)OE/EIS-0021

Final Environmental Impact Statement

(Final of Draft EIS, FEA-DES-77-10 and of
Draft Supplement to Final EIS, FEA-FES-76/77-6)

STRATEGIC PETROLEUM RESERVE

Seaway Group Salt Domes

(Bryan Mound Expansion, Allen,
Nash, Damon Mound and West Columbia)

Brazoria County, Texas

U.S. DEPARTMENT OF ENERGY

June 1978

Volume 2 of 3

Appendices A and B

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Responsible Official

James L. Liverman
Acting Assistant Secretary for Environment

U.S. DEPARTMENT OF ENERGY
Washington, DC 20545
June 1978
Volume 2 of 3
Appendices A and B

Volume 2

Appendix A Detailed Description of Project
Appendix B Detailed Description of Environment

TABLE OF CONTENTS

APPENDIX A

DESCRIPTION OF PROJECT

LIST OF FIGURES

LIST OF TABLES

APPENDIX A

DESCRIPTION OF PROJECT

A.1 INTRODUCTION

A.1.1 Group Description

The Seaway SPR Program Group consists of five salt domes in the southeast Texas counties of Brazoria and Fort Bend (Figure A.1-1). The sites were selected for their engineering feasibility, convertible existing storage capacity, accessibility to pipeline and port facilities for crude oil distribution and their overall environmental suitability. For the purposes of this report, SEAWAY salt domes are planned to have a total of approximately 163 million barrels (MMB) of crude oil storage capacity in existing and new solution-mined caverns. This oil would be distributed through the port facility at Brazosport (Port of Freeport, Texas). From this facility, oil will be distributed to inland refineries via SEAWAY Pipeline System and via tankers to East Coast, Gulf Coast, and Caribbean refineries.

The potential storage sites are Bryan Mound, Allen dome, West Columbia dome and Damon Mound in Brazoria County, and Nash dome in Fort Bend County. For the early storage phase of the project, up to 63 MMB of existing storage capacity is presently being modified at Bryan Mound.

Development of the SEAWAY Group to a total storage capacity of approximately 163 MMB would require the further construction of at least 100 MMB of new storage at one of the five sites within the group. The proposed development plan is to expand Bryan Mound by an additional 100 MMB. Development of 100 MMB of storage capacity at either Allen dome, West Columbia dome, Damon Mound or Nash dome is an alternative to the 100 MMB expansion at Bryan Mound.

The proposed water source for the expansion is increased withdrawals from the Brazos River Diversion Channel; alternatives include ground water from the Evangaline Aquifer and reservoirs operated by the Dow Chemical

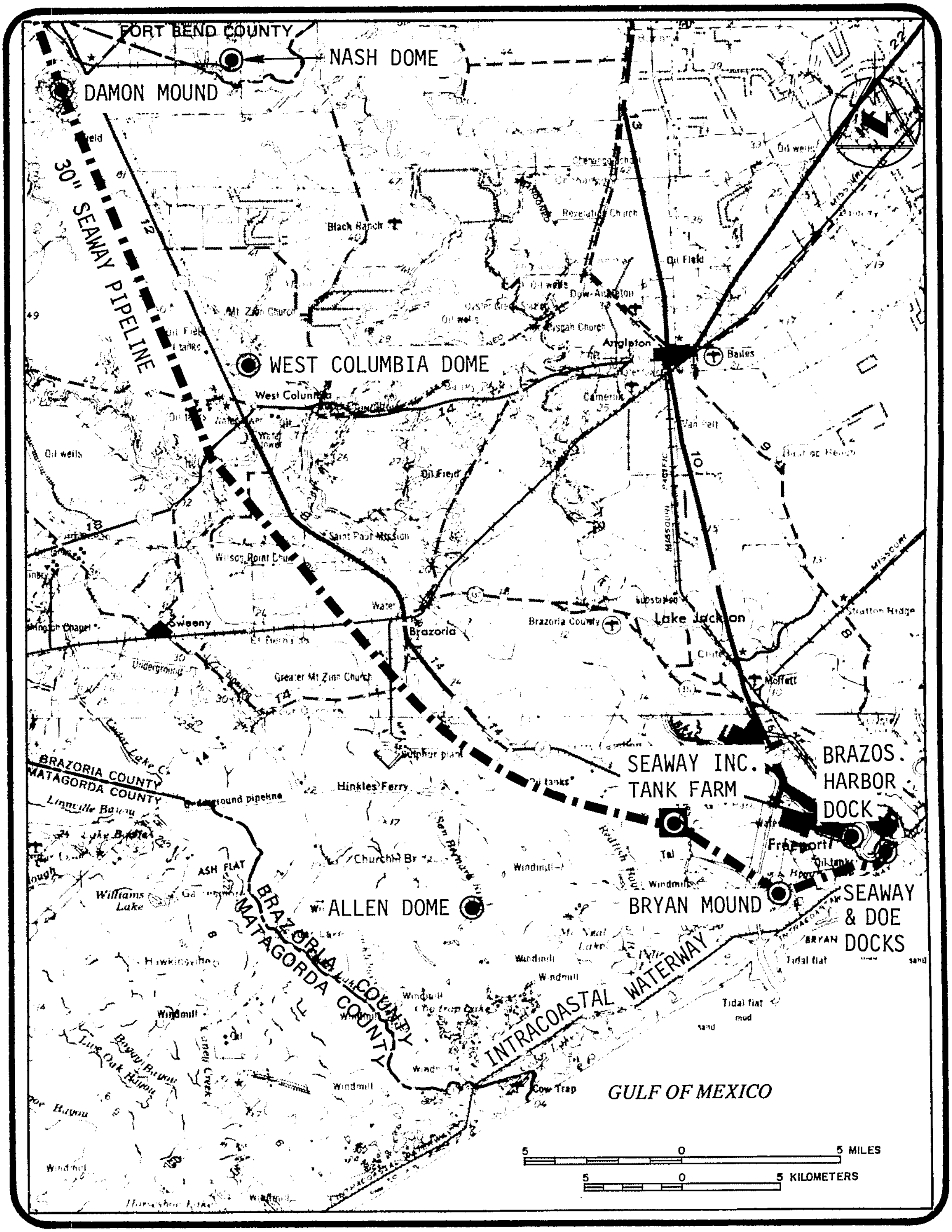


FIGURE A.1-1 Seaway Group salt dome location map - showing proposed site (Bryan Mound) and four alternative candidate sites.

Company. Displaced brine would be pumped to a brine diffuser in the Gulf of Mexico for each of the sites. Deep brine injection wells will provide a backup to the brine disposal system.

A.1.2 Presentation Format

Section A.3 of this appendix presents the proposed development of the SEAWAY Group (early storage site combined with Bryan Mound expansion) and details the construction and operation of proposed site facilities and their alternatives.

Development alternatives are provided in Sections A.4 through A.7, together with discussion of the proposed and alternative facilities for each development combination.

Appendices B and C detail the existing environment and anticipated environmental impacts, respectively, for the SEAWAY Group region and for each individual site combination. Impact discussions include both proposed and alternative facilities for each site combination.

A.2 CONCEPT OF STORAGE IN SALT DOMES

A.2.1 Introduction

It has long been recognized that caverns in salt domes are attractive storage sites for petroleum products due to both the relative low cost of bulk storage and the geological stability of deep rock salt masses. The formation of salt domes in the Gulf Coast region and the geological properties of the domes are discussed fully in the SPR Programmatic Environmental Impact Statement (FES-2). The single property of salt that makes it most attractive for crude oil storage is its in situ impermeability. No other common rock type could contain crude oil as safely. In addition, underground salt domes provide security from natural catastrophies or sabotage.

Salt domes are a major source of brine feedstock for the chemical and salt industries in the Gulf region. The salt in the domes is removed by conventional mining techniques or by solution mining. In the solution mining process, salt is dissolved by injecting raw water into the dome, and allowing the water to leach (or dissolve) the salt (Figure A.2-1). The resulting brine is then displaced by injecting more raw water. Solution mining of a salt dome requires that about 7 barrels of fresh water, or about 8 barrels of sea water, be used to leach one barrel of cavern space.

Caverns may be mined specifically for use as storage of petroleum products rather than as a by-product of obtaining brine feedstock. Expansion of the SPR Program storage capacity will use the same solution mining (leaching) method that has created many existing caverns except that the brine created will exceed the needs for feedstock and will be disposed of to the environment. To store petroleum products in the caverns formed by the leaching of the salt, the products would be injected into the dome to displace the brine (Figure A.2-1).

During an oil supply interruption, the oil would be withdrawn from the cavities (Figure A.2-1). The crude oil would be distributed to refineries by the SEAWAY Pipeline and tankers from the dock facilities at the Port of Freeport, Texas. The raw (displacement) water would also dissolve the walls of the storage cavities, enlarging them somewhat.

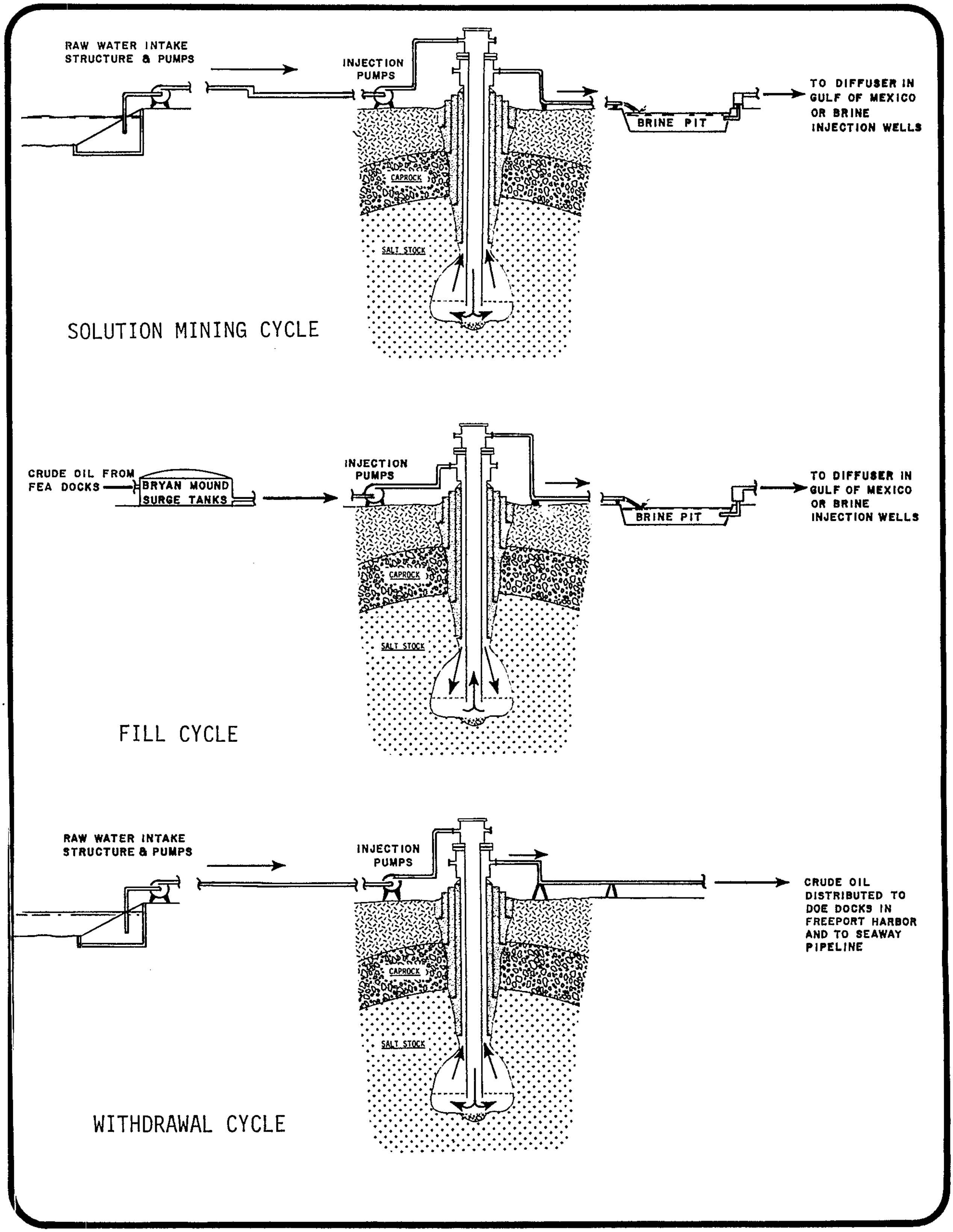


FIGURE A.2-1 Schematic representation of SPR facility operation

Although crude oil storage in salt dome caverns does not present particular technical problems, the technique has been utilized primarily in other countries. In the United States, the products stored in salt dome caverns have largely been fuel oil and LPG products such as propane and ethylene.

A.2.2 Generalized SPR Site Facilities

This section describes those construction and operating procedures and methods that are common to all potential storage sites. Site-specific procedures and methods are described in Sections A.3 through A.7.

The storage system at each SPR site would consist of a series of caverns. New caverns would be leached to a capacity of approximately 10 million barrels. Existing caverns that would be converted for oil storage would be solution mined (leached) caverns that have been developed to obtain brine as feedstock for chemical plants. A solution mined oil storage cavern (basically a large subterranean pressure vessel connected to the surface by at least two vertical pipelines) usually contains both oil and brine. If oil is pumped into one of the pipelines, brine will come out of the other (or vice versa). Because oil will float on brine, the oil pipeline must connect to the top of the vessel and the brine line must connect to the bottom.

Control of cavern construction and oil storage withdrawal operations would be established in a central pumping plant area, and each cavern would be linked to the central plant by electronically controlled valves and by oil pipelines plus water and brine lines as appropriate. All controlling, monitoring, and metering operations would be performed in the central plant area at the cavern storage sites. General operations associated with a storage site are shown in the schematic drawing in Figure A.2-2.

Raw water for cavern leaching and for oil displacement during withdrawal would be supplied to each site from an off-site source. A pipeline would connect the water source to the plant area. Sources of

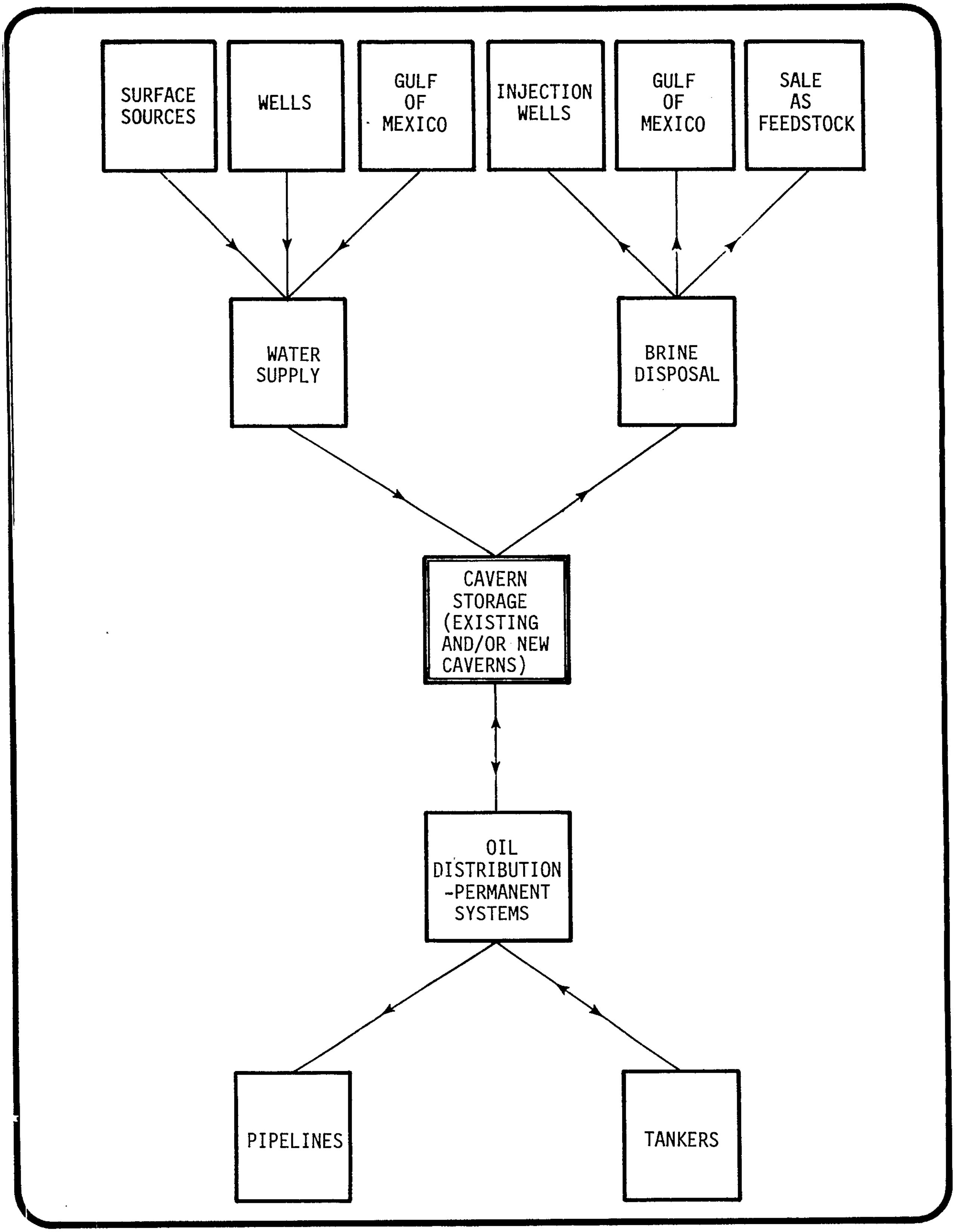


FIGURE A.2-2 Schematic of crude oil storage systems.

raw water could include nearby streams or other bodies of relatively fresh water, subsurface aquifers containing either fresh or brackish water, or sea water from the Gulf of Mexico.

Both cavern leaching and crude oil storage in leached caverns require disposal of displaced brine. Brine would be piped to the Gulf of Mexico or to subsurface disposal injection wells. Depending on factors such as proximity to potential users, some brine could also be sold as feedstock to chemical plant operators.

Oil distribution would be handled through a regional facility and pumped via pipeline to each storage site. During withdrawal, oil would be pumped to the regional facility where transfer to tankers or pipeline would be made. Crude oil entering storage would be received from the regional facility.

A.2.2.1 Construction Techniques

A.2.2.1.1 Cavern Storage System

As was stated previously, new caverns would be formed by solution mining the salt domes. This section describes the general techniques used in the construction of new caverns. Detailed descriptions of construction processes are presented in subsequent sections.

Prior to commencement of actual leaching activities, an entry well must be drilled. It is planned that conventional oil well drilling rigs would be used for this purpose. Well diameters are determined by the desired leaching or oil withdrawal rate, where the rate of oil withdrawal is based on emptying the cavern within 150 days.

During the drilling process, the casing string would be placed and grouted in the borehole to provide a sealed passage between the salt dome and the surface. Telescoping casing strings would be used, the largest casing being approximately 42 inches in diameter. Outer casings would use cement as the grouting material to prevent leakage into the caprock and to protect freshwater and brackish aquifers from contamination by brine or oil (Figure A.2-3). Cementing would also serve to stabilize the casing against possible movement and damage. After the drill hole penetrates through the dome caprock, a minimum additional five hundred

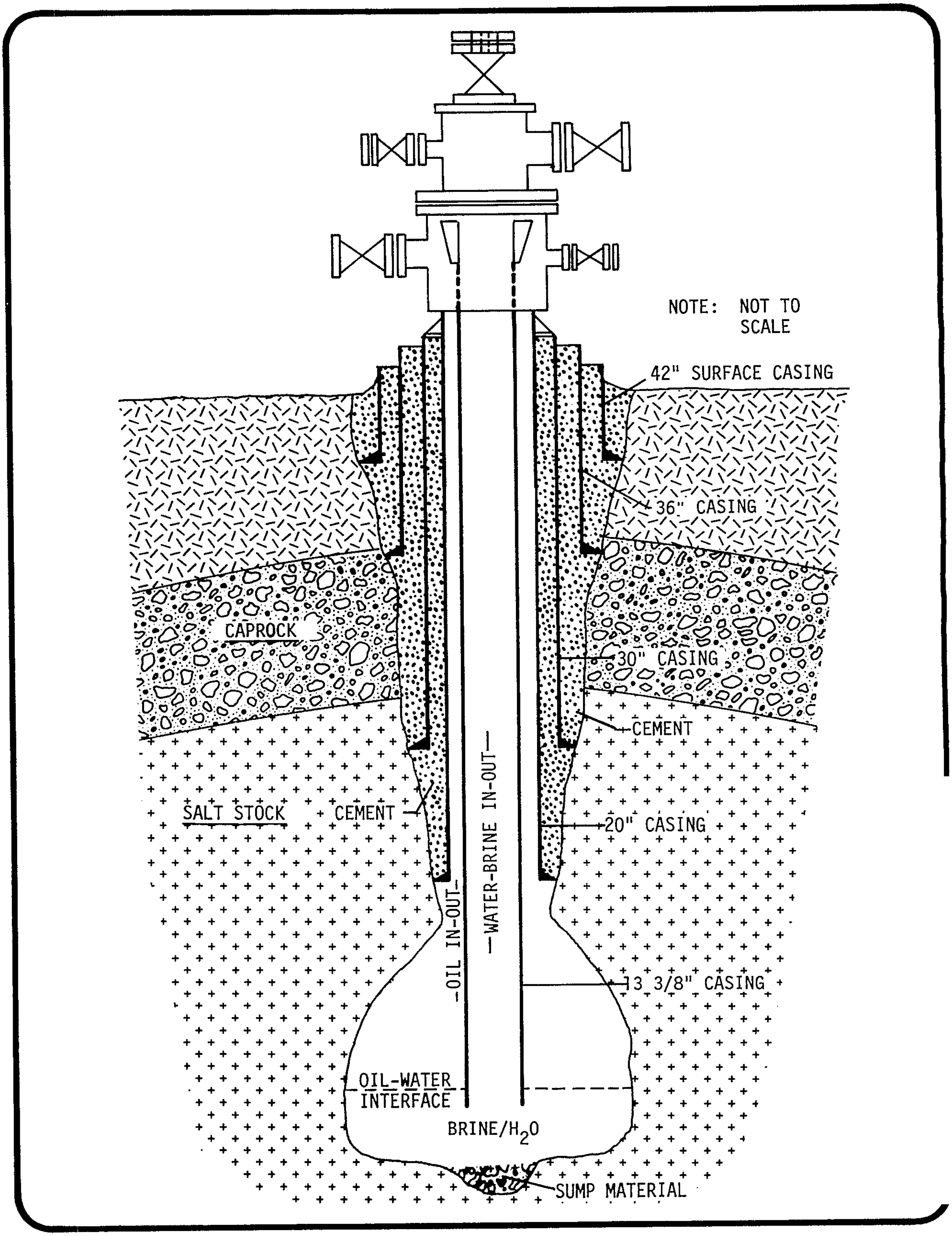


FIGURE A.2-3 Typical storage well casing diagram.

feet would be drilled into the salt before the final casing would be placed and grouted. The bottom of the casing would be the location of the top of the cavern to be developed. Drilling then proceeds to the bottom of the sump. (A sump is an extension of the cavern that provides a place for insoluble material to stay in the cavity and not impair operation as a storage cavern.)

The drilling equipment would then be removed and the strings of pipe used for leaching inserted. Pipe strings for leaching would consist of two pipes of different diameters which would be placed concentrically in the well. The larger diameter pipe would extend just below the top of the proposed cavern ceiling. The smaller inner pipe would extend to the bottom of the drilled well. Each well would require 60 to 90 days of rig time for preparation for leaching. During leaching operations, a smaller, more portable workover rig would be used to adjust casings for proper leaching.

Leaching a storage cavity of the desired size and shape would be accomplished by varying the rate of raw water input and the positions of casings within the well. Blanket oil would be installed on the brine surface when necessary to restrict the ceiling of the cavity from further upward migration. The finished cavern would be approximately 1000 feet in height and 300 feet in diameter, with a conical sump about 400 feet deep at the bottom. Each cavern would require about 24 months to be leached to a 10 MMB capacity.

In an estimated 20 percent of the wells drilled, difficulty in drilling through the caprock overlying the salt is expected. Difficulty results when cavernous zones are encountered in the caprock. The cavernous zones derive from natural leaching of the anhydrite and gypsum layers during formation of the salt dome and may require the installation of a smaller casing to get through the caprock. The smaller casing would reduce the flow rates obtainable during oil withdrawal, and less oil could be removed during the 150-day withdrawal period. The cavern would therefore be leached only to the capacity which could be withdrawn in 150 days, or about 5 to 6 MMB.

Drilling muds utilized at each cavern site would be self-contained within each site using mud tanks or mud pits for storage. At completion of each well, the mud would be removed for reuse at other wells or hauled away for disposal. Mud pits would then be buried.

Newly developed caverns will have a design capacity of 10 MMB, although approximately 20 percent of the caverns will have reduced capacities resulting from drilling difficulties. With each oil fill and withdrawal cycle, up to five of which are anticipated over the life of the project, the capacity of the cavern will increase, resulting in an ultimate capacity of approximately 20 MMB. As discussed above, the entry well diameter and casing size are determining factors in the rate of oil fill and withdrawal. It is planned that each cavern will only be refilled to its original design capacity and that water introduced to force the oil out will remain in place to fill the excess capacity.

An 800-foot design spacing of storage cavities has been selected (except Nash dome, where a 600-foot spacing would be used) which for 300-foot diameter caverns, would allow a minimum of 500 feet between adjacent walls. A distance of 600 feet would be allowed from any cavity to the estimated extremity of the dome flanks. A minimum salt barrier of 500 vertical feet would be provided between the ceiling of each storage cavity and the caprock.

Existing leached caverns (i.e., Bryan Mound) would potentially be utilized and would require inspection, testing, and conversion prior to inclusion in the storage program. Inspection and testing of existing caverns would include both the well apparatus and the cavern itself. Surface equipment and casing string integrity would be inspected using conventional techniques. Through these procedures, all equipment would be measured for wear and corrosion and checked for soundness and leakage. Casing strings would be pressure tested to an appropriate safety factor above working pressure. A sonar caliper survey would be performed on each cavity to record actual existing size and shape, and proximity to other existing and/or proposed caverns would be computed.

Conversion procedures would depend on the type and size of existing casing and surface equipment. Caverns with sound, adequately sized casing would require only installation of equipment for crude oil displacement and connection to water, brine, and oil pipelines. Other caverns would require more substantial conversions, possibly including the drilling of new entry wells to provide adequate flow rates.

Cavern Development

Underground caverns used for storage of crude oil can be of two basic types, solution-mined construction or conventionally mined. A solution-mined storage cavern is basically a large subterranean pressure vessel, connected to the surface by at least two vertical pipelines and usually contains both oil and brine. If oil is pumped into one of the pipelines, brine will come out of the other (or vice versa). Because oil will float on brine, the oil pipeline must connect to the top of the vessel and the brine line must connect to the bottom. To insure stability of the cavern, it is maintained in a continuously filled condition (either brine or oil or both), with the contents under an externally applied pressure.

A completed solution-mined cavern usually has a cased borehole terminating at the roof of the cavern and a suspended pipe terminating near the floor. Water or brine is inserted into the suspended pipe to displace oil upward through the borehole annulus during withdrawal of oil from storage. During filling, oil is pumped into the annulus forcing brine to surface through the suspended pipe (see Figure A.2-4) During withdrawal, fresh or saline water is injected into the cavern to displace the stored oil, as a result the cavern walls are dissolved and brine is formed.

Oil storage caverns constructed using conventional mining methods are designed with internal support provided by salt pillars, a technique not available with solution mining. The maintenance of a continuously filled condition is therefore not required for cavern stability. A single vertical pipeline extending to the bottom of the cavern is used as both the fill inlet and pump sump for withdrawal of oil. No brine is produced by conventional mined storage.

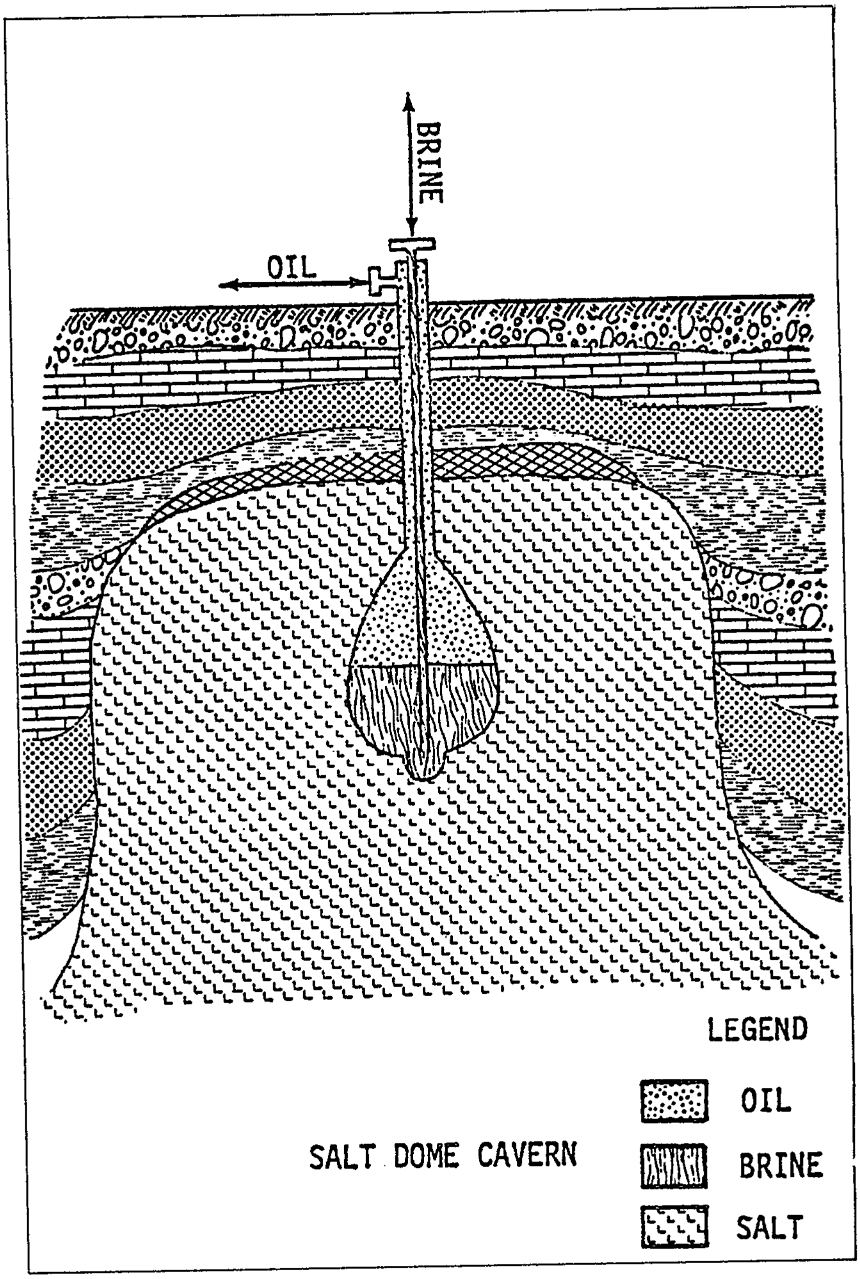


FIGURE A.2-4 A typical storage cavern.

Size Relationship - Borehole Versus Cavern Size

Salt dome caverns are usually leached through single boreholes. The size of those boreholes has a significant effect on both the rate of cavern development and on the usefulness of the completed caverns. Many commercial caverns storing LPG could meet operating requirements through cased boreholes as small as nine inches, yet have been developed through holes as large as 12-1/2 inches to facilitate rapid leaching.

The proposed strategic storage system presents a unique combination of criteria. Unlike commercial facilities, the stored product will rarely, if ever, be cycled. DOE has directed that caverns be designed to tolerate enlargement caused by fresh water displacement of oil during five cycles of storage. The basic objective is to develop the cheapest possible system capable of delivering its contents within a period of 150 days. Since solution mining is very sensitive to scale, this objective could be achieved by developing each cavern to the maximum capacity that could be emptied through its borehole during the prescribed period. There is, however, the consideration that to receive public acceptance and to expedite regulatory approval, the strategic storage cavern design must be based on proven technology.

A limit of 20 million barrels was selected for the final cavern, a size approximately equivalent to the largest salt dome caverns now used for brine production. The initial cavern size that would permit five cycles of storage without exceeding 20 million barrels was calculated and an initial volume of 10 million barrels was selected. (A 10 million barrel cavern cycled five times with fresh water and refilled each time with 10 million barrels of oil would grow to a size of about 18.6 million barrels. If refilled to its maximum capacity after each cycle, it would grow to about 22.1 million barrels. Design criteria for these caverns is presented in Appendix F.

Because of the DOE criterion that a cavern would be refilled only to its original capacity after each storage cycle, the borehole delivery requirement would be only 10 million barrels in 150 days, regardless of how large the cavern grew. This objective can be achieved in most cases through a 15-inch cased borehole. The mining rate for solution-mined caverns would, however, require that 20-inch casing be used. If drilling difficulties are encountered in the often unpredictable caprock, it is sometimes necessary to set a string of 15-inch casing to complete the hole. Thus even with the anticipated 20 percent likelihood of drilling difficulty, the oil withdrawal rate would not be altered. A related standardization adopted as part of the design is a maximum rate of brine discharge of 3000 gallons per minute for the 20-inch borehole, permitting a rate of cavern enlargement of approximately 15,000 barrels per day. This rate represents a point on the power consumption curve where the cost of accelerating flow may exceed the savings from accelerating leaching.

Leaching Well Design

Storage wells are drilled with "oil field" type rotary drilling procedures. A rotary bit is connected to surface by pipe. The bit supports the lower portion of the pipe, thereby deriving the downward thrust necessary to penetrate the rock. The lower portion of pipe - a series of drill collars - is very stiff, heavy, and resistant to buckling. The upper pipe - known as drill pipe - is kept in tension and consequently can be much more flexible.

Most drilling is done by rotating the bit with torque transmitted from the surface through the drill pipe and collars. Bits generally consist of three rolling cones, each serrated with short, husky teeth. As each tooth is presented against the bottom of the hole, a small chip is fractured away from the parent rock.

For drilling to proceed, chips must be transported from the face of the cutters to the surface. This is accomplished by pumping a fluid, known as mud, down the pipe to the bit where it exists, picking up the cuttings and carrying them to the surface through the borehole annulus. Besides transporting cuttings, the mud also cools the bit and supplies a stabilizing pressure to the borehole walls.

Many sedimentary rocks are so weak that they would cave if mud support were not available. Maintaining the proper composition and quality of mud is a critical factor in any drilling program. The wrong mud can cause hydration of shales, dissolve salt, slow drilling penetration, cause walls to fail and pipes to stick, and numerous other problems.

Regardless of how good the mud is, however, circulation must be maintained if the mud is to do its job. Many rocks are porous, permeable, and contain fluids existing at pressures less than that of the borehole mud. Consequently, the mud must be able to seal the walls of the hole or it will flow into the rock rather than back to the surface. Although the drilling industry has developed muds for almost every drilling condition, vugular or cavernous structures occasionally defy sealing, and circulation fails.

If the uncased borehole is composed of competent rocks when circulation is lost, the driller can utilize many materials including cement to seal the loss zone. In some instances, he may be able to proceed with drilling by sacrificing his mud and allowing cuttings to be deposited into the loss zone. If he can tolerate a reduction in hole size, he may choose to place steel casing across the zone.

The leaching well design established for this study is considered relatively conservative. Most of the problems encountered in drilling into salt domes have stemmed from the unpredictability of caprock. Adjacent holes in the same dome may behave quite differently from one another. One may permit strong circulation throughout drilling and cementing, while the other may prove so troublesome that an extra casing string must be set to achieve completion. The standard design must be conductive to successful completion, even under relatively difficult conditions. A possible design is shown in Figure A.2-3.

If circulation problems develop while drilling the caprock, the driller may choose from a number of options. He may try to reestablish good circulation by blending filler materials into the mud, attempt to advance to the projected casing point in the salt by drilling without fluid returns using brine injection, or try to seal the void with cement. If all else fails, he may attempt to set the 20-inch casing through the problem zone, and if successful, proceed to set 15-inch casing into the salt.

Regardless of his tactics, his drilling fluid, be it mud or brine, must be saturated with salt before penetrating the top of the salt mass. If the salt is drilled with unsaturated fluid the borehole will enlarge, causing problems in maintaining directional control, tool joint failures from buckling of the drill collars, and difficulties in obtaining good cementation of the product casing.

The cementing program should be designed to raise the cement column well into the 30-inch pipe. In most instances, it would be unadvisable to attempt cementation to surface in a primary stage. If full cementation is deemed imperative, a stage collar should be installed as the 20-inch casing is run to permit secondary cement placement after the primary stage has hydrated. If the hole has been completed without mud circulation, special nitrogen procedures may be required to achieve primary cementation into the 30-inch pipe.

<u>Leach-Then-Fill Cavern Construction</u>

The fundamental technique of cavern development is to expose the salt in a drilled hole, inject raw (fresh or low salinity) water into the hole, allow time for the water to dissolve the salt, and displace the resulting brine from the hole. The hole enlarges as the salt dissolves, eventually forming a cavern. In actual practice, the procedure for cavern development is somewhat more complex as described in the following paragraphs.

Raw water injected into a cavern makes contact with salt by circulation and diffusion. Circulation is the dominant factor, being caused by both density and pressure differentials. Being lighter than brine, injected raw water tends to rise, causing a "rolling" effect throughout the cavern. This agitation is responsible for the major portion of the dissolution. During the initial leaching effort, the pressure differential between points of fluid entry and exit establishes the direction of fluid movement across the salt face. As the cavern grows, the rolling effect may cause fluid at the salt face to move in the opposite direction.

Two basic washing methods - direct circulation and reverse circulation - are normally used. Direct circulation is more common, involving injection of raw water near the bottom of the cavern and withdrawal of brine through the casing annulus near the top of the cavern. In reverse circulation, water is injected down the casing annulus and enters near the top of the cavern, displacing brine into the tubing at the bottom of the cavern. Both methods employ the same drilling and casing procedures.

When direct circulation methods are used, the maximum diameter occurs near the bottom of the cavern interval and the minimum diameter forms near the top. The reverse circulation method causes development of a large diameter cavern roof, with the diameter decreasing toward the bottom of the cavern, resulting in the so-called "morning glory" type cavern.

To construct large caverns for most storage purposes, modified techniques using direct circulation initially, reverse circulation during primary leaching, and blanket material for control of upward growth are used. Casing strings would not be moved during cavern leaching.

Blanket material is any noncorrosive, lighter than water substance (gas, propane, butane, diesel oil, crude oil) which occupies the space in the topmost interval of the cavern. The purpose of blanket material is to prohibit leaching of salt from around the cemented casing. It also protects the casing from internal corrosion and can be used to initially depress leaching to the bottom of the borehole for construction of a sump.

The protective blanket is extremely important, requiring careful monitoring and maintenance. Protection of cemented casing serves the dual purpose of insuring a pressure-tight cavern and prohibiting development of high spots from which the stored product could not be retrieved.

Some insoluble material is present in most salt. As leaching proceeds, an accumulation of insoluble material builds up in the bottom of the cavern, sometimes plugging the wash pipe. This condition can be rectified if a small cavern is first leached below the storage interval. The pipe is then raised to wash the major cavern, allowing solids to accumulate in the sump.

The above techniques would be utilized for all caverns, using the casing configuration shown in Figure A.2-4, with an inner string of 8-5/8-inch casing installed for leaching. After approximately two years of leaching, the cavern would be fully formed, the 8-5/8-inch casings would be removed and the filling cycle begun. By sequencing the leaching and filling operations at a storage site, relatively uniform leach and fill could be achieved.

Leach/Fill Cavern Construction

A modified technique which permits the entire cavern interval to be leached without moving the tubing strings is proposed for the SPR program. The procedure involves setting blanket casing in the lower half of the cavern interval, maintaining the blanket at the final cavern roof elevation, and injecting raw water into the lower portion of the cavern. The entire interval would be leached simultaneously, yet saturated brine can be withdrawn from the bottom of the cavern. This method would be very efficient (see Figure A.2-5).

The modified leaching procedure would also permit the upper portion of the cavern to be used for cyclical storage while leaching continues. Stored product would be used as blanket material and the blanket level is lowered or raised as dictated by the storage cycle. During storage periods the lower portion of the cavern would continue to enlarge. The upper portion would be enlarged by removing the blanket material (crude oil). By introducing raw water at the correct depth, balanced cavern growth could be achieved.

To develop caverns by this method, conventional oil field techniques would be used to drill a hole to about 500 feet below the projected cavern floor. Casing would be cemented from the surface to the projected cavern roof, at least 500 feet below the top of the salt. Blanket casing would be suspended to the projected floor and concentric tubing suspended to the bottom of the hole. Oil would be placed in the hole around the blanket casing and raw water injected down the tubing. Brine would be withdrawn from the blanket casing, thereby leaching the lower portion of the sump. A few joints of tubing would then be removed and the direction of water/ brine flow is reversed. Brine of increasing salinity would be produced until the sump is of sufficient size to handle anticipated insoluble material.

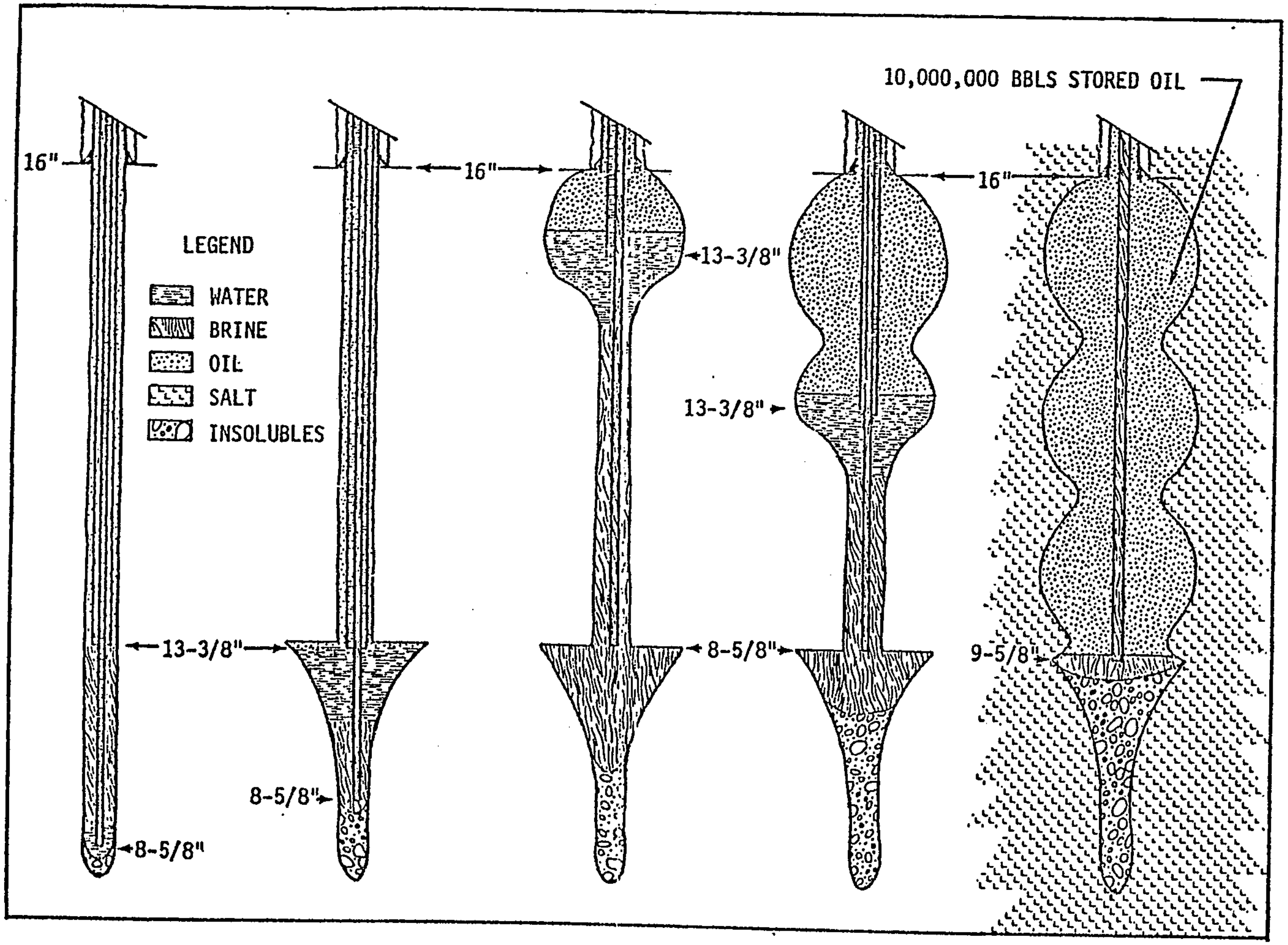


FIGURE A.2-5 Concept for commencing storage while leaching.

After completion of the sump, the oil (blanket material) is withdrawn to the elevation of the projected cavern roof and blanket casing relocated at a point about 170 feet below the oil. Tubing is relocated at the top of the sump. Raw water would be injected down the tubing and unsaturated brine withdrawn from the blanket casing until the borehole has been enlarged. Flow direction can then be reversed, causing raw water to enter the cavern at the base of the blanket casing and saturated brine to be withdrawn from the tubing. Blanket oil would be added as required until the cavern roof reaches a diameter of about 140 feet. The cavern would then be ready for acceptance of stored crude oil at a rate equal to the rate of cavern enlargement.

When the oil-water interface approaches the bottom of the blanket casing, the casing must be repositioned to a point about 500 feet below the roof of the cavern. When the oil-water interface approaches that point, casing would again be repositioned, this time to a point about 840 feet below the roof. Leaching would continue under that condition until the designed volume of 10 million barrels has been developed. The two suspended pipes are then replaced with a single string of 9-5/8-inch casing reaching to the top of the sump. The final increment of oil required to bring the total to 10 million barrels would be added and the cavern would be complete.

The cavern's actual shape would depend on the rate and regularity of oil additions, physical characteristics of the salt, and field decisions regarding leaching procedures. Assuming reasonably steady conditions, a trilobed cavern with a maximum diameter of about 330 feet would be expected. More lobes of smaller diameter could be developed if the suspended pipes were repositioned more frequently.

The preceding descriptions called for raw water to enter the cavern at a point below the oil-brine interface. Thus, gravity stratification of oil over water would not be disturbed and no significant agitation would occur to mix the oil with water. Since the types of crude that will be stored or their tendencies to emulsify with brine is not known, a standardized design that would minimize the risk of emulsification would be used.

A different procedure using fewer pipe movements and resulting in an almost cylindrical cavern might be possible with specific types of crude oil. If laboratory testing demonstrated that a particular crude did not tend to emulsify, or that an emulsion quickly broke under cavern conditions, it might be practical to allow the raw water to fall through the oil. Thus, the following procedure could be used to develop the configuration shown in Figure A.2-6.

The sump would be completed as described in the preceding technique. The oil blanket would then be withdrawn to the elevation of the projected cavern roof and blanket casing relocated to that point. Tubing would be repositioned to the top of the sump. Raw water would be injected down the tubing and unsaturated brine withdrawn from the blanket casing until the borehole has been enlarged. Flow direction would then be reversed, causing raw water to enter at the projected roof of the cavern and saturated brine to be withdrawn from the tubing. Blanket oil would be added as required until the cavern roof has reached a diameter of about 270 feet.

The cavern then would be ready for acceptance of stored crude oil at a rate equal to the rate of cavern enlargement. If oil were added at about the same rate that leaching occurs, a relatively cylindrical cavern should develop. Water would be moving rapidly enough down the blanket casing to keep oil from rising into that annulus and consequently, water injection pressure would be essentially the same as would be required in the earlier standardized design.

Startup pressure following any stoppage of water injection would be much higher, however, for oil would rise into the annulus during the lull. Following completion of leaching, the two suspended strings of pipe would be replaced with a single string of 9-5/8-inch casing run to the top of the sump.

<u>Selected Cavern Development</u>

Either the leach-then-fill or leach/fill cavern development technique could be used for the SPR program. However, the leach/fill design has not been widely used for crude oil and would require special precautions.

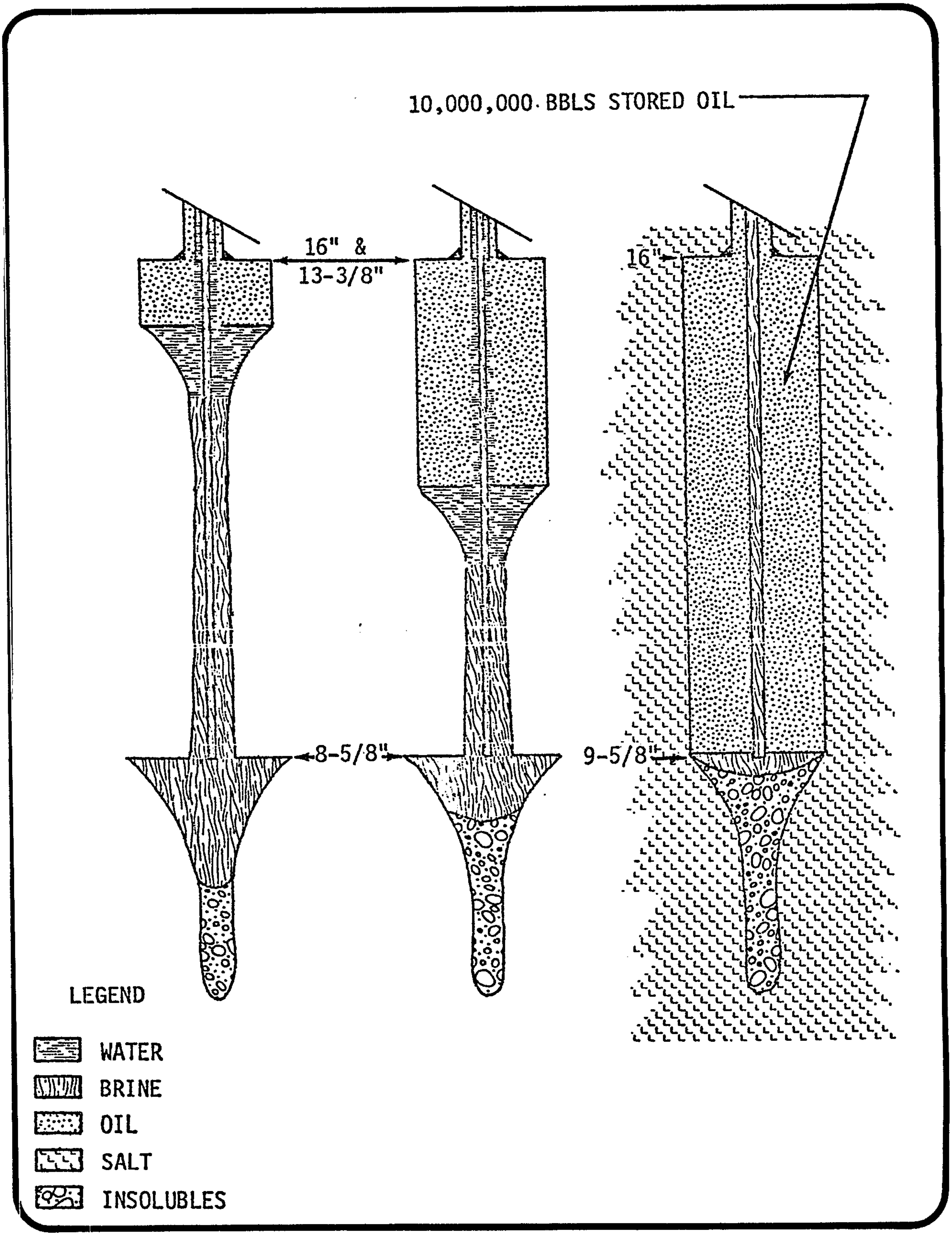


FIGURE A.2-6 Alternate concept for concurrent leaching and storage.

If crude oil is injected into a cavern during the period of cavern development, the oil-brine interface is always in reasonable proximity to the active leaching zones. Raw water dissolves the walls of the cavity, becomes brine, and is displaced out of the cavern. If crude oil becomes mixed with the brine due to the agitation caused by injection, it may be forced out of the cavern with the brine, resulting in the release of hydrocarbons to the environment. If the leach/fill method is used, it will first be tested to determine if hydrocarbon levels can be maintained at low levels that would not be harmful to the environment. It should be noted that leach/fill technology is being used successfully in West Germany for the creation of a storage facility.

Oil injection rates and water supply rates for the simultaneous leach and fill process would be somewhat less than those required for the separate leach then fill process. Brine disposal rates would essentially be the same during cavern leaching which presents higher brine rates than cavern filling. Therefore, the separate leach then fill process would present the worst-case for environmental impact consideration, and it is this more extreme case which is assumed in this document for environmental impact assessment purposes.

A.2.2.1.2 Central Plant Area

The central plant area would contain all facilities necessary for operation and maintenance of the storage site. During construction, management activities and the fabrication and laydown yard would also be located in the plant area.

Central plant areas would typically be 10 to 12 acres in size, with about 5 to 6 acres required for construction and the remainder for permanent facilities. Included in the central plant area are a pump building, electrical equipment (transformer or generating station), tanks for water and blanket oil, a brine pond, and a support building for offices, laboratory, storage, and shops.

The pump building would house all pumps necessary to inject water into the storage caverns, transport brine to the disposal area, and transfer displaced crude oil into the pipeline to the regional distribution network. Appropriate piping and valving would be located in or adjacent to the pump building. Pumps and valves would be operated remotely in the pump building.

Electrical power for operating the storage sites would be either generated on-site or obtained from local utilities. A portion of the plant area would be required for the generating or transformer equipment.

Blanket oil would be used during cavern leaching to prevent unwanted upward migration of the cavern ceiling. The oil would be stored at the surface in a tank (from 5000 to 20,000 barrel capacity) and piped to the caverns or returned to the tank as required.

Raw water piped from a local supply would be stored in an on-site tank or pond to provide a reservoir for charging the cavity injection pumps and for fire protection. The tank level would be maintained automatically and would act to remove surges from the raw water injection pump lines.

Brine discharged from cavities would be directed through a lined brine pond for settling of solids prior to being pumped into the disposal system. The pond would relieve line surges and eliminate insoluble particles which could damage pumps or clog injection well screens.

The central plant area would contain a cluster of support buildings necessary for operation and maintenance of the facility. The support buildings would include an office, laboratory, warehouse, and shops.

A security fence would be constructed around the perimeter of each site to prevent casual trespassers by identifying the site as a restricted area. The fence would be of eight-foot chain link or similar construction.

Roadways, Levees, and Filled Areas

Substantial lengths of roadway and acreages of filled area would be required at some SPR sites, since these sites would be located in low-lying areas. Several feet of fill would be required to provide permanent access to wellheads and along pipeline routes and to provide protection from storms.

Roadways through low-lying areas would be constructed directly on the existing vegetation, the fibrous nature of the vegetation and roots providing a base for the roadway fill. Crushed rock or shells would be used to cap the roads and provide an all-weather surface. In soft areas, felled trees, boards, or artificial mats might be utilized to support the roadway. Due to the soft subsoils, proper compaction of fill materials cannot be achieved, and all heavy structures such as bridges or plant facilities would therefore be supported on piles.

Levees would be required at some sites for flood protection. Depending on the degree of seepage integrity required, levees would be constructed either directly on existing vegetation, or the vegetation would be removed. Draglines would be used to construct levees, by digging a ditch alongside and using the spoil for levee fill. A capping of stone or shells would then be provided if the levee were to be used as a roadway.

A.2.2.1.3 Pipelines

Three basic techniques of construction could be used for pipeline construction: 1) conventional dry land method, 2) push-ditch method, and 3) flotation canal method.

Conventional dry land construction methods would be used through dry portions of pipeline routes where heavy construction equipment can be supported. The push-ditch method of construction would be used in freshwater swamp portions of pipeline routes where the ground can support marsh buggy-mounted excavating and backfilling equipment, but cannot support conventional dry land pipeline construction equipment. The flotation canal method of construction would be required in marshy portions of pipeline routes. The ground in marshy areas cannot support heavy construction equipment. Therefore, the work would have to be done on barges operating in the canal. Use of the potentially more environmentally disruptive flotation canal method would be avoided where possible, by utilizing the preceeding methods.

These methods, and procedures for construction of pipeline crossings, are summarized below.

Conventional Dry Land Pipeline Laying

With the conventional dry land method, a right-of-way width of approximately 100 feet is cleared. Excavation equipment then travels along the right-of-way digging the pipe ditch to a depth of approximately six feet so that the pipeline will have a minimum cover of three feet. The pipe joints are then strung along the pipe ditch, welded together, the required corrosion protection is applied, and the pipe is lowered into the ditch and tested.

Pipeline backfill equipment then travels along the right-of-way, backfilling the open ditch with the spoil removed in excavation. Restoration of the right-of-way is made to permit continued use of the land. A maintenance width of 75 feet is generally utilized.

Push-Ditch Method

In the push-ditch method of construction, a right-of-way width of approximately 80 feet is cleared. The push ditch is then excavated down the right-of-way by marsh buggy-mounted excavation and backfilling equipment. The excavated ditch is full of water. Several push sites are selected at convenient locations along the right-of-way on dry land. These sites are used to assemble the pipe joints into a completed pipeline and to push it into the ditch. The pipe in the ditch is then floated into position.

The fabrication and assembly of the pipeline consists of welding together joints of pipe (each pipe is about 40 feet long) on the push site. When operations on each joint at the push site are complete, the assembled pipeline is pushed forward into the push ditch by the length of another joint of pipe, and the assembly procedure is repeated. A marsh buggy, or similar equipment, travels along the right-of-way with the front end of the pipeline to guide the pipeline down the push ditch and to aid in starting and stopping the pipeline as the assembly continues.

After the pipeline is assembled and in its desired location, it is filled with water, causing the line to sink to its final position, and is then tested. Draglines, mounted on marsh buggies, then travel along the right-of-way, filling the ditch with the spoil that was stockpiled along the right-of-way.

Flotation Canal Method

In the flotation canal (or barge lay) method, a canal is dug along the surveyed pipeline route to accommodate construction barges. The canal is dredged to provide a water depth of approximately 7 feet. The canal may be 40 to 50 feet wide at the bottom and up to 75 feet wide at the top. The equipment needed for construction includes a dredge, a pipe lay barge, materials barges, personnel boats, and special equipment barges required for tie-ins and work at pipeline crossing. The required right-of-way is approximately 120 feet.

A pipe ditch is dug in each flotation canal to accommodate the proposed pipeline. The spoil removed in dredging the flotation canal and pipe ditch is placed alongside of the flotation canal until after the pipeline has been installed. The pipe lay barge travels along the flotation canal while the joints of pipe are being welded together. The completed pipeline is lowered off the stern of the barge into the pipe ditch. After hydrostatic testing, a barge-mounted dipper dredge travels along the flotation canal backfilling the canal behind it.

River Crossings

Pipeline river crossings require the pipe to be buried in a trench on the river bottom for protection from currents, floating debris, and river traffic. River crossings are located in protected locations away from hazards. An enlarged right-of-way is required at each end of the crossing.

Barge-mounted excavation equipment is used to dig the pipe trench from bank to bank, to a depth sufficient to completely bury the pipe and provide a soil cover. The pipe is assembled on shore and is floated to the desired location. The flotation devices are then removed or flooded, the pipe is positioned in the trench, and the trench is backfilled. Warnings of the pipeline crossing are posted at each bank.

Levee Crossings

Crossing of a levee with a pipeline requires that the water barrier provided by the levee is not lessened by the pipeline installation. Levee crossings are often constructed above grade for this reason. When below-grade construction is required, conventional pipeline lay methods are used with the exception that steps are taken to reduce seepage along the pipe and subsequent internal erosion of the levee. Clay or concrete seepage barriers are sometimes constructed at intervals along the pipeline through the levee crossing. An expanded right-of-way is required for crossing construction.

Highway Crossings

Pipelines crossing highways are constructed by ditching in the conventional method or by tunneling under the roadway. Sufficient soil cover or an outer casing is used to protect the pipeline from the weight of passing traffic. Construction right-of-way widths are wider at the highway crossing location.

Offshore Method

Offshore pipelines would be constructed from a conventional lay barge which has the capability to dredge the submerged pipe trench and lay the weighted pipe in a continuous operation. The pipelines would be laid with a minimum 10 foot cover from onshore to the ten foot depth contour and would then decrease to a three foot cover at greater water depths.

Offshore Diffuser

The offshore brine diffuser pipelines would be buried at the same three foot depth below the Gulf bottom in approximately 50 feet of water using lay barges. Risers for the diffuser jets would stand at 5 feet above and at a 90^{0} angle to the Gulf bottom.

A.2.2.2 Operation

When the storage facility at each site has been completed and the crude oil is in storage, there would be an interim period during which the only activities at the site would be security and maintenance checks. However, readiness for activation during an emergency requires keeping personnel available.

During that standby storage period, all equipment would be serviced and tested on a regular basis to insure proper working order. Maintenance crews would be on duty on a 24-hour basis.

It is possible that certain national emergencies could occur before the planned total reserve capacity of the SPR is met. In order to prepare for such a contingency, the facilities are designed to provide for oil return bypass valves to allow immediate recovery of oil already stored.

The SPR program plan calls for an emergency deliverability of stored oil over a 5-month period. The Seaway Group has a design capacity of 1 MMB per day. The facility's systems would be designed to handle this maximum capacity.

A.2.2.2.1 Cavern Operation

Initial Fill

Crude oil to fill the SPR storage cavities will arrive at Freeport Harbor terminal via tank ship. The terminal area currently can handle ships up to 50,000 dead weight tons (DWT), about 160,000 barrels. It is presently anticipated that Very Large Crude Carrier (VLCC) tankships would transport oil from distant sources to the Gulf of Mexico. There, the oil would be lightered into 50,000 DWT tankers which would offload at the terminals. The oil would be pumped to the DOE terminal, from which it would be transported to the storage cavities. Surges in the oil distribution system would temporarily be stored in surge tanks at Bryan Mound. The oil would be metered at the dock and also at the storage site for discharge detection purposes. One of these measurements would provide data necessary for U.S. Customs requirements.

An automated crude oil sampling system would accumulate an approximate 20 gallon representative sample for each batch of crude oil offloaded. These samples would be gathered proportionally through the entire batch, and would be analyzed for percentage content of basic sediment and water (BS & W). As a part of custody transfer procedure, the percentage of BS & W will be deducted from the temperature- and pressure-corrected batch volume (gross $60^{O}F$ volume) to yield a net volume for the crude oil batch. After gauging, the oil would be tranferred from the surge tankage to storage caverns by pipeline. Use of the surge tanks would permit a smooth oil fill rate into the cavities.

Injection of crude oil into the cavities would displace brine into an on-site brine pit. After allowing time for solids to settle out, brine would be pumped through a pipeline to underground disposal or into the Gulf of Mexico. The brine disposal rate would equal the oil injection rate.

Oil Withdrawal

During an oil supply interruption, crude oil stored in every cavity would be withdrawn by injecting raw water into the bottom of the cavity, displacing the oil through the annular space at the top of the cavity. Injection of unsaturated water would cause additional leaching of the cavities. It is anticipated that the cavities would gain up to 86 percent of their original volume during five cycles of storage and withdrawal.

The crude oil would leave each site at a pressure capable of transporting the oil to the SEAWAY Pipeline at the Tank Farm and to tankers at the terminal docks.

Subsequent Refills

After an oil supply interruption has ended, refill of the SPR storage facility is planned. The rate of fill would depend on the availability of crude, but is currently planned for fill over a 24-month period. Refill is assumed to begin six months after the end of the supply interruption.

Refills of the storage caverns would be operationally identical to the initial fill, but the brine displaced would have been exposed to the oil/brine interface and the oil in the cavern walls from the first storage cycle. Another source of hydrocarbons in brine would result from emulsions created at the brine/oil interface. Hydrocarbons in the displaced brine would contribute to emissions during the period it is in the brine pit and is a potential contaminant when injected into deep formations or diffused into the Gulf of Mexico. Hydrocarbon concentrations in the displaced brine are discussed in Appendix D.

A.2.2.2.2 General Safety Measures

Safety measures common to the oil industry will be employed during all phases of the project. Protective control devices will be installed on well heads and on all major pumping equipment. Fire pumps and extinguishers will be available at critical points. Buried pipelines will be coated with a protective coating. The main storage facility acreage will be enclosed with a security fence. These and other precautions will serve to protect the employees, the public, and the environment.

A.2.2.2.3 Development Timetable

The Seaway Group SPR facilities would consist of both the early storage phase development currently under construction and new storage caverns and associated facilities at one or more of the Seaway candidate sites.

The present schedule for development of the required 100 MMB SPR capacity reserve requires the leaching of five or six new caverns capable of storing 50 MMB of crude oil during the first 32 months of the program. Filling of these caverns would then proceed while the remaining caverns were leached.

The master development timetable (Figure A.2-7) shows the relationship of solution mining to cavern filling. Estimates of water supply and brine disposal rates (534 MB/D) indicate that five to six caverns could be leached simultaneously. At this rate site development could be complete in about 62 months (including initial fill).

A.2.2.3 Termination and Abandonment

The design life of the SPR is five fill-withdrawal cycles. For planning purposes, this is assumed to be on the order of 20 to 25 years (although there is no physical limit to the amount of time that crude oil could remain in cavern storage if the five cycles have not been completed).

Once the storage capacity of the SPR is no longer needed, it is intended that the facility continue to serve a beneficial use, perhaps by storing light petroleum products, LPG or other industrial products. If no users could be found, the facility could be mothballed for future use.

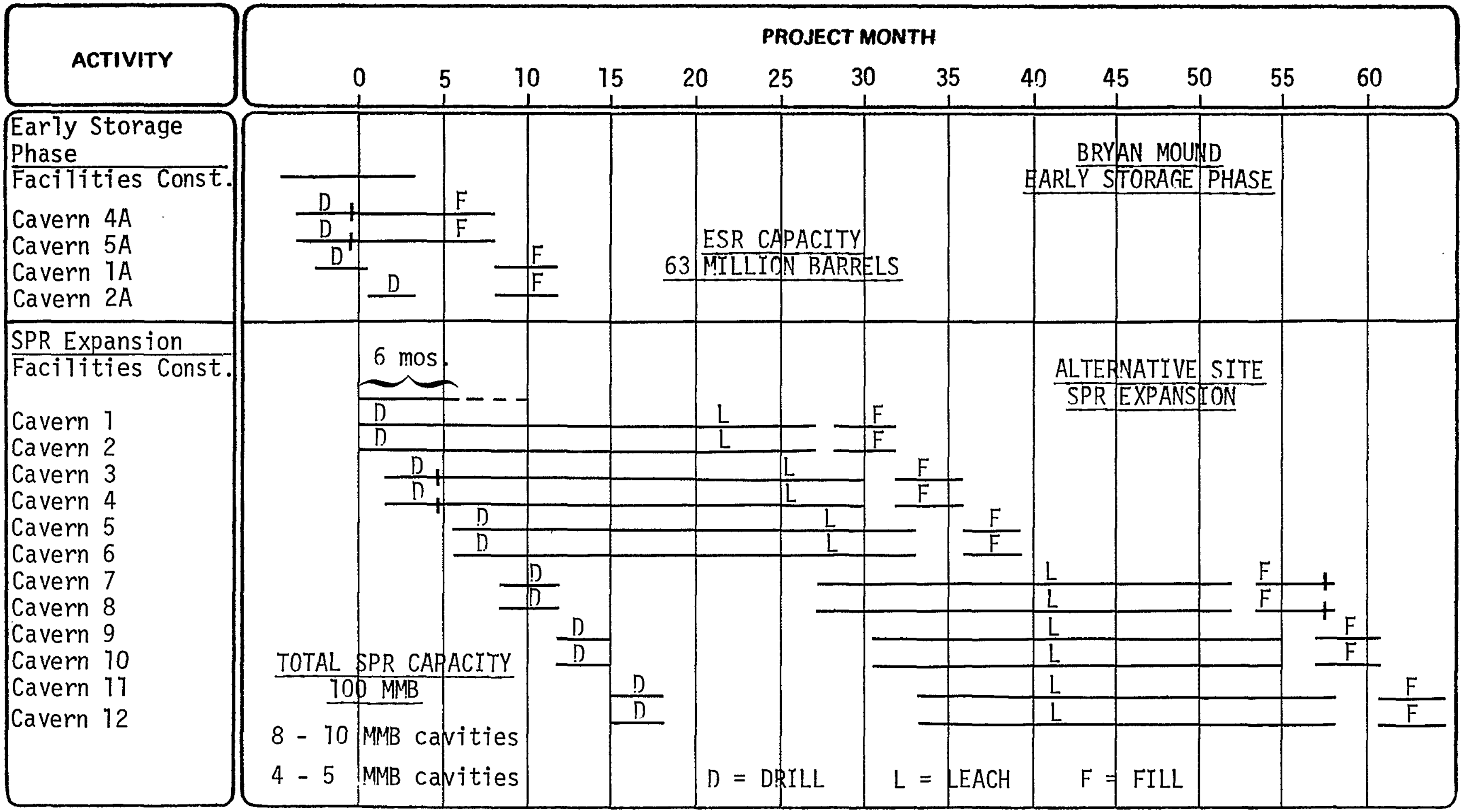


FIGURE A.2-7 SPR development timetable.

Ultimately, the facility would be abandoned, even though it is not possible to project a specific date this might occur. At that time, surface equipment would be removed and sold or scrapped. Brine injection wells and cavity access would be sealed with concrete (a common and effective oil field procedure). No long-term surveillance or maintenance requirement is anticipated.

A.2.3 Early Storage Facilities at Bryan Mound

Facilities for the early storage phase (ESR) of the SPR program are currently being developed at Bryan Mound. A total of 63 MMB of crude oil will be stored in four existing caverns developed by Dow Chemical Company to obtain brine feedstock for chemical plant operations.

Crude oil pipelines are being constructed to connect the dome with the SEAWAY docks at Brazosport and the SEAWAY Tank Farm. In the event of an oil supply interruption, crude oil would be withdrawn from storage and piped to the SEAWAY Tank Farm (to be made available to inland refineries) or back to the docks for shipment to Gulf Coast, Caribbean or East Coast refineries via tanker. Other major support facilities to be constructed as part of the early storage phase include: a raw water intake and injection system; a deep well brine disposal system using 5 wells; four 200 MB floating roof storage tanks; a central pumping plant; and an electrical power system (Figure A.2-8).

The raw water intake is to be located on the Brazos River Diversion Channel and will provide water for displacement of the stored crude oil. The system also may include a centrifugal desander for clearing excess sediment from the water. Effluent from the desander will be returned to the diversion channel; a desilting pond may be constructed if needed to prevent silt buildup in the channel.

Displaced brine will be passed through a brine pit and pumped to five brine injection wells (each with a 1000-gallon-per-minute capacity) which will provide for brine disposal during early storage.

Four 400,000 barrel surge tanks were addressed in FES 76/77-6, however DOE has determined that four 200,000 barrel tanks will be sufficient. These are under construction at the Bryan Mound early storage facility.

