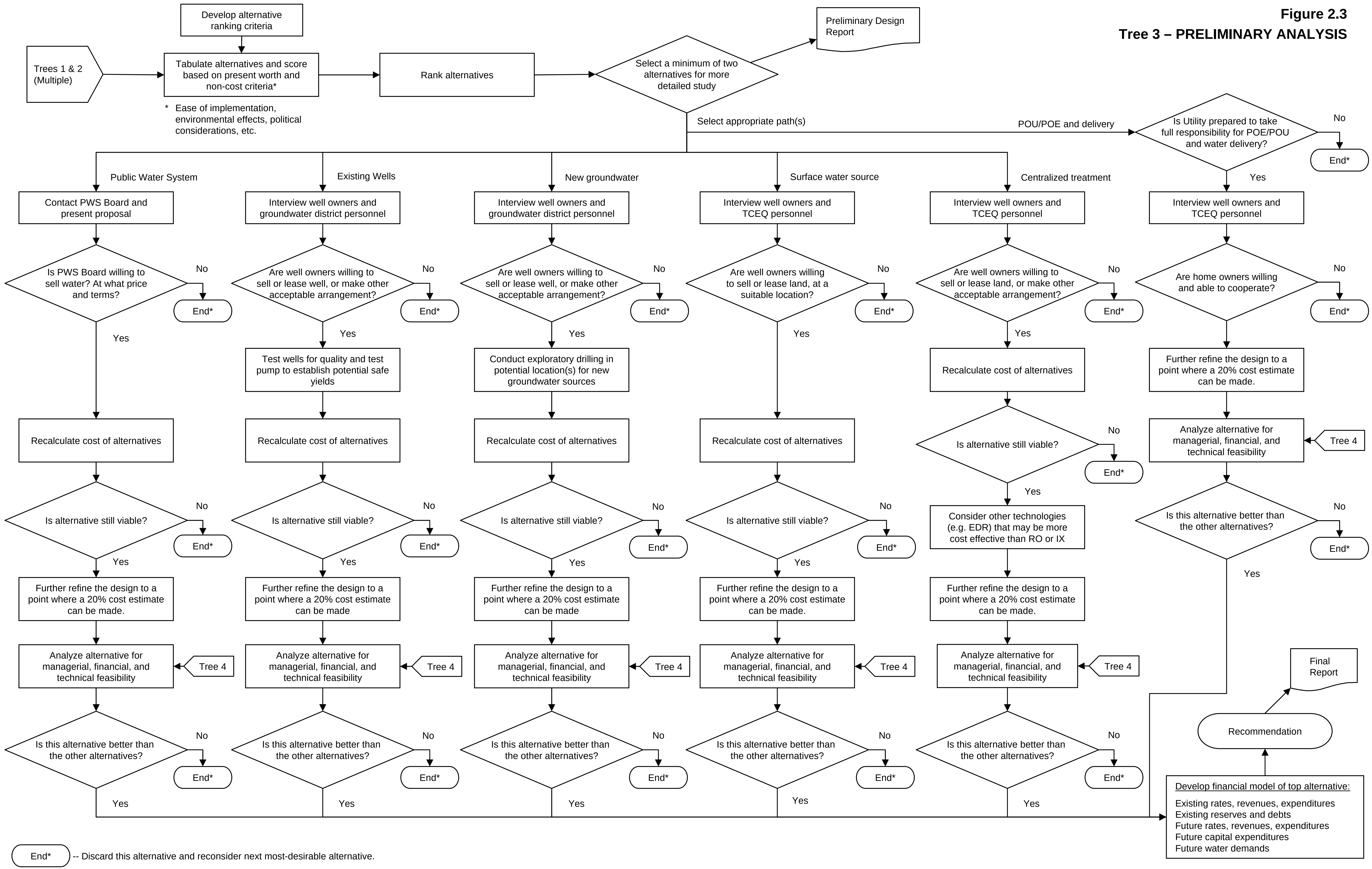
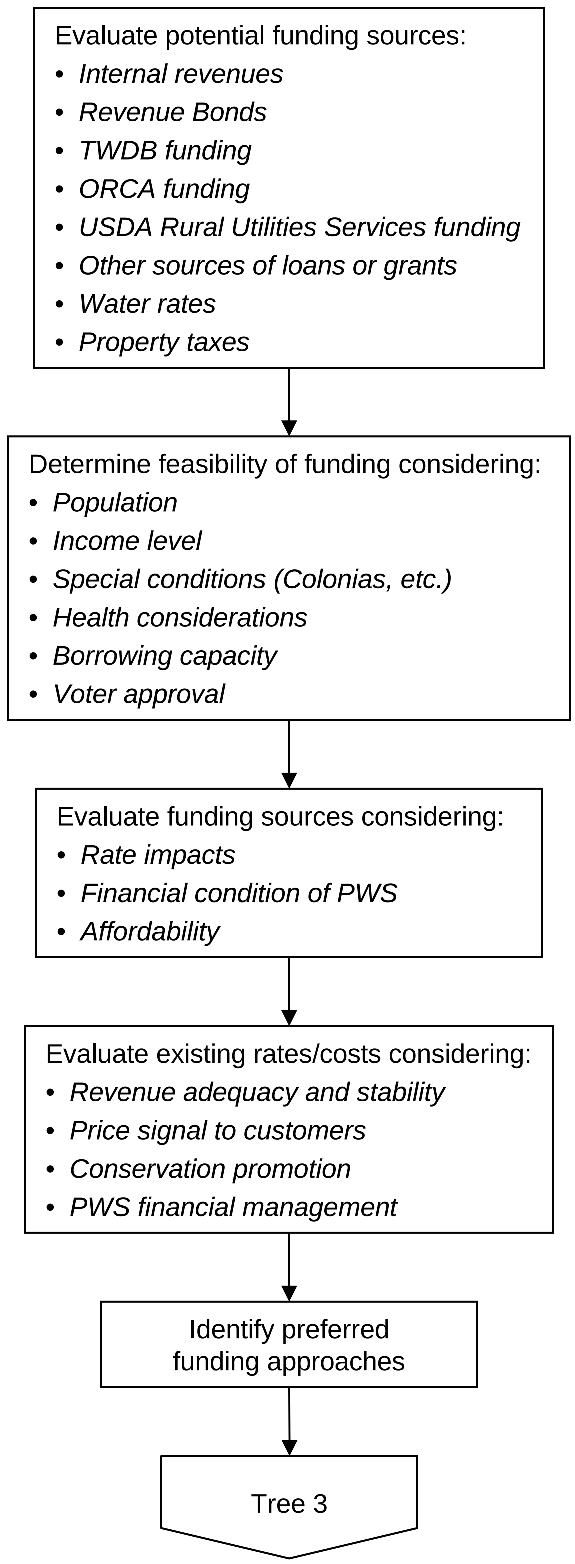


Figure 2.3
Tree 3 – PRELIMINARY ANALYSIS

Figure 2.4
TREE 4 – FINANCIAL



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

These files were reviewed for the PWS and surrounding systems.

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

- Texas Commission on Environmental Quality www.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 Trinity/Woodbine aquifer was investigated as a potential tool for identifying available and suitable groundwater resources.

2.2.1.5 Water Availability Model

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

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

2.2.1.6 Financial Data

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

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

2.2.1.7 Demographic Data

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

2.2.2 PWS Interviews

2.2.2.1 PWS Capacity Assessment Process

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

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

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

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

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

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

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

Assessment of the FMT capacity of the PWS was based on an approach developed by the New Mexico Environmental Finance Center (NMEFC), which is consistent with the 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 PWSs

The neighboring PWSs were identified, and the extents of their systems were investigated. PWSs farther than 15 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 (>500 mg/L) and sulfate (116 mg/L) in the well water, IX is not economically feasible. RO and EDR can also reduce TDS which is higher than the USEPA secondary MCL of 500 mg/L. Adsorption and coagulation/filtration processes remove arsenic only without significantly affect 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-economical factors were also identified. Ease of implementation was considered, as well as the reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant 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 Census is used as the basis for MHI. In addition to consideration of affordability, 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 has MHIs broken down geographically by block group and by ZIP code. The MHIs can very 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 by ZIP code based on the 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 the average annual residential water bill represents.
- The first year in which a water rate increase would be required
- The total increase in water rates required, compared to current rates

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

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

2.4.5.2 General Assumptions Embodied in Financial Plan Results

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

- No account growth (either positive or negative).
- No change in estimate of uncollectible revenues over time.
- Average consumption per account unchanged over time.
- No change in unaccounted for water as percentage of total (more efficient water use would lower total water requirements and costs).

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

2.4.5.3 Interpretation of Financial Plan Results

Results from the financial plan model for each alternative are presented in Table 4.4 in Section 4 of this report. The model used six funding alternatives: paying cash up front (all revenue); 100 percent grant; 75 percent grant; 50 percent grant, State Revolving Fund (SRF); and obtaining a Loan/Bond. Table 4.4 shows the projected average annual water bill, the maximum percent of household income, and the percentage rate increase over current rates.

2.4.5.4 Potential Funding Sources

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

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

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

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

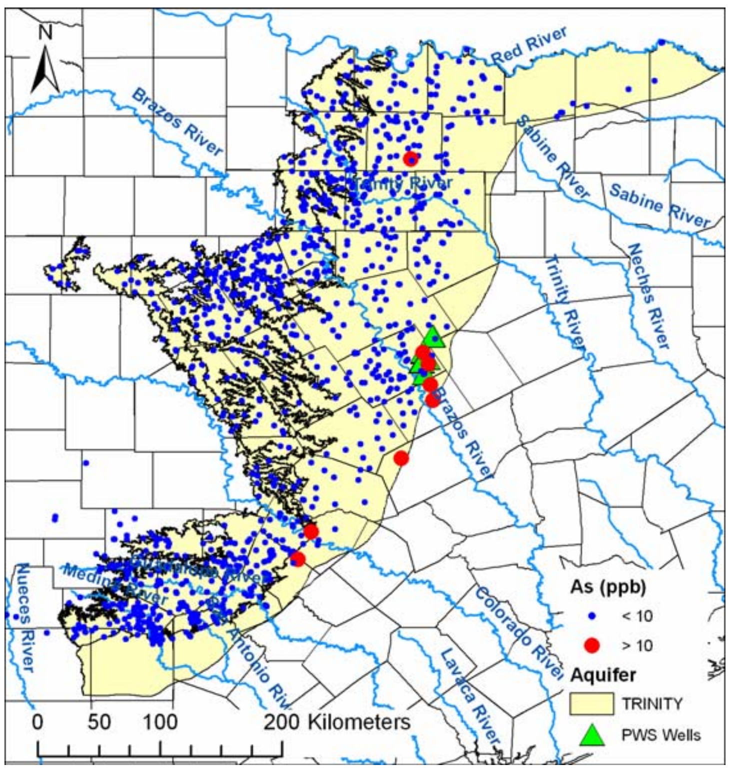
- United States Department of Agriculture, Rural Utilities Service, and
- United States Housing and Urban Development.

SECTION 3
UNDERSTANDING SOURCES OF CONTAMINANTS

3.1 ARSENIC IN THE TRINITY AQUIFER

Aquifers of Cretaceous age in North-Central Texas consist of the main three sandy units of the Trinity Group, to which can be added the Woodbine aquifer. They are the Hosston Sand, the Hensell Sand, and the Paluxy formation. The former two are often grouped, with other units, into the Travis Peak/Twin Mountains formation. The PWS wells of concern are located in Limestone County and are completed in the Twin Mountain formation (Aquifer code 218TWMT). In general, arsenic concentrations in the Trinity aquifer are low and most samples are below the arsenic MCL of 10 parts per billion (ppb) (Figure 3.1). Arsenic concentrations >10 ppb are found in the eastern part of the aquifer in McLennan and Falls Counties.

Figure 3.1 Detectable Arsenic Concentrations in the Trinity Aquifer



Data in Figure 3.1 are from the TWDB groundwater database. The most recent sample is shown for each well (1,094 wells in the analysis).

3.2 REGIONAL GEOLOGY

Subsurface deposits of Hill and McLennan counties are mostly of Cretaceous age (Klemt, *et al.* 1975; Baker, *et al.* 1990; R.W. Harden & Associates, Inc (RWHA) 2004 and overly a Paleozoic basement located at a depth of about 800 feet in northern Hill County to more than 3,000 feet in eastern McLennan County marking the complex transition to the deeper East

Texas Basin and its thick sediment accumulation. The sediments were deposited on a mostly flat stable platform and transitions between different depositional facies and rock types (sand, shale, carbonate) are generally laterally smooth. Sandy units suggest proximity to the continent where the sediments were deposited while shaley units suggest a greater distance from the continent. The development of important carbonate accumulations imply periodic limited clastic input. The terminology is somewhat variable and confusing and that used by RWHA (2004) has been retained. The base of the Cretaceous sediments consists of a basal conglomerate grading into sandy material (Hosston Sand) overlain by mostly calcareous rock. This marks the beginning of a more shaley and calcareous series of sediments until the deposition of another continuous sand unit (Hensell Sand). Hosston Sand and Hensell Sand, as well as the intermediate sediments, have been traditionally called the Travis Peak formation in central Texas, and the Twin Mountains formation in northern Texas. The latter term is also applied when transitions between subunits are not obvious (RWHA 2004, p. 2-17). Drillers typically call the Hosston Sand “Lower Trinity Sand” or “Second Sand” (RWHA 2004, p. 4-3). The Travis Peak / Twin Mountains formation is overlain by the thick accumulation of the Glen Rose formation, itself overlain by the Paluxy Sand. All previously described sediments make up the Trinity Group. Westward, outside McLennan and Hill Counties, the Trinity Group is much thinner and overall sandier and is called the Antlers Sand (Klemt, *et al*. 1975; Baker, *et al*. 1990, p. 13). The Woodbine Sand is separated from the top of the Trinity Group (Paluxy formation) by mostly calcareous accumulations of the Fredericksburg and Wachita Groups (including the Edwards Limestone and the Del Rio Clay) that top the Lower Cretaceous. The Woodbine Sand is the first unit of the Upper Cretaceous. The Austin Chalk and other Cretaceous formations of the Taylor Group overlie the Woodbine Sand. The Nacatoch Sand of the Navarro Group form the last sandy unit of Cretaceous age. It crops out a few miles east of McLennan and Hill Counties. They are followed by the Gulf Coast succession of Tertiary age, starting with the shaley Midway Group. The general strike of the Cretaceous sediments is north and gently dipping toward the Gulf of Mexico. On a geological map, this results in a succession of strips representing younger and younger formations eastward. In both McLennan and Hill Counties, the outcropping formations run from the Edwards Limestone on the western edges of the counties to the base of the Navarro Group on the eastern edges. Both counties are intersected by north-trending faults that impact the distribution of groundwater quality.

