Freese AND Nichols, INC.
CONSULTING ENGINEERS

May 26, 1988

Mr. Dwayne Hargesheimer
Director of Water Utilities
City of Abilene
P.O. Box 60
Abilene, Texas 79604

Re: Water Reclamation
Research Project
Final Report
ABL 86233/2.10
TWDB Contract No. 55-61027

Dear Mr. Hargesheimer:

We are pleased to submit our report entitled Water Reclamation Research Project. The document is in two parts: the Summary Report and the Technical Memoranda. The Summary Report discusses each aspect of the research study and provides a condensed version of study findings. Detailed technical data are included, in memorandum form, in the accompanying Technical Memoranda. All recommendations included in this report further the goals of protecting the quality and aesthetic characteristics of the receiving streams and lakes, and the health and safety of users of these waters.

The research project concluded that water reclamation was technically and economically viable for the City of Abilene. As such, Abilene is encouraged to pursue water reclamation, along with other conventional water supply options, in meeting their overall water supply needs.

The recommended course of action is to construct a 3 mgd water reclamation plant discharging to a tributary of Lake Fort Phantom Hill and developing a non-potable water supply system. If the City of Abilene constructs the Westside WWTP described in the May 1987 Wastewater Collection System Analysis, City of Abilene, Texas, it is recommended the plant be constructed as a water reclamation facility. If the Westside WWTP is not constructed, the water reclamation improvements can be integrated into the existing Hamby WWTP, although at a higher overall cost.

In the report, a discussion is presented on the water rights issues associated with a water reclamation project. They are a major consideration and should be resolved during the initial stages of program implementation.

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We appreciate very much your assistance and the aid of Mr. Alton Hughes and his laboratory staff, Ms. Cindy Manning, Ms. Linda Simpson and others of the City of Abilene in preparing this study.

We would like to acknowledge the participation of CH2M-Hill, Dr. J.L. Melnick and Dr. T.J. Metcalf of the Baylor College of Medicine, and researchers at Fairleigh Dickinson Laboratories, Inc., as well as the members of the Public Advisory Committee for their input and guidance. We look forward to working with you in implementing the proposed improvements.

Very truly yours,

FREESE AND NICHOLS, INC.

Raymond R. Longoria

Raymond R. Longoria, P.E.
Project Manager

RRL:pka.01
enclosure

SUMMARY REPORT

Water Reclamation Research Project

TEXAS WATER DEVELOPMENT BOARD

AND

CITY OF ABILENE, TEXAS

TWDB CONTRACT NO. 55-61027

MAY 1988

Freese AND Nichols, INC.
CONSULTING ENGINEERS

CH2M HILL

John H. Cook
STATE OF TEXAS
JOHN H. COOK
29496
REGISTERED PROFESSIONAL ENGINEER
May 20, 1988

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ABILENE WATER RECLAMATION RESEARCH PROJECT

EXECUTIVE SUMMARY

The Abilene Water Reclamation Research Project investigated the technical and economic feasibility of reclaiming wastewater to supplement the City's water supply and to reduce potable water demand by providing an alternative supply of turf irrigation water. The challenges of reclaiming water in Abilene are similar to those that have been confronted elsewhere. Successful reclamation projects currently in operation supplement the drinking water supply in El Paso, Texas; Alexandria, Virginia; Tampa, Florida, and other cities. The success of these projects was a factor in the research team's finding that water reclamation was both feasible and desirable for the City of Abilene.

Major conclusions of the study include the following:

- Reclaimed water can be safely produced and used. Design criteria include use of proven treatment processes, redundancy of key treatment units, and multiple barriers to preserve the water quality of the receiving reservoir. By discharging reclaimed water into a tributary several miles from Lake Fort Phantom Hill, an extra margin of safety is provided.
- Use of a combination of proven biological phosphorus and alum coagulation treatment processes will produce reclaimed water that meets all state and federal water quality standards and will maintain or improve the quality of the receiving stream

and Lake Fort Phantom Hill.

- A full-scale pilot reclamation facility with a total capacity of 3 million gallons per day (mgd) is recommended.
- A 3 mgd discharge of reclaimed water would have minimal or benefical impacts on water quality in Lake Fort Phantom Hill.
- The cost of producing reclaimed water under the recommended alternative is comparable to the $.67 per 1,000 gallons estimated for the increased supplies from Hubbard Creek Reservoir. If the terms to obtain the water rights are favorable the total cost would probably be less than $0.67 per 1,000 gallons.
- Water reclamation for turf irrigation is also recommended. This use may be limited to sites with controlled access when it is deemed appropriate. Up to 500,000 gallons per day of turf irrigation water would be available.
- The initial turf irrigation supplies provided under the recommended alternative would supplant the use of potable supplies which now cost industrial users $1.25 per 1,000 gallons.
- To meet long-term demand, all means of increasing water supply, including use of Stacy Reservoir, conservation, and water reclamation, will need to be exploited.

The recommended course of action is:

<u>PHASE I</u>

a) Construct a 3 mgd reclamation facility providing 1.5 to 2 mgd of supplemental supply to a tributary of Lake

Fort Phantom Hill. (Cost: $10 million to $12 million.)

b) Construct a pipeline from the tributary reclamation facility to Dyess Air Force Base. The pipeline would provide 500,000 gpd of turf irrigation to the Base. Also install an 825,000 gpd water treatment facility at Kirby Lake to improve the quality of the turf irrigation water presently drawn from Kirby Lake. (Cost: $500,000 to $600,000.)

PHASE II

a) Expand the 3 mgd reclamation facility to 7 mgd. (Cost: $9 million to $10 million.)

b) Construct infrastructure works that would provide reclaimed turf irrigation water to the east, south and west sides of Abilene. (Cost: $1.6 million.)

The proposed reclamation works may be built as a new Tributary plant or as a modification of the Hamby Wastewater Treatment Plant. The additional pipelines and infrastructure required by the Hamby alternative would add about $9 million to overall project costs.

The most attractive sources of financing appear to be the State Revolving Fund and/or certificates of obligation with ad valorem tax and a pledge of revenue surplus.

The primary benefits to the City of Abilene of undertaking these projects would be to:

- Increase raw water supply in Lake Fort Phantom Hill by 1.5 to 2 mgd or enough to supply about 3,000 new homes.
- Provide higher quality water to a tributary to Lake Fort

Phantom Hill, enhancing the tributary's water quality.

- Allow the City to develop expertise in managing water reclamation facilities, thus beginning to develop a resource that will become increasingly important over time.
- Provide up to 500,000 gpd in high quality turf irrigation water in the short term, and up to 2.2 mgd of turf irrigation supply over the longer term, thereby reducing potable water demand by a corresponding amount. Over the long term, this supply also opens up the potential for developing urban water vistas and other aesthetic features in Abilene.

All recommendations included in this report further the goals of protecting or enhancing the quality and aesthetic characteristics of streams, lakes and reservoirs. The potential for development of algal blooms, accelerated eutrophication and undesirable taste and odor will be controlled in the treatment processes by limiting the levels of nitrogen and phosphorus in reclaimed water.

The water rights issues associated with implementation of this water reclamation project are a major consideration, and these concerns have not been fully resolved. Water rights are essentially a legal matter, and the research investigation was not intended to resolve them. For purposes of this study, it has been assumed that Abilene would have a valid claim to the reclaimed water if used for municipal purposes through the City's potable water distribution system. Water rights associated with non-potable reuse for turf irrigation are believed to be a more complex subject, based on Abilene's previous experience with such rights at the Hamby plant. If the City elects to proceed with this project, it is recommended that the water rights be addressed as soon as possible, since they are of fundamental importance to the feasibility of the reuse concept.

The summary report discusses each aspect of the research study and provides a condensed version of the study findings. Detailed technical data gathered and analyzed for the project, together with a discussion of methodology, are included in the accompanying Technical Memoranda, which as a group comprise the Appendix to this report.

The Abilene Water Reclamation Research Project was undertaken jointly by the City of Abilene and the Texas Water Development Board, which contracted with a research team led by the consulting engineering firm of Freese and Nichols, Inc., and including CH2M HILL, Drs. J. L. Melnick and T. J. Metcalf of the Baylor College of Medicine, and researchers at Fairleigh Dickinson Laboratories, Inc. Mr. Dwayne Hargesheimer, the City's Director of Water Utilities, directed the research team. A seven-member Public Advisory Committee of selected Abilene citizens provided guidance during the project and visited water reclamation projects in other cities.

1. PROJECT DEFINITION AND FORMATION

The City of Abilene and the Texas Water Development Board have maintained policies of seeking out additional water supplies to meet the growing needs of Texas homes and industries. This study was undertaken as a part of those ongoing efforts to ensure that a lack of water does not constrain future growth and development.

1.1 Project Objectives and Goals

The overall goal of this project was to plan, test, and verify the feasibility of reclaiming water from wastewater as a resource for augmenting the Abilene potable water supply and for reducing current demand for potable water supplies.

The specific objective was to identify a system of treatment processes for reclamation that could be implemented by the City of Abilene without detrimental effects to water quality.

Abilene is situated in a water-short area and is located entirely within the watershed that feeds its primary water supply reservoir, Lake Fort Phantom Hill. The first condition motivates the City to pursue the evaluation of non-conventional means for developing water supplies and the second motivates a desire for high quality product water and highly reliable treatment process performance.

Additional objectives and goals included:

- Providing a meaningful increase in water supply.
- Preventing adverse effects on water quality in Lake Fort Phantom Hill which would limit its potential uses.
- Complying with state and federal water quality regulations on

wastewater effluent discharges.

- Providing a source of drinking water of equal or higher quality than that currently produced.
- Maintaining or enhancing the aesthetic conditions of waters in Lake Fort Phantom Hill.
- Reducing or preventing increases in public health risks associated with the potable water supply and the wastewater treatment and disposal system.
- Recommending implementation of water reclamation only if it is shown to be economically favorable.
- Selecting treatment technology consistent with the City's operations and maintenance capabilities.
- Investigating non-potable water reuse options to reduce demands on the potable water supply.
- Securing public involvement and participation in the development and execution of the project.

Additional information on project objectives and goals and a statement of the problem and research methodology appears in Technical Memorandum No. 1.

1.2 Public Participation

Two avenues were provided for public participation. First, a Public Advisory Committee (PAC) was formed as an advisory group to the City of Abilene and the research team. Second, a public meeting was held to provide a forum for the whole community to discuss the project.

The PAC's charter was to review and comment on the study and to make recommendations to the City on potential projects. The PAC also served to reflect the interests of the community.

The PAC consisted of seven Abilene citizens of diverse backgrounds. The members were:

Jackie Cox	-	Geologist
Jeanette Davis	-	Former State Board Member, League of Women Voters
George Dawson, M.D.	-	General practitioner in family medicine
Dr. Terry Foster	-	Director, Biomedical Division, Fairleigh Dickinson Laboratories, Inc.
Bill Hollowell, P.E.	-	Professional engineer, Tippett and Gee, Inc.
Harold Nixon	-	City Council member and businessman
Dr. Clark Stevens	-	Professor emeritus of biology, Abilene Christian University

Ms. Davis was elected chairperson at the initial meeting and presided at the remaining meetings.

Regular meetings were held at various stages in the project. The subjects covered were as follows:

Meeting 1	April 15, 1987	PAC formation; discussion of objectives.
Meeting 2	July 23, 1987	Baseline physical and water quality data.
Meeting 3	August 23, 1987	Water quality effects and proposed concepts to be developed.
Meeting 4	September 24, 1987	Water quality standards and evaluation of

		process alternatives.
Meeting 5	October 15, 1987	Presentation of the draft report.
Meeting 6	January 13, 1988	Presentation of revised final draft report and discussion of public meeting format and content.
Public Meeting	February 23, 1988	Presentation of draft final report in an open forum.

The final draft summary report was made available to the public prior to the public meeting held on February 23, 1988 to enable interested parties to study the issues presented.

PAC members also participated in field orientation visits to three operating water reclamation projects: Fred Hervey Water Reclamation Plant in El Paso, Texas; Upper Occoquan Regional Water Reclamation Plant in northern Virginia; and the Denver Metro Water Reclamation Full-Scale Pilot Plant.

Additional information on PAC meetings and activities appears in Technical Memorandum No. 2 in the Appendix to the final report.

1.3 Is Water Reclamation Needed?

The City of Abilene has been subject to water shortages of various intensities in recent years. The severe drought of 1984 was a key factor in the development of this water reclamation research project. Despite these circumstances, the question "Is Water Reclamation Needed?" was the logical starting point for the study.

The research team assembled to review the question and assess the merits of embarking on a full-scale water reclamation program.

The question was taken in two parts. The first issue addressed was whether an increase in water supply was needed, regardless of source. The second issue was whether conventional sources of water supply could meet the water demand.

A major conclusion drawn was that all potential water resources available to Abilene need to be developed. This was clear to the City administrators when they initiated the steps leading to the current project. It was clear to the research team from their review of the historical and long-term water supply picture in Abilene and West Texas in general.

The research team identified and discussed several alternatives for meeting the City's needs. Some involved reclaiming wastewater, others did not. The "non-reclamation" alternatives were found to be unwarranted or inconsistent with the City's goals and objectives. The first non-reclamation alternative centered around a conventional wastewater treatment plant that would divert effluent around Lake Fort Phantom Hill. The cost would be low, but this alternative did nothing to promote the City's goal of increasing overall water supply. The second alternative involved earlier-than-planned construction of the supply line from Stacy Reservoir. Viewing the overall water supply picture, it became apparent that Stacy was not an alternative to water reclamation, or vice versa. Rather, the two projects complement each other.

The research team accepted the conclusions of previous studies which had evaluated groundwater and brackish water supplies, and found them to be inadequate or economically undesirable.

The research team resolved that water reclamation was needed in Abilene and proposed development of this source after careful evaluation of its technical and economic feasibility and acceptability in terms of health risks. The following section evaluates various reclamation alternatives based on these criteria.

The City's water supply is not in immediate danger of depletion. Lake Fort Phantom Hill and Hubbard Creek Reservoir have reliable yields. A parallel pipeline from Hubbard Creek Lake is under construction and the City has secure commitments on water supply from Stacy Reservoir. Should a reuse alternative be found acceptable in terms of health, economic, and technical feasibility, the challenge would then be to establish when and how to incorporate water reclamation into the overall water supply equation.

Economically, it is desirable to implement water reclamation in conjunction with planned wastewater collection and treatment plant improvements. A report prepared in May 1987 under separate contract, the Wastewater Collection System Analysis, defined two such opportunities.

The objective of that report was to recommend improvements to the wastewater collection system to meet the future needs of the City. Two alternatives were identified. The first involved upgrading the collection system to convey the wastewater to the existing Hamby WWTP and expand the treatment plant as necessary. The second involved construction of a new wastewater treatment plant located near where the future wastewater flow increase was expected to occur. The improvements under each alternative were divided into implementation phases. Based on the growth projections, the first phase was targeted for completion in 1992 and the second in 1998.

The water reclamation research team chose to parallel the alternatives suggested in the collection system report and to adopt the implementation schedule proposed in that report. The advantages and disadvantages of the alternatives are described in detail in Section 3, Water Reclamation Evaluation and Selection.

A primary motivation in paralleling the implementation plan of the previous report was the flexibility allowed by the phasing. Wastewater treatment plant improvements are targeted for both phases. Although the following evaluation presumes incorporation of water reclamation in the first phase, it is possible to defer water reclamation until the second phase. The cost of implementing the first phase of a water reclamation system would be approximately $1.5 million more than the cost of a conventional wastewater treatment plant. Section 3 of this report includes estimates of probable cost for the alternatives studied.

1.4 Is Water Reclamation Technically Feasible?

The planned reuse of domestic wastewater has been practiced for many years in the United States and undoubtedly will play an increasing role as water becomes scarce in the future. A majority of the existing projects generate water for nonpotable uses, such as turf irrigation; however, several supplement potable water supplies. Some of these facilities are located in El Paso, Texas; Alexandria, Virginia; Tampa, Florida; and Denver, Colorado.

The Fred Hervey Water Reclamation Plant in El Paso, Texas is a 10 mgd plant that discharges into the Hueco Bolson aquifer. The reclaimed water helps to recharge the dwindling aquifer, which is the City's primary water supply source.

The Upper Occoquan Sewage Authority (UOSA) water reclamation plant in Alexandria, Virginia, most closely resembles the project concept for the Abilene Water Reclamation Research project. The UOSA plant reclaims up to 15 mgd of water, which is discharged to Bull Run Creek. The creek is a tributary of the Occoquan Reservoir, the primary source of drinking water for nearly three-quarters of a million residents of northern Virginia.

The Hookers Point Supplemental Treatment Facility is capable of providing 20 mgd of reclaimed water to supplement the water supply for Tampa, Florida. The reclaimed water is discharged to the Tampa Bypass Canal, then pumped to the Hillsborough River approximately five miles upstream of the City's water treatment plant.

The City of Denver Metro plant is a demonstration plant producing 1 mgd of potable water. Presently, the water is not introduced into the Denver potable water supply. It is part of a research project evaluating the feasibility of introducing reclaimed water directly into the potable water system instead of indirectly to a large aquifer like the Hueco Bolson or a large lake such as the Occoquan Reservoir.

All of these projects include extensive water quality monitoring, both of the reclaimed water and the receiving waters. Each of these plants has a good track record in performance and reliability, supporting the concept that water reclamation is technically feasible.

2. BASELINE DATA

2.1 Basic Data Development

Data gathered at the outset of the project were selected to help determine current and future water demand, water quality, and treatment capacity and requirements. Such factors as population growth, climate, reservoir yields, and the results of past water quality monitoring were studied. Information was summarized in fact sheets that were combined into a single document, which appears as Technical Memorandum No. 3 in the Appendix.

The data developed were used as the basis of evaluating the need for water reclamation and the adequacy of potential treatment processes, and also provided a context within which alternatives were considered.