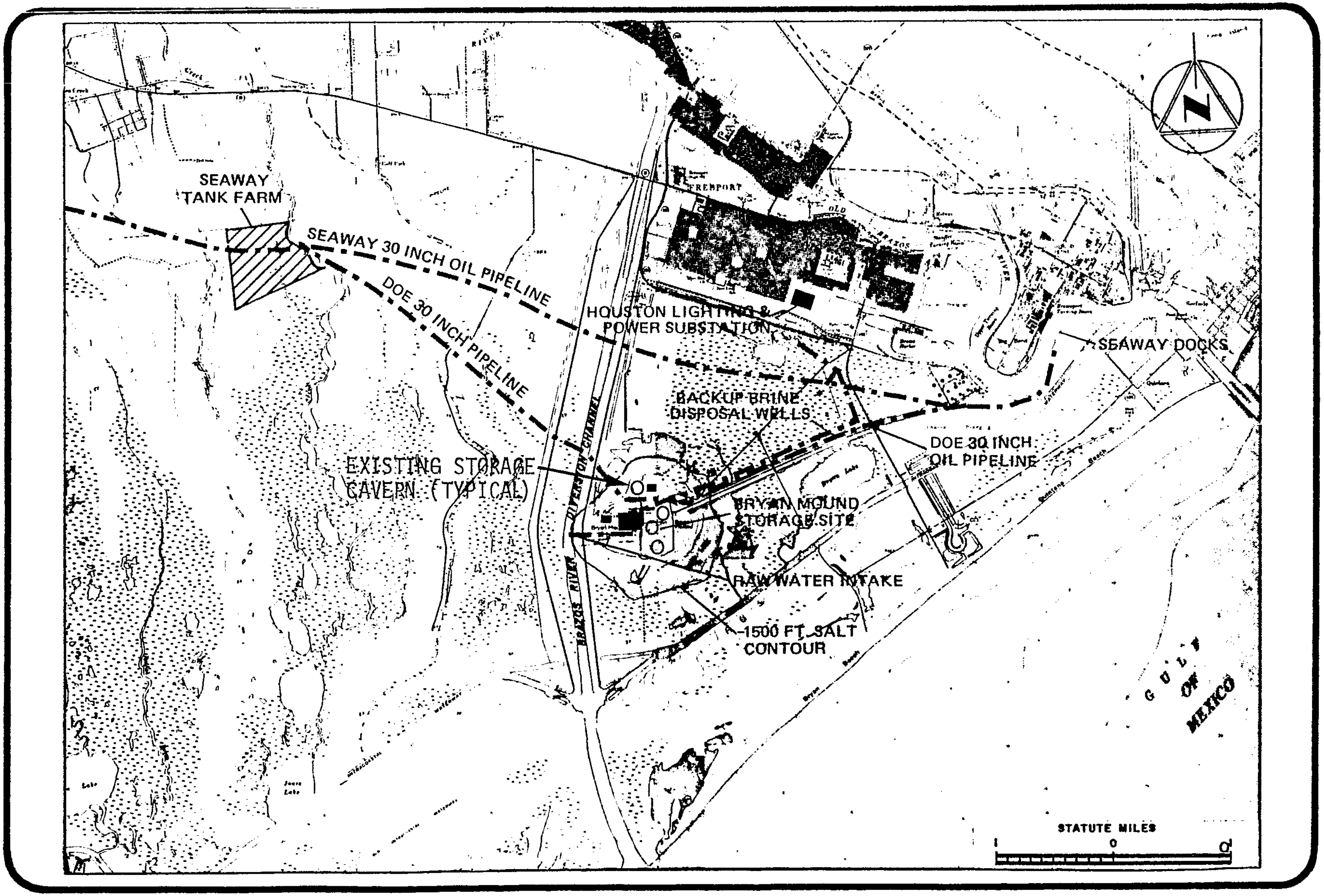


FIGURE A.2-8 Bryan Mound early storage facilities - assessed in FES 76/77-6. Facilities noted (proposed) were assessed in the July 1977 Draft Supplement.

The four storage tanks suitably diked for spill protection will act as surge tanks to provide a continuous flow to or from cavern storage. The central pumping plant and connecting pipelines on-site provide for all of the transfers of raw water, crude oil and brine. Power from the Houston Lighting and Power Company (HL&P) substation in Freeport will be supplied to an on-site transformer via a 1.5-mile transmission line.

Some of these support facilities will be constructed and placed in operation as early as late 1977 (Figure A.2-7). A detailed description of the early storage phase facilities at Bryan Mound and their environmental impacts is provided in the Final Environmental Impact Statement (FES 76/77-6 and supplement).

A.3 BRYAN MOUND (PROPOSED SITE)

The Bryan Mound SPR facility is planned to store a total of 163 MMB of crude oil for the Seaway Group. Early storage facilities capable of storing 63 MMB are under construction and will be completed and filled by December 1978. A detailed description of the early phase of the SPR storage was assessed and described in FES 76/77-6 and its supplement of December 2, 1977. Briefly, the site was chosen because of its proximity to dock facilities at Freeport and to the SEAWAY Pipeline four miles to the west. Through the Freeport dock facilities, crude can be delivered to Bryan Mound for storage and subsequently transported to any refinery serviced by port facilities. In addition, Bryan Mound crude can be delivered to inland refineries serviced by the SEAWAY Pipeline.

Expansion and filling of the Bryan Mound storage facility by 100 MMB to a total capacity of 163 MMB would take about five years after start of construction. Most of this time would be required to solution mine new storage cavities; most other site-related facilities with the exception of the brine diffuser to the Gulf of Mexico will have been constructed for the early storage phase of the SPR.

A.3.1 Location

The Bryan Mound salt dome is in the southern part of Brazoria County, Texas, about three miles southwest of the city of Freeport, 45 miles southwest of the Texas City/Galveston area, and 65 miles south of Houston. The Brazos River Diversion Channel borders the site to the west, the Intracoastal Waterway (ICW) and the Gulf of Mexico lie one and two miles to the south, respectively.

A.3.1.1 Site Access

A paved road leads from the city of Freeport, along the top of the levee beside the Brazos River Diversion Channel, and past the entrance to the storage site. Shell roads provide access to the facilities on the site including the four wellheads at the caverns used for the initial 63 MMB storage facility. A shell road passes through the center of the storage site, connects to the South Freeport Hurricane Protection Levee and continues on top of the levee to Freeport Harbor. Roads constructed to all onsite facilities for early storage provide access to most of the site. Access to the ICW is about one mile (via shell road) directly south of the dome. Pipelines constructed for the early storage facility will provide for distribution of crude oil to the docks and tank farm, raw water to and from the site and brine from the site to the injection wells.

A.3.1.2 Site Description

Bryan Mound lies at the southwestern vertex of a triangular area south of the city of Freeport which is protected by levees. At Bryan Mound, the dome has an actual surface expression which rises about 15 feet above the surrounding marshland (Figure A.3-1). The 150 acre barbed wire enclosed site in which the early storage facility is located was previously owned by Dow Chemical Company to keep grazing cattle from entering the site.

The site has been used for brine solution mining in the past by Dow, while the surrounding land was used for grazing cattle. The brine has been used as a feedstock for their chemical complexes in Freeport. The dome is defined by numerous oil and gas wells, but hydrocarbon production ceased in 1964. Sulfur mining operations were conducted on the dome from 1912 through 1935, and a pilot plant removed a small amount of sulfur during 1967-1968. As a result of these activities many areas of the dome were filled, excavated or otherwise modified, prior to DOE's initial development for the early storage phase of the SPR.

A.3.2 Capacity

For the Strategic Petroleum Reserve Program, the Bryan Mound site has been designed for a total 163 MMB capacity. This includes 63 MMB existing early storage phase capacity and 100 MMB of new capacity to be developed. New capacity would be created by drilling and brine solution mining of up to twelve additional cavities (Figure A.3-2).

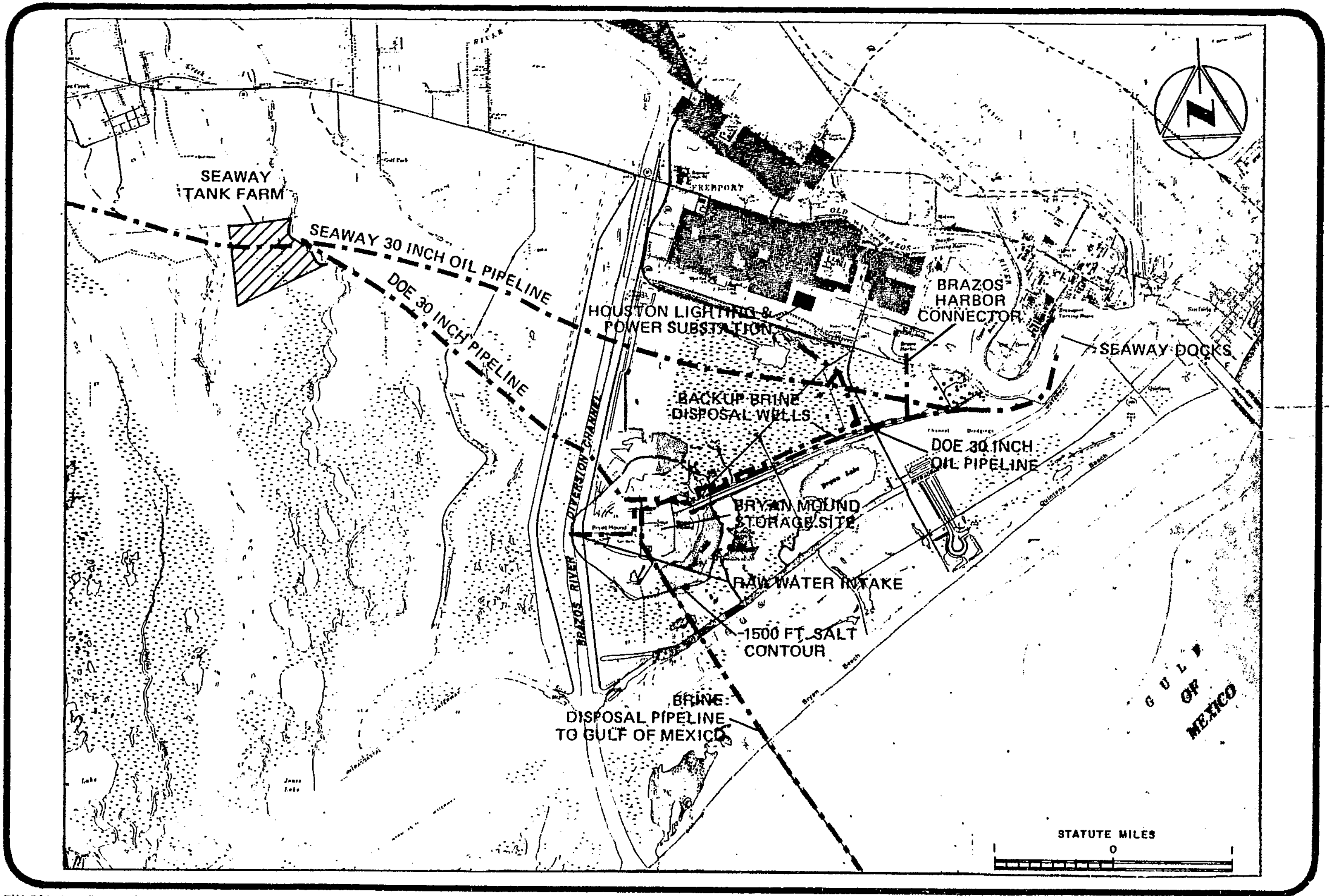


FIGURE A.3-1 Vicinity map - Bryan Mound (proposed site for Seaway SPR development).

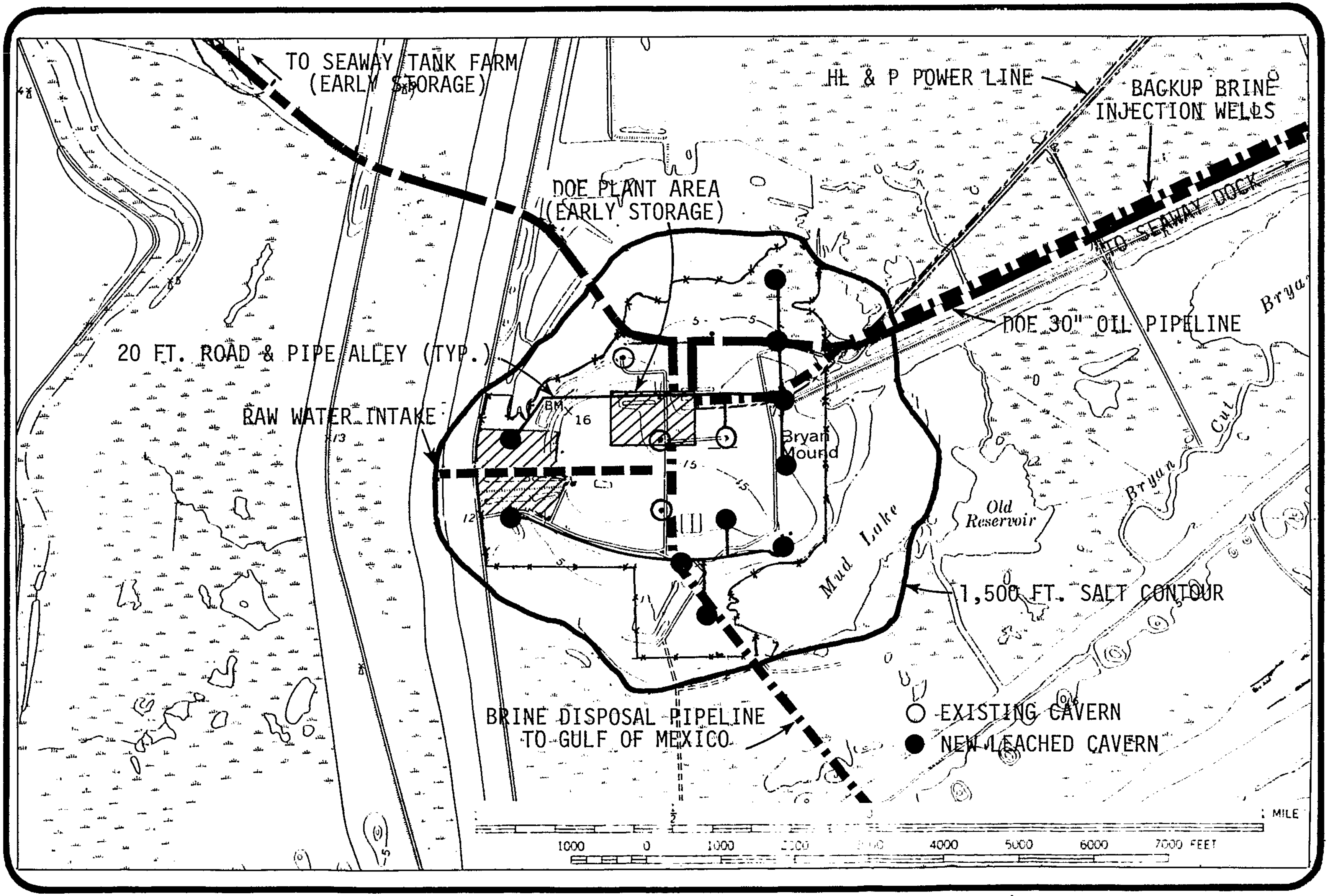


FIGURE A.3-2 Site map - Bryan Mound dome (proposed site for Seaway SPR development).

A.3.3 General System Description

A.3.3.1 Proposed Systems

Introduction

The general physical plant for the proposed Strategic Petroleum Reserve facility at Bryan Mound consists of storage cavities with pipeline connections to a central pumping and control facility, a crude oil distribution network, crude oil surge tanks, a raw water supply system and a brine disposal system utilizing injection wells. These systems are being built at Bryan Mound for the early storage phase of the SPR. During expansion of the site to the total 163 MMB storage capacity and subsequent operation, increased use of these systems is planned. New systems that would be built for the Bryan Mound expansion are described below.

Storage Cavity System

Up to 12 new solution mined storage cavities with their crude oil, raw water, and brine pipeline connections to the central pumping and control areas are planned.

Crude Oil Distribution System

Crude oil distribution would use pipelines to the SEAWAY docks and tank farm and four 200,000 bbl oil storage tanks constructed on the Bryan Mound site for the early storage phase. New tanker terminal facilities for the SPR program would be constructed at two sites in Freeport Harbor. The first would be located adjacent to the SEAWAY docks near the Brazosport Turning Basin. The second would be located in Brazos Harbor (Figure A.3-1).

Raw Water and Brine Disposal Systems

Raw water supply from the Brazos River Diversion Channel will use early storage facilities at Bryan Mound. A new 5.8 statute mile (5.0 nautical mile) offshore pipeline to a brine diffuser in the Gulf of Mexico would be constructed for brine disposal related to SPR activities at Bryan Mound. Five brine disposal wells (a part of early storage facilities), each of 1000 gallons per minute capacity, would serve as a partial backup to the brine disposal to the Gulf. The raw water supply and the brine disposal wells are discussed in the December, 1977 Supplement to FES 76/77-6.

Power System

Power from the Houston Lighting and Power Company (HL & P) substation in Freeport is supplied to the site via a 1.5 mile transmission line (also a part of early storage facilities).

A.3.3.2 Alternative Systems

Crude Oil Distribution System

Construction of a Single Anchor-Leg Mooring (a type of Single Point Mooring -SPM- system) monobuoy in deep water offshore would be an attractive alternative dock facility if it were not for the long lead time and licensing uncertainties associated with deep water port facilities. Licensing work on the SEADOCK deepwater terminal has been in progress for at least five years. Use of the SPM monobuoy facility would also require considerable additional surge tankage on the site.

A second alternative would be to use the existing Phillips Petroleum Company docks for cavern filling on a space-available basis. Due to their committment to supply to Phillips refinery complex, they could only be used on an "as available" basis during the storage phase. A connecting pipeline to the oil pipeline to Bryan Mound would be required.

In the event of the construction of SEADOCK, the SEAWAY docks at Freeport would have surplus capacity. Therefore, construction of a DOE dock would not be necessary, and the conversion of one of the SEAWAY docks to DOE use for loading capability would be an alternative to construction of new docks. The uncertainties of licensing and development of SEADOCK make this a high risk alternative.

Raw Water System

An alternative to the proposed use of surface water from the Brazos River Diversion Channel as a raw water source would be the withdrawal of ground water from the Evangeline aquifer, which is found at approximately 1200 foot depths. In this area, the aquifer is not potable. However the region has been experiencing problems of subsidence associated with extensive withdrawal of potable water from near surface strata. An additional withdrawal of large quantities of water could serve to aggravate a condition already recognized as a regional problem.

Raw water for use at the site might be supplied from Dow Chemical Company's Harris and Brazoria Reservoirs. A pipeline would be required between Dow plant "B" in Freeport and the storage site.

Brine Disposal System

An alternative brine disposal system would involve expanded use of deep subsurface aquifers for injection of brine. Brine ponds built for the early storage phase would allow settling of insolubles and minimize the chance of damage to the pumps or clogging of the wells.

A second alternative to the proposed brine disposal method is to supply all or part of the brine produced to the Dow Chemical Company or other industrial plants in Freeport. Existing pipelines from the site to the plants would be utilized. The brine thus disposed would be used as a chemical feedstock. The large quantities of brine and the requirements of different receiving profiles limit this alternative, however. A third alternative would be an extension of the brine disposal pipeline and relocation of the diffuser to 12.5 statute miles (10.9 nautical miles) offshore. This is the farthest location from shore at which the diffuser could feasibly be located without interfering with nearby shipping.

Power System

An alternative to use of Houston Lighting and Power power would be the construction of onsite power generating capacity. Gas turbine generators, an exhaust stack, and a fuel reserve equal to four days consumption would be stored onsite.

A.3.4 Site Development

A.3.4.1 Proposed Physical Facilities

Introduction

The storage site layout (Figures A.3-2 and A.3-3) presents both early storage and expansion phase facilities. Early storage facilities

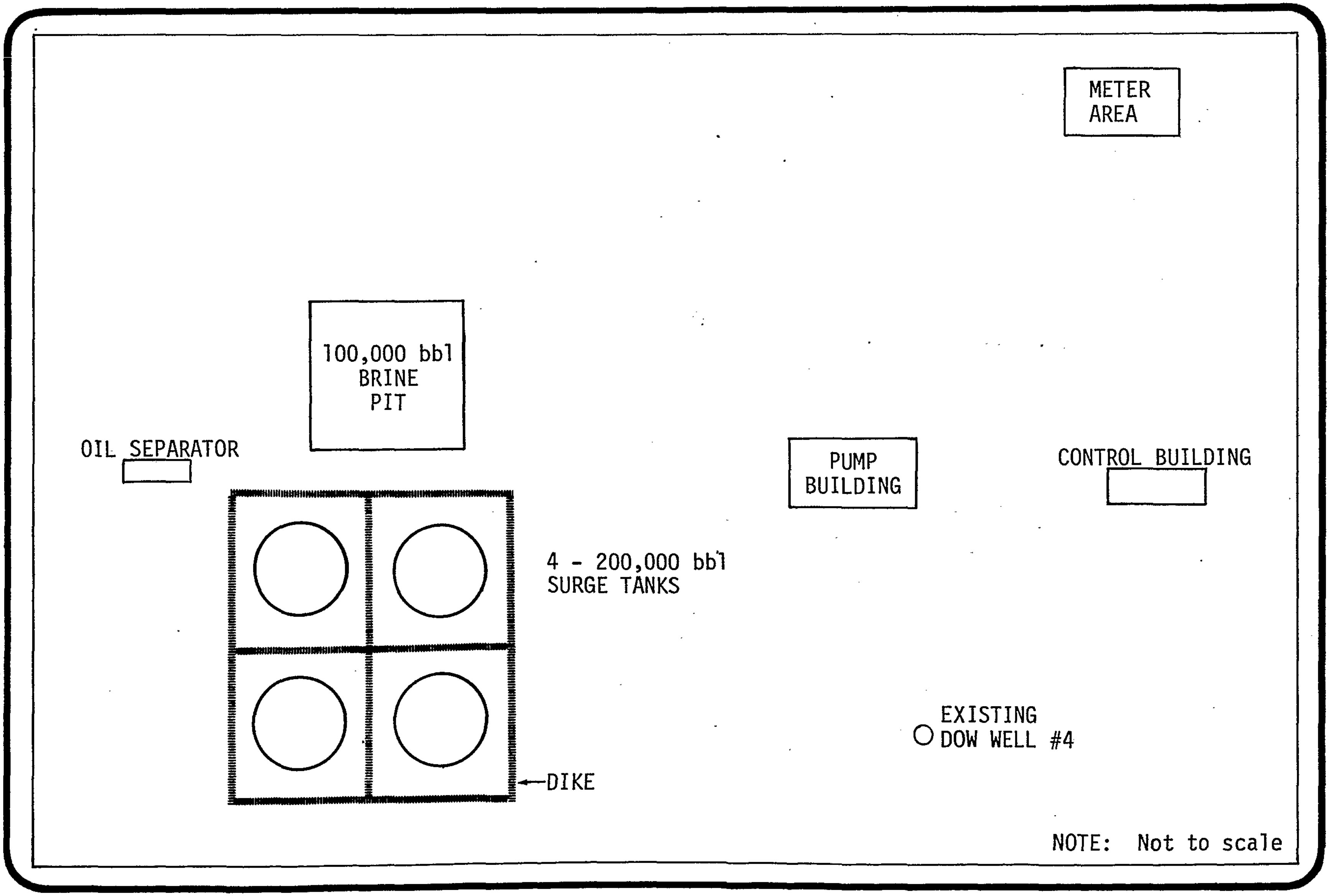


FIGURE A.3-3 Plant layout - Bryan Mound dome (proposed site for Seaway SPR development).

include four existing solution mined cavities; pump and control buildings; the metering area; crude oil pipelines to SEAWAY tank farm and SEAWAY dock areas; four 200,000 bbl crude oil surge tanks; the raw water intake; the brine pits and five backup brine injection wells; the 1.5 mile power line to the Houston Lighting and Power substation in Freeport, and onsite sanitary and storm water-handling facilities. The only new site facilities constructed for the expansion of Bryan Mound to 163 MMB capacity would include: up to 12 new solution mined oil storage cavities with crude oil, a new brine pipeline and diffuser system to the Gulf of Mexico, raw water, and brine pipeline connections to the pump house; new roadways to the wellheads; and new docks and connecting pipelines, one in Brazos Harbor, and a second adjacent to the three existing SEAWAY docks. These new facilities are addressed below. Early storage phase facilities are discussed in FES 76/77-6 and its supplement.

Storage Cavity System

Each new cavity would be leached to a maximum initial capacity of 10 MMB. General techniques of cavern construction have been described in Section A.2.2. Each wellhead would be diked to contain minor (2000 gal) operational spills. Cavity wellheads would be connected to the central pumping plant by pipelines for oil, raw water, and brine. These pipelines would be buried along site roadways.

New access roads would be constructed to each wellhead. In addition to providing access, these roads would permit surveillance and maintenance of the pipelines. The roadways would require some filling and grading.

Crude Oil Distribution System

Tanker docks would be constructed at two locations in Freeport Harbor. One tanker dock would be built on SEAWAY property, adjacent to the three existing SEAWAY Pipeline system docks. It is in the vicinity of the Brazosport Turning Basin. The second dock is in an undeveloped area on Brazos Harbor (Figure A.3-1). This new tanker berth would be built on the south side of the harbor. It would be developed jointly with a private company which would add dry bulk cargo handling capability to be used when oil activities permit. A 0.6 mile connector pipeline would be required from this new dock to the DOE bi-directional pipeline between the SEAWAY docks and Bryan Mound. Each dock would require dredging, installation of mooring dolphins, a trestle pier, oil transfer manifolds, and a small steel-framed office building. Construction of dry bulk cargo handling facilities at the Brazos Harbor dock are not part of the SPR program.

Raw Water System

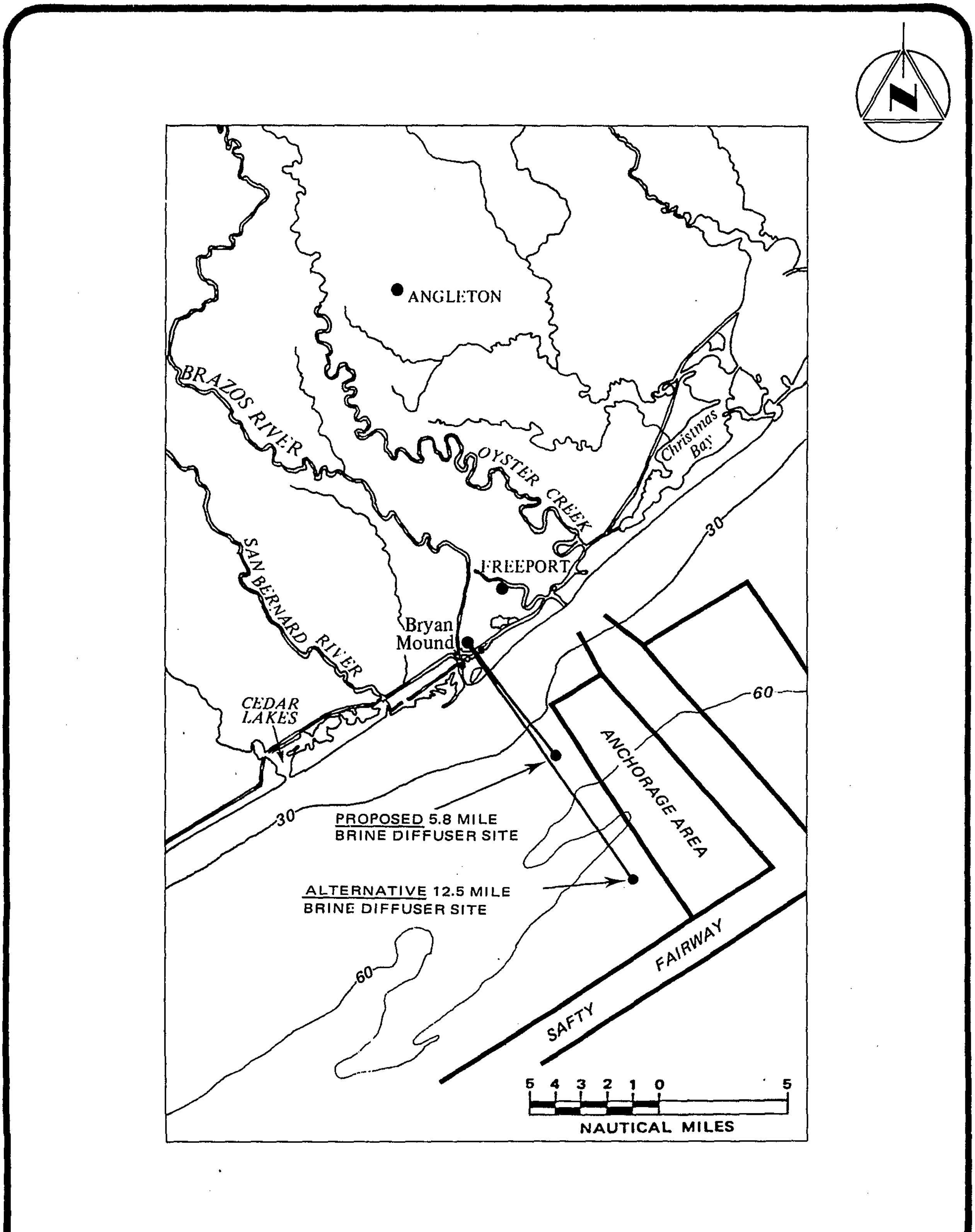
The early storage phase raw water system will be used in the expansion of Bryan Mound. An enlarged desilting pond covering approximately 12 acres will be built (if needed) to contain solids removed from the raw water.

Brine Disposal System

A new brine disposal pipeline to the Gulf of Mexico and attached diffuser system will be constructed, with five injection wells from the early storage phase being used for backup. The proposed brine disposal pipeline (Figure A.3-4) would be constructed from the main pump control facility southeast at a true bearing of 147^{o} across the Intracoastal Waterway (ICWW) and a coastal marsh to Bryan Beach. From the shoreline it would extend 5.8 statute miles (5.0 nautical miles) into the Gulf at a bearing of 143^{o}T to the diffuser location. The brine pipeline would have a 30 inch outside diameter. The 34 port diffusers would be 2006 feet in length and be located in an area with an approximate water depth of 50 feet. Each vertical port would use 5 feet above the surrounding Gulf bottom. Operation of the diffuser would be required during solution-mining or oil filling activities and would accommodate a maximum flow rate of 45 cubic feet per second.

Power System

Power is supplied to the early storage site via a 1.5 mile transmission line. This line is capable of handling the increased power requirements of the expanded storage site.



SOURCE: TEXAS A&M, 1978.

FIGURE A.3-4. Proposed and alternative brine diffuser sites (depth contours in feet).

Land Requirements

The expansion of Bryan Mound to 163 MMB storage capacity would require 221 acres of land to be disturbed for construction offsite and within the fenced area (Table A.3-1). The completed facilities would commit a total of 193 acres to semi-permanent use for storage facilities and their maintenance, including approximately 128 acres previously in use for early storage reserves and 65 acres added for expansion of storage. Overlying the Bryan Mound dome approximately 60 acres would be used for pipelines, cavern wellhead pads, pumping and control facilities. A total of approximately 390 acres overlying the dome would be enclosed by a security fence, including the 60 developed acres. Offsite pipelines, dockage and tank facilities would permanently occupy 133 acres.

The addition of up to 12 new caverns and associated pipeline connections at Bryan Mound would require maintenance of 30 acres of land onsite. Offsite, new tanker docks would be constructed on 14 acres of land at Brazos Harbor with a 0.6 mile pipeline connection to the existing 30" oil pipeline to Bryan Mound using 6 acres for a right-of-way. The proposed brine diffuser right-of-way extending offsite to the Gulf of Mexico would cross 15 acres of coastal prarie, marsh and barrier flats. All other acreages needed for maintenance of the storage facilities was previously committed to similar use during early storage or do not require a permanent dedication of lands.

A.3.4.2 Alternative Physical Facilities

Crude Oil Distribution System

Use of the Phillips Petroleum Company docks in Freeport Harbor would allow greater flexibility in tanker scheduling for "topping off" the SPR. A 0.5 mile connector pipeline would carry the oil from the Phillips docks to the DOE pipeline. Most of this pipeline would be within the Phillips tank farm boundaries.

Construction of SEADOCK would eliminate the need for a new DOE dock adjacent to the existing SEAWAY docks. Addition of tanker loading facilities to one of the existing SEAWAY docks would still be required since SEADOCK is nondirectional. No additional filling or dredging

A.3-13

TABLE A.3-1 Land requirements - Bryan Mound proposed SPR storage site.

	Total Miles Pipeline Row	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres): Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]	Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
A. SPR Facilities											
1) Storage Site											
a) Pipelines to Cavern Wellheads	5.7	30,300	---	24/18	---	---	---	---	---	---	24/18
b) Cavern Wellhead Pads	---	---	Minimal	12/12	---	---	---	---	---	---	12/12
c) Containment Dikes at Cavern Wellheads	---	---	700	---	---	---	---	---	---	---	---
2) Off Site											
a) Pipeline connections to Brazos Harbor	0.6	6,000	---	4/3	---	---	4/3	---	---	---	8/6
b) New Tanker Docks	---	1,050,000	---	14/14	---	---	---	---	---	---	14/14
c) Brine Disposal to Gulf Diffuser	7.5	177,300	---	---	---	20/14	.2/.1	1/.5	142/0	2	163/15
Sub-Total SPR Facilities	13.8	1,263,600	700	54/47	---	20/14	4/3	1/.5	142/0	2	221/65
B. Early Storage Facilities											
1) Storage Site	---	---	---	30/30	---	---	---	---	---	---	30/30
2) DOE 30" Oil Pipeline											
a) Bryan Mound to Seaway Tank Farm	4.1	27,400	---	---	---	39/30	8/6	---	---	---	47/36
b) Bryan Mound to Seaway Docks	4.0	36,500	---	19/14	---	4/3	21/16	---	---	---	44/33
3) Backup Brine Injection Wells											
a) Pipeline Excavation	2.3	30,700	---	---	---	---	---	---	---	1	---
b) Roadways to Wellheads	---	---	564,000	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	5,000	1/1	---	---	4/4	---	---	---	5/5
4) Crude Oil Storage Tanks	---	---	96,000	24/24	---	---	---	---	---	---	24/24
Sub-Total Early Storage Facilities	10.4	94,600	665,000	74/69	---	43/33	33/26	---	---	1	150/128
Total Land Requirements- Early Storage plus SPR at Bryan Mound	24.2	1,358,200	665,700	128/99	---	63/47	37/29	1/1	142/0	3	371/193
C. Alternatives to Proposed Systems											
1) Crude Oil Distribution (Phillips Dock)	0.5	2,500	---	6/6	---	---	---	---	---	---	6/6
2) Brine Disposal (Wells)											
a) Pipeline Excavation	3.6	57,000	---	---	---	---	42/31	---	---	---	42/31
b) Roadways to Wellheads	---	---	42,300	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	19,000	---	---	---	19/19	---	---	---	19/19
3) Brine Disposal to 12.5 mi Gulf Diffuser	14.2	274,600	---	---	---	20/14	.2/.1	1/.5	305/0	2	326/15

[a]Construction Right-of-Way/Maintenance Right-of-Way

TABLE A.3-1 continued.

	Total Miles Pipeline	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres)						Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
				Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]		
4) Brine Disposal to Dow Plant B	USES EXISTING FACILITIES										
5) Groundwater Supply Wells											
a) Pipeline Excavation	8.7	57,000	---	---	---	49/36	---	---	---	3	49/36
b) Roadways to Wellheads	No Additional Land or Fill Required										
c) Wellhead Pads	---	---	Minimal	---	---	20/20	---	---	---	---	20/20
6) Water Supply from Dow Plants	6.0	31,700	---	2/2	5/5	28/28	---	---	2/0	---	37/35
7) Power Supply	USES EXISTING FACILITIES										
8) Oil Line to VLCC Monobouy	30.0	---	---	---	---	---	---	---	---	---	---
a) 50' ROW Land	---	10,800	---	---	---	---	---	3/3	10/0	---	13/3
b) 200' ROW Gulf	---	369,000	---	---	---	---	---	---	727/0	---	727/0

[a]Construction Right-of-Way/Maintenance Right-of-Way

would be required at the dock, but office and gauging areas would have to be constructed at the converted dock. Construction of an SPM would eliminate the need for docks in Freeport Harbor during cavern filling only. Conversion of SEAWAY docks for loading tankers would still be required.

Raw Water System

As an alternative, raw water would be supplied by Dow Chemical Company. A 6-mile pipeline would be laid between Bryan Mound and Dow's Plant "B" along the protected side of the levee adjacent to the Brazos River. Within Dow's Plant "B", water would be taken from a canal which brings water a distance of 15 to 25 miles to both Plants "A" and "B" from two reservoirs, Brazoria Reservoir and Harris Reservoir, developed and owned by Dow Chemical Company. The water for these reservoirs is purchased from the Lower Brazos River Authority during high water stages.

The 6-mile long pipeline between Dow Plant "B" and Bryan Mound would be a concrete-reinforced pipe. This line would be laid along an existing Dow right-of-way to the mound.

Surge capability for the displacement water supply system would be handled through existing pits at the dome site. Water would flow into the pit from the 24-inch line; then, as required, the water would be pumped into the cavities by the appropriate onsite pumps to displace the crude oil.

Brine Disposal System

A system of 23 additional injection wells, each handling 1000 gallons per minute and spaced on 1000 foot intervals could be located southwest of the storage site. Because of the marsh environment, elevated fill of several feet may be required for portions of access roadways to the wellheads. In addition, where sufficient dry land is not available, an area of fill would be required at each well site. This alternative would also require a pipeline crossing of the Brazos River Diversion Channel. An estimated total of up to 61 acres would be primarily affected by the construction of this disposal system.. Drilling of the wells from 5000 to 7000 feet deep would be accomplished by typical oil field equipment. Drilling mud pits would be reclaimed or buried after the completion of each well.

An alternative brine diffuser site 12.5 statute miles offshore would require an additional 6.7 statute miles of pipeline construction in the Gulf. Typical offshore pipeline construction methods and land requirements would occur. The alternative would be considered if its impacts were significantly less than the proposed system.

A third alternative would be to supply part of the brine as feedstock to Dow Chemical Company plants in Freeport. Existing pipelines from the site to the plants would be utilized. As part of the early storage phase, brine from the existing caverns is currently being delivered to Dow as the caverns are being filled with oil. However, the Brazos Diversion Channel could not provide raw water of the quality necessary to produce brine which could meet the specifications necessary for the chemical feedstock. Therefore, use of this alternative would have to be coupled with use of water from the Dow Reservoirs. Moreover, Dow has not expressed a willingness to receive brine at the rates and volumes necessary for leaching new caverns.

A.3.5 Construction Techniques

A.3.5.1 Storage Cavern Construction

Construction of up to 12 new storage caverns at Bryan Mound would employ those techniques described in Section A.2, General Construction Techniques.

A.3.5.2 Road Construction and Other Grading

The Bryan Mound dome site has a number of existing shell roads to each of the early storage cavities. Since new well holes would be drilled for each of the new cavities to allow access for the SPR project, extensions to these roads will be required.

If alternative systems are chosen for brine disposal, access roads along the pipeline routes to the drill pads for construction and maintenance of the wells would be required.

Safety dikes would be constructed around each of the crude oil surge tanks as part of the early storage phase to contain any leakage. Smaller dikes would be constructed around each wellhead to contain small volumes of oil spilled during operation or maintenance.

A.3.6 Development Timetable

The Bryan Mound SPR facility would consist of both the existing early storage phase and new storage cavities. Oil storage will begin at this site as soon as installation of injection pumps, raw water, crude oil, and the brine deep-well injection disposal systems, and conversion of existing cavity wells (all early storage phase facilities) are completed. Concurrent filling of these existing caverns and preparation of new caverns and associated facilities could then proceed. The maximum leach water supply rate would permit a maximum of 15,257 B/D per well of storage space to be created. These rates allow for concurrent leaching of five 10 MMB wells, thus the additional 100 MMB of cavern space could be created and filled in 62 months. The development timetable (Figure A.2-7) is based on these considerations.

A.3.7 Operation and Maintenance

A.3.7.1 General Safety Precautions

Protective Control Devices

All storage cavity wellheads would be equipped with (1) hydrocarbon detection devices to protect against overfill, (2) pneumatic gate valves on crude and brine wellhead openings with high-low pressure switches for remote control of safety valves, and (3) valve limit switches, signal devices and alarms.

Pump control and protective devices would be installed on all major pumping equipment to monitor critical operating variables and to automatically shut down the affected equipment in the event that an unsafe operating condition develops. Pump station emergency shutdown systems would be installed at all stations to allow the shutdown and isolation of the pumping station in the event of an emergency. Pipelines would have meter bases and pressure switches monitored at each end as a precaution against leaks. Pressure relief valves would be installed on piping, equipment, and pressure vessels, as needed, to prevent these systems from exceeding safe limits.

Fire Protection

Pump stations and meter stations would be provided with portable fire extinguishers installed, classified, rated, and selected in accordance with applicable standards of the National Fire Protection Association.

Surface oil holding tanks at the distribution terminal would be equipped with standard sprinkler and foam fire prevention systems.

Corrosion Protection

All buried portions of the pipelines would be externally coated with a protective coating. Where required, the pipeline would be installed in breather casings at highway, railway, or levee crossings, with insulators and spacers to electrically isolate the pipelines from the casing.

Protection from External Damage

All electrical equipment, pumps, and control systems would be housed in buildings and placed on concrete pads for protection against flooding. Protection of the pipelines from external damage would be provided by burying them and by marking their location. Additional mechanical protection for that portion of the pipelines in areas of marsh and at waterway crossings would be provided by an external coating of wire mesh reinforced concrete.

Protection of Local Surface Environment

Points in and around pumping stations, where oil may be drained from the system during normal or emergency operations or maintenance, would be appropriately diked or curbed and provided with waste sumps. Waste oil collected in this manner would be returned periodically to the storage system.

All surface tanks are required to be enclosed in adequate retention dikes to protect the area environment from leakage of crude oil. This is consistent with the Spill Prevention Control and Countermeasures Plan (SPCC plan) requirement of 40 CFR 112-7.

Security

The 150-acre main storage facility presently has a three or four strand, barbed wire fence which keeps cattle grazing in the area from entering the site. This fence from previous development may be replaced by a more secure one, for example a 9-foot chain link fence, surrounding the entire 390 acre SPR project area. This is a standard practice for petroleum storage sites. Additional fencing would be needed around high-voltage areas and other danger zones. Since the facility would operate on a 24-hour basis, personnel would be on duty at all times. All fenced facilities would have warning signs posted conspicuously to warn the public of the nature of the facility.

A.3.7.2 Storage Phase

The storage or standby phase is that relatively dormant time period between when the cavities are filled to design capacity and when the crude is needed for a national emergency. During this interim period, the only activities would be security and maintenance checks. However, readiness for activation during an emergency would require keeping some trained operations personnel available and familiar with the storage facility.

Security Measures

Security measures for the Strategic Petroleum Reserve facility would be those standard for petroleum storage facilities. The main storage site would be fenced and properly lighted. All wellheads would have pneumatic gate valves on brine and crude lines to allow for remote control. These controls plus all electrical equipment would be housed in a secured building. Also, all pipelines would be monitored with pressure switches at each end of the line for early detection of leaks. The facility would maintain standard fire prevention systems and warning devices.

Equipment Testing and Maintenance

During the storage period, all equipment would be serviced and tested on a regular basis to ensure proper working order. Pumps, pressure valves and safety equipment would be lubricated and operated at least once a month. Maintenance crews would be on duty on a 24-hour basis.

A.3.7.3 Extraction Phase

The Strategic Petroleum Reserve Program requires an emergency deliverability of stored oil over a 5 month period. Thus, average delivery rates for a 163 million barrel facility would be 1,000,000 barrels per day (29,170 gallons per minute); however, considering that delivery through tankers might be required, the system is designed for simultaneous delivery of (typically) 60 percent to the SEAWAY Pipeline and 40 percent to the docks. The facility's systems are designed to handle maximum delivery rate. The oil would be displaced by one million barrels of water each day which would be pumped by three pumps, located on an intake structure in the Brazos River.

Raw water would be delivered via a 36-inch pipeline to the battery of injection pumps. These pumps force raw water into any combination of the four existing and 12 new leached caverns. Oil displaced from each cavern would be metered. Individual turbine meters would record volumes of oil from each well, and the meter bank would provide standby capability. Oil would be displaced directly from the wells into one of the four surge tanks or to SEAWAY Docks or Tank Farm. Four pumps near the tanks would deliver the crude oil to the SEAWAY Tank Farm or the docks. Manifolding at the pumps and valves in the 30-inch pipeline would allow, if required, simultaneous delivery to tankers at the DOE docks, and to the SEAWAY Tank Farm, about four miles to the northwest.

Distribution

Both the DOE docks at Freeport Harbor and the SEAWAY Pipeline through the SEAWAY Tank Farm are anticipated distribution systems for the Bryan Mound facility. Crude oil shipped through the dock facilities would be loaded on tankers (up to 50,000 DWT) for transportation to refineries along the Atlantic, Gulf, or Caribbean coasts. The crude distributed through the SEAWAY Pipeline system would reach inland refineries.

A.3.7.4 Refill Phase

After an oil supply interruption has ended, refill of the Strategic Petroleum Reserve storage facility is planned, provided that supplies are stabilized and crude oil is available for additional storage reserves. The rate of fill depends upon the availability of crude oil, but is expected to take two years at an average fill rate of 150,000 bbl per day (240,000 bbl per day maximum).

Refill Process

The refill process is the reverse of the withdrawal process. The crude oil is injected into the top of the storage cavity, thus displacing the brine, which goes to the brine disposal system in the Gulf of Mexico. The brine disposal system and distribution system is expected to handle a fill rate of up to 240,000 B/D.

Refill Capacity

The Strategic Petroleum Reserve system is planned for five fill and withdrawal cycles. Although the cavern capacity enlarges during each cycle, only the original design capacity for each cavity would be refilled.

A.3.8 Termination and Abandonment

When the nation has developed sufficient independence, the oil storage capacity at Bryan Mound dome may no longer be needed. It is intended that the facility continue to serve a beneficial use, if possible. Storage of light petroleum products, LPG, or other industrial products is possible. If no users can be found, the facility could be mothballed for later use.

Ultimately, the facility would be abandoned. Surface equipment would be removed and sold. Brine injection wells and cavity access would be sealed with concrete, a common oil field procedure. No long term surveillance or maintenance is anticipated.

A.4 ALLEN DOME ALTERNATIVE SITE

The Allen dome alternative site is designed to store 100 MMB of crude oil. Solution mining and subsequent fill operation to reach this storage capacity will be accomplished approximately five years after start of construction of facilities at Allen dome, the docks in Freeport and Brazos Harbors, and the pipelines to Bryan Mound.

Allen dome was chosen as a candidate site due to its proximity to SEAWAY Tank Farm, and the Freeport Harbor docking facilities. Crude oil arriving at Freeport docks may be delivered to surge tanks at Bryan Mound and then to the pipeline connecting to Allen dome. From the storage site, crude oil can be piped to the SEAWAY Pipeline at the SEAWAY Tank Farm or to the Freeport Harbor docks through the Bryan Mound early storage facilities.

A.4.1 Location

The Allen dome site, located in southern Brazoria County, Texas, lies about 15 miles west of the city of Freeport, 70 miles south of Houston, and 7 miles north of the Gulf of Mexico. The SEAWAY Tank Farm at Jones Creek lies 7 miles to the east and SEAWAY docks in the Freeport Harbor lie 14 miles to the east (Figure A.4-1). The San Bernard River borders the site on the east.

A.4.1.1 Site Access

Existing paved roads provide access to the site, however roads would have to be constructed in the plant area to the wells and pipelines.

A.4.1.2 Site Description

The Allen dome is a small dome site covering 300 surface acres within the -2000 foot salt contour (Figure A.4-2) and has been cleared for use as pasture, leaving only scattered groves of trees. Property in the vicinity of the site along the San Bernard River has already been partitioned for residential and vacation home lots. Bernard Acres, a residential community lies adjacent to the proposed southern plant boundary.

A.4.2 Capacity

Proposed capacity for the site is 100 MMB of crude oil stored in ten to twelve solution mined cavities. New caverns would be created by

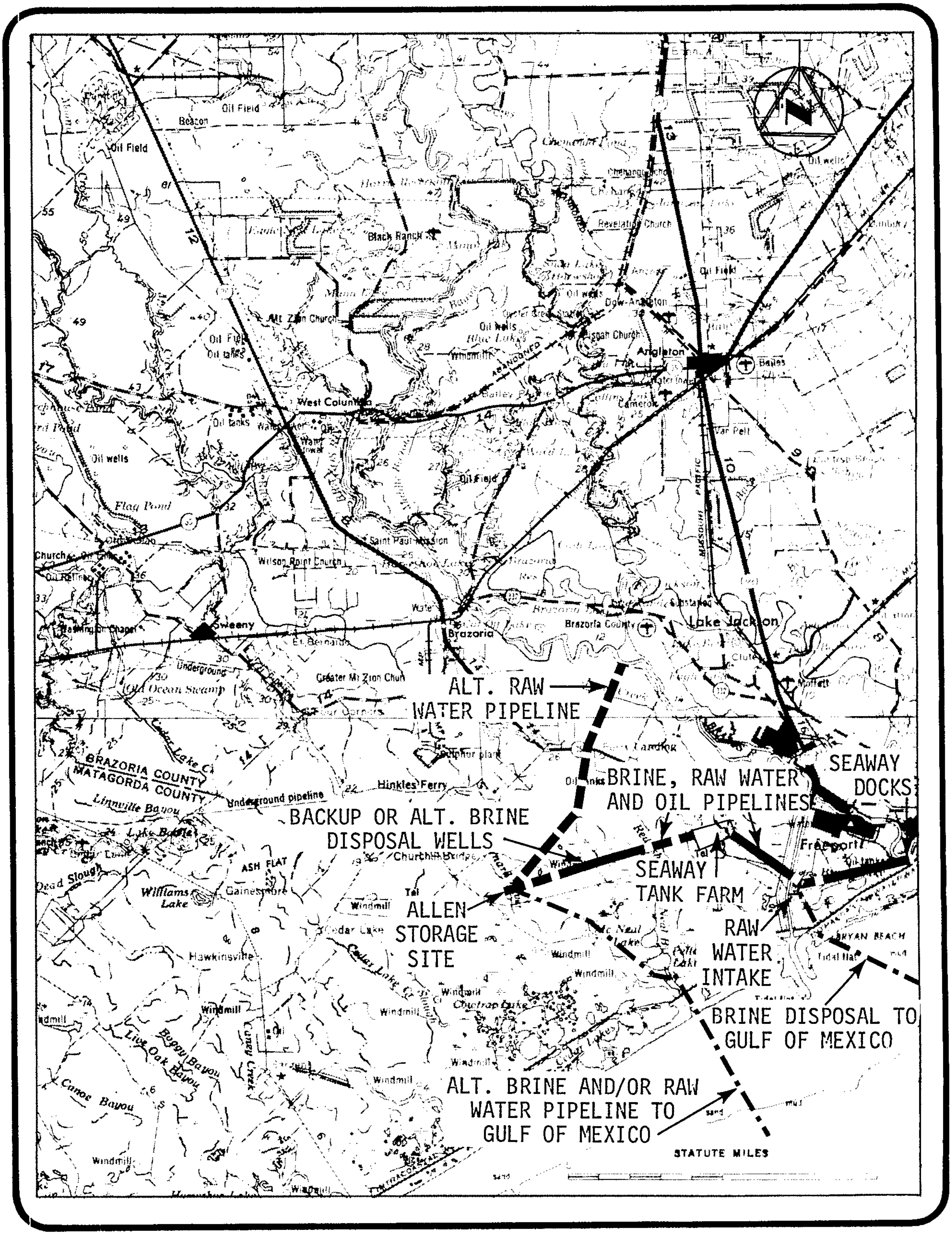


FIGURE A.4-1 Pipeline route map - Allen dome candidate SPR storage site (alternative site).

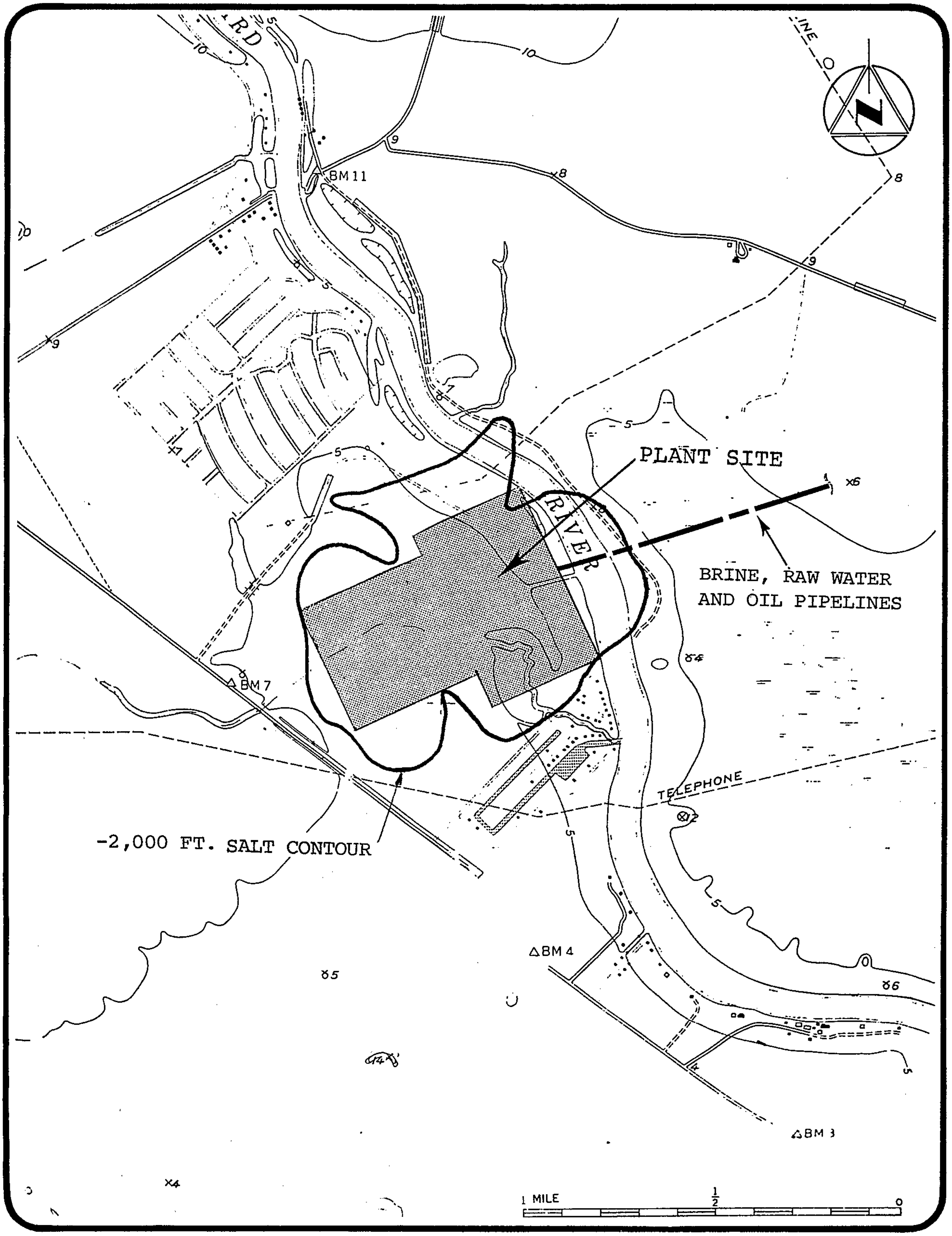


FIGURE A.4-2 Vicinity map - Allen dome candidate SPR storage site (alternative site).

drilling and brine solution mining. Utilizing all available acreage, the dome has a potential for approximately fifteen 10 MMB caverns.

A.4.3 General System Description

A.4.3.1 Proposed Systems

Development of the Allen dome will require use of the raw water intake and crude oil distribution system components built for the early storage phase at Bryan Mound; new docks at Freeport Harbor and Brazos Harbor; raw water and brine disposal pipelines connecting Allen dome to Bryan Mound; brine disposal pipeline to a Gulf diffuser 5.8 miles offshore; crude oil pipelines connecting SEAWAY Tank Farm and Allen dome; and the construction of the site facilities at Allen dome.

The general physical plant proposed at Allen dome facility consists of up to 12 new solution mined storage caverns and pipeline connections to the central pumping and control areas, a crude oil distribution system, a raw water supply system, a brine disposal system and a power system provided by a commercial power company.

Raw water for leaching the cavities would be pumped to the Allen dome storage site from the Brazos River Diversion Channel intake structure which would be built for the early storage phase at Bryan Mound. Displaced brine from the leached cavities would pass through a brine pit and be disposed of by a pipeline to Bryan Mound and then to the new brine diffuser in the Gulf of Mexico. Crude oil would be piped from the new dock facilities in Freeport Harbor through the bi-directional early storage phase crude oil pipelines through Bryan Mound to the SEAWAY Tank Farm, where they would connect with the new DOE pipeline to the Allen dome storage caverns.

As oil is injected into storage caverns, brine is simultaneously displaced. During withdrawal, raw water would be injected to displace crude oil. Oil would return through the DOE pipeline to SEAWAY Tank Farm, where it would connect to the SEAWAY Pipeline for inland refineries, or to the bi-directional early storage pipeline to Bryan Mound and Freeport Harbor tanker docks, for delivery to Gulf of Mexico, East Coast or Caribbean ports.

A.4.3.2 Alternative Systems

Four alternative raw water supply systems are possible: surface water from the San Bernard River east of the site; surface water from an intake on the Brazos River above Freeport; saline water from the Gulf of Mexico; and ground water from the Evangeline aquifer. Additional deep wells spaced along the pipeline between Allen dome and SEAWAY Tank Farm could provide an alternative to the proposed brine disposal system. Brine disposal via a pipeline directly from the site to a diffuser located in a different area of the Gulf of Mexico is an alternative to use of the diffuser through a pipeline to Bryan Mound. Relocation of the Bryan Mound diffuser to a point 12.5 miles offshore is another alternative.

Alternatives to use of the docks at Freeport are the construction of a Single Anchor-Leg Mooring (SALM) monobuoy in deep water offshore; conversion of an existing SEAWAY dock in Brazos Harbor; and use of Phillips Petroleum Company docks.

A possible alternative source of power is onsite generation.

A.4.4 Site Development

A.4.4.1 Proposed Physical Facilities

Introduction

A typical layout of surface facilities at Allen dome, shown in Figure A.4-3, includes storage cavern wells, plant area, road and pipeline alleys and the security fence.

Storage Cavity System

Twelve storage cavity wells, shown on Figure A.4-3, reflect the estimate that 20 percent of the wells would encounter problems that would reduce their capacity from the planned 10 MMB to 5 MMB. Thus, twelve cavities would still meet the required 100 MMB capacity at the Allen dome site.

Since the dome is small, the cavities have to be deeper and narrower than those at Bryan Mound. The cavities would be leached in the -2000 to -3700 foot depth interval. Initially each cavern is expected to be about 1700 feet high and 205 feet in diameter. If the crude oil is

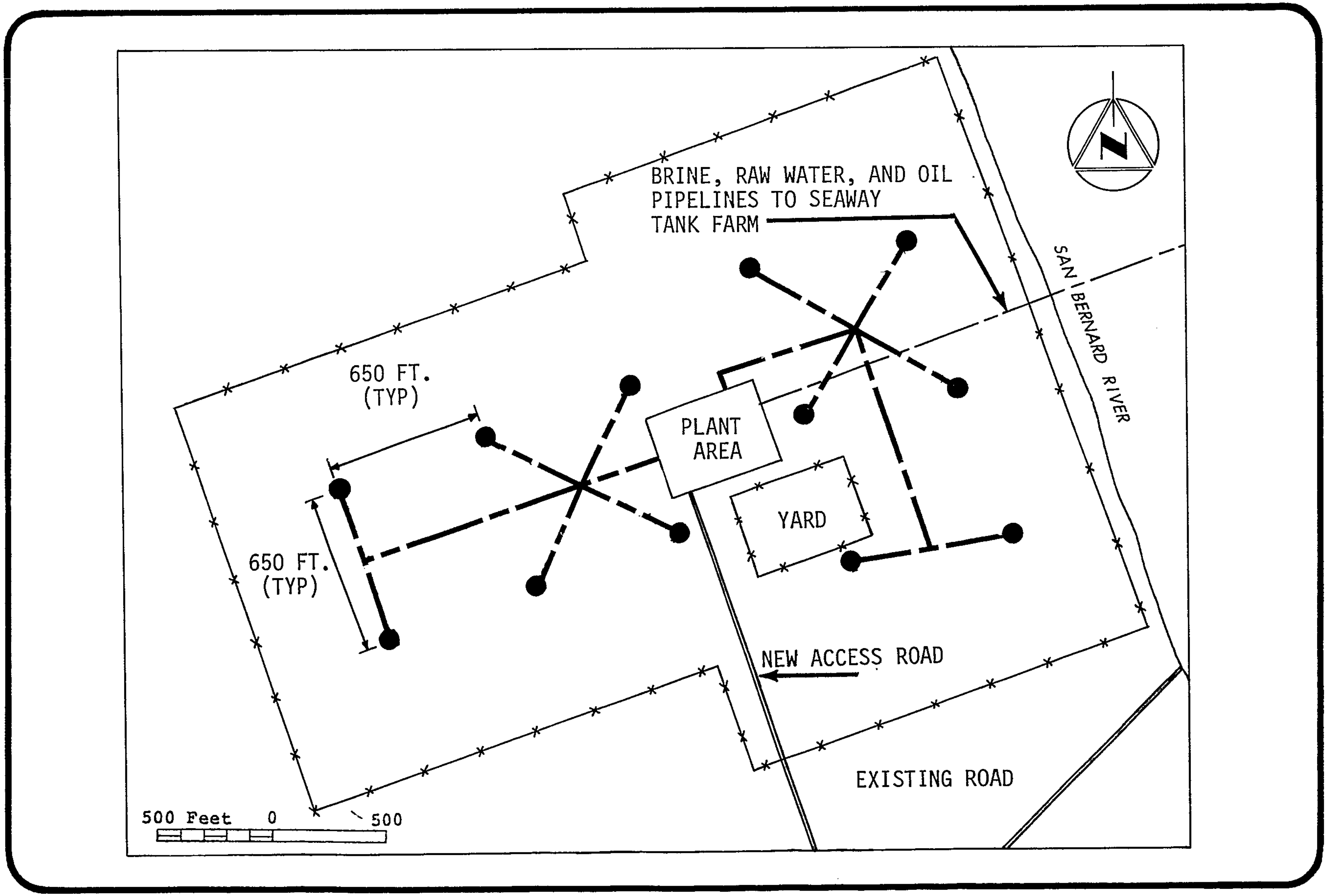


FIGURE A.4-3 Site map - Allen dome candidate SPR storage site (alternative site).

withdrawn five times in response to severe import interruptions, the ultimate diameter would be about 300 feet. The layout in Figure A.4-3 places caverns on 600-foot centers and a minimum of 600 feet from the dome edge, thus providing a 200-foot wall around every cavern.

Each of the 12 planned storage wells would require the construction of a 200 by 200-foot drilling pad. After drilling is completed, the pad would be converted to a small permanent area to allow workover and conversion work.

Onsite pipelines for water, oil and brine would be buried alongside the 20-foot roadways, allowing dual use of roads as pipeline alleys and permitting vehicular access to storage wells.

Plant Area

An area about 10 acres would be required to accommodate facilities necessary to operate and leach the storage cavities. This area (Figure A.4-4) would contain the main pump building, control building, warehouses and office, a blanket oil tank, a lined brine pit, and a raw water tank to prime injection pumps. Adjacent to the plant area would be a material and equipment yard to allow orderly delivery and storage of construction equipment and materials.

The main pump building would be a prefabricated type steel structure on a concrete slab foundation. The building area would be on fill at a suitable height above ground level in order to minimize flooding concerns. In addition to the main building, a smaller building of similar construction would be located nearby to house instrumentation, the office, lab, warehouse, and shop area. A transformer bank would be placed adjacent to the main pump building on the raised fill area.

A blanket oil tank would be contained within a reservoir dike equivalent in capacity to the total contents of the tank to contain any spilled oil. A 3000 barrel raw water tank would be required to prime the raw water injection pumps (Figure A.4-4).

All plant buildings and storage wells would be enclosed by 12,600 linear feet of nine foot high chain link fence. Also, fencing would be required to enclose the material and equipment storage area.

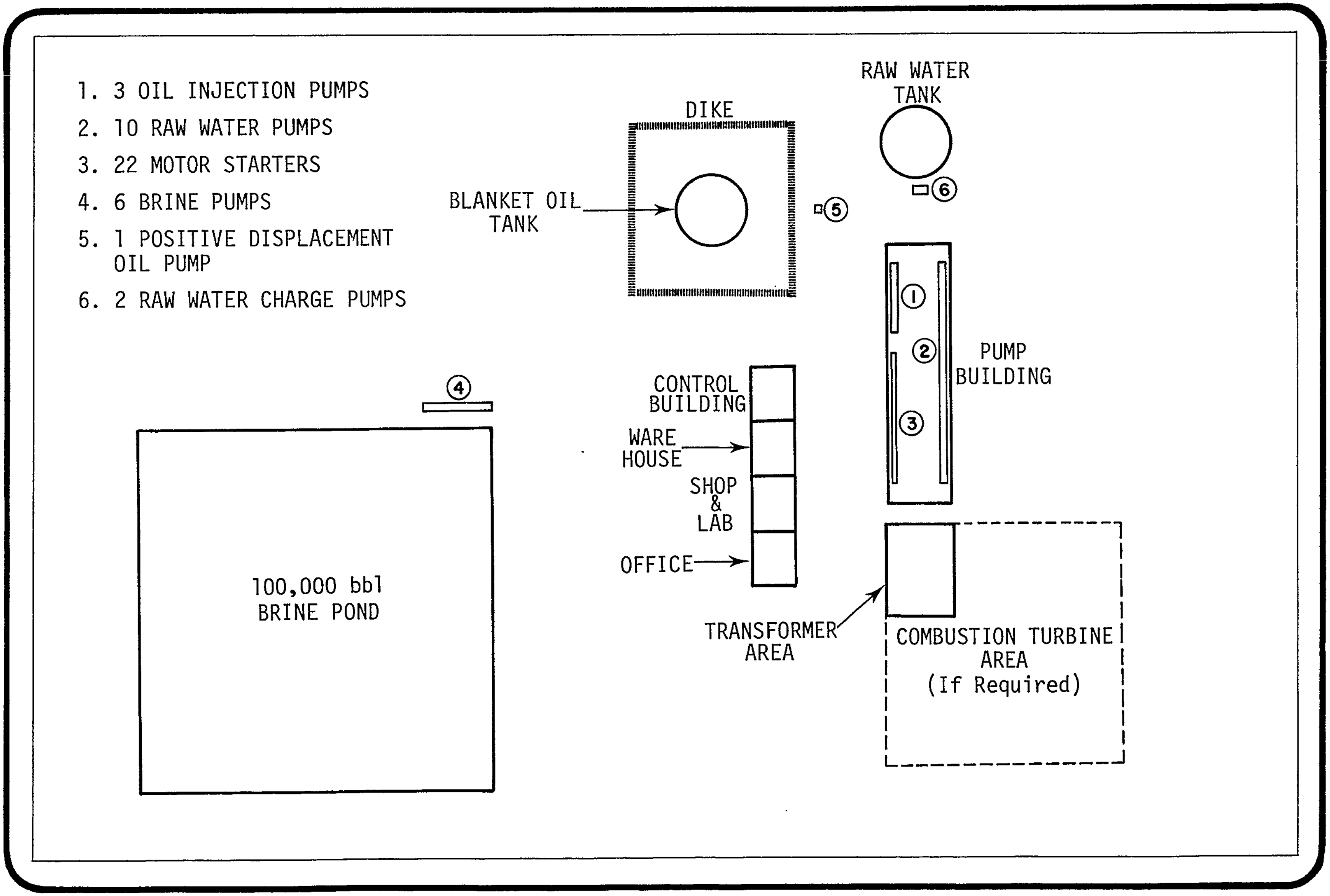


FIGURE A.4-4 Plant area layout - Allen dome candidate SPR storage site (alternative site).

Crude Oil Distribution System

Oil would be delivered to and withdrawn from the site through a 30-inch oil distribution pipeline which would connect Allen dome with the DOE pipeline at the SEAWAY Tank Farm. The existing DOE 30-inch early storage pipeline will connect SEAWAY Tank Farm to the DOE docks at Freeport Harbor through Bryan Mound. These pipelines would be used during both filling and withdrawal phases.

The 8 mile pipeline between the storage site and SEAWAY Tank Farm would be bi-directional. It was sized at 30 inches to pick up oil at the caverns for delivery to the tanker dock, via the SEAWAY Tank Farm and Bryan Mound.

DOE would build one dock adjacent to the three SEAWAY docks in Freeport Harbor to satisfy the cavern filling requirements. A second dock facility would be built in Brazos Harbor (Figure A.3-1). These docks would also be capable of loading out strategic oil in excess of that required for inland distribution. Construction of these facilities is discussed in Section A.3.

Raw Water System

The source for providing the maximum 1 MMB per day of raw water required at the site would be the Brazos River Diversion Channel. The intake structure, part of the Bryan Mound early storage facility, is discussed in detail in the supplement to FES 76/77-6.

The 36-inch pipeline from Bryan Mound to Allen dome would parallel the crude oil pipeline and would be connected to the raw water injection manifold located at the plant. This manifold would supply water to raw water injection pumps. Those pumps would discharge into manifolds for delivery to pipelines serving each storage well.

In addition to supplying water directly to water injection pumps, the 36-inch pipeline would be connected to a 3000 bbl raw water tank.

Brine Disposal System

The means of disposing of brine from the Allen dome facility would be by pipeline to the Gulf of Mexico via a diffuser extending 5.8 miles offshore from the Bryan Mound ESR site at the rate of about 2000 gpm per

10-MMB cavern, or a total of about 20,000 gpm (684,000 bbl per day). The proposed route for the pipeline to Bryan Mound, shown in Figure A.4-1, would run through the SEAWAY Tank Farm paralleling the crude oil pipeline.

A system of three injection wells would be constructed as a backup system.

Bryan Mound ESR Site

Tanker loading and unloading surge rates would be absorbed in four 200,000 bbl floating- roof type oil storage tanks located at Bryan Mound. This tankage quantity gives two days of storage and may not be adequate to allow continuous full rate operation of the system during significant weather-caused delays.

Power System

Power would be supplied from a new 12-mile transmission line originating at Community Service Company's Brazoria substation north of the site. Power would be delivered to the site and stepped down to required voltages for use by various pump motors. The total anticipated load for this site would be about 21,000 hp.

Community Public Service Company does not anticipate any problem in furnishing this demand for the time period required to construct the facility. However, demand charges for the indeterminable storage period are expected to be very high, because the company's energy utilization revenue would be quite small in relation to the very large demand load it would have to maintain on a standby basis.

Land Requirements

The area dedicated to the SPR facility at Allen Dome and its associated offsite systems would be approximately 160 acres. In addition, the continued use of 128 acres of land previously commited at Bryan Mound for early storage reserves would result in a total land requirement for the program of 288 acres. A breakdown of land requirements by system components is provided in Table A.4-1.

The Allen Dome storage facility would be located on a fenced 184-acre tract. Within this area approximately 31 acres would be in semi-permanent

TABLE A.4-1 Land requirements - Allen dome candidate SPR storage site (alternative site).