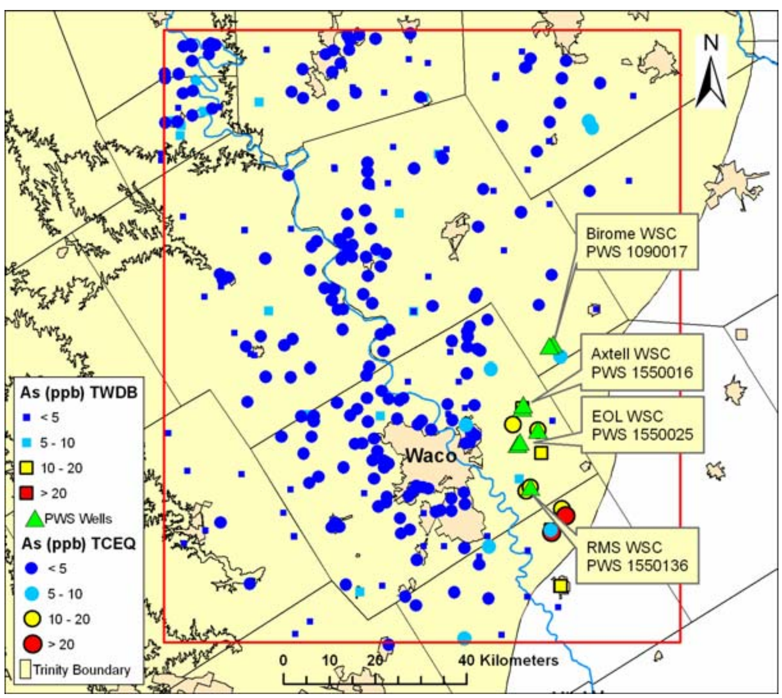
Major water-bearing formations are those of the Travis Peak / Twin Mountain formations and, to a lesser degree, the Paluxy formation (all from the Trinity Group) grouped under the umbrella of the Trinity aquifer (RWHA 2004) and the Woodbine formation (Woodbine Group) (Baker, *et al*. 1990). The Trinity aquifer is recognized as a major aquifer by the State of Texas while the Brazos Alluvium (primarily McLennan County) and the Woodbine aquifer (primarily Hill County) are considered minor aquifers (Ashworth and Hopkins 1995). This translates into confined Trinity aquifer units because the formations crop out farther west and in a Woodbine aquifer with an unconfined section in the outcrop area and a confined section further downdip. Thickness of the Hosston Sand ranges from 100 feet in western Hill County to more than 700 feet at the extreme eastern corner of McLennan County. The average thickness in the study area can be estimated at 250 feet (RWHA 2004, Figure 4.15). Depth to the base of the unit varies from ~1,000 to 3,500 feet. Thickness of the Hensell Sand ranges from 50 to 100 feet while those of the Paluxy formation range from 0 to 100 feet. The Paluxy formation does not currently extend south of McLennan County. The depth to the base of the Paluxy formation varies from 500 to 2,500 feet (RWHA 2004, Figure 4.8). The Woodbine formation is approximately 150 feet thick in Hill County. In the study area, the net sand thickness of the Hosston Sand, Hensell Sand, Paluxy (mainly in Hill County) and Woodbine formations (Hill County only) is high and near the unit total thickness (RWHA 2004, Figures 2.18 to 2.22).

Travis Peak units can yield large amounts of water of good quality across most of the study area. Water quality of the Paluxy formation quickly decreases downdip. Woodbine water has a TDS <1,000 mg/L only in the western half of Hill County (RWHA 2004, Figure 4.16). The regional cone of depression centered on McLennan County and the Waco Area impacts primarily the Hosston Sand, but also the Hensell Sand.

3.3 GENERAL TRENDS IN ARSENIC CONCENTRATIONS

The geochemistry of arsenic is described in Appendix E. A regional analysis of arsenic trends in the eastern part of the Trinity aquifer was conducted to assess spatial trends, as well as correlations with other water quality parameters. Arsenic samples from the TWDB database and the TCEQ public water supply database were used to assess arsenic trends in the central-eastern part of the Trinity aquifer, including Hill and McLennan counties. Arsenic concentrations in the area are generally below the 10 ppb MCL, and only in the eastern part of the aquifer are arsenic concentrations >10 ppb (Figure 3.2).

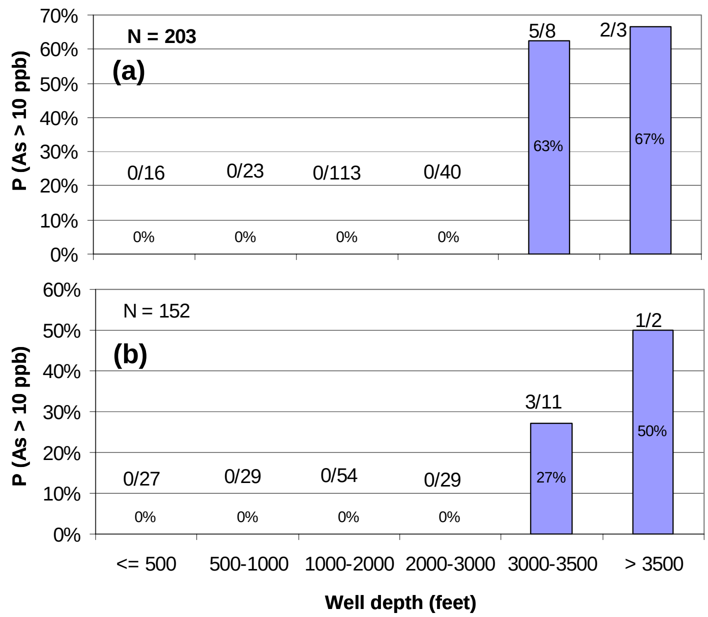
Figure 3.2 Spatial Distribution of Arsenic Concentrations in the Central-Eastern Area of the Trinity Aquifer



The most recent sample is shown for each well. Two types of samples were used in the analysis: raw samples from a single well, and entry point (EP) samples that can be related to a specific well. Data were limited to a bounding area (coordinates: lower left corner -97.8E, 31.2N; upper right corner -96.6E, 32.4N) within the central-eastern area of the Trinity aquifer. A total of 331 samples are shown in Figure 3.2 (203 from the TCEQ database and 153 from the TWDB database). Samples with values less than the detection limit are shown only if the detection limit is 10 ppb or less (total of 24 samples from the TWDB database were less than the detection limit of 10 ppb, and these are shown in the map as between 5-10 ppb).

Relationships between arsenic and well depth (Figure 3.3) show that only wells deeper than 3,000 feet have arsenic concentrations >10 ppb.

Figure 3.3 Relationship Between Arsenic Concentrations and Well Depth Based on (a) Data from the TCEQ Database, and (b) Data from the TWDB Database



The most recent arsenic sample for each well was used in the analysis. N represents the number of samples and the bars represent percentages of arsenic samples >10 ppb for different depth ranges. Numbers on top of the bars give the number of samples >10 ppb and the total number of wells in that depth range.

Relationships between arsenic and other water quality parameters were evaluated using data from the TWDB database. Due to the limited number of arsenic concentrations >10 ppb it is difficult to find trends in the data, and correlations between arsenic concentrations and other parameters are weak (r^2 values <0.1).

3.4 DETAILED ASSESSMENT FOR THE BIROME PWS

There are two wells in the Birome PWS: G1090017A and G1090017B. The wells are within the Twin Mountain formation with screen depths from 3,064 to 3,250 feet (Table 3.1). Arsenic concentrations measured at the PWS are mostly above the 10 ppb MCL (Table 3.2).

Both wells are related to the same entry point (EP1) in the PWS system; therefore, it is not possible to determine if only one well is the source of arsenic to the system. Two raw samples from April 2005 show arsenic concentrations >10 ppb, which indicates that probably both wells have arsenic above the MCL (this is not definitive as the raw samples in the TCEQ database do not indicate which well was sampled).

Table 3.1 Well Depth and Screen Interval Depths for Wells in the Birome PWS

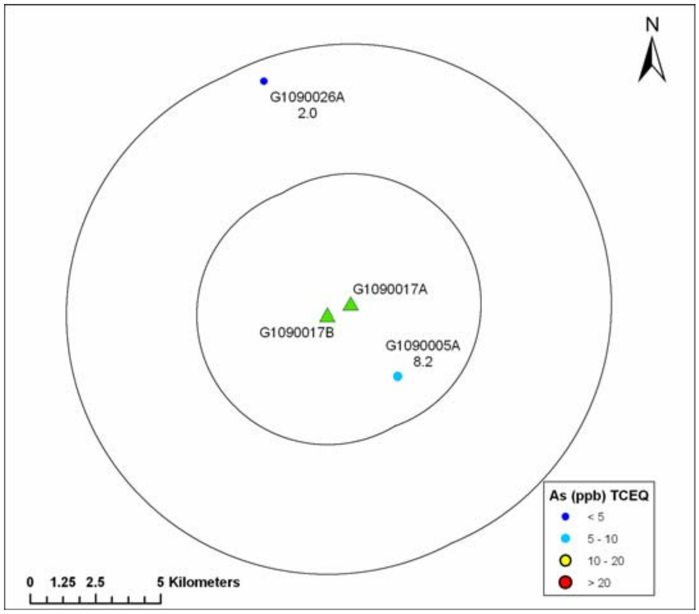
Water source	Depth	Screen depth	Aquifer
G1090017A	3244	3064-3244	Twin Mountain
G1090017B	3311	3100-3120, 3133-3148, 3180-3250	Twin Mountain - Travis Peak

Table 3.2 Arsenic Concentrations in the Birome PWS

Date	As (ppb)	Source
4/30/1997	12	EP 1
10/24/2000	9.09	EP1
2/18/2003	10.5	EP1
1/31/2005	11.6	EP1
4/12/2005	9.7	EP1
4/21/2005	15.3	Raw
4/21/2005	11	Raw

Only two public water supply wells have arsenic analyses in the 5- and 10-km buffers around the Birome PWS wells, and these show arsenic concentrations <10 ppb (Figure 3.4). Well G1090005A is about 3 km southeast of the Birome PWS wells, and well G1090026A is about 9 km northwest of the Birome PWS wells.

Figure 3.4 Arsenic Concentrations in 5- and 10-km Buffers of Birome PWS Wells



Arsenic concentrations shown in Figure 3.4 are from the TCEQ database, and represent the most recent sample in each well. The two wells, G1090026A and G1090005A, are categorized as in the Twin Mountain – Travis Peak formation and have depths of 3,438 and 3,458 feet, respectively. Well G1090026A has a screen interval at depths of 2,909 to 3,057 feet, about 150-200 feet shallower than the Birome PWS wells (that have screen intervals from 3,064 to 3,250 feet). The wells are indicated in the TWDB database as being in the Hosston Member, which is the deeper member in the Travis Peak – Twin Mountain formation.

Potential Sources of Contamination (PSOC) are identified as part of TCEQ's Source Water Assessment Program. The nearest arsenic PSOC identified is about 3 km southeast of the Birome PWS wells; therefore, PSOC sites are not expected to influence arsenic concentrations at the Birome PWS.

3.4.1 Summary of Alternative Groundwater Sources for the Birome PWS

The lack of arsenic data in the vicinity of the PWS wells makes it difficult to suggest alternative sources, though there is some evidence that arsenic concentrations are higher in the deeper wells. Therefore, arsenic concentrations in the PWS wells may be reduced by closing off deeper zones of the wells and opening shallower sections of the wells. Alternative sources with lower arsenic concentrations may exist to the northeast in the direction of well G1090026A, although this is inconclusive and would require further evaluation.

SECTION 4
ANALYSIS OF THE BIROME PWS

4.1 DESCRIPTION OF EXISTING SYSTEM

4.1.1. Existing System

The location of the Birome PWS is shown in Figure 4.1. The population of 1,356 residences is serviced through 496 connections. The water source is from two ground water wells, G1090017A set into the Travis Peak formation to a depth of 3,244 feet and G1090017B set into the Hosston formation to 3,311 feet. Total capacity from the two wells is 0.76 million gallons per day (mgd) and average daily consumption is 0.15 mgd. There are two-55,000-gallon storage tanks and one 10,000-gallon pressure tank. The distribution system consists of approximately 165 to 170 miles of pipe.

After the water is pumped to the surface, the water is pumped through a cooling tower to reduce the water temperature from approximately 135°F. Disinfection with chlorine gas is performed at each wellhead before water is pumped into an adjacent storage tank and then into the distribution system.

Arsenic has been detected between 9.1 µg/L to 15.3 µg/L since 1997, which exceeds the MCL of 10 µg/L. The Birome PWS has not encountered any other water quality issues. Typical TDS concentrations are in the range of 789 to 849 mg/L.

Basic system information is as follows:

- Population served: 1,356
- Connections: 463
- Average daily flow: 0.15 mgd
- Total production capacity: 0.76 mgd
- Typical total arsenic range: 9.1 µg/L to 15.3 µg/L
- Typical TDS range: 789 to 849 mg/L
- Typical pH range: 8.1 to 8.6 s.u.
- Typical calcium range: 3.85 to 4 mg/L
- Typical magnesium range: 0.81 to 1.0 mg/L
- Typical sodium range: 316 to 336 mg/L
- Typical chloride range: 101 to 112 mg/L
- Single bicarbonate (HCO_3) result: 559 mg/L
- Typical fluoride range: 2.1 to 2.5 mg/L
- Typical iron range: 0.01 to 0.24 mg/L

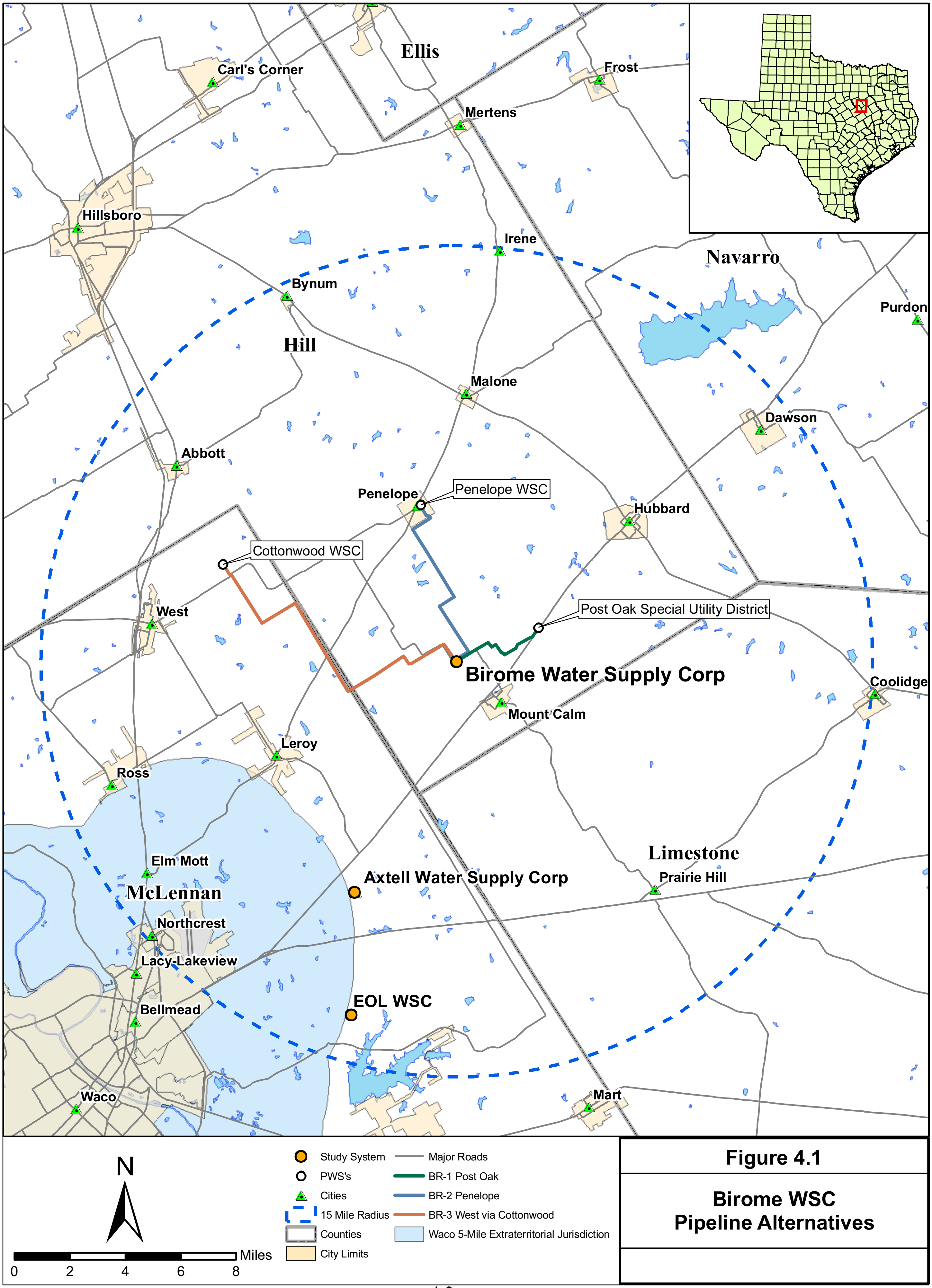


Figure 4.1

Birome WSC Pipeline Alternatives

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4.1.2 Capacity Assessment for the Birome PWS

The project team conducted a capacity assessment of the Birome PWS and this evaluation is 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 technical, managerial, and financial 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.