The data summarized below point to the continuing, long-term need to seek out and develop all feasible means of developing additional water resources and of conserving water whenever possible.

Population. Population projections developed for the City of Abilene's 1987 Wastewater Collection System Analysis estimate the City's current population at 113,000. The entire population is served by the City water system, and an estimated 112,659 people are served by City sewers. Low and high projections of future population were made and used to estimate the most probable level of growth.

The low population projection was based on a growth rate of one percent per year, while the high projection assumes a two percent annual rate. The year 2005 population is thus estimated at between

136,500 and 166,800 people. In a 1980 study of long-range water supply conducted for Abilene and the West Central Texas Municipal Water District, Freese and Nichols used 1978 Texas Water Development Board (TWDB) projections of growth slightly greater than 1 percent per year. More recent (1982) TWDB projections predict growth between 1.0 and 1.3 percent per year. Growth in the early to mid-1980's approached 2 percent. However, long term growth in the past twenty years has been closer to 1 percent. The research project team concluded that the longer-term trend was more indicative of probable future growth. The historical and projected probable population is shown on Figure 2.1.

Climatological Data. Abilene is in a semi-arid region, with normal annual rainfall of 23 inches, mostly occurring in the spring and fall. Thunderstorms account for most of the precipitation. The mean maximum monthly temperature in July is 94°F, and the mean minimum temperature in January is 33°F. The harsh climate leads to major seasonal variations in water demand and to the need for careful water resource planning.

Existing Models of Lake Fort Phantom Hill. A number of studies of Lake Fort Phantom Hill have been conducted to analyze reservoir yield, water quality, pumping costs, and coordinated operation with Hubbard Creek Reservoir. The findings and assumptions used in models developed for the following studies were reviewed and used as a foundation for the Water Quality Model prepared for the research project.

- Report on Lake Fort Phantom Hill Yield. (1976)

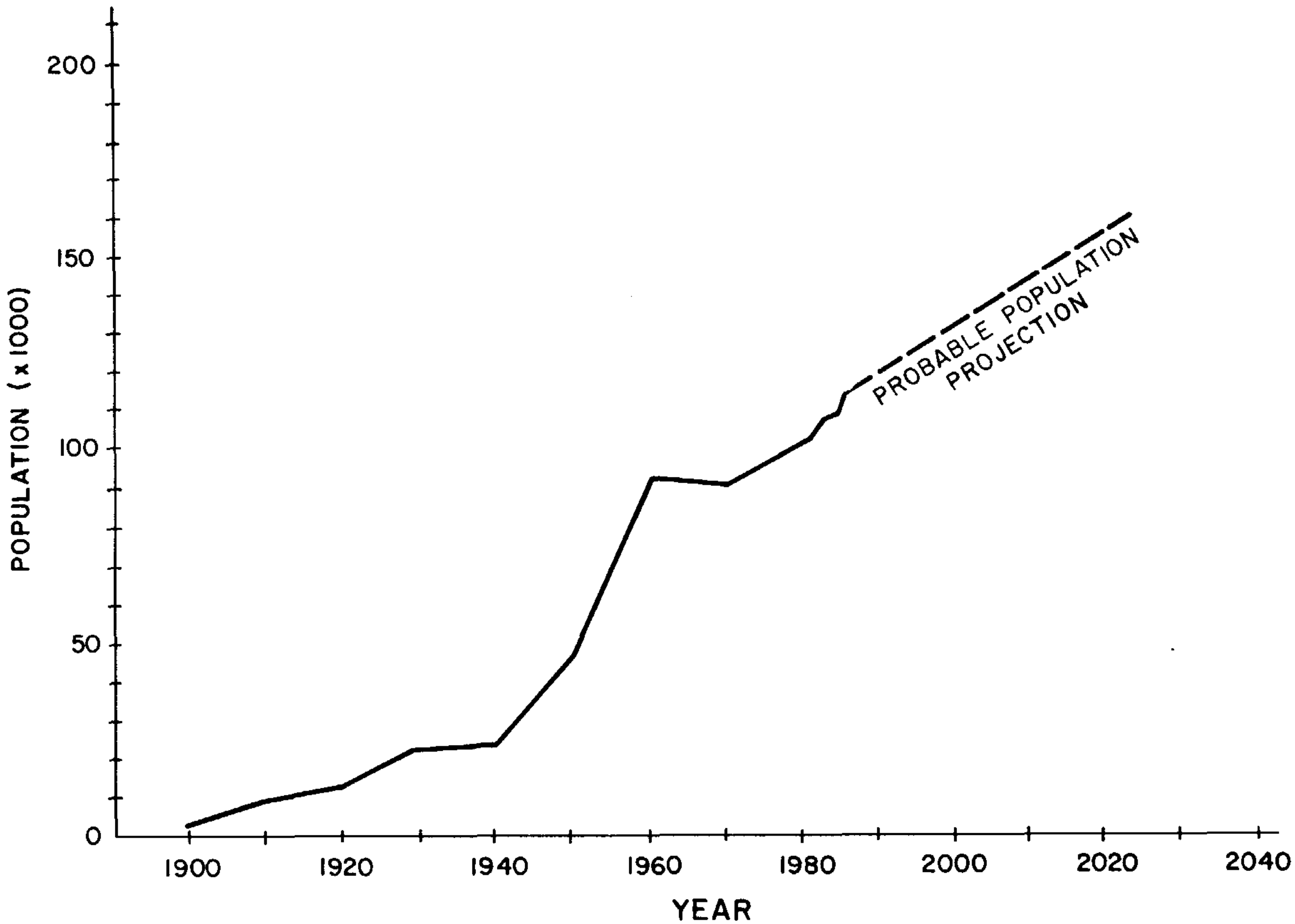


FIGURE 2.1
HISTORIC AND PROJECTED POPULATION
CITY OF ABILENE, TEXAS
FEBRUARY 1988

- Study of Coordinated Operation of Existing Raw Water Supply Sources and Study of Long-Range Water Supply. (1980)
- Evaluation of the Use of Brackish Water and Reclaimed Wastewater for Long-Range Water Supply. (1984)

The only water quality parameter previously modeled for the lake was total dissolved solids (TDS). Modeling for the research project showed the concentrations of TDS should remain at acceptable levels for the assumed conditions.

Historical Water Quality. The historical water quality of Lake Fort Phantom Hill is covered in Section 2.2, Water Quality Assessment.

Water Supply and Demand. The City of Abilene Water Utility Department provides potable water for the City, including residential/ commercial users and major industrial customers, and also sells water to various cities and water corporations in the area. Water supply is principally from Lake Fort Phantom Hill, Hubbard Creek Reservoir, and Lake Abilene. The City also has water rights at other sources as described later in this section.

Figure 2.2 shows existing water supply sources and treatment plants.

Based on analysis of historical water use conducted for a 1980 study of long-range water supply and for an ongoing study of the economy of system operations, projections of future water use have been developed for Abilene and for the entire West Central Texas Municipal Water District. Figure 2.3 shows the projected demands for Abilene through 2030.

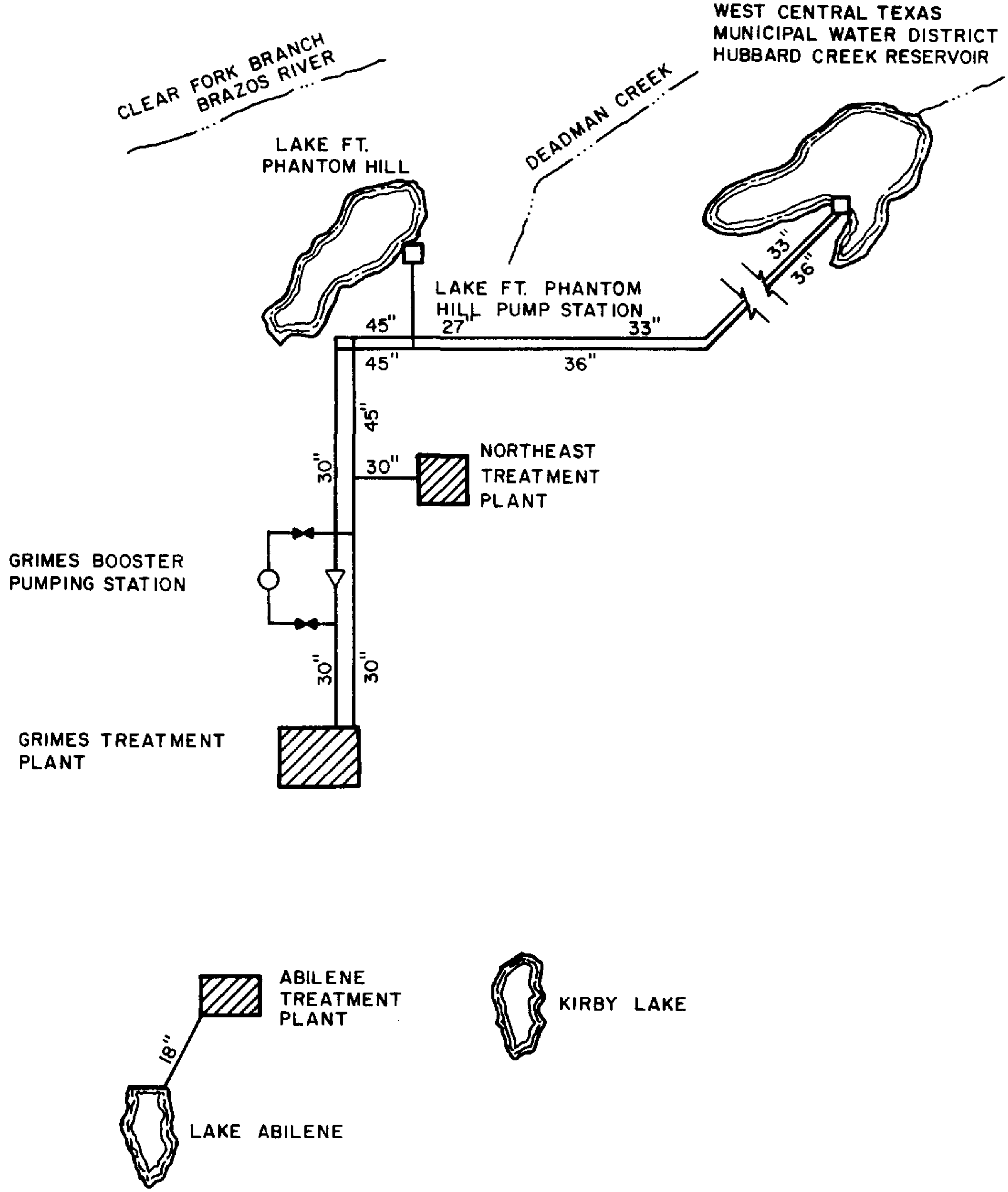


FIGURE 2.2
POTABLE WATER SUPPLY & TREATMENT FACILITIES

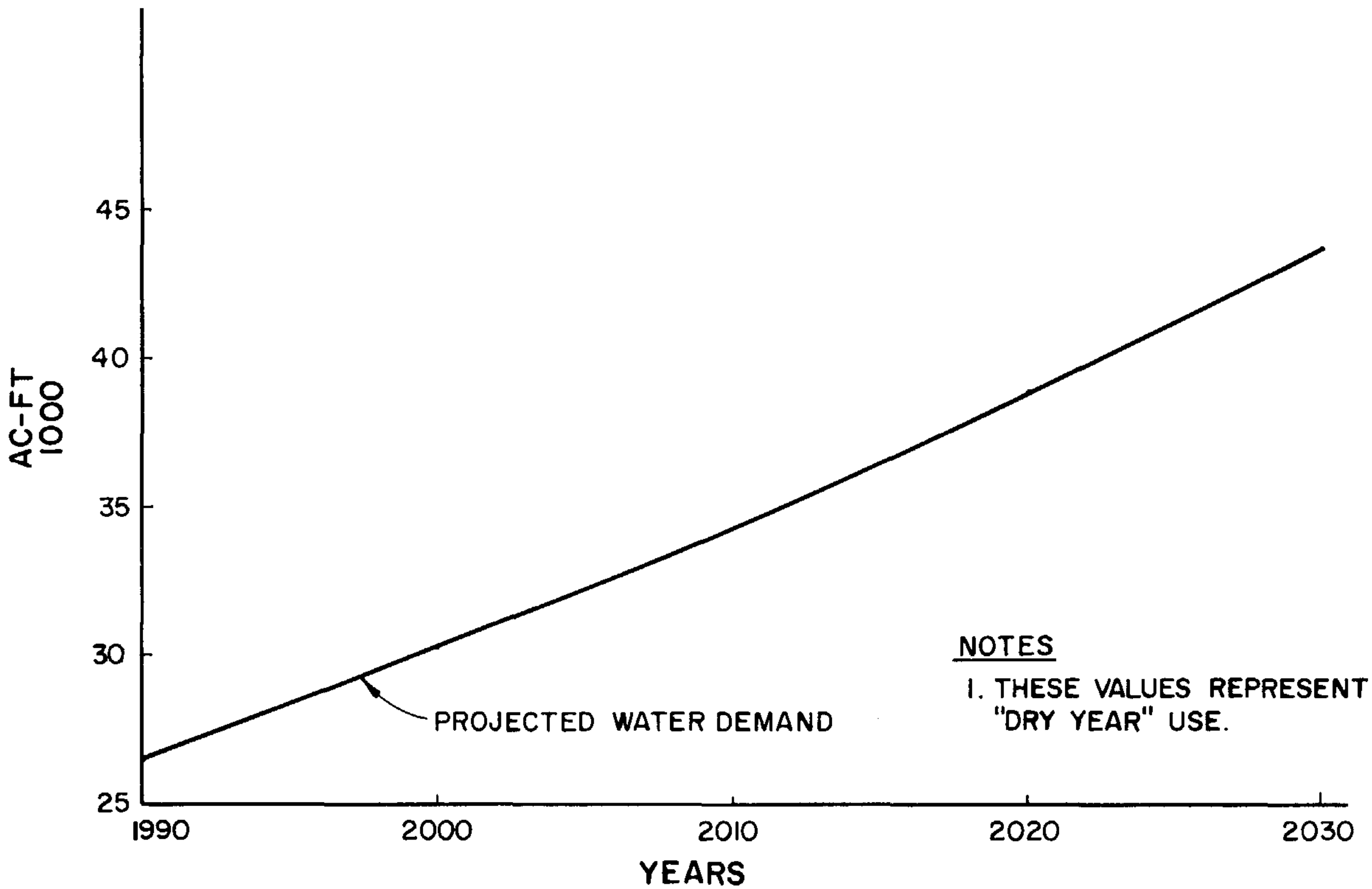


FIGURE 2.3
WATER SUPPLY DEMAND

The ratio of peak-day to average-day demand calculated in this study was 1.89, down from the historical value previously identified in the 1978 water system report. This decrease in peak usage appears to be due to the recently adopted water conservation program. The total average-day demand for Abilene was 22.18 million gallons per day (mgd) in 1985 and is projected to reach 28.79 mgd by 2005.

Water Conservation Program. The City of Abilene began a systematic water conservation program in 1983. A public education program was conducted, and a Water Conservation Ordinance, a Drought Contingency Plan and, in 1986, a broad-based Water Management Plan were adopted. A Water Conservation Advisory Committee and a Xeriscape Advisory Committee were formed to promote the goals and objectives of the Water Management Plan, including the development, management, conservation, and protection of the City's water resources.

Seasonal variations in water consumption began to decline in 1983. The peak-day to average-day ratio prior to 1982 was 2.52, while the post-1982 ratio was 1.89. Although much of the decrease can be attributed to weather and the loss of some industries, it appears that water conservation measures have reduced demand about 5 to 10 percent.

While water conservation efforts of all kinds can and should continue to contribute toward ensuring adequate water supplies, demand created by ongoing economic and population growth is such that conservation alone cannot solve future water supply problems.