	Total Miles Pipeline Row	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres): Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]	Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
A. SPR Facilities											
1) Storage Site											
a) Central Plant Area	---	---	380,560	---	---	10/10	---	---	---	---	10/10
b) Brine Surge Pond	---	---	(included above)	3/3	---	---	---	---	---	---	3/3
c) Plant Access Road	---	---	} 28,800 (c–e)	---	---	1/1	---	---	---	---	1/1
d) Onsite Roads and Pipe Alleys	1.8	27,720		---	---	5/5	---	---	---	---	5/5
e) Cavern Wellhead Pads	---	---		---	---	12/12	---	---	---	---	12/12
f) Containment Dikes at Cavern Wellheads	---	---	840	---	---	---	---	---	---	---	---
2) Offsite											
a) Backup Brine Injection Wells	Follows Proposed DOE Right-of-Way										
1) Pipeline Excavation	1.9	9,780	---	---	---	23/17	---	---	---	---	23/17
2) Roadways to Wellheads	---	---	---	---	---	---	---	---	---	---	---
3) Wellhead Pads	---	---	3,000	---	---	3/3	---	---	---	---	3/3
b) Oil, Brine and Raw Water Pipelines to Seaway Tank Farm	8.0	126,720	---	---	2/2	84/63	12/9	---	1/0	6	99/74
c) Brine and Raw Water to Bryan Mound	4.1	54,800		Follows Proposed DOE Right-of-Way							
d) Brine Disposal to Gulf of Mexico diffuser from Bryan Mound	7.5	177,300	---	---	---	20/14	.2/.1	1/.5	142/0	2	163/15
e) Pipeline Connection to Brazos Harbor	0.6	6,000	---	4/3	---	---	4/3	---	---	---	8/6
f) New Tanker Docks	---	1,050,000	---	14/14	---	---	---	---	---	---	14/14
Sub-Total SPR Facilities - Allen Dome -	23.9	1,452,320	413,200	21/20	2/2	158/125	16/12	1/1	143/0	8	341/160
B. Early Storage Facilities at Bryan Mound	10.4	94,600	665,000	74/69	---	43/33	33/26	---	---	1	150/128
Total Land Requirements- Early Storage plus SPR at Allen Dome	34.3	1,546,920	1,078,200	95/89	2/2	201/158	49/38	1/1	143/0	9	491/288
C. Alternatives to Proposed Systems											
1) Brine Disposal (Wells)	Follows Proposed DOE Right-of-Way										
a) Pipeline Excavation	3.2	19,000	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	19,000	---	---	19/19	---	---	---	---	19/19
2) Brine Disposal (Directly to Gulf of Mexico 5 mi diffuser)	13.4	197,472	---	---	---	17/13	76/57	---	141/0	2	234/70

[a]Construction Right-of-Way/Maintenance Right-of-Way

TABLE A.4-1 continued.

	Total Miles Pipeline Row	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres): Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]	Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
3) Brine Disposal via tank farm and Bryan Mound to 12.5 mi diffuser	14.2	274,600	---	---	---	20/14	.2/.1	1/.5	305/0	2	326/15
4) Raw Water (Brazos River)	5.0	26,540	---	---	45/34	61/46	---	---	---	---	106/80
5) Raw Water (San Bernard River)	---	140	---	---	1/1	5/3	---	---	---	---	6/4
6) Raw Water (Ground water supply wells)	Follows Proposed DOE Right-of-Way										
a) Pipeline Excavation	5.5	28,800	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	---	---	---	22/22	---	---	---	---	22/22
7) Raw Water (Gulf of Mexico)	13.4	197,472	---	---	---	17/13	76/57	---	141/0	2	234/70

[a] onstruction Right-of-Way/Maintenance Right-of-Way

use for the plant area, the brine surge pond, roadways, pipeline alleys, wellhead pads and dikes. The remainder of the site would be relatively undisturbed.

Offsite, approximately 129 acres would be maintained for use during the SPR program. The oil, brine, and raw water pipelines to the SEAWAY Tank Farm would semi-permanently use 74 acres along the pipeline alley. The proposed brine disposal system from Bryan Mound to the Gulf of Mexico would require maintenance of 15 acres of pipeline alleys. The pipeline rights-of-way and wellhead pads for the back-up brine disposal wells along the proposed pipeline right-of-way to the SEAWAY Tank Farm would develop an additional 20 acres. The oil pipeline connection to Brazos Harbor and the new tanker docks would commit 20 more acres to SPR use.

Construction activities would require 491 acres of land for relatively short duration after which the 203 acres not required for maintenance would be available for its previous, or other, use.

A.4.4.2 Alternative Physical Facilities

Alternative physical facility locations are shown in Figure A.4-1. Acreages affected by these alternatives are summarized in Table A.4-1. With each of these alternatives, early storage facilities at Bryan Mound would still be required.

Raw Water System

Ground water is a possible source of raw water, however, withdrawing great quantities of ground water in this area could cause land subsidence and low ground water levels.

A second alternative would be to draw surface water from the San Bernard River. As detailed in Section B.2.2, the San Bernard River discharge is subject to wide fluctuations, but it is a tidal estuary at the site. Due to salt water exchange with the Gulf of Mexico, sufficient supply should be available to meet SPR requirements at all river stages. Use of this water would require construction of an intake structure and pump facilities. The pipeline would be onsite.

A third alternative would be to obtain injection water from the Gulf of Mexico. A pipeline would be required to deliver the water to the injection pumps.

A fourth alternative raw water supply is an intake on the Brazos River above Freeport. Water would be obtained through an intake structure similar to that constructed at Bryan Mound for the early storage program. The water would have to be purchased from the Lower Brazos River Authority. Other commitments of the water from the Brazos would limit the availability of water to the project during low flows, and DOE storage project time limitations would not be amenable to water supply interruptions.

Crude Oil Distribution System

Construction of a Single Anchor-Leg Mooring (a type of Single Point Mooring (SPM) system) monobuoy in deep water offshore would be an attractive alternative dock facility if it were not for the long lead time and licensing uncertainties associated with deep water port facilities. Licensing work on the SEADOCK deepwater terminal has been in progress for at least five years. Use of the SPM monobuoy facility would also require considerable additional surge tankage.

Another alternative would be the use of the Phillips Petroleum Company docks for filling, on a space-available basis. Due to their commitment to supply the Phillips refinery complex, they could only be used on an "as available" basis during the storage phase. A connecting pipeline to the oil pipeline to Bryan Mound would be required.

In the event of the construction of SEADOCK, the SEAWAY docks at Freeport would have surplus capacity. Therefore, construction of an DOE dock would not be necessary, and the conversion of one of the SEAWAY docks to DOE use for loading capability would be an attractive alternative to construction of new docks. The uncertainties of licensing and development of SEADOCK and the necessity of having dedicated dock facilities for the SPR program reduce the viability of this alternative.

Conversion of an existing SEAWAY dock in Freeport Harbor would have less impact than dredging a berth for a new dock. An operations office, monitoring equipment, and loading facilities could be added with only minor disruptions.

Brine Disposal System

Brine disposal via a pipeline directly from the site to a diffuser in the Gulf of Mexico is an alternative (Figure A.4-1). It would be independent of the proposed brine disposal system.

Deep well injection of brine would require a field of nineteen more wells. They would be located along the pipeline right-of-way between Allen dome and SEAWAY Tank Farm. Each well would have a capacity of 1000-gallons per minute and would be spaced at about 1000-foot intervals. An estimated 19 acres would be required for these injection wells. Drilling of the wells to depths of 5000 to 7000 feet would be accomplished by typical oil field equipment. Special design considerations to eliminate adverse effects to overlying fresh water aquifers would be incorporated into this design. Location of a brine diffuser 12.5 miles offshore would extend the proposed offshore pipeline an additional 6.7 miles into the Gulf.

Power System

An alternative to the purchase of power would be the construction of a 22,000 hp generator with oil fuel tank and a 50-foot exhaust stack.

A.4.5 Construction Techniques

A.4.5.1 Storage Cavern Construction

Wells from which the caverns would be developed would be constructed as outlined in Section A.2. If conditions require the use of smaller casing than specified, cavern size would be reduced. This would necessitate development of additional caverns to attain the required storage volume. The storage site design showing 12, rather than 10 wells, reflects this. The assumption is that no more than four wells would encounter problems that would reduce their potential volume from 10 to 5 MMB each.

General techniques of cavern construction are described in detail in Section A.2. For the Allen dome site, it would be necessary to further define the configuration of the salt body. Final design of the cavern arrangement is heavily dependent upon the extent of this relatively small dome. Cavern spacing for the present design allows 600 feet between caverns. This would provide 200-foot minimum wall spacing between developed caverns specified.

A.4.5.2 Road Construction and Other Grading

There is suitable access to the area by existing roads. However, there are no roads over the proposed construction area. Therefore, it would be necessary to construct an access road to the plant area, in addition to roads for each storage well and along the raw water, crude oil, and brine pipelines. It is anticipated that two miles of onsite road construction would be required.

Surface facilities include the well completions, pump stations, offices, oil and raw water storage tanks, sanitary sewage holding tank, and connecting pipelines. Access roadways would provide access to the wellheads and connecting pipelines. All storage and pipeline facilities would be constructed to applicable API standards. The main plant area would be graded to be at least 1 foot above the 100-year flood or about 17 feet above the existing surface. Alternative construction methods such as the use of platforms instead of fill were considered, however, the relative economic costs of this alternative far outweighed the potential environmental damage of the proposed methods.

Two new docks would be constructed: one in the Old Brazos River Harbor, adjacent to the three existing SEAWAY Docks and one in the Brazosport Harbor. These locations provide ready access to the Gulf of Mexico. Presently, the U.S. Army Corps of Engineers is widening the turn at the entrance to the harbor. A 45-foot channel project has also been authorized by Congress. Dredge volumes of approximately 50,000 cy required for each tanker berth are considerably smaller than those in the above mentioned projects.

Safety dikes would be constructed around the blanket oil tank to contain any spilled oil should a leak occur. Small dikes would also be constructed around each wellhead to contain small volumes of oil spilled during operation or maintenance.

A.4.5.3 Pipelines

Pipeline construction techniques appropriate to the area and currently employed by the oil pipeline industry include push-ditch conventional dry-land construction and barge lay methods as described in Section A.2.2.4.3.

A.4.6 Development Timetable

The present schedule for developing the 100 MMB Allen dome SPR facility requires leaching of five to six new 10 MMB caverns during the first two years and then filling these caverns at the same time that five to six more caverns are being developed.

The development schedule (Figure A.2-7) shows graphically the relationship of cavern mining to cavern filling.

A.4.7 Operation and Maintenance

A.4.7.1 General Safety Precautions

General Safety Precautions described in Section A.3.7.1 are directly applicable to the Allen site.

A.4.7.2 Storage Phase

Operation and maintenance procedures for the storage phase are described in A.3.7.2.

A.4.7.3 Extraction Phase

Operation and maintenance procedures for the extraction phase are described in A.3.7.3.

A.4.7.4 Refill Phase

Operation and maintenance procedures for the refill phase are described in A.3.7.4.

A.4.8 Termination and Abandonment

Termination and abandonment of the Allen dome SPR storage facility would be the same as that described in Section A.3.8 for Bryan Mound.

A.5 WEST COLUMBIA DOME ALTERNATIVE SITE

The West Columbia dome facility is designed for storage of 100 MMB of crude oil. Solution mining and subsequent fill operations to reach this storage capacity will be accomplished approximately 5 years after start of construction of facilities at West Columbia dome, the docks in Freeport and Brazos Harbors, and the pipelines to Bryan Mound.

The West Columbia dome was chosen as a candidate site due to its proximity to SEAWAY Tank Farm, Bryan Mound, and the Freeport Harbor docking facilities. Crude oil arriving at Freeport docks may be delivered to surge tanks at Bryan Mound and then to the pipeline connecting to West Columbia dome. From the storage site, crude oil can be piped to the SEAWAY Pipeline at the SEAWAY Tank Farm or to the Freeport Harbor docks through the Bryan Mound early storage facilities.

A.5.1 Location

The West Columbia dome is in west central Brazoria County, Texas, approximately 45 miles southwest of Houston and 1 mile north of the town of West Columbia. The Brazos River lies approximately 2.7 miles southeast, the San Bernard River lies 3.4 miles southwest and Varner Creek lies about 1/2 mile east of the site. SEAWAY Tank Farm is located about 23 pipeline miles to the southwest (Figure A.5-1).

A.5.1.1 Site Access

There is good access to the site from existing roads in the area so new road construction would be confined within the plant area. State Highway 36 runs along the west edge of the dome. Access to SEAWAY Pipeline right-of-way, 2-1/2 miles to the west, is good.

A.5.1.2 Site Description

The West Columbia dome is a small dome consisting of approximately 350 surface acres within the -2000 foot salt contour (Figure A.5-2). There are few trees on the site. A marsh area covers the center of the dome, and the remainder of the dome is grass covered and used for grazing. Oil production is mainly centered north of the storage site, although a few wells are located in close proximity south and east of the site.

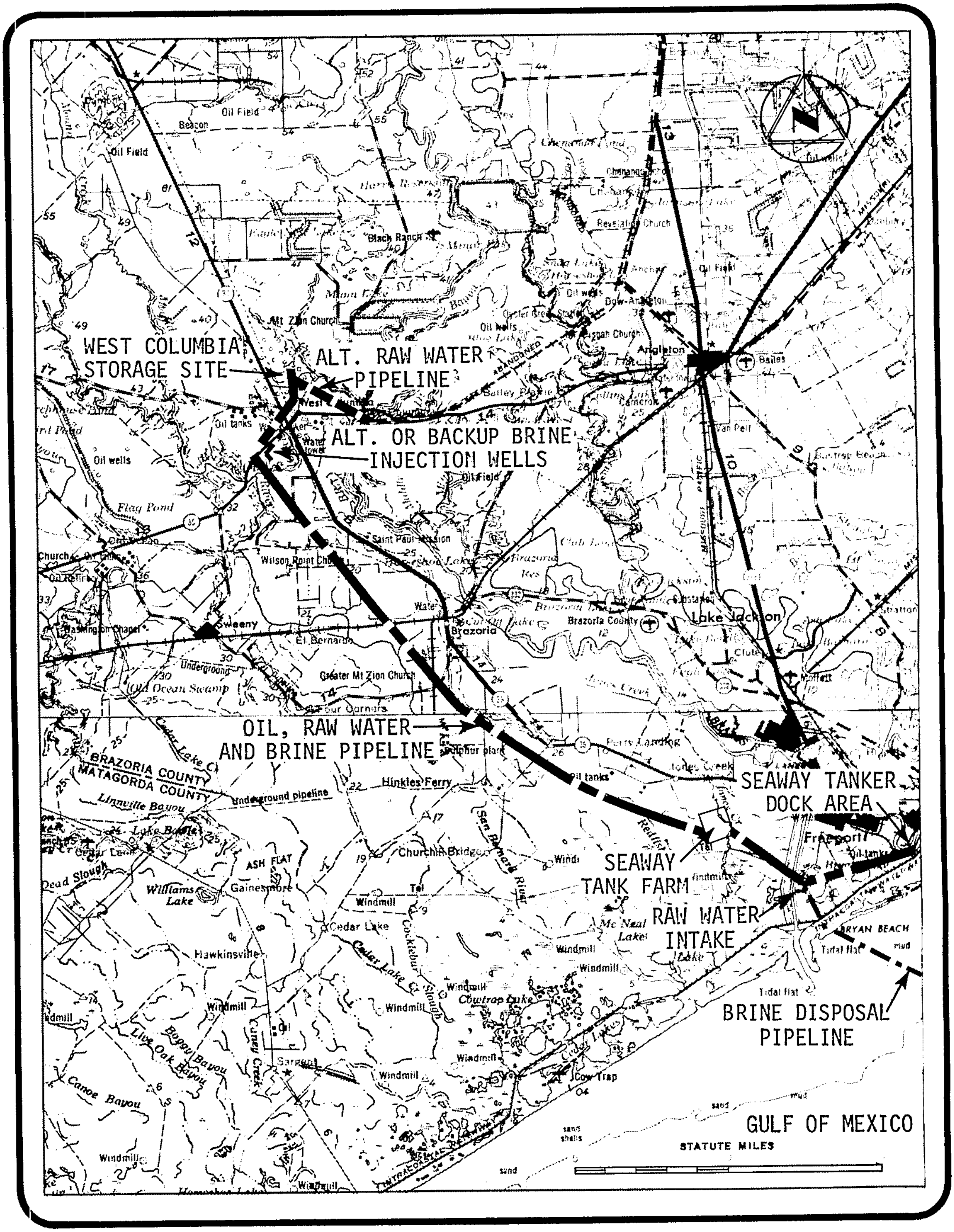


FIGURE A.5-1 Pipeline route map - West Columbia dome candidate SPR storage site (alternative site).

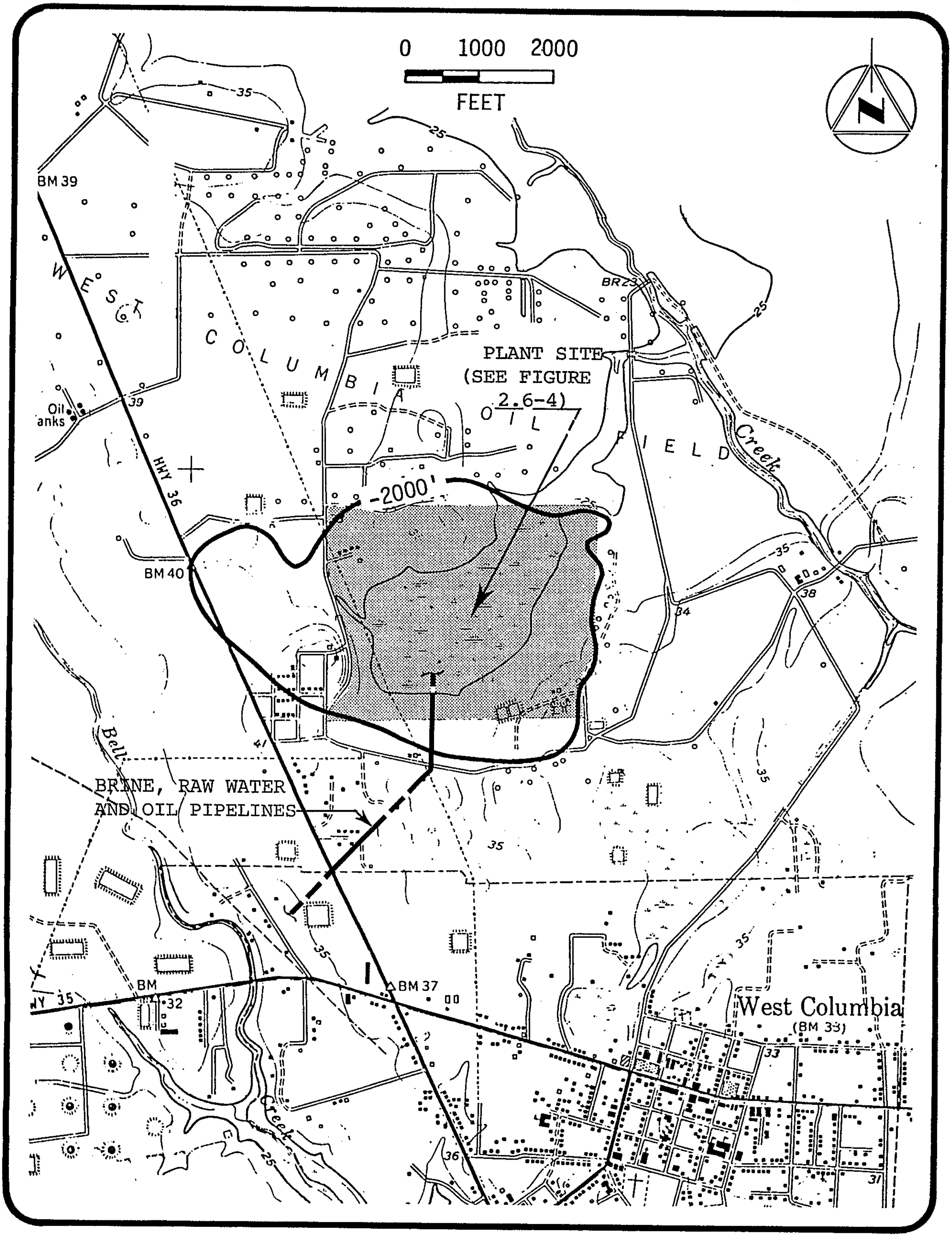


FIGURE A.5-2 Vicinity map - West Columbia dome candidate SPR storage site (alternative site)

A.5.2 Capacity

The capacity planned at this site is 100 MMB of crude oil stored in 10 to 12 solution mined cavities.

Utilizing all available acreage, the dome has a potential for approximately seventeen 10 MMB caverns.

A.5.3 General System Description

A.5.3.1 Proposed Systems

Development of West Columbia dome would require the use of the raw water intake, four 200,000 bbl oil surge tanks, and crude oil distribution system components built for the early storage phase at Bryan Mound. Construction of new docks in Freeport Harbor; raw water and brine disposal pipelines connecting West Columbia dome to Bryan Mound; crude oil pipelines connecting SEAWAY Tank Farm and West Columbia dome; a brine diffuser 5.8 miles offshore in the Gulf of Mexico; and the site facilities at West Columbia dome will be required to complete site development.

The physical plant proposed at West Columbia consists of up to 12 new solution mined storage cavities with crude oil, raw water and brine pipeline connections to the central pumping and control areas, a crude oil distribution system, a raw water supply system, a brine disposal system and a power system provided by a commercial power company.

Raw water for leaching the cavities would be piped to the West Columbia dome storage site from the Brazos River Diversion Channel intake structure which was built for the early storage phase at Bryan Mound. Displaced brine from the leached cavities would pass through a brine pit and be disposed of by a pipeline through Bryan Mound to a brine diffuser in the Gulf of Mexico. Crude oil would be piped from the new dock facilities in Freeport Harbor through the bi-directional early storage crude oil pipeline to Bryan Mound and from Bryan Mound to the SEAWAY Tank Farm, where it would connect with the new DOE pipeline to the West Columbia dome storage caverns. As oil is injected into storage caverns, brine would be simultaneously displaced. During crude oil withdrawal, raw water would be injected to displace crude oil. Oil would return through the DOE pipeline to SEAWAY Tank Farm, where it would connect to the SEAWAY Pipeline to inland refineries, or to the bi-directional early storage pipeline to Bryan Mound and Freeport Harbor tankers, for delivery to Gulf of Mexico, East Coast or Caribbean ports.

A.5.3.2 Alternative Systems

Alternatives to use of the docks at Freeport are the construction of a Single Anchor-Leg Mooring (SALM) monobuoy in deep water offshore; conversion of an existing SEAWAY dock in Brazos Harbor; and use of Phillips Petroleum Company docks.

Two alternative raw water supply systems are possible: surface water from the Brazos River east of the site, and ground water from the Evangeline aquifer. Deep wells spaced along the common pipeline right-of-way between West Columbia dome and SEAWAY Tank Farm could provide an alternative to the proposed brine disposal system. An alternative location for the Gulf brine diffuser is 12.5 miles offshore. A possible alternative to commercial power would be an onsite generator.

A.5.4 Site Development

A.5.4.1 Proposed Physical Facilities

Introduction

A typical layout of surface facilities at the West Columbia dome storage site, shown in Figure A.5-3, includes the storage cavity wells, plant area, road and pipeline alleys and the security fence.

Storage Cavity System

Twelve storage cavity wells, shown on the site map (Figure A.5-3), reflect the estimate that 20 percent of the wells may encounter problems that will reduce their capacity from the planned 10 MMB to 5 MMB. Thus, twelve cavities would still meet the required 100 MMB capacity at the West Columbia dome site.

The cavities would be leached in the 1500 to 2500 foot depth interval. Each cavern is expected to be about 1000 feet high and 300 feet in diameter after completion. If the crude oil is withdrawn

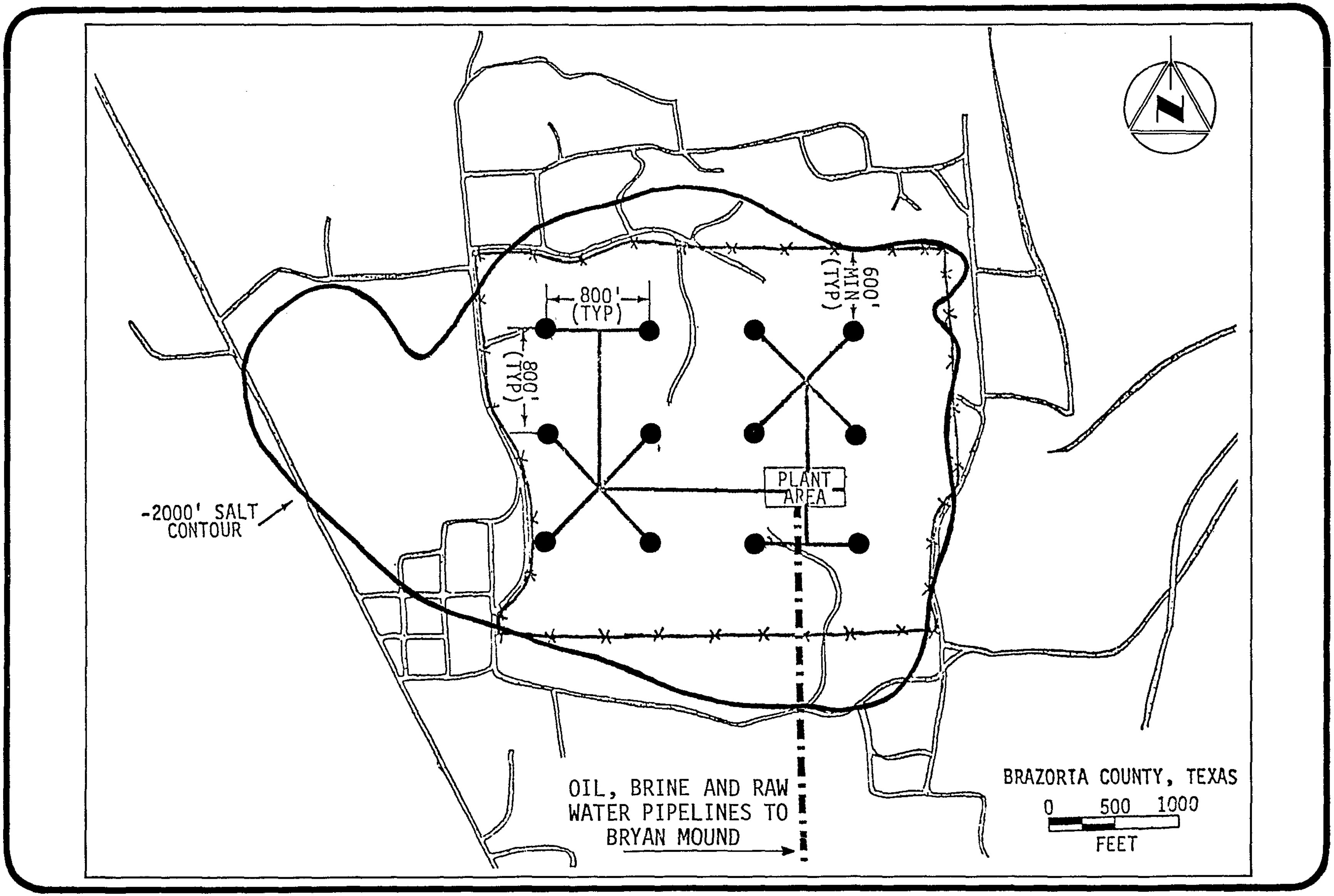


FIGURE A.5-3 Site map - West Columbia dome candidate SPR storage site (alternative site).

five times in response to import interruptions the ultimate diameter of the caverns would be about 400 feet. The layout in Figure A.5-2 places caverns on 800-foot centers and a minimum of 600 feet from the dome edge, thus providing a 400-foot wall around every cavern.

Plant Area

Grading on the site will affect approximately 15 percent of the area enclosed by the security fence. Almost half of this area is marshy, requiring fill. Each cavity well would require construction of a 200-foot square drill pad. Some of these would be located in marshy areas, and would require fill. Twenty-foot wide roadway and pipeline alleys would service each cavity well. Onsite pipelines would be buried. Safety dikes would be constructed around each wellhead and oil storage tank.

The plant area would contain a pump house of steel construction which would house all pumps; a suitably diked blanket oil tank for cavity construction; a raw water tank for priming the raw water injection pumps; a control building of steel construction, housing offices, shops, and warehouse; a transformer area; and a lined brine pit. The plant area layout is similar to the layout shown on Figure A.4-4.

Crude Oil Distribution

Crude oil would be piped from the new dock facilities in Freeport Harbor to the surge tanks at Bryan Mound through the early storage phase bi-directional pipeline as far as the SEAWAY Tank Farm, where it would be delivered to a new 23 mile DOE pipeline to West Columbia dome. Crude oil stored at the West Columbia dome storage facility would be piped through the DOE pipeline to the SEAWAY Tank Farm. From there it would either be piped through the SEAWAY pipeline to inland refineries or to the surge tanks at Bryan Mound and then into tankers at Freeport Harbor for delivery to East Coast, Gulf of Mexico, or Caribbean refineries.

Raw Water System

The early storage intake structure on the Brazos River Diversion Channel would be used to pump raw water to a new DOE pipeline from

Bryan Mound to West Columbia dome storage site along the DOE right-of-way adjacent to SEAWAY Pipeline right-of-way.

Brine Disposal System

Brine displaced from the West Columbia storage cavities would enter a brine pit on the West Columbia site, and then would be piped through the new brine disposal pipeline along the DOE and SEAWAY Pipeline right-of-way to Bryan Mound, where it would connect to the new pipeline from Bryan Mound to the brine diffuser 5.8 miles in the Gulf of Mexico.

The brine disposal pipeline from the storage site to Bryan Mound would be manifolded to backup injection wells paralleling the pipeline.

Raw water injection rates, brine production rates and crude oil distribution rates would be the same as those addressed in Section A.4 for construction and operation of the Allen dome site.

Power System

Power from the Community Public Service Co. West Columbia substation would be supplied to the site via a 0.6 mile transmission line.

Land Requirements

A total of approximately 416 acres of land will be required for operation of the SPR program using the West Columbia site. Early storage facilities would continue to use 128 acres at Bryan Mound while facilities associated with West Columbia would need 288 acres. During construction 231 additional acres of land would be affected for a brief period but would revert to other uses during operation.

The storage facilities would be located on a 232-acre tract enclosed by a fence. Less than 15% (30 acres) of the site would be put to semi-permanent use for storage facilities. Land requirements for site development are summarized in Table A.5-1.

All the facilities at the central storage area overlying the dome would require 30 acres. The brine disposal system would use 18 acres, 15 acres at Bryan Mound for a pipeline to the diffuser and

TABLE A.5-1 Land requirements - West Columbia dome candidate SPR storage site (alternative site).

	Total Miles Pipeline Row	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres) Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Freshwater Marsh Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]	Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
SPR Facilities												
1) Storage Site												
a) Central Plant Area	---	---	16,200	---	---	---	10/10	---	---	---	---	10/10
b) Brine Surge Pond	---	---	19,000	---	---	---	3/3	---	---	---	---	3/3
c) Plant Access Road	---	---	400	---	---	---	---	---	---	---	---	---
d) Onsite Roads and Pipe Alleys	2.2	34,000	8,400	---	---	---	5/5	---	---	---	---	5/5
e) Cavern Wellhead Pads	---	---	17,800	---	---	---	12/12	---	---	---	---	12/12
f) Containment Dikes at Cavern Wellheads	---	---	840	---	---	---	---	---	---	---	---	---
2) Offsite												
a) Backup Brine Injection Wells	Follows Proposed DOE Right-of-Way											
1) Pipeline Excavation	2.3	12,150	---	---	---	---	---	---	---	---	6	---
2) Roadways to Wellheads	---	---	Minimal Fill	---	---	---	---	---	---	---	---	---
3) Wellhead Pads	---	---	---	---	---	3/3	---	---	---	---	---	3/3
b) Oil, Brine and Raw Water Pipelines to Seaway Tank Farm	23.0	364,320	---	---	149/112	130/98	---	---	---	---	---	279/210
c) Brine and Raw Water Pipelines to Bryan Mound	4.1	54,800	---	Follows Proposed DOE Right-of-Way								
d) Brine Disposal to G.O.M. diffuser from Bryan Mound	7.5	177,300	---	---	---	20/14	---	.2/.1	1/.5	142/0	2	163/15
e) Pipeline Connections to Brazos Harbor	0.6	6,000	---	4/3	---	---	---	4/3	---	---	---	8/5
f) New Tanker Docks	---	1,050,000	---	14/14	---	---	---	---	---	---	---	14/14
Sub-Total SPR Facilities - West Columbia Dome -	39.7	1,700,370	62,640	18/17	149/112	153/115	30/30	4/3	1/1	142/0	8	437/277
Early Storage Facilities at Bryan Mound	10.4	94,600	665,000	74/69	---	43/33	---	33/26	---	---	1	150/128
Total Land Requirements Early Storage plus SPR at West Columbia Dome	50.1	1,794,970	727,640	92/86	149/112	196/148	30/30	37/29	1/1	142/0	9	647/416.
Alternatives to Proposed Systems												
1) Brine Disposal (Wells)												
a) Pipeline Excavations	3.2	19,000	---	Follows Proposed DOE Right-of-Way								
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	Minimal	---	17/17	2/2	---	---	---	---	---	19/19
2) Brine Disposal to G.O.M. 12.5 mi diffuser	14.2	274,600	---	---	---	20/14	---	.2/.1	1/.5	305/0		326/15
3) Raw Water (Brazos River)	3.0	16,200	---	---	34/25	4/3	---	---	---	1/0	1	39/28
4) Raw Water (Groundwater Supply Wells)												
a) Pipeline Excavation	5.9	31,200	---	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	Minimal	---	19/19	3/3	---	---	---	---	---	22/22

[a]Construction Right-of-Way/Maintenance Right-of-Way

3 acres for backup wellpads. The oil, brine and raw water pipelines to Seaway Tank Farm would require 210 acres for maintenance. The pipeline connection to Brazos Harbor and the new tanker docks would use 20 acres.

A.5.4.2 Alternative Physical Facilities

Raw Water System

An alternative raw water supply system would draw ground water from a well field in the immediate site vicinity. Present ground water use in the area is not extensive. The town of West Columbia pumps water from the lower unit of the Chicot aquifer at the (1967) rate of about 0.3 mgd (Sandeen and Wesselman, 1973). Land subsidence and lowering of the ground water table caused by the withdrawal of ground water at the required rates would have to be considered in the final design of the well field.

A second alternative raw water system would be to withdraw surface water from the Brazos River, near East Columbia. The water would have to be purchased from the Lower Brazos River Authority. Other commitments of the water from the Brazos would limit the availability of water to the project during low flows and DOE storage project time limitations would not be amenable to water supply interruptions.

Brine Disposal System

Deep well injection of all brine produced by leaching the cavities at West Columbia dome would require nineteen 1000-gallon per minute disposal wells, in addition to the three backup injection wells discussed previously. These 22 wells could handle the maximum brine production rate during cavity leaching with some backup capacity. Additional brine injection pumps would be required for these wells. An alternative brine diffuser 12.5 miles into the Gulf is described in Section A.3.4.1.

Power System

Onsite power generation requirements are projected to be about 45,000 horsepower. The gas turbine generators would be housed near the transformer area. A fuel oil storage tank holding a four-day supply (8500 bbl) and a 100-foot exhaust stack would be built onsite.

A.5.5 Construction Techniques

A.5.5.1 Storage Cavern Construction

Construction of wells and storage caverns would proceed generally as outlined in Section A.2.2.1, wherein standard industry techniques and practices are followed. To meet oil fill schedule requirements, oil may be stored by either a Leach-Then-Fill or Leach/Fill schedule, as described in Section A.2.2.

A.5.5.2 Road Construction and Other Grading

Roadway/pipeline alleys will be constructed between the plant area and each storage well. Where they cross marshy soils, filling would be required. Drill pads would also require filling in marshy areas. General procedures for filling and grading are in Section A.2.3.

A.5.5.3 Pipelines

The conventional lay method (Section A.2.2.4.3) would be used for pipeline construction, however the push ditch method may be required for the brine and raw water pipelines between SEAWAY Tank Farm and Bryan Mound, and the techniques described in Sections A.2.2.4.4, A.2.2.4.5, and A.2.2.4.6 would be required for river, levee, and highway crossings, respectively. Conventional offshore pipeline construction methods would be used for the brine pipeline and diffuser in the Gulf (Sections A.2.2.4.7 and A.2.2.4.8).

A.5.6 Development Timetable

Development of the West Columbia dome site would essentially follow the same timetable as for Bryan Mound. The timetable for Bryan Mound (Figure A.2-7) thus applies to this site. All pipeline construction would take place concurrently with site construction.

A.5.7 Operation and Maintenance

A.5.7.1 General Safety Precautions

General safety precautions described in Section A.3.7.1 are directly applicable to the West Columbia site.

A.5.7.2 Storage Phase

Operation and maintenance procedures for the storage phase are described in Section A.3.7.2.

A.5.7.3 Extraction Phases

Operation and maintenance procedures for the extraction phase are described in Section A.3.7.3.

A.5.7.4 Refill Phase

Operation and maintenance procedures for the refill phase are described in Section A.3.7.4.

A.5.8 Termination and Abandonment

Termination and abandonment of the West Columbia dome would be the same as that described in Section A.3.8 for Bryan Mound.

A.6 DAMON MOUND ALTERNATIVE SITE

The Damon Mound dome facility is designed for storage of 100 MMB of crude oil. Solution mining and subsequent fill operations to reach this storage capacity would be accomplished approximately 5 years after start of construction of facilities at Damon Mound, the docks in Freeport and Brazos Harbors, and the pipelines to Bryan Mound.

The Damon Mound dome was chosen as a candidate site due to its proximity to SEAWAY Tank Farm, Bryan Mound, and the Freeport Harbor docking facilities. Crude oil arriving at Freeport docks may be delivered to surge tanks at Bryan Mound and then to the pipeline connecting to Damon Mound dome. From the storage site, crude oil can be piped to the SEAWAY Pipeline at the SEAWAY Tank Farm or to the Freeport Harbor docks through the Bryan Mound early storage facilities.

A.6.1 Location

The Damon Mound dome is in western Brazoria County, Texas, within a mile of the Brazoria-Fort Bend County boundary. The small town of Damon (estimated population 750) overlies a portion of the mound on the east. The Brazos River, which passes 9 miles east of the dome, ranges from 100 to 200 feet in width and the San Bernard River, almost 50 feet wide, comes within 4.2 miles of the dome. The dome is 36 miles from the Gulf coast. SEAWAY Tank Farm is 32 miles southeast (Figure A.6-1).

A.6.1.1 Site Access

Access to the dome and SEAWAY Pipeline right-of-way is very good. State Highway 36 lies adjacent to the east and there are several county maintained, paved and surfaced roads over the dome. All roads are suitable for use in development of the project with very little maintenance required. The only new construction required would be from existing roads up to the pump station building and to each of the individual cavern wells.

A.6.1.2 Site Description

Damon Mound is clearly defined, rising approximately 80 feet above the surrounding ground. The land overlying the dome is used primarily for cattle grazing, a small limestone quarry is located just west of the site and there is some oil or gas production around the dome.

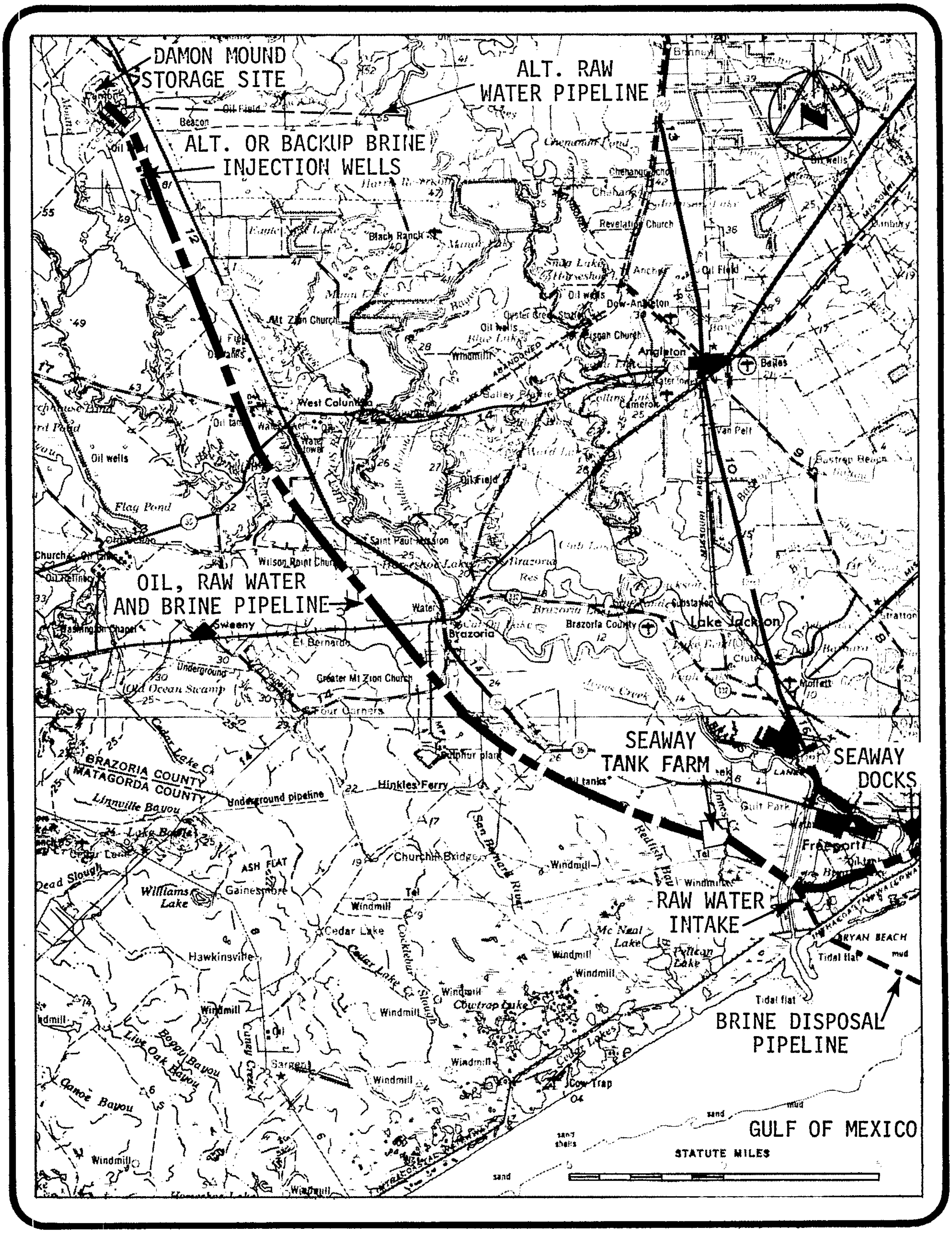


FIGURE A.6-1 Pipeline route map - Damon Mound dome candidate SPR storage site (alternative site).

Approximately 1,500 surface acres are within the -2000 foot salt contour (Figure A.6-2). The south and southeast sides of the dome have some tree cover; the facility location, however, is on the northern third of the dome where no clearing will be required.

A.6.2 Capacity

Proposed capacity for the site is 100-million barrels of crude oil stored in 10 to 12 solution mined cavities.

Utilizing all available acreage, less that occupied by the town of Damon, the dome has a potential for approximately 40 ten million barrel caverns.

A.6.3 General System Description

A.6.3.1 Proposed Systems

Development of Damon Mound would require use of the raw water intake, four 200,000 bbl surge tanks and crude oil distribution system components built for the early storage phase at Bryan Mound. Construction of new docks at Freeport Harbor and Brazos Harbor; raw water and brine disposal pipelines connecting Damon Mound to Bryan Mound; crude oil pipelines connecting SEAWAY Tank Farm and Damon Mound; a brine disposal system and the construction of the site facilities at Damon Mound will be required to develop the site.

The physical plant proposed at Damon Mound facility consists of up to 12 new solution mined storage cavities with crude oil, raw water and brine pipeline connections to the central pumping and control areas, a crude oil distribution system, a raw water supply system, brine disposal system and a power system provided by an onsite generator.

Raw water for leaching the cavities would be pumped to the Damon Mound storage site from the Brazos River Diversion Channel intake structure which was built for the early storage phase at Bryan Mound. Displaced brine from the leached cavities would pass through a brine pit and be disposed of by a pipeline to Bryan Mound and then to the brine diffuser 5.8 miles offshore in the Gulf of Mexico. Crude oil would be piped from the new dock facilities in Freeport Harbor through the bi-directional early storage crude oil pipeline to Bryan Mound and from

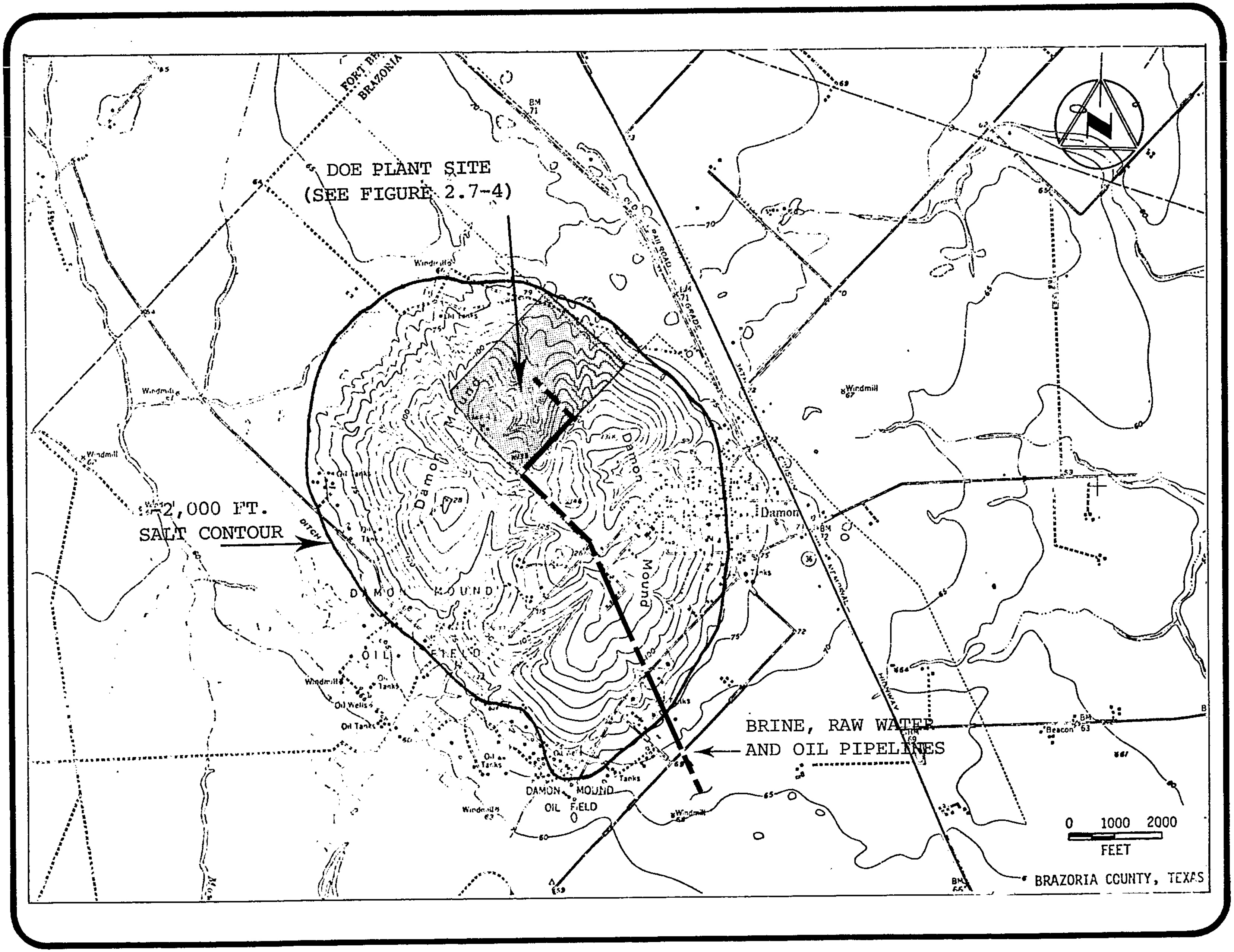


FIGURE A.6-2 Vicinity map - Damon Mound dome candidate SPR storage site (alternative site).

Bryan Mound to the SEAWAY Tank Farm, where it would connect with the new DOE pipeline to the Damon Mound storage caverns. As oil is injected into storage caverns, brine would be simultaneously displaced. During crude oil withdrawal, raw water would be injected to displace crude oil. Oil would return through the DOE pipeline to SEAWAY Tank Farm, where it would connect to the SEAWAY Pipeline to inland refineries, or to the bi-directional early storage pipeline to Bryan Mound and Freeport Harbor tankers, for delivery to Gulf of Mexico, East Coast or Caribbean ports.

A.6.3.2 Alternative Systems

Alternatives to use of the docks at Freeport are the construction of a Single Anchor-Leg Mooring (SPM) Monobuoy in deep water offshore; conversion of an existing SEAWAY Dock in Brazos Harbor; and use of Phillips Petroleum Company docks.

Two alternative raw water supply systems are possible: surface water from the Brazos River east of the site, and ground water from the Evangeline aquifer. Deep wells spaced along the common pipeline right-of-way between Damon Mound and SEAWAY Tank Farm could provide an alternative to the proposed brine disposal system. Another brine disposal alternative would be a diffuser located 12.5 miles offshore in the Gulf of Mexico. A possible alternative to onsite power generation could be to purchase commercial power.

A.6.4 Site Development

A.6.4.1 Proposed Physical Facilities

Introduction

A typical layout of surface facilities at the Damon Mound storage site, shown in Figure A.6-3, includes the storage cavity wells, plant area, road and pipeline alleys and the security fence.

Storage Cavity System

Twelve storage cavity wells, shown on the site map (Figure A.6-3), reflect the estimate that 20 percent of the wells may encounter problems that would reduce their capacity from the planned 10 MMB to 5 MMB. Thus, twelve cavities would still meet the required 100 MMB capacity at the Damon Mound site.

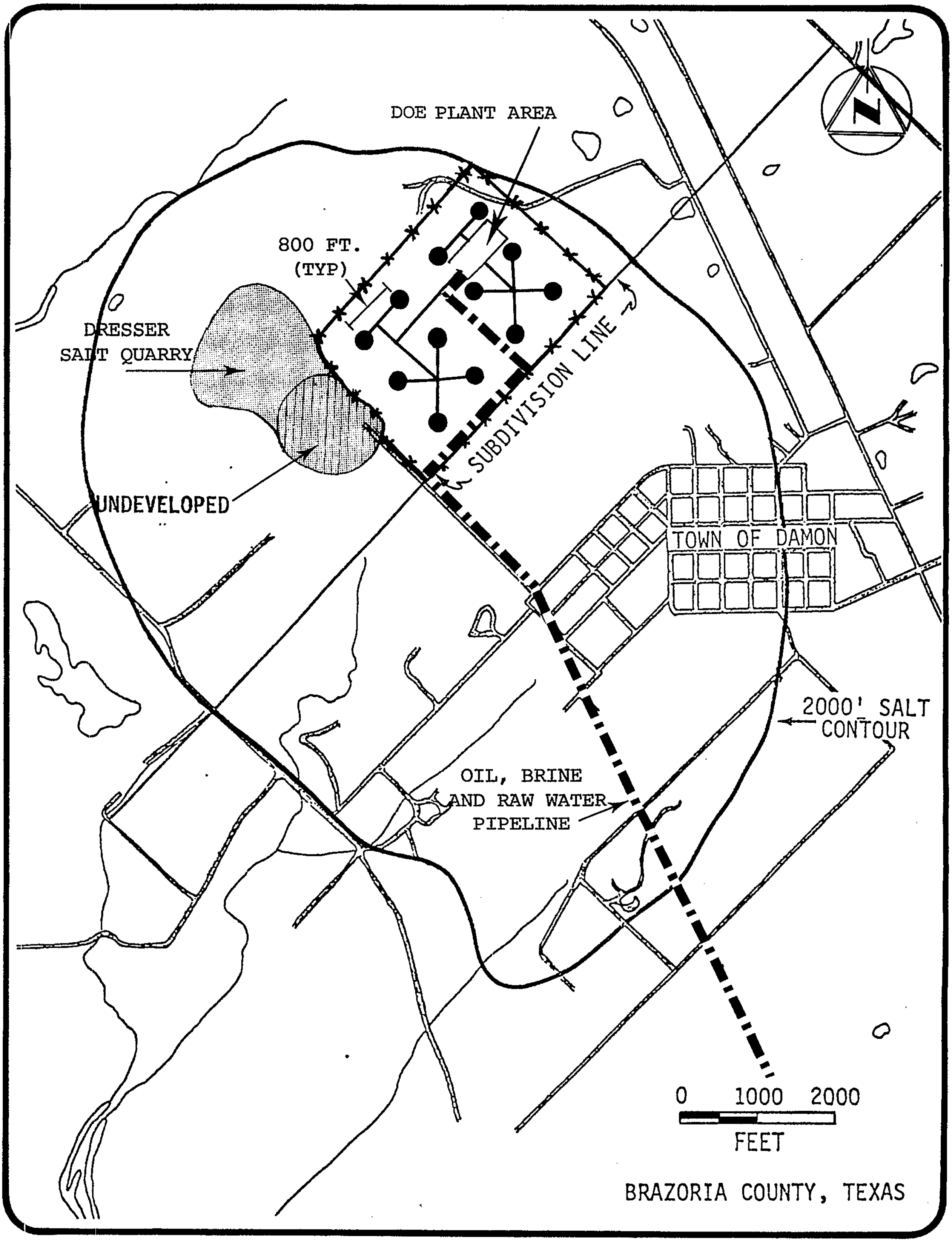


FIGURE A.6-3 Site map - Damon Mound dome candidate SPR storage site (alternative site).

The cavities would be leached in the 1500 to 2500 foot depth interval. Each cavern is expected to be about 1000 feet high and 300 feet in diameter after completion. If the crude oil is withdrawn five times in response to import interruptions, the ultimate diameter would be about 400 feet. The layout in Figure A.6-3 places caverns on 800-foot centers and a minimum of 600 feet from the dome edge, thus providing a 400-foot wall around every cavern.

Plant Area

Site grading would involve less than 15 percent of the total 232 acres dedicated to the storage site (Table A.6-1). Little fill should be required. Roads and pipelines would service each storage well, with a 20-foot wide alley. Safety dikes to contain spilled oil would be constructed around each oil storage tank and wellhead.

The plant area, similar to Allen dome (Figure A.4-4) would contain a control building and a pump house of steel construction, a blanket oil tank, a raw water tank for priming the raw water injection pumps, a transformer and generator area, and a lined brine pit.

Crude Oil Distribution

Crude oil would be piped from the new dock facilities in Freeport Harbor to the surge tanks at Bryan Mound through the early storage phase bi-directional pipeline. The surge tanks would supply crude oil to the early storage bi-directional pipeline as far as the SEAWAY Tank Farm where it would be delivered to a new 32 mile DOE pipeline to Damon Mound. Crude oil stored at Damon Mound storage facility would be piped through the DOE pipeline to the SEAWAY Tank Farm. From there, it would be piped either through the SEAWAY Pipeline to inland refineries or to the surge tanks at Bryan Mound and then into tankers at Freeport Harbor for delivery to East Coast, Gulf Coast or Caribbean refineries.

Raw Water System

The early storage intake structure on the Brazos River Diversion Channel would be used to pump raw water to a new DOE pipeline from Bryan Mound to Damon Mound storage site along the DOE right-of-way, adjacent to the SEAWAY Pipeline right-of-way.

TABLE A.6-1 Land requirements - Damon Mound candidate SPR storage site (alternative site).

	Total Miles Pipeline Row	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres) Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]	Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
A. SPR Facilities											
1) Storage Site											
a) Central Plant Area	---	---	Minimal	---	---	10/10	---	---	---	---	10/10
b) Brine Surge Pond	---	---	Minimal	---	---	3/3	---	---	---	---	3/3
c) Plant Access Road	---	---	Minimal	---	---	5/5	---	---	---	---	5/5
d) Onsite Roads and Pipe Alleys	6.0	31,680	Minimal	---	---	---	---	---	---	---	---
e) Cavern Wellhead Pads	---	---	---	---	---	12/12	---	---	---	---	12/12
f) Containment Dikes at Cavern Wellheads	---	---	840	---	---	---	---	---	---	---	---
2) Offsite											
a) Backup Brine Injection Wells	Follows Proposed DOE Right-of-Way										
1) Pipeline Excavation	2.9	15,280	---	---	---	---	---	---	---	---	---
2) Roadways to Wellheads	---	---	min. fill	---	---	---	---	---	---	---	---
3) Wellhead Pads	---	---	Minimal	---	---	3/3	---	---	---	13	3/3
b) Oil, Brine and Raw Water Pipelines to Seaway Tank Farm	32.3	511,632	---	5/4	182/136	210/158	---	---	---	---	397/298
c) Brine and Raw Water Pipelines to Bryan Mound	4.1	54,800	---	Follows Proposed DOE Right-of-Way							
d) Brine Disposal to 5.8 mi diffuser	7.5	177,300	---	---	---	20/14	.2/.1	1/.5	142/0	2	163/15
e) Pipeline Connection to Brazos Harbor	0.6	6,000	---	4/3	---	---	4/3	---	---	---	8/6
f) New Tanker Docks	---	1,050,000	---	14/14	---	---	---	---	---	---	14/14
Sub-Total SPR Facilities - - Damon Mound -	53.4	1,846,692	840	23/21	182/136	263/205	4/3	1/1	142/0	15	615/366
B. Early Storage Facilities at Bryan Mound	10.4	94,600	665,000	74/69	---	43/33	33/26	---	---	1	150/128
Total Land Requirements Early Storage plus SPR at Damon Mound	63.8	1,941,292	665,840	97/90	182/136	306/238	27/29	1/1	142/0	16	765/494
C. Alternatives to Proposed Systems											
1) Brine Disposal (Wells)	Follows Proposed DOE Right-of-Way										
a) Pipeline Excavation	3.2	17,000	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	Minimal	---	---	19/19	---	---	---	---	19/19
2) Brine Disposal to 12.5 mi diffuser	14.2	274,600	---	---	---	20/14	.2/.1	1/.6	305/0		326/15
3) Raw Water (Brazos River)	10.0	52,940	---	---	4/3	115/86	---	---	3/3	4	122/92
4) Raw Water (Groundwater Supply Wells)	Follows Proposed DOE Right-of-Way										
a) Pipeline Excavation	6.1	32,280	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	---	---	---	22/22	---	---	---	---	22/22

[a]Construction Right-of-Way/Maintenance Right-of-Way

Brine Disposal System

Brine displaced from the Damon Mound storage cavities would enter a brine pit on the site, and then would be piped through the new brine disposal pipeline along the DOE and SEAWAY Pipeline right-of-way to Bryan Mound, where it would connect to the new pipeline from Bryan Mound to the brine diffuser 5.8 miles in the Gulf of Mexico. Backup brine disposal wells would be built along the common pipeline right-of-way.

Raw water injection rates, brine production rates and crude oil distribution rates are the same as those addressed in Section A.4 for construction and operation of the Allen dome site.

Power System

Generating capacity at Damon Mound would consist of 45,000 HP of gas turbine generator capacity. Storage of a four-day fuel supply to run these generators would require an 8500 bbl fuel tank onsite. Fuel would be trucked into the site. A 100-foot exhaust stack would be required.

Land Requirements

The total land required for the Damon Mound storage site and associated facilities would be approximately 366 acres. An additional 249 acres would be used during construction activities then allowed to return to other uses. The storage site would be located within a fenced 232 acre area immediately overlying the dome. Only approximately 13% of the area would hold SPR facilities. The land requirements for each of the facility's systems is summarized in Table A.6-1.

The central plant area, wellheads and associated roads and pipelines would require 30 acres at Damon Mound. The brine disposal system would use 18 acres, 15 for the pipeline alley from Bryan Mound to the Gulf and 3 acres for wellhead/pads for the backup injection wells. Approximately 298 acres would be required for maintenance of the oil, brine and raw water pipelines to Bryan Mound. The pipeline connection to Brazos Harbor would use 6 acres and the new tanker docks would use 14 acres.

A.6.4.2 Alternative Physical Facilities

Raw Water System

Sources of alternative supplies of raw water to leach the cavities have previously been discussed. It would be logical to pump surface water from the Brazos River near the Damon Mound site, instead of pumping it a further distance from the Brazos River Diversion Channel. However, water rights in the river near Damon Mound are under the jurisdiction of the Lower Brazos River Authority which may not be able to meet the water supply requirements of the Damon Mound facility.

Ground water would also be a possible source of raw water, however, withdrawing large quantities of ground water in this area could cause land subsidence and low ground water levels.

Brine Disposal System

Deep well injection of all brine produced by leaching the cavities at Damon Mound would require nineteen 1000-gallon per minute disposal wells in addition to the three backup injection wells discussed previously. These 22 wells could handle the maximum production rate during cavity leaching with some backup capacity. Additional brine injection pumps would be required for these wells. Use of a 12.5 mile offshore diffuser system would require 6.7 additional miles of offshore pipeline construction.

Power System

Purchase of power from a utility would require construction of a power transmission line from the nearest Houston Lighting and Power substation, but would eliminate the need for the generating equipment and fuel tankage on the site. Standby charges for the facility may be substantial, because of the large load which may periodically be required.

A.6.5 Construction Techniques

A.6.5.1 Storage Cavern Construction

General techniques of constructing the storage caverns in the salt dome are discussed in Section A.2.2.1. Standard industry techniques and practices would be used. To meet oil fill schedule requirements, oil may be stored by either a Leach-Then-Fill or Leach/Fill schedule, as described in Section A.2.2.

A.6.5.2 Road Construction and Other Grading

Roadway/pipeline alleys would be constructed between the plant area and each storage well. General procedures are described in Section A.2.3.

A.6.5.3 Pipelines

The conventional lay method (Section A.2.2.4.1) would primarily be used for pipeline construction, however the push ditch method (Section A.2.2.4.2) may be required for the brine and raw water pipelines between SEAWAY Tank Farm and Bryan Mound, and the techniques described in Sections A.2.2.4.4, A.2.2.4.5, and A.2.2.4.6 would be required for river, levee, and highway crossings, respectively. Conventional offshore pipeline construction methods would be used for the brine pipeline and diffuser in the Gulf (Sections A.2.2.4.7 and A.2.2.4.8).

A.6.6 Development Timetable

Development of the Damon Mound site would follow essentially the same timetable as Bryan Mound. Figure A.2-7 shows the relationship of solution mining to filling. All pipeline construction would take place concurrently with site construction.

A.6.7 Operation and Maintenance

A.6.7.1 General Safety Precautions

General safety precautions described in section A.3.7.1 are directly applicable to the Damon Mound site.

A.6.7.2 Storage Phase

Storage phase operations and maintenance procedures are described in Section A.3.7.2.

A.6.7.3 Extraction Phase

Operation and maintenance procedures for the extraction phase are described in A.3.7.3.

A.6.7.4 Refill Phase

Operation and maintenance procedures for the refill phase are described in A.3.7.4.

A.6.8 Termination and Abandonment

Termination and abandonment of the Damon Mound dome site would be the same as that described in Section A.3.8.

A.7 NASH DOME ALTERNATIVE SITE

The Nash dome facility is planned for storage of 100 MMB of crude oil. Solution mining and subsequent fill operations to reach this storage capacity would take approximately 5 years after start of construction of facilities at Nash dome, the docks in Freeport and Brazos Harbors, and the pipelines to Bryan Mound.

The Nash dome was chosen as a candidate site due to its proximity to SEAWAY Tank Farm, Bryan Mound, and the Freeport Harbor docking facilities. Crude oil arriving at Feeport docks may be delivered to surge tanks at Bryan Mound and then to the pipeline connecting to Nash dome. From the storage site, crude oil can be piped to the SEAWAY Pipeline at the SEAWAY Tank Farm or to the Freeport Harbor docks through Bryan Mound.

A.7.1 Location

Nash dome is located in southern Fort Bend County, extending into the northern end of Brazoria County, Texas. The town of Richmond lies approximately 25 miles north, and Houston is approximately 35 miles northeast of the site. The Brazos River lies approximately 6 miles east of the dome, the Gulf of Mexico is 36 miles to the south, and Cow Creek borders the dome on the south.

A.7.1.1 Site Access

Since there are existing roads providing suitable access to the site, the only new road construction anticipated would be access roads to the plant area and individual well locations. The site is located 32 miles northwest of the SEAWAY Tank Farm, providing good access for oil distribution (Figure A.7-1).

A.7.1.2 Site Description

The Nash Dome encompasses 600 surface acres within the -2000 foot salt contour (Figure A.7-2). There is no surface expression of the salt dome. There are trees on the southern reaches of the dome, but since the facility area on the northern end has been cultivated, land clearing will not be necessary. Three farmsteads are within the site boundaries and would have to be displaced.

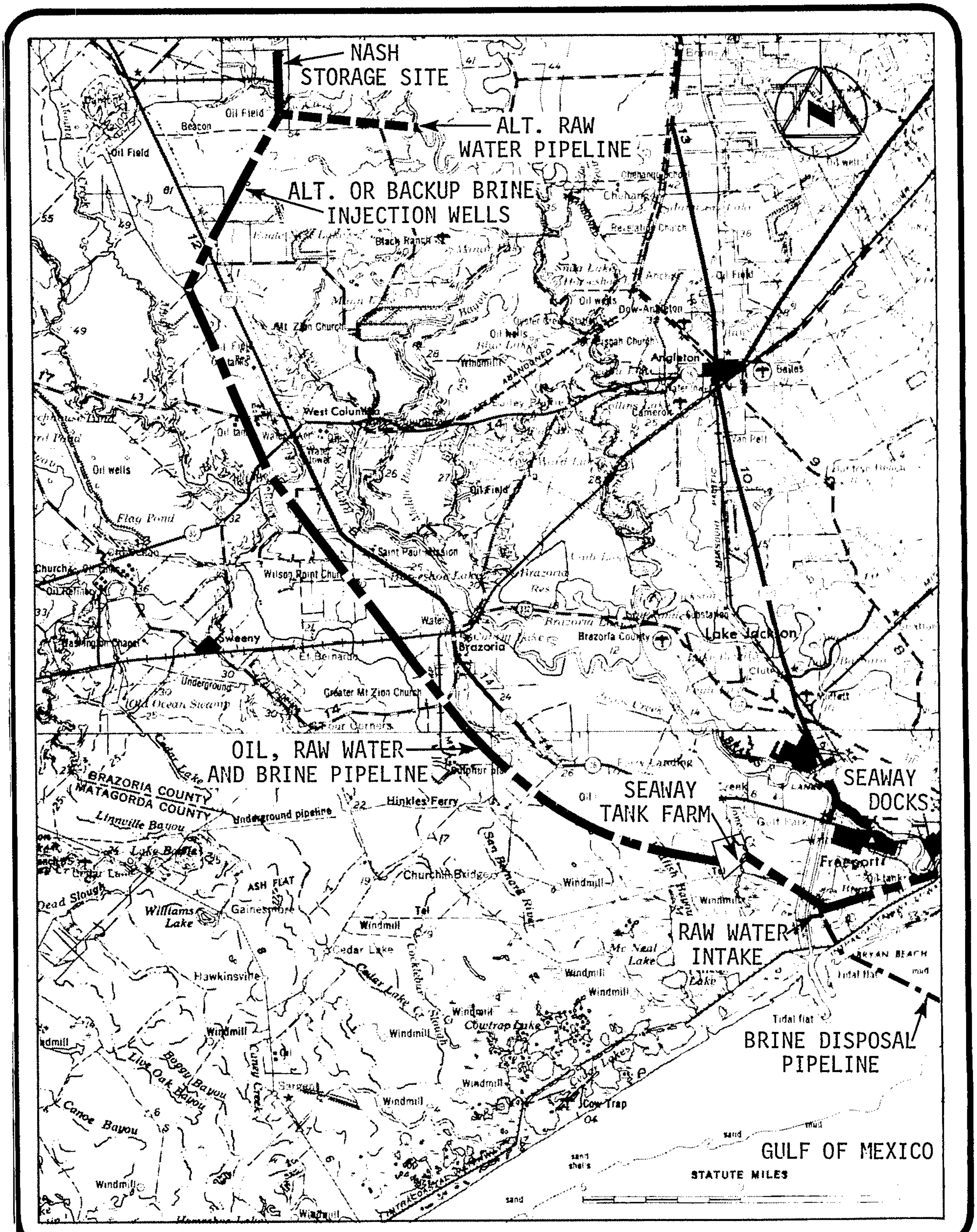


FIGURE A.7-1 Pipeline route map - Nash dome candidate SPR storage site (alternative site).

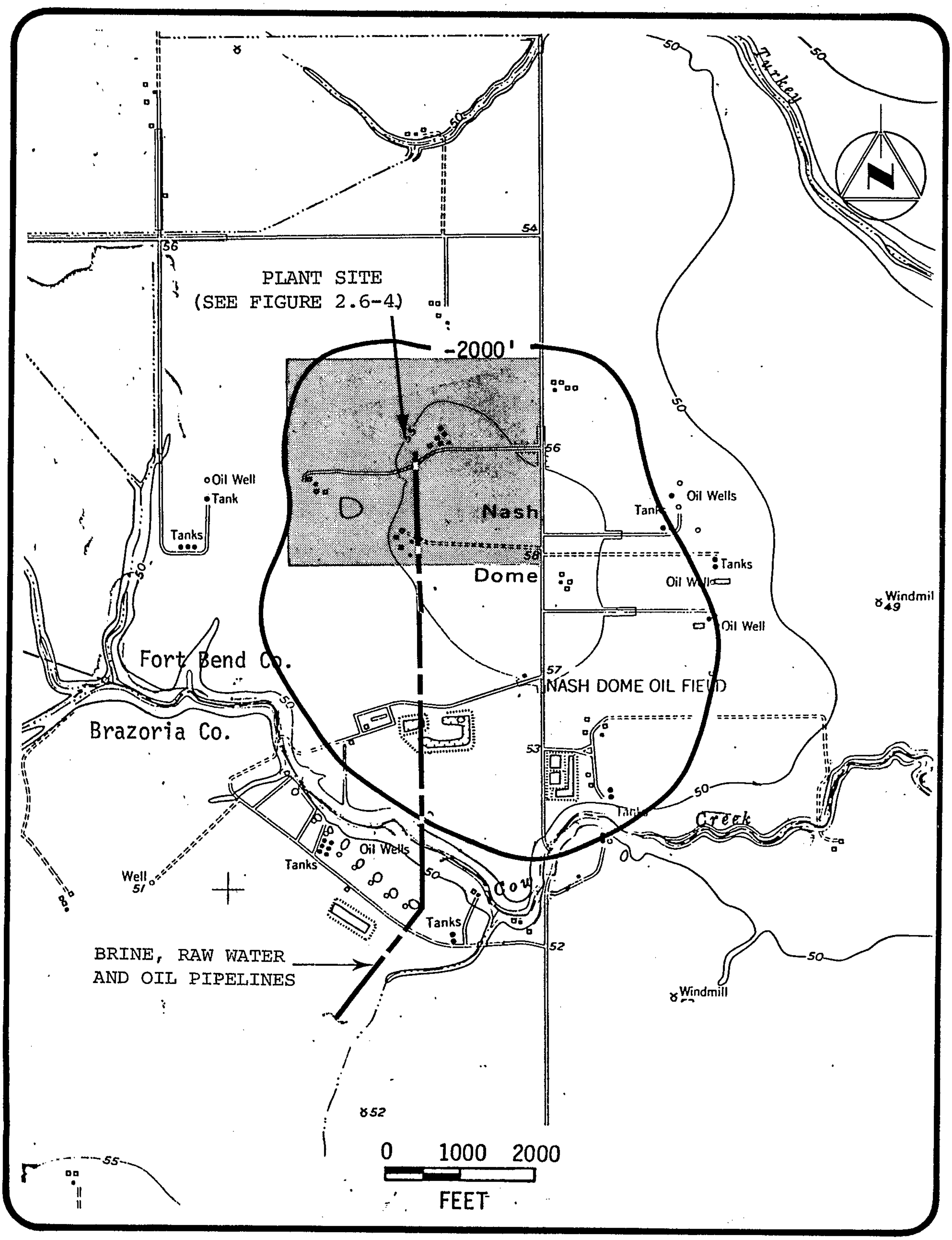


FIGURE A.7-2 Vicinity map - Nash dome candidate SPR storage site (alternative site).

Oil production has been established around the dome, and some sulfur has been mined on a 50 acre tract in the southwest corner of the dome.

A.7.2 Capacity

Proposed capacity for the site is 100 MMB of crude oil stored in ten to twelve solution mined cavities. The dome has an ultimate development potential for approximately thirty 10 MMB caverns.