- Charles Beseda - Manager, Operator
- Milton Stuckley - Board President
- Joyce Childre - Board of Directors
- Mary Klaus - Bookkeeper
- Gene Hawthorne - Secretary, Treasurer

All interviews were conducted in person.

4.1.2.1 General Structure

The Birome PWS serves a population of 1,356 with 463 connections. The system is governed by a nine-member board of directors. The staff consists of the manager/certified operator, bookkeeper, and meter reader. All positions are salaried. A contractor is hired for major repairs. The system consists of two wells, two storage tanks, and two pressure tanks. The distribution system is quite large and the meter reader covers about 283 miles in his job.

4.1.2.2 General Assessment of Capacity

Based on the team's assessment, this system has a very good level of capacity. There are several positive managerial, financial and technical aspects of the water system, but there are also some areas that need improvement. The deficiencies noted could prevent the water system from being able to meet compliance now or in the future and may also impact the water system's long-term sustainability.

4.1.2.3 Positive Aspects of Capacity

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

- **Knowledgeable and Dedicated Staff and Board of Directors – The** system general manager/operator has been there for 30 years and is on call 24 hours a day. He indicated that while his position is part-time, he often works many more hours. He is involved in several water organizations, including Texas Rural Water Association. The meter reader has been with the system for ten years and the bookkeeper for 16 years. The board of directors is very knowledgeable about the system and water issues.
- **Successful Annual Membership Meetings** – The system gets excellent attendance at their annual meeting by providing door prizes. The prizes consist of either $25 or $10 off the next monthly bill and other prizes donated by suppliers. This meeting allows the system to share information with its members and gets a large number of members to vote on issues.
- **Inventory** – The systems keeps approximately $17,000 worth of spare parts inventory. This enables the system to make repairs in a timely manner.
- **Customer Relations** – The system tries to notify customers prior to shutting down the system for repairs. Recently, the bookkeeper contacted 80 customers by phone to notify them of a water outage. Also, if a customer is concerned about the accuracy of his water meter, the system will send the meter to a facility to have it checked. If the meter is within tolerance, the customer must pay the $75 cost for the meter check as well as the water bill. If the meter is not within tolerance, the system will pay for the meter test and will adjust the customer's bill. This program greatly reduces customer complaints regarding meter readings.
- **Water Loss Control** - To locate leaks in the system, they offer $35 off the water bill for any customer who reports a legitimate leak. By providing an incentive, this program has decreased the system's water loss.
- **Regional Cooperation** –The system participates in the FHLM Regional Water Planning Group. There are about 16 entities represented in the group, which was organized to plan for additional water sources for 5 – 15 years in the future. The group has expanded its mission to include other issues. The manager/operator of the Birome PWS is on the board of this group.

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.

- **Water Losses –** The system does not have a program to measure or manage water system losses. The staff estimated a water loss as high as 50 percent during the previous year, mostly as a result of construction activities. A reduction in this loss would significantly reduce the amount of water that must be pumped and/or treated, depending on the compliance alternative implemented. Birome PWS does not have a company program or policy to address water losses at a system level.
- **Lack of Written Long-Term Capital Improvements Plan –** While there appears to be some process in place to plan for future improvements, there is no formal process or 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. It can also negatively impact the ability of the system to meet the arsenic standard or other future SDWA regulations.

4.1.2.5 Potential Capacity Concerns

The following items were concerns regarding capacity but no particular operational, managerial, or financial problems can be attributed to these items at this time. The system should focus on addressing the deficiencies noted above in the capacity deficiency section, but should address the items listed below to further improve technical, managerial, and financial capabilities.

- **Emergency Plan -** The system does not have a written emergency plan, nor does it have emergency equipment such as generators. 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.
- **Written Operational Procedures –** According to the manager, there are only a few written operations procedures. The operator is very experienced and knowledgeable. However, if additional operators are hired, the lack of written operating procedures may cause problems.

4.2 ALTERNATIVE WATER SOURCE DEVELOPMENT

4.2.1 Identification of Alternative Existing Public Water Supply Sources

Using data drawn from the TCEQ drinking water and TWDB groundwater well databases, the PWSs surrounding the Birome PWS were reviewed with regard to their reported drinking water quality and production capacity. PWSs that appeared to have water supplies with water quality issues were ruled out from evaluation as alternative sources, while those without identified water quality issues were investigated further. Owing to the large number of small (<1 mgd) water systems in the vicinity, small systems were only considered if they were established residential systems within 15 miles of the Birome PWS. 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 selected PWSs within approximately 15 miles of the Birome PWS. This distance was selected as the radius for the evaluation owing to the relatively small number of PWSs in the proximity of the Birome PWS and because 15 miles was considered to be the upper limit of economic feasibility for constructing a new water line.

Table 4.1 Selected Public Water Systems within 15 Miles of the Birome PWS

PWS ID	PWS Name	Distance from Birome PWS	Comments/Other Issues
1090005	City of Mount Calm	2.0 miles	Small (>1 mgd) system with WQ issues: As (moderate).
1090030	Post Oak WSC	3.9 miles	Small system with no WQ issues. Available capacity. Located near Hubbard. ***Evaluate further.***
1090026	Penelope WSC	5.7 miles	Small system with WQ issues: As (moderate). Consider installing a well to a shallower depth. ***Evaluate further.***
1550027	Leroy Tours Gerald Water Supply	8.3 miles	Small system with WQ issues: As
1550022	Cottonwood WSC	9.3 miles	Small system with no WQ issues. Limited available capacity; however have an emergency line that connects to City of West water supply which does have excess capacity. ***Evaluate further.***
1090004	Malone WSC	9.5 miles	Small system with no WQ issues. Opted not to contact since there were larger systems that were nearer.
1470011	Prairie Hill WSC	10.3 miles	Small system with WQ issues: As.
1550032	Hilltop WSC	10.4 miles	Small system with no WQ issues. Opted not to contact since there were larger systems that were nearer.
1550009	City of West	11.5 miles	Small system with no WQ issues. Consider as an option by connecting to the emergency line at Cottonwood. ***Evaluate further.***
1550127	Moores Water System	11.9 miles	Small system with WQ issues: As.
1090015	City of Abbott	12.3 miles	Small system with no WQ issues. Opted not to contact since there were larger systems that were nearer.
1550042	Ross Water Supply Corp	13.1 miles	Small GW system with no WQ issues. Opted not to contact since there were larger systems that were nearer.

PWS ID	PWS Name	Distance from Birome PWS	Comments/Other Issues
1550039	Pure Water Supply Corporation	13.2 miles	Small GW system with no WQ issues, however unable to contact PWS manager due to incorrect information in the TCEQ data base.
1550002	McLennan County WCID 2 Elm Mott	13.3 miles	Small GW system with no WQ issues. Opted not to contact since there were larger systems that were nearer.
1550118	Bold Springs WSC	13.7 miles	Small SW system with no WQ issues. Opted not to contact since there were larger systems that were nearer.
1550005	City of Mart	14.5 miles	Small system with WQ issues: As, however this PWS blends ground water with surface water.
1550008	City of Waco	>15 miles	Large surface water system with lots of available capacity. Note that access to City of Waco water lines is east of Bellmead along Hwy 84. Since City of West receives a portion of their water from Waco, the City of Waco could be viewed as a possible indirect supplier.

Based upon the initial screening summarized in Table 4.1 above, three alternatives were selected for further evaluation. These are summarized in Table 4.2. Note that the distances presented in the table are the distances along roadways and are used in the cost estimate to represent pipeline lengths.

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

PWS ID	PWS Name	Pop	Conn	Total Production (mgd)	Ave Daily Usage (mgd)	Dist. from Birome PWS Along Roads	Comments/Other Issues
1090030	Post Oak WSC	2106	718	0.67	0.30	3.9 miles	Available capacity.
1090026	Penelope WSC	291	96	0.13	0.02	7.5 miles	Limited capacity, however can consider installing a well.
1550009	City of West	2720	935	0.88	0.37	12.6 miles	Available capacity via the emergency supply line to Cottonwood.
1550022	Cottonwood WSC	576	192	0.23	0.06	12.6 miles	Cottonwood has limited capacity; however they have an emergency treated water supply line to the City of West which does have available capacity.

4.2.1.1 Post Oak WSC

The Post Oak Water Supply Company is located on the east side of Hubbard, about 10 miles east of Birome. One of the 3-inch water lines associated with Post Oak WSC is approximately 4 miles from the Birome PWS storage tanks. Post Oak WSC purchases treated water from Corsicana which has an intake line on Lake Navarro Mills approximately 15 miles from the Corsicana water treatment plant. Post Oak PWS had an intake on the same lake; however it was located in a shallower portion of the lake and eventually the intake pipe silted in. Post Oak WSC's intake is about 5 miles from City of Corsicana's intake. According to the manager of the Post Oak WSC, Lake Navarro Mills is a runoff-fed lake and the Army Corps of Engineers has indicated to the manager that it would be cheaper to build a new lake rather than dredge the existing lake. In the late 1980s, Post Oak PWS signed over their water rights for Lake Navarro Mills to the Corsicana PWS so the Post Oak PWS could continue receiving water for its customers. Several other PWSs also had silting issues associated with their intake pipes on Lake Navarro. These additional systems also signed over their Lake Navarro water rights to the Corsicana PWS and are now receiving water from the Corsicana PWS.

Post Oak PWS provides water via 700 miles of distribution lines to rural residential areas outside the City of Hubbard, southwest toward Mount Calm, and southeast toward the City of Coolidge. The City of Hubbard relies on two water wells. Due to the weak condition of the older pipes in the City of Hubbard's water distribution system, the higher pressures required to service the Post Oak PWS could possibly damage the water lines at the City of Hubbard. However, Post Oak PWS does serve as an emergency back-up water supply to City of Hubbard. Post Oak PWS services 718 active connections with an average consumption of 0.3 mgd. According to the system manager, they are growing at a rate of two connections per month. Through their contract with the City of Corsicana, Post Oak is allowed 240 million gallons per year or 0.67 mgd, and therefore, Post Oak WSC has a current excess of 0.37 mgd.

4.2.1.2 City of Penelope

The City of Penelope is located approximately 6 miles northeast of the Birome PWS. The PWS is supplied by a single groundwater well (G1090026A) which is completed in the Trinity Group at a depth of 3,138 feet. The City is capable of providing 0.13 mgd for 96 connections. Average consumption for the city is 0.02 mgd. According to the system manager, the town is not growing. At this time, it does not have sufficient capacity to provide water to a nearby PWS; however, based on the available water quality data, the location may be a suitable point for a new groundwater well. The arsenic levels in the water reported by the city's current well have been classified as marginal since 1997, but a well installed to a shallower depth as suggested in Subsection 3.4.1 may result in lower arsenic levels reported for the groundwater.

4.2.1.3 City of West

The City of West is located approximately 10 miles due west of the Birome PWS. A portion of its water supply is from three wells set to a depth of 2,000 feet and the other source of their water supply is through a contract with the City of Waco where they are contracted to receive 0.5 mgd. When all three wells are operating at capacity, the wells can produce

0.8 mgd. The temperature of the water from the three wells varies between 106ºF and 110ºF and the water is not cooled. On average, consumption of water via the 930 connections in West is 0.6 mgd and therefore, West may have an excess of 0.7 mgd. The City of West has connections to three nearby municipalities (Cottonwood, Hilltop, and Bold Springs) to provide water in emergency situations. Since the City of Cottonwood is located in between the City of West and Birome, approximately 5 miles west of Birome, a possible alternative for the Birome PWS to have access to treated water from the City of West, would be for the Birome PWS to connect directly to the emergency 4-inch water line at the Cottonwood PWS.

The City of Cottonwood PWS is supplied by a single groundwater well (G1550022A) which is completed in the Hosston formation at a depth of 2,365 feet. According to the system manager, it is not necessary to cool the water once it is pumped to the surface. (Note that sample results reported since 1997 have indicated no exceedances of MCLs in the groundwater and as suggested in Subsection 3.4.1, shallower well depths in this area east of Waco may be associated with lower arsenic levels in the groundwater.) The City of Cottonwood is capable of providing 0.23 mgd for 192 connections. Average consumption for the city is 0.06 mgd. According to the system manager, the town is not growing, but at this time, they do not feel it has sufficient capacity to provide water to a nearby PWS. However, the City of Cottonwood has the emergency connection to the City of West which does have excess capacity. Access to treated water from the City of West would be through a pipeline installed from the water storage tank in the Birome PWS to the emergency tie-in point at the City of Cottonwood, a distance of approximately 12 miles along roadways.

4.2.1.4 City of Waco

The City of Waco is located southeast of the Birome PWS. The City of Waco is classified as the "primary provider" for the counties included in the TWDB's Regional Water Planning Group G. In addition, Waco has the authority and obligation to provide water service within their Extraterritorial Jurisdiction (ETJ) which extends five miles beyond the city limits and is delineated in Figure 1.2. Residences within this ETJ have the choice of connecting to the City of Waco water supply or to a local water supply company.

Water is pumped from the primary source, Lake Waco, to the 24 mgd Riverside Treatment Plant via a 54-inch raw water line and the 63 mgd Mount Carmel Treatment Plant via 36-inch and 48-inch raw water lines. With their current pumping equipment, the City of Waco can provide 70 mgd of treated water. Peak demand during the summer is usually 55 mgd. In 2008, they anticipate upgrading the Mount Carmel treatment plant from a 63 mgd plant to a 90 mgd facility. They are currently implementing an $80 million water quality upgrade to address the taste and odor issues that have resulted from the algae blooms in Lake Waco. Funding for the current upgrade came from a combination of a $350,000 USEPA grant and bonds. The last upgrade was completed in 2003 and included raising the height of the dam seven feet which increased the lake capacity by 20,000 acre-feet.