Water Treatment Plant Capabilities. The City of Abilene is served by three surface water treatment plants:

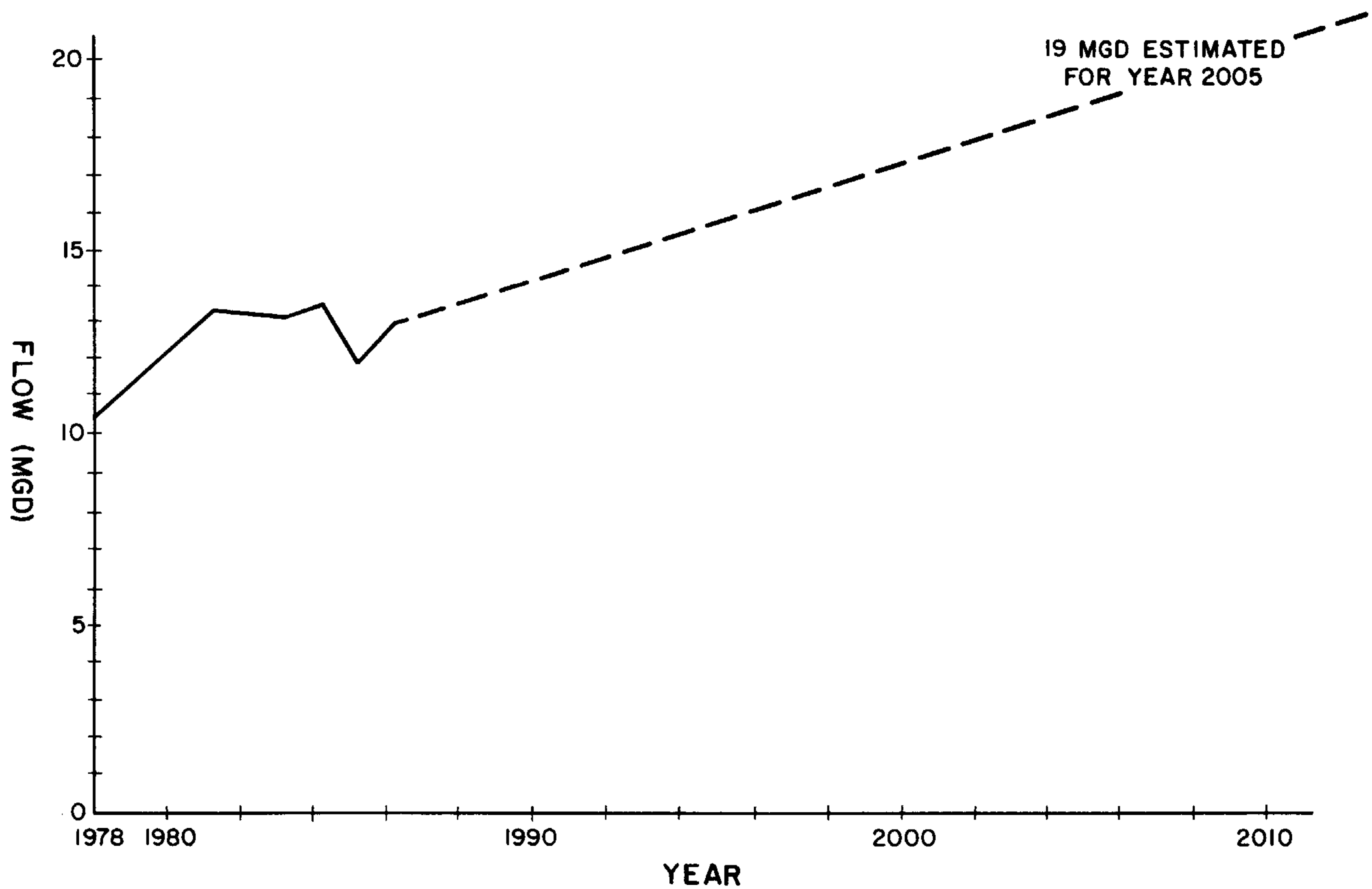
Name:	Northeast	Grimes	Abilene
Capacity:	24 mgd	25 mgd	3 mgd
Lime softening:	Yes	No	No
Principally Supplied by:	Lake FPH	Lake FPH	Lake Abilene

Locations of the three facilities are shown in Figure 2.2. The Northeast and Grimes WTPs produce more than 90 percent of the potable water for Abilene each year. Both have a back-up supply of up to 15 mgd available from Hubbard Creek Reservoir when necessary. During winter months when water demand is low, the Grimes and Abilene plants are only partially utilized or taken completely off-line.

Current estimates indicate that water treatment capacity will be adequate to serve Abilene's needs until the 1995 to 2000 year range.

Wastewater Flows and Quality. Wastewater from throughout the system flows to the Buck Creek Lift Station located northeast of town. It is then pumped five miles to the Hamby Wastewater Treatment Plant (WWTP). The average flow to the plant in 1986 was 13.0 mgd. Based on the population estimates and projections used, the estimated wastewater flow for the year 2005 is 19.0 mgd. Historical and projected flows are shown in Figure 2.4.

The wastewater treated at Hamby WWTP is characterized as a moderately strong waste that is primarily domestic sewage. During periods of heavy rainfall, the incoming wastewater is diluted to a level categorized as weak. Typical values for key wastewater constituents and the average values of the key wastewater parameters for wastewater



CITY OF ABILENE, TEXAS
JULY, 1987

FIGURE 2.4
HISTORIC AND PROJECTED WASTEWATER FLOW

FREESE AND NICHOLS, INC.

flowing to Hamby WWTP are as follows:

Constituent	Typical Composition of Untreated Domestic Wastewater (mg/l)	Average Abilene Values (mg/l)
Biochemical Oxygen Demand (BOD_5)	220	236
Total Suspended Solids (TSS)	220	191
Total Organic Carbon (TOC)	160	71
Chemical Oxygen Demand (COD)	500	460
Ammonia-Nitrogen (NH_3-N)	25	26

Wastewater Treatment Plant Capabilities. Hamby WWTP handles the entire wastewater flow from the City of Abilene. The plant is a conventional activated sludge plant rated at 13.4 mgd daily flow/24 mgd peak flow.

Most of the effluent from the plant is discharged to Freewater Creek which flows into Deadman Creek and eventually to the Brazos River. A part of the effluent is used for irrigation of adjoining crop lands. No wastewater effluent flows into Lake Fort Phantom Hill.

The Texas Water Commission's permit for the Hamby WWTP allows plant effluent with maximum levels of:

20 mg/l of BOD5

20 mg/l of TSS

1.0 mg/l of chlorine residual

These are common effluent limits and can be consistently achieved by a conventional secondary treatment facility like the Hamby WWTP. These limits are compatible with discharge to the current receiving stream but would not be acceptable for discharge to a drinking water reservoir like Lake Fort Phantom Hill.

Water Rights. The City of Abilene currently obtains water supplies from a number of sources, including Lake Abilene, Lake Fort Phantom Hill, the Clear Fork of the Brazos River, Deadman Creek, and Hubbard Creek Reservoir. In the future, the City plans to obtain water from Stacy Reservoir.

A summary of the water rights for municipal use is shown in Table 2.1. Abilene holds other water rights for recreational purposes and back-up supplies as described in Technical Memorandum No. 3.

2.2 Water Quality Assessment

An evaluation of the historic water quality of Lake Fort Phantom Hill, supplemented by an intensive program to monitor current water quality, was fundamental to the development and calibration of a valid water quality computer model. Technical Memorandum No. 4 presents the results of this effort. A summary of the findings is presented later in this section.

Lake Fort Phantom Hill has a surface area of approximately 4,000 acres and a volume of 69,000 acre-feet at the top of the conservation pool. It receives runoff from a 470-square-mile watershed, some of which is controlled by Lake Abilene and other upstream impoundments. Elm and Cedar Creeks are the major tributaries.

The yield of the reservoir is supplemented by diversions of up to 30,000 acre-feet per year from the Clear Fork of the Brazos River when water quality from that source is suitable, and occasionally from Dead-

Table 2.1[1]

Summary of Water Rights
City of Abilene

Rights Held by Abilene Used for Municipal Water Supply

Permit No.	Source	Quantity
1249 A[2]	Lake Fort Phantom Hill (LFPH) Diversions from Clear Fork of Brazos River to Lake Fort Phantom Hill	20,690 ac. ft. (municipal) 10,000 ac. ft. (industrial)
1481 C	Diversions from Clear Fork of Brazos River to Lake Fort Phantom Hill	30,000[2] ac. ft.
253	Lake Abilene	1,675 ac. ft.
1726	Diversion from Deadman Creek	3,000 ac. ft.

Water Supply Contracts

1890[3]	Contract Flow from Hubbard Creek Reservoir	1.5 mgd
3866A[4]	Contract Flow from Stacy Reservoir	15,000 ac. ft.

NOTES:

[1]Miscellaneous additional rights for recreation, cooling water, etc. are not shown.

[2]The diversions are for later use and are not considered in addition to the LFPH water rights.

[3]Held by West Central Texas MWD.

[4]Held by Colorado River MWD.

man Creek. To prevent taste and odor problems resulting from stratification of the water, the City has installed an aeration system within the lake which keeps the reservoir relatively well-mixed.

The Texas Water Commission has designated Lake Fort Phantom Hill as Segment 1236 of the Brazos River Basin and has established specific numerical criteria for water quality parameters to protect its designated uses of contact recreation, high quality aquatic habitat, and public water supply. The established water quality parameters for this segment are:

- Annual mean chloride concentration less than 200 milligrams per liter (mg/l)
- Annual mean sulfate concentration less than 100 mg/l
- Annual mean total dissolved solids concentration less than 600 mg/l
- Dissolved oxygen levels in the epilimnion not less than 5.0 mg/l
- pH levels within the range of 6.5 to 9.0
- 30-day geometric mean fecal coliform density less than 200 colonies/100 ml
- Temperature less than 34°C

The Texas Water Commission is currently proposing revisions to its surface water quality criteria statewide and has proposed modification of the criteria for Segment 1236 to lower the chloride criteria to 130 mg/l, raise the sulfate criteria to 150 mg/l, and lower the total dissolved solids criteria to 550 mg/l. These changes are in response to measured changes in historical values for these parameters.

Because Lake Fort Phantom Hill is a public water supply, Texas Drinking Water Standards are also applicable. The standards are included in Table 2.2 and include both primary and secondary levels. The primary standards are designed to protect human health, while the secondary levels are intended to minimize non-health related problems such as taste and odor.

Historical Water Quality Data. Water quality data on Lake Fort Phantom Hill has been collected in the past by the City of Abilene, the Texas Water Commission (TWC) and the U.S. Geological Survey (USGS).

The City of Abilene has routinely collected water samples from the lake near their intake structure. A period extending from 1976 to 1987 was chosen for analysis because it includes periods of both high and low rainfall. The City has analyzed 32 parameters during that period. The Texas Water Commission has collected water samples from two sampling locations during the period from 1976 to 1986. One site is located at mid-lake near the dam while the other, shown on Figure 2.5, is located near the West Texas Utilities cooling water discharge outfall.

The TWC data are particularly useful since vertical profiles of water quality were commonly evaluated. Samples were collected at 10-foot intervals in depth, beginning at one foot. These samples indicated that for the most part the lake was not stratified. The lake was distinctly stratified on at least one occasion, indicating that it has the potential for stratification when the aeration system is not operating.

The U.S. Geological Survey has collected water quality samples

Table 2-2

Comparison of Water Quality Sampling Results (3/87-9/87)
From the Abilene Water Reuse Study
With State Drinking Water Standards
(Values are in mg/l unless otherwise noted)

Parameter	Drinking Water Standard	Mean Concentration: Lake Station No. 1	Lake Station No. 2	WWTP Effluent	Creek Composite
Primary Standard					
Arsenic	0.05	0.002	0.002	0.003	0.025
Barium	1	0.130	0.152	0.052	0.230
Cadium	0.01	0.001	0.001	LD	LD
Chromium	0.05	0.006	0.001	0.005	0.003
Fluoride	4.0				
Lead	0.05	0.012	0.002	0.003	LD
Mercury	0.002	ID	ID	ID	ID
Nitrate-N	10	LD	LD	8.600	0.200
Selenium	0.01	0.008	0.005	0.003	0.002
Silver	0.05	0.018	0.022	0.037	0.025
Endrin	0.0002	LD	LD	LD	LD
Lindane	0.004	ND	ND	ND	ND
Methoxychlor	0.1	LD	LD	LD	LD
Toxaphene	0.005	LD	LD	LD	LD
2,4-D	0.1	LD	LD	LD	LD
2,4,5-T	0.01	LD	LD	LD	LD
Turbidity (Turbidity units)	1	27	14.6	8	74
Total Coliforms	1[a]	1[b]	62.4[b]	1[b]	533[b]
Secondary Levels					
Chloride	300	81	81.4	229	102
Fluoride	2.0	0.264	0.304	1.340	0.213
Copper	1	0.008	0.012	0.010	0.017
MBAs	0.5	0.2	0.14	1.024	0.175
Iron	0.3	0.722	0.380	0.118	0.933
Manganese	0.05	0.043	0.610	0.040	0.073
Odor (threshold odor no.)	3	3.5	5	35	6.750
Sulfate	300	64	64	192	70
TDS	1,000	434	438	992	491
Zinc	5	0.009	0.067	0.322	0.021
TTHM (mg/l)	0.1	ID	0	0.013	LD
TTHMFP (mg/l)	0.1	ID	0.09	ID	ID

Table 2-2, Continued

Parameter	Drinking Water Standard	Mean Concentration Lake Station No. 1	Lake Station No. 2	WWTP Effluent	Creek Composite
Other Constituents					
Nitrite-N	NA	0.02	0.07	13.63	0.22
Ammonia-N	NA	0.39	0.21	4.93	1.84
Total Kjeldahl Nitrogen	NA	1.75	3.15	7.08	5.09
Dissolved Ortho-P	NA	LD	LD	6.63	0.04
Total Phosphorus	NA	0.07	0.08	8.1	0.16
Chlorophyll a	NA	0.002	0.001	0.001	0.04
Total Organic Carbon	NA	34.2	34.2	15.6	37.8
Volatile Organic Carbon	NA	17.4	20.6	25.8	27.1
Total Organic Halogen	NA	0.014	0.014	0.280	63.3
Total Alkalinity	NA	144	144	181	142
Calcium	NA	52	58	76	59
Magnesium	NA	22	24	59	28
Hardness	NA	224	213	314	226
Sodium	NA	52	52	157	44
Potassium	NA	13	11	16	11
Silica	NA	5	4	15	7
Bromide	NA	0.35	0.60	ND	0.22
Fecal Streptococcus (#/100 ml)	NA	23	20	ND	1.700
Standard Plate Count (#/100 ml)	NA	3,186	4,753	6,853	6,000
Aluminum	NA	1.1	0.74	0.09	1.68
Iodide	NA	0.9	0.56	1.40	0.75
Strontium	NA	0.4	0.50	0.58	0.25
Boron	NA	0.2	0.12	0.40	0.14
Cobalt	NA	0.001	LD	0.001	0.001

LD indicates less than laboratory detection limit.
ND indicates that no determinations were made for a constituent.
NA indicates that no standard has been established.
ID invalid data

[a]One coliform per 100 ml as the arithmetic mean of all samples examined per month.
[b]Fecal coliforms.

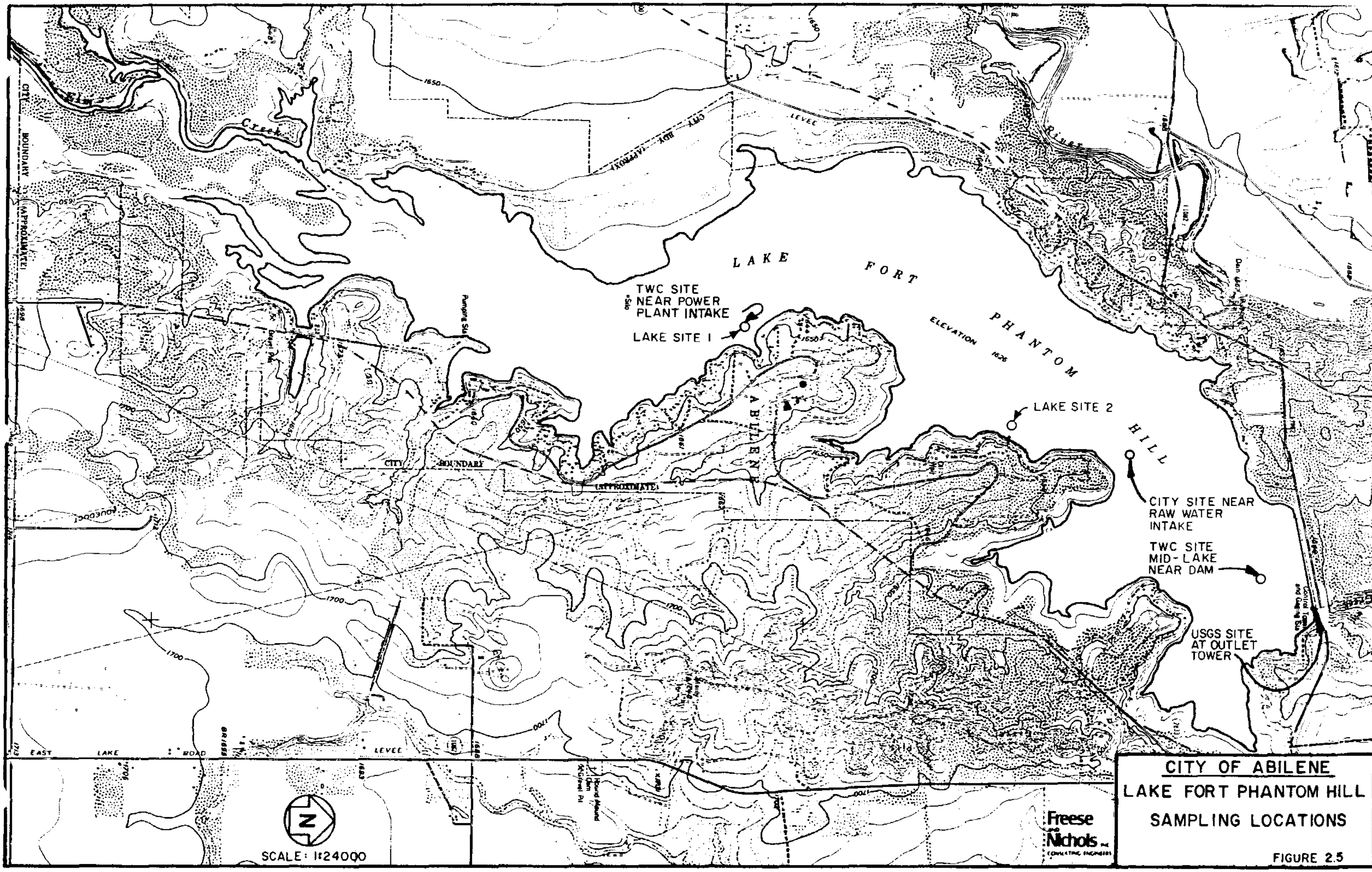

LAKE FORT PHANTOM HILL
ELEVATION 1626
TWC SITE NEAR POWER PLANT INTAKE
LAKE SITE 1
LAKE SITE 2
CITY SITE NEAR RAW WATER INTAKE
TWC SITE MID-LAKE NEAR DAM
USGS SITE AT OUTLET TOWER
ABILENE
CITY BOUNDARY (APPROXIMATE)
Pumping Sta
Gravel Pits
Control Tower and Gaging Sta
Elm Creek
LEVEE
EAST LAKE ROAD
SCALE: 1:24000
N
Freese and Nichols
CONSULTING ENGINEERS
CITY OF ABILENE
LAKE FORT PHANTOM HILL
SAMPLING LOCATIONS

FIGURE 2.5

at the service outlet tower near the dam shown on Figure 2.5. This data since 1976 is comparable to that reported by the City of Abilene and the Texas Water Commission.