A.7.3 General System Description

A.7.3.1 Proposed Systems

Development of Nash dome would include use of the raw water intake, four 200,000 bbl surge tanks and crude oil distribution system components built for the early storage phase at Bryan Mound. Construction of new docks at Freeport Harbor and Brazos Harbor; raw water and brine disposal pipelines connecting Nash dome to Bryan Mound; crude oil pipelines connecting SEAWAY Tank Farm and Nash dome; the brine diffuser system; and the site facilities at Nash dome would be required to complete development of this site.

The physical plant proposed at Nash dome facility consists of 12 new solution mined storage cavities with crude oil, raw water and brine pipeline connections to the central pumping and control areas, a crude oil distribution system, a raw water supply system, a brine disposal system and a power system provided by an onsite generator.

Raw water for leaching the cavities would be piped to the Nash dome storage site from the Brazos River Diversion Channel intake structure constructed as part of the early storage phase at facilities at Bryan Mound. Displaced brine from the leached cavities would pass through a brine pit and be disposed of by a pipeline to Bryan Mound, and then to the brine diffuser in the Gulf of Mexico. Crude oil would be piped from the new dock facilities in Freeport Harbor through the bidirectional early storage crude oil pipeline to Bryan Mound and from Bryan Mound to the SEAWAY Tank Farm, where it would connect with the new DOE pipeline to the Nash dome storage caverns. As oil is injected into storage caverns, brine is simultaneously displaced. During withdrawal, raw water would be injected to displace crude oil. Oil would return through the DOE pipeline to SEAWAY Tank Farm, where it would connect to the SEAWAY Pipeline for inland refineries, or to the bi-directional early storage pipeline to Bryan Mound and Freeport Harbor tankers, for delivery to Gulf Coast, East Coast or Caribbean ports.

A.7.3.2 Alternative Systems

Alternatives to use of the docks at Freeport are the construction of a Single Anchor-Leg Mooring (SPM) monobuoy in deep water offshore; conversion of an existing SEAWAY dock in Brazos Harbor; and use of Phillips Petroleum Company docks.

Two alternative raw water supply systems are possible: surface water from the Brazos River east of the site, and ground water from the Evangeline aquifer. Deep wells, spaced along the common pipeline right-of-way between Nash dome and SEAWAY Tank Farm, could provide an alternative to the proposed brine disposal system. An alternative brine diffuser system 12.5 miles offshore from Bryan Mound could be constructed. A possible alternative to onsite power generation would be to purchase power from Houston Lighting and Power Company.

A.7.4 Site Development

A.7.4.1 Proposed Physical Facilities

Introduction

A typical layout of surface facilities at the Nash dome storage site, shown in Figure A.7-3, includes the storage cavity wells, plant area, road and pipeline alleys and the security fence.

Storage Cavity System

Twelve storage cavity wells, shown on the site map (Figure A.7-3), reflect the estimate that 20 percent of the wells will encounter problems that will reduce their capacity from the planned 10 MMB to 5 MMB. Thus, 12 cavities would still meet the required 100 MMB capacity at the Nash dome site.

The cavities would be leached in the 1500 to 2500 foot depth interval. Each cavern is expected to be about 1000 feet high and 300 feet in diameter after completion. If the crude oil is withdrawn five

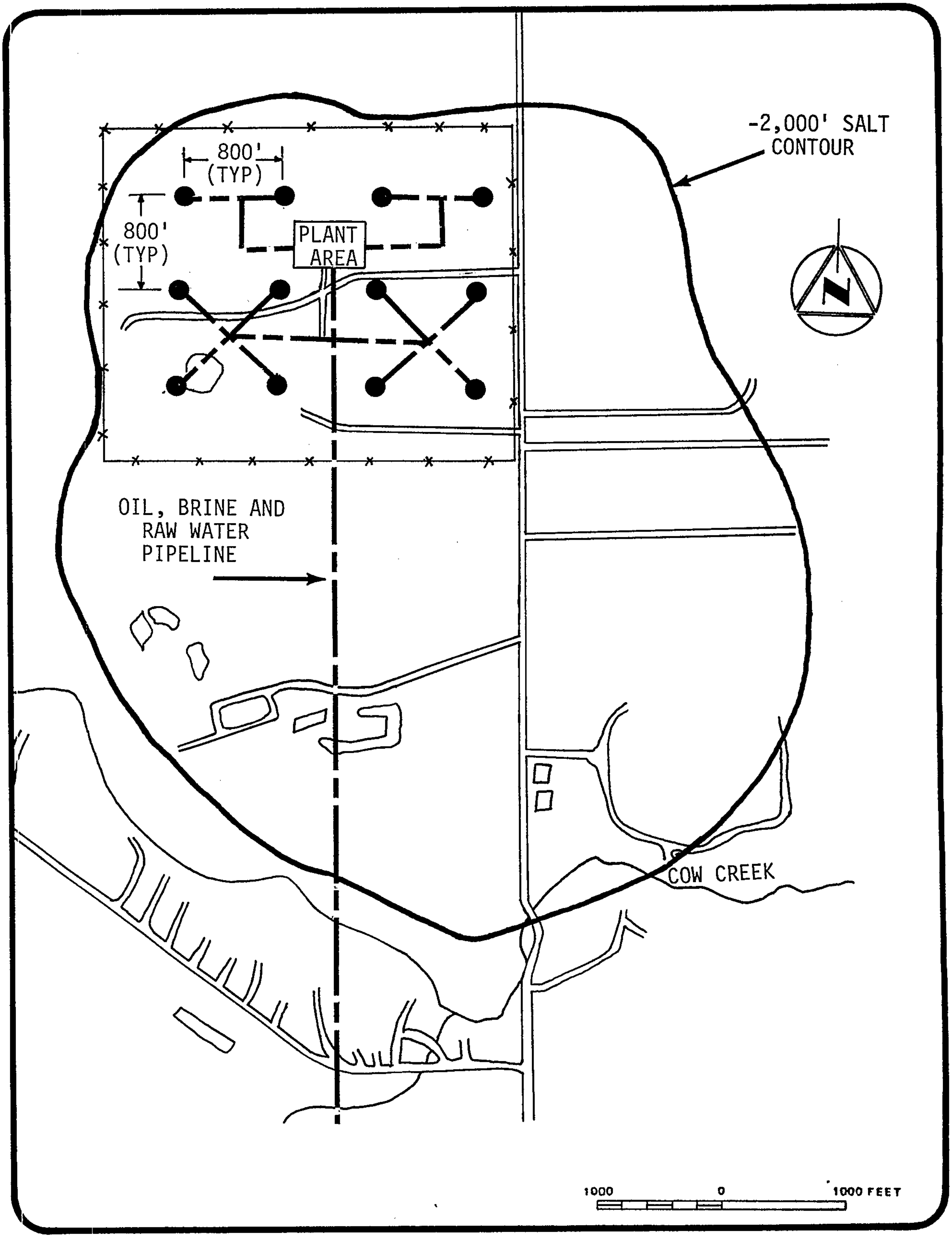


FIGURE A.7-3 Site map - Nash dome candidate SPR storage site (alternative site).

times in response to import interruptions, the ultimate diameter would be about 400 feet. The layout in Figure A.7-3 places caverns on 800-foot centers and a minimum of 600 feet from the dome edge, thus providing a 400-foot wall around every cavern.

Plant Area

The plant area layout is the same as shown for Allen dome site (Figure A.4-4), including pump and control buildings, a blanket oil tank, a brine surge pond, and a raw water storage tank for priming the raw water injection pumps. A combustion turbine generator and associated oil fuel tank and 100-foot exhaust stack would also be required.

Grading of less than 15 percent of the land within the security fence is anticipated (Table A.7-1). Little fill should be required, except for retention dikes around oil storage tanks and each wellhead. Onsite pipelines would be buried.

Crude Oil Distribution

Crude oil would be piped from the new dock facilities in Freeport Harbor to the surge tanks at Bryan Mound through the early storage phase bi-directional pipeline. The surge tanks would supply crude oil to the early storage bi-directional pipeline as far as the SEAWAY Tank Farm where it would be delivered to a new 33-mile DOE pipeline to Nash dome. As crude oil is withdrawn from Nash dome storage facility it would be piped through the SEAWAY Pipeline to inland refineries or to the surge tanks at Bryan Mound and then into tankers at Freeport Harbor for delivery to East Coast, Gulf Coast or Caribbean refineries.

Raw Water System

The early storage intake structure on the Brazos River Diversion Channel would be used to pump raw water to a new DOE pipeline from Bryan Mound to Nash dome storage site along the DOE right-of-way adjacent to SEAWAY Pipeline right-of-way.

Brine Disposal System

Brine displaced from the Nash storage cavities would enter a brine pit on the Nash site, and then would be piped through the new brine disposal pipeline along the DOE and SEAWAY Pipeline right-of-way to

TABLE A.7-1 Land requirements - Nash dome candidate SPR storage site (alternative site).

	Total Miles Pipeline ROW	Excavation (c.y.)	Fill (c.y.)	Required Right-of-Way and Affected Habitat (Acres) Cleared Land Constr/Maint[a]	Fluvial and Oak Woodlands Constr/Maint[a]	Coastal Prairies Constr/Maint[a]	Brackish to Freshwater Marsh Constr/Maint[a]	Shell Ramp Barrier Flat Constr/Maint[a]	Coastal and Inland Waters Constr/Maint[a]	Number of Water Crossings	Total Acreage Impacted Constr/Maint[a]
A. SPR Facilities											
1) Storage Site											
a) Central Plant Area	---	---	Minimal	10/10	---	---	---	---	---	---	10/10
b) Brine Surge Pond	---	---	Minimal	3/3	---	---	---	---	---	---	3/3
c) Plant Access Road	---	Minimal	---	---	---	---	---	---	---	---	---
d) Onsite Roads and Pipe Alleys	5.7	30,100	---	5/5	---	---	---	---	---	---	5/5
e) Cavern Wellhead Pads	---	---	---	12/12	---	---	---	---	---	---	12/12
f) Containment Dikes at Cavern Wellheads	---	---	840	---	---	---	---	---	---	---	---
2) Offsite											
a) Backup Brine Injection Wells	Follows Proposed DOE Right-of-Way										
1) Pipeline Excavation	2.5	13,200	---	---	---	---	---	---	---	---	---
2) Roadways to Wellheads	---	Minimal	---	---	---	---	---	---	---	---	---
3) Wellhead Pads	---	---	---	---	---	3/3	---	---	---	14	3/3
b) Oil, Brine and Raw Water Pipelines to Seaway Tank Farm	32.6	517,180	---	---	210/158	219/165	---	---	---	---	429/323
c) Brine and Raw Water Pipelines to Bryan Mound	4.1	54,800	---	Follows Proposed DOE Right-of-Way							
d) Brine Disposal to 5.8 mi diffuser	7.5	177,300	---	---	---	20/14	.2/.1	1/.5	142/0	2	163/15
e) Pipeline Connections to Brazos Harbor	0.6	6,000	---	4/3	---	---	4/3	---	---	---	8/6
f) New Tanker Docks	---	1,050,000	---	14/14	---	---	---	---	---	---	14/14
Sub-Total SPR Facilities - Nash Dome -	53.0	1,848,580	840	48/47	210/158	242/182	4/3	1/1	142/0	16	647/391
B. Early Storage Facilities at Bryan Mound	10.4	94,600	665,000	74/69	---	43/33	33/26	---	---	1	150/128
Total Land Requirements- Early Storage plus SPR at Nash Dome	63.4	1,943,180	665,840	122/116	210/158	285/215	37/29	1/1	142/0	17	797/519
C. Alternatives to Proposed Systems											
1) Brine Disposal (Wells)	Follows Proposed DOE Right-of-Way										
a) Pipeline Excavation	3.2	17,000	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	Minimal	---	---	19/19	---	---	---	---	19/19
2) Brine Disposal to 12.5 mi diffuser	14.2	274,600	---	---	---	20/14	.2/.1	1/.5	305/0		326/0
3) Raw Water (Brazos River)	6.1	31,820	---	---	4/3	69/52	---	---	---	2	73/55
4) Raw Water (Groundwater Supply Wells)	Follows Proposed DOE Right-of-Way										
a) Pipeline Excavation	6.1	32,200	---	---	---	---	---	---	---	---	---
b) Roadways to Wellheads	---	---	Minimal	---	---	---	---	---	---	---	---
c) Wellhead Pads	---	---	---	---	---	22/22	---	---	---	---	22/22

[a]Construction Right-of-Way/Maintenance Right-of-Way

Bryan Mound, where it would connect to a pipeline from Bryan Mound to the brine diffuser 5.8 miles in the Gulf of Mexico. Three backup brine disposal wells would be located along the DOE and SEAWAY Pipeline right-of-way.

Raw water injection rates, brine production rates and crude oil distribution rates are the same as those addressed in Section A.4 for construction and operation of the Allen dome site.

Power System

A combustion turbine generator area, fuel tank, and 100-foot exhaust stack would be required for the 45,000 HP onsite power generator. The fuel tank would provide a minimum of four days fuel supply and would be constructed in accordance to API and ASME construction codes.

Land Requirements

Approximately 647 acres of land would be affected by the development of storage facilities at, or related to, the Nash Dome site. Only approximately 391 acres would be kept in a state of semi-permanent development for facilities operation and maintenance. The storage facilities at Nash would be located on a fenced 206 acre site only 13 percent of which would be directly developed. The land requirements for each of the systems associated with the Nash site and its alternatives are shown in Table A.7-1.

Approximately 30 acres would be in use at the storage site itself for plant area, wellheads, brine pond, etc. The brine, oil and raw water pipelines to the SEAWAY Tank Farm would require maintenance of approximately 323 acres along the pipeline right-of-way. The brine disposal system would use approximately 18 acres, 15 for the pipeline from Bryan Mound to the Gulf for the diffuser system, and 3 acres for the wellhead pads for the backup wells. The oil pipeline connection to Brazos Harbor and the new tanker docks would require 20 additional acres.

A.7.4.2 Alternative Physical Facilities

Construction of SEADOCK would eliminate the need for a new DOE dock adjacent to the existing SEAWAY Docks. Addition of tanker loading facilities to one of the existing SEAWAY Docks would be required. No additional filling or dredging would be required at the dock, but office and gauging areas would have to be constructed at the converted dock.

Raw Water System

Sources of alternative supplies of raw water to leach the cavities have previously been discussed. It would be logical to pump surface water from the Brazos River near the Nash dome, instead of pumping it a further distance from the Brazos River Diversion Cannel. However, water rights in the river near Nash dome are under the jurisdiction of the Lower Brazos River Authority, which may not be able to meet the water supply requirements of the Nash dome facility.

Ground water is also a possible source of raw water; however, withdrawing large quantities of ground water in this area could cause land subsidence and lower the water level in the aquifers to be pumped.

Brine Disposal System

Deep well injection of all brine produced by leaching the cavities at Nash dome would require nineteen 1000-gallon per minute disposal wells in addition to the three backup injection wells discussed previously. These 22 wells could handle the maximum brine production rate during cavity leaching with some backup capacity. Additional brine injection pumps would be required for these wells. Another alternative would require the extension of the brine diffuser pipeline 12.5 miles offshore Bryan Mound into the Gulf.

Power System

Power could be purchased from Houston Lighting and Power Company and supplied to the site by a 6-mile transmission line. Standby charges might, however, make this power source economically unfeasible.

A.7.5 Construction Techniques

A.7.5.1 Storage Cavern Construction

Construction of wells and storage caverns would follow the general procedures in Section A.2.2.1, where standard industry techniques and practices are used. To meet oil fill schedule requirements, oil may be stored by either a Leach-Then-Fill or Leach/Fill schedule, as described in Section A.2.2.

A.7.5.3 Road Construction and Other Grading

Roadway/pipeline alleys would be constructed between the plant area and each storage well. Safety dikes would be constructed around the blanket oil tank, small dikes would also be constructed around wellheads to contain small volumes of oil spilled during operation or maintenance.

Construction of site facilities, pipelines and drilling of wells for cavern development would precede initial leaching operations by three to four months. The maximum raw water supply rate would allow concurrent leaching of five caverns. Each cavern could be leached at a rate of 15,257 B/D of storage space created.

A.7.5.3 Pipelines

Conventional lay methods would be used for pipeline construction, as described in Section A.2.2.4 for the brine and raw water pipelines between SEAWAY Tank Farm and Bryan Mound, and the brine diffuser in the Gulf.

A.7.6 Development Timetable

Development of the Nash dome site would follow essentially the same timetable as Bryan Mound. Figure A.2-7 shows the relationship of solution mining to filling. The additional pipeline construction would be completed during construction of onsite facilities. All pipeline construction would take place concurrently with site construction.

A.7.7 Operation and Maintenance

A.7.7.1 General Safety Precautions

General safety precautions are described in Section A.3.7.1.

A.7.7.2 Storage Phase

Storage phase operations and maintenance procedures are described in Section A.3.7.2.

A.7.7.3 Extraction Phase

Operation and maintenance procedures for the extraction phase are described in Section A.3.7.3.

A.7.7.4 Refill Phase

Operation and maintenance procedures for the refill phase are described in Section A.3.7.4.

A.7.8 Termination and Abandonment

Termination and abandonment of the Nash dome site would be the same as that described in Section A.3.8.

APPENDIX B

DESCRIPTION OF THE EXISTING ENVIRONMENT

LIST OF FIGURES

LIST OF TABLES

APPENDIX B

DESCRIPTION OF THE ENVIRONMENT

B.1 INTRODUCTION

This chapter presents descriptions of the environment, both natural and manmade in the region of the proposed project and in the immediate vicinity of sites.

The regional environment, discussed in Section B.2, includes information on the "region" as this pertains to the specific disciplines discussed. For land features, the region can be considered to include the Gulf Coast of southeast Texas; for surface water, the region includes the Brazos and San Bernard River basins and the nearshore Gulf of Mexico; and for socioeconomics, the region is the four-county area including Brazoria, Fort Bend, Harris, and Galveston Counties.

In Section B.3, the environment of each of the five candidate sites -Bryan Mound, Allen dome, West Columbia dome, Damon Mound, and Nash dome -is presented. Because there are many environmental characteristics which are similar at two or more sites, the description of the proposed site, Bryan Mound, is most complete. The descriptions for the four alternative sites are more abbreviated and are cross-referenced to sections where similar site characteristics exist.

Aspects of the region and of the five sites which are of greatest significance with regard to impacts of the project (discussed in Appendix C) are summarized in Section B.4, and references cited are included in Section B.5. Additional physical, chemical and biological oceanographic data describing the region and the proposed sites from a supplemental study is included in Appendix G and referred to in the text.

B.2 REGIONAL ENVIRONMENT

B.2.1 Land Features

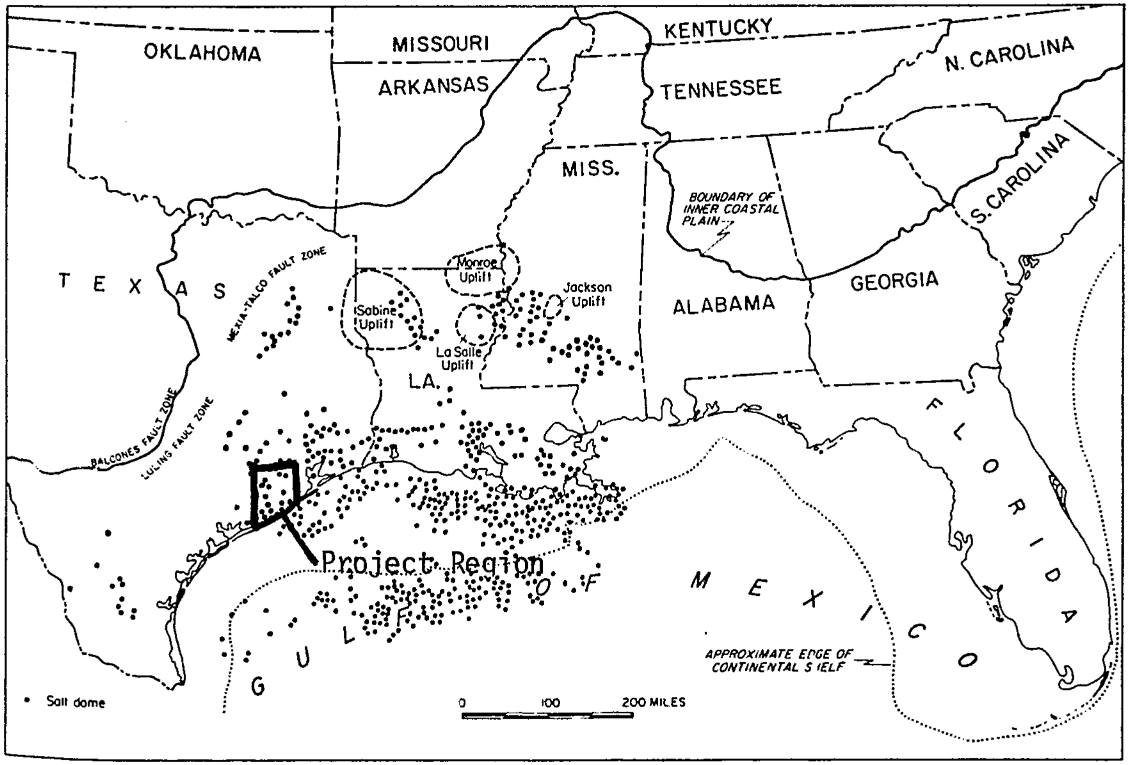
Physiography

The Seaway Group of SPR sites is situated in a region which includes the gulfward margin of the Gulf Coastal Plain and the nearshore Gulf Continental Shelf (Figure B.2-1). The Gulf Coastal Plain physiographic province is characterized as a relatively flat, featureless prairie terrace. Its poorly developed surface drainage is to the Gulf of Mexico. Marshes, swamps, and low gradient streams are common (Figure B.2-2), and natural levees are often found along the streams.

The Gulf Coastal Plain slopes almost imperceptibly toward the Gulf of Mexico; at an average rate of about 5 feet per mile. The major topographic relief in the region is associated with salt dome structures which have forcibly risen through younger sediments. Relief at Bryan Mound salt dome, for example, is on the order of 15 feet above the surrounding country, while at Damon Mound salt dome, the sediments rise 76 feet from the surrounding country to a maximum elevation of 146 feet above sea level.

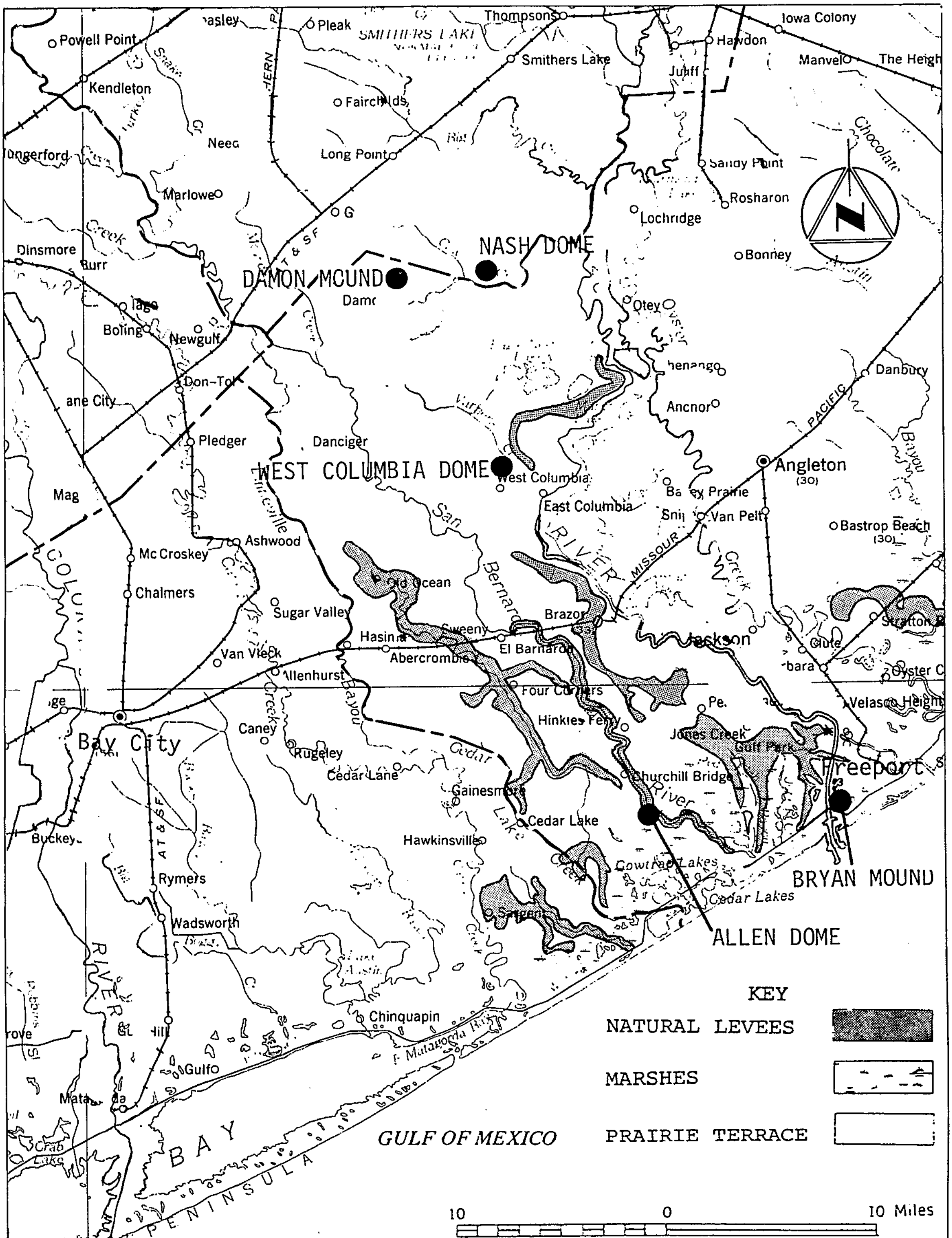
The coastal region in the vicinity of the Seaway Group of SPR sites is located between Christmas Bay and East Matagorda Bay (Figure B.2-2). It is unique for the Texas coast, because the barrier island chain is separated from the mainland by narrow, restricted bays which are almost filled by marshes. The broad, shallow bays characteristic of the rest of the Texas coast are absent here.

The offshore region in the vicinity of the Seaway Group is in the Gulf Continental Shelf physiographic province, the submerged extension of the Gulf Coastal Plain province. Offshore, the bathymetry is virtually featureless with the bottom sloping gently offshore to the 50 fathom depth where it falls off rapidly. Typical offshore depths and distances from shore are 30 feet at 2.5 miles, 60 feet at 6.5 miles and 90 feet at 19.5 miles. The bottom plain is occasionally broken by dredged channels and small shell ridges, artificial reefs and offshore platforms. Also, several coral heads are located off the mouth of the Brazos River Diversion



SOURCE: Thornbury, 1965.

FIGURE B.2-1 Coastal Plain and Continental Shelf of the Gulf Coast of the United States, showing distribution of known salt domes and uplifts



Source - Bureau of Economic Geology, Universtiy of Texas, at Austin 1976

FIGURE B.2-2 Physiographic Map of Region

Channel. Significant bottom movements have occurred in the study area in the last 40 years. Some bottom contours may have changed as much as 10 feet within the 40 foot contour and the shoreline within the area of the proposed brine pipeline moved several thousand feet gulfward (U.S. Department of Commerce, 1977).

Geology

The dominant geologic feature of coastal Texas is the Gulf Coast geosyncline. The axis of this geosyncline generally corresponds with the present coastlines of Texas, Louisiana, Mississippi, Alabama, and Florida (Figure B.2-3). The stratigraphic record indicates that the geosyncline has been slowly and more or less continuously subsiding since Cretaceous times. Table B.2-1 presents a generalized geologic time chart for the period subsequent to Cretaceous time. The area of subsidence received voluminous deltaic accumulations of sediments, which are derived from broad portions of central North America. These accumulations are expressed as a large wedge of Mesozoic and Cenozoic sediments that progressively thicken toward the south. In the vicinity of the coast, the wedge is reported to be about 40,000 feet thick (King, 1969). Individual stratigraphic units also thicken and dip southward. The same depositional processes are still active. A generalized cross-section of the Gulf Coast geosyncline is presented in Figure B.2-4.

Another dominant feature of the region is the presence of salt domes scattered along the gulf coast (Figure B.2-1 and B.2-3). Typically, these domes are roughly cylindrical in shape, one to five miles in diameter, and extend from a few tens or feet to several thousand feet below the surface (Figure B.2-5). The domes are believed to be derived from the thick Louann Salt Formation of probably Jurassic age which rests near the base of the sediments. Aided by bouyancy provided by the relatively low specific gravity of salt, local portions of the deep salt layer have plastically protruded upwards and pierced the overlying strata. In response to this upward flow, the adjacent strata are locally upturned and create excellent traps for petroleum accumulation.

It should be recognized that at least some salt domes, particularly offshore or coastal domes, are generally considered dynamic features,

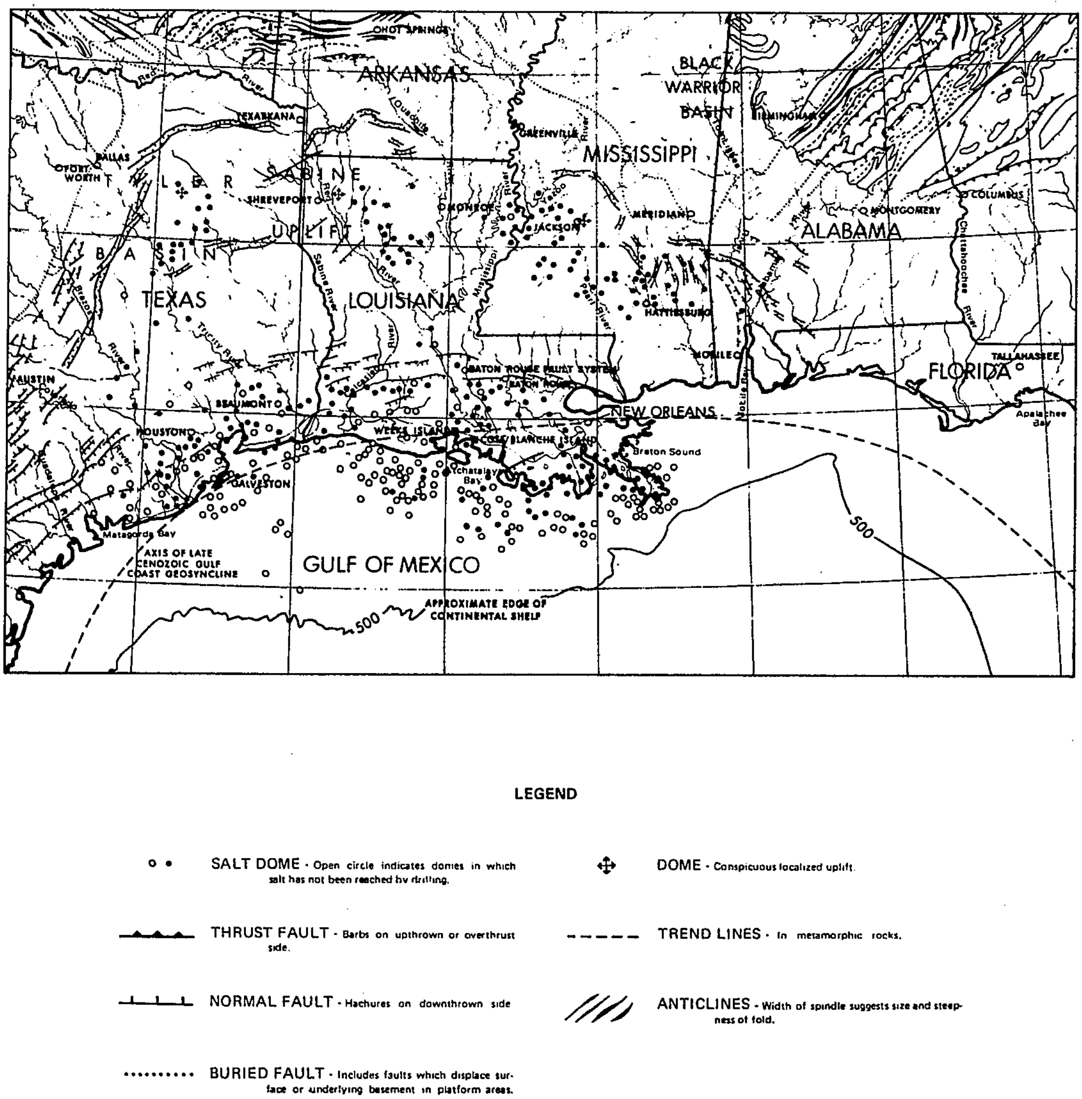


FIGURE B.2-3 Regional geologic structure. (Modified from King, Phillip B., 1969, Tectonic Map of North America: USGS.)

TABLE B.2-1 Generalized geologic time chart.

Generalized Standard Section: System	Series	Group or Stage	Texas Gulf Coast: Formation	Member	Foraminifera	Generalized Depositional Cycles (Clastic Section) Transgressive / Regressive	Stratigraphic Facies Below Site	Approx. Thickness Feet	Aquifer
QUATERNARY	REC-ENT							5-15	Chicot: Upper
QUATERNARY	PLEISTOCENE	HOUSTON	BEAUMONT MONTGOMERY LISSIE WILLIS	Terrace Deposits	(Becomes marine only in downdip)		Nearshore Fluvio-Marine	2,000'	Chicot: Lower
		—1.85*—	—?—	—?—					
TERTIARY	PLIOCENE	CITRONELLE	GOLIAD	Marine zones in post-Anahuac present only in downdip land and offshore	Buliminella sp				Evangeline
		—5.5—							
TERTIARY	MIOCENE	FLEMING	LAGARTO		Robulus (E) Bigenerina (A) Cristellaria (K) Discorbis (5) Textularia (L) Bigenerina nodosaria directa Textularia (W) Bigenerina humblei Cristellaria (I) Cibicides opimus			5,500'	
TERTIARY	MIOCENE	FLEMING	OAKVILLE		Amphistegina (B) Robulus (43) Discorbis bolivarensis Marginulina ascensionensis Siphonina davisi				
		—22.5—	—?—	—?—					
TERTIARY	OLIGOCENE	CATAHOULA	ANAHUAC		Discorbis nomada Discorbis gravelli Heterostegina sp Bolivina perca Marginulina idiomorpha Marginulina vaginata Marginulina howei		Pro Delta to Basinal	10,000'	
TERTIARY	OLIGOCENE	CATAHOULA	FRIO	[illegible]	Cibicides hazzardi Marginulina texana Gyroidina scalata Bolivina alazanensis and others Nonion struma Nodosaria blanpiedi Textularia seligi Anomalina bilateralis				
TERTIARY	OLIGOCENE	VICKSBURG			Textularia warreni Textularia tumidula and association				
TERTIARY	OLIGOCENE	VICKSBURG	RED BLUFF	(Only in downdip subsurface)					
		—38—							
TERTIARY	EOCENE	JACKSON	WHITSETT	Fashing Clay Calliham Sd Dubose Sd-Sh Stones Switch Sd	Discorbis texana Massilina pratti		Basinal	22,500'	
TERTIARY	EOCENE	JACKSON	Mc ELROY	Manning Clay Wellborn Sd Wooleys Bluff Clay	Textularia hockleyensis				
TERTIARY	EOCENE	JACKSON	CADDELL	East Texas [illegible]	Textularia dibollensis [illegible]				
TERTIARY	EOCENE	CLAIBORNE	YEGUA		Discorbis yeguaensis & Eponides yeguaensis				
TERTIARY	EOCENE	CLAIBORNE	CROCKETT		Ceratobulimina eximia Operculinoides sabinensis				
TERTIARY	EOCENE	CLAIBORNE	SPARTA						
TERTIARY	EOCENE	CLAIBORNE	WECHES		Textularia smithvillensis				
TERTIARY	EOCENE	CLAIBORNE	QUEEN CITY						
TERTIARY	EOCENE	CLAIBORNE	REKLAW						
TERTIARY	EOCENE	CLAIBORNE	CARRIZO						
TERTIARY	EOCENE	WILCOX	SABINETOWN		Cytheridea sabinensis (Ostracoda)				
TERTIARY	EOCENE	WILCOX	ROCKDALE						
TERTIARY	EOCENE	WILCOX	SEGUIN		Ostrea multilirata (Pelecypoda)				
		—54—							
TERTIARY	PALEOCENE	MIDWAY	WILLS POINT	Solomon Creek Kerens Mexia	Robulus midwayensis Vaginulina longiforma; Vaginulina midwayana Marginulina tuberculata Polymorphina cushmani				
TERTIARY	PALEOCENE	MIDWAY	KINCAID	Tehuacana Pisgah Littig Glauc	Discorbis newmanae Robulus pseudocostatus				
		—65—							

*Age in million years before present
Modified after Rainwater and Zingula, 1962.

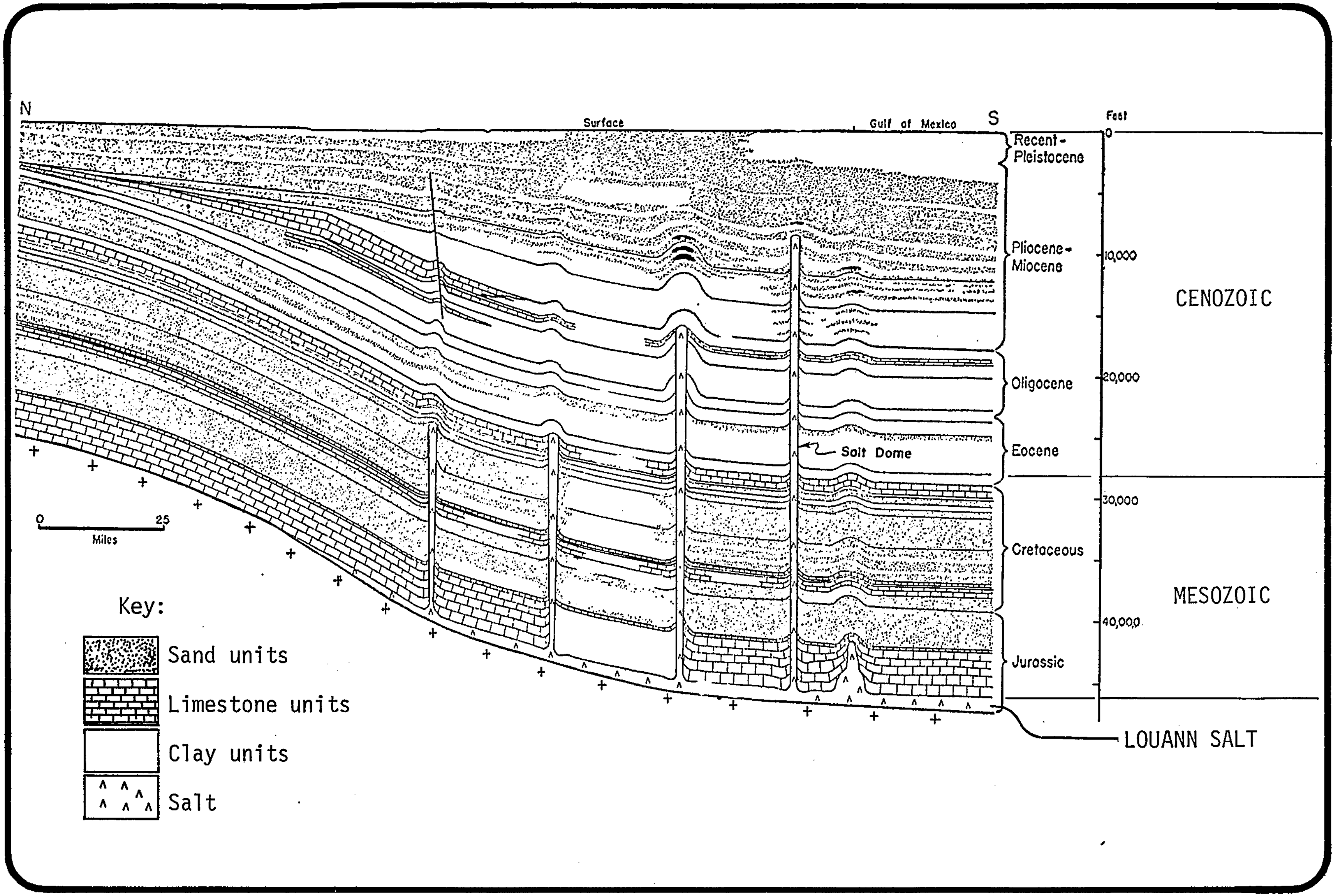


FIGURE B.2-4 Generalized Cross-Section of Gulf Coast Geosyncline

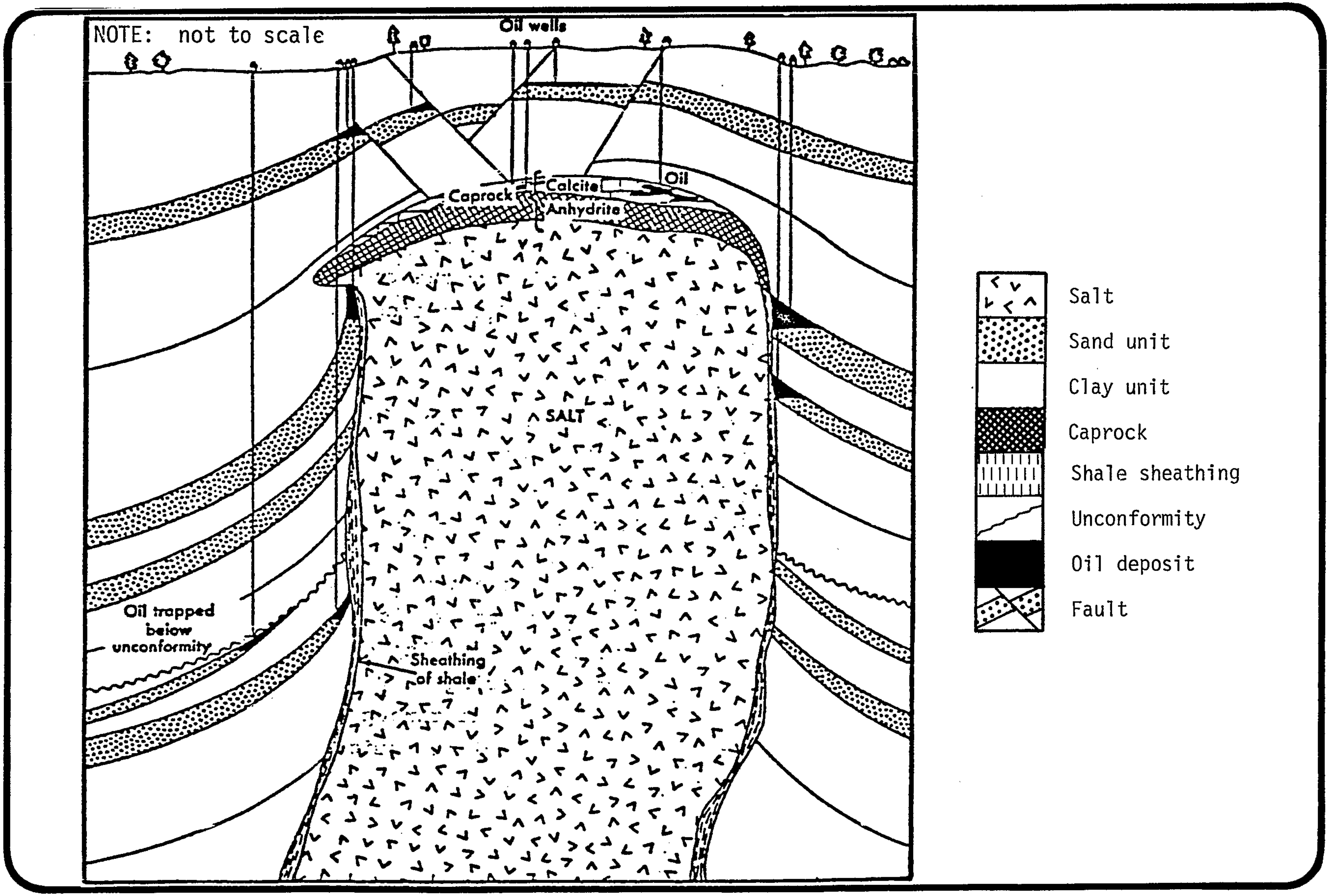


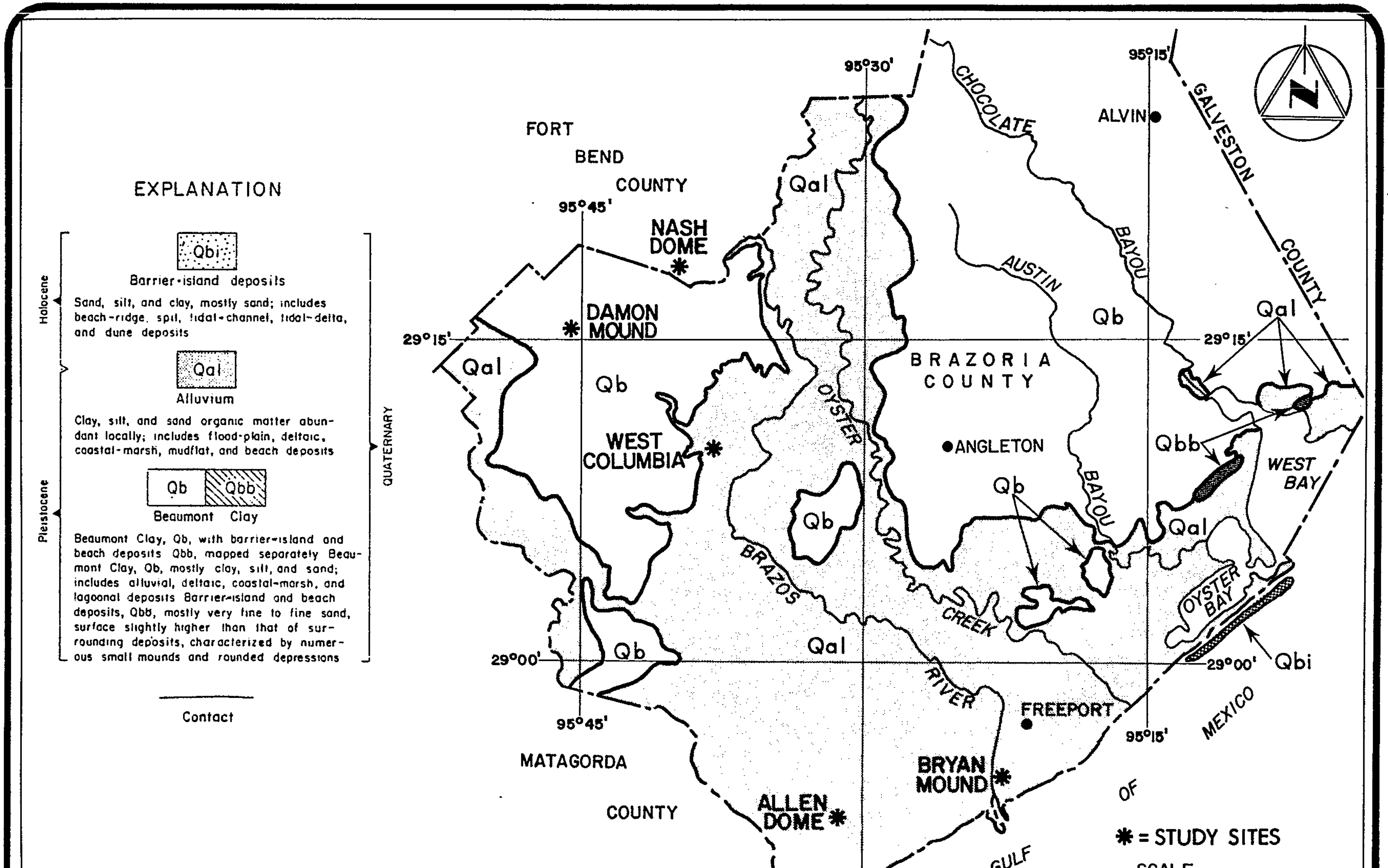
FIGURE B.2-5 Typical salt dome structure and related strata viscoplastically rising more or less continuously at a small but finite rate on the order of 1 millimeter per year. The domes are concomitantly consumed at the upper surface through dissolution by ground water.

Most investigators now agree that salt dome caprock represents an accumulation of insoluble material, originally transported within the salt. As the salt moved upward relative to the surface of the earth, its upper face was apparently leached by unsaturated water from above. As the salt dissolved, anhydrite was concentrated as an insoluble residue. Gypsum, native sulfur and other minerals may have evolved as the products of altered anhydrite.

Stratigraphy

The sediments in the upper Gulf Coast are principally Eocene to Miocene although rocks as old as Cretaceous are encountered in wells along the inland margin of the area and Pliocene to Recent deposits mantle the coastal belt. These sediments represent a complex of deltaic deposits interfingering gulfward with marine wedges which carry a sequence of well known fossil zones. The relatively simple homoclinal regional structure often referred to as the north limb of the Gulf Coast geosyncline is interrupted coastward by a series of strike faults and by a number of salt domes which have produced the structural traps for large accumulations of oil and gas.

Most of the shallow surficial sediments of the Texas gulf coast are composed of recently derived modern (Holocene) sediments which lie on top of the older (Pleistocene) sediments. Pleistocene sediments crop out in the Freeport area. There, they include clays, fine sands, shells, and limey concretions indicative of their marine origins. A surface geologic map of the region which includes the Seaway Group is presented as Figure B.2-6. The three major units mapped include: barrier island deposits composed of sand, silt, and clay (mostly sand); alluvium composed of clay (dominant), silt, sand, and organic material; and the Beaumont clay formation, with barrier island and beach deposits mapped separately. The Beaumont Formation was deposited about 100,000 years



SOURCE: Bryan Mound, FES/77-6.

FIGURE B.2-6 Regional Geological Map

ago during a Pleistocene interglacial stage. The formation was formed as a depositional plain, by a series of coalescing alluvial and deltaic plains of ancient river systems.

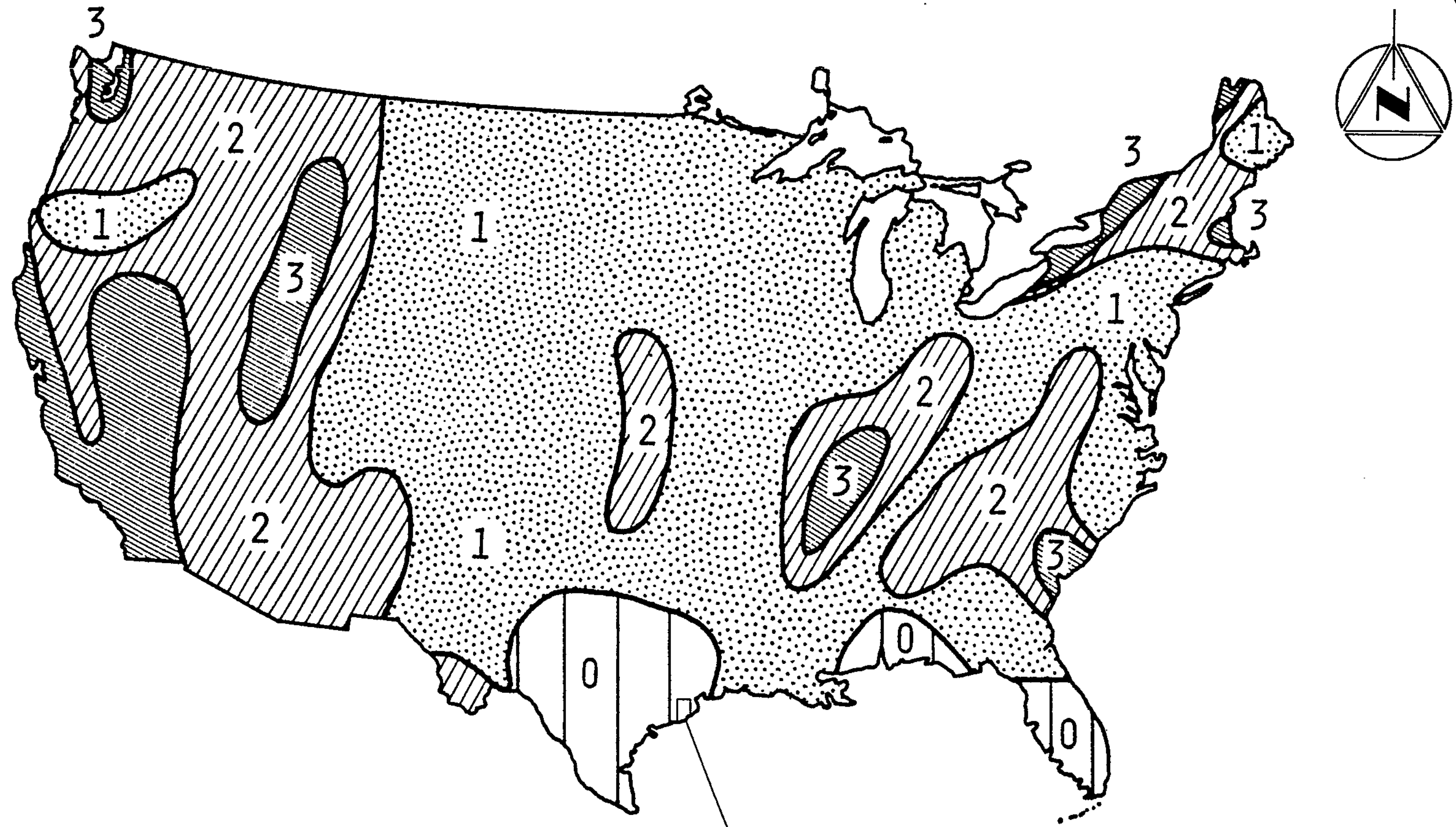
The Beaumont Formation was deeply disected by streams during the last glacial period when sea level was about 350 feet lower than its present level. The streams readjusted their gradients to the lower sea level, and became well entrenched by eroding deep valleys in the coastal areas. With the retreat and melting of the ice sheets, immense amounts of water were released to the ocean, sea levels rose, and the entrenched deep valleys of the streams were drowned and became estuaries. Present-day examples of these estuaries in Texas are Galveston Bay and San Antonio Bay. The Brazos, Colorado, and Rio Grande Rivers have filled their estuary systems with sediment and these rivers now discharge directly into the Gulf of Mexico (Hammond, 1969).

Structure

The major regional geologic structure is the Gulf Coast geosyncline. Superimposed on the goesyncline are several minor structures (Figure B.2-3). The most noticeable minor structure is a fault system that approximately parallels the geosynclinal axis. Faults composing the system are typically normal and downthrown to the south. The faulting associated with this system is believed to have occurred gradually but concurrently with the geosynclinal development. Many other smaller faults are locally associated with individual salt domes. Reportedly, they have resulted from salt plug emplacement (Johnson and Bredeson, 1971).

Seismicity

The National Oceanic and Atmospheric Administration (NOAA) has classified the United States into four zones with differing degrees of expected siesmic risk (Figure B.2-7). These sub-divisions are based upon the recorded history of past seismic activity, using the Modified Mercalli Intensity Scale (Table B.2-2). Zone 0 covers areas having no reasonable expectancy of surface earthquake damage; Zone 1, expected



ZONE 0 - NO DAMAGE
ZONE 1 - MINOR DAMAGE
ZONE 2 - MODERATE DAMAGE
ZONE 3 - MAJOR DAMAGE

After: Algermissen, 1969

FIGURE B.2-7 Seismic risk map of the United States

TABLE B.2-2 Modified Mercalli Scale of Earthquake Intensity.

I. Not felt except by very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well-water levels. Disturbs persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks.

XI. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upwards into the air.

minor damage; Zone 2, expected moderate damage; and Zone 3, possible major destructive earthquakes. The Seaway Group region is within Seismic risk Zone 0.

A computer-aided search of recorded seismic events within a 200 mile radius was conducted. The result is the following earthquake list:

DATE	LAT (NORTH)	LONG (WEST)	INTEN (MM)	MAGNI-TUDE	REF	DISTANCE (MILES)
8 JAN 1891	31.7	95.2	VII		EQH	186
24 APR 1964	31.5	93.8	V	3.7	CGS	199
28 APR 1964	31.5	93.8	V	3.4	CGS	199
28 APR 1964	31.2	93.9	V	4.4	CGS	179
3 JUN 1964	31.3	94.0	IV	4.2	CGS	182

Mineral and Energy Resources

Chief among the mineral and energy resources of the Texas coastal zone are oil and gas. Important sources of sulfur; salt; chlorine and magnesium bases for chemical products; shell, clay, and sand for construction aggregate; and industrial sand are also found there.

The main petroleum producing horizon in the area is the Oligocene Frio Formation. Oil and gas are extracted from natural traps in the strata which are commonly associated with the disturbed strata around salt domes. Oil production occurs in both onshore and offshore areas.

Sulfur and salt are extracted from salt domes. Salt is produced by solution and conventional mining of the salt core of a dome. Most is used as salt brine, primarily for a feedstock in the manufacture of chlorine, soap, and soda ash.

Sulfur is produced by the Frasch process, in which superheated water is pumped into wells open to sulfur-bearing caprock material to melt the sulfur; the molten sulfur is forced up to the surface by compressed air.

Chlorine and magnesium for chemical processes is derived from Gulf of Mexico seawater. Dow Chemical Company in Freeport produces 93 percent of the total United States production of magnesium metal.

Gravel for construction aggregate is scarce in the gulfward edge of the Gulf Coastal Plain, therefore, reliance is on the locally available fine sand and shell resources. About half of the shell production in the area goes to construction aggregate. The remainder is used in the production of cement, lime and chemicals. Fine grained sand is used extensively for fill.

Soils

The parent materials for soil development in the gulf coast are the surface and near-surface Pleistocene and Holocene sediments. These are fluvial and deltaic sediments deposited by the San Bernard and Brazos Rivers.

Surficial soils in the region consist of sandy to clayey loam, with minor concentrations of organics and salts.

For the purposes of mapping soils, soil associations are defined. A soil association is a landscape that has a distinctive proportional distribution of soils. It normally consists of one or more major soil and at least one minor soil, and it is named for the major soil. The soil associations found in the region include the Lake Charles-Edna-Bernard, the Harris-Veston-Galveston, the Miller-Norwood-Pledger and the Moreland-Pledger-Norwood. Their characteristics are summarized in Table B.2-3. Figure B.2-8 shows the distribution of the major soil associations which occur in the region. The map was taken from a portion of the "General Soil Map of Texas" (Texas Agricultural Experiment Station, 1973).

A detailed description of offshore sediments is provided in Appendix G.

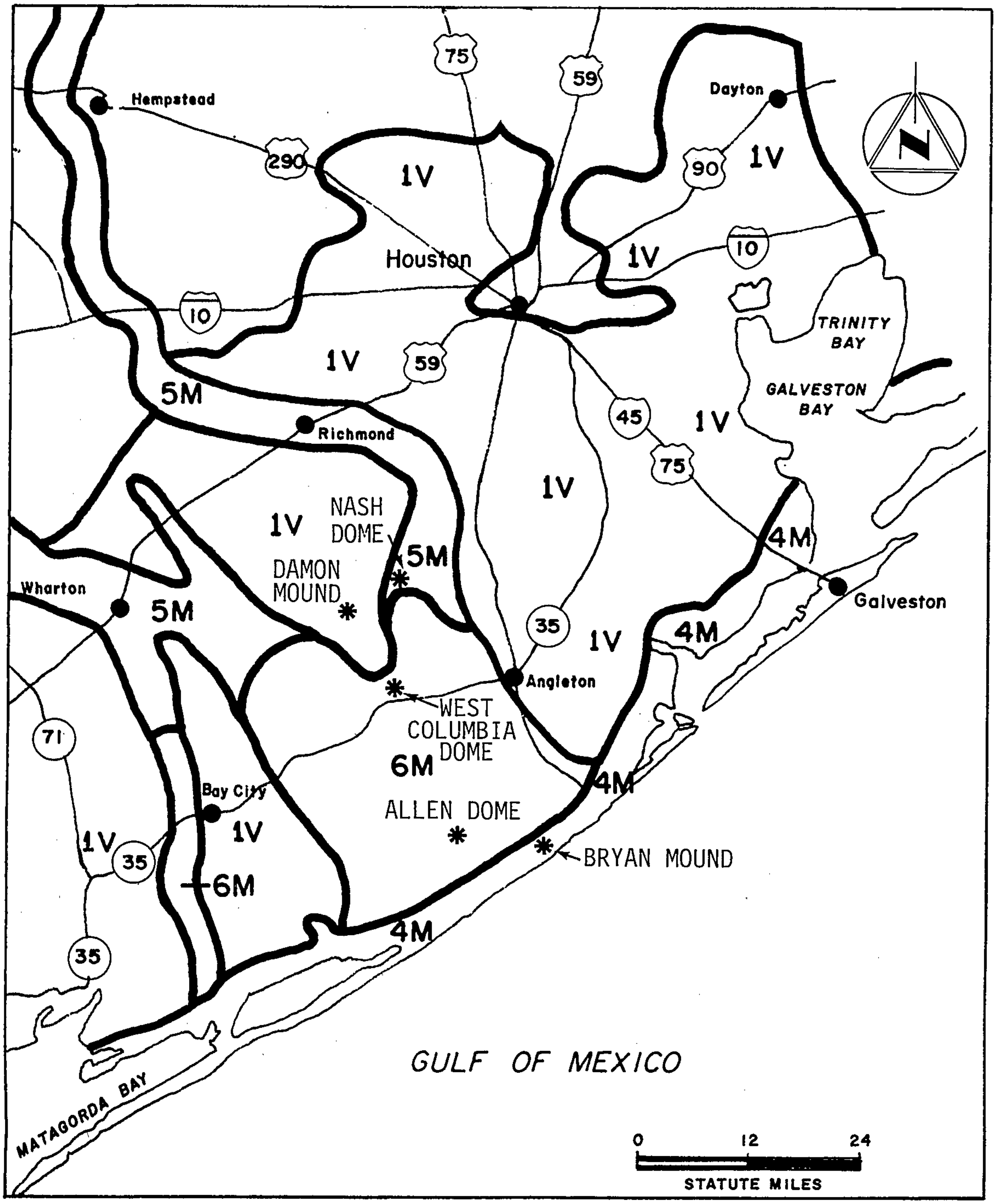
Recent studies indicate that the marine sediments in this section of the Gulf are of Hologene origin and composed of loose, fine sands, clays and silts ranging in thickness from a few feet to 50 feet along the coast between deltaic areas. NOAA studies indicate the bottom is hard sand to the 18 foot depth and softer silts and clays out beyond the 50 foot depth with no bottom irregularities (U.S. Dept. of Commerce, 1977).

In the vicinity of river mouths, fans of sand and shell aggrade offshore to silts and clay. Beyond the 5 fathom depth, the sand grain-size distribution decreases to become silt and clays. Sediments along the shelf in the areas 6 to 10 miles from the shore are primarily

TABLE B.2-3 Soil characteristics of four regional soil associations.

Soil Association	Annual Rainfall on Soil	Setting: Parent Material	Setting: Relief	Mineral and Chemical Properties	Typical Vegetation	Limitations and special Features	Land Uses
Lake Charles - Edna - Bernard	25-50 inches	Clayey and loamy, deltaic sediments	Level to nearly level	Montmorillonite, strongly acid to moderately alkaline in surface layer, increasing alkalinity with depth	Tall grasses, live oak	Wet, high shrink-swell potential, very slow permeability; high corrosion potential; high sodium in lower layers; severe residential foundation problems	Crops, irrigated crops, pasture, range, wildlife,
Harris - Veston - Galveston	25-55 inches	Clayey to sandy, marine and deltaic sediments	Level to gently undulating	Montmorillonite and mixed; neutral in surface layer; salinity common	Cord grasses and other bunch grasses, sedges	Wet, high corrosion potential, high shrink-swell	Range, urban, recreation, wildlife
Miller - Norwood - Pledger and Moreland - Pledger - Norwood	38-45 inches	Clayey and loamy, calcareous recent flood plain alluvium	Level	Mixed with montmorillonite; moderately alkaline and calcareous to neutral in surface, moderately alkaline and calcareous below	Hardwood forest, shade tolerant tall grasses	High shrink-swell potential; occasional flooding, high corrosion potential	Crops, irrigated crops, pasture, urban, parks

Source: Texas Agricultural Experiment Station, 1973.



Soil Associations

IV	Lake Charles-Edna-Bernard	5M	Miller-Norwood-Pledger
4M	Harris-Veston-Galveston	6M	Moreland-Pledger-Norwood

SOURCE: Department of Agricultural Communications, Texas A&M University, 1973

FIGURE B.2-8 Regional Soils map

heavily weathered, coarse grained sands (SEADOCK, 1975). A detailed description of the sediments found in the offshore region is presented in Appendix G.

B.2.2 Water Environment

B.2.2.1 Surface Water Systems

Introduction

As described in Section B.2.1, the Texas Gulf Coastal Plain is a fairly flat, low gradient prairie with poorly developed surface drainage. The major surface water systems in the region include the Brazos River and its tributaries, the San Bernard River and its tributaries, the coastal marshes, Freeport and Brazos Harbors, the Intracoastal Waterway, and the Gulf of Mexico (Figure B.2-9).

The Brazos River

The Brazos River basin is the largest drainage basin in Texas. Its area encompasses 44,340 square miles, about 15 percent of the state. The tidal portion extends from the Gulf of Mexico to Brazoria, about 25 river miles. Estuarine conditions are present in the lower reaches of the tidal Brazos River. Diurnal tidal range at the mouth is 1.8 feet.

The Lower Brazos River was diverted in the early 1940s to provide a suitable harbor in the old river for the Freeport area. This diverted channel, the Brazos River Diversion Channel, is about 6 miles long from the point of diversion to the Gulf of Mexico (Figure B.2-9). Ten-foot depths are reported between the Intracoastal Waterway and Brazoria. Controlling depth at the mouth of the river is approximately 3 to 4 feet.

The U.S. Geological Survey (USGS) streamflow monitoring station nearest to the proposed sites is station number 08116650 near Rosharon, Texas. Streamflow characteristics over the period of record (since April 1967) are summarized in Table B.2-4 below.

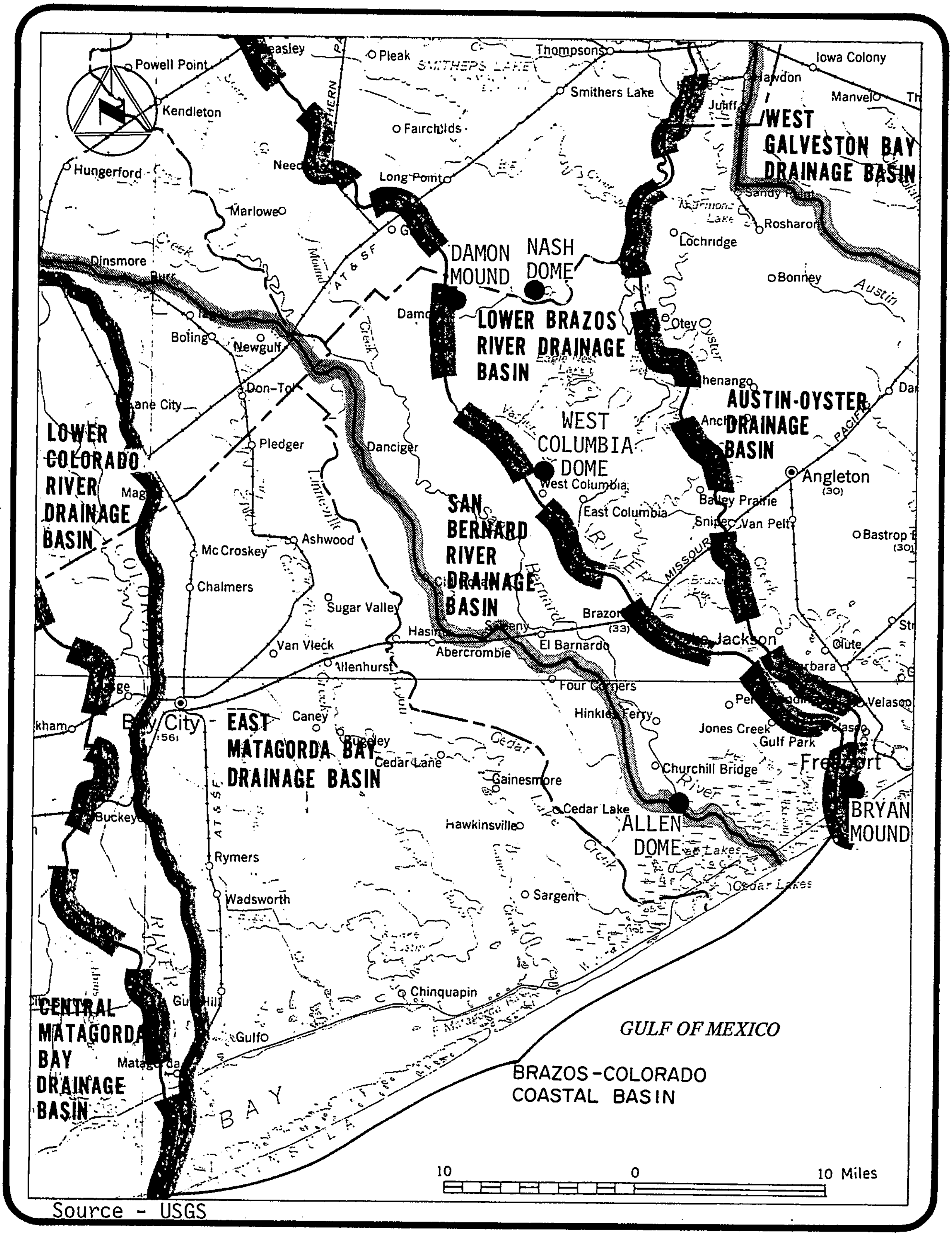


FIGURE B.2-9 Regional surface water features

TABLE B.2-4 Streamflow Characteristics of Brazos River at Rosharon, Texas

Event	Date	Flow Cubic Feet Per Second (cfs)
Period of Record (since April 1967)		
Average Discharge	Period of Record	8,357
Maximum Daily Discharge	May 14, 1968	79,900
Minimum Daily Discharge	April 7-10, 1967	40
Water year 1975 (October 1974 to September 1975)		
Maximum Daily Discharge		61,900
Minimum Daily Discharge		1,660
Maximum Average Monthly Discharge	November	33,580
Minimum Average Monthly Discharge	August	4,395

The water of the Brazos River has not been widely developed for municipal and industrial use because it is often too saline. Most of the salt load is from solution of salt domes, and from springs and seeps in the upper river basin. Several large reservoirs have been built in the basin, but use of the stored water has been limited due to high salinity. However, the water is generally suitable for irrigation (Texas Water Quality Board, 1976).

Dow Chemical represents the major industrial installation utilizing the lower Brazos River, both as a source of water and as a waste water receiving stream. During high water stages, Dow purchases fresh water from the Lower Brazos River Authority and stores it in Brazoria and Harris Reservoirs. The annual volume of fresh water transferred to Dow ranges from 42 billion to 84 billion gallons. In addition, Dow uses approximately 467 to 509 billion gallons of saltwater from the Gulf of Mexico annually (FES, 76/77-6). The city of Freeport obtains approximately 550 million gallons of fresh water from Dow annually. Waste water from Dow (Table B.2-5) enters the Brazos River from two canals. The total discharge rate averages about 1.05 million gallons per minute or about 550 billion gallons per year (FES 76/77-6).

Texas Water Quality Board (TWQB) standards for water quality, approved by the Federal government, classify the tidal portion of the lower Brazos River as suitable for both contact and noncontact recreation and for propagation of fish and wildlife. From the head of the

TABLE B.2-5 Water quality data for waste water discharged by DOW Chemical Corporation at Freeport.

Parameter*	Range of Values (lb/day)
Change in biological oxygen demand	15,000 to 20,000
Change in total suspended solids	-20,000 to -80,000
Change in total chromium	9 to 34

*All water quality data are expressed in terms of the change in the water quality parameter from its original value when removed from the Brazos River to its final value when returned to the river.