In addition to the surface water supply, the City of Waco also owns three water wells which pump water from the Trinity formation at depths ranging from 2500 to 3000. One of the wells is used for irrigation of the city golf course and the other two wells which were acquired when City of Waco annexed Harris Creek Water Supply Corp, are part of City of Waco's emergency water supply.

City of Waco maintains several treated water lines that extend east beyond the City of Bellmead. The nearest tie-in location for the Birome PWS to access City of Waco treated water, would be a 16-inch treated water supply line located on the north side of Highway 84 between Aviation Parkway and Tehuacana Creek near the Dr. Pepper facility. The pipeline distance along the roadways between the City of Waco tie-in and the Birome plant would be greater than 15 miles, which makes the alternative of purchasing water directly from the City of Waco cost prohibitive.

4.2.2 Potential for New Groundwater Sources

4.2.2.1 Installing New Compliant Wells

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

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 PWS is already familiar with operation of a water well. As a result, existing nearby wells with good water quality should be investigated. Re-sampling and test pumping would be required to verify and determine the quality and quantity of water at those wells.

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

Some of the alternatives suggest new wells be drilled in areas where existing wells are compliant with the arsenic MCL of 10 µg/L. In developing the cost estimates, Parsons assumed the aquifer in these areas would produce the required amount of water with only one well. Site investigations and geological research, which are beyond the scope of this study, could indicate whether the aquifer at a particular site and depth would provide the amount of water needed or if more than one well would need to be drilled in separate areas. As suggested in Subsection 3.4.1, a well installed into a shallower groundwater bearing zone (*i.e.*, depths less than 3,000 feet) may result in lower arsenic levels reported for the groundwater.

4.2.2.2 Results of Groundwater Availability Modeling

The Birome PWS is located in the eastern edge of the Trinity aquifer downdip that extends along several counties in central and north Texas. According to TCEQ records, the basal unit of the Trinity Group, the Travis Peak formation, is the main groundwater source throughout most of Hill County where the Birome PWS is located. The Travis Peak formation has five members, of which the Hosston formation is the most often utilized in completed wells located within 20 miles of the PWS.

The Trinity aquifer water supply is expected to moderately decrease over the next 50 years. The 2002 Texas Water Plan anticipates a supply of 150,317 acre-feet by the year 2050, a 4 percent decline in supply relative to value estimated for the year 2000. A GAM for the Northern Trinity was completed in August 2004 (RWHA 2004). In general, the results of the 50-year simulations indicate the water levels will remain relatively stable in outcrop zones, while levels in downdip zones are likely to rise by several hundred feet. The increase in water level is expected in response to a planned decrease in future pumpage from the northern Trinity aquifer. A minimum difference was observed between simulations under average rainfall and under drought-of-record conditions. For the Hosston formation, the predominant groundwater source in Hill County, the simulated recovery in water levels is in the 200 to 300-foot range. The county groundwater use is projected to moderately increase from 748 acre-feet per year (AFY) in 2000 to 861 AFY in the year 2050 (RWHA 2004).]

The northern Trinity aquifer GAM was not run for the Birome PWS as 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.

An issue related to the groundwater availability modeling done in this area is a new processing facility being constructed by Sanderson Farms (SF). Sanderson Farms is currently constructing a chicken processing facility in the vicinity of Highways 84 and 340 in McLennan County. R.W. Harden, the developers of the GAM for the area, is currently contracted by SF's ground water consultant as SF installs and prepares to operate three 3,000-foot (approximate depth) wells as part of the new processing plant. Additional information confirming the anticipated pumping rates and the subsequent effect it could have on nearby PWSs was unavailable at the time this Feasibility Analysis Report was prepared; however, information and associated reports should be available through the TWDB in the future (Bene, James – R.W. Harden - pers. comm., June 2006).).

Due to the coarse discretization (cell size of 1 square mile) of the northern Trinity aquifer GAM grid, the model was not designed to estimate drawdown resulting from pumping at a single location. A more localized model grid separate from the GAM would need to be established where exact pumping well locations, pumping rates, screen intervals, and available data for the aquifer could be incorporated into a model to estimate the effect the new SF wells may have on wells associated with the Birome PWS.

4.2.3 Potential for New Surface Water Sources

There is a low potential for development of new surface water sources for the PWS system as indicated by limited water availability within the site vicinity. The Birome PWS is located in the lower Brazos Basin where current surface water availability is expected to decrease up to 17 percent over the next 50 years according to the 2002 Texas Water Plan (from approximately 1,423,071 AFY to 1,177,277 AFY during drought conditions). Approximately 10 miles east of the Birome PWS, the Brazos Basin transitions into the Trinity Basin where water availability is expected to decrease up to 11 percent over the next 50 years.

The vicinity of Birome PWS has a minimum availability of surface water for new uses. The TCEQ availability map for the Brazos Basin indicates that in the site vicinity, and within the entire Hill County, unappropriated flows for new uses are typically available up to 50 percent of the time. This supply is inadequate as the TCEQ requires 100 percent supply availability for a PWS.

4.2.4 Options for Detailed Consideration

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

1. Post Oak WSC. A pipeline would be constructed from the water treatment plant at the Post Oak WSC and treated water would be piped to the Birome PWS (Alternative BR-1).

2. City of Penelope. A new groundwater well would be completed in the vicinity of the well at the City of Penelope and a pipeline would be constructed from the City of Penelope to the Birome PWS (Alternative BR-2).

3. City of West. A pipeline would be constructed the Birome PWS to the City of Cottonwood’s emergency water supply line that connects directly to the City of West (Alternative BR-3).

4. New well at 10 miles. A pipeline would be constructed from a well located at an arbitrary distance of 10 miles from the Birome facility and raw water would be piped to the Birome PWS (Alternative BR-4).

5. New well at 5 miles. A pipeline would be constructed from a well located at an arbitrary distance of 5 miles from the Birome facility, and raw water would be piped to the Birome PWS (Alternative BR-5).

6. New well at 1 mile. A pipeline would be constructed from a well located at an arbitrary distance of one mile from the Birome facility, and raw water would be piped to the Birome PWS (Alternative BR-6).

4.3 TREATMENT OPTIONS

4.3.1 Centralized Treatment Systems

Centralized treatment of the well water is identified as a potential option. RO, EDR, Adsorption and Coagulation/Filtration treatment could all be potentially applicable. Central RO treatment alternative is BR-7; central EDR treatment is BR-8; central Adsorption is BR-9; and Coagulation/Filtration is BR-10.

4.3.2 Point-of-Use Systems

POU treatment using resin-based adsorption technology or RO is valid for arsenic removal. The POU treatment alternative is BR-11.

4.3.3 Point-of-Entry Systems

POE treatment using resin based adsorption technology or RO is valid for arsenic removal. The POE treatment alternative is BR-12.

4.3.4 Bottled Water

Providing bottled water is considered an interim measure to be used until a compliance alternative is implemented. Even though the community is small and people know each other; it would be reasonable to require a quarterly communication advising customers of the need to take advantage of the bottled water program. An alternative to providing delivered bottled water is to provide a central, publicly accessible dispenser for treated drinking water. Alternatives addressing bottled water are BR-13, BR-14, and BR-15.

4.4 ALTERNATIVE DEVELOPMENT AND ANALYSIS

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

4.4.1 Alternative BR-1: Purchase Water from the Post Oak WSC

This alternative involves purchasing compliant water from Post WSC, which would be used to supply the Birome PWS. The City has indicated it does have excess production capacity and would be willing to consider selling water to nearby PWSs, assuming a suitable agreement could be negotiated.

For purposes of this report, in order to allow direct and straightforward comparison with other alternatives, this alternative assumes the Birome PWS would obtain all its water from the new well. As mentioned in Subsection 1.4.1.1, blending should be considered as a possible option; however it will not be directly addressed here. 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 would require a control system to ensure the blended water is compliant.

This alternative would require constructing a pipeline from the Birome plant to a tie-in with a Post Oak 3-inch distribution line near the intersection of County Road 3344 and Highway 31. The required pipeline would be 3.8 miles long, and be constructed of 8-inch pipe. Note that additional design would be required along with possible, additional capital costs associated with the 3-inch line from the Post Oak WSC and the 8-inch line that continues to the Birome PWS. The pipeline would connect directly to the storage tank located at the main plant associated with the Birome PWS. A pump station would also be required to overcome pipe friction and the elevation differences between the Post Oak WSC tie-in and the Birome PWS. The required pump horsepower would be 19 hp.

The pump station would include two pumps, including one standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Birome PWS, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the purchase price for the treated water 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 $1.35 million, and the alternative's estimated annual O&M cost is $63,366. If the purchased water was used for blending rather than for the full water supply, the annual O&M cost for this alternative could be reduced because of reduced pumping costs and reduced water purchase costs. However, additional costs would be incurred for equipment to ensure proper blending, and additional monitoring to ensure the finished water is compliant.

The reliability of adequate amounts of compliant water under this alternative should be good. If the decision were made to perform blending, then the operational complexity would increase. As mentioned in Subsection 4.4.1, additional details for a blending alternative are not addressed as part of this feasibility report.

The feasibility of this alternative is dependent on an agreement being reached with the Post Oak WSC to purchase compliant drinking water

4.4.2 Alternative BR-2: New Well in the Vicinity of Penelope WSC

This alternative involves completing a new well in the vicinity of Penelope WSC, and constructing a pump station and pipeline to transfer the pumped groundwater to the Birome PWS. Based on the water quality data in the TCEQ database, it is expected that groundwater from this well would be compliant with drinking water MCLs. An agreement would need to be negotiated with Penelope WSC to expand its well field.

This alternative would require completing a new well and storage tank at the Penelope WSC, and constructing a pipeline from that well to the existing intake point for the Birome

PWS. A pump station would also be required to overcome pipe friction and the elevation differences between Penelope WSC and Birome PWS. The required pipeline would be constructed of 8-inch pipe and would follow the route depicted in Figure 4.1 to the Birome PWS. Using this route, the pipeline required would be approximately 7.5 miles long. The pipeline would terminate at the existing storage tanks owned by the Birome PWS. The required pump horsepower would be 28 hp

The pump station would include two pumps, including one standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Birome PWS, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes completing the new well, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $2.70 million, and the alternative's estimated annual O&M cost is $25,510. If the purchased water was used for blending rather than for the full water supply, the annual O&M cost for this alternative could be reduced because of reduced pumping costs and reduced water purchase costs. However, additional costs would be incurred for equipment to ensure proper blending, and additional monitoring to ensure the finished water is compliant. As mentioned earlier in this Section, additional details for a blending alternative are not addressed as part of this feasibility report.

From the perspective of the Birome 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. The reliability of adequate amounts of compliant water under this alternative is not certain due to the potential of encountering elevated levels of naturally-occurring arsenic.

The feasibility of this alternative is dependent on the success in installing a well that produces an adequate supply of compliant water. It is likely that an alternate groundwater source would not be found on land owned by the Birome PWS, so landowner cooperation would likely be required.

4.4.3 Alternative BR-3: Purchase Water from the City of West PWS via City of Cottonwood PWS

This alternative involves purchasing compliant water from the City of West, which would be used to supply the Birome PWS. The City has indicated it does have excess production capacity and would be willing to consider selling water to PWSs east of Waco. The City of West has connections to three nearby municipalities (Cottonwood, Hilltop, and Bold Springs) to provide water in emergency situations. Since the City of Cottonwood is located in between the City of West and Birome at approximately 5 miles west (straight line distance) of Birome, a possible alternative for the Birome PWS to have access to treated water from the City of West without installing a line all the way to the City of West, would be for the Birome PWS to connect directly to the emergency 4-inch water line at the Cottonwood PWS. This alternative depends on whether a suitable agreement could be negotiated between all three PWSs involved.

This alternative would require constructing a pipeline from a tie-in with a City of Cottonwood's emergency treated water supply line. The required pipeline would be 12.6 miles long, and be constructed of 8-inch pipe. Note that additional design would be required along with possible, additional capital costs associated with the 4-inch line from the City of West and the 8-inch line that continues to the Birome PWS. The pipeline would connect directly to the storage tank located at the main plant associated with the Birome PWS. A pump station would also be required to overcome pipe friction and the elevation differences between the City of Cottonwood tie-in and the Birome PWS. The required pump horsepower would be 40 hp.

The pump station would include two pumps, including one standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the Birome PWS, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the purchase price for the treated water plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $3.92 million, and the alternative's estimated annual O&M cost is $70,742. If the purchased water was used for blending rather than for the full water supply, the annual O&M cost for this alternative could be reduced because of reduced pumping costs and reduced water purchase costs. However, additional costs would be incurred for equipment to ensure proper blending, and additional monitoring to ensure the finished water is compliant.

The reliability of adequate amounts of compliant water under this alternative should be good. The City of West has adequate O&M resources. If the decision were made to perform blending, then the operational complexity would increase. As mentioned in Subsection 4.4.1, additional details for a blending alternative are not addressed as part of this feasibility report.

The feasibility of this alternative is dependent on an agreement being reached with the Cities of West and Cottonwood to purchase compliant drinking water.

4.4.4 Alternative BR-4: New Well at 10 miles

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

This alternative would require constructing one new 2500-foot deep well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the existing intake point for the Birome PWS. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be approximately 10 miles long, and discharges to an existing storage tank at the Birome PWS. The pump station would include two pumps, including one standby, and would be housed in a building. Since naturally occurring arsenic is so prevalent throughout the area east of Waco, existing data will need to be carefully reviewed to properly locate a well in an area that has a lower probability of having elevated levels of arsenic above the MCL.

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

The estimated capital cost for this alternative includes installing the wells, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes O&M for the pipeline and pump station, plus an amount for plugging and abandoning (in accordance with TCEQ requirements) the existing Birome PWS wells. The estimated capital cost for this alternative is $3.24 million, and the estimated annual O&M cost for this alternative is $26,097.

The reliability of adequate amounts of compliant water under this alternative is not certain due to the potential of encountering elevated levels of naturally-occurring arsenic.

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 that an alternate groundwater source would not be found on land owned by the Birome PWS, so landowner cooperation would likely be required.

4.4.5 Alternative BR-5: New Well at 5 miles

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

This alternative would require constructing one new 2,500-foot deep well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the existing intake point for the Birome PWS. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be approximately 5 miles long, and discharges to an existing storage tank at the Birome PWS. The pump station would include two pumps, including one standby, and would be housed in a building. Since naturally occurring arsenic is so prevalent throughout the area east of Waco, existing data will need to be carefully reviewed to properly locate a well in an area that has a lower probability of having elevated levels of arsenic above the MCL.

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

The estimated capital cost for this alternative includes installing the wells, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes O&M for the pipeline and pump station, plus an amount for plugging and abandoning (in accordance with TCEQ requirements) the existing Birome PWS wells. The estimated capital cost for this alternative is $1.95 million, and the estimated annual O&M cost for this alternative is $20,780.

The reliability of adequate amounts of compliant water under this alternative is not certain due to the potential of encountering elevated levels of naturally-occurring arsenic.

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 that an alternate groundwater source would not be found on land owned by the Birome PWS, so landowner cooperation would likely be required.