Intensive Water Quality Monitoring Program. The City of Abilene has recently completed a seven-month intensive sampling program to obtain additional baseline water quality data on Lake Fort Phantom Hill. Fifty-nine parameters were analyzed on a monthly, quarterly, or bi-annual basis at four sampling locations. Two samples were taken within the lake, one sample was a composite of water collected from Elm and Cedar Creeks at the locations shown on Figure 2.5, and one sample was from the effluent of the wastewater treatment plant. A summary of the results from the monitoring program is presented in Table 2.2.

Current Water Quality Assessment. The water quality data collected to date indicate that water in Lake Fort Phantom Hill is of good to excellent quality. There were few parameters which would limit its use as a domestic water supply or for propagation of aquatic life. In fact, the reservoir supports an excellent fishery.

Turbidity within the reservoir is relatively high and the restriction of light may be a limiting factor in preventing high levels of algal productivity and eutrophication.

Total organic carbon, trihalomethane forming potential, and odor also were elevated. This probably reflects the presence of naturally occurring humic substances in the lake and its associated runoff.

Nutrient levels were relatively low in the 1987 intensive sampling data. Previous data have indicated that the lake may be alternately nitrogen and phosphorus limited. A few isolated occurrences of organic compounds were identified during the analysis, including phtalates, acetone, trichloroethane, and methylene chloride. Most of these samples probably reflect contaminated sampling containers or isolated contamination events. Most were found in the creek samples. None of the levels were of concern.

The lake is naturally high in iron and manganese. While these constituents do not represent a risk to health, they can cause objectionable taste and staining problems.

Special Microbiological Testing for Viruses and Parasitics. Tests to identify viruses and parasitic organisms were conducted on the Hamby WWTP influent and effluent, Northeast WTP, and selected sites in Lake Fort Phantom Hill. Tests for viruses only were conducted on tributaries to the lake. Specific details of these tests are presented in Technical Memorandum No. 4.

The virology study was performed by Drs. J. L. Melnick and T. J. Metcalf, Baylor College of Medicine, Department of Virology and Epidemiology. A full report of the study is presented in Appendix E to Memorandum No. 4.

Testing was performed for Hepatitis A, human rotavirus, enterovirus (BGM cells), and other enteric viruses from samples collected from Lake Fort Phantom Hill, Elm and Cedar Creeks and the Hamby WWTP. In addition, testing was performed on four samples of effluent from the existing wastewater treatment plant treated with lime to a pH of 10.4.

The results of these tests were similar to the findings of previous studies with regard to the number and types of viruses identified.

The analysis of existing wastewater identified several types of enteroviruses. Viruses identified in the wastewater were:

- Poliovirus, types 1, 2, and 3
- Coxsackie virus B, types 4 and 5
- Echovirus, type 7

The existing wastewater treatment plant provides two log viral reduction, without disinfection by chlorination. Additional analyses were made on wastewater plant effluent treated with lime. These analyses indicated a four-log removal rate (99.99%) when the pH was raised to 10.4. This confirmed previously reported viral reduction through the use of lime.

The viral analysis of the lake and its tributaries indicated that enteroviruses were present in both Elm and Cedar Creeks. The type identified was Reovirus type 2. Because this type of virus occurs in both human an animal populations, its origin is difficult to ascertain. One lake site was also positive for the Reovirus during the April sampling.

The primary findings of the viral studies were:

- No viruses were identified in the raw water at the City's intake.
- Viruses are present in the tributaries and the upper portion of the lake.
- Viruses are present in large numbers in the raw wastewater.

- Existing wastewater treatment provides significant reduction of viral concentration.
- Processes which raise the pH to greater than 10.4 (to the 10.8 to 11.0 range) provide significant destruction of viruses.
- Processes which produce high clarity waters (low turbidity levels), such as coagulation and filtration, greatly enhance the ability of disinfectants like chlorine and ozone to destroy viruses.

Continued testing for viruses should be an integral part of any reclaimed water system.

Fairleigh Dickinson Laboratories, Inc. of Abilene performed a qualitative and quantitative assessment of selected parasitic organisms from Lake Fort Phantom Hill and from the City's wastewater and drinking water. A full report of the study is presented in Technical Memorandum No. 4.

Water samples were analyzed for the following parasites:

- Giardia lamblia
- Cryptosporidium sp.
- Entamoeba hartmanni
- Entamoeba coli
- Endolimax nana
- Nagleria sp.
- Harmanella sp.
- Acanthamoeba sp.

The primary conclusions and recommendations of the study are:

- No parasitic organisms were identified in the drinking water.
- A nonpathogenic amoeba, Entamoeba hartmanni, which is used as an indicator of fecal deviated organisms, was identified in Lake Fort Phantom Hill at concentrations of 14 per liter.
- Entamoeba hartmanni and Entamoeba coli were identified in concentrations of 130 and 66 per liter, respectively, in the wastewater effluent.
- Entamoeba hartmanni (860 per liter), Entamoeba coli (286 per liter), Endolimax nana (143 per liter), and Acanthamoeba sp. (3 per liter) were identified in the wastewater influent. These are significantly higher concentrations than found in the effluent.
- The significance of the concentrations identified is difficult to ascertain due to a lack of historic and comparative data.
- The primary results are that parasitic organisms exist in the wastewater and Lake Fort Phantom Hill. None were identified in the drinking water.
- Parasitic organisms are not effectively removed by existing wastewater treatment technologies.
- Routine testing for parasitic organisms should be integrated into any future reclaimed water plans.
- TWDB should support future development of new monoclonal antibody assay methods to lower costs and simplify future

analyses.

The results of the special microbiological testing confirmed the presence of viruses and parasitics in the wastewater and tributaries to LFPH. The types and concentrations were as expected for the environment. No viruses or parasitic organisms were detected in the treated drinking water.

Water Quality Computer Model. The computer model allowed the research team to evaluate the water quality effects of a discharge at various flows and with different degrees of treatment in Lake Fort Phantom Hill. Key findings of the model are presented in Section 3.2.

3. WATER RECLAMATION EVALUATION AND SELECTION

In this section, the alternatives for water reclamation are developed and evaluated.

Before water reclamation alternatives could be developed, appropriate water quality standards for the reclaimed effluent had to be established and treatment processes that could meet the water quality requirements were identified.

Water reclamation effluent quality standards and their anticipated effect on Lake Fort Phantom Hill are described below. An evaluation of treatment process alternatives and an evaluation of a non-potable water supply system to be incorporated into the water reclamation plan are also presented.

3.1 Water Quality Standards

A crucial element of the research project was the establishment of appropriate water quality standards for treated effluents and receiving streams. Criteria were selected based on existing regulations and review of the findings of the Lake Fort Phantom Hill Water Quality Model. Technical Memorandum No. 6 in the Appendix covers the development of water quality standards in detail.

Review of Existing Regulations: At a minimum, the proposed water reclamation program must comply with the following basic water regulations:

1. Wastewater Discharge Regulations (NPDES Permit) for Discharges to Surface Waters

   Typical limits for treated effluent quality for discharge to a tributary of a water supply reservoir are summarized below:

° BOD	10 mg/l
° Total suspended solids	15 mg/l
° Ammonia	3/10 mg/l (seasonal)
° Dissolved oxygen	>5 mg/l
° pH range	6 - 9
° Chlorine	1 mg/l

These limits are based on similar discharges at a distance greater than five miles upstream of a Texas water supply reservoir. Site-specific conditions that may require greater treatment levels would be considered as warranted.

2. <u>Non-Potable Water Reuse Regulations for Landscape Irrigation and for Unrestricted Public Contact</u>

Current regulations allow irrigation of controlled areas with an effluent that has undergone secondary treatment and has a 1 mg/l chlorine residual. The State of Texas has drafted proposed changes to these criteria, which have been adopted for the purposes of this study. Proposed State of Texas regulations governing wastewater to be used for irrigation are summarized below:

Effluent quality for controlled public access areas:

° BOD	20 mg/l
° Total suspended solids	20 mg/l

- Fecal Coliform 100/100 ml
- Disinfection 1.0 mg/l after 15 min. at Qp

Effluent quality for controlled access areas abutting residential property:

- Free of fecal coliforms and pathogens

It is recognized that the present TWC standards are under revision. It is not yet known whether the State of Texas will adopt specific disinfection standards or chlorination design criteria. Several states have in recent years adopted more specific standards for both treatment criteria and performance for disinfection. The most notable of these are the California Title 22 Standards adopted in 1976. It may be that the State of Texas will adopt similar specific disinfection standards some time in the future rather than chlorination design criteria. The water quality goals for this study were based on standards similar to California Title 22 requirements.

3. Surface Water Standards (Texas Surface Water Quality Standards - TWC, 1985)

The current State of Texas surface water quality criteria expressed in annual mean levels applicable to Lake Fort Phantom Hill are as follows:

Chloride	<200 mg/l
Sulfate	<100 mg/l
TDS	<600 mg/l

° Dissolved oxygen not less than 5.0 mg/l

° pH Range 6.0 to 9.0

° Fecal coliform
(No./100 ml - 30 day mean) <200

° Temperature <34°C

4. Federal and State Drinking Water Regulations (National Safe Drinking Water Act; Drinking Water Standards Governing Drinking Water Quality and Reporting and Requirements for Public Supply - TDH, 1987)

Current drinking water standards are presented in detail in Technical Memorandum No. 4.

Drinking water regulations are undergoing major revisions as a result of the 1986 amendments to the federal Safe Drinking Water Act. A list of contaminants currently regulated or for which maximum contaminant levels (MCLs) must soon be developed is included in Table 2.2.

5. Criteria for Viruses and Pathogenic Parasites

No generally accepted criteria setting acceptable levels of viruses or parasitics in wastewater effluents currently exist. The State of Arizona has criteria addressing viruses that use enteric virus as a general indicator. The adequacy of enteric virus as a general indicator is still under evaluation by Arizona. There are no published regulatory agency criteria on parasitics.

The State of Texas has a general criterion that effluent should be free of pathogens, but because of the lack of specific criteria recommendations on viruses and pathogenic parasites have not been developed in this study.

Current practice addresses the issue of these organisms indirectly. It is commonly felt that the probability of an effluent containing these organisms is inversely proportional to the clarity of the water; that is, the higher the clarity, the lower the probability of viruses and parisitics. Minimum treatment process levels for most plants are set to provide a highly clarified effluent.

Findings of the Lake Fort Phantom Hill Water Quality Model. The water quality model developed on Lake Fort Phantom Hill furnished additional data for selecting appropriate water quality standards.

The computer model allowed the research team to evaluate the effects of a discharge at various flows and with different degrees of treatment on water quality in the lake. Key findings of the model were:

- Significant elevation in biological activity occurs at flows greater than 3 MGD with advanced biological treatment.
- Lake Fort Phantom Hill is sensitive to discharge of nitrates, due to its limited ability to convert nitrates to nitrogen.
- The lake is sensitive to discharges of nutrients (nitrogen and phosphorous) which promote eutrophication (algal blooms). The model suggests that phosphorous is the limiting nutrient. Controlling phosphorous helps to control algal growths.
- A discharge of 3 MGD of reclaimed water would produce an increase in total dissolved solids (TDS) of 100 to 150 mg/l.

- At flows greater than 7 MGD, controls for nitrate and TDS may be required.

<u>Establishment of Water Quality Standards</u>. The establishment of water quality standards was based on existing regulations and the changes in reservoir water quality predicted by the computer model.

Water quality criteria and goals were developed and served as the basis for selection of appropriate treatment processes. Where appropriate, criteria were defined for each basic element of the overall water reclamation scheme including:

- Reclaimed water used for irrigation
- Reclaimed water discharged to a tributary stream of Lake Fort Phantom Hill
- Reclaimed water discharged directly to Lake Fort Phantom Hill
- Water within Lake Fort Phantom Hill

In all cases, the goals and objectives for reliability and protection of public health were kept in mind. To this end, the project team adopted the concepts of process operation redundancy and multiple barriers.

Any proposed treatment system would have an adequate backup and more than one barrier for protection of the public health. To increase the system's effectiveness, the type, physical location, and operating personnel for each process should be varied, and any process selected should be able to meet the design criteria at peak monthly flows with one unit out of service. More than one barrier should be provided for contaminants which affect public health.

The recommended criteria for the four elements of the overall water reclamation scheme are as follows:

1. <u>Reclaimed Water for Irrigation</u>

   Irrigation of controlled access areas (e.g., Dyess AFB Golf Course)

   - Secondary effluent with disinfection
     - 20 mg/l BOD_5
     - 20 mg/l TSS
     - 1.0 mg/l chlorine residual
   - Maximum fecal coliform level of 100/100 ml.

   Irrigation of limited control access areas (e.g., Municipal Golf Course)

   - Secondary effluent treatment (20 mg/l BOD_5, 20 mg/l TSS with coagulation, filtration and disinfection)
   - <2.2 total coliform/100 ml (mean)
   - <2 NTU

2. <u>Reclaimed Water Discharged to a Tributary of Lake Fort Phantom Hill</u>

° BOD	5 mg/L
° Turbidity	2 NTU
° Ammonia nitrogen	2 mg/L
° Nitrate/nitrite nitrogen	20 mg/L at Q $\leq$ 3mgd
	10 mg/L at Q > 3 mgd
° Total phosphorus	2.0 mg/L at Q $\leq$ 3 mgd
	0.2 mg/L at Q >3 mgd
° Dissolved oxygen	>5.0 mg/L

° Coliform organisms	<100/100 ml (mean) <2.2/100 ml (as a goal)
° Viruses	Free of pathogenic viruses; >1.0 pfu/100 l Enteroviruses
° Parasitics	Free of pathogenic parasites; <1.0 active entamoeba hartmanni/liter

3. <u>Reclaimed Water Discharged Directly to Lake Fort Phantom Hill</u>

   The concept of multiple barriers would mean not discharging directly into the lake until a successful performance record has been established. Accordingly, the project team does not propose direct discharge to LFPH at this time, and probably not until beyond the year 2000. Setting criteria for an event that distant had little meaning and was discounted. However, the standards would be as stringent as or more stringent than those established for discharge to a tributary of the lake.

4. <u>Water Within Lake Fort Phantom Hill</u>

   No deviations from the current surface water and drinking water standards are proposed.

Under current State regulations, the standards for wastewater effluent to be discharged to a stream are defined in terms of specific water quality criteria, while the standards for effluent to be used for irrigation are defined in terms of the required treatment processes.

In effect, however, the two standards produce effluent of nearly the same quality, with the major difference being the level of nutrient removal. For this reason, treatment as described in Item 1 for irrigation would produce an effluent quality similar to that described in Item 2 for discharge to a stream. A water reclamation plant using either process could potentially produce effluent for either application.

3.2 Lake Fort Phantom Hill Water Quality Model

A computer model of the water quality of Lake Fort Phantom Hill was developed using historic water quality data and current water quality monitoring data. The computer model used was the U.S. Army Corps of Engineers River and Reservoir Water Quality Model (WQRSS).

Water quality modeling was performed to predict the impacts of discharges on Lake Fort Phantom Hill under a critical condition of two-year drought. The variables in the model were 1) the quantity of reclaimed water discharged to the reservoir and 2) the degree of treatment provided to the water. The values used were:

1. Flow Quantities: 3, 7, 12, and 17 mgd.
2. Degree of Treatment:

Effluent Set	BOD5	TSS	O-PO4	NH3	NO3
A	3.0	1.0	0.2	2.0	10.0
B	5.0	5.0	2.0	3.0	25.0
C	10.0	15.0	10.0	3.0	25.0

The research team that a flow of 3 mgd was the lowest value which would have meaningful impacts. At this flow, there would be a noticeable increase of 5 to 10 percent in the lake's volume and measurable positive or negative impacts on the lake's water quality. The 3 mgd capacity was also determined to be the minimum level allowing economy of scale in construction costs and valid results to be used as a basis for expansion of the facilities in the future. This determination is covered in further detail in Technical Memorandum 7A. The 17 mgd level was set as a practical limit of wastewater that would be available for reclamation during the study period.

Effluent Set A represents a reasonable best practical treatment level obtainable by current treatment process. Higher quality could be achieved; however, the research team concluded that the small absolute improvements in quality achieved with a higher treatment level would not justify the increased costs. Effluent Set C represents the normal quality requirements set by the State of Texas for discharge into a lake. Compared to most stream requirements throughout the state, it is considered a high level of treatment and requires an advanced wastewater treatment plant. Level B represents a middle-ground effluent set.

Basic conclusions drawn from the modeling results are that there are two primary concerns relating to discharge of reclaimed water to Lake Fort Phantom Hill:

° The reservoir was shown to be very sensitive to increased concentrations of phosphorus, a primary nutrient which stimulates algae growth. Such growth is undesirable due to the unpleasant taste and odors that result. Two recommendations were made to counteract this sensitivity:

- Reclaimed water phosphorous concentrations should be 0.2

mg/l at flows greater than 3.0 mgd and less than 2.0 mg/l at flows less than 3.0 mgd in order to minimize the growth of algae and related problems.

- The release and/or discharge of organic nitrogen and ammonia nitrogen during the algal decay cycle is a related problem. Ammonia concentrations greater than about 2 mg/l in the reservoir may be toxic to fish and should therefore be kept below this level.

° A potential increase of nitrate-nitrogen in the reservoir is also a concern. The concentration must be maintained at less than 10 mg/l as nitrogen to be in compliance with drinking water standards.

  - As reclaimed wastewater flows increase, the nitrate-nitrogen concentrations must be decreased or they will approach the standard. Ultimately, it appears the nitrate-nitrogen concentration in the reclaimed water discharge should be limited to approximately 10 mg/l.