Source: M. Moos, Private Communication, Texas Water Quality Board, Austin, Texas, June 3, 1976.

tide to Whitney Dam, the Brazos River is classified for all of the above plus for domestic water supply. TWQB's water quality standards and classification of desirable uses of water bodies in the study area are presented in Table B.2-6. U.S. Environmental Protection Agency numerical criteria for water quality for public water supply intake, marine aquatic life, and freshwater aquatic life are also presented in Table B.2-7.

In addition to streamflow monitoring, water quality analyses are being performed by the USGS at Rosharon. Chemical, biochemical and water temperature determinations have been made since October 1967, pesticide analysis since February 1968, and sediment recording began in October 1974. A summary of the published water quality data for the year October 1974 to September 1975 are summarized in Table B.2-8. The TWQB standards for chloride, sulfate, total dissolved solids (TDS), dissolved oxygen and temperature were easily met for all samples taken, but pH fell below the specified range for two samples. Fecal coliform count exceeded the TWQB criterion for 7 of the 12 samples taken during the year. The average fecal coliform count was also in excess of the criteria.

The most recent detailed analysis of water quality in the tidal portion of the Brazos River was conducted by the TWQB at six sampling locations in 1971 (Figure B.2-10) (Texas Water Quality Board, 1972). Data gathered at each of the sampling stations (Figures B.2-11 through B.2-20) included: average surface and bottom dissolved oxygen (DO); temperature; conductivity; water clarity; average surface and bottom alkalinity, hardness, biological oxygen demand, and total and fecal coliform concentrations. A comparison of these data with the TWQB standards indicates that:

1. Near the mouth, at Stations 1 and 1A, the DO level at both the surface and the bottom was low, especially at the bottom of Station 1A. This is possibly due to the direct influence of the oxygen demand of Dow Plant B waste water.

TABLE B.2-6 Texas water quality standards, regional surface water system.

River Basin/Water Body Name Segment Name (Where Applicable)	WATER USES DEEMED DESIRABLE: Contact Recreation	Noncontact Recreation	Propogation of Fish & Wildlife	Domestic Raw Water Supply	CRITERIA: Chloride (mg/l) Avg. not to exceed	Sulphate (mg/l) Avg. not to exceed	TDS (mg/l) not to exceed	DO (mg/l) not less than	pH Range	Fecal Col. Avg. not to exceed	Temp (^{o}F)
1. Brazos River Basin											
a. Brazos River - Tidal	X	X	X					4.0	7.0 - 9.0	200	95
b. Brazos River - Above Tidal to Whitney Dam	X	X	X	X	600	225	1500	5.0	6.5 - 8.5	200	95
2. Brazos - Colorado Coastal Basin											
a. San Bernard River - Tidal	X	X	X					4.0	6.5 - 8.5	200	95
b. San Bernard River - Above Tidal	X	X	X	X	100	50	500	5.0	6.5 - 8.5	200	90
3. Freeport Harbor/ICWW		X			-			4.0	6.0 - 9.0	1000	95
4. Gulf of Mexico	X	X	X					5.0	6.5 - 9.0	70	95

TABLE B.2-7 EPA numerical criteria for water quality[a].

Parameter	Public Water Supply Intake (μg/l)	Marine Water Constituents (Aquatic Life) (μg/l)	Freshwater Aquatic Life (μg/l)
Arsenic	50	50	---
Cadmium	10	5	12 (hardness > 100 μg/l) 4 (hardness < 100 μg/l)
Chromium	50	100	100
Copper	1000	1/10 LC 50	1/10 LC 50
Lead	50	50 [b]	1/100 LC 50
Mercury	2.0	0.10	0.05
Nickel	---	1/100 LC 50	1/100 LC 50
Zinc	5000	1/100 LC 50	1/100 LC 50
Cyanides	---	5	5
Aldrin	minimal	0.003	0.003
DDT	minimal	0.001	0.001
Dieldrin	minimal	0.003	0.003
Chlorodane	minimal	---	0.01
Endrin	0.2	0.004	0.004
Heptachlor	minimal	0.001	0.001
Heptachlor epoxide	0.1 [b]	---	---
Lindane	4	0.004	0.01
Phenols	1.0	---	1
Oil and Grease	---	(a) 0.01 of the lowest continuous flow 96-hour LC 50 to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals. (b) Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed. (c) Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum derived oils.	(a) 0.01 of the lowest continuous flow 96-hour LC 50 to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals. (b) Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed. (c) Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum derived oils.
pH	---	6.5 - 8.5	6.5 - 9.0
Ammonia	---	400 [b]	20
Hydrogen Sulfide	---	2	---
Sulfides	---	---	2
Dissolved Oxygen	---	5.0 mg/l	5.0 mg/l (>31°C)
Phosphorus	---	0.1	---
Diazinon	---	---	0.009 [b]
Malathion	---	---	0.1
Parathion	---	---	0.1
Suspended and settleable solids	---	---	Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonably established norm for aquatic life.
Turbidity and light penetration	---	---	10% change in compensation pt

TABLE B.2-7 continued.

Parameter	Public Water Supply Intake (μg/l)	Marine Water Constituents (Aquatic Life) (μg/l)	Freshwater Aquatic Life (μg/l)
Color	---		Waters shall be virtually free from substances producing objectionable color for aesthetic purposes; the source of supply should not exceed 75 color units on the platinum-cobalt scale for domestic water supplies; and increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.
Toxaphene	5	0.005	0.005

[a]Source (except where otherwise noted): "Quality Criteria for Water", U.S. Environmental Protection Agency, 1976.

[b]Source: "Proposed Criteria for Water Quality", Vol. I, U.S. Environmental Protection Agency, 1973.

TABLE B.2-8 Summary of chemical water quality data of the regional surface water system.

		Brazos River Near Rosharon [a]		San Bernard River Near West Columbia [a]		Jones Creek Below Highway 36 [b]		Lower Brazos River [c]		Freeport Harbor & ICW [d]		Gulf of Mexico [e]	
Chemical Water Quality Parameters		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Dissolved Silica (SiO_2)	(mg/l)	14	6.9	31	9.6								
" Calcium (Ca)	"	76	38	67	20								
" Magnesium (Mg)	"	18	6	16	4.6								
" Sodium (Na)	"	120	22	77	14								
" Potassium (K)	"	5.0	2.9	5.4	2.8								
Bicarbonate (HCO_3)	"	244	112	244	70								
Carbonate (CO_3)	"	0	0	0	0								
Dissolved Sulfate (SO_4)	"	99	32	41	10	130	5			250	125		
" Chloride (Cl)	"	170	30	130	24	1130	80			11,000	5,200	15,000	13,000
" Fluoride (F)	"	0.3	0.2	0.4	0.1								
Total Nitrate (NO_3^-)	"	0.67	0.01										
" Nitrite (NO_2^-)	"	0.02	0										
Ammonia Nitrogen	"	0.11	0									.1	
Total Organic Nitrogen (N)	"	2.5	0.35									.2	
" Kjeldahl Nitrogen (N)	"	2.5	0.39							5.0	<1.0	0.3	0.2
" Phosphorus (P)	"	0.86	0.15										
Dissolved Solids (Residue at 180°C)	"	621	205										
" " (Sum of Constituents)	"	611	201	458	175								
Total Nonfiltrable Residue	"	846	669			2200	420						
Vol. " "	"	619	93							7800	2250	9700	5580
Hardness (Ca, Mg)	"	270	120	230	69			4070	237				
Non-Carbonate Hardness	"	91	21	43	11								
Sodium Adsorption Ratio	(Dimensionless)	3.2	0.9	2.2	0.7								
Specific Conductance	(Micromhos)	1150	355	861	224	3090	690						
pH	(units)	7.9	6.3	7.5	6.9	38.3	7.9	8.7	7.2	.9	7.6	9.5	9
Temperature	(°C)	29.0	10.0	27.0	8.0	26.9	26.0	31.5	27.0	2373	16.7	26.5	16.0

TABLE B.2-8 continued.

Chemical Water Quality Parameters		Brazos River Near Rosharon [a] Max	Min	San Bernard River Near West Columbia [a] Max	Min	Jones Creek Below Highway 36 [b] Max	Min	Lower Brazos River [c] Max	Min	Freeport Harbor & ICW [d] Max	Min	Gulf of Mexico [e] Max	Min
Color	(platinum cobalt units)	50	10										
Turbidity	(JTU)	350	45			60	38			20	10	20	5
Dissolved Oxygen	(mg/l)	11.8	6.1			8.5	4.9	7.6	1.6	9	0.8	7	6
Biochemical Oxygen Demand	(5-day)	2.3	0.1			13	8	9.3	0.5	1.5	1.0		
Immediate Coliform	(coliform per ml)	110,000	1600					17	7				
Fecal Coliform	"	3300	23			< 2400	1100	460	4	45	3		
Streptococci	"	1700	15										
Total Organic Carbon (C)	(mg/l)	32	5.3			25	18					14	
Dissolved Aluminum (Al)	(μg/l)	100	0										
Total Arsenic (As)	"	34	4							.8	0	< 10	2
Dissolved Arsenic (As)	"	5	2										
Dissolved Boron (B)	"	160	30										
Total Cadmium (Cd)	"	< 10	< 10										
Dissolved Cadmium (Cd)	"	0	0							.4	3	.50	< 10
Total Chromium (Cr)	"	60	10							40	30	< 301	13
Dissolved Chromium (Cr)	"	0	0										
Total Cobalt (Co)	"	50	< 50										
Dissolved Cobalt (Co)	"	0	0										
Total Copper (Cu)	"	60	10							370	70	210	< 20
Dissolved Copper (Cu)	"	6	1										
Total Iron (Fe)	"	43000	2000										
Dissolved Iron (Fe)	"	70	30							2500	80		
Total Lead (Pb)	"	< 100	< 100										
Dissolved Lead (Pb)	"	5	0							< 1000	10	230	< 50
Dissolved Lithium (Li)	"	20	0										
Total Manganese (Mn)	"	1300	180										
Dissolved Manganese (Mn)	"	10	0										
Total Mercury (Hg)	"	0.6	0										

TABLE B.2-8 continued.

Chemical Water Quality Parameters		Brazos River Near Rosharon [a] Max	Min	San Bernard River Near West Columbia [a] Max	Min	Jones Creek Below Highway 36 [b] Max	Min	Lower Brazos River [c] Max	Min	Freeport Harbor & ICW [d] Max	Min	Gulf of Mexico [e] Max	Min
Dissolved Mercury (Hg)	(μg/l)	0.3	0							1.2	0.33	14	<0.2
Dissolved Nickel (Ni)	"	7	1							60	20	40	<20
Total Selenium (Se)	"	1	0										
Dissolved Selenium (Se)	"	0	0										
Dissolved Strontium (Sr)	"	900	490										
Total Zinc (Zn)	"	210	40										
Dissolved Zinc (Zn)	"	70	10							<2000	140	90	<20
Total Aldrin	"	0	0										
" DDD	"	0	0										
" DDE	"	0.02	0										
" DDT	"	0	0										
" Dieldrin	"	0	0										
" Endrin	"	0	0										
" Heptachlor	"	0	0										
" " Epoxide	"	0	0										
" Lindane	"	0	0										
" Chlordane	"	0	0										
" PCB	"	0	0										
" Diaeinon	"	0	0										
" Malathion	"	0	0										
" Methyl Parathion	"	0	0										
" Parathion	"	0	0										
" 2, 4-D	"	0.11	0										
" Silvex	"	0	0										
" 2,4,5-T	"	0.02	0										
Suspended Sediment	(mg/l)	2300	172			64	39						
Chemical Oxygen Demand	"					41	26			257	66	104	8.2
Oil & Grease	"					2	2			60	<1.0	2.0	0
Transparency	(cm)					6.0	2.5						

TABLE B.2-8 continued.

Chemical Water Quality Parameters		Brazos River Near Rosharon [a]		San Bernard River Near West Columbia [a]		Jones Creek Below Highway 36 [h]		Lower Brazos River [c]		Freeport Harbor & ICW [d]		Gulf of Mexico [e]	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Salinity	(pnt)					2.0	0.5			40	8	29	28
Clarity (Secchi Disc)	(ft)							4.0	1.1				
T-Alkalinity	(mg/l)							191	90				
Conductivity	(umhos/cm)							28,278	680	32,700	20,000		
Total Coliform	(mg/l)							1720	7	495	3		

[a] Source: USGS "Water Resources Data for Texas", water year 1975.

[b] Source: FES 76/77-6, Table 2.2. Data taken on July 10, 1975 at three locations shown on Figure 3.2-6.

[c] Source: FES 76177-6, Appendix B.3. Data taken in 1971 by TWQB at six locations shown in Figure 3.2-5.

[d] Source: FES 76177-6, Appendix B.5. Data taken in 1971-1975 by U.S. Army Corps of Engineers and TWQB at numerous locations.

[e] Source: FES 76177-6, Appendix B.6. Data taken in 1974-1975 by U.S. Army Corps of Engineers off Freeport Harbor.

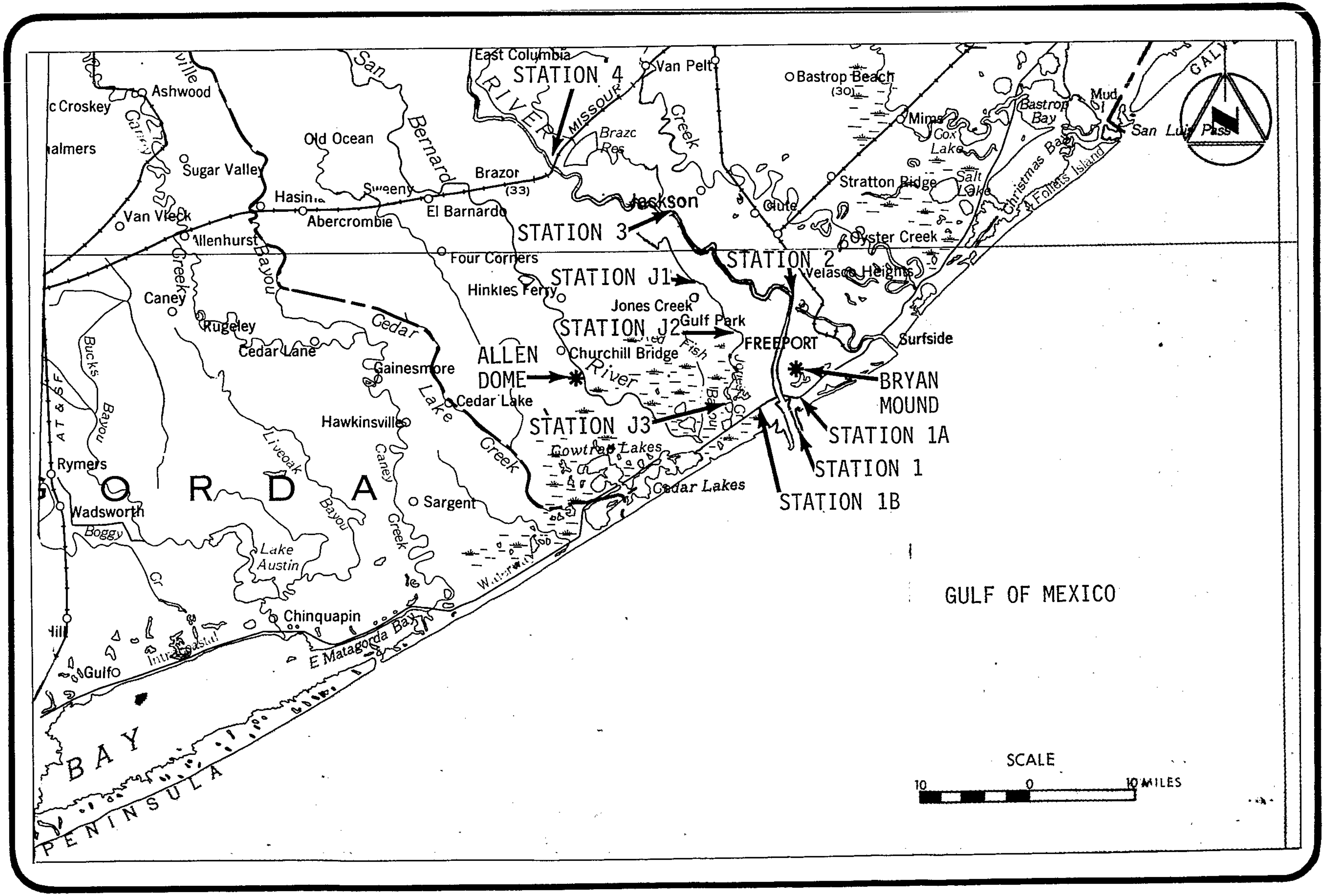
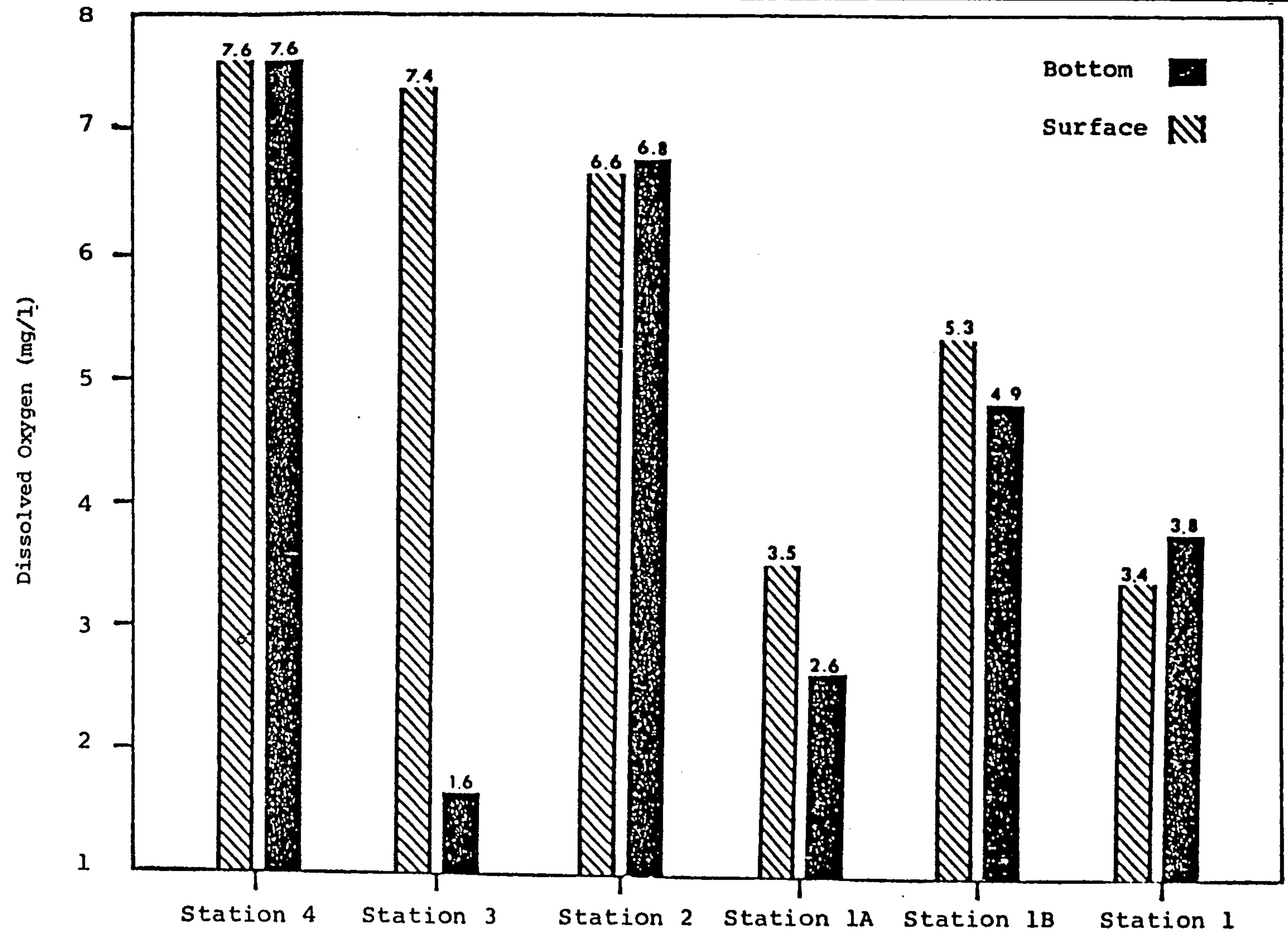
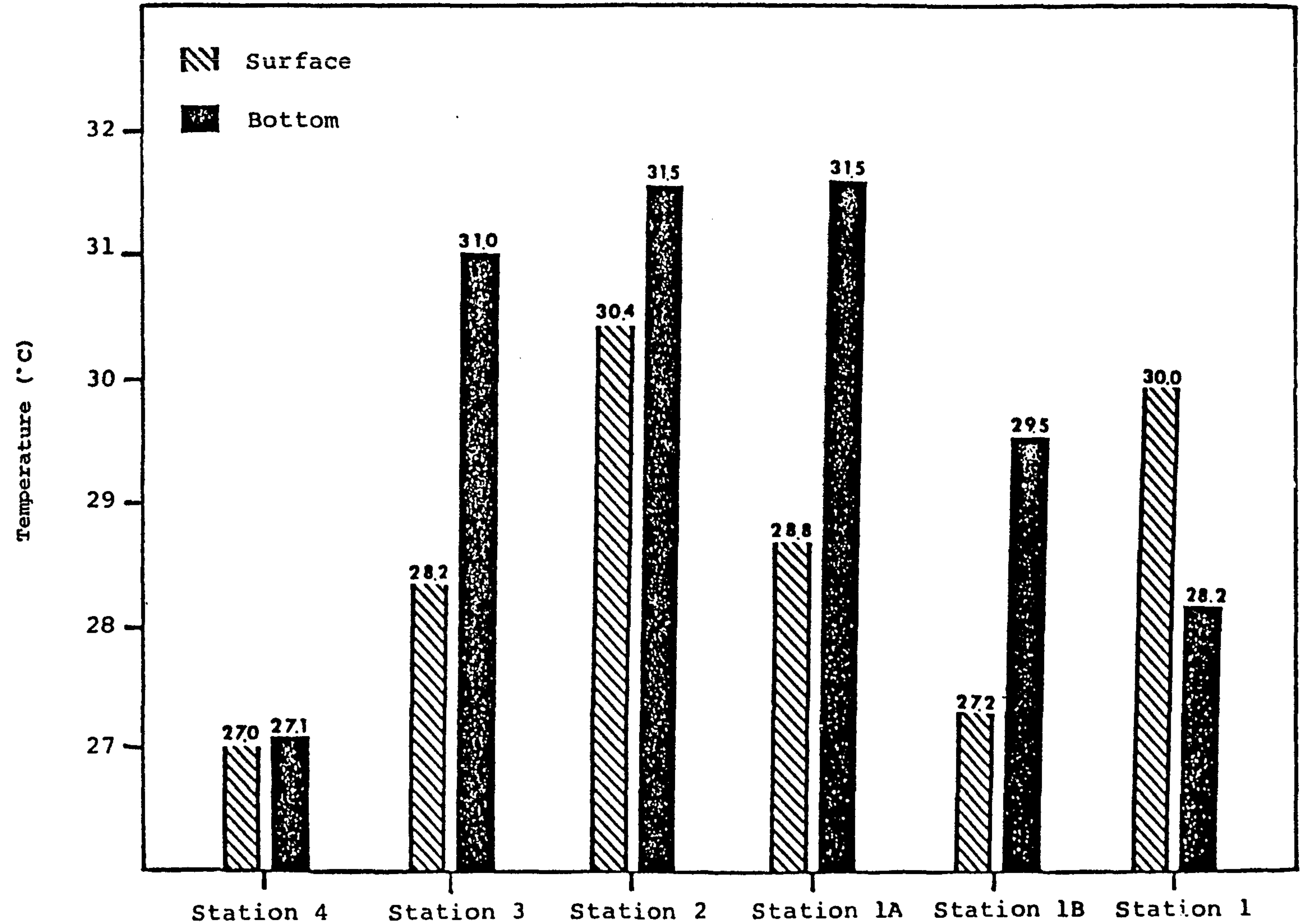


FIGURE B.2-10 Locations of Texas Water Quality Sampling Stations on the Brazos River and the SEADOCK Water Quality Sampling Stations on Jones Creek



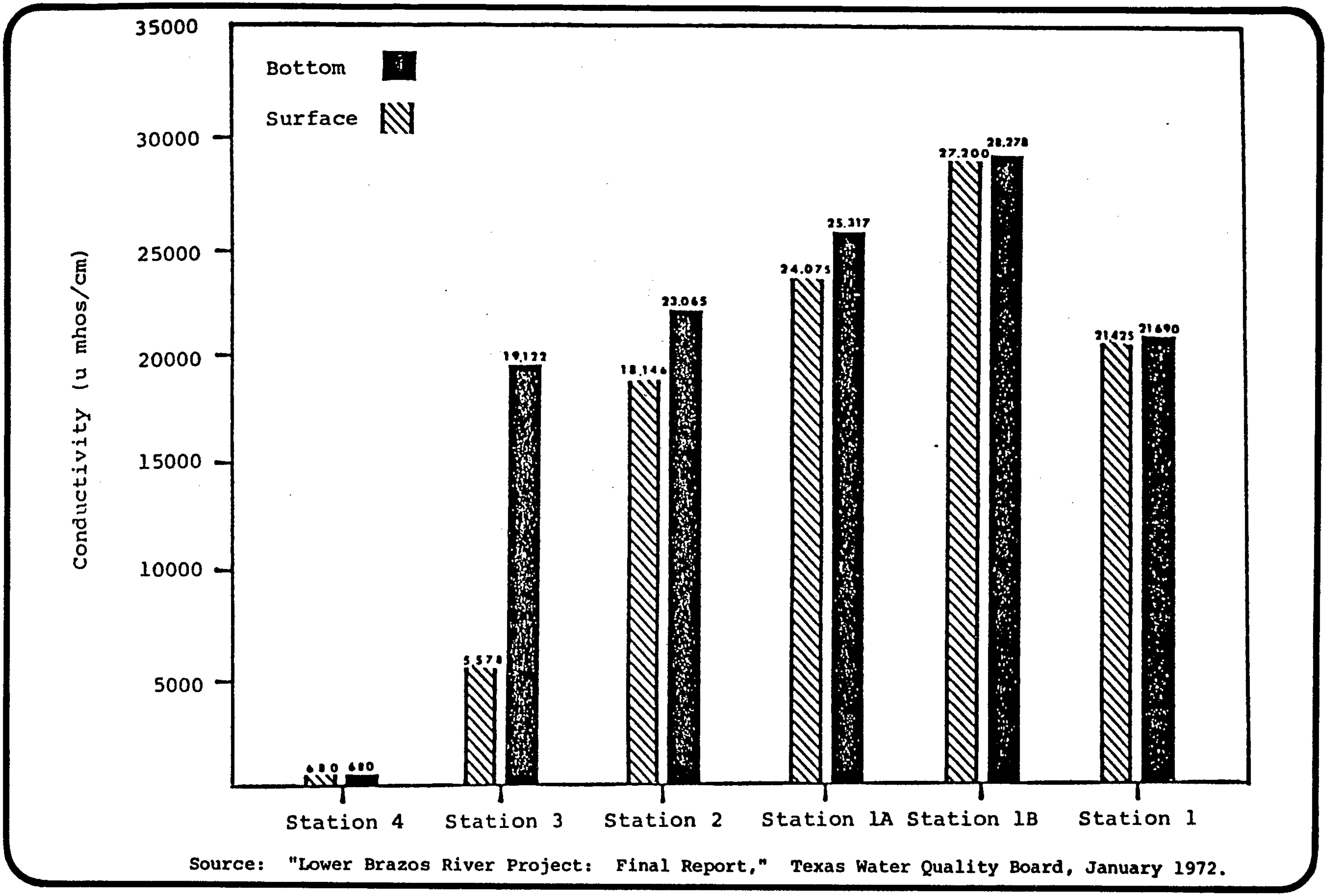
Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-11 Average Surface and Bottom dissolved Oxygen Values at each station for the Brazos River



Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-12 Average Surface and Bottom Temperature Values at Each Station for the Brazos River



Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-13 Average Surface and Bottom Conductivity Values at Each Station for the Brazos River

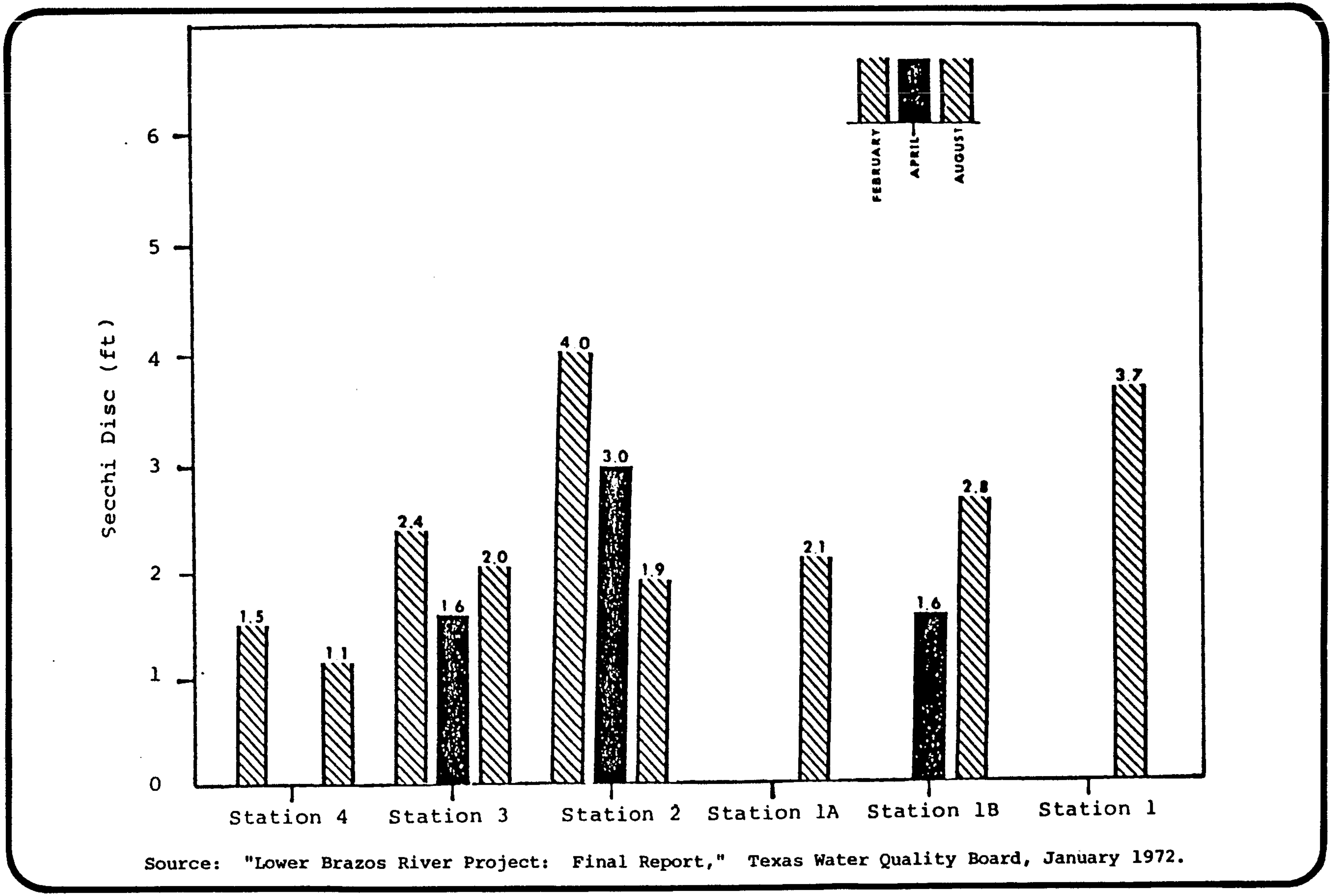
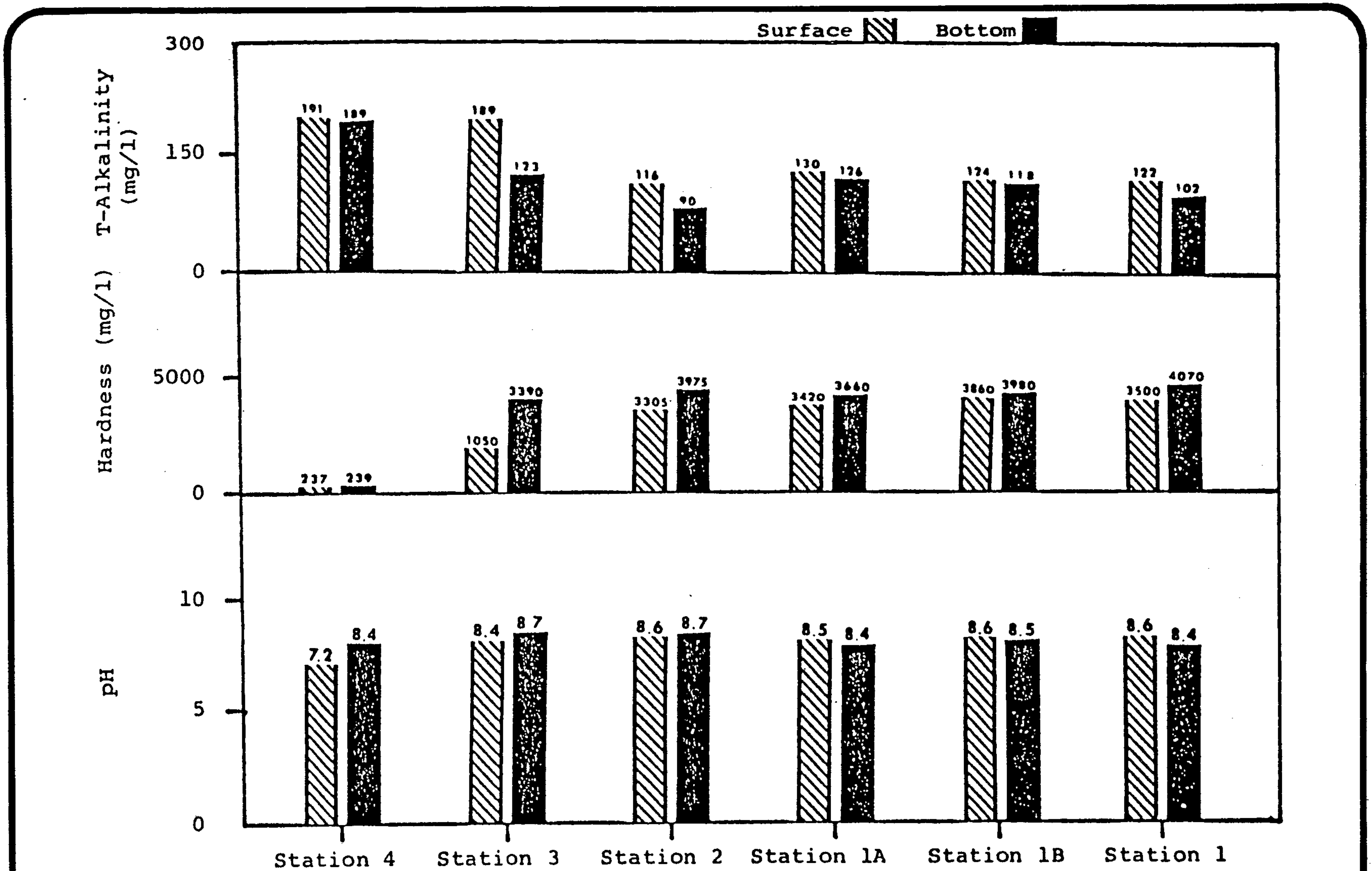


FIGURE B.2-14 Water Clarity at Each Station on the Brazos River During February, April, and August, 1971



Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-15 Average Surface and Bottom Alkalinity, Hardness, and pH Values at Each Station for the Brazos River

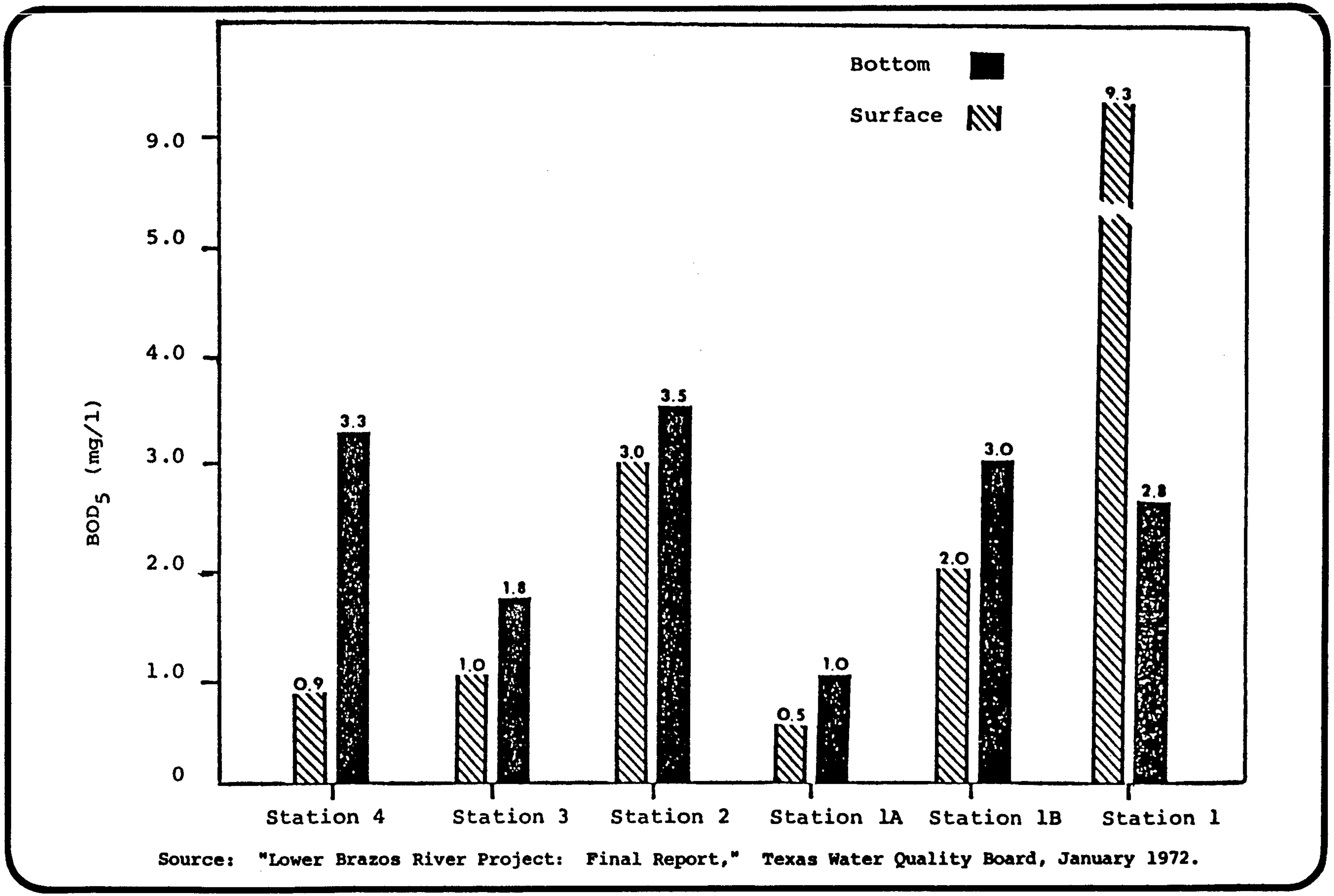
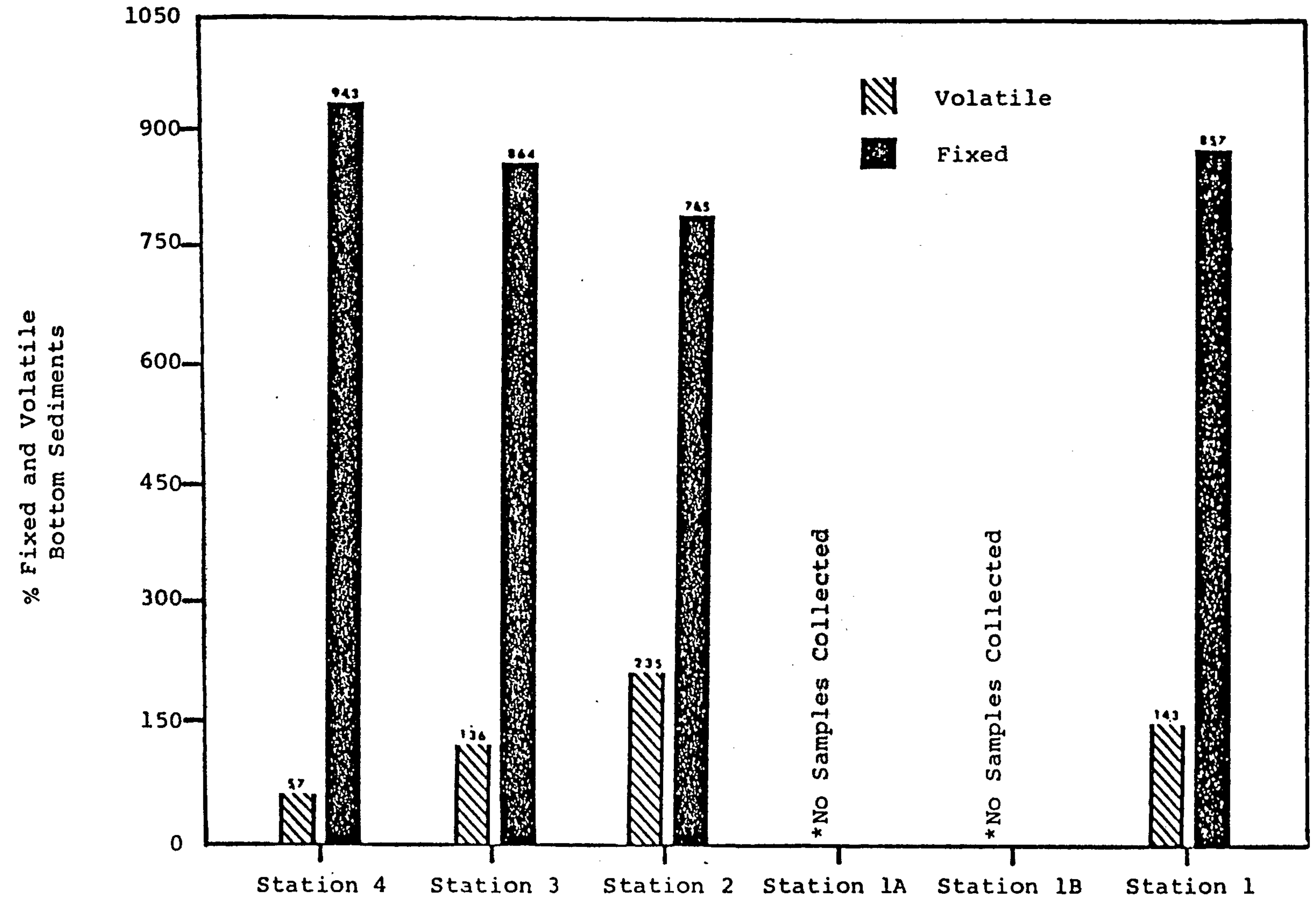


FIGURE B.2-16 Average Surface and Bottom Biological Oxygen Demand values at Each Station for the Brazos River



Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-17 Representative % Fixed and Volatile Solids Content of the Bottom Sediments at Each Station for the Brazos River

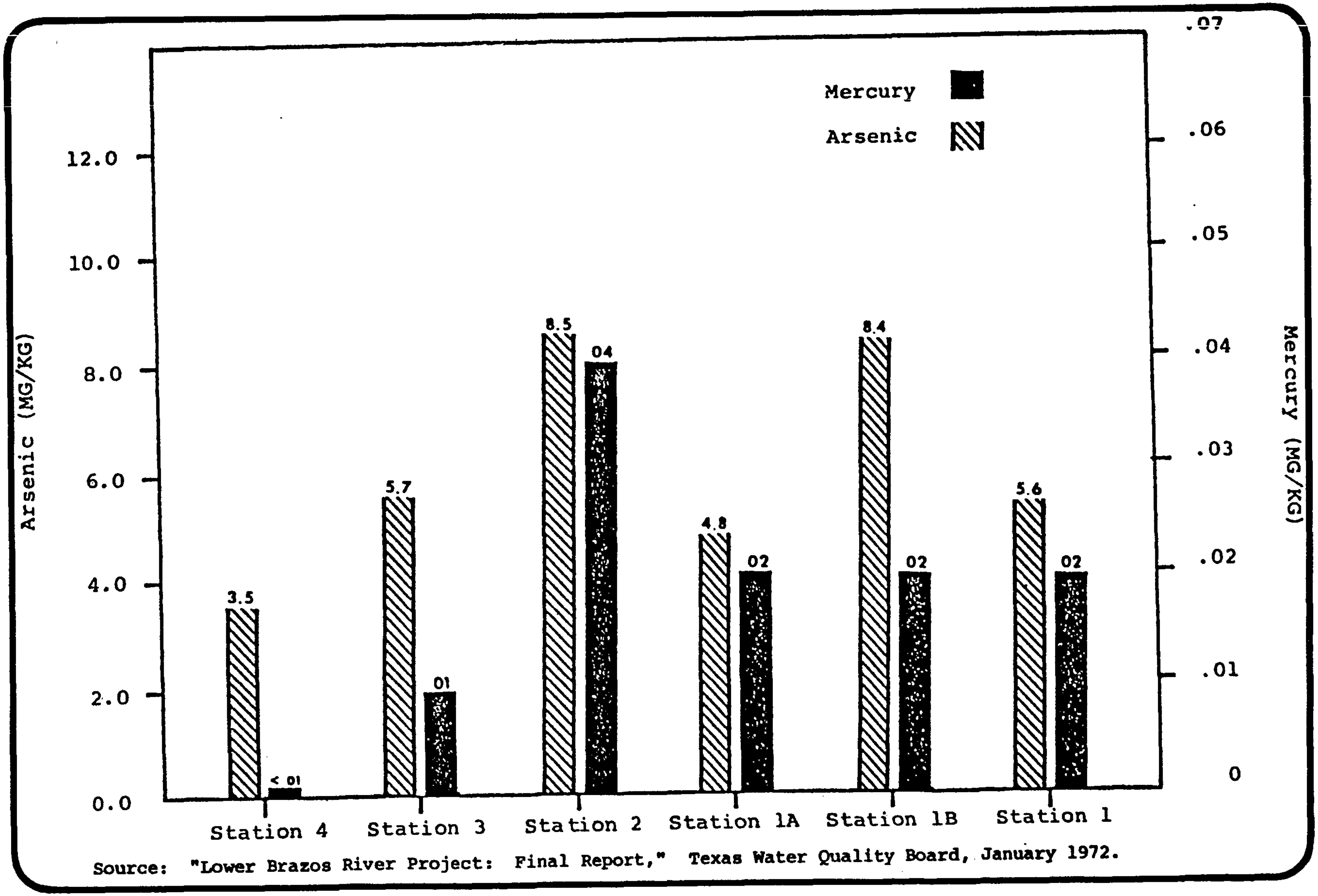
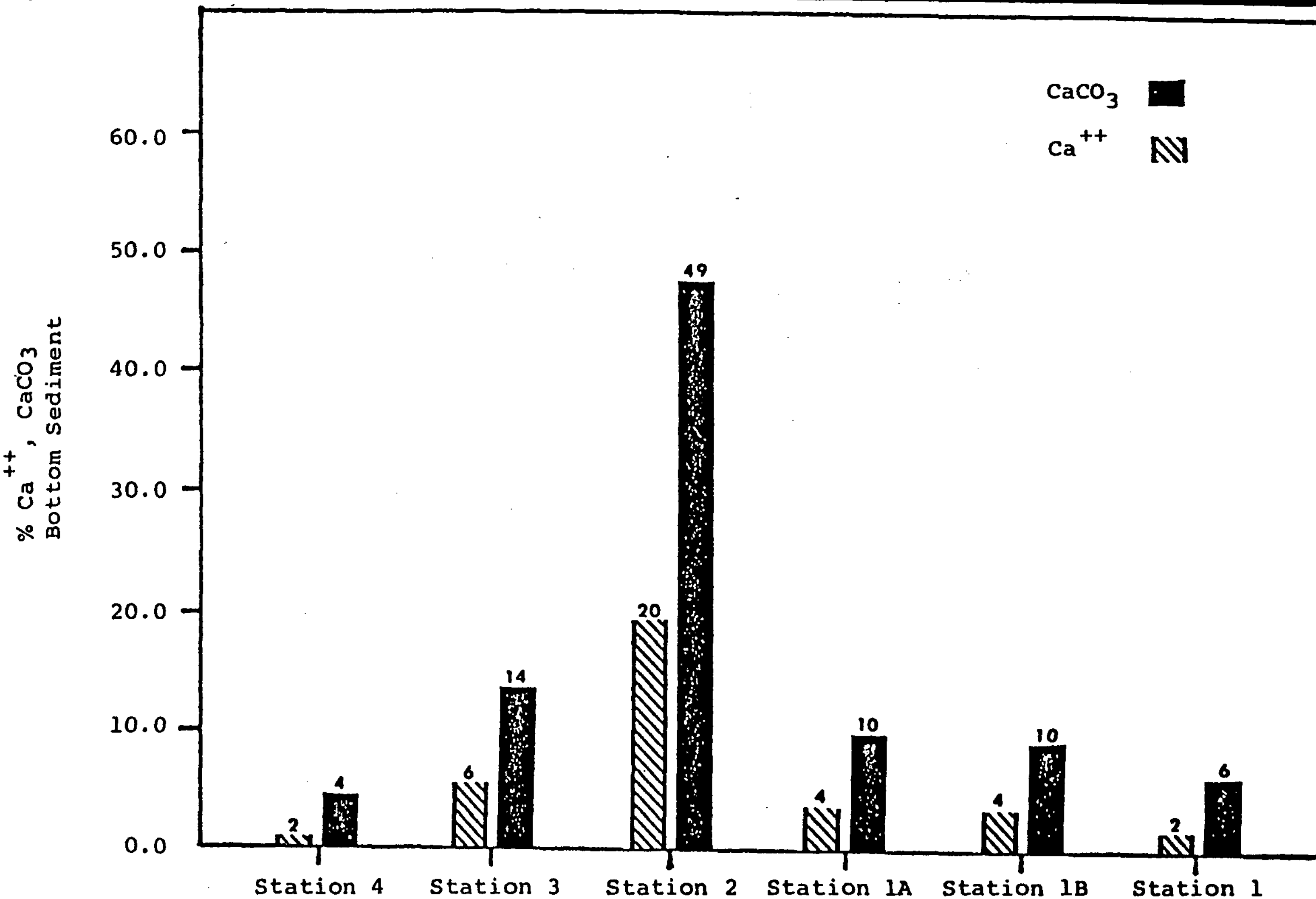
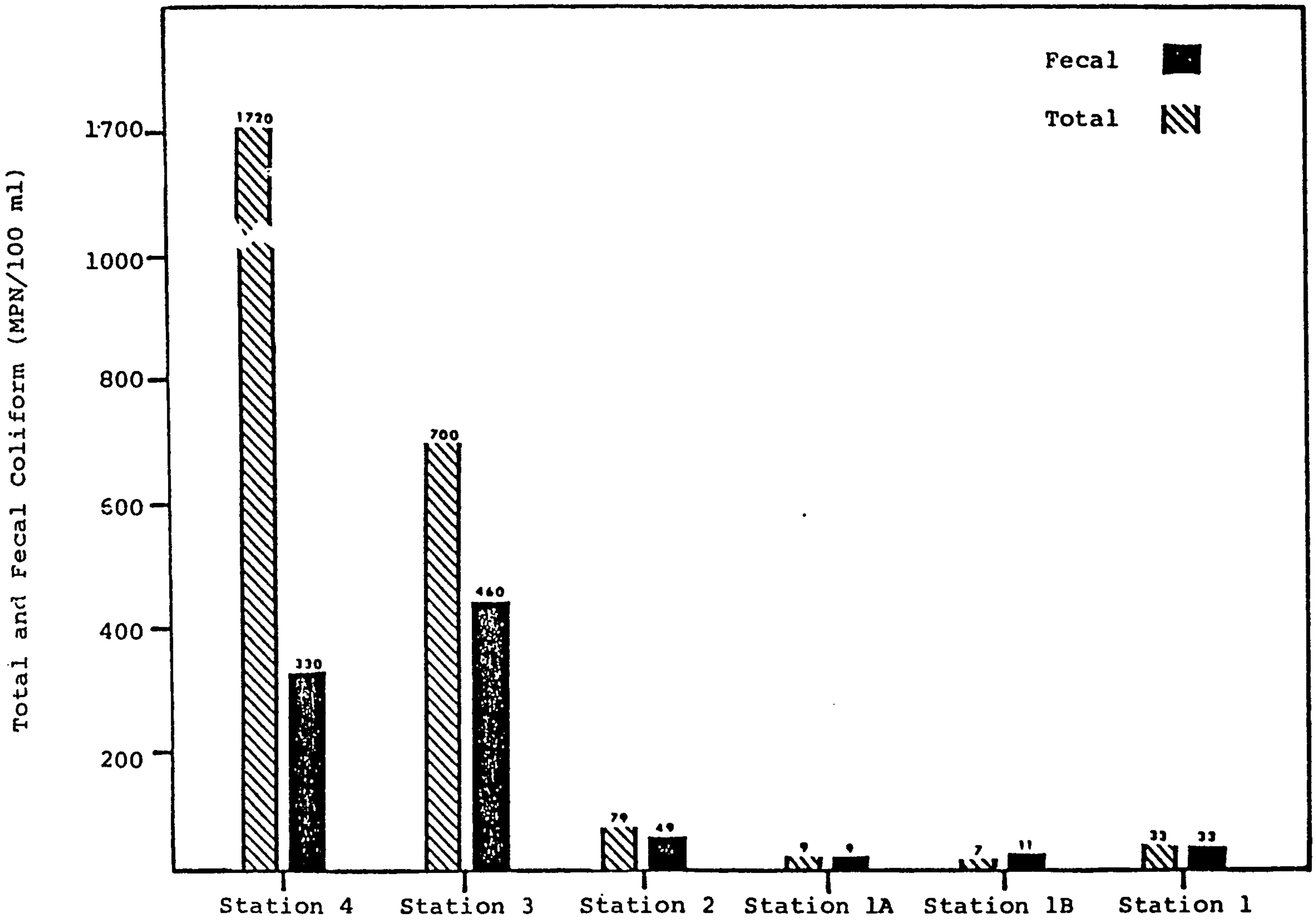


FIGURE B.2-18 Representative mercury and arsenic content of the Bottom Sediments at Each Station for the Brazos River



Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-19 Representative % Calcium and Calcium carbonate content of the Bottom Sediments at Each Station for the Brazos River



Source: "Lower Brazos River Project: Final Report," Texas Water Quality Board, January 1972.

FIGURE B.2-20 Total and Fecal Coliform Concentrations at Each Station during April, 1971 for the Brazos River

2. At Station 3, the DO level was only an average of 1.6 mg/l at the bottom. This may be caused by the relatively stagnant saltwater intrusion wedge at the bottom of the river at this station where there is little vertical mixing.
3. The pH values were on the high end of the acceptable range throughout the entire sampling area. This poses a potential problem for the growth and maintenance of most marine organisms.
4. The temperatures of all the recorded samples were well under the TWQB criteria; however, temperatures of 36^{o}C have often been recorded at Station 2 during periods of low river flow rates in mid and the late summer.
5. The data taken at Station 4 (near Dow Chemical Company's raw water stations for Brazoria Reservoir) met all Texas water quality standards except that the average fecal coliform count in April 1971 exceeded the State standard.

The primary source of leaching and displacement water for all sites would be the Brazos River Diversion Channel. The intake on the Diversion Channel would be located approximately at mile 2 of the river, which is adjacent to Bryan Mound. Recent data taken by Texas A & M University (Kehle, 1968) shows the region to be an estuarine environment with surface salinity levels as high as 20 ppt and bottom salinity levels as high as 27 ppt (summer months). Dissolved oxygen at mile 2 ranges from 9.3 mg/l (winter surface) down to 4.8 mg/l (spring bottom). All other water quality measurements made by Texas A & M University in this portion of the Brazos River were normal for a typical river/estuarine system. Seasonal variations in flow rates range from about 400 cfs to nearly 20,000 cfs.

A natural saltwater wedge, which generally has very little dissolved oxygen (DO), occurs in the bottom water in the upper portion of the estuary. This "dead saltwater wedge" is subject to frequent changes in position.

In summary, these data show that the Brazos River is subject to wide variations in water quality. These changes are primarily a function of river flow rate, although tidal interactions are an important factor in the lower river reaches.

The San Bernard River

The Brazos-Colorado Coastal basin lies between the Brazos River basin and the Colorado River basin, and has a drainage area of 1850 square miles. The San Bernard River, with a drainage area of 1005 square miles, is the major watercourse within the Brazos-Colorado Coastal Basin (Figure B.2-9).

San Bernard River streamflow characteristics, monitored since 1940 by USGS gaging station 08117500 near Boling, Texas, are summarized in Table B.2-9 below.

TABLE B.2-9 Streamflow Characteristics of San Bernard River near Boling, Texas

Event	Date	Cubic Feet Per Second (cfs)
Period of Record (since May 1954)		
Average Discharge	Period of Record	508
Maximum Daily Discharge	June 28, 1960	21,200
Minimum Daily Discharge	Nov. 27-30, 1956	2.4
Water Year 1975 (October 74 - September 75)		
Maximum Daily Discharge		15,000
Minimum Daily Discharge		33
Maximum Average Monthly Discharge	June	2,635
Minimum Average Monthly Discharge	March	84.7

Chemical analyses of streams indicate that runoff throughout the basin is generally of good to excellent quality. Limited data on the San Bernard River indicate that high to moderate flows usually contain less than 250 mg/l dissolved solids, and that high flows in the upper part of the river often contain less than 100 mg/l dissolved solids. Irrigation-return flows and oil-field brines are probably degrading the chemical quality of the river throughout its reach.

The nearest USGS station to the sites which monitors water quality is station 08117700 near West Columbia, where intermittent records are available from October 1969. Data at this station for water year 1975 (October 1974 to September 1975) are presented in Table B.2-8.

The TWQB standards for sulfate, TDS, pH and temperature were easily met for all samples taken at the West Columbia station. TWQB criterion of chloride concentration was exceeded twice. Dissolved oxygen concentrations and fecal coliform counts were not determined.

Coastal Wetland in the Brazos-Colorado Coastal Basin

The coastal area from the mouth of the Brazos River to the mouth of the San Bernard River (Figure B.2-9) is low lying, containing numerous ponds and creeks which drain to the coast after periodic tidal inundation. The wetlands between the Brazos and San Bernard Rivers drain an area of approximately 46 square miles. The major drainage path is Jones Creek, which flows in a southerly direction, interconnecting numerous small ponds and lakes, and finally discharging into the Intracoastal Waterway. No volumetric flow data are available for Jones Creek.

Jones Creek shows tidal influence with saltwater intrusion as far upstream as State Highway 36. Water quality samples for Jones Creek have been collected on only one date, July 10, 1975 (SEADOCK, Inc., 1975). Three points along Jones Creek were sampled (see Figure B.2-10). These data indicate that salinity at Station J-1, the sampling area furthest upstream, was 0.5 ppt which is the maximum salinity limit for fresh water classification. Table B.2-8 summarizes the water quality data which was obtained. TWQB Standards for the tidal reach of the San Bernard River were selected as a point of reference because of the proximity of the San Bernard to Jones Creek, and because no standards have been established exclusively for Jones Creek.

The information presented indicates that Jones Creek is an organically polluted stream. The biological oxygen demand (BOD), and the fecal coliform count exceeded TWQB (1972) standards for the San Bernard River. High fecal coliform counts are probably caused by inadequate sewage treatment. The community of Jones Creek is not serviced by public sewage treatment facilities. Individually owned septic tanks could be the cause of high BOD as well as high fecal coliform counts. Decaying vegetation from surrounding marshes probably contributes to the observed high BOD. With the exception of the high fecal coliform counts, the TWQB criteria for dissolved oxygen, pH, and temperature were within acceptable limits during the sampling period.

Freeport Harbor and Intracoastal Waterway

As noted previously, the original channel for the Lower Brazos River has been modified to provide a harbor for the city of Freeport. Freeport Harbor is a federally maintained deep draft navigation project that extends from deep water in the Gulf of Mexico through a jettied entrance to Freeport, Texas, a distance of about 7 miles. The present harbor components are pictured in Figure B.2-21. An easing of the bend from Station 65 to Station 139 and a widening of the entrance to the Brazos Harbor Channel were approved by the U.S. Army Corps of Engineers in 1975, with construction beginning later that year. Furthermore, through the River & Harbor Act of 1970, authorization has been given to deepen the 36 foot channels and turning basins to 45 feet and the Brazos Harbor Channel to 36 feet. The effect of these approved modifications on the harbor dimensions, and the maintenance dredging requirements associated with the existing harbor and the modification are summarized in Tables B.2-10 and B.2-11.

The Intracoastal Waterway connects with Freeport Harbor, the Brazos River Diversion Channel and the San Bernard River about 1 mile upstream from the Gulf. The U.S. Army Corps of Engineers operates a set of locks on each side of the Brazos River Diversion Channel. These locks are intended to keep detritus and silt from entering the Intracoastal Waterway during periods of high river flows. When the locks are closed, most of the Brazos River water goes directly into the Gulf. When the locks are open, however, there is evident mixing of waters between the Brazos River and the Intracoastal Waterway.

Freeport Harbor and the Intracoastal Waterway are tidal bodies. The diurnal tide in Freeport Harbor has a mean range of about 1.8 feet, and the mean high water is about 1.0 foot above mean sea level. During

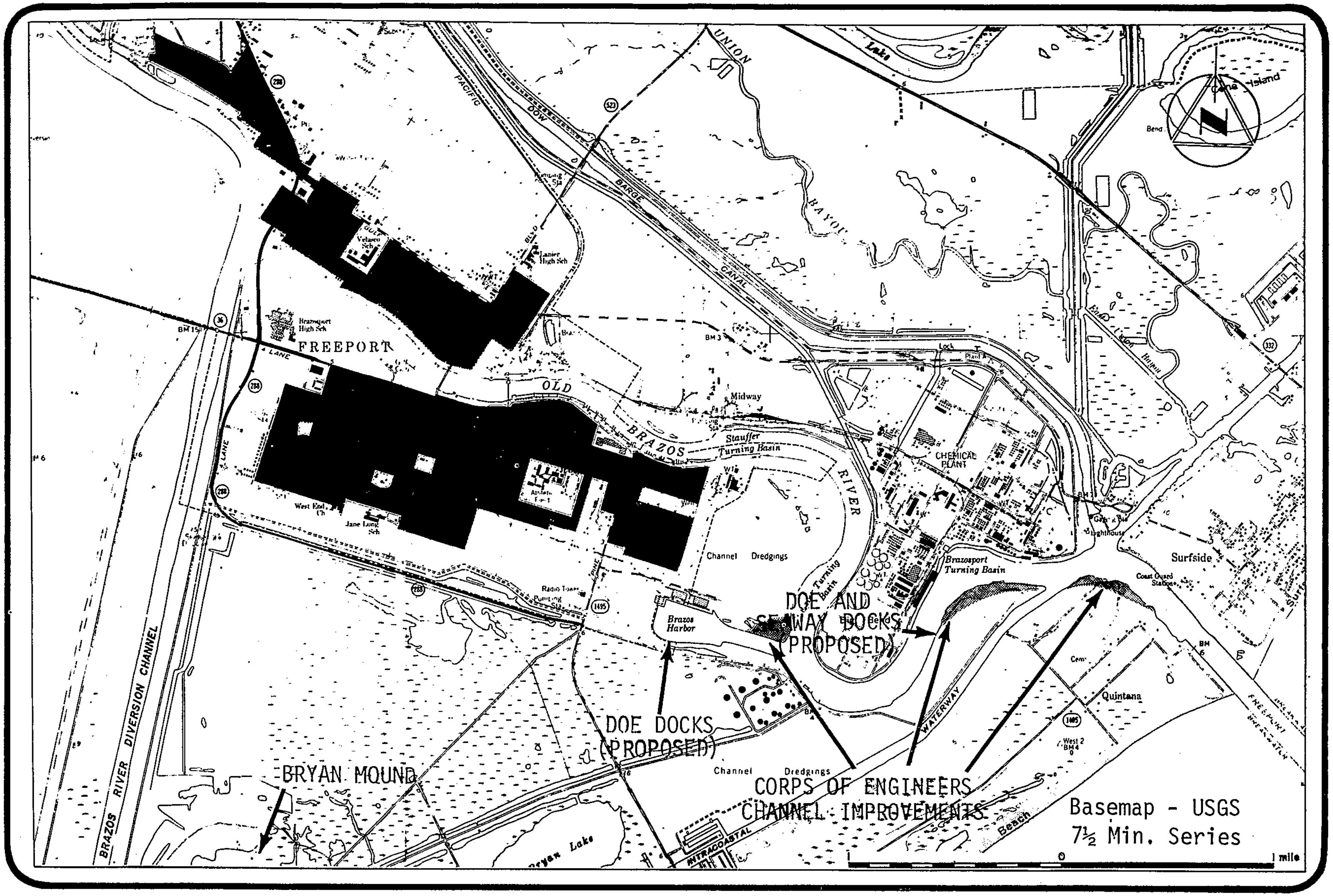


FIGURE B.2-21 Components of Freeport Harbor

TABLE B.2-10 Freeport Harbor Project Dimensions

Section of Waterway	Depth in Ft. Below low tide	Bottom Width in Feet	Length of Channel in Feet
Outer Bar Channel	38 [45]	300	16,000
Jetty Channel	36 [45]	200	4,400
Quintana Turning Basin			
Channel to Brazosport Turning Basin	36 [45]	200-350 [450]	6,351
Brazosport Turning Basin	36 [45]	744-800 [1050]	667
Channel to Upper Basin	36 [45]	350-375 [550]	7,156
Upper Turning Basin	36 [45]	600	600
Channel to Stauffer Chemical Plant	30[a]	200	6,090
Stauffer Turning Basin	30[a]	500	500
Brazos Harbor Channel Entrance	30 [36]	200 [450]	
Brazos Harbor Channel	30 [36]	200	2,690
Brazos Harbor Turning Basin	30 [36]	525	675

[a]Improved by local interest to a depth of 25 feet. Available depths are adequate for present commerce and maintenance to the authorized depth of 30 feet has not been required.

Note: Numbers in [] indicate approved modification.

Source: Maintenance Dredging of Freeport Harbor, Texas, Final Environmental Statement, U.S. Army Engineer District, Galveston, Texas, 10 July 1975.

TABLE B.2-11 Annual Shoaling Rates and Frequency of Dredging

	Outer Bar and Jetty Channel	Brazosport Basin in Upper Turning Basin	Brazos Harbor Channel and Turning Basin
Frequency of Dredging	12 months	24 months	60 months
Existing 36-Foot Project [a]	1,000,000 Cubic Yards	550,000 Cubic Yards	50,000 Cubic Yards
Modification of 36-Foot Project [b]	1,000,000 Cubic Yards	640,000 Cubic Yards	50,000 Cubic Yards
Proposed 45-Foot Project [a]	1,563,000 Cubic Yards	757,000 Cubic Yards	56,000 Cubic Yards

[a] Average annual shoaling rates experienced.

[b] Estimated average shoaling rates following construction of proposed modification.

Source: Maintenance Dredging of Freeport Harbor, Texas, Final Environmental Statement, U.S. Army Engineer District, Galveston, Texas, 10 July 1975.

prolonged periods of strong north winds in the winter, the water surface may be depressed as much as 3.5 feet below mean sea level. Sustained south and southeast winds during the summer raise the water level. Extreme fluctuations in water levels are caused by tropical storms and hurricanes.

As part of Freeport Harbor maintenance and modification dredging projects over the past several years, fairly complete water quality data have been collected for Freeport Harbor and the Intracoastal Waterway between Freeport Harbor and the Brazos River Diversion Channel. Table B.2-12 provides water quality data for Freeport Harbor and the Intracoastal Waterway collected by the U.S. Army Corps of Engineers in 1971 and 1974. Sediment quality data for Freeport Harbor, collected in 1971 by the Corps are presented in Table B.2-13. Water quality data for Freeport Harbor, obtained by the Texas Water Quality Board in 1972 and 1973 are provided in Table B.2-14. Table B.2-15 contains water and sediment quality data collected by the Corps during 1975. This table is especially noteworthy because it provides data before, during and after dredging in the harbor.

Figure B.2-22 provides the locations of the sampling stations for the data provided in Table B.2-12 and B.2-13, while the station locations for the data in Table B.2-15 are indicated in Figure B.2-23.

With the exception of high pH and low dissolved oxygen levels these data for Freeport Harbor generally conform with the TWQB criteria, and with the proposed EPA numerical criteria for water quality. Levels of zinc, copper, and lead were also notably high.

Nearshore Gulf of Mexico

The shallow coastal waters of the Gulf of Mexico southeast of Bryan Mound constitute the primary brine disposal location for all sites. To attain the necessary 50 foot depth for disposal, a site would be approximately 5 nautical miles offshore.

The large scale prevailing water circulation patterns in the western Gulf of Mexico along the Texas coast are toward the west and south as shown in Figure B.2-24. Water from the Mississippi Delta area

TABLE B.2-12 Water quality data collected by the U.S. Corps of Engineers (1971 and 1974) for Freeport Harbor, Texas and Intracoastal Waterway.

Station*	Date	Depth (ft)	Water Temp (°C)	Dissolved Oxygen (mg/l)	pH	Salinity (ppt)	Iron (mg/l)	Sulfate (mg/l)	Volatile Solids (mg/l)	Chemical Oxygen Demand (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Oil and Grease (mg/l)	Mercury (μg/l)	Lead (mg/l)	Zinc (mg/l)
1W	7/28/71	1.0	-	5.9	8.0	27.5	-	-							
		27.0		5.0	8.0	28.5			7800	227	1.0	60	< 0.5	< 1.0	< 0.2
	2/11/74	35.0	18.0	7.0	8.0	28.0	-	-							
2W	7/28/71	1.0	-	5.5	8.0	32.0									
		35.0	-	4.4	8.0	32.2			6700	205	1.1	< 1.0	< 0.5	< 1.0	< 0.2
	2/11/74	26.0	18.0	7.0	8.0	29.0									
3W	7/28/71	1.0	-	5.1	8.0	33.5	-	-							
		35.0	-	4.4	8.0	20.5	-	-	7600	216	1.3	< 1.0	< 0.5	< 1.0	< 0.2
	2/11/74	40.0	18.0	6.0	9.0	29.0	-	-							
4W	7/28/71	1.0	-	4.8	8.0	33.5	-	-							
		33.0	-	4.6	8.1	33.5	-	-	7200	193	1.4	< 1.0	< 0.5	< 1.0	< 0.2
	2/11/74	36.0	18.5	7.0	8.4	30.0	-	-							
5W	7/28/71	3.0	-	1.6	8.2	34.5	-	-	7000	203	4.9	< 1.0	< 0.5	< 1.0	< 0.2
	2/11/74	1.0	18.0	7.0	8.0	16.0	0.45	250							
		12.0	18.0	7.0	8.0	22.0	0.40	225							

TABLE B.2-12 continued.