4.4.6 Alternative BR-6: New Well at 1 mile

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

This alternative would require constructing one new 2,500-foot well, a new pump station with storage tank near the new well, and a pipeline from the new well/tank to the existing intake point for the Birome PWS. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be approximately 1 mile long, and discharges to an existing storage tank at the Birome PWS. The pump station would include two pumps, including one standby, and would be housed in a building. Since naturally occurring arsenic is so prevalent throughout the area east of Waco, existing data will need to be carefully reviewed to properly locate a well in an area that has a lower probability of having elevated levels of arsenic above the MCL.

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

The estimated capital cost for this alternative includes installing the wells, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes O&M for the pipeline and pump station, plus an amount for plugging and abandoning (in accordance with TCEQ requirements) the existing Birome PWS wells. The estimated capital cost for this alternative is $533,125, and the estimated annual saving for this alternative is $1,906.

The reliability of adequate amounts of compliant water under this alternative is not certain due to the potential of encountering elevated levels of naturally-occurring arsenic.

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 that an alternate groundwater source would not be found on land owned by the Birome PWS, so landowner cooperation would likely be required.

4.4.7 Alternative BR-7: Central RO Treatment

This system would continue to pump water from the existing wells, and would treat the water through an RO system prior to distribution. For this option, a fraction of the raw water (70%) would be treated and the blended with the untreated stream 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 80,000 gallons per day when the system is operated at full flow.

This alternative consists of constructing the RO treatment plant near the existing Sherwood Estates service pumps. The plant is composed of a 1,200 square foot (ft^2) building with a paved driveway; a skid with the pre-constructed RO plant; two transfer pumps, a 20,000-gallon tank for storing the treated water, and a 400,000-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 existing pressure tanks would continue to be used to accumulate feed water from the well field. 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 $975,764, and the estimated annual O&M cost is $124,800.

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.

4.4.8 Alternative BR-8: Central EDR Treatment

The system would continue to pump water from the existing wells, and would treat the water through an EDR system prior to distribution. For this option the EDR 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 76,000 gpd when the system is operated at full flow.

This alternative consists of constructing the EDR treatment plant near the existing Sherwood Estates service pumps. The plant is composed of a 1,200 ft^2 building with a paved driveway; a skid with the pre-constructed EDR system; two transfer pumps; a 20,000-gallon tank for storing the treated water, and a 400,000-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 existing pressure tanks would continue to be used to accumulate feed water from the wells. 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 $1.21 million, and the estimated annual O&M cost is $103,800.

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.

4.4.9 Alternative BR-9: Central Adsorption Treatment

The system would treat groundwater from the existing wells using an iron-based adsorption system prior to distribution. This alternative consists of constructing the adsorption treatment plant at or near the Well No. 1 site. The plant comprises a 1,200 ft^2 building with a paved driveway, the pre-constructed adsorption system on a skid (*e.g.*, two Severn Trent APU-300 package units), and a 15,000-gal backwash wastewater equalization tank. 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 discharged to the sewer or recycled to the APU-300 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 $54,000.

The estimated capital cost for this alternative is $843,320 and the estimated annual O&M cost is $62,540 which includes the annualized media replacement cost of $27,000. 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.

4.4.10 Alternative BR-10: Central Coagulation/Filtration Treatment

The system would treatment groundwater from the wells using a coagulation/filtration system prior to distribution. This alternative consists of constructing the coagulation/filtration plant at or near the Well No. 1 site. The plant comprises a 1,200 ft^2 building with a paved driveway, the pre-constructed coagulation/filtration system on a skid (*e.g.*, three Macrolite filters from Kinetico), a ferric chloride feed and storage system, and a 10,000-gallon backwash wastewater equalization tank. 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 10,000-gal tank and discharged to the sewer or 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 $933,170, and the estimated annual O&M cost is $91,600. 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.

4.4.11 Alternative BR-11: Point-of-Use Treatment

This alternative consists of the continued operation of the Birome 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.

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

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

This alternative does not present options for a shared solution.

The estimated capital cost for this alternative includes the cost to purchase and install the POU treatment systems. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $305,580, and the estimated annual O&M cost for this alternative is $322,989. For the cost estimate, it is assumed that one POU treatment unit will be required for each of the 496 connections currently included in the Birome PWS. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets to meet regulatory requirements, making purchase and installation more expensive.

The reliability of adequate amounts of compliant water under this alternative is fair, since it relies on the active cooperation of the customers for system installation, use, and maintenance, and only provides compliant water to single tap within a house. Additionally, the O&M efforts required for the POU systems will be significant, and the current personnel are inexperienced in this type of work. From the perspective of the Birome PWS, this alternative would be characterized as more difficult to operate owing to the in-home requirements and the large number of individual units.

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

4.4.12 Alternative BR-12: Point-of-Entry Treatment

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

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

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

This alternative does not present options for a shared solution.

The estimated capital cost for this alternative includes cost to purchase and install the POE treatment systems. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $5.35 million, and the estimated annual O&M cost for this alternative is $681,814. For the cost estimate, it is assumed that one POU treatment unit will be required for the 496 connections currently included in the Birome 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 the customers for system installation, use, and maintenance, and compliant water is supplied to all taps within a house. Additionally, the O&M efforts required for the POE systems will be significant, and the current personnel are inexperienced in this type of work. From the perspective of the Birome PWS, this alternative would be characterized as more difficult to operate owing to the on-property requirements and the large number of individual units.

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

4.4.13 Alternative BR-13: Public Dispenser for Treated Drinking Water

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

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

This alternative does not present options for a regional solution.

The estimated capital cost for this alternative includes purchasing and installing the treatment system to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes purchasing and replacing filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $46,400, and the estimated annual O&M cost for this alternative is $77,200.

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

4.4.14 Alternative BR-14: 100 Percent Bottled Water Delivery

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

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

This alternative does not present options for a regional solution.

The estimated initial capital cost is for setting up the program. The estimated O&M cost for this alternative includes program administration and purchase of the bottled water. The estimated capital cost for this alternative is $29,733, and the estimated annual O&M cost for this alternative is $820,096. For the cost estimate, it is assumed that each person requires one gallon of bottled water per day.

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

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

4.4.15 Alternative BR-15: Public Dispenser for Trucked Drinking Water

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

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

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

The estimated capital cost for this alternative includes purchasing a water truck and construction of the storage tank to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes O&M for the truck, maintenance for the tank, water quality testing, record keeping, and water purchase, The estimated capital cost for this alternative is $150,945, and the estimated annual O&M cost for this alternative is $71,212.

The reliability of adequate amounts of compliant water under this alternative is fair because of the large amount of effort required from the customers and the associated inconvenience. Current personnel have not provided this type of service in the past. From the perspective of the Birome 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.

4.4.16 Summary of Alternatives

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

Table 4.3 Summary of Compliance Alternatives for the Birome PWS

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
BR-1	New Well in the Vicinity of the City of Penelope	- Purchase water - Pump station - 7.5-mile pipeline	$ 1,352,521	$ 63,366	$ 181,285	Good	N	Agreement must be successfully negotiated with the City of Penelope. Blending may be possible. Possible to share costs with other small systems along pipeline route.
BR-2	Purchase Water from City of West via City of Cottonwood's Emerg Supply Line to the City of West	- Purchase water - Pump station - 12.6-mile pipeline	$ 2,701,889	$ 25,510	$ 261,073	Good	N	Agreement must be successfully negotiated with both the Cities of Cottonwood and the City of West. Blending may be possible.
BR-3	Purchase Water from Post Oak WSC	- Purchase water - Pump station - 17.6-mile pipeline	$ 3,919,734	$ 70,742	$ 412,483	Good	N	Agreement must be successfully negotiated with the City of Mart. Blending may be possible.
BR-4	New Well within 10 Miles	- New well - Storage tank - Pump station - 10-mile pipeline	$ 3,235,358	$ 26,097	$ 308,170	Good	N	The required quality and quantity of groundwater would need to be located. Costs could be shared with other systems.
BR-5	New Well within 5 Miles	- New well - Storage tank - Pump station - 5-mile pipeline	$ 1,954,481	$ 20,780	$ 191,181	Good	N	The required quality and quantity of groundwater would need to be located. Costs could be shared with other systems.
BR-6	New Well within 1 miles	- New well - Storage tank - Pump station - 1-mile pipeline	$ 533,125	$ (1,906)	$ 44,574	Good	N	May be difficult to find well with good water quality.

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
BR-7	Central Treatment - RO	Central RO treatment plant	$ 975,764	$ 124,800	$ 209,872	Good	T, M	Costs could possibly be shared with nearby small systems.
BR-8	Central Treatment - EDR	- Central EDR treatment plant	$ 1,207,764	$ 103,800	$ 209,098	Good	T, M	Costs could possibly be shared with nearby small systems.
BR-9	Central Treatment - Absorption	- Central treatment plant	$ 843,320	$ 62,540	$ 136,064	Good	T, M	Costs could possibly be shared with nearby small systems.
BR-10	Central Treatment – Coag/Filtration	- Central coag/filtration treatment plant	$ 933,170	$ 91,600	$ 172,958	Good	T, M	Costs could possibly be shared with nearby small systems.
BR-11	Point of Use Treatment	- POU treatment units.	$ 305,580	$ 322,989	$ 349,631	Fair	T, M	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.
BR-12	Point of Entry Treatment	- POE treatment units.	$ 5,347,650	$ 681,814	$ 1,148,046	Fair (*better than POU*)	T, M	All home taps compliant and less resident cooperation required.
BR-13	Public Dispenser for Treated Drinking Water	Treatment unit, dispenser and truck	$ 46,400	$ 77,200	$ 81,245	Fair, interim method.	T	Does not provide compliant water to all taps, and requires a lot of effort by customers.
BR-14	Supply Bottled Water to 100% of Population	Bottled water and delivery system.	$ 29,733	$ 820,096	$ 822,688	Fair, interim method.	M	Does not provide compliant water to all taps, and requires customers to order and use. Management of program may be significant.
BR-15	Central Trucked Drinking Water	Dispenser and truck.	$ 150,945	$ 71,212	$ 84,372	Fair, interim method.	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

1 *2 – 20-year return period and 6 percent interest*

4.6 COST OF SERVICE AND FUNDING ANALYSIS

To evaluate the financial impact of implementing the compliance alternatives, a 30-year financial planning model was developed. This model can be found in Appendix D. The financial model is based on estimated cash flows, with and without implementation of the compliance alternatives. Data for such models are typically derived from established budgets, audited financial reports, published water tariffs, and consumption data. Information that was available to complete the financial analysis included the 2005 Birome WSC Financial Statement with revenues and expenses for the water district and the "Capacity Assessment" document prepared after conducting interviews with the Birome personnel. It is estimated that Birome customers use on an average 301 gpd per connection.

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.

4.6.1 Financial Plan Development

Since no financial data was available, the total revenues generated by water sales and service for the Birome PWS were estimated using a population of 1,356, a per capita water usage rate of 110 gpd, and an average net billing rate of $4.40 per 1,000 gallons. This billing rate is similar to that of other PWS of similar size and per capita water usage in the region. It is estimated that the Birome PWS water sales generated an annual revenue of $259,550. Using the annual revenues of $259,550, results in an average monthly water bill per customer of $40.25, which is in line with competing PWS. This value was entered into the financial model.

No operating expenses are available for Birome PWS; however, in comparing similar size PWSs in the area, it is estimated that total expenses would be less than total revenues, which would result in a modest positive cash flow.

4.6.2 Current Financial Condition

4.6.2.1 Cash Flow Needs

Using the estimated water usage rates as noted above, the current average annual water bill for Birome WSC PWS customers is estimated at $483 or about 1.5 percent of the Zip Code 76673 Tract MHI of $32,404.

It is not known whether Birome PWS operates with a sufficient cash reserve to fund the necessary capital improvements to address the arsenic compliance issues. However, PWSs similar in size to Birome found it necessary to raise their rates in the future to pay for any capital improvements that addressed water quality compliance issues.

4.6.2.2 Ratio Analysis

Current Ratio

The Current Ratio, which is a measure of liquidity, can not be calculated because of the lack of financial data.

Debt to Net Worth Ratio

A Debt to Net Worth ratio, which is a measure of financial liquidity and stability, can not be calculated because of the lack of financial data

Operating Ratio

The Operating Ratio can not be calculated because of the lack of financial data.

4.6.3 Financial Plan Results

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

For State Revolving Fund (SRF) funding options, customer MHI compared to the state average determines the availability of subsidized loans. According the 2000 U.S. Census data, the Zip Code MHI for customers of Birome PWS was $32,404, which is 81 percent of the statewide income average of $39,927. As a result, the Birome PWS may qualify for a loan at an interest rate of 3.8 percent from the SRF. In the event SRF funds would be unavailable, Birome WSC PWS would need to rely on revenue bonds as a funding alternative.

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 (3,954 gallons/month consumption), shows the following:

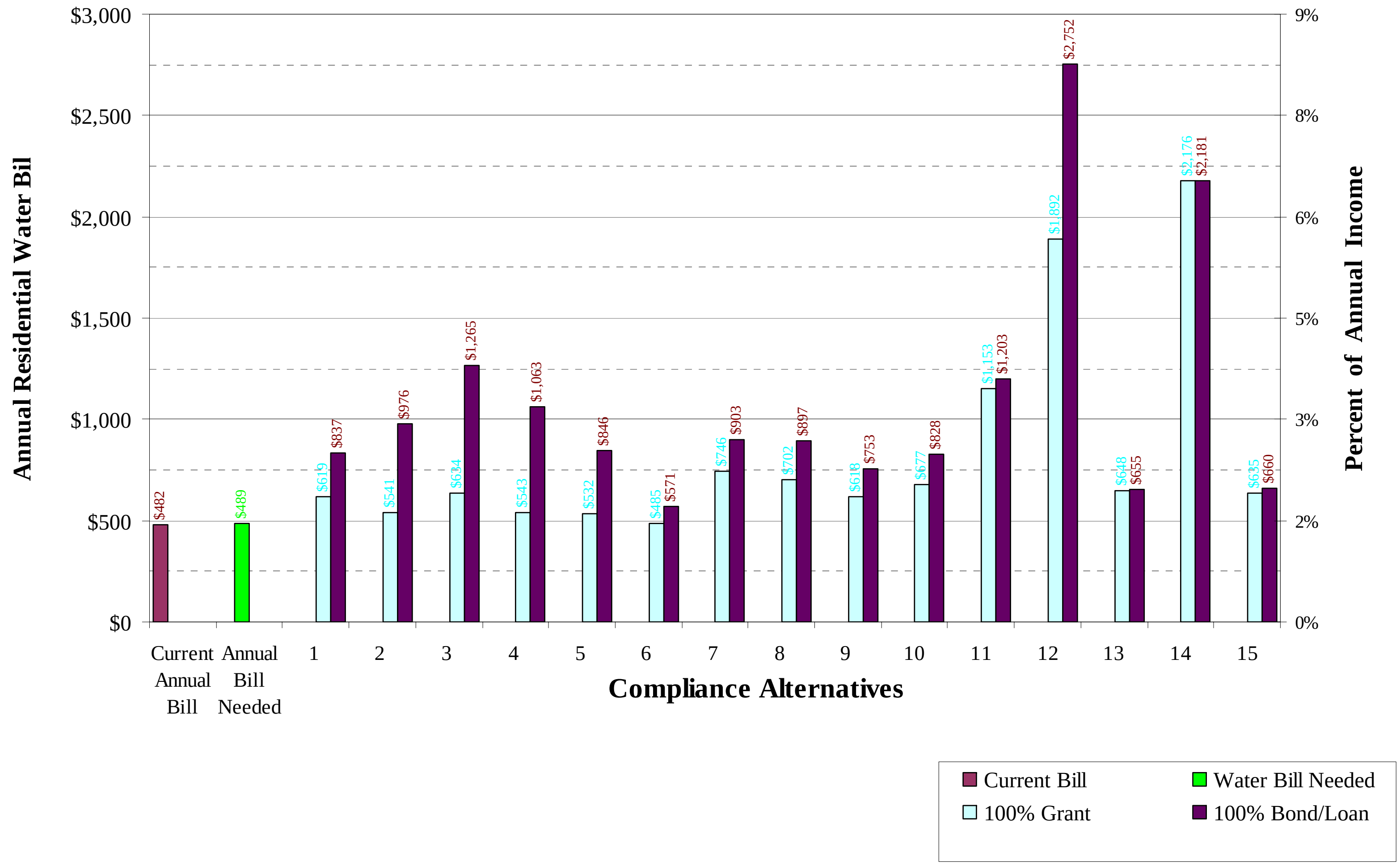
- Current annual average bill,
- Projected annual average bill including rate increase, if needed, to match existing expenditures, and
- Projected annual bill including rate increases needed to fund implementation of a compliance alternative (this does not include funding for reserve accounts).