The high concentration of phosphorus and nitrogen in the natural drainage of the lake contributes a significant portion of the overall loading. Control of these non-point sources was assumed to be impracticable; therefore, control must be exercised at the discharge point.

The model projected an increase of 100 to 150 mg/l in total dissolved solids (TDS) in the lake using the recommended treatment processes. This increase would raise TDS to the 500 to 600 mg/l range under normal conditions and to 850 to 950 mg/l under drought conditions. The projected drought-condition levels exceed Texas surface water criteria; however, the TDS concentration during a drought would be comparable to levels in Hubbard Creek Reservoir, and slightly more than historic levels in Lake Fort Phantom Hill during droughts.

3.3 Detailed Process Alternative Evaluation

From the findings of the water quality model and the recommended water quality standards, four alternative process configurations were developed. Detailed descriptions of treatment processes and operations that would produce an effluent of the required water quality for discharge to a tributary of Lake Fort Phantom Hill are presented in Technical Memorandum No. 7. Bench-scale tests to establish design criteria for key treatment processes were performed at the Hamby plant. The tests included high lime coagulation, alum coagulation, and the determination of appropriate nitrification and denitrification rates. Detailed descriptions of the bench-scale tests are contained in Technical Memoranda Nos. 8A and 8B. The four alternatives, shown schematically in Figures 3.1, 3.2, 3.3, and 3.4, are:

Alternative 1: High Lime

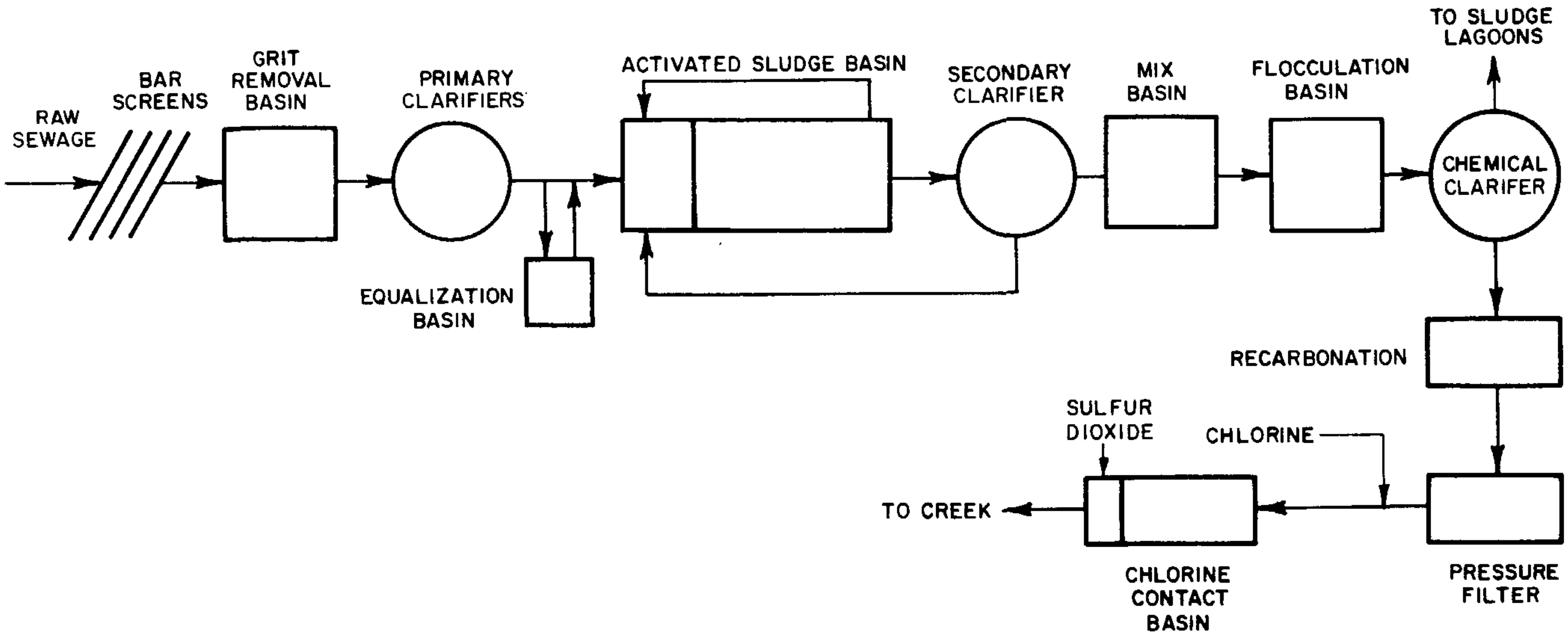
Alternative 2: Alum Coagulation

Alternative 3: Alum Coagulation/Biological Phosphorous (P) Removal

Alternative 4: Biological P Removal/Pump During Drought

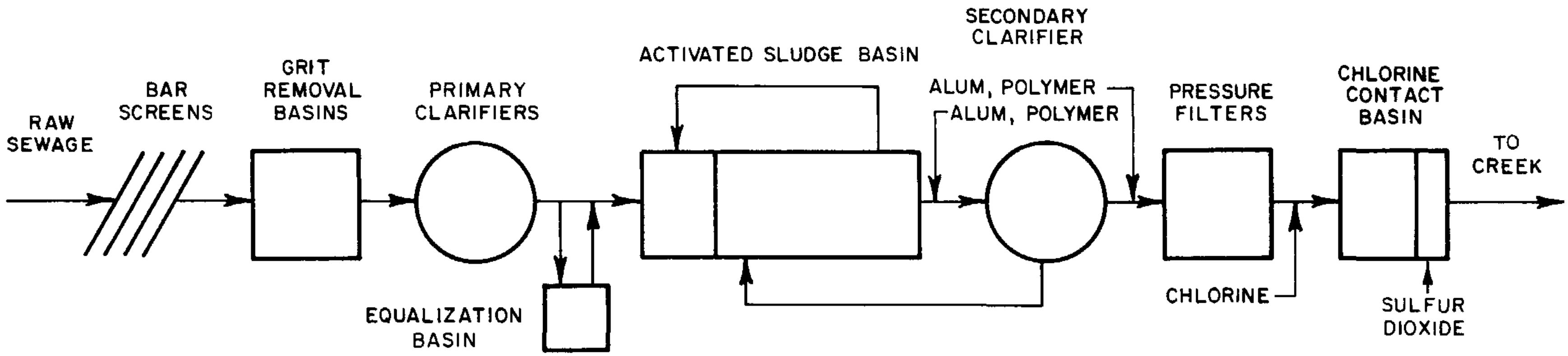
Each treatment alternative yields slightly different effluent qualities, but each can be equated to a specific effluent set used in the water quality modeling work.

Alternatives 1, 2 and 3 will produce the effluent quality re-



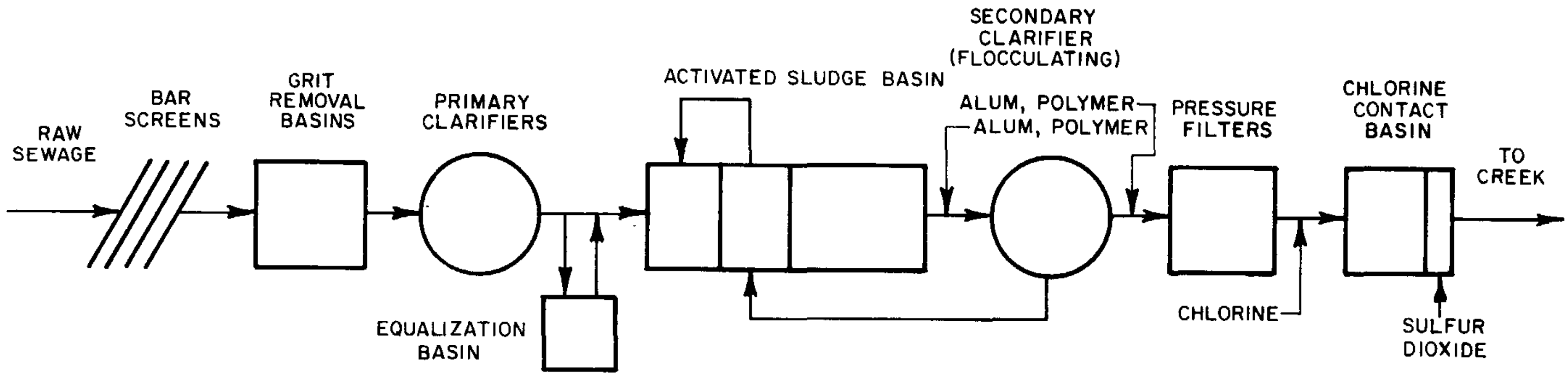
ALTERNATIVE I: SINGLE STAGE HIGH LIME, FILTRATION AND CHLORINATION

FIGURE 3.1
SUGGESTED PROCESS CONFIGURATION TRIBUTARY WWTP



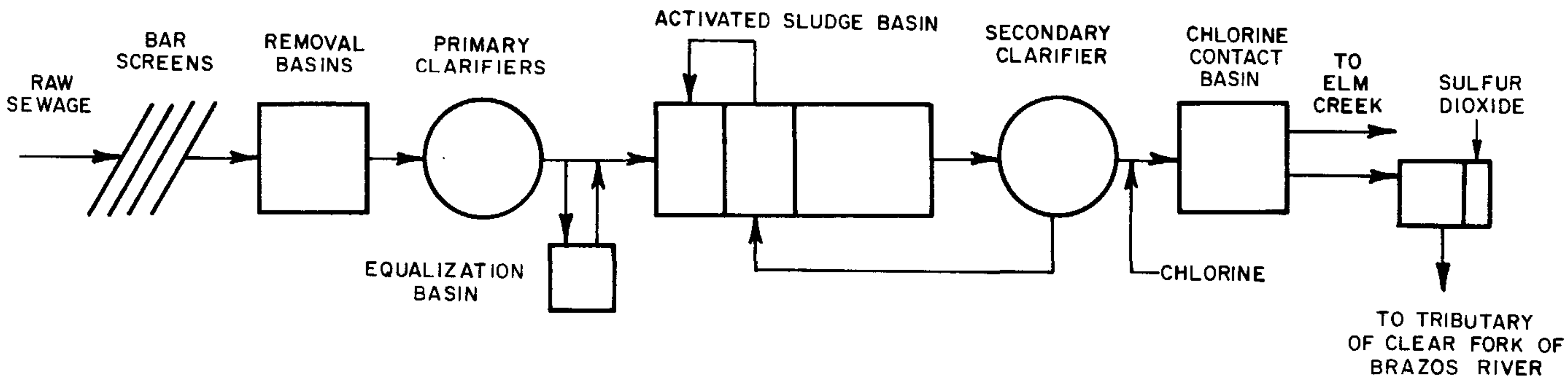
ALTERNATIVE 2 : ALUM-P REMOVAL, FILTRATION AND BREAK-POINT CHLORINATION

FIGURE 3.2
SUGGESTED PROCESS CONFIGURATION
TRIBUTARY WWTP



ALTERNATIVE 3: BIO-P, ALUM COAGULATION, FILTRATION AND BREAK-POINT CHLORINATION

FIGURE 3.3
SUGGESTED PROCESS CONFIGURATION
TRIBUTARY WWTP



ALTERNATIVE 4 : BIO-P, NITRIFICATION ONLY, BY-PASS ELM CREEK OPTION

FIGURE 3.4
SUGGESTED PROCESS CONFIGURATION
TRIBUTARY WWTP

quired for flows of up to about 7 mgd. Alternative 4 produces an effluent quality suitable for discharge of up to 3 mgd.

The same basic treatment processes are suggested for preliminary (bar screens and grit basins) and primary treatment (primary clarification). The suggested secondary systems are also the same, with the exception that biological P removal is suggested for Alternatives 3 and 4. Nitrification and denitrification are suggested as components of all activated sludge systems, with the exception of Alternatives 3 and 4, which only achieve nitrification.

Alternative 1 is a high lime tertiary system similar to those used at all of the existing water reclamation facilities supplementing potable water supplies. The high pH conditions of the lime treatment enhance the destruction of virus and bacteria in the wastewater. Since the lime dose will be independent of the P concentration, and P will be removed in the process, there is no need to use biological P removal in conjunction with high lime. A single stage system is suggested, so that recarbonation will only take place after the chemical clarifier. In addition to lime treatment with recarbonation, filtration would be needed to achieve a lower concentration of suspended solids and lower turbidity in the effluent. The chief disadvantages of this system are the large volume of sludge it generates and its high cost.

The tertiary segment of Alternatives 2 and 3 is an alum coagulation/filtration system. Biological P removal is suggested for Alternative 3 to cut down on the alum dose required. Alternative 2, a purely alum P removal system, is included to proved a cost comparison against biological P removal. To ensure that the solids carried over from the secondary system will not overload the filters, flocculating type clarifiers are suggested for the secondary clarifiers of Alternatives 2 and 3.

Other recommendations for Alternatives 2 and 3 include facilities for adding alum and polymer either to the clarifiers or just upstream of the filters. Conventional dual-media pressure filters are suggested for filtration for both alternatives. Chlorination/dechlorination with an acceptable free chlorine residual is suggested for disinfection.

An oxidation channel type of activated sludge system could potentially be used for Alternative 4, although the benefits of an oxidation channel do not completely outweigh the problems of its application.

The primary benefit of an oxidation channel is its ease of operation and low staffing requirements. However, the plan will require a relatively high level of operator attention even with an oxidation channel, because of the tertiary treatment process to be used. In addition, the land requirements for an oxidation channel at the 3.0 mgd scale are fairly large, and at 7 mgd become limiting. The power requirements for an oxidation channel are also high compared to a conventional activated sludge system. For these reasons oxidation channel systems were not evaluated.

Table 3.1 compares the effluent quality and estimated cost of each alternative. Table 3.2 compares their relative advantages and disadvantages.

Alternative 3, combining biological phosphorus removal and alum coagulation, is the recommended alternative. It produces an effluent quality compatible with the standards established in Section 3.1,

Table 3.1

Treatment Process Alternatives

TREATMENT TYPE	1 HI-LIME	2 ALUM.	3 ALUM. & BIO. P.	4 NITRIFICATION
PROCESS DESCRIPTION[1]	Activated Sludge	Activated Sludge	Activated Sludge	Activated Sludge
	Nitrification	Nitrification	Nitrification	Nitrification
	De-Netrification	De-Nitrification	Biological Phosphorous	Biological Phosphorous
	Clarification	Coagulation	Coagulation	Clarification
	Hi-Lime	Chem. P. Removal	Filtration	Filtration
	Re-Carbonation	Clarification	Clarification	Chlorination
	Filtration	Filtration	Filtration	Post Aeration
	Chlorination	Break-Pt. Chlorination	Break-Pt. Chlorination	Pump Station and
	Post Aeration	Post Aeration	Post Aeration	Force Main
EFFLUENT QUALITY	Design/Average Operating Conditions			
BOD	5.0/2.0	5.0/2.0	5.0/2.0	5.0/3.0
TSS	5.0/<1.0	5.0/<2.0	5.0/<1.0	5.0/5.0
TKN	2.0/1.0	2.0/0.1	2.0/0.1	2.0/1.5
Nitrate	10.0/5-7	10.0/5-7	15-20/15-20	15-20/15-20
Phosphorous	.2/.1	.2/.15	.2/.15	2.0/2.0
Dissolved Oxygen	5.0/6.0	6.0/6.0	5.0/6.0	5.0/6.0
Coliform	2.2/2.0	2.2/N.D.	2.2/N.D.	200.0/100
NTU	2.0/1.0	2.0/1.0	2.0/1.0	N.A./4-10
COST PRELIMINARY per 1,000,000				
Capital	13.41	11.26	10.12	11.58
O&M	0.70	0.56	0.46	0.35
Equivalent Annual[2]	2.09	1.73	1.51	1.55

NOTES: 1. All preceded by preliminary treatment, screening, and grit removal; dechlorination also provided.
2. Based on 20 years @ 8% interest.

Table 3.2

Subjective Evaluation of Treatment Process Alternatives

	1 HI-LIME	2 ALUM.	3 LUM. & BIO. P.	4 NITRIFICATION
Advantages	1. Total organic carbon reduction.	1. Total organic carbon reduction.	1. Total ortganic carbon reduction.	1. Lowest capital cost.
	2. Total dissolved solids reduction.	2. Relatively easy sludge handling, if discharged.	2. Relatively easy sludge handling.	2. Lowest O&M cost.
	3. Track record of success.	3. Track record of succes for P removal.	3. Track record of success for P removal.	3. Least complex operation.
	4. Relatively stable process.	4. Removes viruses/pathogens.	4. Removes viruses/ pathogens.	4. Has ability to pump out of basin for reliability.
	5. High reliability because of Hi-Lime.	5. Easier maintenance than Hi-Lime.	5. Easier maintenance than Hi-Lime.	5. Removes NH_3.
	6. High disinfection capabilities, both pH and Cl_2 removals,	6. High disinfection capabilities with break-pt Cl_2	6. High disinfection capabilities with break-pt Cl_2	6. Removes majority of phosphorous.
	7. Removes NH_3.	7. Removes NH_3.	7. Removes NH_3.	
	8. Denitrified effluent.	8. Denitrified effluent.	8. Lower capital cost than Hi-Lime and Alum.	