Station*	Date	Depth (ft)	Water Temp (°C)	Dissolved Oxygen (mg/l)	pH	Salinity (ppt)	Iron (mg/l)	Sulfate (mg/l)	Volatile Solids (mg/l)	Chemical Oxygen Demand (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Oil and Grease (mg/l)	Mercury (µg/l)	Lead (mg/l)	Zinc (mg/l)
6W	7/28/71	2.0	-	1.5	8.2	35.7	-	-	6400	219	4.9	< 1.0	< 0.5	< 1.0	< 2.0
	2/11/74	1.0	18.0	9.0	7.7	13.0	0.18	225							
		12.0	18.0	7.0	7.7	22.0	0.61	225							
7W	7/28/71	1.0	-	0.8	8.3	35.0	-	-	7200	257	5.1	< 1.0	< 0.5	< 1.0	< 0.2
	2/12/74	[illegible].0	18.0	7.0	8.4	8.0	-	-							
		10.0	18.0	8.0	8.0	16.0	2.50	150							
8W	7/28/71	2.5	-	1.0	8.3	35.5	-	-	[illegible]000	219	5.0	< 1.0	< 0.5	< 1.0	< 0.2
	2/12/74	1.0	18.5	9.0	7.8	8.0	-	-							
		11.0	18.5	7.0	8.4	19.0	0.55	125							
9W	7/28/71	1.0	-	4.3	8.1	35.0	-	-							
		36.0	-	5.4	8.1	34.0	-	-	6900	250	1.4	4.0	< 0.5	< 1.0	< 0.2
	2/11/74	1.0	-	8.0	7.6	18.0	0.15	150							
		35.0	-	7.0	7.8	24.5	0.15	200							
10W	2/12/74	1.0	-	7.0	8.0	22.0	0.13	140							
		11.0	-	7.0	7.8	28.0	0.08	150							
11W	2/12/74	1.0	18.0	7.0	7.8	20.0	0.18	150							
		9.0	19.0	9.0	7.8	24.5	0.15	200							
12W	2/12/74	1.0	-	8.0	7.6	18.0	0.15	150							
		12.0	-	7.0	7.8	24.5	0.15	200							

*Sample locations shown on Figure B.5-1

Source: Maintenance Dredging of Freeport Harbor, Texas, Final Environmental Statement, U.S. Army Engineer District, Galveston, Texas, 10 July 1975.

TABLE B.2-13 Sediment quality data collected by U.S. Army Corps of Engineers (1971) for Freeport Harbor, Texas.

Station* Number	Date Sampled	Vol Sol mg/kg dry wt	COD mg/kg dry wt	Tot Kjel Nitrogen mg/kg dry wt	Oil and Grease mg/kg dry wt	Mercury mg/kg	Lead mg/kg	Zinc mg/kg
1S	7/27/71	44,900	38,400	7,400	910	0.6	26	58
2S	7/27/71	45,900	35,400	5,100	1,240	0.4	23	75
3S	7/27/71	46,700	29,600	6,100	740	0.5	25	49
4S	7/27/71	47,200	35,300	7,000	630	0.6	23	59
9S	7/27/71	49,400	27,200	4,600	720	0.9	23	49

* Sample locations shown on Figure B.5-1

Source: Maintenance Dredging of Freeport Harbor, Texas, Final Environmental Statement, U.S. Army Engineer District, Galveston, Texas, 10 July 1975.

TABLE B.2-14 Water quality data furnished by Texas Water Quality Board (1972 and 1973) for Freeport Harbor, Texas.

Location*	No. of Observa-tions	Water Temp °C	Turbid-ity (JTU)	Dissolved Oxygen (mg/l)	pH	Salinity (ppt)	Biochemical Oxygen Demand (mg/l)	Chemical Oxygen Demand (mg/l)	Coliform MPN/100 ml Total	Fecal
1-Freeport Harbor	1	16.7	10	7.30	8.4	36	1.0	114	3	3
2-Freeport Harbor	1	18.3	15	5.20	8.3	36	1.5	173	9	9
3-Freeport Harbor	1	18.3	12	5.50	8.3	36	1.0	122	23	23
4-Freeport Harbor	1	18.9	12	6.20	8.3	36	1.0	165	43	43
5-Freeport Harbor 2/	2	23.3	-	8.50	-	23	-	-	495	35
6-Freeport Harbor	1	18.9	15	7.75	8.3	34	1.0	179	15	15
7-Jetty Channel	1	16.7	20	8.20	8.4	40	1.0	185	3	3

1/ Sampled 16 November 1972 except as noted.

2/ Averaged data of samples taken 6 and 13 November 1973.

* Station locations are not precisely known.

Source: Maintenance Dredging of Freeport Harbor, Texas, Final Environmental Statement, U.S. Army Engineer District, Galveston, Texas, 10 July 1975.

TABLE B.2-15 Water quality monitoring data (1975) for Freeport Harbor, Texas.

	Sample* No.	Date Sampled	Dist ft From ^{c}L	Water Depth MLT-Ft	Water Temp °C	Dissolved Oxygen mg/l	pH	Salinity ppt	Conductivity umos/cm	Air Temp °C	Wind Direction	Moisture Content % Dry Wt	Total Solids mg/l	Total Solids % by Wt.	Total Volatile Solids mg/l	Total Volatile Solids % dry wt	Total Kjeldahl Nitrogen µg/l	Total Kjeldahl Nitrogen mg/kg
				CHANNEL AREA BEFORE DREDGING														
Sediment	F-75A-3S	4/23/75	0	39.0								100		50		6.3		1,400
Water	F-75A-3W	4/23/75	0	39.0	22.0	7	9.0	20.5	32,700	27.0	SE		24,300		5,500		0.22	
Sediment	F-75A-13S	4/23/75	150N	40.0								138		42		9.0		1,900
Water	F-75A-13W	4/23/75	-150N	40.0	22.0	8	9.0	20.0	32,000	26.0	SE		22,100		4,500		0.33	
Sediment	F-75A-4S	4/23/75	0	36.0								100		50		8.0		1,500
Water	F-75A-4W	4/23/75	0	36.0	22.0	9	9.0	20.0	32,000	26.0	SE		22,300		4,350		0.25	
Sediment	F-75A-14S	4/23/75	0	38.0								104		49		7.7		1,600
Water	F-75A-14W	4/23/75	0	38.0	22.0	9	9.0	19.5	31,300	25.0	SE		20,300		4,200		0.27	
				DURING DREDGING (See Note 4)														
Water	F-75B-3W	5/23/75	0	35.5	28.0	6	9.0	24.0	37,700	30.0	SE		25,100		4,400		3.5	
Water	F-75B-13W	5/23/75	150N	34.5	28.0	7	9.0	25.0	39,100	30.0	SE		26,800		5,000		1.1	
Water	F-75B-4W	5/23/75	0	34.5	28.0	7	9.0	23.0	36,200	30.0	SE		28,200		5,400		1.3	
				(See Note 5)														
Water	F-75C-4W	6/10/75	0	36.0	25.0	2.6	9.0	31.0	47,500	26.0	S		35,700		6,600		1.3	
Water	F-75B-14W	6/10/75	0	36.0	25.0	4	9.0	30.0	46,200	26.0	S		34,200		5,800		1.2	
				AFTER DREDGING														
Sediment	F-75C-3S	9/18/75	0	38.0								94		52		7.2		1,260
Water	F-75C-3W	9/18/75	0	38.0	29.0	6	9.0	24.0	37,700	31.0	SE		26,700		4,100		0.8	
Sediment	F-75C-13S	9/18/75	150N	37.0								158		39		10.8		1,710
Water	F-75C-13W	9/18/75	150N	37.0	29.0	6	9.0	23.0	36,200	31.0	SE		26,600		4,200		0.9	
Sediment	F-75D-4S	9/18/75	0	36.0								83		55				1,010
Water	F-75D-4W	9/18/75	0	36.0	29.0	6	9.0	23.0	36,200	31.0	SE		27,500		5,100	8.4	1.4	
Sediment	F-75C-14S	9/18/75	0	39.0								77		56				1,620
Water	F-75C-14W	9/18/75	0	39.0	29.0	7	9.0	25.0	39,100	31.0	SE		26,100		4,200	6.6	1.4	

TABLE B.2-15 continued.

	Sample* No.	Oil and Grease mg/l	Oil and Grease mg/kg	Chemical Oxygen Demand mg/l	Chemical Oxygen Demand mg/kg	Chlorides mg/l	Arsenic µg/l	Arsenic mg/kg	Cadmium mg/l	Cadmium mg/kg	Chromium (Total) mg/l	Chromium (Total) mg/kg	Copper mg/l	Copper mg/kg	Lead mg/l	Lead mg/kg	Mercury µg/l	Mercury mg/kg	Nickel mg/l	Nickel mg/kg	Zinc mg/l	Zinc mg/kg
CHANNEL AREA BEFORE DREDGING																						
Sediment	F-75A-3S		670		16,600			5.8		2.4		16		15		20		0.37		22		75
Water	F-75A-3W	6.6		66		11,000	8		0.004		0.04		0.23		0.02		0.33		0.06		0.29	
Sediment	F-75A-13S		630		27,100			6.9		3.5		22		17		26		<0.1		30		158
Water	F-75A-13W	3.9		107		9,000	2		0.004		0.03		0.13		0.01		0.69		0.03		0.22	
Sediment	F-75A-4S		560		20,900			4.0		2.4		20		17		22		<0.1		25		90
Water	F-75A-4W	2.8		144		9,800	0		0.004		0.04		0.20		0.01		0.82		0.06		0.32	
Sediment	F-75A-14S		610		24,800			5.7		2.8		20		19		25		0.11		30		103
Water	F-75A-14W	2.3		113		8,500	0		0.003		0.03		0.37		0.01		0.51		0.06		1.0	
DURING DREDGING (See Note 4)																						
Water	F-75B-3W	0		106		12,500	2		<0.001		0.03		0.08		0.02		<0.2		0.02		0.08	
Water	F-75B-13W	0		101		13,000	3		<0.001		0.03		0.10		0.01		<0.2		0.02		0.15	
Water	F-75B-4W	0		188		13,200	1		<0.001		0.03		0.11		0.02		<0.2		0.02		0.12	
(See Note 5)																						
Water	F-75C-4W	0		314		8,200	0		<0.003		0.04		0.16		0.04		<0.2		0.06		0.16	
Water	F-75B-14W	0		133		17,000	1		<0.003		0.04		0.09		0.03		<0.2		0.05		0.40	
AFTER DREDGING																						
Sediment	F-75C-3S		470		16,600			0.3		0.5		18		10		22		<0.1		24		61
Water	F-75C-3W	8.6		59		12,200	0.1		<0.003		0.07		0.13		0.01		<0.2		0.08		0.13	
Sediment	F-75C-13S		745		27,500			0.5		1.2		28		18		28		<0.1		36		85
Water	F-75C-13W	8.8		59		13,000	0.2		<0.002		0.01		0.18		0.01		0.47		0.08		0.13	
Sediment	F-75D-4S		500		19,600			0.4		0.9		21		13		20		<0.1		35		73
Water	F-75D-4W	5.6		49		13,400	0.1		<0.002		0.06		0.14		0.00		0.26		0.08		0.14	
Sediment	F-75C-14S		405		21,300			0.4		0.4		21		8		14		<0.1		30		64
Water	F-75C-14W	7.5		31		12,800	0.5		<0.003		0.09		0.34		0.00		0.39		0.15		0.22	

TABLE B.2-15 continued.

	Sample* No.	Date Sampled	Dist ft From C	Water Depth MLT-Ft	Water Temp °C	Dissolved Oxygen mg/l	pH	Salinity ppt	Conductivity umos/cm	Air Temp °C	Wind Direction	Moisture Content % Dry Wt	Total Solids mg/l	Total Solids % by Wt.	Total Volatile Solids mg/l	Total Volatile Solids % Dry wt.	Total Kjeldahl Nitrogen µg/l	Total Kjeldahl Nitrogen mg/kg
				SPILLWAY AREA BEFORE DREDGING														
Water	F-75A-15W	4/23/75	0	12.0	24.0	9	9.0	14.0	23,000	26.0	SE		13,800		2,650		0.28	
Water	F-75A-16W	4/23/75	0	13.0	24.0	9	9.0	12.0	20,000	26.0	SE		10,800		2,250		0.38	
				DURING DREDGING (See Note 4)														
Water	F-75A-17W	5/23/75	–	---	28.0	7	9.0	30.0	46,200	30.0	SE		33,300		5,800		14	
Water	F-75B-15W	5/23/75	0	8.5	28.0	8	9.0	14.0	23,000	30.0	SE		13,700		2,200		1.5	
Water	F-75B-16W	5/23/75	0	6.5	28.0	8	9.0	13.0	21,500	30.0	SE		12,400		2,200		1.9	
				(See Note 5)														
Water	F-75B-17W	6/10/75	–	---	28.0	18	9.5	15.0	24,500	26.0	S		15,100		2,700		5.5	
Water	F-75C-15W	6/10/75	0	9.0	28.0	7	9.0	16.0	26,000	26.0	S		15,500		2,500		1.8	
Water	F-75C-16W	6/10/75	0	10.0	28.0	7	9.0	17.0	27,600	26.0	S		10,000		1,500		1.3	
				AFTER DREDGING														
Water	F-75D-15W	9/18/75	0	11.0	28.5	7	9.0	20.0	32,000	31.0	SE		22,800		4,100		1.5	
Water	F-75D-16W	9/18/75	0	11.0	28.5	6	9.0	20.0	32,000	31.0	SE		22,300		3,900		1.1	

TABLE B.2-15 continued.

	Sample No. *	Oil and Grease mg/l	Oil and Grease mg/kg	Chemical Oxygen Demand mg/l	Chemical Oxygen Demand mg/kg	Chlorides mg/l	Arsenic µg/l	Arsenic mg/kg	Cadmium mg/l	Cadmium mg/kg	Chromium (Total) mg/l	Chromium (Total) mg/kg	Copper mg/l	Copper mg/kg	Lead mg/l	Lead mg/kg	Mercury µg/l	Mercury mg/kg	Nickel mg/l	Nickel mg/kg	Zinc mg/l	Zinc mg/kg
						SPILLWAY AREA BEFORE DREDGING																
Water	F-75A-15W	0.0		90		6,500	1		0.004		0.03		0.12		0.01		0.69		0.04		0.16	
Water	F-75A-16W	2.1		83		5,200	1		0.004		0.04		0.07		.0.01		1.2		0.02		0.14	
						DURING DREDGING (See Note 4)																
Water	F-75A-17W	0		162		17,200	6		<0.001		0.03		0.06		0.02		<0.2		0.04		0.08	
Water	F-75B-15W	3		87		7,000	0		<0.003		0.04		0.10		0.02		0.22		0.05		0.14	
Water	F-75B-16W	1		102		6,000	0		<0.001		0.04		0.20		0.04		0.28		0.06		0.25	
						(See Note 5)																
Water	F-75B-17W	2		102		7,800	4		<0.002		0.01		0.08		0.02		0.28		0.02		0.15	
Water	F-75C-15W	0		102		7,500	0		<0.001		0.04		0.16		0.03		<0.2		0.06		0.16	
Water	F-75C-16W	2		80		4,500	5		<0.002		0.04		0.08		0.02		0.21		0.04		0.21	
						AFTER DREDGING																
Water	F-75D-15W	8.2		45		11,100	0.2		<0.001		0.06		0.17		0.02		0.26		0.09		0.13	
Water	F-75D-16W	7.5		45		10,800	0.2		<0.001		0.06		0.15		0.02		0.21		0.07		0.16	

NOTES: 1. EPA Manual states: "When the chloride level exceeds 1,000 mg/l, the minimum accepted value for the COD (of water) will be 250 mg/l. COD levels which fall below this value are highly questionable because of the high chloride correction which must be made." Actual COD results are shown.

2. Tests for Cd, Cu, Pb, Ni and Zn were performed on chelated samples.

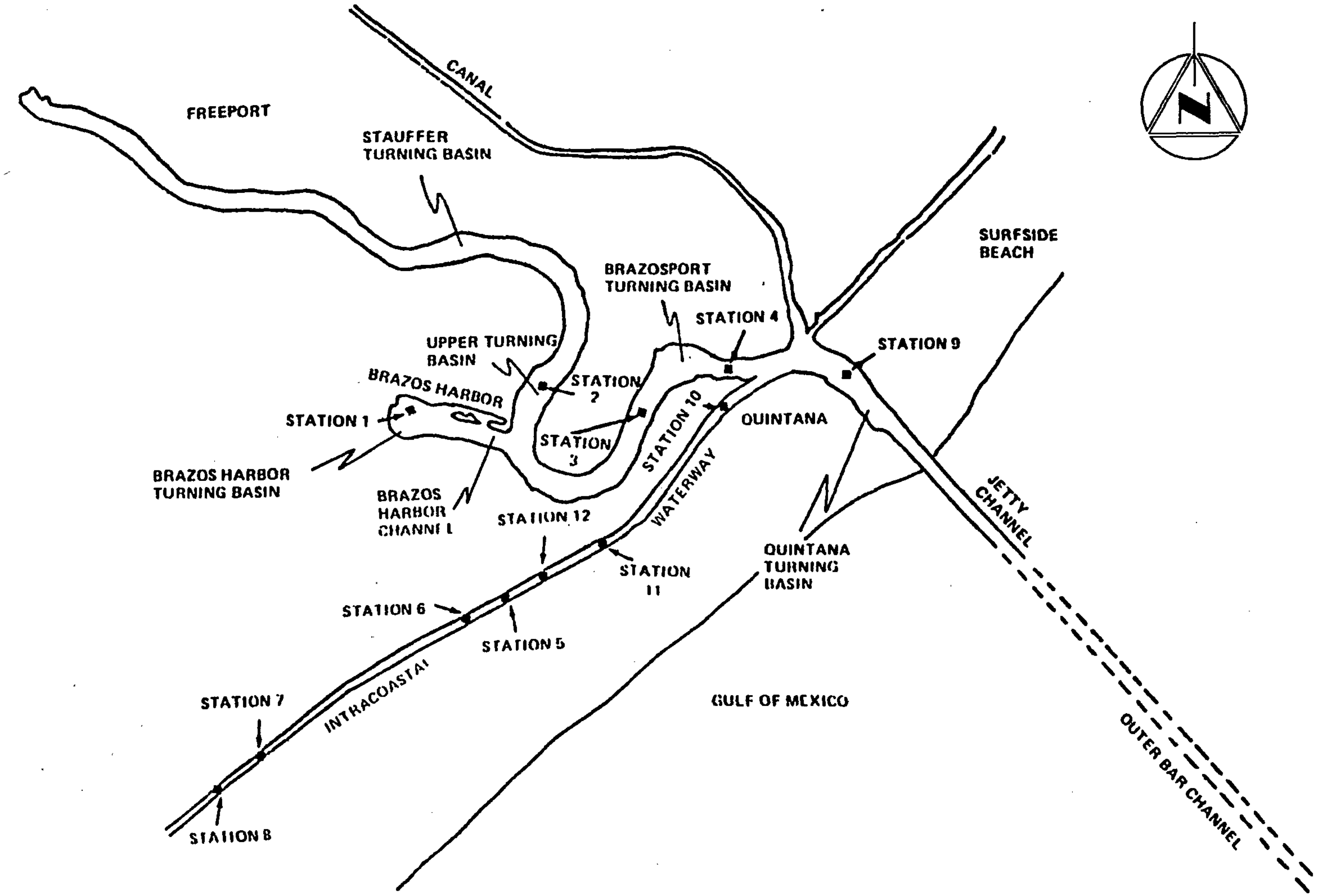
4. Dredge located at Freeport Harbor Station 108+00 at time of sampling.

5. Dredge located at Freeport Harbor Station 75+00 at time of sampling.

6. Recent tests have indicated that the container used to collect water samples was contaminating samples with excess copper and zinc. Therefore, resuls for copper and zinc are not considered valid for all water samples tested.

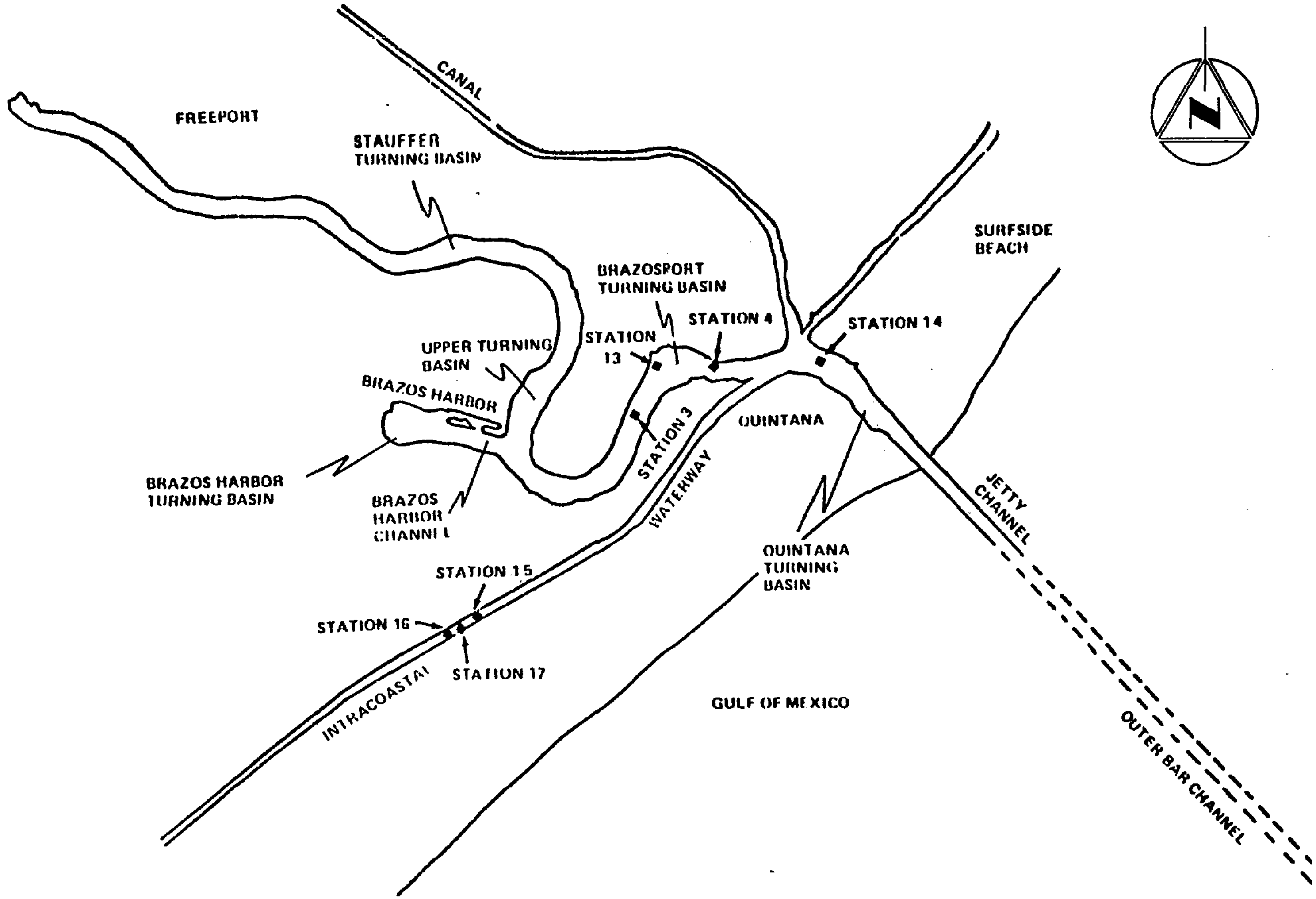
*The last one or two digits in the sample number correspond to the sampling station number. The locations of these stations are indicated in Figure B.5-2.

Source: Water Quality Monitoring Program Results for Hopper Dredging of the Entrance and Jetty Channels of Freeport Harbor, Texas, U.S. Army Engineer District, Galveston, Texas, 2 September 1975.



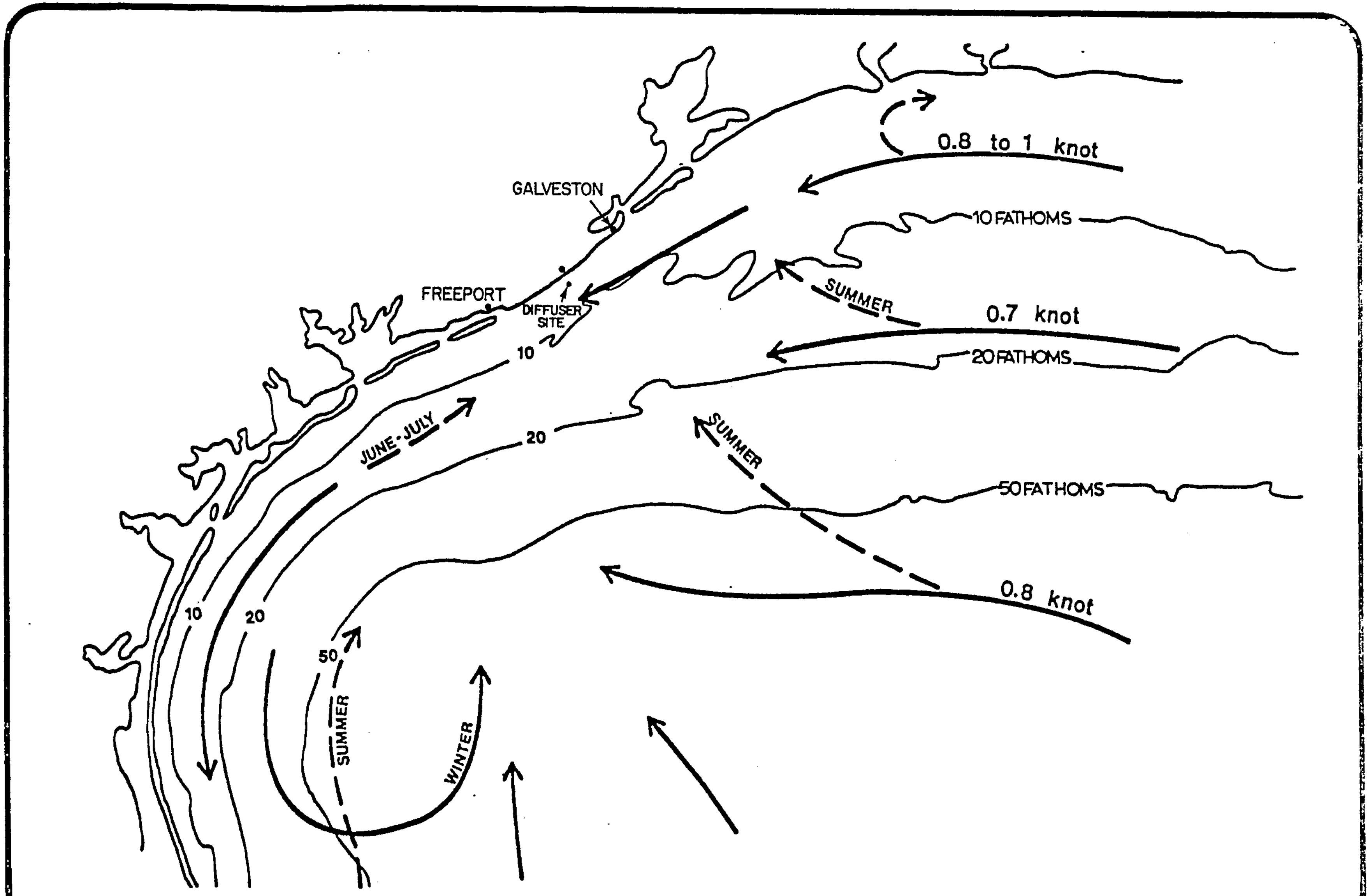
Source: Maintenance Dredging of Freeport Harbor, Texas, Final Environmental Statement, U.S. Army Engineer District, Galveston, Texas, 10 July 1975.

FIGURE B.2-22 Location of Sampling Stations for 1971 and 1974, Survey by U.S. Corps of Engineers



Source: Data received from Texas Water Quality Board from Corps of Engineers' Freeport Harbor Dredging Project. Monitoring Program, 25 March 1976.

FIGURE B.2-23 Location of Sampling Stations for 1975 Survey by U.S. Corps of Engineers



SOURCE: SEADOCK, 1975.

FIGURE B.2-24. Currents off the Texas coast.

flows westward in the Gulf of Mexico toward a zone of convergence off the Texas coast. The surface currents in the region are variable and strongly affected by wind patterns, large scale permanent currents and tidal currents. Surface water movements respond principally to prevailing offshore wind patterns, as described in Section B.2.3, and flow generally toward the southwest except in the summer when the zone of convergence shifts from southern Texas to the Freeport vicinity, and the current moves toward the northeast. Typical current speeds in the area range from 0.3 to 0.8 knots, while maximum speeds rarely exceed 2.0 knots. While stagnation periods are known to occur in the water movements in the region, it is estimated that the maximum period would not exceed 2 days. Differences in currents at the surface and bottom have been reported in shallow waters, especially in summer.

In the Galveston area wave heights are usually four feet or less, however, heights over 10 feet have been experienced throughout the year, and heights over 20 feet have occurred in 9 months of the year. The tidal range in Freeport Harbor is estimated to be 1.8 feet and is predominantly diurnal. Hurricanes produce surges as great as 15 feet. Tidal velocity over the nearshore continental shelf is estimated at 0.5 knots, however, near tidally influenced bay entrances values of 3.7 knots have been recorded.

Average ambient temperatures of the surface waters in the nearshore region of the Texas coast range from 54^{o}F in January to 85^{o}F in August. Throughout most of the year positive temperature and salinity gradients occur toward the south and east from the Texas coastline. Only during the summer months do the isotherms and isohalines become perpendicular to the coastline when large quantities of fresh water flow into the Gulf from coastal rivers. Density patterns generally follow temperature and salinity, however, values decrease with distance toward the south and east of Galveston. Vertical profiles of temperature, salinity and density show that weak to moderate thermal gradients generally occur in nearshore waters from October to May but these waters are nearly isothermal during the summer. Salinity and density are relatively homogeneous most of the year at depths less than 20 to 25 meters.

Most of the chemical parameters measured in Gulf of Mexico waters in the vicinity of the proposed Bryan Mound brine diffuser site are within the range of expected values for coastal marine waters. However, some unusual aspects are apparent. For example, nutrient salt levels (NH_3, NO_2, NO_3, and PO_4) in the water column near the diffuser site are often low, but increase in concentration during the late winter period. Dissolved oxygen values are generally above 5.0 mg/l, but occasionally are low in the bottom waters during the summer. These low DO values are also reflected in the reducing nature of the sediment during the summer. The low levels of the these parameters could cause a reduction in biological productivity and diversity in the diffuser area. Heavy metals in water column and sediments in the area of the brine diffuser are within the range expected for coastal regions. Oil and grease concentrations increase with distance offshore from the proposed site to the shipping lanes. Suspended matter varies seasonally due to river input and biological productivity. Chemical water quality and sediment data collected at two sampling stations in the region (Figure B.2-25) are presented in Tables B.2-16 to -19. A complete discussion of the physical and chemical water quality data is presented in Appendix G.

B.2.2.2 Subsurface Water Systems

Occurrence of Ground Water

The subsurface materials of the region are characterized by more than 9000 feet of Miocene and younger, poorly consolidated sediments consisting primarily of sands and shales (see Section B.2.1). Sand units comprise about 40 percent of the total thickness and generally qualify as aquifers in that they contain sufficient saturated permeable material to yield significant quantities of water to wells. Fresh to slightly saline water is found only in the uppermost units. Traditionally, only those formations containing fresh water are studied in detail by ground water hydrologists. Therefore, information regarding the characteristics of deeper formations or those containing saline water is normally lacking except in areas where extensive petroleum exploration has taken place.

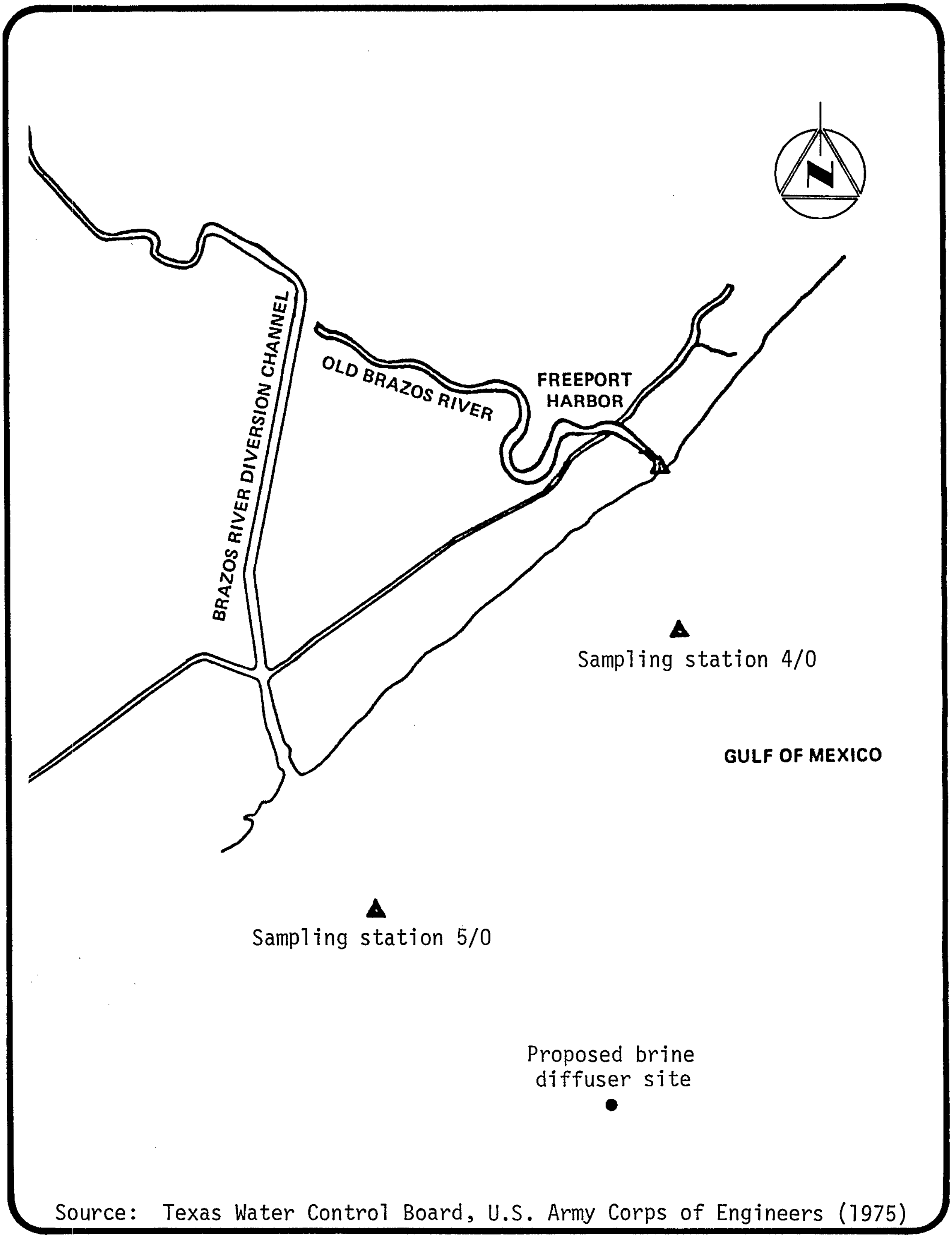


FIGURE B.2-25 Location of sampling stations in the Gulf of Mexico near Bryan Mound. (Data in Tables B.2-17, B.2-18, B.2-19)

TABLE B.2-16 Water quality data for the Gulf of Mexico near the Bryan Mound site (4/15/74)

Field Sample Number	4-W/O
Date Sampled	15 Apr 74
Source	Filtered Composite of 9 Samples from Station 4/0 (figure b.2-25)
Total Solids	32,100
Total Volatile Solids	9,700
Total Kjaldahl Nitrogen	0.3
Total Organic Nitrogen	0.2
Ammonia Nitrogen	0.1
Total Organic Carbon	14
Oil and Grease	0.0
Chemical Oxygen Demand	8.2
Arsenic as µg/l	2
Cadmium Cd	0.05
Chromium (Total) Cr µg/l	13
Copper Cu	0.06
Lead Pb	0.23
Mercury Hg µg/l	14
Nickel Ni	0.04
Zinc Zn	0.07
Chlorides Cl	13,000

NOTES: 1. All results in mg/l except as noted.

2. EPA Manual states: "When the chloride level exceeds 1,000 mg/l, the minimum accepted value which falls below this value is highly questionable because of the high cloride correction shown."

3. Lead and Zinc tests were performed on acid-digested samples.

Source: Water Quality Monitoring Program Results for Hopper Dredging of the Entrance and Jetty Channels of Freeport Harbor, Texas, U.S. Army Engineer District, Galveston, Texas, 2 September 1975.

TABLE B.2-17 Water and bottom sediment quality data for the Gulf of Mexico near the Bryan Mound site (9/17/75)

Type	Sediment	Water
Sample No.	FH-75A-3S	FH-75A-3W
Date Sampled	9/17/75	9/17/75
Station (see figure B.2-25)	4/0	4/0
Turbidity FTU	-	5
Dissolved Oxygen mg/l	-	6
pH	-	9.5
Salinity ppt	-	28.0
Water Temp °C	-	26.5
Air Temp °C	-	25.0
Wind Direction	-	N
Moisture Content % Dry Weight	37.9	-
Total Solids mg/l	-	31,000
Total Solids % By Wt.	62.1	-
Tot. Vol. Solids mg/l	-	5,580
Tot. Vol. Solids % By Wt.	6.2	-
Tot. Kjeldahl Nitrogen mg/l	-	0.2
Tot. Kjeldahl Nitrogen mg/kg	360	-
Oil & Grease mg/l	-	2
Oil & Grease mg/kg	306	-
Chem. Oxygen Demand mg/l	-	104
Chem. Oxygen Demand mg/kg	18,600	-
Chlorides mg/l	-	15,000

TABLE B.2-17 continued.

Type	Sediment	Water
Sample No.	FH-75A-3S	FH-75A-3W
Date Sampled	9/17/75	9/17/75
Station (see figure B.2-25)	4/0	4/0
Arsenic μg/l	-	<10
Arsenic mg/kg	5.3	-
Cadmium mg/l	-	<0.01
Cadmium mg/kg	<1	-
Chromium (Total) mg/l	-	<0.03
Chromium (Total) mg/kg	18	-
Copper mg/l	-	0.21
Copper mg/kg	15	-
Lead mg/l	-	<0.05
Lead mg/kg	24	-
Mercury μg/l	-	<0.2
Mercury mg/kg	<0.1	-
Nickel mg/l	-	<0.02
Nickel mg/kg	21	-
Zinc mg/l	-	0.09
Zinc mg/kg	88	-

Source: Data received from Texas Water Quality Board from Corps of Engineers' Freeport Harbor Dredging Project. Monitoring Program, 25 March 1976.

TABLE B.2-18 Water and bottom sediment quality data for the Gulf of Mexico near the Bryan Mound site (12/2/75).

Type	Sediment	Water
Sample No.	FH-75B-3	FH-75B-3
Date Sampled	12/2/75	12/2/75
Station (see figure B.2-25)	4/0	4/0
Turbidity FTU	-	20
Dissolved Oxygen mg/l	-	7
pH	-	9.0
Salinity ppt	-	29.0
Water Temp °C	-	16.0
Air Temp °C	-	17.0
Wind Direction	-	SE
Moisture Content % Dry Weight	39.9	-
Total Solids mg/l	-	32,000
Total Solids % By Wt.	60.1	-
Tot. Vol. Solids mg/l	-	5,740
Tot. Vol. Solids % By Wt.	5.6	-
Tot. Kjeldahl Nitrogen mg/l	-	0.3
Tot. Kjeldahl Nitrogen mg/kg	310	-
Oil & Grease mg/l	-	<1
Oil & Grease mg/kg	248	-
Chem. Oxygen Demand mg/l	-	93
Chemical Oxygen Demand mg/kg	19,300	-
Chlorides mg/l	-	15,000

TABLE B.2-18 continued.

Type	Sediment	Water
Sample No.	FH-75B-3	FH-75B-3
Date Sampled	12/2/75	12/2/75
Station (see figure B.2-25)	4/0	4/0
Arsenic µg/l	-	<10
Arsenic mg/kg	3.5	-
Cadmium mg/l	-	<0.01
Cadmium mg/kg	<1	
Chromium (Total) mg/l	-	<0.03
Chromium (Total) mg/kg	10	-
Copper mg/l	-	<0.02
Copper mg/kg	7	-
Lead mg/l	-	<0.05
Lead mg/kg	10	-
Mercury µg/l	-	<0.2
Mercury mg/kg	<0.1	-
Nickel mg/l	-	<0.02
Nickel mg/kg	14	
Zinc mg/l		<0.02
Zinc mg/kg	45	-

Source: Data received from Texas Water Quality Board from Corps of Engineers' Freeport Harbor Dredging Project, Monitoring Program, 25 March 1976.

TABLE B.2-19 Sediment quality data for the Gulf of Mexico near the Bryan Mound site (4/16/74)

Field Sample No.*	5-S /O
Date Sampled	4/16/74
Source	Undisturbed Area
Total Solids % by Wt.	56
Total Volatile Solids % by Wt.	8.0
Tot. Kjel Nitrogen mg/kg Dry Basis	890
Ammonia Nitrogen mg/kg Dry Basis	64
Tot. Organic Nitrogen mg/kg Dry Basis	830
Tot. Organic Carbon mg/kg Dry Basis	4600
Oil and Grease mg/kg Dry Basis	480
COD mg/kg Dry Basis	29,000
Arsenic mg/kg Dry Basis	2.9
Cadmium mg/kg Dry Basis	1.6
Chromium mg/kg Dry Basis	3.6
Copper mg/kg Dry Basis	13
Lead mg/kg Dry Basis	23
Mercury mg/kg Dry Basis	0.32
Nickel mg/kg Dry Basis	46
Zinc mg/kg Dry Basis	57

*Sample Station Locations shown on Figure B.6-1.

Source: Water Quality Monitoring Program Results for Hopper Dredging of the Entrance and Jetty Channels of Freeport Harbor, Texas, U.S. Army Engineer District, Galveston, Texas, 2 September 1975.

In the study region, fresh to slightly saline water occurs only in the Chicot and the Evangeline aquifers. Each comprises parts of several geologic formations (Table B.2-20) that are regionally grouped into the Gulf Coast Aquifer. The following summary of ground water conditions in the region is based on the work of Sandeen and Wesselman (1973) and Hammond (1969).

Water in the Gulf Coast Aquifer occurs under both water table (unconfined) and artesian (confined) conditions. Where water table conditions occur, there is no confining bed and the water is exposed to atmospheric pressure only. Water in a well tapping a water table aquifer will stand at the top of the zone of saturation. Water table conditions occur principally in the shallow water sands, less than 100 feet deep. The shallow water table sands may be recharged from rainfall on the land surface directly overlying them.

Artesian conditions exist in the deeper aquifers, where a confining bed of clay or shale causes the water to be under pressure greater than atmospheric pressure. A well tapping an aquifer under artesian conditions will become filled with water above the depth where the sand was first encountered. If pressure is sufficient the well may flow at the surface. Artesian wells, however, do not necessarily flow. Artesian sands are usually recharged from rainfall on distant outcrops. The regional dip of the Gulf Coastal Plain toward the Gulf of Mexico was described in Section B.2.1, as was the increase in dip with depth. From this, it may be seen that a formation yielding artesian water to a well at a depth of 1000 feet is probably recharged from rainfall on an outcrop area 35 to 40 miles inland.

The Gulf Coast Aquifer also includes the sediments which filled the post glacial estuaries of the Brazos, Colorado, and Rio Grande Rivers (Section B.2.1). The valley fill sediments are generally coarser than the underlying sediments of the Beaumont Formation and thus may act as conduits for discharge from or recharge to aquifers or for movement of contaminants.

The Evangeline aquifer consists of alternating sands and clays ranging from about 2000 feet in thickness near the inland margin of the

TABLE B.2-20 Regionalized geologic and hydrologic units (Sandeen and Wesselman, 1973).

GEOLOGIC CLASSIFICATION			Brazoria County Region	
System	Series	Stratigraphic Unit	Aquifer	Unit
QUATERNARY	Holocene PLEISTOCENE	Quaternary alluvium	CHICOT	Upper
		Beaumont clay		Lower
		Montgomery Formation		
		Bentley Formation		
TERT(?)IARY	PLIO(?)CENE	Willis Sand		
TERTIARY	PLIOCENE	Goliad Sand	EVANGELINE	(approximate base of beds mapped in this report)
	MIOCENE	Fleming Formation		

region to more than 3500 feet in thickness at the coast. Beds containing fresh (less than 1000 mg/l TDS) and slightly saline water (1000 to 3000 mg/l TDS) reach a total thickness of about 1100 feet. Most units vary considerably in thickness from location to location. Thicknesses of individual beds of sand and clay generally range from a few feet to about 100 feet in sections containing fresh and slightly saline water. In general, there is more sand than clay in the aquifer.

The Evangeline aquifer is present in the subsurface everywhere in the region except local areas where it has been penetrated by piercement salt domes. Only the upper beds of the Evangeline in Brazoria County contain fresh water. The average dip of the fresh water bearing beds is approximately 30 feet per mile to the southeast. Over salt domes, the dip approaches zero and may even be reversed. Local dips away from salt domes are more than 30 feet per mile.

Based on electrical log interpretation, the maximum thickness of fresh water sands in the Evangeline aquifer in Brazoria County is 415 feet. Assuming the average thickness to be about 400 feet and the average permeability to be 250 gpd per square foot, the maximum coefficient of transmissibility expected in a fresh water well would be approximately 100,000 gpd per foot (Sandeen and Wesselman, 1973).

Separation of the Chicot aquifer from the underlying Evangeline aquifer is based on differences in lithology, permeability, water level, and stratigraphic position. The Chicot is subdivided into upper and lower units which in most places are separated by clay. In Brazoria County, the upper unit is either a water table or an artesian aquifer; the lower unit is an artesian or a leaky artesian aquifer.

The hydraulic characteristics of the Chicot aquifer have been determined by aquifer tests in parts of Brazoria County. The field coefficients of transmissibilities were as much as 275,000 gpd per foot for the lower unit and 66,000 gpd per foot for the upper unit. The maximum permeability for the sand in each unit exceeded 1000 gpd per square foot. Most of the tests showed field permeabilities in excess of 600 gpd per square foot, ranging from more than two to six times the average assumed for the Evangeline aquifer.

Wells completed in the Chicot aquifer in Brazoria County yield up to 2600 gpm. Specific capacities of 11 wells tested ranged from 2.8 to 44.2 gpm per foot of drawdown. In all cases where tests were made to determine the coefficient of storage, the aquifer was under artesian conditions. Sixteen values were determined for the coefficient of storage; the range was from 0.00006 to 0.004. The coefficient of storage (specific yield) of the watertable part of the upper unit of the Chicot aquifer, though not determined, is estimated to be about 0.15 (Sandeen and Wesselman, 1973).

In areas not affected by pumping, the ground water movement in the region is southeast toward the Gulf of Mexico. In areas of large ground water withdrawals, the direction of movement may be modified or reversed due to changes in the gradient of water table or piezometric surface. The piezometric surface is related to artesian or confined aquifers and is defined as an imaginary surface that everywhere coincides with the hydrostatic pressure level of the water in the aquifer. In areas of large and extensive withdrawals, ground water moves from all directions toward the areas of pumpage or lowered pressure (Hammond, 1969).

Withdrawal of large quantities of water may cause lowering of the piezometric level in the pumped zone, land subsidence, and intrusion of the pumped zone by waters of different salinities. Land subsidence and saltwater intrusion result directly from drawdown or reduction of the piezometric level in the aquifer. This, in turn depends upon such factors as pumping rate, well spacing and completion, and aquifer thickness. Data provided in publications by Pettit and Windslow (1957), Hammond (1969) and Sandeen and Wesselman (1973) indicate that about one foot of subsidence results from 100 feet of drawdown in the Texas coastal area. Subsidence on the order of 1.6 feet in Freeport and 2.7 feet in Texas City had already occurred by 1959. Most of that pumping was restricted to the fresh water zones of the upper Chicot aquifer, about 150 feet thick. The lower unit of the Chicot aquifer and the Evangeline aquifer provide a total of over 1000 feet of sand containing moderately saline water on the other hand, thus providing more water with the same magnitude of drawdown. In addition, the deeper formations may be consolidated to a greater extent with a higher elastic modulus, which, in turn, would result in less subsidence per 100 feet of drawdown.

The Pliocene and Miocene sandstones underlying the Chicot and Evangeline aquifers to a depth of 9000 feet or more contain moderately saline to very saline water. Examination of well logs and of data from side wall core samples from oil exploration wells in the project region indicates a net sand thickness of 1000 feet to 1500 feet in the depth interval from 3000 feet to 8000 feet. Porosity decreases linearly with depth, ranging downward from about 40 percent at -3000 feet to about 30 percent at -8000 feet. This range and systematic variation of porosities with depth concurs with values derived from other electrical and geophysical surveys of Texas-Louisiana Gulf Coast wells. The permeability of these deep formatations is less than that of the overlying Chicot and Evangeline aquifers. This is sufficient, however, for successful development of substantial saline water supplies or for subsurface brine emplacement via injection wells.

Uses of Ground Water

As might be expected, water use in the region has increased steadily with increased population and industrialization. Data available for Brazoria County (Sandeen and Wesselman, 1973) show that in 1967 the total use of fresh and saline water included 43 mgd of ground water, 317 mgd of fresh surface water, and 3503 mgd of sea water. The primary use of ground water in the county was for irrigation. Most of the irrigation water is used to grow rice, and row crops such as cotton and maize. In 1967, 4 mgd were used to maintain lake levels at recreational sites.

The second largest use of ground water is industrial. From 1913 to 1940, the extraction of sulfur from salt domes by the Frasch process consituted the largest use of ground water. At each of three sulfur mines (Bryan Mound, Hoskins Mound, and Clemens dome), about 2 mgd was reportedly used during the respective periods of operation. By 1958, all of the sulfur mines were closed.

By 1962, industry in Brazoria County was obtaining more than 95 percent of its fresh water needs from surface water. Industrial usage of ground water totaled about 13 mgd in 1967 (Sandeen and Wesselman, 1973).

Public supply and rural domestic use (including consumption by animals) of ground water was almost 8 mgd in 1967. Drinking water, except for less than 0.5 mgd produced from the desalinization plant at Freeport, is obtained exclusively from the ground.

The most widespread freshwater aquifer in Brazoria County, and the only aquifer containing fresh water in much of the southern part of the county, is the upper unit of the Chicot aquifer. Water from this aquifer is used for public and domestic supplies and for part of the water for industries in the Brazosport area. It is utilized by the industries and towns in the Sweeny and Old Ocean areas. Because of the large drawdown in the area, the thin section of freshwater sand, and the proximity of water of poorer quality, the aquifer is fully developed and may be over-developed in the Brazosport area. Except at Freeport, the aquifer contains little or no fresh water in a band several miles wide along the coast.

The lower unit of the Chicot aquifer has a high coefficient of transmissibility; therefore, where the thickness of freshwater-bearing sand exceeds 100 feet, freshwater wells having a capacity of between 1000 and 3000 gpm can be constructed. This is generally limited, however, to the northern half of Brazoria County where the Evangeline aquifer also contains some fresh water. These are artesian aquifers, and in the early days of development, water flowed from the wells without pumping. Flowing wells were still common in the late 1930s, but by 1943 the potentiometric surface had been sufficiently lowered so that there were few flowing wells left in Brazoria County. None were found in 1967 (Sandeen and Wesselman, 1973).

Water in the lower unit of the Chicot and in the Evangeline aquifers is moving toward the cones of depression caused by pumping in Harris and Galveston Counties and toward local cones of depression surrounding well fields in the region. A large cone of depression occurs in the water-level surface in the Brazosport area of southern Brazoria County as a result of pumping from the upper part of the Chicot.

Land surface subsidence of more than 1.5 feet, attributed mostly to ground water removal, has taken place in northeast Brazoria County. Subsidence of as much as 1.6 feet has taken place in the Freeport area (Sandeen and Wesselman, 1973).

The lower unit of the Chicot aquifer contains a large amount of slightly saline water. Through the central part of Brazoria County, sand thicknesses of more than 100 feet, and as much as 300 feet, bear this type of water. Large (tens of mgd), sustained withdrawals of this water could be made without excessive drawdown.

Large wells (3000 gpm or more) producing saline water can be constructed anywhere in Brazoria County where the lower unit of the Chicot contains 100 feet or more of saline water-bearing sand. Wells that produce slightly and moderately saline water from this unit have been constructed and used by industry in the Freeport area (Sandeen and Wesselman, 1973).

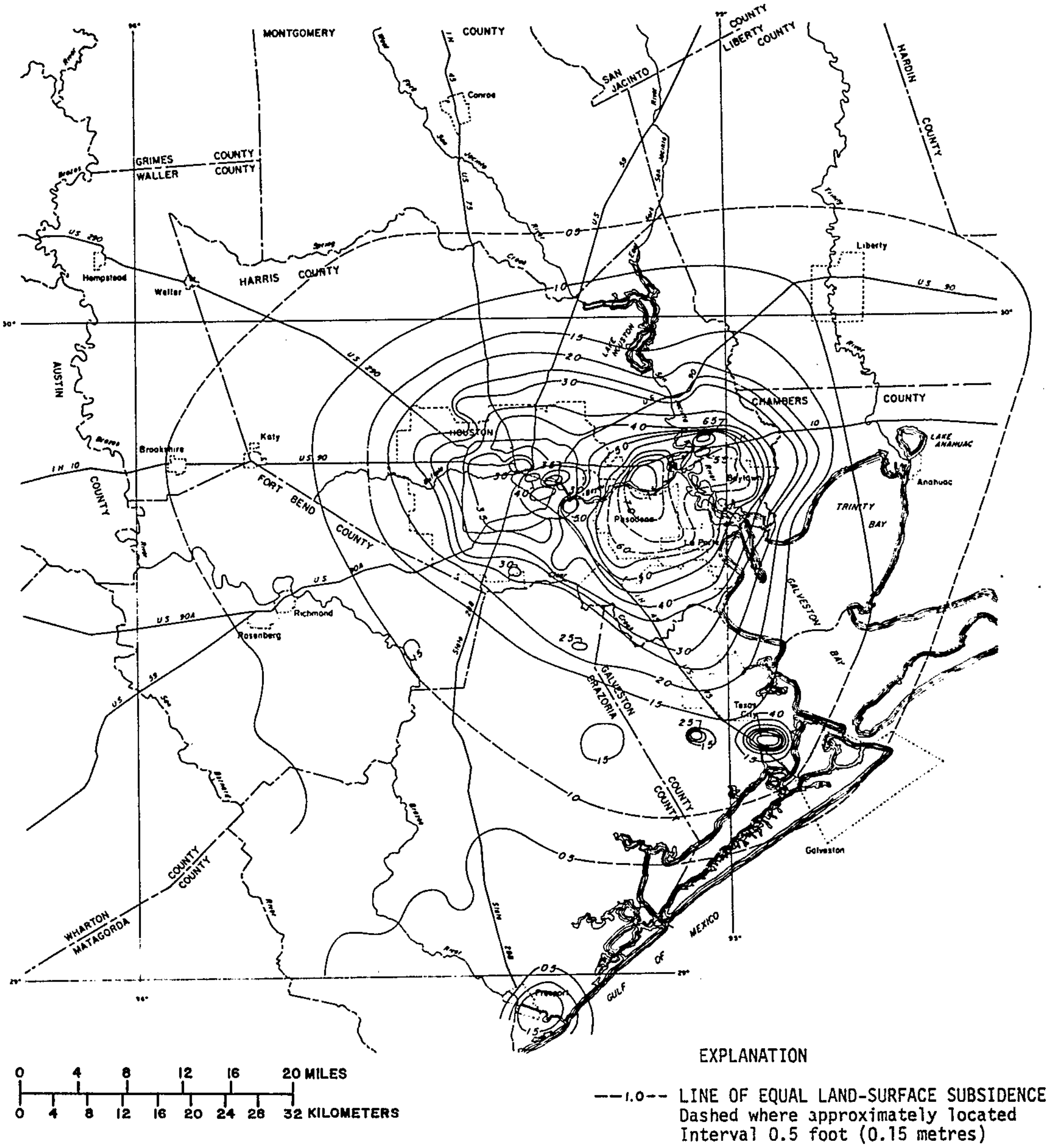
A study published by the Texas Water Resources Institute (Jones & Larson, 1975) concluded that: "Damages and property value losses associated with land subsidence in the Texas Gulf Coast are high and extensive over a large portion of the coastal area. The resulting costs, as estimated in this study, are so high that continued pumping of ground water at rates that cause subsidence cannot be justified. The pursuit of alternative sources of water to meet area needs and institutional measures for controlling subsidence are fully justified from a standpoint of reducing total costs to the area."

Land surface subsidence in the region from 1943 to 1973, resulting from ground water withdrawal, is shown in Figure B.2-26.

B.2.3 Climatology and Air Quality

B.2.3.1 Climatology

The general classification of the climate of this region is humid subtropical with long, hot summers and short, mild winters. The proxim-



SOURCE: R.K. Gabrysch, "Ground Water Development and Land Surface Subsidence, Houston-Galveston Region, Texas", 1974 Water for Texas Conference, Texas Water Resources Institute, Texas A&M University, September 20, 1974.

FIGURE B.2-26 Subsidence of the land surface, 1943-1973 ity of the warm Gulf of Mexico and the prevailing south to southeasterly winds result in a climate that is predominantly marine. Precipitation is distributed rather evenly throughout the year; heavy downpours may occur during any month but are most likely to occur in association with tropical disturbances. High relative humidity is characteristic throughout the year.

The prevailing wind direction in this region is southerly, with a secondary maximum from the southeast. The annual average wind speed is 11.5 mph at Galveston (USDC, 1973) and 10.0 mph at Hobby Field, Houston (USDC, 1972). Slack wind periods can occur frequently, but in most cases prevail for only a short period of time, usually less than five hours. Slack winds occur most frequently between May and September.

Based on data from Galveston and Hobby Field, Houston (USDC, 1969), the annual mean temperature over the region is almost $70^{O}F$. In summer, the highest average daily maximum temperatures range from the upper 80s (^{O}F) along the coast to the lower 90s (^{O}F) inland. The lowest average daily minimum temperatures range from near $50^{O}F$ along the coast to the middle 40s (^{O}F) farther inland.

The average relative humidity is extremely high in the region. The annual average is approximately 78 percent at Galveston and 74 percent at Hobby Field (USDC, 1969). Monthly averages are lowest in October at both stations and highest in January at Galveston and during the spring at Hobby Field.

The average number of days each year with heavy fog (visibility reduced to one-quarter mile or less) is 42, based on a 30-year period of record at Hobby Field (USDC, 1969). The number of days with heavy fog peaks in winter, with few occurrences during summer.

Annual precipitation in the region is normally 42-46 inches (USDC, 1964; USDC, 1969; USDC, 1971). Monthly average rainfall is highest in summer (particularly along the coast) and lowest in spring. Daily rainfall amounts of one-half inch or more can be expected approximately 27 days each year (USDC, 1964).

Thunderstorms occur 59 days each year in the region, based on data from Houston's Hobby Field (USDC, 1969). Thunderstorm frequency reaches a peak during July and August (10 and 9 occurrences, respectively) with only 2 or 3 thunderstorm days per month from October through March. Severe thunderstorms accompanied by high winds, hail, or tornadoes are infrequent.

During the period 1955 through 1967, 46 tornadoes occurred within the one-degree latitude-longitude square nearest the region (Pautz, 1969). This is a mean annual frequency of 3.5 occurrences, but the probability of a tornado hitting a point in a given year is only .00238 (Thom, 1963).

Tropical storm statistics indicate that a hurricane can be expected about every 7-10 years, while a great hurricane (winds greater than 124 mph) can be expected only about every 28 years.

B.2.3.2 Climatology-Factors Affecting Dispersion

Atomospheric stability in conjunction with the general ventilation (winds) indicates the ability of the atmosphere to disperse airborne effluents. The degree of atmospheric stability determines the amount of vertical and lateral mixing or dispersion of air pollutants as they are carried away from their source.

Meteorological conditions which lead to high air pollution potential are light winds accompanied by surface inversions and above-surface stable layers (limited mixing). Surface inversions are short-term, early morning phenomena; usually, heating eliminates them and creates a uniform mixing layer by mid-afternoon. Mixing depth is defined as the surface layer in which relatively vigorous vertical mixing takes place.

Holzworth (1972) has compiled isopleths of seasonal and annual mean mixing depths for both morning and afternoon. Estimated mean morning mixing depths for the Seaway region range from a minimum of just over 400 meters in winter to about 700 meters in summer. Values in the spring and fall are 600 and 475 meters, respectively. Afternoon mixing depths are much higher, averaging 1200 meters annually. Holzworth has also compiled data on the number of forecast days of high meteorological potential for air pollution in the contiguous United States; this value is near zero for the Seaway area.

The mean annual frequency distribution of stability classes at Galveston and Houston (Hobby Field) are presented in Table B.2-21 (USDC, 1972b; USDC, 1973b). The stability classes are based on Pasquill's classification as defined in Table B.2-21 (Turner, 1964). The mean annual frequency of inversion conditions (stability classes E, F, and G) is 34 percent at Hobby Field, but is only 22 percent at Galveston. The seasonal inversion frequency at Hobby Field is approximately 26 percent in winter, 23 percent in spring, 46 percent in summer, and 43 percent in the fall.

TABLE B.2-21 Annual Stability Class Percent Frequency Distributions

Pasquill Stability Class	Definition	Galveston (1958-1962) (percent)	Hobby Field (1964-1968) (percent)
A	Extremely Unstable	3.3	0.5
B	Unstable	5.2	4.1
C	Slightly Unstable	14.7	9.2
D	Neutral	57.6	51.9
E,F,G	Slightly, Moderately or Extremely Stable	22.2	34.3

Since the average wind speed for the region is moderately high (greater than 10 mph; see Section B.2.3.1) and the atmosphere is stable only about one-quarter of the time, dispersion conditions are considered to be excellent.

B.2.3.3 Air Quality

Air Quality Legislation

The Federal Clean Air Act provides for the prevention and control of air pollution. Several categories of air quality standards (i.e., the National Ambient Air Quality Standards (NAAQS), the air quality regulations of the state of Texas, and federal significant deterioration regulations) were reviewed to extract all of those applicable to the Seaway region. The NAAQS issued by the U.S. Environmental Protection

Agency (EPA), in April 1971, are listed in Table B.2-22. These include primary standards which are intended to protect public health, and secondary standards that are intended to protect public welfare. In addition, Texas regulations specify single source standards for sulfur dioxide (SO_2), hydrogen sulfide (H_2S), and total suspended particulates (TSP). These standards are summarized in Table B.2-23.

In November 1974, the EPA issued a regulation to prevent significant deterioration (PSD) of air quality in areas with air cleaner than the standards at the time of issuance of the regulation (EPA, 1974). The Clean Air Act Amendments of August 1977 contain significant changes in PSD requirements. Major changes affecting this project include the expansion of PSD designated source categories from 19 to 28, one of which is petroleum storage and transfer facilities with a capacity exceeding 300,000 barrels, and the extension of the regulations to all criteria pollutants and not just SO_2 and TSP. However, except for SO_2 and TSP where allowable incremental increases in baseline concentrations are specified, other criteria pollutants are to be controlled using Best Available Control Technology (BACT) at present. Therefore, hydrocarbon emissions from crude oil storage tanks would probably have to be controlled using floating roofs equipped with double seals.

The Clean Air Act requires each state to institute an air quality control program and to issue a State Implementation Plan (SIP) defining measures to be taken by the state to achieve the ambient air quality standards within the state.

Currently, Texas regulations require crude oil storage tanks in the Seaway region in excess of 10,000 barrels to be equipped with a floating roof or a vapor recovery system. Vapor emission from ship loading and unloading activities are not regulated at this time, but an interim strategy to attain the NAAQS for photochemical oxidants by controlling reactive hydrocarbon emissions has recently been proposed by the EPA for the Texas SIP (EPA, 1976a). This is a revision of the previous Transportation Control Plan for Texas. Additional controls for the Houston/Galveston area interim plan include crude oil storage controls (floating roof or vapor recovery system) and ship and barge vapor recovery (gasoline loading only) (EPA, 1976a).

TABLE B.2-22 National ambient air quality standards[a].

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Particulate matter	Annual (Geometric mean)	75 μg/m^3	60 μg/m^3 (b)
	24-hour	260 μg/m^3	150 μg/m^3
Sulfur Dioxide	Annual (Arithmetic mean)	80 μg/m^3 (0.03 ppm)	--
	24-hour	365 μg/m^3 (0.14 ppm)	
	3-hour	--	1300 μg/m^3 (0.5 ppm)
Carbon Monoxide	8-hour	10 mg/m^3 (9 ppm)	Same as primary
	1-hour	40 mg/m^3 (35 ppm)	
Photochemical oxidants(c)	1-hour	160 μg/m^3 (0.08 ppm)	Same as primary
Hydrocarbons(d) (nonmethane)	3-hour (6 to 9 a.m.)	160 μg/m^3 (0.24 ppm)	Same as primary
Nitrogen Dioxide	Annual (Arithmetic mean)	100 μg/m^3 (0.05 ppm)	Same as primary

(a) All standards (other than annual standards) are specified as not to be exceeded more than once per year.

(b) A guide to be used in assessing implementation plans to achieve the 24-hour standard.

(c) Expressed as ozone by the Federal Reference Method.

(d) For use as a guide in devising implementation plans to achieve oxidant standards.

Source: EPA, 1971

TABLE B.2-23 Texas single source standards.

Pollutant	Averaging Period	Specification	Standard[a]
Sulfur Dioxide	30-minute	Harris, Galveston Counties	0.28 ppm
		Orange, Jefferson Counties	0.32 ppm
		All other counties	0.40 ppm
Hydrogen Sulfide	30-minute	Affecting property used for residential, business or commercial purposes	0.08 ppm
		Affecting property used for other than the above; e.g., vacant land, range land, industrial property	0.12 ppm
Particulate matter	5-hour	-	100 $\mu g/m^3$
	3-hour	-	200 $\mu g/m^3$
	1-hour	-	400 $\mu g/m^3$

[a]Net ground-level concentrations (downwind concentration minus the upwind concentration) not to be exceeded.

Another requirement for SIP's to meet the NAAQS is new source review. The most recent ruling from EPA regarding new source review has established the emissions offset system (EPA, 1976b). Under this provision, new sources are required to show that emissions from the new source plus SIP-required reductions from existing sources equal a net decrease in emissions. That is, the new source should not delay progress toward achieving the NAAQS in non-attainment air quality control regions. This regulation, however, applies only to permanent onshore facilities and is expected to exclude new sources with "potential" emissions less than 100 tons/year. EPA has determined that, because of the temporary and intermittant nature of emissions associated with the Bayou Choctaw SPR site, the emission offset policy does not apply to this particular activity. EPA has informally confirmed that this determination applies to other/ similar SPR sites. In any event since double-seal floating roof storage tanks are planned for the Seaway SPR program, "potential" emissions are expected to be less than 100 tons/year. DOE has been advised by EPA that the offset policy is under review, and that a clarification will be forthcoming in the near future. DOE will take any necessary actions consistent with this clarification.

Existing Air Quality

In order to characterize the existing air quality of the Seaway region, several air quality monitoring surveys conducted in the vicinity were reviewed. Two of these surveys, one at Clute, Texas by the Texas Air Control Board (TACB), and another, near Jones Creek by the Southwest Research Institute (SRI) were presented in Appendix D of FES 76/77-6.

The results of these surveys show that air quality in the region is very good with the exception of high non-methane hydrocarbon and oxidant concentrations. Concentrations of carbon monoxide (CO), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are minimal, and, in some cases, below the minimum detectable limits. Particulate levels are low, characteristic of rural areas subject to reasonably consistent winds due to the flat terrain and influence of the Gulf of Mexico.

Concentrations of non-methane hydrocarbons are very high; approximately 30 percent of the time measurements made by SRI near Jones Creek exceeded the NAAQS of 160 μ/m^3. At Clute, the TACB records show high levels of non-methane hydrocarbons. From 74.5 to 98 percent of the hours sampled exceeded 160 μ/m^3. Hourly oxidant concentrations measured at Clute for this same period exceeded the NAAQS (.08 ppm) only about three percent of the time.

A short-term monitoring program was also conducted by the Texas Air Control Board from October 15, 1973 to April 3, 1974 at three sites in Freeport and Clute, to determine ambient air quality (Susskind and others, 1974). Again, analysis of the data suggests that the Freeport area is relatively unpolluted with the exception of non-methane hydrocarbon and ozone levels. While ozone concentrations exceeded the NAAQS only 15 out of 2017 (0.7 percent) hours of monitoring at the three sites combined, non-methane hydrocarbon values were greater than 160 μ/m^3 on 37 out of 42 days that data were obtained between 6 and 9 a.m.

The guideline for non-methane hydrocarbons (160 μ/m^3, 6-9 a.m. average) is intended as an indirect control on the ultimate formation of photochemical oxidants. Moreover, measurements by the TACB have shown that oxidant levels in air of rural origin (background concentrations) occasionally exceed national ambient air quality standards (Wallis and others, 1975). Additional measurements have also shown that non-methane hydrocarbon levels in excess of the federal guideline may occur in the Gulf of Mexico, over 100 miles from shore (Richardson and others, 1973).

Regional data from TACB continuous monitoring stations during 1974, including the heavy industrialized areas of Houston and Texas City are presented in Table B.2-24. Of these stations, only Clute is considered representative of ambient air quality in the Seaway area.

Results of particulate and SO_2 measurements at 22 periodic sampling stations in the Houston metropolitan area during 1973 and 1974 (TACB, 1973-74) show that several locations are in excess of the NAAQS for particulates while some were near the NAAQS for SO_2.

Emissions Inventory

The proposed and alternative sites of the Seaway Group are located in Brazoria County and adjacent Fort Bend County which, together with 12 other counties, constitute Air Quality Control Region (AQCR) 216 (Texas AQCR 7). Estimates of the annual rates for pollutant emissions from

TABLE B.2-24 Regional summary of 1974 air quality data at continuous monitoring stations in the region (ppm).

	Houston (Mae Drive)	Houston (Aldine)	Texas City	Clute	Standard
Nitrogen Dioxide					
Annual Mean	0.02	0.02	Missing	0.01	0.05
Sulfur Dioxide					
High 3-hour Avg.	0.15	0.00	0.01	0.01	0.50
High 24-hour Avg.	0.03	0.00	0.00	0.00	0.14
Annual Mean	0.00	0.00	0.00	0.00	0.03
Photo. Oxidants (Measured as Ozone)					
Highest 1-hour Avg.	0.219	0.204	0.277	0.116	
2nd Higest 1-hour Avg.	0.205	0.165	0.234	0.110	0.08
% hrs. >.08 ppm	3.0	3.4	4.2	1.3	
Non-methane Hydrocarbons					
Highest 6-9 a.m. avg.	7.2	2.2	2.3	2.8	
2nd highest 6-9 a.m. avg.	3.9	2.1	2.2	3.5	0.24
% of 6-9 a.m. avg. >.24 ppm	81.8	90.9	76.9	98.1	
Period of Record	1/1 to 12/31	4/25 to 12/31	6/14 to 12/31	7/19 to 12/31	

Source: Texas Air Control Board, 1974.

both point and area sources for each county in AQCR 216 for the year 1972 are presented in Table B.2-25 (TACB, 1972). Total emissions for AQCR 216 in 1972 were nearly 3 million tons, of which approximately 450,000 tons/year (15 percent) originated in Brazoria County. The largest regional sources of pollutants are petroleum refineries and petrochemical industries. Transportation sources and the combustion of industrial fuels are also important sources.

B.2.4 Background Ambient Sound Levels

Background ambient sound levels in the Seaway Group region show great diversity. These background levels are directly related to the land use within the area. Ambient sound surveys made under earlier studies at similar sites and principal land uses identified from topographic maps and site visit reports have formed the basis for the ambient sound estimations in this report.

A wide diversity of sound sources have been identified for the region. In the area of many of the salt domes, brining activities, oil wells, and petrochemical plants produce sound levels typical of industrial areas. Similarly, the population centers of the region exhibit sound levels typical for small urban centers. Outside of these areas, in regions where the oil and brine pipelines will eventually pass, sound levels are typical of secluded, undeveloped, moderately wooded areas. Sound levels, in these areas, are dominated by wind in trees and marshland vegetation and insect, bird, and wildlife activity.