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

Table 4.4 Financial Impact on Households

Alternative	Description		All Revenue	100% Grant	75% Grant	50% Grant	SRF	Bond
1	Purchase Water from Post Oak WSC	Max % of HH Income	11%	3%	4%	4%	5%	5%
		Max % Rate Increase Compared to Current	1112%	268%	304%	340%	395%	413%
		Average Water Bill Required by Alternative	$ 3,422	$ 1,037	$ 1,137	$ 1,237	$ 1,389	$ 1,437
2	New Well at Penelope	Max % of HH Income	20%	3%	4%	4%	5%	6%
		Max % Rate Increase Compared to Current	2007%	207%	280%	352%	462%	497%
		Average Water Bill Required by Alternative	$ 5,937	$ 876	$ 1,076	$ 1,276	$ 1,579	$ 1,675
3	Purchase Water from Cottonwood Water Supply	Max % of HH Income	28%	4%	4%	5%	7%	7%
		Max % Rate Increase Compared to Current	2878%	280%	385%	490%	649%	700%
		Average Water Bill Required by Alternative	$ 8,379	$ 1,069	$ 1,359	$ 1,649	$ 2,088	$ 2,228
4	New Well at 10 Miles	Max % of HH Income	23%	3%	4%	4%	6%	6%
		Max % Rate Increase Compared to Current	2373%	208%	295%	382%	513%	555%
		Average Water Bill Required by Alternative	$ 6,965	$ 878	$ 1,118	$ 1,357	$ 1,720	$ 1,836
5	New Well at 5 Miles	Max % of HH Income	15%	3%	3%	4%	4%	5%
		Max % Rate Increase Compared to Current	1491%	200%	252%	305%	384%	409%
		Average Water Bill Required by Alternative	$ 4,488	$ 856	$ 1,000	$ 1,145	$ 1,364	$ 1,434
6	New Well at 1 Mile	Max % of HH Income	6%	2%	3%	3%	3%	3%
		Max % Rate Increase Compared to Current	498%	163%	178%	192%	214%	221%
		Average Water Bill Required by Alternative	$ 1,704	$ 759	$ 799	$ 838	$ 898	$ 917
7	Central Treatment - RO	Max % of HH Income	9%	4%	5%	5%	5%	5%
		Max % Rate Increase Compared to Current	903%	366%	392%	418%	458%	471%
		Average Water Bill Required by Alternative	$ 2,830	$ 1,299	$ 1,371	$ 1,443	$ 1,553	$ 1,588
8	Central Treatment - EDR	Max % of HH Income	11%	4%	4%	5%	5%	5%
		Max % Rate Increase Compared to Current	1045%	333%	365%	397%	446%	462%
		Average Water Bill Required by Alternative	$ 3,231	$ 1,209	$ 1,299	$ 1,388	$ 1,524	$ 1,567
9	Central Treatment - Adsorption	Max % of HH Income	8%	3%	4%	4%	4%	4%
		Max % Rate Increase Compared to Current	762%	267%	289%	312%	346%	357%
		Average Water Bill Required by Alternative	$ 2,440	$ 1,034	$ 1,096	$ 1,158	$ 1,253	$ 1,283
10	Central Treatment - Coag-Filt	Max % of HH Income	9%	4%	4%	4%	5%	5%
		Max % Rate Increase Compared to Current	847%	313%	338%	363%	401%	413%
		Average Water Bill Required by Alternative	$ 2,676	$ 1,157	$ 1,226	$ 1,295	$ 1,400	$ 1,434
11	Point-of-Use Treatment	Max % of HH Income	7%	7%	7%	7%	8%	8%
		Max % Rate Increase Compared to Current	683%	683%	691%	700%	712%	716%
		Average Water Bill Required by Alternative	$ 2,183	$ 2,143	$ 2,165	$ 2,188	$ 2,222	$ 2,233
12	Point-of-Entry Treatment	Max % of HH Income	41%	13%	14%	15%	17%	18%
		Max % Rate Increase Compared to Current	4346%	1257%	1401%	1544%	1762%	1831%
		Average Water Bill Required by Alternative	$ 12,452	$ 3,671	$ 4,066	$ 4,462	$ 5,062	$ 5,253
13	Public Dispenser for Treated Drinking Water	Max % of HH Income	4%	4%	4%	4%	4%	4%
		Max % Rate Increase Compared to Current	290%	290%	291%	292%	294%	295%
		Average Water Bill Required by Alternative	$ 1,102	$ 1,096	$ 1,100	$ 1,103	$ 1,108	$ 1,110
14	Supply Bottled Water to 100% of Population	Max % of HH Income	15%	15%	15%	15%	15%	15%
		Max % Rate Increase Compared to Current	1479%	1479%	1479%	1480%	1481%	1482%
		Average Water Bill Required by Alternative	$ 4,264	$ 4,260	$ 4,262	$ 4,264	$ 4,267	$ 4,268
15	Central Trucked Drinking Water	Max % of HH Income	4%	4%	4%	4%	4%	4%
		Max % Rate Increase Compared to Current	294%	280%	284%	288%	295%	297%
		Average Water Bill Required by Alternative	$ 1,127	$ 1,071	$ 1,082	$ 1,093	$ 1,110	$ 1,115

Figure 4-2 Alternative Cost Summary



SECTION 5
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APPENDIX A
PWS INTERVIEW FORM

CAPACITY DEVELOPMENT ASSESSMENT FORM

*Prepared By*___________________________________ *Date*___________________________

Section 1. Public Water System Information

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

3. County [ ]

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

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

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

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

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

11. Source Type [ ]

12. Total PWS Annual Water Used [ ]

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

    Total Coliform [ ] Chemical/Radiological [ ]

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

A. Basic Information

1. Name of Water System:

2. Name of Person Interviewed:

3. Position:

4. Number of years at job:

5. Number of years experience with drinking water systems:

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

7. Certified Water Operator (Yes or No):

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

   7b. How long have you been certified?

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

B. Organization and Structure

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

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

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

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

   3b. May we see a copy?

C. Personnel

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

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

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

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

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

D. Communication

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

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

3. How are your work priorities set?

4. How are work tasks delegated to staff?

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

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

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

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

9. Describe communication between utility and customers.

E. Planning and Funding

1. Describe the rate structure for the utility.

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

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

3. How often are the rates reviewed?

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

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

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

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

8. How is the budget approved or adopted?

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

   9a. How are budget shortfalls handled?

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

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

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

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

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

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

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

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

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

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

F. Policies, Procedures, and Programs

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

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

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

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

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

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

7. Approximately how many complaints are there per month?

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

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

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

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

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

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

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

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

G. Operations and Maintenance

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

    a. Process Control

    b. Purchases of supplies or small equipment

    c. Compliance sampling/reporting

    d. Staff scheduling

2. Describe your utility's preventative maintenance program.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

H. SDWA Compliance

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

2. How were the violations handled?

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

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

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

I. Emergency Planning

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

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

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

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

Attachment A

A. Technical Capacity Assessment Questions

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

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

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

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

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

   YES ☐ NO ☐

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

   _____NM Small System _____Class 2

   _____NM Small System Advanced _____Class 3

   _____Class 1 _____Class 4

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

   YES ☐ NO ☐ No Deficiencies ☐

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

   Source ☐ Storage ☐

   Treatment ☐ Distribution ☐

   Other _____

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

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

   Radionuclides YES ☐ NO ☐ Doesn't Apply ☐

   Arsenic YES ☐ NO ☐ Doesn't Apply ☐

   Stage 1 Disinfectants and Disinfection By-Product (DBP)

   YES ☐ NO ☐ Doesn't Apply ☐

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

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

   YES ☐ NO ☐

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

   YES ☐ NO ☐

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

   Drought _____ Limited Supply _____

   System Failure _____ Other _____

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

   YES ☐ NO ☐ Don't Know ☐

   If YES, please complete the following table.

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

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

   YES ☐ NO ☐

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

   Source ☐ Storage ☐

   Treatment ☐ Distribution ☐

   Other ☐ _____

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

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

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

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

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

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

YES ☐ NO ☐

14. Does the system have a flushing program?

YES ☐ NO ☐

If YES, please describe.

15. Are there any pressure problems within the system?

YES ☐ NO ☐

If YES, please describe.

16. Does the system disinfect the finished water?

YES ☐ NO ☐

If yes, which disinfectant product is used? ______

Interviewer Comments on Technical Capacity:

B. Managerial Capacity Assessment Questions

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

YES ☐ NO ☐

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

YES ☐ NO ☐

18. Does the system have written operating procedures?

YES ☐ NO ☐

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

YES ☐ NO ☐

20. Does the system have:

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

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

Water quality violations
YES ☐ NO ☐

Public notification
YES ☐ NO ☐

Sampling exemptions
YES ☐ NO ☐

22. Please describe how the above records are maintained:

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

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

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

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

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

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

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

If yes, from which agency and how much?

Describe the project?

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

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

YES ☐ NO ☐

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

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

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

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

Interviewer Comments on Managerial Capacity:

C. Financial Capacity Assessment

30. Does the system have a budget?

YES ☐ NO ☐

If YES, what type of budget?

Operating Budget ☐

Capital Budget ☐

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

YES ☐ NO ☐

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

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

YES ☐ NO ☐

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

34. Are rates reviewed annually?

YES ☐ NO ☐

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

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

Operation & Maintenance ☐

Infrastructure Repair & replacement ☐

Staffing ☐

Emergency/Reserve fund ☐

Debt payment ☐

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

YES ☐ NO ☐

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

YES ☐ NO ☐

If yes, is this policy implemented?

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

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

[Convert to % of active connections

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

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

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

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

YES ☐ NO ☐

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

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

YES ☐ NO ☐

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

YES ☐ NO ☐

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

YES ☐ NO ☐

If yes, please describe.

41. Has the system ever had a financial audit?

YES ☐ NO ☐

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

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

Interviewer Comments on Financial Assessment:

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

APPENDIX B
COST BASIS

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

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

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

Unit costs for pipeline components are based on 2006 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 PVC pipe. Other pipe materials could be considered for more detailed development of attractive alternatives.

Pump station unit costs are based on experience with similar installations. The cost estimate for the pump stations include two pumps, station piping and valves, station electrical and instrumentation, minor site improvement, installation of a concrete pad, building, and tools. Construction cost of a storage tank is based on 2006 RS Means Building Construction Cost Data.

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

Electrical power cost is estimated to be $0.15 per kWH, as supplied by Texas Utilities. The annual cost for power to a pump station is calculated based on the pumping head and volume, and includes 11,800 kWH for pump building heating, cooling, and lighting, as recommended in USEPA publication, *Standardized Costs for Water Supply Distribution Systems* (1992).

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

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

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

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

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

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

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

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

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

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

APPENDIX REFERENCES

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

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

Table B.1
Summary of General Data
Birome WSC
PWS #1090017
General PWS Information

Service Population	1,356	**Number of Connections**	463
Total PWS Daily Water Usage	0.148 (mgd)	**Source**	TCEQ website

Unit Cost Data
Central TEXAS

General Items	**Unit**	**Unit Cost**
Treated water purchase cost	*See alternative*	
Water purchase cost (trucked)	$/1,000 gals	$ 1.60
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, 08"	LF	$ 37
Bore and encasement, 12"	LF	$ 70
Open cut and encasement, 12"	LF	$ 40
Gate valve and box, 08"	EA	$ 690
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, 08"	EA	$ 4,000
Gate valve, 08"	EA	$ 890
Check valve, 08"	EA	$ 1,300
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
3 Storage Tanks - 30,000 gals ea	EA	$ 111,300
Electrical Power	$/kWH	$ 0.150
Building Power	kWH	11,800
Labor	$/hr	$ 37
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	$ 37
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	$ 50
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	$ 0.150
Equipment power	kwh/yr	$ 0.150
Labor, O&M	hr	$ 37
Analyses	test	$ 200
Reverse Osmosis		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
RO package plant	UNIT	$ 280,000
Transfer pumps (5 hp)	EA	$ 5,000
Permeate tank	gal	$ 3
RO materials	year	$ 5,000
RO chemicals	year	$ 5,000
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	$ 450,000
EDR materials	year	$ 5,000
EDR chemicals	year	$ 4,000
Backwash disposal mileage cost	miles	$ 1.00
Backwash disposal fee	1,000 gal/yr	$ 5.00
Adsorption		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
Adsorption package plant	UNIT	$ 280,000
Backwash tank	GAL	$ 2.00
Sewer connection fee	EA	$ 15,000
Spent media disposal	CY	$ 20
Adsorption materials	year	$ 27,000
Backwash discharge to sewer	MG/year	$ 5,000
Coagulation/filtration		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
Coagulation package plant	UNIT	$ 300,000
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	$ 5,000
Backwash discharge to sewer	MG/year	$ 5,000

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.15. 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 ***Birome WSC***
Alternative Name ***Purchase Water from Post Oak WSC***
Alternative Number ***BR-1***