	1 HI-LIME	2 ALUM.	3 LUM. & BIO. P.	4 NITRIFICATION
	9. High level of phosphorous and heavy metal removal.	9. Lower capital costs.	9. Lower O&M cost than than Hi-Lime and Alum.	
	10. Color and hardness removal.	10. Lower O&M than Hi-Lime.	10. Less of an increase of TDS than Alum.	
	11. Lower THM formation than BP-Cl_2.	11. Less complex operations than Hi-Lime or Alum & B.P.		
Disadvantages	1. Highest capital cost.	1. Increases TDS.	1. Increases TDS.	1. Less effective in removal of viruses/pathogens.
	2. Highest O&M cost.	2. Higher chemical cost than Bio-P.	2. Requires specially trained operations staff.	2. Not as easily expanded without additional unit operation for P-removal and nitrate reduction.
	3. Requires specially trained operations staff.	3. Requires specially trained operations staff.	3. More complex operation than Alum alone.	3. Request trained operational staff, but less complex than other alternative.
	4. Limes sludge handling and disposal.		4. Higher capital cost than Alum alone.	4. Requires careful operation of Bio-P.
	5. High maintenance with scaling problems.			

"Water Quality Standards," is reliable and has the lowest cost of the four alternatives evaluated.

An opinion of T.G. Metcalf, a professor in the Department of Virology and Epidemilogy at Baylor College of Medicine, on the effectiveness of viral removal by alum coagulation is included in Appendix A to the Summary Report. Dr. Metcalf states in this opinion that alum treatment would be beneficial in promoting virus removal.

The largest drawback to Alternative 3 is that no existing facility uses alum coagulation exclusively for solids removal. Should public support require more exact replication of treatment processes of existing water reclamation plants, the additional cost for Alternative 1 may be warranted.

Table 3.3 lists the process units and sizes required for Alternative 3. Based on these units and sizes, the research team's opinion of the estimated construction cost for the plant is $10.12 million and opinion of annual operational cost is $460,000. A detailed cost breakdown is presented in Table 3.4.

3.4 Non-Potable Water System

The inclusion of a non-potable water system study in this project was based on the concept that non-potable water supplied to a user who would otherwise use the potable supply was the equivalent of developing a new source of potable water.

A review of Abilene water use as presented in Table 3.5 suggests that further reductions in potable water demand can best be achieved by reducing demand for turf irrigation water.

Table 3.3

Tributary WWTP Preliminary Unit Sizing

Process	Design Criteria	Total Size
Primary Clarifiers	1800 GPD/SF at Peak Flow	5,556 SF
Equalization Basin		1 mg
Aerobic Zones	8.0 Day SRT at PM Load 0.7 Solids Yield	1.49 mg
Anaerobic Zones	2 HR HRT at PM Flow	0.33 mg
Total Activated Sludge System		1.81 mg
Secondary Clarifier	500 gpd/SF at Avg. Flow	7,182 SF
Alum Use	40 mg/l at Avg.	801 lbs/day
Pressure Filters	5.5 gpm/SF at MEF	861 SF
Chlorine Contact Basin	30 minutes at MEF	142,073 gal
Chlorine Demand	30 mg/l at Avg.	601 lbs/day
SO_2 Demand	5 mg/l at Avg.	100 lbs/day

Table 3.4

Summary of Opinion of Probable Costs
3 MGD-Alum Coagulation Treatment Plant

Capital Cost	Opinion of Probable Cost
Bar Screen and Grit Basin	$ 140,000
Primary Clarifier	440,000
Equalization Basin	300,000
Activated Sludge Basins	2,050,000
Secondary Clarifier	890,000
Chemical Feed System	40,000
Filters	740,000
Chlorine Contact Basin	250,000
Miscellaneous Structures (including dechlorination)	600,000
Non Component Costs	
° Piping at 10%	550,000
° Electrical at 8%	440,000
° Instrumentation at 5%	270,000
° Site Preparation at 5%	270,000
Contingency, Engineering and Related Costs at 45%	3,140,000
TOTAL	$10,120,000

Operations Cost	
Annual Power Cost	$ 130,000
Annual Operations and Maintenance Cost	330,000
TOTAL	$ 460,000

Table 3.5

Abilene's Home Water Use by Type*

Type	Percent of Total
Exterior Irrigation	51.0
Laundry	6.7
Bathing	15.3
Kitchen	7.7
Toilet	19.3
	100.0

*Source: Abilene's Water Management Plan

The use of reclaimed water for turf irrigation has long been successfully practiced both in this country and overseas. Using reclaimed water for private lawn irrigation would, however, require construction of separate water transmission and distribution systems to supply residential neighborhoods, which is likely to be prohibitively expensive. Because of its cost and safety considerations related to this type of uncontrolled use, this idea was eliminated from detailed consideration.

However, a modified system to provide reclaimed water only to large turf irrigation water users, such as golf courses or parks, was considered practical. Technical Memorandum No. 11 reports in detail on the project team's investigation of the possibility of a non-potable water system using treated wastewater effluent for turf irrigation to reduce demands for potable water.

For this type of program to be successful, sufficient demand for non-potable water must exist, a significant amount of non-potable water must be available, and the water must be of acceptable quality at a cost substantially below potable water costs.

Demand for Non-Potable Water Supply. At present, two non-potable water systems are operated in Abilene. One uses surface water from Lake Kirby for turf irrigation of three golf courses on the south side of the City. The second uses reclaimed wastewater from the Hamby plant for agricultural crop irrigation on the north side of the City.

A typical 18-hole golf course in the 20 to 25 inch isohyet creates an average demand of 250,000 gallons per day (gpd) and a peak demand of 500,000 gpd.

The golf course at Dyess AFB is located distant from the Lake

Kirby system and currently must use potable water for irrigation. This is a significant existing demand and is a favorable candidate for use of nonpotable water. The municipal airport, Dyess AFB fields, and future golf courses would also be likely users of a non-potable supply.

In addition to turf irrigation, other possible areas of demand for non-potable water were investigated. These uses included:

- Agricultural
- Industrial/Commercial
- Recharge of Existing Sources
- Aesthetic Uses

The City is currently operating an agricultural irrigation system using effluent from the Hamby plant. It is anticipated that this operation will continue at about the same use level as currently practiced. Beyond this application a long-term agricultural demand is not expected in Abilene.

Industrial and commercial potable water users were evaluated for possible future demands of non-potable water. Of the major water users reviewed, only one potential user, Dyess Air Force Base (AFB), was identified. However, due to the relatively small quantity and the special needs of this single user no further detailed investigation was made. If non-potable water is brought to Dyess AFB for turf irrigation, then the Base may wish to consider installing an internal non-potable distribution system to allow other uses of the non-potable supply.

Recharging existing sources is possible and is addressed in detail in Technical Memorandum No. 9 for Lake Fort Phantom Hill. Other sources are too distant to be considered at this time.

Aesthetic demands for water exist throughout Abilene. The demand for water vistas and fountains in an urban semi-desert environment is always present if it can be fulfilled at a reasonable cost.

The most promising potential demand for non-potable water appears to be turf irrigation. Sufficient demand exists from the City's golf courses to warrant further evaluation.

Availability of Non-Potable Water. Three sources of non-potable water are available for use:

- Hamby Wastewater Treatment Plant
- Proposed New Wastewater Treatment Plant
- Lake Kirby

These sources will provide more than 7 mgd of water for non-potable use, although 40 percent of the water consumed by the City must be returned to the Brazos River Basin by agreement.

Of these three sources the proposed new wastewater treatment plant and Lake Kirby represent the most practical choices for a non-potable water system.

Lake Kirby is presently supplying water to nearby golf courses. The current users have indicated that the non-potable water now being supplied contains a high concentration of clay particles which adhere to the golf course grass and created undesirable playing conditions. Continuation of the present irrigation practices may require that some level of treatment be provided by a non-potable water treatment plant at Lake Kirby. The need for and treatment level provided by such a plant should be determined by the requirements of the present users of Lake Kirby water.

Lake Kirby could potentially provide non-potable water to the east side of the City, while the proposed new wastewater treatment plant could provide non potable water to the west and southwest side of the City.

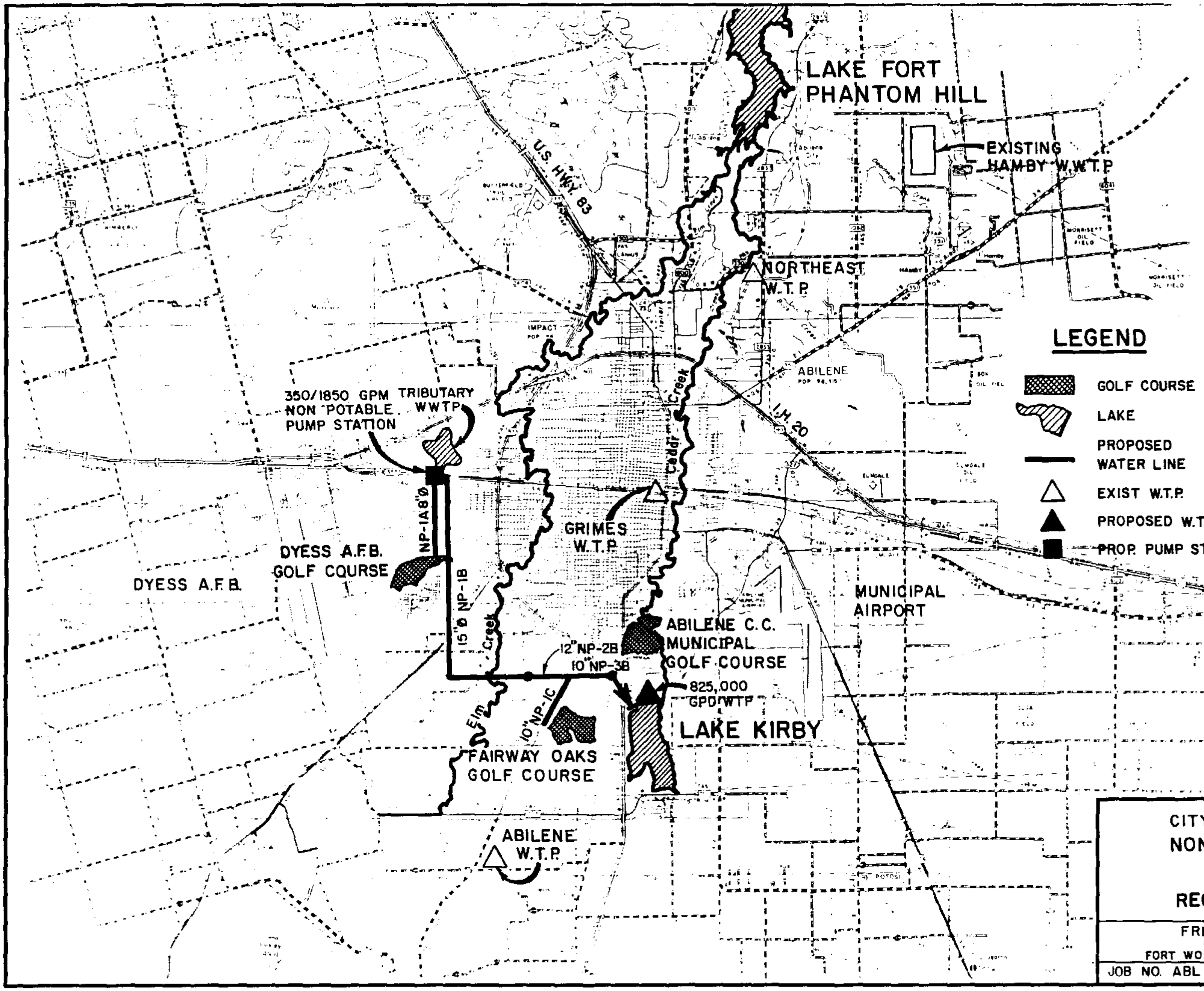
Acceptable Water Quality. Water for reuse must meet standards higher than those normally required for discharge to a stream because of the potential health risks related to contact with reclaimed water. Recommended quality standards for non-potable water were described in Section 2.2 of this report.

Costs Substantially Below Potable Water Costs. The development and evaluation of three alternative non-potable water system plans are outlined in Technical Memorandum No. 11.

The recommended plan is shown in Figure 3.5. The estimated costs for each phase of the recommended improvements are:

Phase	Description	Unit Cost (1000 gal)	Construction Cost
1	Lake Kirby WTP	$0.30	$ 350,000
1	Dyess AFB System	$0.25	$ 220,000
2	Completed Non-Potable System	$0.41	$1,600,000

These costs do not include the cost of the raw water, current pumping costs, or costs associated with obtaining rights for this



NON POTABLE WATER SUPPLY PHASED IMPROVEMENTS

PHASE 1
- 825,000 GPD WATER TREATMENT PLANT AT LAKE KIRBY

PHASE 2
- 350 GPM PUMP STATION AT WESTSIDE WWTP
- 12,000 LF OF 8"Ø PVC (NP-1A)

PHASE 3
- ABANDON PHASE 1 WTP
- EXPANSION OF PUMP STATION TO 1850
- 32,000 LF, 15" PVC (NP-1B)
- 5,000 LF, 12" PVC (NP-2B)
- 9,000 LF, 10" PVC (NP-3B)
- 6,000 LF, 10" PVC (NP-1C)

CITY OF ABILENE, TEXAS
NON-POTABLE WATER SYSTEM STUDY
RECOMMENDED SYSTEM

FREESE AND NICHOLS, INC.
CONSULTING ENGINEERS
FORT WORTH, ARLINGTON, AUSTIN, TEXAS

JOB NO. ABL 86233 | DATE OCTOBER, 1987

FIGURE 3.5

water. However, the total cost to users of water from the proposed system would be significantly less than the current industrial rate charge of $1.25/1,00 gallon for potable water.

The project team recommends that the City of Abilene pursue the development of a non-potable system of the scope and magnitude illustrated on Figure 3.5 as part of the overall water reclamation plan.

3.5 Water Reclamation Alternatives

Two basic alternatives exist for supplying reclaimed water. One is to convert the existing wastewater treatment facility to a water reclamation facility. The other is to construct a new facility at a different site.

The alternatives developed for the Abilene Reclamation project are:

- Alternative 1 - Hamby WWTP Alternative. A water reclamation system centered around upgrading a portion of the existing Hamby WWTP to a water reclamation plant discharging to Lake Fort Phantom Hill.
- Alternative 2 - Tributary WWTP Alternative. A water reclamation system centered around a dedicated water reclamation plant on one of the tributary streams to Lake Fort Phantom Hill.

The alternatives were evaluated as complete systems, including the water reclamation plant, the interceptors necessary to convey the wastewater to the plant and the non-potable water system. Both alternatives are based on the following:

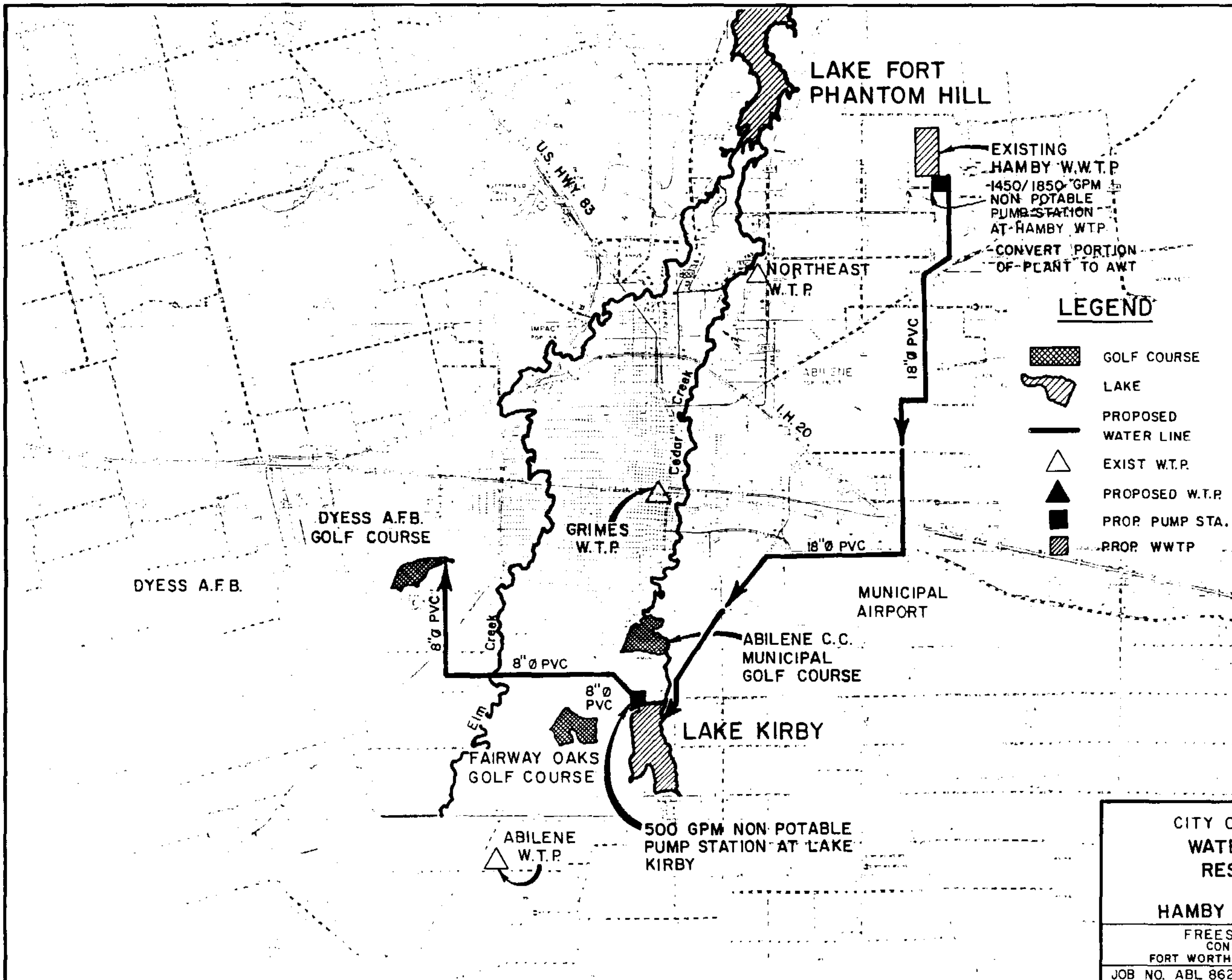
- Treatment units and operations consistent with the alum coagulation treatment process recommended in Section 3.3 "Detailed Process Alternative Evaluation."
- 3 mgd of treatment capacity in 1992 and an additional 4 mgd in 1998.
- Wastewater interceptors, lift stations, diversion structures and other structures necessary to convey the wastewater to the reclamation plant.