Figure B.2-27 (EPA, 1974) presents examples of sound levels for various locations from rural to busy urban areas.

The Environmental Protection Agency (EPA) has identified levels for limits of L_{dn} requisite for the protection of public health and welfare with an adequate margin of safety for both activity interference and hearing loss.*

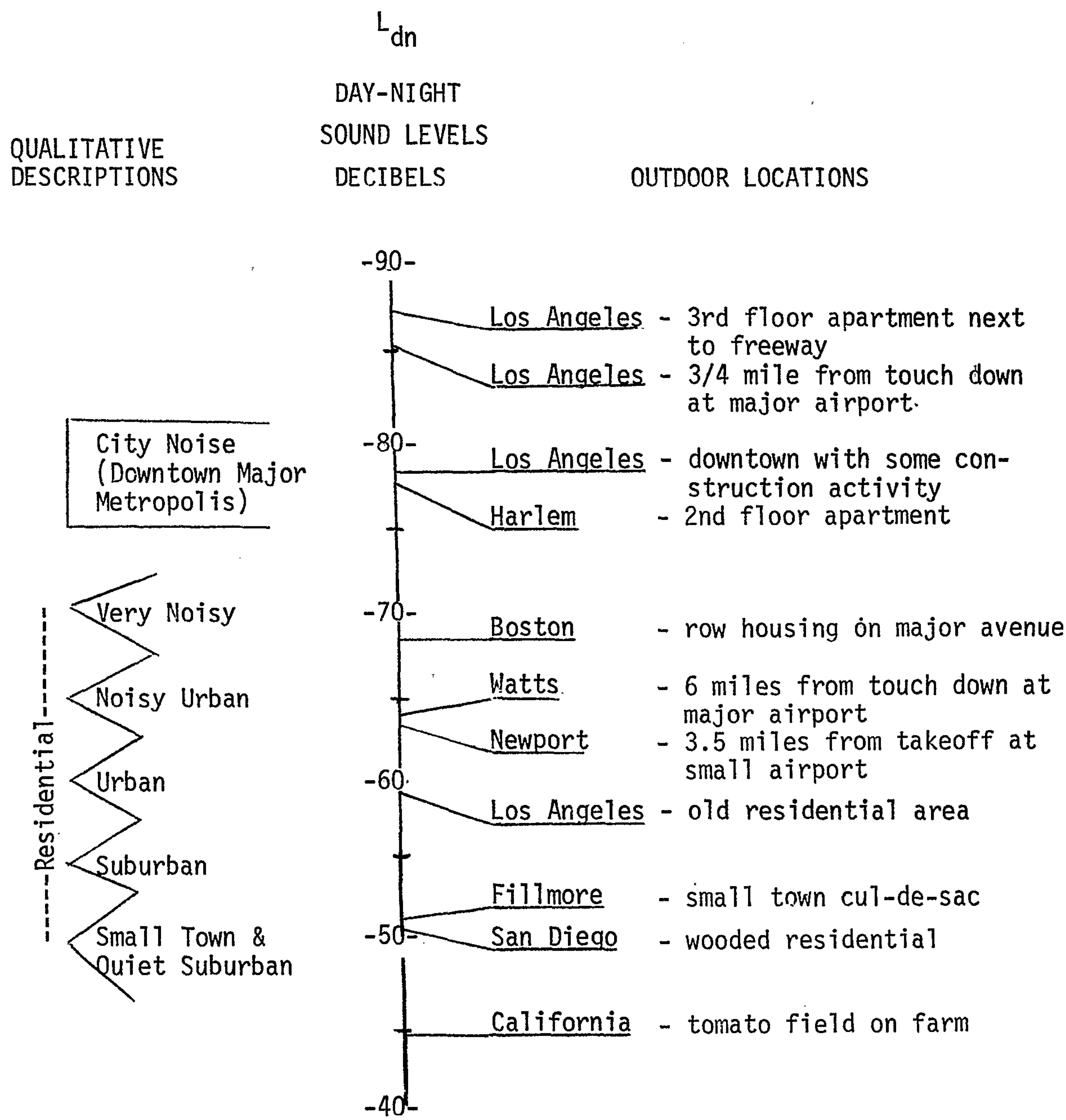
According to EPA information, outdoor ambient sound levels, L_{dn}, below 55 dB will not degrade public health and welfare.

*The State of Texas has no noise control regulation pertaining to the construction or operation of this project.

TABLE B.2-25 1972 emission inventory - AOCR 216.

County	Total: Area Sources (tons/year)	Total: Point Sources (tons/year)	Total (tons/year)
Austin	10,363	666	11,029
Brazoria	44,675	405,299	449,974
Chambers	19,492	29,124	48,616
Colorado	14,532	11,604	26,136
Galveston	59,844	430,383	490,227
Harris	628,288	1,078,222	1,706,510
Liberty	19,772	3,357	23,129
Matagorda	14,941	22,418	37,359
Montgomery	34,464	86,480	120,944
Walker	- -	5,521	- -
Wharton	18,638	12,636	31,274
Waller	10,632	11,891	22,523
Total	875,641	2,097,601	2,967,721

Source: Texas Air Control Board, 1972.



Source:

Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U.S. EPA, 550/9-74-004, March, 1974.

FIGURE B.2-27 Examples of outdoor day/night sound level in dB measured at various locations

SUMMARY OF NOISE LEVELS IDENTIFIED AS REQUISITE TO PROTECT PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY

Effect	Level	Area
Hearing Loss	$L_{eq(24)} \leq 70$ dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq(24)} \leq 55$ dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{eq(24)} \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

$L_{eq(24)}$ represents the sound energy averaged over a 24-hour period.
L_{dn} represents the L_{eq} with a 10 dB nighttime weighting.

Terminology used in this and subsequent sections on noise is defined in the following glossary of acoustical terminology.

ACOUSTICAL TERMINOLOGY

The range of sound pressures that can be heard by humans is very large. This range varies from two ten-thousand-millionths (2×10^{-10}) of an atmosphere for sounds barely audible to humans to two thousandths

(2×10^{-3}) of an atmosphere for sounds which are so loud as to be painful. The decibel notation is used to present sound levels over this wide physical range. Essentially, the decibel unit compresses this range to a workable range using logarithms. It is defined as:

Sound pressure level (dB) - $20 \log_{10} (\frac{P}{P_0})$

when P_0 is a reference sound pressure required for a minimum sensation of hearing.

Zero decibels is assigned to this minimum level and 140 decibels to sound which is painful. Thus a range of more than one million is expressed on a scale of zero to 140.

The human ear does not perceive sounds at low frequencies in the same manner as those at higher frequencies. Sounds of equal intensity at low frequency do not seem as loud as those at higher frequencies. The A-weighted network is provided in sound analysis systems to simulate the human ear. A-weighted sound levels are expressed in units of dBA. These levels in dBA are used by the engineer to evaluate hearing damage risk (OSHA) or community annoyance impact and are also used in federal, state, and local noise guidelines and ordinances.

Sound is not constant in time. Statistical analysis is used to describe the temporal distribution of sound and to compute single number descriptors for the time-varying sound. The following are commonly used statistical descriptors:

L_{90} - This is the sound level exceeded 90 percent of the time during the measurement period and is often used to represent the "residual" sound level.

L_{50} - This is the sound level exceeded 50 percent of the time during the measurement period and is used to represent the "median" sound level.

L_{10} - This is the sound level exceeded 10 percent of the time during the measurement period and is often used to represent the "intrusive" sound level.

L_{eq} - This is the equivalent steady sound level which provides an equal amount of acoustic energy as the time-varying sound.

L_d - Equivalent sound level, L_{eq}, for the daytime period (0700-2200) only.

L_n - Equivalent sound level, L_{eq}, for the nighttime period (2200-0700) only.

L_{dn} - Equivalent day/night sound level, defined as:

$$L_{dn} = 10 \log_{10} ([15 \times 10^{L_d/10} + 9 \times 10^{(L_n + 10)/10}]/24)$$

Note: A 10 dB correction factor is added to the nighttime equivalent sound level when computing L_{dn}.

B.2.5 Species and Ecosystems

The five salt domes and primary pipeline routes for the Seaway Group of SPR sites are located in the southeastern Coastal Zone of Texas. This zone extends from the inner Continental Shelf inland about 45 linear miles. The coastal zone includes a myriad of estuaries and tidally-influenced streams, rivers and their associated wetlands (marshlands). The entire Texas Coastal Zone is a large area of about 20,000 square miles, and includes approximately 2,100 square miles of bays and estuaries, 367 statute miles of Gulf coastline and 1,425 miles of bay, estuary and lagoon shoreline.

For the purpose of this discussion and to describe the regional baseline ecological characteristics and biological species of the project region, this region has been defined as that area within the coastal zone of Texas within the confines of Brazoria and Fort Bend Counties. The region is bounded on the south by the Gulf of Mexico and extends to the north to the vicinity of Damon Mound salt dome, a distance of about 35 linear miles (Figure B.2-28). The DOE oil distribution pipeline from Bryan Mound to Damon Mound is about 45 statute miles long.

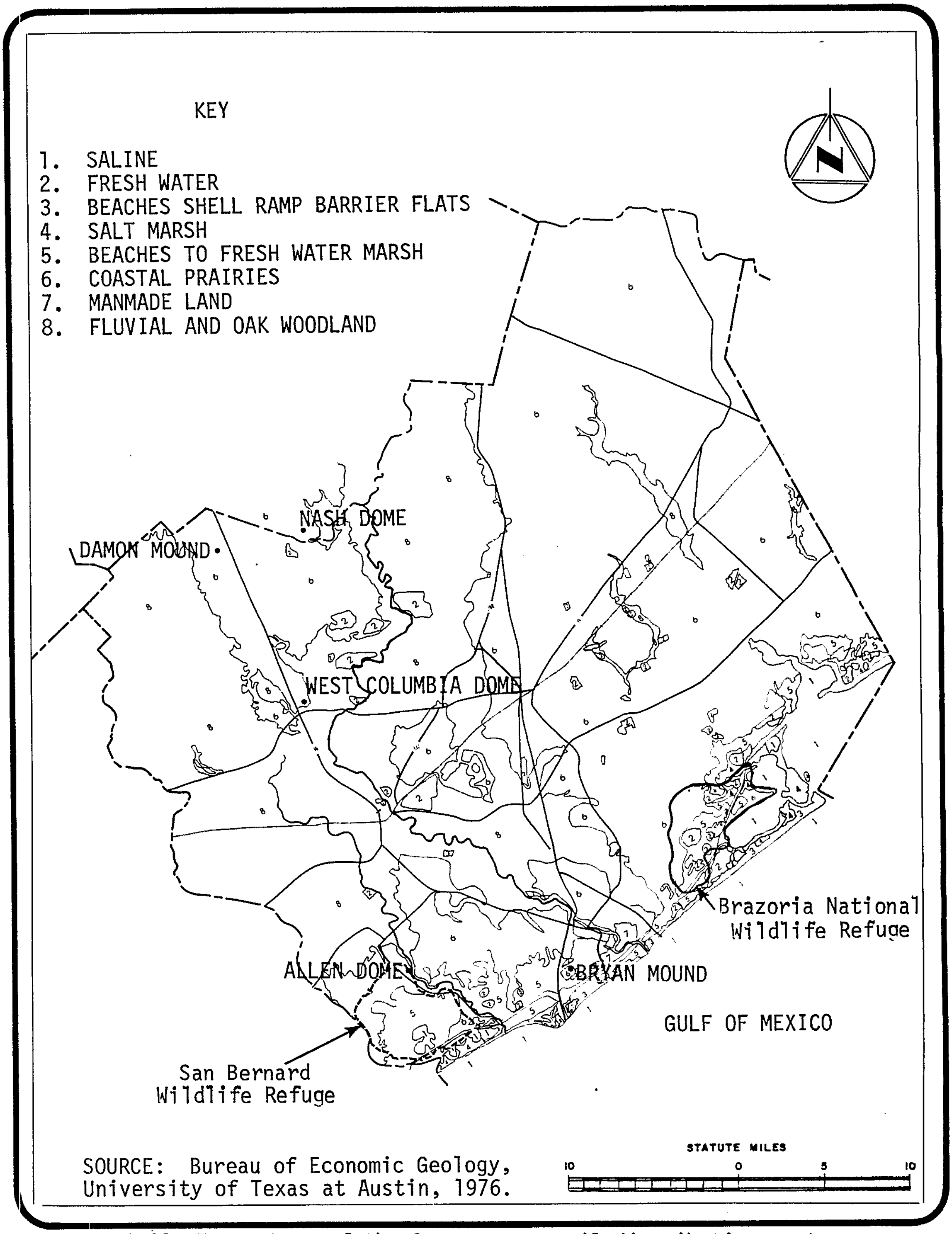


FIGURE B.2-28 Ecosystems of the Seaway group oil distribution systems.

The Texas shoreline has many interconnecting natural waterways, restricted bays, lagoons and estuaries. This region is also characterized by low to moderate fresh water inflow, long and narrow barrier islands and a low tidal range. Interspersed among the natural environment are bayside and intrabay oil fields, bayside refineries, petrochemical plants, dredged intracoastal canals and channels and many other urban or industrial facilities. The relatively flat relief of the onshore area continues into the coastal waters.

The project region is part of the Gulf Coastal Plain Physiographic Province and is an area of large and deep alluvial deposits. These deposits and the low relief of the coastal plains have played a significant role in shaping the ecological communities which inhabit the region.

The subtropical climate of the Texas Coastal Zone strongly influences the relative abundance and distribution of many of the terrestrial plants and animals in the region. Effective precipitation controls the type and density of coastal vegetation. Average annual rainfall in the region is about 45 inches. Regional temperatures range from an average winter minimum of about $45^{o}F$, to an average summer maximum of about $90^{o}F$.

There are few regions in the United States which provide as rich and diverse a composition of birds, mammals, amphibians, reptiles and aquatic life as the Coastal Province of Texas.

The numerous marine, estuarine, and freshwater marshes in the project locale provide habitat, food, and cover for a large variety of valuable resident and migratory biological resources.

One of the important biological resource areas in the region is the San Bernard National Wildlife Refuge which is located about 15 miles west of Bryan Mound and about 5 miles south of the Allen dome (Figure B.2-28).

The following sections describe the ecosystems and associated biological species found in the project region. Plants and animals discussed for the various ecosystems are considered to be the typical residents of each system. Commercially and recreationally valuable species, and threatened and endangered species are discussed in separate sections. Site specific characteristics of each of the candidate storage sites in the Seaway Group are discussed in Section B.3. A summary of the important flora and fauna typical of the project region is presented in Table B.2-26. Bird, amphibian and reptile, and mammal species likely to occur in the study area are listed in Tables B.2-27, B.2-28, and B.2-29, respectively.

B.2.5.1 Ecosystems

The main ecological components (based principally on floral assemblages) of the Texas Coastal Zone are: the beach and local island dune areas; Gulf Coast prairies and marshlands; cleared lands; fluvial and oak woodlands; and coastal and inland waters. These ecosystems generally trend in successive north-south bands which parallel the local fluvial environment. These systems correspond to the major biological assemblages as described in McGowen and others, 1976, "Environmental Geologic Atlas of the Texas Coastal Zone - Bay City-Freeport Area".

Beach and Local Island Dunes

Adjacent to the shoreline of the Gulf of Mexico, the beach and island dune areas consist mostly of bare sand and shell, some of which is stabilized by vegetation. Maximum elevations in this area reach 18 feet. The typical biological assemblage associated with this component consists of salt-tolerant plants such as marshhay cordgrass, morning glory, sea purslane, sea oats, and sea coast bluestem, salt cedar, "rare" mesquite, ghost crabs, small rodents, snakes, and several species of birds and water fowl.

Gulf Coast Prairies and Marshlands

This ecosystem, covering approximately 500,000 acres, is located inland of the island dunes and is made up of two major subdivisions: the coastal prairie (Bluestem-Sacahuista Prairie); and the coastal marshlands (Southern Cordgrass Prairie) (Gould, 1962; Kuchler, 1964). Both of these sub-divisions are located within the Texas Biotic Province as described by Blair (1950).

TABLE B.2-26 Major ecosystems and typical organisms in the region of the Seaway **Group of SPR sites.**

TYPICAL OR IMPORTANT ORGANISMS

	Ecosystem									
	Marshlands			Coastal Prairies	Fluvial and Oak Woodlands	Cleared Lands		Coastal and Inland Waters		Beaches, Shell Pamp-Barrier Flats
	Freshwater Marsh	Brackish Marsh	Salt Marsh			Urban and Suburban	Crops and Future Lands	Freshwater	Saline	
Key to Fig. 3.2-7	5	5	4	6	8	7	6	2	1	3
Plants, herbs, grasses and trees	Maiden cane cordgrass sedges water hyacinth pennywort	cordgrass soilbind morning glory fiddle leaf morning glory sea purslane coastal sacahuista bulrush cattail rushes	smooth cordgrass salt grass lazy daisy shortgrass glasswort salt matrimonyvine batis sea myrtle Carolina wolfberry bulrush Harstem bulrush	Gulf cordgrass bunchgrass Indian grass switchgrass bluestem live oak huisache ragweed prairie pleatleaf	live oak pecan sugar berry pignut hickory bluestem cordgrass Bermuda grass green birer yaupon seamyrtle blackjack oak hybrid oak water oak	Various residential species	rice soybeans prairie grass	diatoms bluegreen algae green algae	diatoms dinoflagellates sea lettuce other attached algae sargasso weed	sea oats cordgrass mesquite morning glory seacoat bluestem
Mollusks and crustaceans	snails mussels clams crayfish	snails crabs crayfish clams shrimp oysters	fiddler crabs mud crabs clams oysters snails shrimp	snails	NA	NA	NA	clams snails oysters	clams oysters shrimp crabs snails	snails clams ghost crabs
Water snakes, amphibians, and reptiles	turtles Western cottonmouth toads frogs	Western cottonmouth Gulf salt marsh snake Western diamondback rattlesnake	Gulf salt marsh snake Western cottonmouth	ornate box turtle leopard frogs Western diamondback rattlesnake Eastern garter-snake Gulf Coast toad spotted chorus toad	ornate box turtle five-lined skink Eastern garter-snake Hurter's spadefoot gray tree frog	NA	NA	turtles frogs water snakes	Ridley turtle Leatherback turtle	sea turtles
Fish	minnows crappie sunfish catfish gar	killifish	killifish cyprinids immature mullet spot	NA	NA	NA	NA	crappie catfish black bass gar shad buffalo-fish	mullet anchovy silver-sides cyprinids menhaden red drum sea trout tarpon flounder sea catfish croaker spat	NA
Mammals	muskrat raccoon nutria	muskrat rabbits rice rat Canid sp.	Canid sp. raccoon rice rat cattle	Canid sp. cattle hispid cotton rat rice rat rabbits striped skunk	gray and fox squirrel opossum armadillo raccoon cottontail rabbit white-footed mouse bobcat coyote bats fox skunk	opossum domesticated animals bats rabbits striped skunk	cattle rabbits hispid cotton rat	muskrat nutria	whales porpoises	small rodents mice
Birds	gulls terns black skimmer red-winged blackbird willet black duck mottled duck blue-winged teal Great Blue heron Snowy egret	American coot yellowlegs terns Seaside sparrow yellow-crowned night heron mottled duck blue-winged teal Great Blue heron Great egret Green heron Louisiana heron snow goose	plovers geese Great Blue heron Little Blue heron egrets Least bittern ibis Roseate spoonbill ducks clapper rail sandpipers	sparrows marsh hawk Eastern meadow-lark egrets vultures kites upland plover killdeer bobwhite quail sandhill crane	turkey vulture Coopers hawk great horned owl red-bellied woodpecker gray catbird tufted titmouse prothenotary warbler brown thrasher chestnut-sided warbler scarlet tanager cardinal Indigo bunting Northern oriole white-eyed vireo	blackbirds robins starlings	blackbirds hawks killdeer Eastern meadowlark mourning dove sparrows	ducks gulls coots geese	frigate bird gulls terns ducks	waterfowl terns seagull geese ducks

[a] Site specific biological species are presented in Section 8.3.

TABLE B.2-27 Bird species likely to occur in the study region.

Common Name (Scientific Name)	A	B	C	D	E
Horned grebe (Colymbus auritus)		X			X
Pied-billed grebe (Podilymbus podiceps)		X			X
White pelican (P. erythrorhynchos)		X			X
Brown pelican (Pelacanus occidentalis)		X			X
Double-crested cormorant (Phalacrocorax auritus)		X			X
Olivaceons cormorant (P. olivaceus)		X			X
Anhinga (Anhinga anhinga)					X
Great blue heron (Ardea herodias)		X			X
Green heron (Butorides virescens)		X			X
Little blue heron (Florida caerulea)		X			X
Cattle egret (Bubulcus ibis)	X	X		X	X
Reddish egret (Dichromanassa rufescens)		X			X
Great egret (Casmerodius albus)	X	X			X
Snowy egret (Leucophoyx thula)	X	X			X
Louisiana heron (Hydranassa tricolor)	X	X			X
Black-crowned night heron (Nycticorax nycticorax)	X	X			X
Yellow-crowned night heron (Nyctanassa violacea)	X	X			X
Least bittern (Ixobrychus exilis)	X	X			X
American bittern (Botaurus lentiginosus)	X	X			X
Wood ibis (Mycteria americana)	X	X			X
White-faced ibis (Plegadis chihi)	X	X			X
White ibis (Eudocimus albus)	X	X			X
Roseate spoonbill (Ajaia ajaja)	X	X			X
Canada goose (Branta canadensis)	X	X			X
White-fronted goose (Anser albifrons)	X	X			X
Snow goose (Chen hyperborea)	X	X			X
Fulvous tree duck (Dendrocygna bicolor)	X	X			X
Mallard (Anas platyrhynchos)	X	X			X
Black duck (A. rubripes)	X	X			X
Mottled duck (A. fulvigula)	X	X			X
Gadwall (A. strepera)	X	X			X
Peregrine falcon (Falco peregrinus)	X		X	X	X
Pigeon hawk (Falco columbarius)	X	X			X
Sparrow hawk (F. sparverius)	X			X	X
Greater prairie chicken (Tympanuchus cupido)	X				
Bobwhite (Colinus virginianus)					X
Wild turkey (Meleagris gallopavo)				X	X
Sandhill crane (Grus canadensis)	X				X
King rail (Rallus elegans)		X			X
Clapper rail (Rallus longirostris)		X			X
Virginia rail (R. limicola)		X			X
Sora (Porzana carolina)		X			X
Yellow rail (Coturnicops noveboracensis)	X	X			X
Black rail (Laterallus jamaicensis)	X	X			X
Purple gallinule (Porphyrula martinica)					X
Common gallinule (Gallinula chloropus)					X
American coot (Fulica americana)		X			X
Semipalmated plover (Charadrius semipalmatus)		X			X
Snowy plover (Charadrius alexandrinus)		X			X
Wilson's plover (C. wilsonia)		X			X
Killdeer (C. vociferus)	X				X
American golden plover (Pluvialis dominica)	X				X

Common Name (Scientific Name)	A	B	C	D	E
Pintail (A. acuta)	X	X			X
Green-winged teal (A. carolinensis)	X	X			X
Blue-winged teal (A. discors)	X	X			X
Cinnamon teal (A. cyanoptera)					X
American widgeon (Mareca americana)	X	X			X
Shoveler (Spatula clypeata)	X	X			X
Wood duck (Aix sponsa)			X		X
Redhead (Aythya americana)		X			X
Ring-necked duck (A. collaris)		X			X
Canvasback (A. valisineria)		X			X
Lesser scarp (A. affinis)		X			X
Common goldeneye (Bucephala clangula)		X			X
Bufflehead (B. albeola)		X			X
Ruddy duck (Oxyura jamaicensis)		X			X
Hooded merganser (Lophodytes cucullatus)		X			X
Turkey vulture (Cathartes aura)	X		X	X	X
Black vulture (Coragyps atratus)	X		X	X	X
White-tailed kite (Elanus leucurus)	X			X	
Mississippi kite (Ictinia mississippiensis)	X			X	
Sharp-shinned hawk (Accipiter striatus)	X		X	X	
Cooper's hawk (A. cooperii)	X		X	X	
Red-tailed hawk (Buteo jamaicensis)	X		X	X	
Red-shouldered hawk (B. lineatus)	X		X	X	X
Broad-winged hawk (B. platypterus)			X	X	
Swainson's hawk (B. swainsoni)	X				
White-tailed hawk (B. albicaudatus)	X				
Southern bald eagle (Haliaeetus l. leucocephalus)			X		
Marsh hawk (Circus cyaneus)	X	X			
Osprey (Pandion haliaetus)					X
Caracara (Caracara cheriway)	X				
Lesser yellowlegs (T. flavipes)	X	X			X
Pectoral sandpiper (Erolia melanotos)		X			X
White-rumped sandpiper (E. fuscicollis)	X	X			X
Least sandpiper (E. minutilla)		X			X
Dunlin (E. alpina)		X			X
Long-billed dowitcher (L. scolopaceus)		X			X
Stilt sandpiper (Micropalma himantopus)		X			X
Semipalmated sandpiper (Ereunetes pusillus)		X			X
Western sandpiper (E. mauri)		X			X
Buff-breasted sandpiper (Tryngites subruficollis)	X				X
Marbled godwit (Limosa fedoa)		X			X
American avocet (Recurvirostra americana)		X			X
Black-necked stilt (Himantopus mexicanus)		X			X
Wilson's phalarope (Steganopus tricolor)		X			X
Herring gull (Larus argentatus)		X			X
Ring-billed gull (L. delawarensis)		X			X
Laughing gull (L. atricilla)		X			X
Franklin's gull (L. pipixcan)					X
Gull-billed tern (Gelochelidon nilotica)		X			X
Forester's tern (Sterna forsteri)		X			X
Common tern (S. hirundo)		X			X
Least tern (S. albifrons)		X			X

TABLE B.2-27 continued.

Common Name (Scientific Name)	A	B	C	D	E
Black-bellied plover (Squatarola squatarola)		X			X
Ruddy turnstone (Arenaria interpres)		X			X
American woodcock (Philohela minor)	X		X		X
Common snipe (Capella gallinago)	X	X			X
Long-billed curlew (Numenius americanus)	X	X			X
Upland plover (Bartramia longicauda)	X				
Spotted sandpiper (Actitis macularia)		X			X
Solitary sandpiper (Tringa solitaria)		X			X
Willet (Catoptrophorus semipalmatus)	X	X			X
Greater yellowlegs (Totanus melanoleucus)	X	X			X
White-winged dove (Zenaida asiatica)	X				X
Mourning dove (Zenaidura macroura)	X			X	X
Inca dove (Scardafella inca)					X
Yellow-billed cuckoo (Coccyzus americanus)	X		X	X	X
Black-billed cuckoo (C. erythropthalmus)	X		X	X	X
Roadrunner (Geococcyx californianus)	X			X	X
Barn owl (Tyto alba)	X		X	X	X
Great horned owl (Bubo virginianus)	X		X	X	X
Burrowing owl (Speotyto cunicularia)	X				
Barred owl (Strix varia)	X		X	X	
Short-eared owl (Asio flammeus)	X	X			X
Chuck-will's widow (Caprimulgus carolinensis)			X		X
Common nighthawk (Chordeiles minor)	X		X	X	X
Chimney swift (Chaetura pelagica)					X
Ruby-throated hummingbird (Archilochus colubris)	X		X	X	X
Belted kingfisher (Megaceryle alcyon)					X
Common flicker (Colaptes auratus)	X		X	X	X
Pileated woodpecker (Dryocopus pileatus)	X		X	X	
Red-bellied woodpecker (M. carolinus)	X			X	X
Red-headed woodpecker (Melanerpes erythrocephalus)	X		X	X	X
Yellow-bellied sapsucker (Sphyrapicus varius)	X		X	X	
Hairy woodpecker (Dendrocopos villosus)	X		X	X	
Downy woodpecker (D. pubescens)	X		X	X	X
Eastern kingbird (Tyrannus tyrannus)					X
Western kingbird (T. verticalis)			X		X
Scissor-tailed flycatcher (Muscivora forficata)	X		X		X
Great-crested flycatcher (Myiarchus crinitus)	X		X	X	X
Eastern phoebe (Sayornis phoebe)					X
Eastern bluebird (Sialia sialis sialis)	X				X
Blue-gray gnatcatcher (Polioptila caerulea)	X		X	X	
Ruby-crowned kinglet (R. calendula)	X		X	X	
Water pipit (Anthus spinoletta)	X	X			X
Sprague's pipit (A. spragueii)	X	X			X
Loggerhead shrike (Lanius ludovicianus)	X			X	X
Starling (Sturnus vulgaris)					X
White-eyed vireo (Vireo griseus)	X			X	
Yellow-throated vireo (V. flavifrons)	X		X	X	
Solitary vireo (V. solitarius)	X		X	X	
Red-eyed vireo (V. olivaceous)	X		X	X	
Philadelphis vireo (V. philadelphicus)	X		X	X	
Warbling vireo (V. gilvus)	X		X	X	
Black-and-white warbler (Mniotilta varia)	X		X	X	
Prothonotary warbler (Protonotaria citrea)			X		X
Worm-eating warbler (Helmitheros vermivorus)	X		X	X	

Common Name (Scientific Name)	A	B	C	D	E
Royal tern (Thalasseus maximus)		X			X
Caspian tern (Hydroprogne Caspia)		X			X
Black tern (Chlidonias niger)		X			X
Black skimmer (Rynchops nigra)		X			X
Rock dove (Columba livia)					X
Acadian flycatcher (E. virescens)	X			X	X
Least flycatcher (E. minimus)	X			X	X
Eastern wood pewee (Contopus virens)	X		X	X	
Olive-sided flycatcher (Nuttallornis borealis)	X		X	X	X
Vermilion flycatcher (Pyrocephalus rubinus)	X				X
Horned lark (Eremophila alpestris)	X				X
Tree swallow (Iridoprocne bicolor)	X		X	X	X
Bank swallow (Riparia riparia)	X				X
Rough-winged swallow (Stelgidopteryx rufficollis)					X
Barn swallow (Hirundo rustica)	X				X
Purple martin (Progne subis)					X
Blue jay (Cyanocitta cristata)	X		X	X	X
Common crow (Corvus brachrhynchos)	X		X	X	X
Carolina chickadee (Parus carolinensis)	X		X	X	X
Tufted titmouse (P. bicolor)	X		X	X	
White-breasted nuthatch (Sitta carolinensis)			X	X	
Red-breasted nuthatch (S. canadensis)	X		X	X	
Brown creeper (Certhia familiaris)	X		X	X	
House wren (Troglodytes aedon)	X		X	X	X
Carolina wren (Thryothorus ludovicianus)	X		X	X	X
Long-billed marsh wren (Telmatodytes palustris)		X			X
Short-billed marsh wren (Cistothorus platensis)	X	X			X
Mockingbird (Mimus polyglottos)	X		X	X	X
Gray catbird (Dumetella carolinensis)	X		X	X	X
Brown thrasher (Toxostoma rufum)	X		X	X	X
Robin (Turdus migratorius)					X
Wood thrush (Hylocichla mustelina)	X		X	X	
Hermit thrush (H. guttata)	X		X	X	
Swainsons thrush (H. ustulate)	X		X	X	
Gray-cheeked thrush (H. minima)	X		X	X	
Veery (Hylocichla fuscescens)	X		X	X	
Ovenbird (Seiurus aurocapillus)	X		X	X	
Northern water-thrush (S. noveboracensis)	X				X
Louisiana waterthrush (S. motacilla)	X				X
Kentucky warbler (Oporornis formosus)	X		X	X	
Yellowthroat (Geothlypis trichas)					X
Yellow-breasted chat (Icteria virens)			X	X	
Hooded warbler (Wilsonia citrina)	X		X	X	
Wilson's warbler (W. pusilla)	X		X	X	
Canada warbler (W. canadensis)	X		X	X	
American redstart (Setophaga ruticilla)	X		X	X	
House sparrow (Passer domesticus)					X
Eastern meadowlark (Sturnella magna)	X				X
Red-winged blackbird (Agelaius phoeniceus)	X	X			X
Orchard oriole (Icterus spurius)					X
Northern oriole (I. galbula)	X		X	X	X
Brewers blackbird (E. cyanocephalus)	X				X
Common grackle (Quiscalus quiscalus)					X
Brown-headed cowbird (Tangavius aeneus)	X		X	X	X

TABLE B.2-27 continued.

Common Name (Scientific Name)	A	B	C	D	E
Golden-winged warbler (Vermivora chrysoptera)	X			X	
Blue-winged warbler (V. pinus)	X			X	
Tennessee warbler (V. peregrina)	X		X	X	
Orange-crowned warbler (V. celata)	X			X	
Nashville warbler (V. ruficapilla)	X		X	X	
Northern parula (Parula americana)	X		X	X	
Yellow warbler (Dendroica petechia)					X
Magnolia warbler (D. magnolia)	X		X	X	
Yellow-rumped warbler (D. coronata)	X		X	X	
Cerulean warbler (D. cerulea)			X		X
Yellow-throated warbler (D. dominica)	X			X	
Chestnut-sided warbler (D. pensylvanica)	X			X	
Bay-breasted warbler (D. castanea)	X		X	X	
Dickcissel (Spiza americana)	X				
American goldfinch (Spinus tristus)	X			X	X
Savannah sparrow (Passerculus sandwichensis)	X	X		X	X
Grasshopper sparrow (Ammodramus savannarum)	X			X	
Le Contes sparrow (Passerherbulus caudacutus)	X			X	
Sharp-tailed sparrow (Ammospiza caudacuta)	X	X			X
Seaside sparrow (A. maritima)		X			
Scarlet tanager (Piranga olivacea)	X		X	X	X
Summer tanager (P. rubra)	X		X	X	X
Cardinal (Richmondena cardinalis)	X		X	X	X
Rose-breasted grosbeak (Pheucticus ludovicianus)	X		X	X	
Blue grosbeak (Guiraca caerulea)	X		X	X	X
Indigo bunting (Passerina cyanea)	X		X	X	
Painted bunting (P. ciris)	X		X	X	X
Vesper sparrow (Pooecetes gramineus)	X			X	
Lark sparrow (Chondestes grammacus)	X			X	X
Bachman's sparrow (Aimophila aestivalis)	X		X	X	
Dark-eyed junco (Junco hyemalis)	X		X	X	
Chipping sparrow (Spizella passerina)	X			X	X
Field sparrow (S. pusilla)	X		X		
Harris' sparrow (Zonotrichia querula)	X			X	
White-crowned sparrow (Z. leucophrys)	X			X	X
White-throated sparrow (Z. albicollis)	X		X	X	
Lincolns sparrow (Melospiza lincolnii)	X		X	X	
Swamp sparrow (M. georgiana)					X
Song sparrow (M. melodia)	X		X	X	X

Note: Habitat types in which individual species are found:

* Rare or endangered
A Gulf Prairie
B Gulf Marsh
C Fluvial Woodlands
D Post Oak Savannah
E Other (Aquatic habitats, wooded stream courses, roadsides, urban areas, mountains, agricultural areas)

General range maps, preferred habitats and known records were used to determine species distribution.

TABLE B.2-28 Amphibians and reptiles likely to occur in the study area.

Common Name (Scientific Name)	A	B	C	D	E
*American alligator (Alligator mississipiensis)		X			X
Alligator snapping turtle (Macroclemys temmincki)					X
Stinkpot (Sternothaerus temmincki)					X
Razor-backed musk turtle (S. carinatus)					X
Mississippi mud turtle (Kinosternon subrubrum hippocrepis)		X			X
Gulf Coast box turtle (Terrapene carolina major)	X	X			X
Ornate box turtle (T. ornata ornata)	X			X	
Texas diamondback terrapin (Malaclemys terrapin littoralis)		X			X
Mississippi map turtle (Graptemys kohni)					X
Texas map turtle (G. versa)					
Red-eared turtle (Pseudemys scripta elegans)					X
Texas slider (P. concinna texana)					X
Missouri slider (P. floridana hoyi)		X			X
Western chicken turtle (Deirochelys reticularia miaria)		X			X
Smooth softshell (Trionyx muticus)					X
Texas softshell (T. spinifer emoryi)					X
Green anole (Anolis carolinensis carolinensis)			X	X	
Collard lizard (Crotaphytus c. collaris)					X
northern fence lizard (Sceloporus undulatus hyacinthinus)	X		X	X	X
Texas horned lizard (Phrynosoma cornutum)					X
Six-lined racerunner (Cnemidophorus sexlineatus)	X		X	X	X
Spotted whiptail (C. sacki gularis)				X	X
Ground skink (Lygosoma laterale)	X		X	X	
Five-lined skink (Eumeces fasciatus)	X		X	X	X
Broad-headed skink (E. laticeps)	X		X	X	X
Western slender glass lizard (Ophisaurus a. attenuatus)	X			X	
Louisiana milk snake (L. doliata amaura)	X		X	X	X
Prairie king snake (L. calligaster calligaster)				X	X
Texas coral snake (Micrurus fluvius tenere)	X		X	X	X
Southern copperhead (Agkistrodon contortrix controtrix)	X		X	X	
Western cottonmouth (A. piscivorus leucostoma)	X	X	X		
Western massasauga (Sistrurus catenatus tergeminus)	X			X	
Canebrake rattlesnake (Crotalus horridus atricaudatus)					X
Western diamondback rattlesnake (C. atrox)	X			X	X
Western lesser siren (Siren intermedia nettingi)					X
Small-mouthed salamander (Ambystoma texanum)					X
Eastern tiger salamander (A. t. tigrinum)					X
Central Newt (Diemictylus viridenscens louisianensis)					X
Hurter's spadefoot (Scaphiopus hurteri)	X		X	X	
*Houston toad (Bufo houstonensis)			X		
Woodhouse's toad (B. w. woodhousei)					X
Fowler's toad (B. w. fowleri)					X
East texas toad (B. w. velatus)					X
Gulf coast toad (B. valliceps)	X				X
Blanchard's cricket frog (Acris crepitans blanchardi)					X
Northern spring peeper (Hyla crucifer crucifer)			X		
Green tree forg (H. cinerea cinerea)					X
Green water snake (Natrix cyclopion cyclopion)		X			X
Diamond-backed water snake (N. rhombifera rhombifera)		X			X
Yellow-bellied water snake (N. erythrogaster flavigaster)		X			X
Broad-banded water snake (N. sipedon confluens)		X			X
Gulf salt marsh snake (N. s. clarki)		X			
Graham's water snake (N. grahami)		X			X
Texas brown snake (Storeria dekayi texana)	X	X			X
Eastern garter snake (Thamnopttis sirtalis sirtalis)	X	X	X		X
Western ribbon snake (T. sauritus proximus)	X				
Rough earth snake (Haldea striatula)	X		X	X	X
Western earth snake (H. valeriae elegans)			X	X	X
Eastern hognose snake (Heterodon platyrhinos)	X			X	
Dusty hognose snake (H. nasicus gloydi)	X				
Mississippi rigneck snake (Diadophtis punctatus stictogenys)			X		
Western mud snake (Faracia abacura reinwardti)	X	X			
Eastern yellow-bellied racer (Coluber constrictor flaviventria)	X				
Eastern coachwhip (Masticophis flagellum flagellum)				X	
Rough green snake (Opheodrys aestivus)			X	X	X
Texas rat snake (Elaphe obsoleta lindheimeri)	X		X	X	
Speckled king snake (Lampropeltis getulus holbrooki)	X				X
Squirrel tree frog (H. squirella)	X				X
Southern gray tree frog (H. versicolor chrysoscelis)			X	X	X
Upland chorus frog (Pseudacris triseriata feriarum)	X		X	X	X
Spotted chorus frog (P. clarki)	X			X	
Eastern narrow-mouthed toad (Gastrophryne carolinensis)	X		X		X
Great plains narrow-mouthed toad (G. olivacea olivacea)	X			X	X
Bullfrog (Rana catesbeiana)					X
Bronze frog (R. clamitans clamitans)			X		X
Rio Grande leopard frog (R. pipiens berlandieri)					X
Southern crawfish frog (R. aerolata aerolata)	X	X			

* Rare, endangered or status undetermined

Note:

Habitat types in which individual species are found.

- A Gulf Prairie
- B Gulf Marsh
- C Fluvial Woodlands
- D Post Oak Savannah
- E Other (Aquatic habitats, urban areas, desert scrub, or mountains)

General range maps, preferred habitats, and known records were used to determine species distribution.

TABLE B.2-29 Mammals likely to occur in the study region.

Common Name (Scientific Name)	A	B	C	D	E
Opossum (Didelphis marsupialis)	X	X	X	X	X
Short-tailed shrew (Blarina brevicauda)			X	X	
Little short-tailed shrew (Cryptotis parva)	X				
Eastern mole (Scalopus aquaticus)	X		X	X	
Georgia bat (Pipistrellus subflavus)			X	X	X
Big brown bat (Eptesicus fuscus)			X	X	X
Red bat (Lasiurus borealis)			X	X	X
Yellow bat (Lasiurus intermedius)			X	X	
Evening bat (Nycticeius humeralis)			X	X	X
Guano bat (Tadarida mexicana)				X	X
Nine-banded armadillo (Dasypus novemcinctus)	X	X			
Eastern cottontail (Sylvilagus floridanus)	X				X
Swamp rabbit (Sylvilagus aquaticus)	X	X			
Black-tailed jack rabbit (Lepus californicus)	X				
Thirteen-lined ground squirrel (Citellus tridecemlineatus)	X				
Gray squirrel (Sciurus carolinensis)	X				X
Fox squirrel (Sciurus niger)	X				X
Southern flying squirrel (Glancomys volans)	X				X
Plains pocket gopher (Geomys bursarius)	X				
Hispid pocket mouse (Perognathus hispidus)	X				
Beaver (Castor canadensis)					
Rice rat (Oryzomys palustris)	X				
Dwarf harvest mouse (Reithrodontomys humulis)	X				
Long-tailed harvest mouse (R. Fulvescens)	X				
Deer mouse (Peromyscus maniculatus)					X
White-footed mouse (P. leucopus)	X		X	X	
Pygmy mouse (Baiomys taylori)	X				
Hispid cotton rat (Sigmodon hispidus)	X			X	
Florida wood rat (Neotoma floridana)			X	X	
Prairie meadow mouse (Microtus ochrogaster)					X
Pine vole (Pitymys pinestorum)			X	X	
Muskrat (Ondatra zibethica)		X			X
Nutria (Myocastor coypus)		X			X
Coyote (Canis latrans)	X	X		X	
*Red wolf (Canis rufus)	X	X			
Gray fox (Urocyon cinereoargenteus)			X	X	X
Raccoon (Procyon lotor)	X	X	X	X	X
Long-tailed weasel (Mustela frenata)	X			X	
Mink (M. vison)		X			X
Spotted skunk (Spilogale putorius)	X		X	X	X
Striped skunk (Mephitis mephitis)	X		X	X	X
Hog-nosed skunk (Conepatus leuconotus)	X		X		X
River otter (Lutra canadensis)		X			X
Bobcat (Lynx rufus)	X		X	X	
White-tailed deer (Odocoileus viginianus)	X		X	X	

1 Habitat types in which individual species are found

- A Gulf Prairie
- B Gulf Marsh
- C Fluvial Woodlands
- D Post Oak Savannah
- E Other (Aquatic habitats, agricultural areas, urban areas, or dense brush)

*Rare, endangered, or status undetermined

General range maps, preferred habitat and known records were used to determine species distribution.

Phylogenetic order follows Hall and Kelson, 1959.

Coastal Prairie

Within the project region, the coastal prairie covers 413,000 acres. Soils within the coastal prairie are of the Moreland-Pledger-Norwood association and are composed primarily of clays or clay loams, although some areas have sandy loams present (Gould, 1962). Surface soil colors range from light brown to light grey. The coastal prairie soils have poor to moderate drainage.

The areas of the prairie which are subject to occasional inundation by saline waters during high tidal flows or floods are dominated by Gulf cordgrass. The coastal uplands originally supported an extensive prairie grassland, but much of the grassland has been converted into agricultural land (see Cleared Lands). In areas used for grazing, western ragweed is the more common plant species. Prairie pleatleaf, bunchgrasses, Indiangrass, and switchgrass are also commonly found on the prairie.

Members of the prairie avifauna are the Savannah, vesper, and song sparrows; eastern meadowlark; upland plover; sandhill crane; cattle egrets; turkey and black vultures; and the marsh hawk. Common mammals in the prairie include domestic cattle, hispid cotton rats, rice rats, eastern cottontail rabbits, striped skunk, and Canid sp. The western diamondback rattlesnake, eastern garter snake, Gulf Coast toad, spotted chorus frog, and the ornate box turtle are prevalent herpetiles of the coastal prairie.

Coastal Marshlands

The coastal marsh and ecosystem is well developed in Brazoria County at elevations of less than 5 feet above mean sea level. These marshlands occur throughout much of the near-shore coastal region, covering about 84,000 surface acres.

The marshland is characterized by various grasses and trees which are zoned according to their frequency and intensity of exposure to water of various salinities. Saline, brackish, and freshwater marshes are found within the study area; salinities in the marine and estuarine marshes (up to 40 ppt) decrease toward the north.

Saline marshes occur primarily on the plains of bayhead deltas, along bay margins, on tidal flats, and on the inland side of barrier islands. In saltwater marshes, smooth cordgrass is the predominant vegetation (Dames & Moore, 1973b; Correll and Johnston, 1970). Saltgrass, glasswort, batis, and salt matrimony vine may also occur. Brackish water marshlands receive water from both the Gulf of Mexico and from the streams of the region. Hardstem bulrush and saltgrass are the most common grasses in these marshes.

Saltwater and brackish marshes provide excellent habitat for mammals, reptiles, and wintering migratory waterfowl. Ducks and geese predominate the avifauna during the winter, but gulls, ibises, herons, plovers, and sandpipers are also common in these marshes. Rice rats, raccoon, nutria, muskrat, rabbits, and Canid sp. are the common mammals in the marshes. Reptiles are common to both the prairies and marshlands and include western diamondback rattlesnake, western cottonmouth, and Gulf salt marsh snake.

Freshwater marshlands in the region are mainly along the flood plains of the Brazos and Colorado Rivers. Typical emergent vegetation of these marshes includes maidencane, pennywort, and water hyacinth. Freshwater marshes are utilized by waterfowl as feeding sites. Avifauna commonly sighted are gulls, terns, herons, egrets, ibises, ducks and geese, and red-winged blackbirds. The most abundant reptiles in the freshwater marsh are the western cottonmouth, southern leopard frog and bullfrog; the most typical mammals include the raccoon and nutria.

Marshlands have a high average level of productivity and support extensive food chains within the marsh and in surrounding areas. Tidal marshes serve as nursery areas, control erosion, serve as flood water barriers and support a variety of wildlife. Marshlands also serve human uses such as recreation, livestock grazing, and mariculture. Although some small changes in marshlands may have severe or widespread consequences, the exact functions served by specific marshes are not known in most cases. In Texas, studies comparing undeveloped marshes and bulkheaded or channeled developments in some areas showed a sharp reduction in organic productivity associated with development activities (Gen. Land Office of Texas, 1976). Wetlands and submerged lands have long been of major concern to various state agencies and federal agencies such as the Corps of Engineers.

Cleared Lands

Approximately 45,000 acres of cleared lands are located within the region. These lands were cleared for agricultural cultivation (including farming for high nutrient pasture grasses), and urbanization.

The typical wildlife which frequents cleared lands is quite varied and is highly influenced by the pressures of specific land use. This fauna includes species which migrate between ecosystems. Residential or ranch areas contain domesticated animals such as cattle, swine, and dogs, in addition to songbirds. More isolated areas provide habitat for furbearers, and predators such as coyotes. Rice fields are favorite feeding grounds for geese and other waterfowl in the winter months.

Fluvial and Oak Woodlands

The fluvial and oak woodlands of the region provide habitat for a variety of resident and migratory avifauna including hawks, crows, woodpeckers, chickadees, wrens, vireos, warblers, thrushes, blackbirds, finches, catbirds and sparrows. Mammal species utilizing these habitats include oppossum, small rodents, bats, gray and fox squirrels, white-footed mouse, deer, fox, coyote, raccoon, bobcat, armadillo, and striped skunk. Herpetofauna species include ornate box turtle, broadheaded skink, eastern garter snake, Hurter's spadefoot, and the gray tree frog.

Accurate recent population estimates of various mammals in Brazoria County are not available in the literature. It has been estimated by the Texas Parks and Wildlife Department that the number of deer (for 1975 to 1976), quail (for 1974) and squirrels (for 1974) in Brazoria County are 7000, 80,000 and 80,000 animals, respectively. Davis (1966) estimated the populations for selected mammals in Texas to be as follows:

Cottontail Rabbits	-	1 rabbit per 4 to 5 acres of Coastal Prairie land
Swamp Rabbits	-	1 rabbit per 7 acres of poorly drained bottom land

Armadillo	-	1 armadillo per 10 acres of land with clay soils
Opossum	-	1 animal per 4 acres of good habitat
Coyote	-	1 animal per square mile (640 acres of land) (but sometimes 4 or more coyotes in productive areas)

No precise record is kept for the Bryan Mound area on harvest of game animals but the Texas Parks and Wildlife Department estimates that during 1975-1976 the deer harvest was 1058 animals. The number of deer hunters in Brazoria County for this same period was 2791.

Fluvial Woodlands

The largest ecosystem in the project region consists of the fluvial woodlands. Most of these woodlands trend in a northwest to southeast direction following the dominant drainage patterns. Fluvial woodlands, in the strictest sense, are woodlands adjacent to riparian or estuarine areas, however, some of the areas included here as fluvial woodlands differ from the strict interpretation. These woodlands occur in depressional basins with impeded drainage characteristics. The vegetation present in these low areas is predominantly of the fluvial hardwood type.

The fluvial woodlands are generally the most heterogeneous of the floral assemblages. Due to their mesophytic-hydrophytic moisture regime, they support vegetation from the surrounding ecosystems in addition to several species not found elsewhere. Plant and grass species of the area include Bermuda grass, greenbrier, yaupon, and seamyrtle. The first three of these species are common to stressed sites. The dominant vegetation of the wetter fluvial areas consists of live oak and pecan tree species. On drier sites including the higher areas with better drained soils, sugarberry, hybrid oak, and hickory are the major overstory components.

Oak Woodlands

The oak woodlands in the region possess elements common to both fluvial woodlands and post oak savannahs. Oak woodlands resemble the fluvial woodlands in that they predominate along the organized drainage patterns and have species similar to those found in fluvial woodlands; they resemble post oak savannahs in that they include live oak, blackjack oak, hybrid oak, water oak, hickory, sugarberry, and pecan. The plant and grass species found in oak woodlands include Bermuda grass, greenbrier, yaupon, mesquite, and bluestem grass.

Coastal and Inland Waters

Within the region, the greatest diversity of environments and biological assemblages occur in the coastal and inland waters. These include the Gulf of Mexico, bays, estuaries, rivers, streams, lakes and ponds. Texas bays and estuaries are relatively low-energy environments which are protected by barrier islands and peninsulas. Water exchange between the Gulf of Mexico and the estuaries is governed by proximity to the tidal passes. During storms, Gulf waters also enter the low-lying areas through washover, or storm channels. Fresh water is furnished to the bays and lagoons by the Brazos, San Bernard, and Colorado Rivers; and several smaller streams which drain local areas. Because of these contributions, the range of salinities in the water bodies is quite variable. This variability plays a large part in governing the abundance and distribution of the biological assemblages found in these ecosystems.

Coastal Waters

Coastal waters, river mouths, and passes along the Texas Gulf Coast provide excellent nursery habitats for juvenile shrimp and fish. Coastal fish and shellfish of Texas are generally abundant and diverse. The finescale menhaden reach their greatest abundance in these coastal areas.

Estuarine waters within Brazoria County are primarily limited to the extreme lower and extreme upper coastline of the County. These waters include Cedar Lakes and Oyster (Christmas) Bay, West Bay, and Chocolate Bay. Circulation within these semi-enclosed lakes and bays is generally poor. Species diversity tends to be low but population densities are high. The lower portion of West Bay near San Luis Pass is a tidal area. This area has good circulation and its species diversity is high, and population densities are relatively low, thus indicating a well-balanced biological system.

Salinity levels in the Intracoastal Waterway (ICW) are usually similar to those concentrations found in the adjacent estuarine waters. The biotic components of the ICW would be similar to those occurring in the brackish to saline waters previously discussed above. Major habitat uses of the coastal and inland waters include feeding and resting by some waterfowl species, gulls, terns, herons, and egrets.

There are two major groups of fish found in the offshore waters of the continental shelf in the region: 1) the inner shelf species including the Atlantic threadfin, Atlantic croaker, sand seatrout and silver seatrout and 2) the more diverse and abundant intermediate shelf assemblage including the longspine porgy, inshore lizard fish and Gulf butterfish. Other seasonally transient species found among the more than 600 species in the waters of the region include the sea catfish, mullet, spot and red drum. White, pink and brown shrimp are important commercial species in the region. The brown shrimp is considered the most important and abundant. The shrimp spawn in coastal waters but post-larval and juvenile forms are found in estuarine nursery areas. The period when young shrimp are most subject to outside pressures is between the egg and post-larval stages, during their migratiion to the nursery grounds.

Biological productivity of the project estuarine and coastal regions is generally high. Phytoplankton are the primary producers of the region and vary seasonally in abundance and composition. Cell densities progressively decrease seaward from the coast. Diatoms are the most abundant type of phytoplankton in the inshore areas. Genera normally encountered in samples include *Melosira*, *Navicula*, *Nitzschia*, and *Chaetoceros*. Dinoflagellates and microflagellates are also common phytoplankton. In the brackish and saline coastal waters, zooplankton populations are seasonally dominated by copepods and nauplii, with *Acartia tonsa* being the most common copepod (U.S. Department of the Interior, 1972). Zooplankton densities vary temporally and spatially, peaking in late spring and early fall following phytoplankton abundance. Zooplankton concentrations also decrease seaward from the coastline.

Two major benthic assemblages have been identified in the region offshore the central Texas coast: 1) a high salinity offshore community, and 2) a low salinity nearshore community. The fauna five miles or more offshore (the highly saline community) is generally more stable in composition due to more stable temperature and salinity, and tends to be dominated by polychaetes. The more variable nearshore community has no single dominant group. Several hundred benthic species have been identified in the region.

Nematodes, copepods, amphipods, ostracods, mollusks, and polychaetes are the predominant benthic animals (Day, et al., 1973). The marsh clam the American oyster, and the blue crab are abundant commercial species found in the region. Several coral heads and rock outcroppings have been observed off the mouth of the Brazos River Diversion Channel. These are considered unique habitat in the area since most benthic areas consist of mud or sand substrates, and they may produce unique floral or faunal assemblages. Good fishing is found in the vicinity. A complete description of biologic assemblages in the offshore region is supplied in Appendix G.

Rivers and Inland Waters

The project region is drained by two major river systems, the Brazos River, and the San Bernard River (Figure B.2-2). Of the two, the Brazos is the most important river. The Brazos has been diverted at Freeport, and a diversion channel carries the water to the Gulf. The original river channel now forms Freeport Harbor.

Numerous creeks, bayous, sloughs, and drainage ditches are located in the region. These bodies are characterized by low gradients and flow rates; many are intermittent. The largest standing water bodies in the region include Harris and Brazoria Reservoirs and Eagle Nest, Manor, and Mallard Lakes, all located in northern Brazoria County. Many lakes are scattered throughout the region.

The dominant floral and faunal components of the fresh waters in Brazoria County include green algae, diatoms, and bluegreen algae. Common macrophytes include the pondweeds, duckweeds, and waterlilies.

Zooplankton includes rotifers, copepods, cladocerans, and nematodes. Common benthic macroinvertebrates are the amphipods, corixids, larval dipterans, and Coleoptera. Fresh water fish typical of the region include gizzard shad, carp, gar, and sport fishes such as largemouth bass, channel catfish, and several species of sunfish and crappie. Wildlife species which either inhabit and/or utilize these aquatic areas to feed or rest include several species of ducks and geese, and also gulls, terns, herons, egrets, nutria, water snakes, turtles, and frogs.

B.2.5.2 Commercially Important Species

Agriculture

Commercially important vegetative species in the region are limited generally to rice, grain, and sorghum production. Principal use of cultivated lands is for the production of rice. A relatively small amount of hay and grain is produced to feed beef and dairy cattle, which range over the pasture land. An extensive irrigation and drainage canal system and tank ponds are utilized in agricultural production. Brazoria County, which comprises most of the region under consideration, is one of 13 coastal Texas counties which account for 30 percent of the nation's rice harvest. Although sorghum is considerably less important than rice, in county-wide farm production (1969), 171,172 bushels were harvested from 7574 acres of land (Boykin, 1972). Overall farmland within the county used for crop production in 1969 was 95,616 acres, approximately 10 percent of the total county acreage.

Use of wooded lands in the project region for commercial timbering is rare. Locally, small areas have been cleared for range and cultivation.

Wildlife

The major commercially valuable wildlife species found within the region include the opossum, skunk, nutria and raccoon. They are trapped for fur.

Aquatic

Commercial fishing is a multimillion dollar business along the Texas coast. Landings for 1976 totaled 93 million pounds having a value of $126 million. The landings were significant on a national basis with major commerical species on the Texas Gulf Coast including shrimp, blue crab, oyster, menhaden, and several common sport fish. The Galveston District alone reported landings of 8.5 million pounds of major species valued at $4.7 million in 1975.

Shrimp are the single most valuable marine product in Texas. Shrimp landings in the state amounted to 92 percent of the total dollar value of finfish and shellfish in 1970 and 1971. From 1966 to 1971, Texas landings accounted for 37 percent of the Gulf shrimp catch. Brown shrimp is the most abundant shrimp in Texas waters and tends to be concentrated in the zone from Galveston to the Rio Grande.

Many species of crabs are collected in Texas coastal waters, but the blue crab is the only one extensively exploited by man. Adult blue crab populations are fished in nearshore bays and the inner shelf of open Gulf waters.

The American oyster occurs in the region in estuaries, bays and lagoons. Most of the oyster production in the last few years has been centered in bays in neighboring counties, especially East Matagora Bay.

B.2.5.3 Recreationally Important Species

Wildlife

The predominant recreationally important species in the region are waterfowl, furbearers, dove, quail, squirrels, cottontail rabbits, and whitetailed deer. During the winter, the marshes on the Texas coast provide habitat for about 30 percent of the ducks and 64 percent of the geese that migrate to the Gulf Coast region (Gusey, 1972). The 1974 goose population estimate for Brazoria County was 80,000 birds (Boydson, 1976). Waterfowl are hunted in the marshes and fields where they feed. Dove and bobwhite are hunted in agricultural areas. In general, all birds can be considered recreationally important to the large number of area bird watchers.

Squirrels are important game animals in areas where suitable habitat is present. An estimated 80,000 squirrels were present in the habitable portions of Brazoria County during 1974 (Boydston, 1976). Some furbearing species are hunted for sport, including raccoon, fox, and coyote. The estimated whitetailed deer population in Brazoria County during 1975-76 was 7000 animals (Boydston, 1976). The 1975-76 deer harvest for the county was 1058 animals (Marsh, 1976).

Aquatic

The black bass, sunfish, catfish, and crappie are the most important sport fish in the fresh waters of the region. The larger lakes and the San Bernard and Brazos Rivers support the major sport fishing pressure in the region; however, many small ponds and creeks also have sports fish. The marshes of the area provide a recreational crab fishery. In coastal waters, red drum (red fish), sea trout, tarpon, and flounder are the primary sport fish species. Sport fishing in the Texas coastal area is extremely popular and supports a large related industry.

B.2.5.4 Rare and Endangered Species

A large number of threatened and endangered wildlife species have been reported to occur in the Texas Gulf Coastal region (Federal Register, June 16, September 30, and October 27, 1976).

Of the list of plant species that have been proposed for endangered status by the U.S. Fish and Wildlife Service (U.S. Department of the Interior, 1976a,b,c) whose range would extend into Texas, none of the specific taxa are known to occur in Brazoria and Fort Bend Counties. However, the botany of these areas is not well known. Several taxa (including *Hoffmanuseggia tenella*) occur further to the south along the Texas coast. *Erigeron geiseri* is reported to be widespread, but the variety *calcicola* is not known in Brazoria or Fort Bend counties. *Atriplex klebergorum* has been listed as an endemic species of south coastal Texas and could occur in Brazoria County. *Brazoria pulcherrima* is known to occur in Leon County and is possible that this species may also occur in Fort Bend County.

Some plant species included in the Texas Organization for Endangered Species list (1973) are found within the Freeport general area. Seaoats were recorded in the area southeast of the Bryan Mound site between Old Reservoir and Bryan Lake, smooth cordgrass (oystergrass) grows along the old Intracoastal Waterway; and black walnut was reported in an area approximately 8 miles northwest of the Bryan Mound site.

Within the coastal prairies and marshlands, several other plants have been described as threatened and endangered species by the University of Texas (1974):

Common Name	Scientific Name	Status
Awnless bluestem	*Bothriochloa exaristata*	Scarce
Giant sedge	*Carex gigantea*	Very rare
Sand sedge	*Carex tribuloides*	Very rare
Texas windmillgrass	*Chloris texensis*	Very rare
Texas bitterweed	*Hymenoxys texana*	Presumed extinct
Houston machaeranthera	*Machaeranthera aurea*	Very rare
Coastal evening primrose	*Oenothera sessilis*	Presumed extinct
Common adder's-tongue	*Ophioglossum vulgatum*	Scarce
Louisiana palm	*Sabal minor*	Scarce
Baldwin stonerush	*Scleria baldwinii*	Very rare/presumed extinct
Minor nutrush	*Scleria minor*	Very rare
Southern marsh fern	*Thelypteris palustris var. Haleana*	Scarce

The Texas Organization for Endangered Species and the U.S. Fish and Wildlife Service lists of threatened and endangered wildlife species contain four species of birds which may be found near the Gulf Coast: southern bald eagle, peregrine falcon, whooping crane, and brown pelican (Texas Parks and Wildlife, 1976; U.S. Department of the Interior, 1976b). The reddish egret and roseate spoonbill are on the list of peripheral birds; those birds whose occurrence in the United States is on the edge of its natural range and which are threatened with extinction in that portion of their range (Office of Endangered Species and International Activities, 1973). Relatively few of these species are expected to nest or breed near the candidate sites or along the pipeline right-of-way because of their proximity to human habitation.

Brown pelican numbers are extremely low in the Texas Gulf Coast region. Only one observation has been recorded in the Freeport area (Emanuel, 1970), and their occurrence at the candidate storage sites is unlikely.

Whooping cranes winter only at the Aransas National Wildlife Refuge, which is located more than 100 miles southwest of the project area. Therefore, their occurrence at the candidate sites is highly unlikely.

The southern bald eagle is known to nest in the study area.

Because of the wide ranging mobility of the peregrine falcon and its attraction to open areas, this bird may be endangered in the project region. The peregrine falcon has been observed during field surveys in the coastal prairie and marshlands near the coast in Brazoria County during the 1976-Christmas Freeport bird count (Emanuel, 1977).

The reddish egret is another inhabitant of the Coastal Zone. Thirty-five of these egrets were also sighted during the 1976 Freeport bird survey (Emanuel, 1977). Several individuals were encountered in the coastal marshes during field surveys conducted by Dames & Moore (1973b).

The roseate spoonbill is now thriving and extending its range in Texas (Wallace and others, 1972). Fifty-five observations of this species were recorded during the 1976 Christmas bird count in Freeport (Emanuel, 1977).

The red wolf is the only species of mammal on the Federal and State lists which may occur in the region. The red wolf formerly ranged over much of the southeastern United States, but now its range is restricted to a few southeastern counties of Texas and to Cameron Parish, Louisiana. Excessive trapping, hunting, and extensive disturbance to its habitat have been the principal reasons for the decline of this species (Pimlott and Joslin, 1968; Russell and Shaw, 1972). In addition, competition with coyote populations and probably hybridization with the coyote also would be contributing factors (Pimlott and Joslin, 1968). Observation of a true red wolf has not been confirmed west of the Brazos River for at least five years.

The American alligator and Houston toad are two species of herpetofauna on the Federal list of threatened or endangered species that occur in the project region (Federal Register, 1976). These species have been reported in Brazoria County but should not be affected by the project.

Three additional species, the Atlantic Ridley turtle, the Hawksbill turtle and the leather back turtle, which are presently on the Federal list of endangered species, occur in the Gulf of Mexico and could occur in the project region. None of these species have been observed in the area surrounding the proposed diffuser site.

The U.S. Department of Interior (1976b) considers five species of freshwater fish to be endangered and threatened in Texas; three additional fish are included on the Texas Parks and Wildlife Department (1976) list. None of these fish are known to inhabit the freshwater bodies existing in the project region. Seven species of endangered marine mammals have been reported in the waters of the Gulf. This is based on scattered sightings and does not represent indigenous populations (Appendix G).

The U.S. Department of Interior (1976b) lists many aquatic invertebrate species as endangered and threatened but none of these species are known to have a range that extends into Texas or into its coastal waters.

Critical Areas of Concern

Although the Texas Parks and Wildlife Department, in response to an inquiry from the Texas General Land Office for use in preparing a Coastal Zone Management Plan, nominated several areas in the vicinity of the Seaway Group as "areas of particular state concern," the Coastal Management Program ultimately issued by the Land Office did not designate any of those as "areas of particular concern." The Texas Coastal Management Program Briefing Paper for Federal Reviewers, issued by the Land Office in March of 1978, designated four site-specific areas of particular concern: (1) National Audubon Society leases, (2) Snake Island (West Bay), (3) state-owned marshes on the bay side of Matagorda Island, and (4) St. Charles Bay. None of these is located in the vicinity of the Seaway Group.

The Texas Coastal Management Program says also that sand dunes in general are another area of particular concern and the General Land Office is preparing criteria by which the commissioner in the future will designate dunes critical to the protection of public lands. The

State Natural Resources Council also will evaluate the need for additional areas of particular concern and, if appropriate, will designate those areas over which the state has sufficient management policies and authority.

B.2.6 Natural and Scenic Resources

B.2.6.1 Natural Resources

The region surrounding the Seaway Group SPR sites in Brazoria and Fort Bend Counties contains several fresh water lakes and two major rivers, the Brazos and the San Bernard Rivers, which flow into the Gulf of Mexico. The coastal shoreline consists of many miles of bay shore and Gulf frontage. East and West Galveston Bays constitute a major bay system in the area. The lakes and rivers, in addition to the saltwater beaches, marshes, bays, and the open gulf, provide the area with an abundance of resources to support a variety of recreational activities.

The Brazos and the San Bernard Rivers flow through Brazoria County, providing excellent wildlife habitat. There are numerous freshwater lakes and saltwater marshes and bays to provide scenic resources for passive types of recreation as well as good fishing and hunting sites (U.S. Department of Transportation, 1976).

The majority of the region's park and recreational land is under public management, including three national wildlife refuges administered by the United States Fish and Wildlife Service. These refuges, the San Bernard (15,414 acres), Brazoria (9525 acres), and Anahuac (9836 acres), are located in close proximity to the gulf coast. Two of these (Brazoria and San Bernard) are within Brazoria County. San Bernard National Wildlife Refuge, which was established in November of 1968, is Texas' newest wildlife refuge. The refuge is currently administered by the Angleton office of the U.S. Fish and Wildlife Service, and in 1970 received 538 visitors.

The Bureau of Sport Fisheries and Wildlife administers five wildlife refuges on the Texas coast.

Brazoria National Wildlife Refuge is located on the Coastal Plain of southeast Texas (17 miles southeast of Angleton), in coastal marsh and prairie in Brazoria County. The refuge offers public hunting and fishing in limited areas, sightseeing, birdwatching, and nature photography. It is the smallest refuge on the Texas coast and had 524 visitors in 1970.

The National Audubon Society owns several tracts of land in the Texas Coastal Zone which are used as wildlife refuges. Some of these are located near national wildlife refuges and serve to extend the sanctuary provided by these refuges. West Bay Bird Island is one such sanctuary located east of Brazoria National Wildlife Refuge in West Galveston Bay.

The Texas Parks and Wildlife Department administers four state parks having a total area of 3617 acres. These parks are: Geyar Beach, 554 acres; Mud Island, 1075 acres; Galveston Island, 1922 acres; and Varner-Hogg, 66 acres. There are four developed beach areas in the vicinity of Freeport (Bryan, Quintana, Surfside, and San Luis Pass beaches). The Bryan Mound Beach State Recreation Area was recently acquired by the Texas Parks and Wildlife Department. This area is located approximately one mile south of Bryan Mound, consists of 877 acres, and recreational facilities are being planned for future public use.

There are 67 public and private recreational areas in Brazoria County, including marinas, parks, camps, beaches, and other areas. There are 27 historic sites in the county, including the Varner-Hogg Plantation State Park near West Columbia (Dallas Morning News, 1975). There are 31 city and county parks and playgrounds in the Brazosport area and a natural recreation area made up of approximately 25 miles of open beaches (Houston-Galveston Area Council, 1972).

Fort Bend County has 19 designated recreation sites. Among these are the six municipal parks operated by the cities of Richmond and Rosenburg. Other sites provide a variety of recreational experience. There are also 14 designated historical sites within Fort Bend County (Houston-Galveston Area Council, 1972). None of these recreational sites would be directly affected by the project.

Coastal resources dominate recreation in Brazoria and Galveston Counties. Much of the recreation in these counties is related to water-sports, fishing, hunting, and related tourist activities, such as Galveston's Shrimp Festival. Fort Bend and Harris Counties offer some of these same activities, but also offer cultural activities. Houston is a center for urban recreation including professional sports, amusement parks, colleges and universities, museums, and the Johnson Space Center.

B.2.6.2 Scenic Resources

The scenic resources in Brazoria and Fort Bend Counties surrounding the sites are also dominated by the abundant coastal resources. Over half of Brazoria County's Gulf coastline is sandy beaches. Many miles of bay and coastal shorelines are coastal marshes.

Inland, the study area is mainly flat plains with few areas of topographic variation. Low-lying areas tend to be marshy, due to the poor drainage. These wetlands and the areas along the Brazos River, San Bernard River, and Jones Creek are surrounded by woodlands of natural scenic beauty. These areas predominate in western Brazoria County and in the southwest and southeast portions of Fort Bend County. The remainder of the two counties is primarily cleared land in agricultural use, whose aesthetic appeal comes from the broad open vistas provided.

B.2.7 Archaeological, Historical and Cultural Resources

The Texas Coastal Zone contains archaeological sites providing evidence that humans have inhabited the region for as long as 15,000 years. Brazoria County contains 37 archaeological sites. These sites are similar to many found in the coastal zone, in that they contain middens of ostrea and rangia shells, and most are located on or near the beach.

One historic site in Brazoria County is on the National Register (U.S. Department of the Interior, 1977), the John McCroskey Cabin, located two miles northeast of Cedar Lake on Stringfellow Ranch. Two additional sites have been chosen by the Texas State Board of Review for submission to the National Register: These sites are the Levi Jordan

Plantation and the Varner-Hogg Plantation. The Levi Jordan Plantation is located approximately 10 miles north of Bryan Mound and the Varner-Hogg Plantation is located near West Columbia.

In compliance with Section 2(a) of Executive Order 11593, "Protection and Enchancement of the Cultural Environment" (May 13, 1971), a survey will be carried out to locate, inventory and nominate eligible historic, architectural and archeological properties to the National Register of Historic Places that may occur on lands affected by the chosen development alternative. The results of this survey will insure the proposed undertaking will not result in the transfer, sale, demolition or substantial alteration of eligible National Register Properties. As the project progresses, additional surveys will be carried out to determine that no additional eligible properties have been uncovered.

In compliance with Section 1(3) of the Executive Order 11593 it has been determined that the proposed project will not result in the destruction or deterioration of non-federally owned districts, sites, buildings, structures or objects of historical, architectural or archeological significance.