Distance from Alternative to PWS (along pipe)	3.8	miles
Total PWS annual water usage	54.020	MG
Treated water purchase cost	$ 1.21	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	4	n/a	n/a	n/a
PVC water line, Class 200, 08"	20,272	LF	$ 37	$ 750,064
Bore and encasement, 12"	-	LF	$ 70	$ -
Open cut and encasement, 12"	200	LF	$ 40	$ 8,000
Gate valve and box, 08"	4	EA	$ 690	$ 2,798
Air valve	4	EA	$ 1,000	$ 4,000
Flush valve	4	EA	$ 750	$ 3,041
Metal detectable tape	20,272	LF	$ 0.15	$ 3,041
Subtotal				**$ 770,943**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 890	$ 3,560
Check valve, 08"	2	EA	$ 1,300	$ 2,600
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
3 Storage Tanks - 30,000 gals ea	1	EA	$ 111,300	$ 111,300
Subtotal				**$ 161,830**
Subtotal of Component Costs				**$ 932,773**
Contingency	20%			$ 186,555
Design & Constr Management	25%			$ 233,193
TOTAL CAPITAL COSTS				**$ 1,352,521**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	3.8	mile	$ 200	$ 768
Subtotal				**$ 768**
Water Purchase Cost				
From Source	54,020	1,000 gal	$ 1.21	$ 65,364
Subtotal				**$ 65,364**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.150	$ 1,770
Pump Power	31,282	kWH	$ 0.150	$ 4,692
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 37	$ 13,600
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 22,262**
O&M Credit for Existing Well Closure				
Pump power	61,429	kWH	$ 0.150	$ (9,214)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 37	$ (13,414)
Subtotal				**$ (25,028)**
TOTAL ANNUAL O&M COSTS				**$ 63,366**

Table C.2

PWS Name ***Birome WSC***
Alternative Name ***New Well at Penelope***
Alternative Number ***BR-2***

Distance from PWS to new well location	7.47	miles
Estimated well depth	3000	feet
Number of wells required	2	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	9	n/a	n/a	n/a
PVC water line, Class 200, 08"	39,453	LF	$ 37	$ 1,459,761
Bore and encasement, 12"	-	LF	$ 70	$ -
Open cut and encasement, 12"	450	LF	$ 40	$ 18,000
Gate valve and box, 08"	8	EA	$ 690	$ 5,445
Air valve	7	EA	$ 1,000	$ 7,000
Flush valve	8	EA	$ 750	$ 5,918
Metal detectable tape	39,453	LF	$ 0.15	$ 5,918
Subtotal				**$ 1,502,041**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 890	$ 3,560
Check valve, 08"	2	EA	$ 1,300	$ 2,600
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
3 Storage Tanks - 30,000 gals ea	1	EA	$ 111,300	$ 111,300
Subtotal				**$ 169,330**
Well Installation				
Well installation	6,000	LF	$ 25	$ 150,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 192,000**
Subtotal of Component Costs				**$ 1,863,371**
Contingency	20%			$ 372,674
Design & Constr Management	25%			$ 465,843
TOTAL CAPITAL COSTS				**$ 2,701,889**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	7.5	mile	$ 200	$ 1,494
Subtotal				**$ 1,494**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.150	$ 1,770
Pump Power	46,808	kWH	$ 0.150	$ 7,021
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 37	$ 13,600
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 24,591**
Well O&M				
Pump power	57,591	kWH	$ 0.150	$ 8,639
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 37	$ 13,414
Subtotal				**$ 24,452**
O&M Credit for Existing Well Closure				
Pump power	61,429	kWH	$ 0.150	$ (9,214)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 37	$ (13,414)
Subtotal				**$ (25,028)**
TOTAL ANNUAL O&M COSTS				**$ 25,510**

Table C.3

PWS Name ***Birome WSC***
Alternative Name ***Purchase Water from City of West via City of Cottonwood***
Alternative Number ***BR-3***

Distance from Alternative to PWS (along pipe)	12.6	miles
Total PWS annual water usage	54.020	MG
Treated water purchase cost	$ 1.21	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	11	n/a	n/a	n/a
PVC water line, Class 200, 08"	66,575	LF	$ 37	$ 2,463,275
Bore and encasement, 12"	200	LF	$ 70	$ 14,000
Open cut and encasement, 12"	550	LF	$ 40	$ 22,000
Gate valve and box, 08"	13	EA	$ 690	$ 9,187
Air valve	13	EA	$ 1,000	$ 13,000
Flush valve	13	EA	$ 750	$ 9,986
Metal detectable tape	66,575	LF	$ 0.15	$ 9,986
Subtotal				**$ 2,541,435**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 890	$ 3,560
Check valve, 08"	2	EA	$ 1,300	$ 2,600
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
3 Storage Tanks - 30,000 gals ea	1	EA	$ 111,300	$ 111,300
Subtotal				**$ 161,830**
Subtotal of Component Costs				**$ 2,703,265**
Contingency	20%			$ 540,653
Design & Constr Management	25%			$ 675,816
TOTAL CAPITAL COSTS				**$ 3,919,734**

Annual Operations and Maintenance Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline O&M				
Pipeline O&M	12.6	mile	$ 200	$ 2,522
Subtotal				**$ 2,522**
Water Purchase Cost				
From Source	54,020	1,000 gal	$ 1.21	$ 65,364
Subtotal				**$ 65,364**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.150	$ 1,770
Pump Power	68,762	kWH	$ 0.150	$ 10,314
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 37	$ 13,600
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 27,884**
O&M Credit for Existing Well Closure				
Pump power	61,429	kWH	$ 0.150	$ (9,214)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 37	$ (13,414)
Subtotal				**$ (25,028)**
TOTAL ANNUAL O&M COSTS				**$ 70,742**

Table C.4

PWS Name	***Birome WSC***
Alternative Name	***New Well at 10 Miles***
Alternative Number	***BR-4***

Distance from PWS to new well location	10.0	miles
Estimated well depth	2500	feet
Number of wells required	2	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	

Capital Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	10	n/a	n/a	n/a
PVC water line, Class 200, 08"	52,800	LF	$ 37	$ 1,953,600
Bore and encasement, 12"	-	LF	$ 70	$ -
Open cut and encasement, 12"	500	LF	$ 40	$ 20,000
Gate valve and box, 08"	11	EA	$ 690	$ 7,286
Air valve	10	EA	$ 1,000	$ 10,000
Flush valve	11	EA	$ 750	$ 7,920
Metal detectable tape	52,800	LF	$ 0.15	$ 7,920
Subtotal				**$ 2,006,726**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 890	$ 3,560
Check valve, 08"	2	EA	$ 1,300	$ 2,600
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
3 Storage Tanks - 30,000 gals ea	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 57,555**
Well Installation				
Well installation	5,000	LF	$ 25	$ 125,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 167,000**
Subtotal of Component Costs				**$ 2,231,281**
Contingency	20%			$ 446,256
Design & Constr Management	25%			$ 557,820
TOTAL CAPITAL COSTS				**$ 3,235,358**

Annual Operations and Maintenance Costs

Cost Item	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pipeline O&M				
Pipeline O&M	10.0	mile	$ 200	$ 2,000
Subtotal				**$ 2,000**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.150	$ 1,770
Pump Power	57,552	kWH	$ 0.150	$ 8,633
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 37	$ 13,600
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 26,203**
Well O&M				
Pump power	47,388	kWH	$ 0.150	$ 7,108
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 37	$ 13,414
Subtotal				**$ 22,922**
O&M Credit for Existing Well Closure				
Pump power	61,429	kWH	$ 0.150	$ (9,214)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 37	$ (13,414)
Subtotal				**$ (25,028)**
TOTAL ANNUAL O&M COSTS				**$ 26,097**

Table C.5

PWS Name	***Birome WSC***
Alternative Name	***New Well at 5 Miles***
Alternative Number	***BR-5***

Distance from PWS to new well location	5.0	miles
Estimated well depth	2500	feet
Number of wells required	2	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	5	n/a	n/a	n/a
PVC water line, Class 200, 08"	26,400	LF	$ 37	$ 976,800
Bore and encasement, 12"	1,800	LF	$ 70	$ 126,000
Open cut and encasement, 12"	100	LF	$ 40	$ 4,000
Gate valve and box, 08"	5	EA	$ 690	$ 3,643
Air valve	5	EA	$ 1,000	$ 5,000
Flush valve	5	EA	$ 750	$ 3,960
Metal detectable tape	26,400	LF	$ 0.15	$ 3,960
Subtotal				**$ 1,123,363**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 890	$ 3,560
Check valve, 08"	2	EA	$ 1,300	$ 2,600
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
3 Storage Tanks - 30,000 gals ea	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 57,555**
Well Installation				
Well installation	5,000	LF	$ 25	$ 125,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 167,000**
Subtotal of Component Costs				**$ 1,347,918**
Contingency	20%			$ 269,584
Design & Constr Management	25%			$ 336,980
TOTAL CAPITAL COSTS				**$ 1,954,481**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	5.0	mile	$ 200	$ 1,000
Subtotal				**$ 1,000**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.150	$ 1,770
Pump Power	28,776	kWH	$ 0.150	$ 4,316
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 37	$ 13,600
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 21,886**
Well O&M				
Pump power	47,388	kWH	$ 0.150	$ 7,108
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 37	$ 13,414
Subtotal				**$ 22,922**
O&M Credit for Existing Well Closure				
Pump power	61,429	kWH	$ 0.150	$ (9,214)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 37	$ (13,414)
Subtotal				**$ (25,028)**
TOTAL ANNUAL O&M COSTS				**$ 20,780**

Table C.6

PWS Name	***Birome WSC***
Alternative Name	***New Well at 1 Mile***
Alternative Number	***BR-6***

Distance from PWS to new well location	1.0	miles
Estimated well depth	2500	feet
Number of wells required	2	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	0	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	-	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 08"	5,280	LF	$ 37	$ 195,360
Bore and encasement, 12"	-	LF	$ 70	$ -
Open cut and encasement, 12"	50	LF	$ 40	$ 2,000
Gate valve and box, 08"	1	EA	$ 690	$ 729
Air valve	1	EA	$ 1,000	$ 1,000
Flush valve	1	EA	$ 750	$ 792
Metal detectable tape	5,280	LF	$ 0.15	$ 792
Subtotal				**$ 200,673**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 08"	-	EA	$ 4,000	$ -
Gate valve, 08"	-	EA	$ 890	$ -
Check valve, 08"	-	EA	$ 1,300	$ -
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	$ -
3 Storage Tanks - 30,000 gals ea	-	EA	$ 7,025	$ -
Subtotal				**$ -**
Well Installation				
Well installation	5,000	LF	$ 25	$ 125,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 167,000**
Subtotal of Component Costs				**$ 367,673**
Contingency	20%			$ 73,535
Design & Constr Management	25%			$ 91,918
TOTAL CAPITAL COSTS				**$ 533,125**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	1.0	mile	$ 200	$ 200
Subtotal				**$ 200**
Pump Station(s) O&M				
Building Power	-	kWH	$ 0.150	$ -
Pump Power	-	kWH	$ 0.150	$ -
Materials	-	EA	$ 1,200	$ -
Labor	-	Hrs	$ 37	$ -
Tank O&M	-	EA	$ 1,000	$ -
Subtotal				**$ -**
Well O&M				
Pump power	47,388	kWH	$ 0.150	$ 7,108
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 37	$ 13,414
Subtotal				**$ 22,922**
O&M Credit for Existing Well Closure				
Pump power	61,429	kWH	$ 0.150	$ (9,214)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 37	$ (13,414)
Subtotal				**$ (25,028)**
TOTAL ANNUAL O&M COSTS				**$ (1,906)**

Table C.7

PWS Name ***Birome WSC***
Alternative Name ***Central Treatment - RO***
Alternative Number ***BR-7***

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	30	CY	$ 1,000	$ 30,000
Building	1,200	SF	$ 60	$ 72,000
Building electrical	1,200	SF	$ 8	$ 9,600
Building plumbing	1,200	SF	$ 8	$ 9,600
Heating and ventilation	1,200	SF	$ 7	$ 8,400
Fence	-	LF	$ 15	$ -
Paving	3,500	SF	$ 2	$ 7,000
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	$ 280,000	$ 280,000
Transfer pumps	2	EA	$ 5,000	$ 10,000
Permeate tank	20,000	gal	$ 3	$ 60,000
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				**$ 603,975**
Contingency	20%			$ 120,795
Design & Constr Management	25%			$ 150,994
Reject water haulage truck	1	EA	$ 100,000	$ 100,000
TOTAL CAPITAL COSTS				**$ 975,764**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Reverse Osmosis Unit O&M				
Building Power	10,000	kwh/yr	$ 0.150	$ 1,500
Equipment power	60,000	kwh/yr	$ 0.150	$ 9,000
Labor	1,000	hrs/yr	$ 37.000	$ 37,000
Materials	1	year	$ 5,000	$ 5,000
Chemicals	1	year	$ 5,000	$ 5,000
Analyses	24	test	$ 200	$ 4,800
Subtotal				**$ 62,300**
Reject Disposal				
Disposal truck mileage	25,000	miles	$ 1.00	$ 25,000
Backwash disposal fee	5,000	kgal/yr	$ 7.50	$ 37,500
Subtotal				**$ 62,500**
TOTAL ANNUAL O&M COSTS				**$ 124,800**

Table C.8

PWS Name *Birome WSC*
Alternative Name *Central Treatment - EDR*
Alternative Number *BR-8*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
EDR Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	30	CY	$ 1,000	$ 30,000
Building	1,200	SF	$ 60	$ 72,000
Building electrical	1,200	SF	$ 8	$ 9,600
Building plumbing	1,200	SF	$ 8	$ 9,600
Heating and ventilation	1,200	SF	$ 7	$ 8,400
Fence	-	LF	$ 15	$ -
Paving	3,500	SF	$ 2	$ 7,000
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Product storage tank	20,000	gal	$ 3.00	$ 60,000
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	$ 450,000	$ 450,000
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				**$ 763,975**
Contingency	20%			$ 152,795
Design & Constr Management	25%			$ 190,994
Reject water haulage truck	1	EA	$ 100,000	$ 100,000
TOTAL CAPITAL COSTS				**$ 1,207,764**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
EDR Unit O&M				
Building Power	10,000	kwh/yr	$ 0.150	$ 1,500
Equipment power	60,000	kwh/yr	$ 0.150	$ 9,000
Labor	1,000	hrs/yr	$ 37.000	$ 37,000
Materials	1	year	$ 5,000	$ 5,000
Chemicals	1	year	$ 4,000	$ 4,000
Analyses	24	test	$ 200	$ 4,800
Subtotal				**$ 61,300**
Reject Disposal				
Disposal truck mileage	17,000	miles	$ 1.00	$ 17,000
Reject disposal fee	3,400	kgal/yr	$ 7.50	$ 25,500
Subtotal				**$ 42,500**
TOTAL ANNUAL O&M COSTS				**$ 103,800**

Table C.9

PWS Name *Birome WSC*
Alternative Name *Central Treatment - Adsorption*
Alternative Number *BR-9*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Adsorption Unit Purchase/Installation				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	1,200	SF	$ 60	$ 72,000
Building electrical	1,200	SF	$ 8	$ 9,600
Building plumbing	1,200	SF	$ 8	$ 9,600
Heating and ventilation	1,200	SF	$ 7	$ 8,400
Fence	-	LF	$ 15	$ -
Paving	3,500	SF	$ 2	$ 7,000
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Adsorption package including:				
4 Adsorption vessels				
E33 Iron oxide media				
Controls & instruments	1	UNIT	$ 280,000	$ 280,000
Backwash Tank	45,000	GAL	$ 2	$ 90,000
Sewer Connection Fee	-	EA	$ 15,000	$ -
Chlorination Point	1	EA	$ 2,000	$ 2,000
Subtotal of Component Costs				**$ 581,600**
Contingency	20%			$ 116,320
Design & Constr Management	25%			$ 145,400
TOTAL CAPITAL COSTS				**$ 843,320**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Adsorption Unit O&M				
Building Power	10,000	kwh/yr	$ 0.150	$ 1,500
Equipment power	6,000	kwh/yr	$ 0.150	$ 900
Labor	500	hrs/yr	$ 37	$ 18,500
Materials (Media replacement)	1	year	$ 27,000	$ 27,000
Analyses	24	test	$ 200	$ 4,800
Backwash discharge disposal	30	kgal/yr	$ 200	$ 6,000
Spent Media Disposal	12	CY	$ 20	$ 240
Subtotal				**$ 58,940**
Haul Backwash				
Waste haulage truck rental	5	days	$ 700	$ 3,500
Mileage charge	100	miles	$ 1.00	$ 100
Subtotal				**$ 3,600**
TOTAL ANNUAL O&M COSTS				**$ 62,540**