To allow cost estimates to be prepared, a specific location was assumed for the tributary WWTP. The general area for the Westside WWTP identified in the City of Abilene Wastewater Collection System Analysis of May 1987 was selected. The costs for a plant similarly located on another tributary to Lake Fort Phantom Hill would be comparable.

The area layouts for the two alternatives are presented in Figures 3.6 and 3.7. Opinions of estimated probable costs for the alternatives, including the anticipated operations and maintenance costs are presented in Table 3.6. Additional information is presented in Technical Memorandum 7A.

The cost for the treatment plant conversion and upgrade for the Hamby WWTP alternative was obviously lower than the cost for constructing a tributary plant at another site. However, the cost for conveying the wastewater to Hamby and the cost for the Hamby-based non-potable system were greater.

The costs for the interceptors required for each alternative were obtained from the City of Abilene Wastewater Collection System Analysis of May 1987. The alternatives above generally parallel the alterna-



ALTERNATIVE IMPLEMENTATION PLAN

PHASE 1

- CONVERT 3 MGD TO AWT
- COLLECTION SYSTEM INFRASTRUCTURE IMPROVEMENTS
- 1450 GPM NON-POTABLE PUMP STATION AND 18" Ø PVC WATER LINE

PHASE 2

- CONVERT ADDITIONAL 4 MGD TO AWT
- COLLECTION SYSTEM INFRASTRUCTURE IMPROVEMENTS
- EXPAND PUMP STATION TO 1850 GPM
- 500 GPM PUMP STATION AND 8" Ø PVC WATER LINE

CITY OF ABILENE, TEXAS
WATER RECLAMATION RESEARCH PROJECT

HAMBY WWTP ALTERNATIVE

FREESE AND NICHOLS, INC.
CONSULTING ENGINEERS
FORT WORTH, ARLINGTON, AUSTIN, TEXAS

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FIGURE 3.6

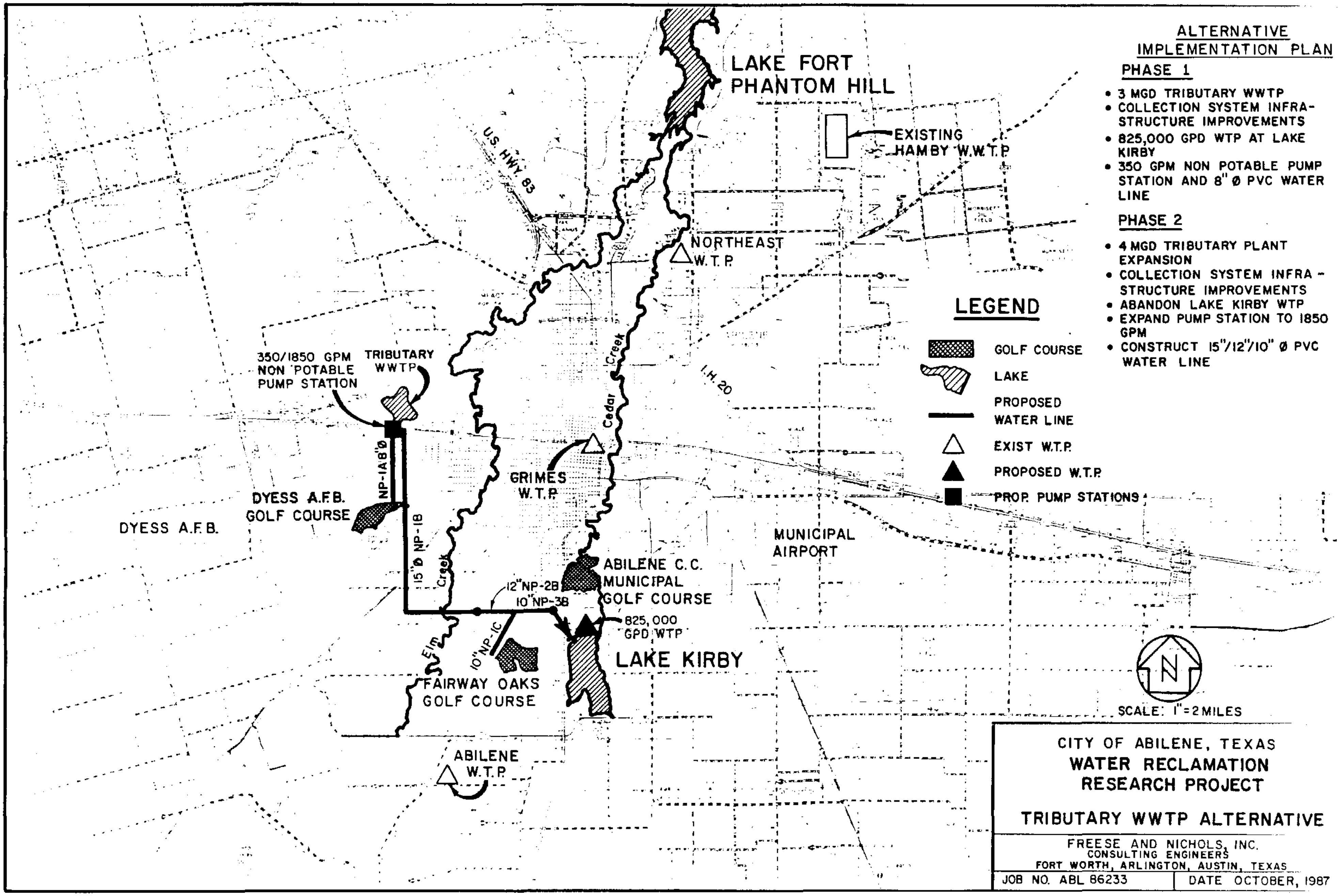

ALTERNATIVE IMPLEMENTATION PLAN
PHASE 1
• 3 MGD TRIBUTARY WWTP
• COLLECTION SYSTEM INFRA-STRUCTURE IMPROVEMENTS
• 825,000 GPD WTP AT LAKE KIRBY
• 350 GPM NON POTABLE PUMP STATION AND 8" Ø PVC WATER LINE
PHASE 2
• 4 MGD TRIBUTARY PLANT EXPANSION
• COLLECTION SYSTEM INFRA-STRUCTURE IMPROVEMENTS
• ABANDON LAKE KIRBY WTP
• EXPAND PUMP STATION TO 1850 GPM
• CONSTRUCT 15"/12"/10" Ø PVC WATER LINE
LEGEND
GOLF COURSE
LAKE
PROPOSED WATER LINE
EXIST W.T.P.
PROPOSED W.T.P.
PROP. PUMP STATIONS
LAKE FORT PHANTOM HILL
EXISTING HAMBY W.W.T.P.
U.S. HWY. 83
NORTHEAST W.T.P.
I.H. 20
Cedar Creek
350/1850 GPM NON POTABLE PUMP STATION
TRIBUTARY WWTP
NP-1A 8" Ø
GRIMES W.T.P.
DYESS A.F.B. GOLF COURSE
DYESS A.F.B.
15" Ø NP-1B
Elm Creek
12" NP-2B
10" NP-3B
10" NP-1C
ABILENE C.C. MUNICIPAL GOLF COURSE
825,000 GPD WTP
LAKE KIRBY
MUNICIPAL AIRPORT
FAIRWAY OAKS GOLF COURSE
ABILENE W.T.P.
N
SCALE: 1"=2 MILES
CITY OF ABILENE, TEXAS
WATER RECLAMATION RESEARCH PROJECT
TRIBUTARY WWTP ALTERNATIVE
FREESE AND NICHOLS, INC.
CONSULTING ENGINEERS
FORT WORTH, ARLINGTON, AUSTIN, TEXAS
JOB NO. ABL 86233
DATE OCTOBER, 1987

FIGURE 3.7

Table 3.6

Economic Comparison of Alternatives
Abilene Water Reclamation Research Project
(in Millions)

	Alternative 1 Hamby AWT	Alternative 2 Tributary AWT
Phase 1 Improvements (1992)[1]		
a. 3.0 MGD AWT	$ 5.55	$10.12
b. AWT O&M (NPW)[2]	2.31	4.52
c. Infrastructure[3]	25.91	9.99
d. Non-Potable System	3.15	0.57
e. Non-Potable O&M (NPW)[2]	0.25	0.50
Sub-Total	$37.17	$25.70
Phase 2 Improvements (1998)		
a. 4.0 MGD AWT Expansion	$ 5.79	$ 9.66
b. AWT Expansion O&M (NPW)[2]	2.89	5.20
c. Infrastructure[3]	20.25	11.03
d. Non-Potable System	0.83	1.60
e. Non-Potable O&M (NPW)[2]	0.12	0.20
Sub-Total	$29.88	$27.69
Net Present Worth (1987 Dollars)[4]	$38.12	$29.37

Notes

1. Phase schedule years based on implementation plan on Figure 4.1

2. Net Present Worth based on (P/A 20, 8%)

3. From Table 5.6 Wastewater Collection System Analysis, May 1987

4. Net Present Worth based on (P/F, 5, 8%) and (P/F, 11, 8%)

tives in the previous report. It was presumed the same collection system improvements would be required to complete a water reclamation project. The costs for the non-potable system were developed in Technical Memorandum No. 11.

Based on a life-cycle cost, including construction and operation and maintenance costs, the Tributary WWTP Alternative is estimated to be less expensive by approximately $9,000,000.

The Tributary plant alternative would require the City to operate two treatment plants at two different sites: 1) the existing Hamby WWTP and 2) the Tributary WWTP. The Hamby alternative also would be like operating two separate plants, since the technologies and level of complexity are so different, although they would be at one site.

Another difference between the alternatives is that the Tributary Plant would discharge to a tributary creek 10 to 12 miles upstream of Lake Fort Phantom Hill, while the Hamby alternative would discharge to Deadman Creek 3 to 4 creek miles upstream of the lake. The further distance of the Tributary discharge would provide a greater barrier to adverse impacts on the lake. However, the Hamby plant would have the option of not discharging to the lake should a problem arise.

If the Westside plant recommended in the previous report is constructed, the research team recommends it be constructed as a water reclamation facility and the Tributary Water Reclamation Plan be implemented. If the Westside plant is not constructed, it is recommended the City of Abilene implement the Hamby Water Reclamation Alternative.

4. IMPLEMENTATION

4.1 Recommended Plan

The research team's recommended plan reflects the consideration of treatment processes, alternative facilities plans, and non-potable use potential outlined in Section 3, and combines structural and non-structural elements in a phased program of improvements. Technical Memorandum No. 9 details the development of the recommended plan. Technical Memorandum No. 11 covers the development of the non-potable supply aspects of these recommendations.

Recommended Facilities to Increase Water Supply. The augmentation of Lake Fort Phantom Hill with water reclaimed from wastewater is technically, economically, and environmentally feasible. The reuse of water is common in nature and in man-made systems. In most river systems in Texas, water discharged by one user is reused by the next consumer downstream, and the next, although each user typically considers itself the prime user.

By implementing a water reclamation plan, Abilene will have the advantage of controlling both the discharge to and the use of water from Lake Fort Phantom Hill.

Phase I of the recommended plan for augmenting flows to Lake Fort Phantom Hill involves using discharge from a new 3 mgd wastewater treatment/water reclamation facility located approximately 10 to 11 miles upstream on a tributary of the lake.

As an alternative approach, water reclamation facilities could be built at the Hamby Wastewater Treatment Plant. However, the additional pipelines and infrastructure works that a Hamby location would entail would add approximately $9 million to overall project costs.

During Phase II, the 3 mgd facility would be expanded to 7 mgd.

Implementation of the recommended plan would provide several benefits:

- Approximately 1.5 to 2.0 mgd of additional water would be supplied to Lake Fort Phantom Hill.
- Major discharges directly into the lake would be avoided.
- No significant risk would be imposed on the drinking water supply due to the size of the discharge relative to the total supply.
- Abilene would gain experience in both the construction and operation of a reclamation facility with only a marginal increase in construction cost over a conventional treatment plant.

The proposed unit processes to reclaim the water from wastewater are described in detail in Section 3. A summary of the process train is presented below:

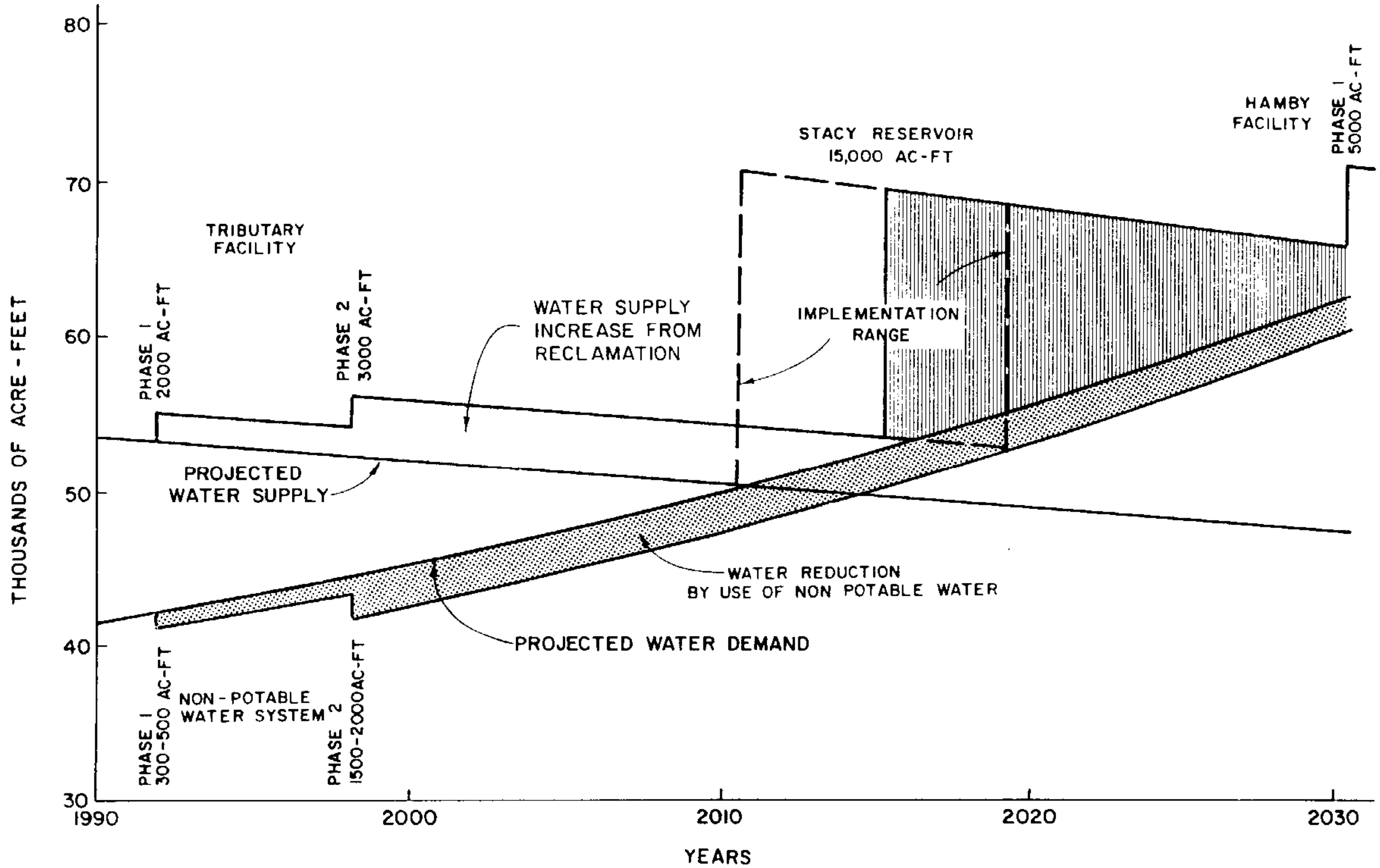
- Biological Treatment (Activated Sludge)
- De-Nitrification
- Biological Phosphorous Removal
- Coagulation (alum)
- Clarification
- Filtration
- Disinfection
- Post-Aeration

The construction cost of the initial 3.0 mgd reclamation facility is estimated at $10 million to $12 million. Constructing a new plant as a water reclamation facility would cost only about $1.5 million more than building a wastewater treatment facility that is not capable of producing reclaimed water. It is presumed a conventional secondary plant with nitrification would be required even if water reclamation were not pursued.

These recommended facilities are based on the assumption that implementation of the Safe Drinking Water Act will require upgrading of Abilene's water treatments plants. It is recommended that piloting studies be initiated within the next few years to address the need for any upgrades in greater detail. These piloting studies should include full-scale granular activated carbon, ozone, air stripping, and combinations thereof. Piloting studies might allow Abilene to reduce its costs in the upgrading of its water treatment plants. This recommendation is made regardless of whether or not a water reclamation facility is implemented.

Recommended Facilities to Decrease Water Demand. A non-potable supply system to be developed in two phases, as described in Technical Memorandum No. 11, is recommended for Abilene. This system could ultimately supply 1.5 to 2.0 mgd to meet existing or future water demands. The proposed non-potable recommendations are shown in Figure 3.5. Key elements of the plan include:

Phase I: Construction of pump station and pipeline from the proposed new Tributary wastewater treatment facility



NOTES:

1. SUPPLY AND DEMAND FIGURE ARE FOR WEST CENTRAL TEXAS MUNICIPAL WATER DISTRICT (ABILENE REPRESENTS 75-80% OF TOTAL).
2. PROJECTED WATER DEMAND IS FOR "DRY" YEAR USE APPROXIMATELY 10% ABOVE NORMAL USE.