Table C.10

PWS Name ***Birome WSC***
Alternative Name ***Central Treatment - Coag-Filt***
Alternative Number ***BR-10***

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	1,200	SF	$ 60	$ 72,000
Building electrical	1,200	SF	$ 8	$ 9,600
Building plumbing	1,200	SF	$ 8	$ 9,600
Heating and ventilation	1,200	SF	$ 7	$ 8,400
Fence	-	LF	$ 15	$ -
Paving	3,500	SF	$ 2	$ 7,000
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Coagulant/filter package including:				
Chemical feed system				
Pressure ceramic filters				
Controls & Instruments	1	UNIT	$ 300,000	$ 300,000
Backwash Tank	30,000	GAL	$ 2	$ 60,000
Coagulant Tank	1,000	GAL	$ 3	$ 3,000
Sewer Connection Fee	-	EA	$ 15,000	$ -
Chlorination Point	1	EA	$ 2,000	$ 2,000
Subtotal of Component Costs				**$ 574,600**
Contingency	20%			$ 114,920
Design & Constr Management	25%			$ 143,650
Backwash water haulage truck	1	EA	$ 100,000	$ 100,000
TOTAL CAPITAL COSTS				**$ 933,170**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	10,000	kwh/yr	$ 0.150	$ 1,500
Equipment power	6,000	kwh/yr	$ 0.150	$ 900
Labor	1,000	hrs/yr	$ 37	$ 37,000
Materials	1	year	$ 2,000	$ 2,000
Chemicals	1	year	$ 5,000	$ 5,000
Analyses	24	test	$ 200	$ 4,800
Backwash discharge disposal	200	kgal/yr	$ 200	$ 40,000
Subtotal				**$ 91,200**
Haul Backwash				
Mileage charge	400	miles	$ 1.00	$ 400
Subtotal				**$ 400**
TOTAL ANNUAL O&M COSTS				**$ 91,600**

Table C.11

PWS Name ***Birome WSC***
Alternative Name ***Point-of-Use Treatment***
Alternative Number ***BR-11***

Number of Connections for POU Unit Installation 463

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POU-Treatment - Purchase/Installation				
POU treatment unit purchase	463	EA	$ 250	$ 115,750
POU treatment unit installation	463	EA	$ 150	$ 69,450
Subtotal				**$ 185,200**
Subtotal of Component Costs				**$ 185,200**
Contingency	20%			$ 37,040
Design & Constr Management	25%			$ 46,300
Procurement & Administration	20%			$ 37,040
TOTAL CAPITAL COSTS				**$ 305,580**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POU materials, per unit	463	EA	$ 225	$ 104,175
Contaminant analysis, 1/yr per unit	463	EA	$ 100	$ 46,300
Program labor, 10 hrs/unit	4,630	hrs	$ 37	$ 172,514
Subtotal				**$ 322,989**
TOTAL ANNUAL O&M COSTS				**$ 322,989**

Table C.12

PWS Name ***Birome WSC***
Alternative Name ***Point-of-Entry Treatment***
Alternative Number ***BR-12***

Number of Connections for POE Unit Installation 463

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POE-Treatment - Purchase/Installation				
POE treatment unit purchase	463	EA	$ 3,000	$ 1,389,000
Pad and shed, per unit	463	EA	$ 2,000	$ 926,000
Piping connection, per unit	463	EA	$ 1,000	$ 463,000
Electrical hook-up, per unit	463	EA	$ 1,000	$ 463,000
Subtotal				**$ 3,241,000**
Subtotal of Component Costs				**$ 3,241,000**
Contingency	20%			$ 648,200
Design & Constr Management	25%			$ 810,250
Procurement & Administration	20%			$ 648,200
TOTAL CAPITAL COSTS				**$ 5,347,650**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POE materials, per unit	463	EA	$ 1,000	$ 463,000
Contaminant analysis, 1/yr per unit	463	EA	$ 100	$ 46,300
Program labor, 10 hrs/unit	4,630	hrs	$ 37	$ 172,514
Subtotal				**$ 681,814**
TOTAL ANNUAL O&M COSTS				**$ 681,814**

Table C.13

PWS Name ***Birome WSC***
Alternative Name ***Public Dispenser for Treated Drinking Water***
Alternative Number ***BR-13***

Number of Treatment Units Recommended 4

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Public Dispenser Unit Installation				
POE-Treatment unit(s)	4	EA	$ 3,000	$ 12,000
Unit installation costs	4	EA	$ 5,000	$ 20,000
Subtotal				**$ 32,000**
Subtotal of Component Costs				**$ 32,000**
Contingency	20%			$ 6,400
Design & Constr Management	25%			$ 8,000
TOTAL CAPITAL COSTS				**46,400**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Treatment unit O&M, 1 per unit	4	EA	$ 500	$ 2,000
Contaminant analysis, 1/wk per ui	208	EA	$ 100	$ 20,800
Sampling/reporting, 1 hr/day	1,460	HRS	$ 37	$ 54,400
Subtotal				**$ 77,200**
TOTAL ANNUAL O&M COSTS				**$ 77,200**

Table C.14

PWS Name ***Birome WSC***
Alternative Name ***Supply Bottled Water to Population***
Alternative Number ***BR-14***

Service Population	1,356	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	494,940	gallons

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Implementation				
Initial program set-up	500	hours	$ 50	$ 24,778
Subtotal				**$ 24,778**
Subtotal of Component Costs				**$ 24,778**
Contingency	20%			$ 4,956
TOTAL CAPITAL COSTS				**$ 29,733**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water purchase costs	494,940	gals	$ 1.60	$ 791,904
Program admin, 9 hrs/wk	468	hours	$ 50	$ 23,192
Program materials	1	EA	$ 5,000	$ 5,000
Subtotal				**$ 820,096**
TOTAL ANNUAL O&M COSTS				**$ 820,096**

Table C.15

PWS Name ***Birome WSC***
Alternative Name ***Central Trucked Drinking Water***
Alternative Number ***BR-15***

Service Population	1,356	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	494,940	gallons
Travel distance to compliant water source (roundtrip)	15	miles

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Storage Tank Installation				
Storage Tank - 5,000 gals	4	EA	$ 7,025	$ 28,100
Site improvements	4	EA	$ 4,000	$ 16,000
Potable water truck	1	EA	$ 60,000	$ 60,000
Subtotal				**$ 104,100**
Subtotal of Component Costs				**$ 104,100**
Contingency	20%			$ 20,820
Design & Constr Management	25%			$ 26,025
TOTAL CAPITAL COSTS				**$ 150,945**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water delivery labor, 4 hrs/wk	832	hrs	$ 37	$ 31,000
Truck operation, 1 round trip/wk	3,120	miles	$ 1.00	$ 3,120
Water purchase	495	1,000 gals	$ 1.60	$ 792
Water testing, 1 test/wk	208	EA	$ 100	$ 20,800
Sampling/reporting, 2 hrs/wk	416	hrs	$ 37	$ 15,500
Subtotal				**$ 71,212**
TOTAL ANNUAL O&M COSTS				**$ 71,212**

APPENDIX D
EXAMPLE FINANCIAL MODEL

Table D.1 Example Financial Model

Water System	Birome
Funding Alternative	Bond
Alternative Description	New Well at Penelope

Sum of Amount		Year																					
Group	Type	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Capital Expenditures	Capital Expenditures-Funded from Bonds	$ -	$ 2,701,889	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Grants	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Revenue/Reserves	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ 2,701,889	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds		$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360
	State Revolving Funds		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
Debt Service Sum			$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360	$ 211,360
Non-Operating Income/Expenditures	Other Expense	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136
Non-Operating Income/Expenditures Sum		$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136	$ 1,136
Operating Expenditures	Administrative Expenses	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661	$ 13,661
	Contract Labor	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Other Operating Expenditures 1	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384	$ 35,384
	Other Operating Expenditures 2	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498	$ 68,498
	Professional and Directors Fees	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Salaries & Benefits	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259	$ 43,259
	Supplies	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126	$ 4,126
	Utilities	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812	$ 52,812
	O&M Associated with Alternative			$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510	$ 25,510
	Other Operating Expenditures 3	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318	$ 8,318
	Other Operating Expenditures 4	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444	$ 10,444
Operating Expenditures Sum		$ 236,502	$ 236,502	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012	$ 262,012
Residential Operating Revenues	Residential Base Monthly Rate	$ 234,077	$ 234,077	$ 474,891	$ 793,240	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774
	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		$ 234,077	$ 234,077	$ 474,891	$ 793,240	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774

Location_Name	Birome
Alt_Desc	New Well at Penelope

		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	$ 125,000	$ 47,773	$(240,814)	$(318,349)	$ (77,535)	$ 240,814	$ 559,163	$ 877,512	########	########	########	########	########	########	########	########	########	########	########	########	########	########
	Sum of Total_Expenditures	$ 237,638	$ 3,150,887	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508	$ 474,508
	Sum of Total_Receipts	$ 234,077	$ 2,935,966	$ 474,891	$ 793,240	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774	$ 870,774
	Sum of Net_Cash_Flow	$ (3,561)	$ (214,921)	$ 383	$ 318,732	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266	$ 396,266
	Sum of Ending_Cash_Bal	$ 121,439	$ (167,148)	$(240,431)	$ 383	$ 318,732	$ 637,081	$ 955,429	########	########	########	########	########	########	########	########	########	########	########	########	########	########	########
	Sum of Working_Cap	$ 39,417	$ 39,417	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669	$ 43,669
	Sum of Repl_Resv	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249	$ 34,249
	Sum of Total_Reqd_Resv	$ 73,666	$ 73,666	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918	$ 77,918
	Sum of Net_Avail_Bal	$ 47,773	$ (240,814)	$(318,349)	$ (77,535)	$ 240,814	$ 559,163	$ 877,512	########	########	########	########	########	########	########	########	########	########	########	########	########	########	########
	Sum of Add_Resv_Needed	$ -	$ (240,814)	$(318,349)	$ (77,535)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	103%	67%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0
	Sum of Percent_Rate_Increase	-5%	-5%	93%	222%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%	253%

APPENDIX E
GENERAL ARSENIC GEOCHEMISTRY

Geochemistry of arsenic is complex because of (1) possible coexistence of two or even three redox states; (2) complex chemistry of organo-arsenicals; and (3) strong interaction of most arsenic compounds with soil particles, particularly iron oxide (and to a lesser degree aluminum and manganese oxide). Fully deprotonated arsenate AsO_4^{-3} is the expected form of arsenic in most soil under aerobic conditions only at high pH (Figure E.1). At more neutral and acid pH's, $HAsO_4^{-2}$ and $H_2AsO_4^{-1}$ forms, respectively, are dominant. General understanding of arsenic mobility in soil and aquifers is that it increases 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 similar to that of arsenates and sorb to soil, preferentially 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, arsenite ion H_3AsO_3 is most stable. Lack of charge renders the ion more mobile and less likely to sorb to soil particles. Arsenite is stable throughout the pH range from acid to alkaline. The first deprotonated form, $H_2AsO_3^{-1}$, exists at significant concentrations only above a pH of approximately 9. Redox processes seem to be mediated by microorganisms (Welch, *et al.* 2000) and to take place adjacent 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 associated minerals. Arsenic metal –As(0)- rarely occurs. Methylated arsenic compounds are generally present at low aqueous concentrations (<1 ppb), 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 or mildly reducing conditions, except perhaps if barium is present (Henry, *et al.* 1982, p. 21). This situation is in contrast to that of other companion oxyanions, which are not as mobile under reducing conditions, except vanadium. In reducing conditions, arsenic precipitates as arsenopyrite (FeAsS), although more commonly in solid solution with pyrite.

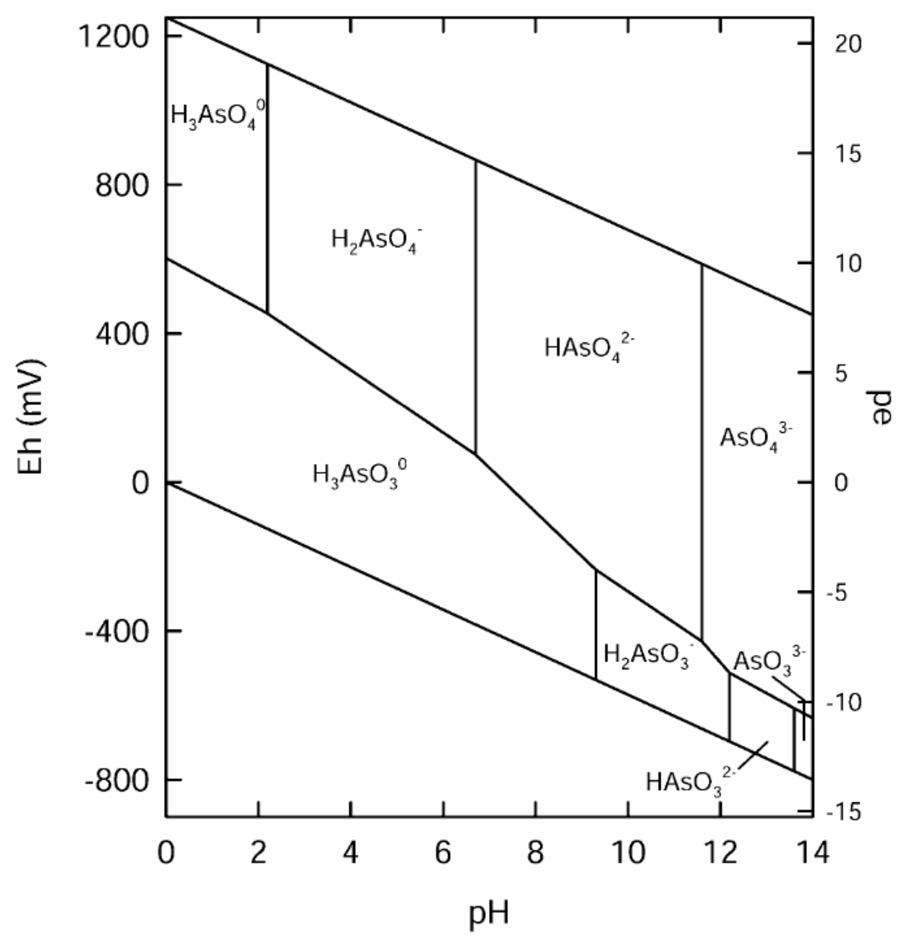

Figure E.1 Eh-pH Diagram for Arsenic Aqueous Species in the As-O_2-H_2O System at 25°C and 1 bar (from Smedley and Kinniburgh 2002)

Appendix References

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