FIGURE 4.1

PROPOSED IMPLEMENTATION SEQUENCE

WATER SUPPLY VERSUS WATER DEMAND

to Dyess AFB Golf Course (estimated construction cost $220,000); and construction of a non-potable water treatment plant at Lake Kirby to provide non-potable water to golf courses on the south side of Abilene (estimated construction cost $350,000).

Phase II: Construction of a loop pipeline and possible chain of lakes on the west, south and east sides of Abilene to provide a source of future non-potable water (estimated construction cost $1.6 million).

A direct reduction in water demand of 300,000 to 500,000 gallons per day has been estimated as a result of Phase I. Based on identification of possible users, a possible reduction of 1.5 to 2 million gallons per day is estimated as a result of Phase II.

Similar quantities of non-potable water could be made available if the Hamby WWTP option were pursued. For this alternative the Phase I and II costs are estimated at $3.2 million and $830,000, respectively.

Program of Implementation. Figure 4.1 charts water demand versus water supply with full implementation of the proposed new or converted water reclamation facility, the non-potable water system, and Stacy Reservoir. Phase I facilities would be on line by 1992, providing immediate benefits. Phase II facilities would begin operation in 1998. If projected growth in demand does not occur, however, Phase II could be delayed at little or no cost until the need for additional supplies arises.

Nonstructural Recommendations. The recommended plan also addresses management and operations needs.

Public Information

Based on the input of the Public Advisory Committee and the results of the public meetings, the research team recommends that the City immediately begin a public information program to disseminate the findings, conclusions, and recommendations of this study to the community. After the initial implementation of one of the alternatives, the City may decide to commit to a larger water reclamation project. In that case, a similar public information program would be advisable.

Financing Options

Abilene should aggressively pursue all possible financing opportunities. More detailed information on this subject is provided in Section 4.2, Financing Evaluation, and in Technical Memorandum No. 10.

Water Rights

If the recommendations of this study are adopted, Abilene will need to proceed as soon as possible to acquire water rights covering the increase in supply. Two different kinds of water rights would be involved: (a) rights relating to reuse of reclaimed water for municipal purposes and (b) rights to reuse for turf irrigation.

For purposes of this study, it has been assumed that Abilene could successfully apply for and obtain a permit to reuse the reclaimed water for municipal purposes. There is a strong precedent for this in the case of the North Texas Municipal Water District, which was recently granted rights for municipal reuse in an essentially similar situation.

Water rights involving reuse for irrigation may be a somewhat more complex matter, however, since the rights under which the City obtains its basic supply do not include irrigation as a permitted use. As a result of the Texas Water Commission's program of statewide water rights adjudication early in the 1980's, Abilene found it necessary to apply for a permit covering irrigation with reclaimed wastewater from the Hamby plant. In order to obtain that irrigation right, it was first necessary to reach a mutually satisfactory agreement with the Brazos River Authority, covering the estimated impact of the irrigation reuse on the Authority's prior water rights at Lake Possum Kingdom. Only when the Authority's existing rights were shown to be protected was the Water Commission willing to grant the irrigation permit needed by Abilene. The contract worked out with the Brazos River Authority to satisfy that requirement was based on the concept that Abilene would either (a) return treated wastewater to the Clear Fork and its tributaries in an annual amount equal to 40 percent of the City's total diversions from Brazos Basin sources or (b) compensate the Authority for the estimated loss in Possum Kingdom yield if the irrigation reuse causes the return flows to be less than 40 percent of the diversions.

It is probable that any additional application for a right to irrigate with reclaimed wastewater would encounter the same insistence by the Commission that the proposed new use first be reconciled with the Authority's prior rights at Possum Kingdom. As a corollary issue, it would also be important to confirm that the added irrigation did not conflict in any way with the existing contract covering present reuse at Hamby. Thus, if the turf irrigation option is found to be desirable, it will be helpful to meet at an early date with representatives of the Brazos River Authority in order to resolve any potential overlap with the Authority's rights.

It should also be noted that the question of water rights is essentially a legal matter and in that sense goes well beyond the scope of this report. Clearly, the City of Abilene will wish to consult with its legal advisors and obtain their assistance on this very significant aspect of the reuse issue.

Water Conservation

Abilene should continue with its strong water conservation program to reduce and control future water demand.

Water Quality Monitoring Program

If the reclamation program is implemented, Abilene should continue its water quality monitoring program, possibly with the involvement of local universities, in order to evaluate the impact of expansions and/or modifications to treatment processes. A recommended detailed monitoring program is presented in Technical Memorandum No. 9.

4.2 Financing Evaluation

Federal, state, and local financing options were investigated as potential sources of funds. A detailed report of potential financing sources appears in Technical Memorandum No. 10.

The most promising source of federal funds is the Environmental Protection Agency; however, EPA's funding is limited at this time.

Possible sources at the state level are the Texas Water Development Board (TWDB) and the new State Revolving Fund (SRF) Program.

Although this study was partially funded by a TWDB grant, the Board makes no commitment to funding recommended construction projects.

The recently adopted SRF program merits further investigation. This program is intended as a replacement for the Federal Construction Grants Program, which will be entirely phased out by 1989, and includes many of its provisions. For wastewater treatment and collection projects, the SRF will provide 20-year, 4 percent loans for 100 percent of the planning, design, and construction costs for eligible projects. Funds are released at the time construction begins and are disbursed in increments as costs are incurred. SRF funds are expected to be available by 1990.

Historically, the City of Abilene's preferred means of financing at the local level is to issue general obligation bonds with an ad valorem tax and a pledge of surplus wastewater/water revenues. In the case of turf irrigation projects benefiting a small user group, the possibility of obtaining financial participation from the users should be explored.

4.3 Summary

The City of Abilene has an opportunity to begin a water reclamation program at minimum cost and with minimal risk. Although there is no immediate need for reclaimed water supplies, currently these sources can be developed at costs competitive with those of other sources of supply. Moreover, in time the growth of demand for water ensures that reclaimed supplies will become an important resource. By taking advantage of the present need to improve the City's wastewater treatment facilities, the City of Abilene can gain valuable experience in building and operating a system for reclaiming a water source that may prove vital in supplying the City's future needs.

BAYLOR
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December 7, 1987

Mr. Ray Longoria
Freeze and Nichols
811 Lamar Street
Fort Worth, TX 76102

Dear Mr. Longoria:

Your request for an opinion on the likely effectiveness of alum flocculation upon virus removals by the Abilene Waste Treatment Plant is answered as follows. Our opinion is based in part upon results of our sampling at Abilene, and in part upon the results of other studies.

Effective virus removals can be expected in plants using tertiary physico-chemical treatment that includes properly executed and controlled flocculation and filtration for removal of fine particulate materials. Results from a five year pilot project at Monterey, California, are cited in support of this opinion. No detectable natural enteric viruses were found in effluents emerging from either of two treatment processes (summation of processes and schemata of treatment trains are enclosed). One process (T-22) was judged more effective based upon removal of a greater percentage of poliovirus seeded into influent secondary treated sewage effluent entering the plant.

Our Abilene data show an apparent 99.8% removal of rotavirus in April, and a 99.4% removal of enteric viruses (non-rotavirus) in August. The percent removal calculated was based upon the difference between virus content of raw sewage entering the plant and effluent discharged. We did not determine temporal aspects of sewage flow through the plant but the effluent samples were collected about 5-7 hours after influent raw sewage samples. If the plant treatment did not include alum or other flocculant, then a possibility of improved virus removal exists with addition of alum to the treatment train. Whether an improved removal would occur is purely conjectural. It must be recognized that even the best operated plant with appropriate tertiary treatment is unlikely to be 100% effective all the time. It should also be recognized that such a plant will be among those least likely to experience a significant release of virus pathogens into the environment.

We are not prepared to recommend any particular flocculant(s) as preferred for virus removal, but certainly alum should be regarded as an effective flocculant enhancing removal of virus remaining in secondary treated effluents. The Monterey study indicated alum plus polymer treatment was most effective when formed flocs were sedimented prior to filtration of treated effluents.

We believe alum treatment would be beneficial in promoting virus removal during treatment of wastewater at the Abilene plant. The possibility of using a second flocculant (i.e. polymer) might be considered and certainly sedimentation of formed flocs prior to filtration of treated water seems to be important for maximizing virus removals.

With best wishes,

Sincerely yours,

TG Metcalf

Theodore G. Metcalf, Ph.D.
Professor

TGM/kjp

cc: Dr. J.L. Melnick

Enclosure

CHAPTER 3

TREATMENT PLANT OPERATION

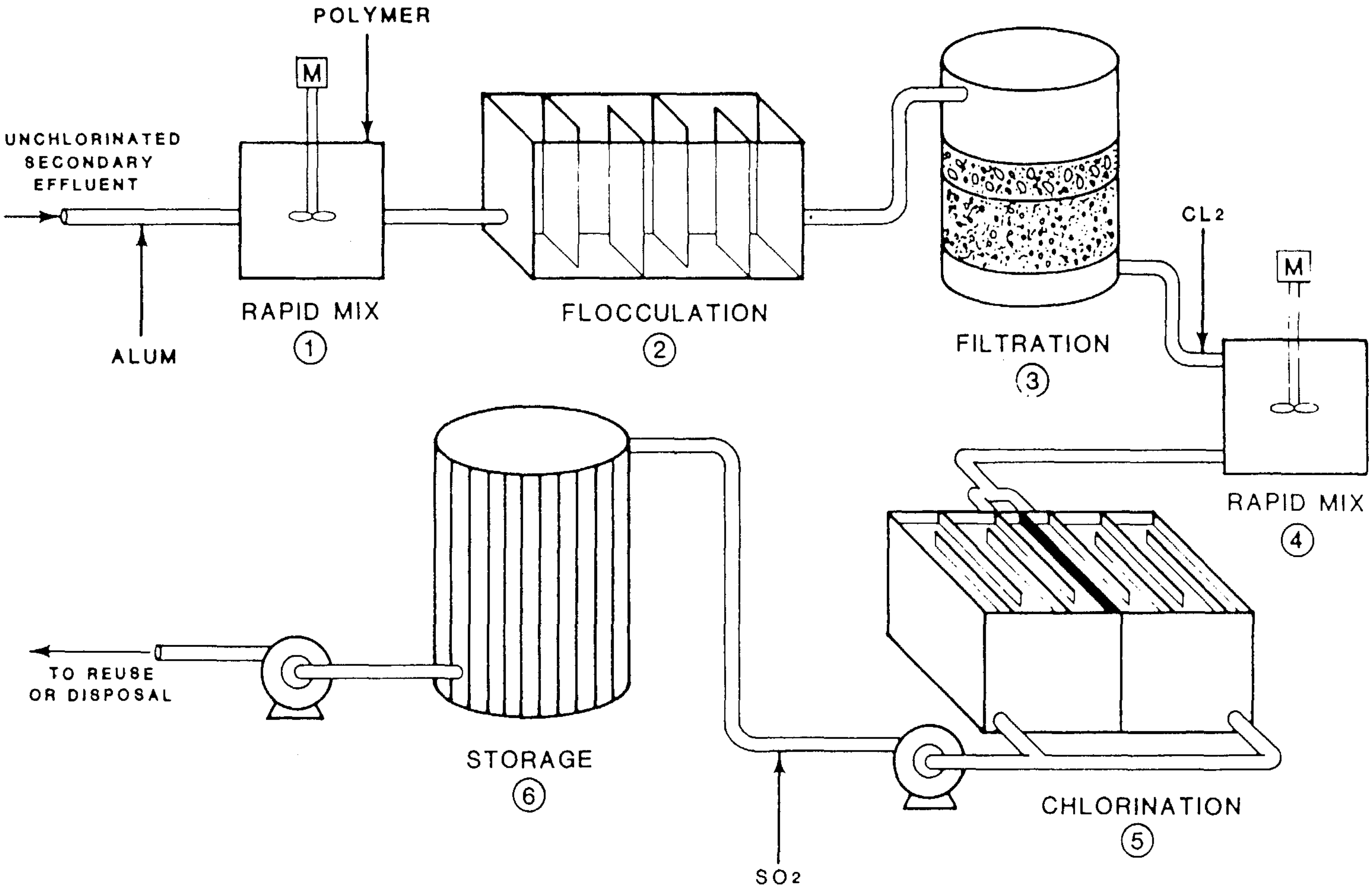
SUMMARY OF TREATMENT PROCESSES

The MWRSA Pilot Advanced Wastewater Treatment (AWT) Plant receives about one-fourth of the secondary effluent produced at the Castroville Treatment Plant and uses two parallel advanced, or tertiary, treatment processes to produce tertiary effluent for irrigation of MWRSA experimental plots. A description of the primary and secondary treatment processes at the Castroville Plant and the tertiary processes at the MWRSA Plant was presented in the MWRSA Year One Report. The following is a summary of the two parallel tertiary treatment methods being compared at the MWRSA plant.

The filtered effluent (FE) process is shown on Figure 3.1. Alum and polymer are added as chemical filter aids; mechanical turbine rapid mix and flocculation chambers provide mixing and flocculation development time; the effluent is filtered by a dual media gravity filter; and, finally, chlorination disinfects the effluent before storage or pumping to the experimental plots. Dechlorination with sulfur dioxide before storage was practiced during Years One through Three of MWRSA, and was discontinued in June 1983.

The Title-22 (T-22) process, shown on Figure 3.2, is more complex. This flowstream conforms strictly to the environmental health regulations in the California Administrative Code, Title 22, Division 4. Higher doses of alum and polymer are used than in the FE flowstream. Flocculation is followed by sedimentation before filtration through a dual-media gravity filter and chlorination. Dechlorination of the Title-22 flowstream with sulfur dioxide was also discontinued in June 1983.

FILTERED EFFLUENT, "FE"



ENGINEERING-SCIENCE INC.

FIGURE 3.1

MRWPCA-MWRSA

TITLE-22 FLOWSTEAM, "T-22"

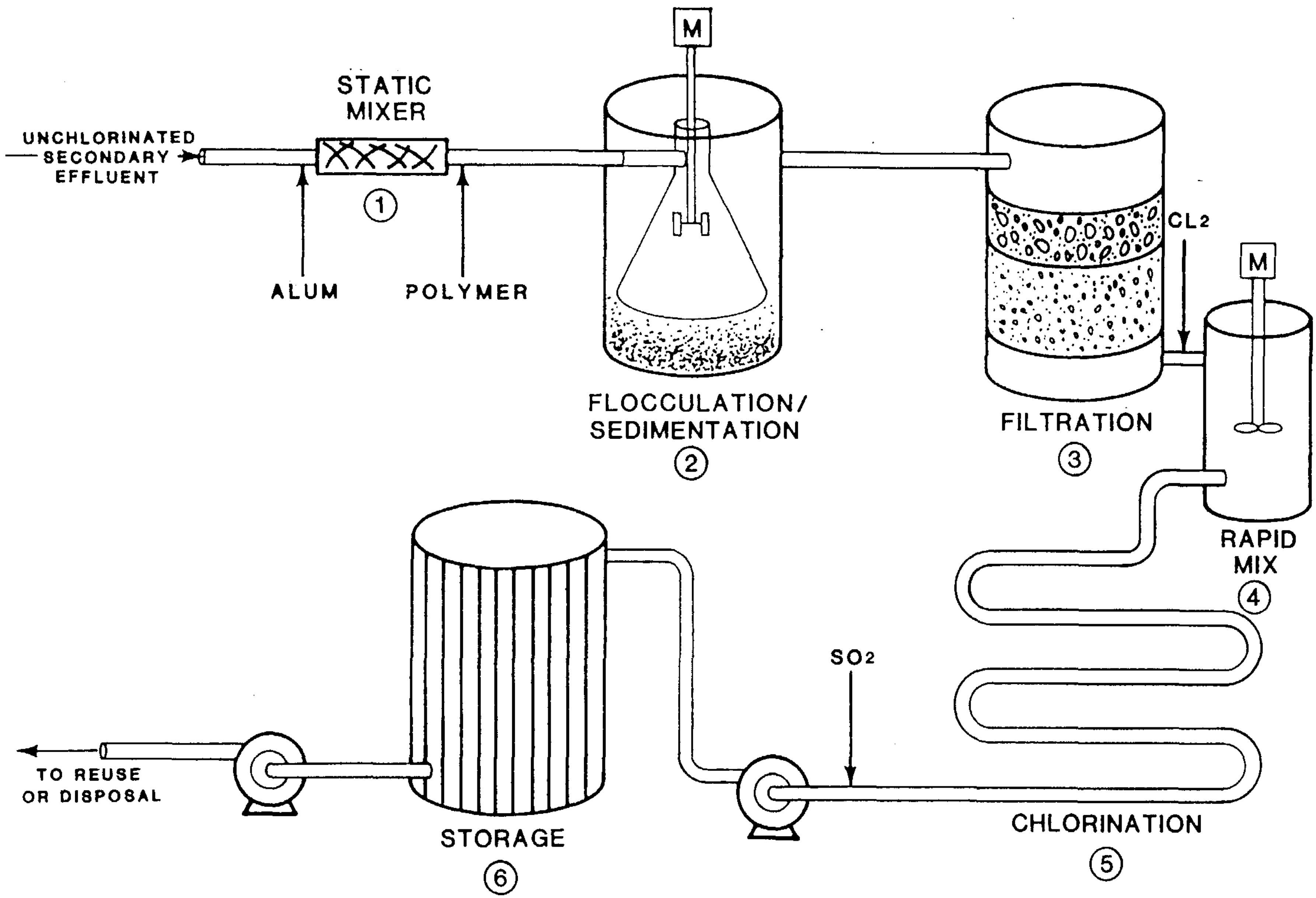


FIGURE 3.2

ENGINEERING-SCIENCE INC.