B.2.8 Socioeconomic Environment

The sites are located in Brazoria and Fort Bend Counties, however, the socioeconomic region in which development would occur include Harris and Galveston Counties. The physical development will be in Brazoria, and possibly Fort Bend Counties; however, the economic and employment effects will involve all four counties.

B.2.8.1 History

Brazoria County, one of the earliest sites of development in what is now Texas, shows continuing and future potential for growth. Six national flags, and possibly a seventh, have flown over the soil of Brazoria County: Spain, France, Mexico, the Republic of Texas, the Confederacy, and the United States all have claimed this area, as did a short-lived government called the Republic of Fredonia. The original owners of the central Texas coast, a tribe of seven foot tall cannibal

Indians called the Karankawas, were present long enough to see all seven flags. Now extinct, the fierce "Kronks" were recorded in the area as late as the early 1900's.

The first European explorers of Texas landed here in the 1500's. Later, the early Texas immigrants came to Freeport by sea to establish Stephen F. Austin's first colony. Brazosport, a group of communities in the Freeport area, was the site of the first armed conflict between Texans and Mexicans in the Battle of Velasco in 1832, four years before the Alamo.

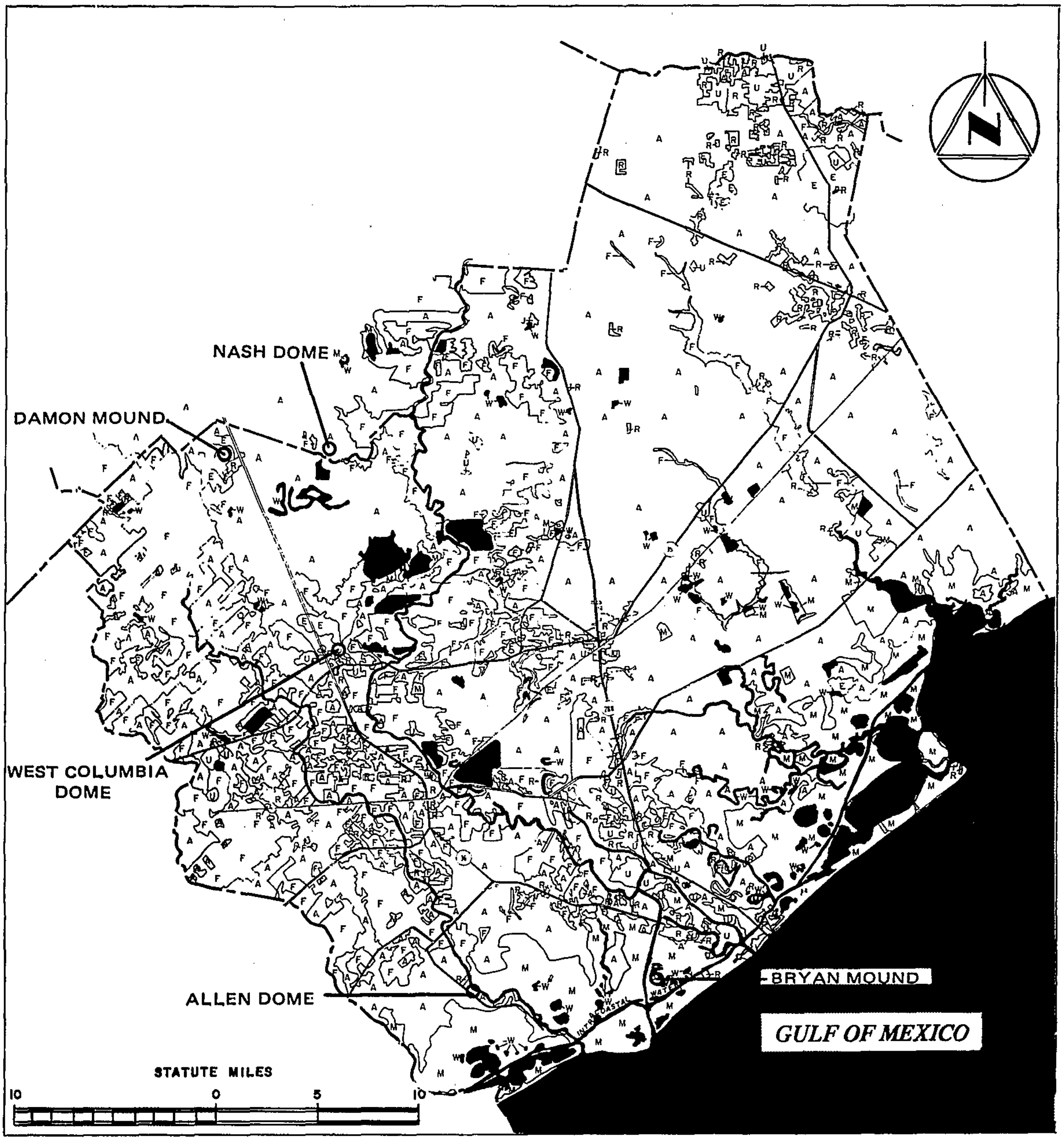
A preponderance of people in the community were born, raised, and educated elsewhere and moved here as adults. According to the Brazosport Chamber of Commerce (FES 76/77-6), persons of Spanish descent and American Negroes are the only significant ethnic and minority groups in Brazosport community.

B.2.8.2 Land-Use Patterns and Planning

Existing Land Use

The general land-use characteristics of the study region are shown in Figure B.2-29. Although the region has undergone very rapid industrialization and urbanization since World War II, only a small portion of the total land is currently in urban use. Most of the industrialization and/or urban development is concentrated in Houston, Galveston, Texas City, and the Brazosport area. Thus, the rural agricultural economy remains significant throughout the region, with total acreage diversified among cropland (mainly cotton and rice), pasture and rangeland for cattle, and forest and woodlands (see Table B.2-30).

Patterns of land use in Brazoria County in 1970 were documented by the Texas Highway Department (Bernard Johnson, Inc., 1975), based on an extensive field survey and review of current aerial photography, tax, and property records. To maintain a common denominator for land-use inventory among adjoining counties, the Texas Highway Department used the Houston City Planning Commission's simplified standard land-use classification (Bernard Johnson, Inc., 1975), which has 10 categories:



KEY

A - AGRICULTURAL
R - RESIDENTIAL
F - FOREST
U - URBAN
E - EXTRACTIVE
M - MARSH
■ - WATER

SOURCE: NASA, 1970.

FIGURE B.2-29 Prominent land uses, Brazoria County, Texas.

TABLE B.2-30 Agricultural characteristics - four county region.

(Acres in Thousands)

County	Total Land Area	Non-farm Land 1969	Land in Farms 1964	Land in Farms 1969	Rangeland and Other 1964	Rangeland and Other 1969	Harvested Cropland 1964	Harvested Cropland 1969
Brazoria	910.8	311.9	697.8	598.9	593.6	503.3	104.2	95.6
Fort Bend	556.0	85.0	506.5	471.0	372.2	332.2	134.3	138.8
Harris	1102.7	551.6	562.3	551.1	478.0	472.2	84.3	78.9
Galveston	255.4	125.9	120.6	129.5	108.8	109.2	11.8	20.3
TOTAL	2824.9	1074.4	1887.2	1750.5	1552.6	1416.9	334.6	333.6

Source: Department of Transportation, 1976.

- o Single family residential
- o Multiple family residential
- o Commercial and service
- o Industrial
- o Educational
- o Open space (including national wildlife refuges)
- o Water
- o Resource production
- o Undeveloped land (including agriculture and oil well production)
- o Highway right-of-way

Under present land-use activity, the region is strongly characterized by urbanization that is concentrated in and about the various cities. The primary exceptions to this pattern, in Brazoria County, are the linear residential and commerical developments following State Highway 288 between Angleton and Lake Jackson, and residential development along county roads in the triangular area formed by Sweeny, West Columbia, and Brazoria.

Petrochemical activities are concentrated in a few large operations, principally: Dow Chemical north and south of Freeport; Monsanto Chemical and Amoco Chemical on Chocolate Bayou north of Farm Road 2004; and Phillips and Allied Chemical Refineries near Ocean, on the western boundary of Brazoria County.

The Gulf of Mexico and the Brazoria County portion of its coast are in multiple use for recreational and commercial purposes. Waterborne commerce, pleasure boating, fishing, and offshore mineral production are important uses of this portion of the Gulf.

Land Use Plans and Projections

The power for direct control or regulation of land use in Texas lies with the local jurisdictions rather than with the State, regional agencies, or the counties, although there are a number of governmental agencies which either assist the local areas with planning or exercise control over certain lands. Within the Seaway Group region, these agencies range from the U.S. Department of the Interior, Fish and Wildlife Service to the Houston-Galveston Area Council of Governments. The involvement of the U.S. Fish and Wildlife Service is limited to those lands under its direct control, which are described in Section B.2.6.

The Texas General Land Office is concerned with statewide land use planning and coastal zone management programs. The office does not directly control or regulate the use of private lands, although it does have responsibilities for the management of some state-owned lands including certain submerged lands through which the offshore pipelines will pass.

The General Land Office also administers the Coastal Zone Management program for Texas (Brown, 1977). As a part of this program, the Bureau of Economic Geology of the University of Texas has prepared a series of detailed analyses of the Texas Coastal Zone.

The Houston-Galveston Area Council of Governments, a regional planning agency which serves a 13-county area including the SPR site, is in the process of carrying out comprehensive planning studies including population and economic forecasts. It does not exercise direct controls on land use (such as by zoning) but does review and coordinate applications for federal funds for a wide variety of projects.

The Houston-Galveston Area Council of Governments has prepared a future land-use map for its 13-county region for the year 2000 which indicates the rapid spread of residential development outward from Houston, particularly along radial highways; along Interstate 45 north, U.S. 90A west and I-10 east. Substantial growth is also expected to occur southward along I-45 toward Galveston, in the northern part of Brazoria County between Alvin and Houston (Harris County), and in the southern part northward from Freeport to Lake Jackson, Clute, Richmond, and Angleton.

Industrial development in the region is expected to occur along the Houston Ship Channel. Additional smaller industrial areas are expected to develop throughout the region, particularly in the vicinity of Galveston Bay. In Brazoria County, substantial expansion of industry is foreseen in the Freeport area and spreading eastward. At Chocolate Bayou, a major industrial complex is anticipated; the largest in the region other than the Houston Ship Channel (DOT, 1976). Future offshore mineral development is currently being planned for this region. The U.S. Army Corps of Engineers is currently planning a substantial harbor maintenance and improvement project in the Freeport area (U.S. Army Corps of Engineers, 1977).

B.2.8.3 Transportation Systems

The region is well served by highways, railroad lines, navigable waterways, and airports, with Houston as the hub of the transportation systems. Interstate 45 links Galveston and Houston, State Highways 288 and 35 connect Southern Brazoria County with Houston, and State Highway 36 links Freeport with I-59, west of Houston. A new two-lane highway along Galveston Island, which crosses the San Luis Pass Bridge, provides good access between the Galveston-Texas City area and the Brazosport area. Routes 288, 35, and 36, shown in Figure B.2-30, lead south from the Houston expressway network into Brazoria County. Within Brazoria County, these roads are all two- or three-lane highways except for a segment of Route 35 which bypasses Alvin, and an expressway segment of Route 288 from Angleton to the Lake Jackson-Freeport area.

Future plans call for the upgrading of both Route 35 and 288 to expressway status for their entire length through Brazoria County. This will enable the 50-mile trip from Freeport to Houston to be made in less than one hour and will mean that the middle and southern portions of Brazoria County will be within easy commuting distance from Houston. The completion of these expressway projects, currently held in abeyance because of a shortage of expressway construction funds, will constitute an important segment of the planned radial-circumferential expressway system for the greater Houston-Galveston area.

Railroads providing service to the region include the Southern Pacific, which serves Houston and connects this area with New Orleans to the east and with Los Angeles to the west. The Atchison, Topeka and Santa Fe serves Freeport and Houston and links the region with the West

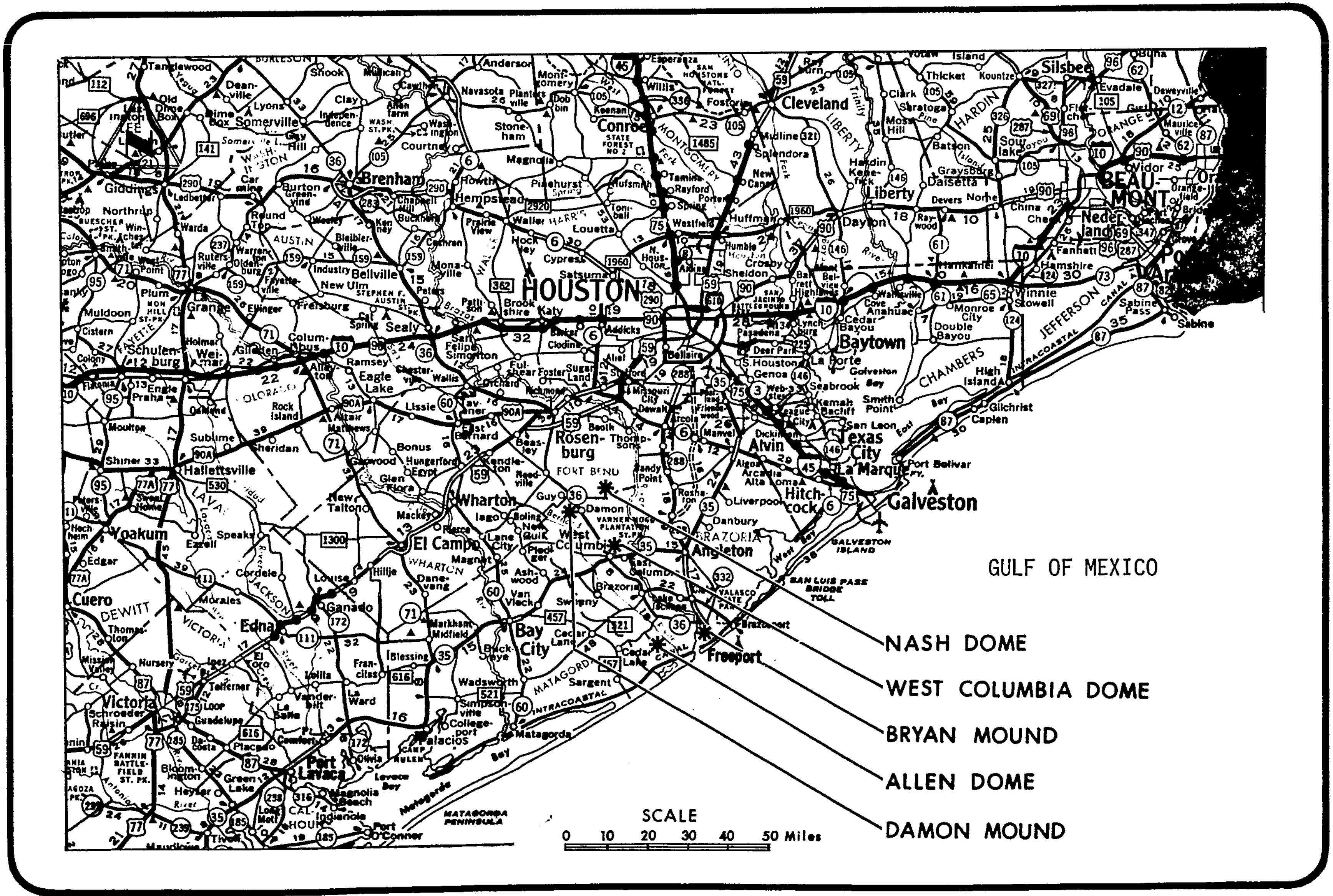


FIGURE B.2-30 Regional Freeway and Highway network.

and North. The Missouri-Pacific serves Brazoria County and Houston and links these areas with Baton Rouge and northern cities. The Intracoastal Waterway also links Freeport and Galveston (DOT, 1976).

Waterborne transportation on the Intracoastal Waterway (ICWW) and in the Gulf is vital to industry. The ICWW links the region with the eastern United States providing shallow draft barge transportation. In 1974 over 70 million tons of cargo were shipped over this waterway (Texas Coastal and Marine Council, 1977). Oceangoing vessels traverse the Gulf to ports such as Freeport. Because of this activity there is now a shipping anchorage offshore near Freeport. Two shipping lanes pass east-west about 14 miles offshore and one lane passes into the Old Brazosport.

B.2.8.4 Population Characteristics

Population Centers

There are two outstanding socio-cultural characteristics of the region. First, the population is highly concentrated in the few cities that are highly urbanized and, second, the area is dominated by the fastgrowing Houston area.

There are only nine cities and towns in the region (Brazoria, Fort Bend, Harris, and Galveston Counties) with a population of 10,000 or more, and only four of these have populations of 25,000 or more (DOT, 1976).

Historical Growth and Trends

Throughout the region, the population is growing at a very rapid rate, in comparison with the State and Nation. Brazoria County and Harris County show the most significant growth rates, 42.1 and 40.1 percent, respectively, between 1960 and 1970. A great deal of this growth is associated with the expansion of the Houston metropolitan area. Brazoria County has also expanded, as coastal towns such as Freeport have grown rapidly. Fort Bend and Galveston Counties are growing more slowly but still at relatively rapid rates. These counties are expected to continue to grow rapidly as Houston expands.

Much of the difference in growth rates among the counties can be explained through the net migration rates. The net migration is the percent of the 1960 population that moved into the area between 1960 and 1970. In Brazoria and Harris Counties, net migration was 12 to 17 percentage points higher than in Fort Bend and Galveston. These figures are consistent with the rapid physical growth of Houston observed in the last 15 years. The dramatic influx being experienced in the Houston area is more impressive when compared with the net migration rate for the state, 1.5 percent, and that of the nation as a whole, 1.7 percent.

Increasing economic opportunities in the Houston metropolitan area are expected to maintain rapid growth patterns within the impact area (U.S. Dept. of Commerce, 1972).

B.2.8.5 Housing

As can be seen in Table B.2-31, the overwhelming majority of the housing stock in the region is in Harris County. The majority of the units in Harris County surround the Houston metropolitan area. Brazoria County has the greatest proportion of owner-occupied units in the four-county area.

The vacancy rate in units for sale was very low in all counties. The vacancy rate of units for rent was very high in all counties except Fort Bend County, although Fort Bend County's rate was still above the national average rate of 6.6 percent. This high vacancy rate for rental units tends to indicate that the counties have the housing stock to accommodate any increase in population resulting from the SPR program.

The median value of single family houses in the region is well above the State average, and was highest in Houston area (U.S. Dept. of Commerce, 1973a).

B.2.8.6 Economy

The basic economy of the region is dominated by manufacturing and the petroleum and chemical industry. Brazoria County has an extensive mineral extraction industry including oil and gas, with an income of over $260 million annually. Petroleum and chemical industries, fishing, tourism and agriculture are also important to the County economy. Fort

TABLE B.2-31 Housing characteristics, 1970.

County	Number of Units	Number of Persons/Unit	% Owner-Occupied	Vacancy Rate For Sale	Vacancy Rate For Rent	Median Value Single Family Home
Brazoria	30,567	3.5	71.5	2.1	12.1	13,508
Fort Bend	13,858	3.7	65.9	1.5	7.5	13,249
Harris	540,929	3.2	58.6	1.8	11.8	14,889
Galveston	52,987	3.2	62.5	2.3	9.7	13,327
Texas	3,433,573	3.2	53.7	2.0	11.1	12,359

Source: U.S. Department of Commerce, 1970.

Bend County relies heavily on the mineral extraction and the petrochemical industry but also has an active agricultural industry. Many residents of this county are employed in the Houston area.

Port activities dominate the economy in the Galveston-Texas City area, with the surrounding areas of Galveston County active in agribusiness, tourism, and mineral extraction.

The regional center of business activity is in Houston (Harris County), a highly industrialized area with over 2500 manufacturing plants. Mineral extraction, especially oil and gas, has a combined production of over $200 million annually in Harris County. In addition, port activities, tourism, and service industries are important to the local economy of the County as well as the surrounding region (Dallas Morning News, 1975).

Large employers in the region that are not dependent upon the chemicals industry include the Texas Department of Corrections, the shrimp industry, and various recreational activities. The Texas Department of Corrections has over 200 employees at its Clemens and Retrieve facilities, both of which are located in or near the Brazosport area. The shrimp industry is one of the world's largest, with as much as 15 million pounds of shrimp landed annually (DOT, 1976).

Employment

The region is subdivided into two areas: Brazoria and Fort Bend Counties, where the project will be located, and the Houston-Galveston area, where most of the workers are expected to live. Both areas are expected to experience substantial growth in refining and petrochemical manufacture using crude oil from SEADOCK, the proposed offshore oil port, if it is built. Continued development of refining and petrochemicals will occur whether or not this project is constructed (DOT, 1976).

There were a total of 26,178 jobs and a population of 108,312 in Brazoria County in the early 1970's. The largest employment sector was manufacturing. Refining and petrochemicals are the two largest industries, accounting for 71.3 percent of all manufacturing employment and

30.5 percent of all jobs in the county. Other large employment sectors include retail trade, which accounts for 16.2 percent of employment; construction, 14.5 percent; and service, 10.3 percent. Fishing is an important industry in Freeport; however, direct employment is less than 200, but this amounts to 9.1 percent of that industry's total employment in the state. Efforts are being made to diversify the economy of this area by encouraging the development of industries for servicing and fabricating offshore oil equipment, the fishing industry, and recreation (DOT, 1976).

The employment structure of Houston reflects its role as a regional center. It has large shares of its employment in manufacturing, service, retail trade, construction, wholesale trade, and transportation and public utilities. Overall, Houston has the largest labor pool and the most diversified economic base in the region. Galveston and Fort Bend Counties have the greatest proportion of employment in the manufacturing and wholesale and retail trade (see Table B.2-32). Employment in government in Galveston is also important.

Most of the region has a moderate level of unemployment, with some areas having higher or lower levels depending on local factors. Table B.2-33 shows the existing unemployment levels as of February, 1977. Galveston County has a significantly higher level of unemployment than the other counties. Almost 44 percent of those unemployed live in the city of Galveston. Harris County has the largest total pool of unemployed, with 55,366 persons out of work.

Income

In general, the data indicate the relative wealth of the region's population. The median family income and home value is well above the average for the state of Texas as a whole. The relative wealth of the impact areas is related to their degree of urbanization and industrial structure. The Houston SMSA, for example, is one of the wealthiest of the large SMSA's (those over 2 million population) in the United States (DOT, 1976).

TABLE B.2-32 Percentage employment in major industrial categories, 1974[a].

	Brazoria	Fort Bend	Galveston	Harris
Industry				
Manufacturing	29.6	23.3	20.2	20.1
Wholesale and Retail Trade	16.8	20.7	18.8	22.8
Services	7.9	8.4	8.7	10.2
Educational Services	7.5	6.2	8.5	6.5
Construction	13.3	10.7	9.8	8.9
Government	12.1	11.9	19.9	10.7
Unemployment[b]	5.1	4.4	7.6	5.3

Note: does not include agriculture, mining.

[a] Dallas Morning News, 1975.

[b] Perkins, 1977.

TABLE B.2-33 Unemployment - four county region, February 1977.

	Number Unemployed	Percent Unemployed
Counties		
Brazoria	3,158	5.1
Fort Bend	1,222	4.4
Galveston	6,630	7.6
Harris	55,366	5.3
Cities		
Freeport	505	6.6
Galveston	2,898	9.0
Houston	40,855	5.5

Source: Perkins, 1977.

Brazoria County has the highest median family income of any of the four counties and it also stands among the highest in value of single-family homes (although not as high as the average for the Houston SMSA as a whole). This wealth is largely attributable to the high wages paid by the local chemical industry in Brazoria County, for close to a third (29.5 percent) of the employed labor force is in the manufacturing category, and chemicals and related industries.

B.2.8.7 Government

Introduction

The provision of services such as education, police and fire protection, health, and local roads is primarily carried out by counties, cities, and special districts. In Texas these governments are heavily dependent upon real property for their revenues. For example, in 1967, local governments in Texas received nearly half of their revenue from this source, compared with about one third in the other seven south-central states. Per capita expenditures for local government services in Texas were highest in this region due partly to the fact that a larger proportion (55.3 percent) of governmental expenditures was made for schools. Approximately 75 percent of all local government revenue in Texas counties is from locally raised taxes and 25 percent is received from the state (DOT, 1976).

Discussions of the provision of public services to each site is provided in Section B.3 of this report.

Education

Within Brazoria County, there are eight major independent school districts (ISD). Three of these school districts have experienced declines in enrollments despite moderate to impressive population gains within the school district boundaries. This decrease in enrollments may be attributable to a local manifestation of the nationwide decline in birth rates. Except in small areas of concentrated population growth, the remaining schools have had modest increases in enrollment (Texas Education Agency, 1976).

Brazosport College, a fully accredited public junior college, is located in Richwood in Brazoria County. It was established in 1968, and the campus was completed in 1971. Current enrollment is about 2400, and occupational training programs are offered in addition to standard junior college curricula. Opportunities for higher education can also be found at the three major universities and numerous other school located in the Houston area.

B.3 SITE SPECIFIC ENVIRONMENT - BRYAN MOUND

The proposed development alternative for the SPR expansion of the Seaway Group of storage sites is expansion of the Bryan Mound early storage site. Bryan Mound is located conveniently close to the Freeport Harbor port facilities, to the SEAWAY, Inc. Pipeline System, and to large surface water sources of the Brazos River Diversion Channel and the Intracoastal Waterway, and to the Gulf of Mexico for brine disposal (Figure A.3-1). Current development of the site reflects its past uses for oil production, sulfur mining, brine mining, and for the early storage phase of the SPR.

The regional environmental setting of the proposed Bryan Mound site has been discussed in Section B.2, above. This section describes the environment of the site.

B.3.1 Land Features

B.3.1.1 Physiography and Topography

Bryan Mound is a topographically high area, surrounded by coastal marshes. Maximum elevation on the dome is 16 feet. The dome is bounded by a levee system. The levees, built to contain the Brazos River Diversion Channel border the site to the west, while the Freeport hurricane levee crosses the dome and proceeds east to Freeport Harbor. Dikes around the Phillips Petroleum Company storage tanks connect the hurricane levee to another dike which runs from Freeport Harbor to the Brazos River Diversion Channel Levee, separating Freeport from the marshy area around Bryan Mound. The areas in which the diffuser is to be located are relatively flat with a slight Gulfward slope as described in the regional setting, Section B.2.1. A shell ridge is located immediately offshore of the proposed diffuser with a small trough adjacent to the inshore portion of the ridge. The East Bank, a rock formation on the Gulf bottom, is also located adjacent to and offshore of the diffuser site (Graham, 1977). A more detailed discussion of offshore physiography is presented in Appendix G.

B.3.1.2 Local Geology

Bryan Mound salt dome is the principal structural element of the local geology. The dome is circular in plan view, with a diameter of about 6000 feet (Figure A.3-1). Discovery of the dome was confirmed in 1901 by wells which pierced the salt. Subsequent oil drilling on the flanks of the dome defined the salt core to have a volume of about 1.5 cubic miles to a depth of 10,560 feet.

Deformation caused by the combination of upward movement of the salt and settling and compaction of the sediments has produced a system of subsurface faults and flexures over the flanks of the dome. Away from the dome the sedimentary rock formations have a gentle to moderate dip toward the southeast. Unconsolidated and partially consolidated muds, sands, and shales of Holocene, Pleistocene, and Pliocene age overlie the central portion of the dome. Unconsolidated and partially consolidated sands and shales of Tertiary age extend to a depth of 15,000 feet on the flanks of the dome. Above the dome, the sediments have been forced upward by the salt, forming a mound with an elevation of 15 feet above the mean terrain. Surface sediments are of the Pleistocene Beaumont formation, which consists of fine sand and mud.

The salt (halite) is coarsely crystalline with individual crystals averaging about one centimeter in size. About 3 percent of the mass of the dome consists of anhydrite, with traces of other minerals including calcite, dolomite, barite, pyrite, quartz, celestite, iron minerals, and sulfur.

The caprock is a maximum of 480 feet thick and is composed primarily of anhydrite and limestone. The upper portion of the caprock has a zone of very porous and cavernous limestones and gypsum mixed with sulfur. In addition, there is hot sulfur water and hydrogen sulfide in the caprock. The presence of the hot sulfur water will require that two cemented strings of pipe be installed through the caprock during cavern development to protect the casing in those areas.

B.3.1.3 Economic Geology

Oil production began at Bryan Mound in 1949, but was always low. Less than 11,000 barrels of crude oil were produced in 1965. No active oil production is presently underway. Production was from the Miocene, at about 3400 foot depths. The deepest well reported was 7530 feet; it bottomed in Oligocene strata (Houston Geological Society, 1953). More than five million tons of sulfur were extracted from the caprock during the period 1912 through 1935, and a small amount of sulfur was extracted by a pilot plant in 1967-1968. More than 900 test and production wells were drilled into the caprock during the sulfur production period (Halbouty, 1967). Since the wells were drilled only into the caprock, they will not affect the integrity of the proposed and existing caverns below.

Dow Chemical Co. has created five solution cavities in the salt mass by brine solution mining operations. The brine has been used as a petrochemical process feedstock.

B.3.1.4 Soils

Soil associations in the vicinity of the Bryan Mound site include the Harris-Veston-Galveston association and the Moreland-Pledger-Norwood association. The Harris-Veston-Galveston association occupies the area from the Gulf of Mexico shoreline to the Intracoastal Waterway. The area north of the Intracoastal Waterway, and including the Bryan Mound dome contains the Moreland-Pledger-Norwood association.

Soils in the Harris-Veston-Galveston association vary from the clayey Harris series in old tidal flat, through a loamy Veston series, to sandy Galveston soils which occupy the highest elevations. The Harris soils are largely montmorillonite clay, while the Veston soils are intermediate between Harris and Galveston soils and are loamy in texture. These soils are derived from marine and deltaic sediments and are near neutral to alkaline (calcareous) in the surface layer. Many soils in the Bryan Mound vicinity of the Harris-Veston-Galveston association are classified as saline-sodic and have an extremely high salinity which limits plant growth. Many of the areas covered by these soils are subjected to frequent inundation by seawater.

The Moreland-Pledger-Norwood soils are somewhat poorly drained clayey soils on alluvium. Surface horizons are dark brown to black, clayey, slightly acid to mildly alkaline underlain by reddish brown, clayey, alkaline alluvium. Permeability is low. In unprotected areas, this association floods occasionally. These are rich, fertile soils and only their poor drainage limits crop production. The major potentials of these soils are for intensive row crop farming that must include large-scale drainage improvement plans. On the dome site, vegetation in some areas has been stunted as a result of sulfur spills which occurred during sulfur mining operations.

Studies conducted for the SEADOCK Project (DOT, 1976) indicate that surficial sediments in the offshore area vary from loose, fine sand and silt near shore to soft mud farther offshore. These sediments generally vary in thickness from 25 to 30 feet near shore to less than 2 feet at a depth of 100 feet. Pleistocene sediments vary from sand to clay and are normally more dense than the overlying sediments. Areas of shelly sand and silt attributable to reworked glacial shorelines also occur, as do nearshore sediments consisting of barrier island sands overlying inter-bedded sand and silt-clay layers. Geophysical studies have shown the distribution of calcium carbonate-cemented Pleistocene beach ridges which are also present offshore. Recent sediment deposition in the area is occurring from the Brazos River discharges. A line of coral heads off the mouth of the Brazos River Diversion Channel are several miles west of the proposed brine disposal system in the Gulf. Bottom strata along the marine portion of the proposed brine pipeline are primarily marine deposited, not dredged spoil (SEADOCK, 1975). Sediments at the proposed site are primarily firm clays overlain by a thin layer of very soft silt which may shift during stormy periods. A more detailed description of these sediments and their characteristics is provided in Appendix G.

B.3.2 Water Environment

B.3.2.1 Surface Water Systems

As described earlier (Section A.3.1), the Bryan Mound site is bordered by four major surface water bodies; the Brazos River Diversion Channel, Freeport Harbor (including Brazos Harbor), the Intracoastal Waterway, and the Gulf of Mexico. Several lakes and reservoirs exist within the triangular area protected by the levee system, and more, including Mud Lake and Bryan Lake, occur outside the levees. Regional characteristics of the Brazos River, Intracoastal Waterway, and Freeport

Harbor are discussed in Section B.2.1.2. This section addresses the specific portions of those surface water systems which are local to the storage site and other associated facilities.

The Brazos River was diverted at Freeport, Texas in the early 1940's to improve navigation in the Harbor. The diversion channel now leads 6 miles from the diversion dam to the Gulf of Mexico, passing just west of the proposed SPR storage site. This channel is now a straight "channelized" reach of the river, bordered on both sides by flood levees. A depth of 10 feet upriver from the Intracoastal Waterway at ordinary river stages was reported in November 1972 (U.S. Department of Commerce, 1976). The major commercial traffic besides barge traffic on the river is petroleum industry support vessels which dock along the east bank of the Diversion Channel, just south of Freeport.

Texas Water Quality Board sampling stations 1, 1A, 1B and 2 (Figure B.2-10) are located close to the Bryan Mound site. The average condition for dissolved oxygen concentration, temperature, conductivity, water clarity, alkalinity, hardness, pH, biological oxygen demand, total and fecal coliform in concentration, and percentage of fixed and volatile solids content, representative mercury and arsenic content and representative percent calcium and calcium carbonate content of the bottom sediments are shown in Figures B.2-11 through B.2-20.

The federally approved Texas water quality standards classify the tidal portion of the Lower Brazos River as suitable for both contact and noncontact recreation and for propagation of fish and wildlife.

Ongoing baseline environmental studies of the environmental conditions in the offshore area surrounding the proposed diffuser are being undertaken to supplement regional data currently available (Section B.2.2.1). Preliminary findings from September through December, 1977 from these other studies have been used to characterize the water conditions at the diffuser site.

Over-the-side current measurements showed mean speeds in the diffuser area of 14.1 cm/sec (.27 knots) to 38.0 cm/sec (.74 knots) with a maximum speed of 64.3 cm/sec (1.25 knots). These speeds are slightly higher than the regional average and generally flowed in a northeasterly direction in December 1977, opposite the expected direction. The tidal range at the proposed site is approximately three feet. Wave frequencies and heights are similar to those discussed in Section B.2.2.1. Observations throughout the water column showed that temperatures at the site were relatively homogeneous at the top and bottom and decreased during the study from September to December. Salinities were also similar throughout the the water column except in December when flow of freshwater from the Brazos River decreased surface salinities. Weak water density gradients occurred except in December when unseasonally strong stratification occurred. This area is influenced by a mass of dense water of higher salinity and temperature than coastal waters which originates deep in the offshore Gulf and by large freshwater inflows from the Mississippi Delta area which can induce stratification.

The dissolved oxygen, biological oxygen demand, chemical oxygen demand and pH values recorded in the diffuser area are not unusual for coastal waters and sediments (Table B.3-1). The redox potential (Eh) values showed sediment in the site area changed from an oxidizing environment in winter and spring to a reducing environment in summer. Nutrient salt levels in the water column near the diffuser site are often low as Table B.3-2 shows. Heavy metal concentrations in the site vicinity are shown on Table B.3-3 and are in the range expected for coastal waters. Hydrocarbon levels, despite heavy oil production activity, were the same order of magnitude as found in the open ocean. Suspended solids and turbidity are variable due to large seasonal changes in the sediment load.

The water environment at the alternative diffuser site is very similar to that of the proposed site. Differences include a water depth of 68 feet, slightly greater stratification of the water column in certain months, greater transparency and slightly higher oil and grease levels. A more detailed description of the proposed and alternative diffuser sites is presented in Appendix G.

TABLE B.3-1 Dissolved oxygen and pH balance parameters at Stations in the vicinity of the proposed brine diffuser site.

	DO (mg/l)	BOD (ppm)	COD (ppm)	Alkalinity (mg/l)	pH	Eh
SPRING[a]						
Surface	6.5	<1		130		
Mid	6.8	<1		131		
Bottom	0.2	2		136		
Sed 0-8 cm		340	5800		7.3	+62
Sed 16-25 cm		250	8700			
SPRING[b]						
Surface	8.0				8.4	
Mid	7.5				8.4	
Bottom	7.5				8.4	
SUMMER[a]						
Surface	6.2					
Mid	5.7					
Bottom	4.9					
Sediment			11300		7.6	-73
AUTUMN						
Sed 0-10[c]					7.55	
Sed 10-20[c]					7.85	
Sed 20-30[c]					7.55	

[a] SEADOCK, 1975; Station 28.

[b] FEA, 1977b;sampled at the proposed diffuser site.

[c] Texas A&M, 1978; mean of Stations L and N.

[d] Texas A&M, 1978; mean of sediment depths 0-40 cm, Station 9.

[e] Texas A&M, 1978; mean of sediment depths 0-30 cm, Station 20.

TABLE B.3-2 Inorganic nutrient and organic carbon parameters at stations in the vicinity of the proposed diffuser site.

	NH_3 (ppm)	NO_2 (ppm)	NO_3 (ppm)	Total Kjeldahl N (ppm)	PO_4 (ppm)	TOC (ppm)	% Volatile Solids	% Organic C
SPRING[a]								
Top	<0.01	<0.01	0.02		<0.1	3		
Mid	<0.01	<0.01	0.02		<0.1	9		
Bottom	<0.01	<0.01	0.03		<0.1	4		
Sed 0-8 cm		<0.03	<0.02	360	2.9		4.8	
Sed 16-25 cm		<0.03	<0.02	405	4.8		2.3	
SUMMER[a]								
Top	<0.01	<0.01	<0.01		<0.1	10		
Mid	<0.01	<0.01	<0.01		<0.1	8		
Bottom	<0.01	<0.01	<0.01		0.2	10		
Sediment		0.44	8.5	365	1.6		4.7	
AUTUMN								
Sed 0-10 cm[b]							6.2	0.69
Sed 10-20 cm[b]							6.35	0.71
Sed 20-30 cm[b]							6.8	0.61

[a] SEADOCK, 1975; Station 28, in the diffuser vicinity.

[b] Texas A&M, 1978; mean of Stations L and N, at the diffuser site.

TABLE B.3-3. Heavy metal concentrations from various studies in the vicinity of the proposed Bryan Mound brine diffuser site.

	As	Ba	B	Cd	Cr	Cu	Ag	Fe	Pb	Mn	Hg	Ni	Sb	Se	V	Zn	Ca	Mg
SPRING[a]																		
Surface (ppb)						3.0			<1.0			<1.0				21.0		
Mid (ppb)				0.5		3.3			<1.0			<1.0				19.0		
Bottom (ppb)				0.2		1.3			<1.0			<1.0				14.0		
Sed 0-8 cm (ppm)		79			15.0	10.0			21.0	303	0.036	19.0			16.0	42		
Sed 16-25 cm (ppm)		13			8.0	9.0			13.0	39	0.070	66.0			2.0	135		
SPRING[b]																		
Surface (μg/l)	<50	30	2760	8	60	18	<2		230	13	2.9	60	<10	<80		120	332.0	1150.0
Mid (μg/l)	<50	30	2800	8	60	18	<2		230	13	2.4	70	<10	<80		120	336.0	1157.0
Bottom (μg/l)	<50	30	3700	6	90	17	<2		220	13	2.1	70	<10	<80		120	328.0	1150.0
SUMMER[a]																		
Surface (ppb)				<0.1		1.1			4.2	<3.0		<1.0				1.6		
Mid (ppb)				<0.1		<0.5			<1.0			2.6				4.8		
Bottom (ppb)				<0.1		0.9			<1.0			<1.0				3.7		
Sed (ppm)		71		0	17.0	9.0			20.0	260	0.059	10.0			11.0	48		
SUMMER[c]																		
Surface (ppb)	<20			<1.0	<0.5	1.2	<0.5		2	1.6	0.2	4	<10	<20		5.3		
Mid (ppb)	<20			<1.0	<0.5	1.6	<0.5		4	2.1	0.17	4	<10	<20		3.7		
Bottom (ppb)	<20			<1.0	<0.5	1.2	<0.5		2	1.8	0.2	4	<10	<20		3.2		
AUTUMN[d]																		
Sed 0-10 cm (mg/kg dry wt)[d]				<0.1	17.5	10.1		15035	7.7	517.5	0.11	31.0				54	26400	11750
Sed 10-20 cm (mg/kg dry wt)[d]				<0.1	18.0	9.65		14355	7.35	470.0	0.08	27.5				51	26250	10450
Sed 20-30 cm (mg/kg dry wt)[d]				0.14	23.0	10.45		17390	7.25	500.0	0.075	36.0				55.5	39450	16500
Sed (mg/kg dry wt)[e]				<0.1	15.25	7.75		16198	5.75	401.25	0.070	25.0				45.25	21175	9925
Sed (mg/kg dry wt)[f]				<0.1	18.33	8.9		17970	6.2	478.33	0.070	29.67				51.0	30667	10767

[a]Station 28; Seadock, 1975.

[b]Sampled at the proposed diffuser site, total metals; FEA, 1977.

[c]Sampled at the proposed diffuser site, dissolved metals; FEA, Personal Communication.

[d]Mean of Stations L and N; Texas A&M, 1978.

[e]Mean of sediment depths 0-40 cm, Station 9; Texas A&M, 1978.

[f]Mean of sediment depths 0-30 cm, Station 20; Texas A&M, 1978.

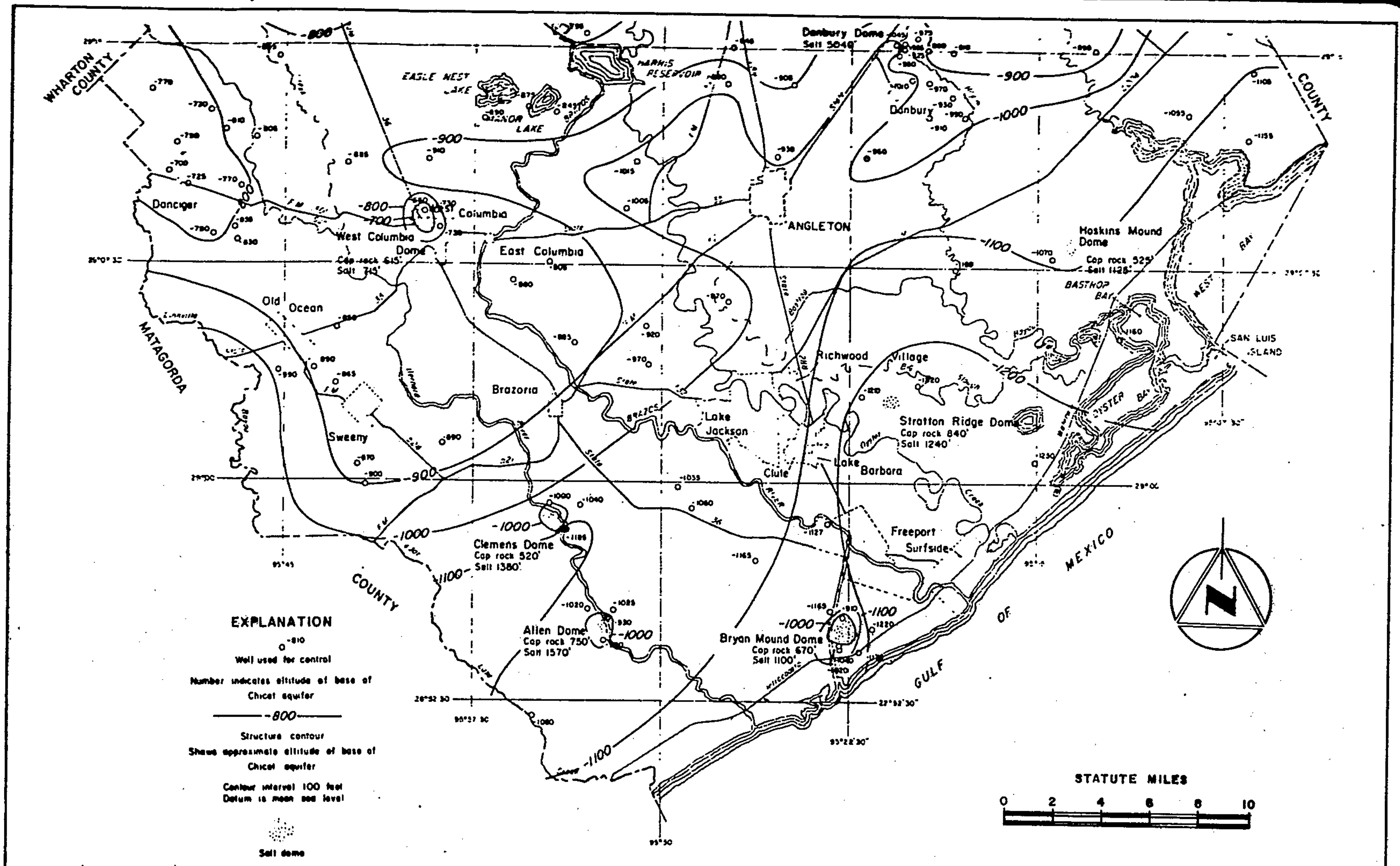
B.3.2.2 Subsurface Water Systems

Bryan Mound is one of seven salt domes in Brazoria County that penetrate through the Evangeline aquifer and into the Chicot aquifer. The base of teh Chicot aquifer is about 1100 feet below sea level in the vicinity of the dome (Figure B.3-1) (Sandeen and Wesselman, 1973). Fresh water occurs in the upper 80 feet of the aquifer over the dome, and slightly saline water (1000 to 3000 mg/l dissolved solids), from 80 to about 225 feet. At a radius of about 1.5 miles from the center of the dome, the base of the slightly saline water extends to a depth of 500 feet. The water in the formations adjacent to the dome and the caprock is probably highly mineralized, with a total dissolved solids concentration on the order of 60,000 mg/l or greater. At some distance from the dome, and below a depth of about 2000 feet, the water is expected to contain about 35,000 mg/l dissolved solids.

The upper unit of the Chicot aquifer is the primary source of fresh water. Ground water use in the urban area to the east of Bryan Mound is extremely heavy and perhaps overdeveloped. The hydraulic gradient in that aquifer is about 50 feet per mile.

Deeper aquifers in the vicinity of Bryan Mound are capable of delivering large quantities of slightly to moderately saline water to properly completed wells. Aquifer porosities are on the order of 40 percent, with permeabilities in the range of 600 to 1000 gpd per square foot. In the Evangeline aquifer, below a depth of about 1100 feet, permeabilities decrease with depth to an estimated 250 gpd per square foot.

Beneath the Evangeline aquifer, Miocene sands continue to a depth of 6500 feet. Although little data are available concerning these sands, analysis of a single well, located 15 miles to the northeast of Bryan Mound, indicates that these sands occur in 70 to 120 foot thick layers interspersed with layers of clay (FES 76/77-6). These sands should contain saline water. The Miocene formations below 6500 feet are mostly silt and clay. No major sand units were encountered.



Source: W.M. Sandeen and J.B. Wesselman, "Groundwater Resources of Brazoria County, Texas, Texas Water Development Board, Report No. 163, 1973.

FIGURE B.3-1 Approximate altitude of the base of the Chicot Aquifer

B.3.3 Climatology and Air Quality

B.3.3.1 Climatology

The climatic conditions discussed in Section B.2.3.1 are applicable to Bryan Mound. Specifically, the data from Galveston are representative of the more pronounced coastal effects expected at Bryan Mound than further inland. Bryan Mound is expected to experience higher wind speeds and more frequent east to southeasterly winds, smaller diurnal ranges of temperature, slightly higher humidity, and significantly fewer stable periods than the sites further inland. Similar wind conditions prevail offshore in the Bryan Mound vicinity. The mean annual wind speed in the area has been 12.7 mph (11 knots). A detailed discussion of climatology in the Bryan Mound area is provided in Appendix G.

Because of the proximity of Bryan Mound to the coast, additional data on tropical cyclones are presented. The size and intensity distribution of 143 tropical cyclones observed passing within approximately 300 miles of the site between 1871 and 1970 are shown in Table B.3-4 (ISR, 1973).

Wind and storm activity off the coast have a strong effect on variations in water heights. As reported by the U.S. Army Corps of Engineers, during strong northwesterly winds, water levels can drop to as low as -4.0 feet and during hurricanes the high levels can be +15.0 feet.

B.3.3.2 Air Quality

Data presented in Section B.2.3.3 for the Freeport, Clute, and Jones Creek area are considered to be representative of ambient air quality at Bryan Mound. Existing air quality levels are very good with the exception of high non-methane hydrocarbon and oxidant concentrations which exceed NAAQS part of the time (Section B.2.3.3).

B.3.4 Background Ambient Sound Levels

It is important to evaluate prefacility sound levels in order to properly assess the potential impact due to construction and operation

TABLE B.3-4 Size and intensity distribution of 143 tropical storms observed within 300 miles of Bryan Mound.

Intensity (Maximum Wind Speed, mph)	Number of Storms			
	Small[a]	Medium[b]	Large[c]	Total
Extreme (>135)	3	7	2	12
Major (101-135)	3	9	3	15
Minimal (74-100)	19	21	1	41
Minor (<74)	49	26	0	75
Total	74	63	6	143

[a]Average radius of 20 mph winds equals 100 nautical miles.

[b]Average radius of 20 mph winds equals 200 nautical miles.

[c]Average radius of 20 mph winds equals 300 nautical miles.

Source: Institute of Storm Research, 1973.

noise associated with the SPR project. Since site-specific ambient sound data were not available, data from an ambient sound survey in the Jones Creek area (SEADOCK, Inc., 1975) and similar surveys conducted at other sites were used to estimate baseline sound levels in the Bryan Mound site area. The Jones Creek area is within three miles of Bryan Mound.

Activities influencing sound levels in the Bryan Mound area include brining operations on the dome, traffic on the intracoastal waterway and Brazos River, petrochemical activity at Freeport, and traffic in the town of Freeport. In addition, construction and operational noise associated with the early storage phase at the dome and Corps of Engineers channel dredging in Freeport Harbor affect the local sound levels in these areas. To the west of the site, at locations more distant from the industrial activity, in the essentially unpopulated areas, sound levels are dominated by animal and insect activities and wind rustling foliage. To the south of Bryan Mound along the proposed brine disposal pipeline right-of-way are relatively quiet undeveloped beaches and marshlands. The Bryan Beach Recreation area may be somewhat noisier during summer peak usage.

The principal noise sensitive land uses are residential areas, schools and houses of worship in Freeport, two to three miles from the Bryan Mound Storage site. The unpopulated areas of the Gulf coastline and the marshes west of Bryan Mound are also somewhat noise sensitive.

A summary of the estimate of background ambient sound levels in terms of L_d (daytime), L_n (nighttime) and L_{dn} (day/night) sound levels is presented in Table B.3-5. Definitions of L_d, L_n, and L_{dn} are presented in Section B.2.4. These values may be compared with levels identified by the Federal EPA as requisite to protect public health and welfare (Section B.2.4). Note that levels in the immediate region of the Bryan Mound will be somewhat higher due to brine mining and early storage phase activities.

TABLE B.3-5 Summary of prefacility sound level (dB) estimates for Bryan Mound Site (proposed site for Seaway SPR development)

Area	L_d	L_n	L_{dn}
Along Intracoastal Waterway and near Industrial Activities	59	54	61
Noise Sensitive Land Use[a] (Freeport)	58	39	56
Undeveloped Area[b]	51	45	54
Noise Sensitive Land Use[b] (Small communities)	52	45	54

[a] FES 76/77-6

[b] Ambient survey at Jones Creek, SEADOCK Inc., March, 1974.

B.3.5 Species and Ecosystems

B.3.5.1 Site Area

For this discussion, the Bryan Mound site environment is limited to the 730 acre area within the -1500 foot salt contour (Table B.3-6). A total of about 390 acres would be enclosed for onsite construction activities for the total early storage phase-SPR program. Most of the Bryan Mound site consists of disturbed or built up areas. The remaining portion of the site that would be used for the SPR facilities consists of coastal prairie, Gulf Coast marshland, open water bodies.

Coastal Prairie and Gulf Coast Marshlands

Vegetation

The coastal prairie is composed of medium to tall grasses characterized by an open to moderately dense wildlife cover. Soils for the coastal prairie are primarily acid clays or clay loams, but in some areas sandy loams are present (Gould, 1962).

Vegetation common in the coastal prairie is switch grass, bunch grass, Indian grass, ragweed, and prairie pleat leaf. Gulf Coast prairie is the climax vegetation of the area and is greatly influenced by the low elevations. The parts of the prairie subjected to the influence of highly saline waters is dominated by Gulf cordgrass.

The Gulf Coast marshlands (Southern Cordgrass Prairie) dominate all of the lowlying environs of the site except for the northern flank of the mound where the coastal prairie extends along the built up levees which parallel the Brazos River Diversion Channel. This brackish marshland ecosystem is composed of medium to very tall grasses (Table B.3-7) which form a moderate to a very dense cover for wildlife. These grasses are usually found in the site area where the soil moisture extends to great depth. The common plants and animals in the brackish marshland are coastal sacahuista, marshy cordgrass, big cordgrass, bulrush, cattail, rushes, small mammals, snakes and water fowl. Many ducks, sea birds, pink spoonbills, and wading ducks were observed in the marshland to the northeast of the site.

TABLE B.3-6 Estimated site acreage analysis for Bryan Mound (proposed site for Seaway SPR development).

Total For Fenced Site Area	390 Acres
Total Within -1500 Foot Salt Contour	730 Acres
Total for Cleared Land	190 Acres
Total for Coastal Prairie	297 Acres
Total for Marsh	73 Acres
Total for Open Water	170 Acres

SYSTEM	Total Miles of Pipeline	Acreage for Construction	Acreage for Operation
Proposed Brine Disposal System (5.8 Mile Gulf Diffuser)	7.5	163.2	14.6
Coastal Prairie		20.0	14.0
Shell Ramp Barrier Flat		1.0	0.5
Marsh		0.2	0.1
Open Water		142.0	0.0
(total water crossings 2)			
Proposed Oil Distribution System (New Tanker Docks)	0.6	22.0	20.0
Cleared Land		18.0	17.0
Marsh		4.0	3.0
Alternate Brine Disposal System (Wells)	3.6	61.0	50.0
Marsh		61.0	50.0
Alternate Brine Disposal System (12.5 Mile Gulf Diffuser)	14.2	326.2	14.6
Coastal Prairie		20.0	14.0
Shell Ramp Barrier Flat		1.0	0.5
Marsh		0.2	0.1
Open Water		305.0	0.0
(total water crossings 2)			
Alternate Raw Water System (Ground Water Wells)	8.7	69.0	56.0
Coastal Prairie		69.0	56.0
Open Water		0.0	0.0
(total water crossings 3)			
Alternate Raw Water System (Dow)	6.0	37.0	35.0
Cleared Land		2.0	2.0
Fluvial Woodland		5.0	5.0
Coastal Prairie		28.0	28.0
Open Water		2.0	0.0
(total water crossings 0)			
Alternate Crude Oil Distribution System (Phillips Dock)	0.5	6.0	6.0
Cleared Land		6.0	6.0
Alternate Crude Oil Distribution System (VLCC Monobuoy)	30.0	740.0	3.0
Shell Ramp Barrier Flat		3.0	3.0
Open Water		737.0	0.0

[a]Based on features of USGS topographic maps (15 minute series).

[b]Cleared land includes agricultural, industrial and rural, and land already disturbed.

TABLE B.3-7 Ecosystems and typical flora and fauna of the Bryan Mound dome site (proposed site for Seaway SPR development)

	Ecosystem									
	Marshlands			Coastal Prairies	Fluvial and Oak Woodlands	Cleared Lands		Coastal and Inland Waters		Beaches, Shell Pamp-Barrier Flats
	Freshwater Marsh	Brackish Marsh	Salt Marsh			Urban and Suburban	Crops and Future Lands	Freshwater	Saline	
Key to Fig. B.2-28	5	5	4	6	8	7	6	2	1	3
Plants, herbs, grasses and trees	Maiden cane cordgrass sedges water hyacinth pennywort	smooth cordgrass soilbind morning glory fiddle leaf morning glory sea purslane rushes cattail coastal sacahuista marsh cordgrass big cordgrass bulrush	smooth cordgrass salt grass lazy daisy shortgrass glasswort salt matrimonyvine batis sea myrtle Carolina wolfberry bulrush Harstem bulrush	Gulf cordgrass bunchgrass Indian grass switchgrass bluestem live oak huisache ragweed prairie pleatleaf	live oak pecan sugar berry pignut hickory bluestem cordgrass	Various residential species	rice soybeans prairie grass	N/A	N/A	sea oats cordgrass mesquite morning glory seacoat bluestem
Mollusks and crustaceans	snails mussels clams crayfish	snails crabs crayfish clams shrimp oysters	fiddler crabs mud crabs clams oysters snails shrimp	snails	NA	NA	NA	clams snails oysters	clams oysters shrimp crabs snails	snails clams ghost crabs
Water snakes, amphibians, and reptiles	turtles western cottonmouth toads frogs	western cotton-mouth Gulf salt marsh snake Western diamondback rattlesnake	Gulf salt marsh snake Western cotton-mouth	ornate box turtle leopard frogs Western diamondback rattlesnake Eastern garter-snake Gulf Coast toad	ornate box turtle five-lined skink Eastern garter-snake	NA	NA	turtles frogs water snakes	NA	sea turtles
Fish	minnows crappie sunfish catfish gar	killifish	killifish cyprinids immature mullet spot	NA	NA	NA	NA	crappie catfish black bass gar shad buffalo-fish	mullet anchovy silver-sides cyprinids menhaden red drum sea trout tarpon flounder Atlantic croaker	NA
Mammals	muskrat raccoon nutria	muskrat rabbits rice rat Canid sp.	Canid sp. raccoon rice rat cattle	Canid sp. cattle hispid cotton rat rice rat rabbits striped skunk	gray and fox squirrel opossum armadillo raccoon cottontail rabbit white-footed mouse bobcat coyote	opossum domesticated animals bats rabbits striped skunk	cattle rabbits hispid cotton rat	muskrat nutria	whales porpoises	small rodents mice
Birds	gulls terns black skimmer red-winged blackbird willet black duck mottled duck blue-winged teal Great Blue heron Snowy egret black-necked stilt	American coot yellowlegs terns Seaside sparrow yellow-crowned night heron mottled duck blue-winged teal Great Blue heron Great egret Green heron Louisiana heron snow goose	plovers geese Great Blue heron Little Blue heron egrets Least bittern ibis Roseate spoonbill ducks clapper rail sandpipers	sparrows marsh hawk Eastern meadow-lark egrets vultures kites upland plover killdeer bobwhite quail sandhill crane scissor-tailed flycatcher loggerhead shrike	turkey vulture Coopers hawk great horned owl red-bellied woodpecker gray catbird tufted titmouse prothenotary warbler brown thrasher chestnut-sided warbler scarlet tanager cardinal Indigo bunting Northern oriole white-eyed vireo	blackbirds robins starlings common grackle	blackbirds hawks killdeer Eastern meadowlark mourning dove sparrows	ducks gulls coots geese	frigate bird gulls terns ducks	waterfowl terns seagull geese ducks

Wildlife

The Bryan Mound site is located approximately equidistant between the San Bernard and Brazoria National Wildlife Refuges (Figure B.2-28). Both of these refuges are very important to the ecology of the Texas Coastal Zone because of their large areas of critical habitat and the great diversity and abundance of the resident wildlife. Both of these refuges are located in coastal marshlands.

Bird life on the coastal prairies and marshlands of Texas is highly diverse (Table B.3-7). The most common bird species observed in the area include:

Great blue heron	little blue heron
Louisiana heron	least bittern
wood ibis	clapper
American coot	willet
spotted sandpiper	greater and lesser yellowlegs
black-necked stilt	laughing gull
least tern	common nighthawk
scissor-tailed flycatcher	loggerhead shrike
starling	eastern meadowlark
red-winged blackbird	common grackle
seaside sparrow	

Large bird concentrations are not uncommon in the area since the mound lies within an area of the Texas coast which during the winter contains about 28 percent of the ducks and 34 percent of the geese that migrate to the Gulf Coast (Gusey, 1972).

Species of mammals which inhabit the coastal prairies and marshlands of the Bryan Mound site (Table B.3-7) include the opossum, cottontail rabbit, Canid sp. and hispid cotton rat. Small rodents are usually the most abundant mammals found at Bryan Mound. Other mammal species observed included the armadillo, nutria, and raccoon. The absence of forest habitat at Bryan Mound limits the abundance of species such as opossum, raccoon, and armadillo. In addition, because of the human activity at Bryan Mound, nutria were not often encountered at the site, but these animals are more common in the remote areas of the mound.

Population estimates of various mammals in Brazoria County are discussed in Section B.2.5.1.

Cattle are the second most abundant quadruped found on the site. Their ability to consume large amounts of vegetation puts them in direct competition with the numerous small rodents and rabbits for the available food resources and therefore affects the abundance of the rabbits at the site.

At least four species of amphibians and four species of reptiles are found in the vicinity of Bryan Mound, including the ornate box turtle, chicken turtle, Gulf salt marsh snake, western diamondback rattlesnake, southern leopard frog, Gulf Coast toad, green treefrog, and bullfrog. The Gulf salt marsh snake was the most prevalent species encountered.

None of the commercial, recreational, threatened and endangered species discussed in Section B.2.5 are known to inhabit the Bryan Mound site.

B.3.5.2 Open Water Bodies

Inland Waters

Bryan Mound is surrounded by numerous bodies of water, both large and small, which provide a diverse range of aquatic habitat for wildlife (Figure B.3-1). The three major aquatic environments near the site include the Brazos River on the west, the ICW on the south, and Brazos Harbor on the east. Other inland water bodies in the vicinity of the site include the many small tidal and marsh lakes as well as several drainage canals. The largest of these lakes are Mud Lake (87 acres), Old Reservoir (35 acres), and Unnamed Lake (150 acres). Salinities in these lakes vary from fresh water up to 15 parts per thousand, depending on the location of the pond, the season of the year, and the flood stage of the Brazos River.

Circulation is generally poor within these semi-enclosed lakes and ponds. Species diversity tends to be low within these areas, but population densities are relatively high. The Brazos River and the ICW have relatively good circulation, and species diversity is high, but population densities are generally low. Salinities in the Intracoastal Waterway are expected to be similar to the other estuarine waters near the site; the biotic components of the Intracoastal Waterway would be similar to those species occurring in the estuarine waters as discussed in Section B.2.5. This diversity-density relationship indicates a stable and well-balanced biological system. Major uses of the coastal and inland water for the biological communities include feeding, cover, and nursery areas. Waterfowl in particular, such as gulls, terns, herons, and egrets, use these areas for feeding, resting and nesting.

In the fresh and slightly brackish waters, pennate and centrate diatoms are generally the most common phytoplankton. In the Bryan Mound area, however, green algae are the most abundant member of the plankton flora. In the more eutrophic water bodies, the filamentous blue-green algae are both recurring and abundant. Blue-green algae were absent in winter samples but made up 11 percent of summer phytoplankton samples. The dinoflagellates Ceratium and Peridinium are also common aquatic organisms in many of the water bodies.

Phytoplankton primary productivity has been reported to average 2.25 mg-carbon per liter per day in area canals. This amount, on the average, was 8 percent higher than values measured in area marshes and 49 percent higher than values estimated for West Galveston Bay. Primary production in the brackish or saline waters at Bryan Mound and Brazos Harbor is expected to be similar to the productivity values measured in the Galveston area canals and marshes.

Zooplankton in the aquatic habitats near Bryan Mound consists of a relatively rich and diverse fauna which is dominated by the eurhaline copepod Acartia tonsa. Zooplankton samples taken from the vicinity of Freeport were predominantly made up of nauplii and copepods (Dames & Moore, 1973b). Nauplii were present in all seasons of the year but these larvae were particularly abundant during the summer in the bay and estuarine waters. These organisms utilize the low-salinity, nutrient-rich and protected waters of the area to mature. Zooplankton densities in nearshore waters southwest of Galveston are reported to be greater than 0.5 grams per cubic meter. Similar values would be expected for the Bryan Mound project area. The benthic communities in the freely flowing water bodies at Bryan Mound are greatly influenced by the position of the saltwater wedge in these bodies.

Most benthic samples taken in the project area are dominated by polychaete worms but gastropods (snails), pelecypods (clams), and crustacea are also common. No known oyster beds are located near Bryan Mound. The closest oyster beds to the site are found in Bryan Lake which is located about two miles southeast of Bryan Mound, but these beds should not be influenced by development of the site. Blue crabs have been taken from the waters of Mud Lake which connects with the Intracoastal Waterway and subsequently the Brazos River. Blue crab abundance is much higher in undisturbed areas such as Bryan Lake (Texas Parks & Wildlife Department, 1974) as compared to Mud Lake.

Brackish water and estuarine areas which have cordgrass cover on the banks provide important sources of nutrients and organic matter to these ecosystems and also provide habitat for numerous invertebrates which include periwinkles and mussels.

Marshes and tidal ponds such as Mud Lake and Bryan Lake which connect with the Gulf of Mexico by way of the Intracoastal Waterway or the Brazos River are very productive in terms of the numbers of animals present when all species are combined. Most abundant important aquatic organisms in these habitats are brown shrimp, white shrimp, spot, Atlantic croaker, menhaden, silverside, mullet, seatrout, and cyprinids.

The most important freshwater system within Brazoria County is the Brazos River. The river has been dammed, and the Brazos River Diversion Channel passes to the west of the Bryan Mound site. The original channel now forms Brazos Harbor, which lies to the east of the site.

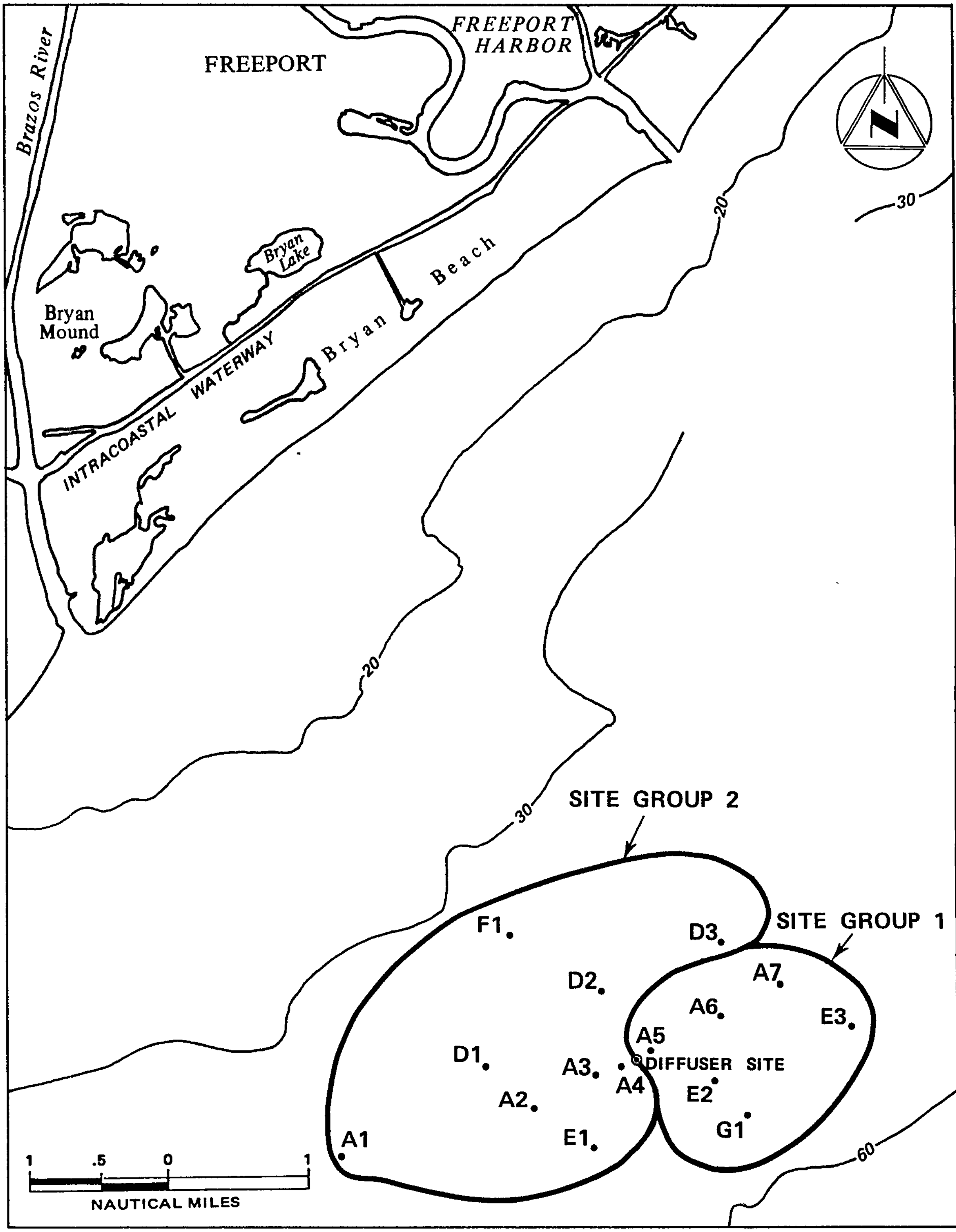
Dominant floral and faunal components of fresh waters in Brazoria County include green algae, diatoms, and blue-green algae. Common macrophytes include the pondweeds, duckweeds, and water lilies. Zooplankton samples include rotifers, copepods, cladocerans, and nematodes. Common benthic macroinvertebrates are the amphipods, corixids, larval dipterans, and Coleoptera. Predominant fishes of fresh waters include gizzard shad, carp, gar, and sport fishes such as largemouth bass, channel catfish, and several species of sunfish and crappie. Wildlife species which either inhabit and/or utilize these areas to feed or rest include some species of ducks and geese, gulls, terns, herons, egrets, nutria, water snakes, turtles, and frogs.

Gulf of Mexico

The biological community on the inner continental shelf in the vicinity of the proposed diffuser system is typically highly productive. The primary producers (phytoplankton) consist of diatoms which dominate the community throughout the year and dinoflagellates which codominate periodically. Diatoms account for over half the total number of phytoplankton in all seasons with predominant genera including Rhizosolenia, Nitzschia, Thalassiothrix, Thalassionema, Skeletonema, Chaetoceros and Asterionella, many forming chains of small cells. Primary productivity at the site is expected to range from 20 to 30 mg C/m^3/day as an annual average, with maximum values occurring in later winter and early spring and minimums in summer. Zooplankton groups common to the area include copepods and meroplanktonic stages of several benthic invertebrates. The copepod Acartia tonsa is the numerically dominant species in the vicinity.

Over 290 species of benthic macroinvertebrate infauna (0.5 mm in diameter or larger) have been identified in the vicinity of the proposed diffuser site. Sampling at fifteen stations surrounding the diffuser site produced 107 species of benthic invertebrates, dominated by 51 species of polychaetes. Prionospia pinnata was the most abundant polychaete species with other common taxa including amphipods, decapod crustacea, nemerteans, gastropods, and pelecypods. The frequency of occurrence and/or abundance of the amphipods Ampelisca abdita and Ampelisca agassizi and the bivalve Nuculana concentrica help set apart two distinct benthic assemblages in the diffuser area as seen in Figure B.3-2.

Two distinct nekton communities have also been identified in the vicinity of the proposed diffuser with names derived from the dominant



SOURCE: Texas A & M, 1978.

FIGURE B.3-2. Areal distribution of benthic macroinvertebrate site groups (depth contours in feet).

commercial shrimp fishery in each area. The white shrimp grounds are dominated by the Atlantic croaker and the brown shrimp grounds by the longspine porgy. The white shrimp grounds tend to have fewer species and lower biomass, and the indigenous fish tend to be more dependent on the estuaries than those found in the brown shrimp grounds. However, in the vicinity of the proposed brine diffuser, trawl surveys showed the brown shrimp grounds to have a lower biomass of common species than the white shrimp grounds. Nekton families found in the white shrimp grounds (Inner Shelf depths 12-72 feet) include drums, cutlassfishes, threadfins and sea catfishes. The brown shrimp grounds (Intermediate Shelf depths 72-300 feet) include porgies, searobins and drums. During summer months predatory pelagic fish are found in the area including dolphins, bill fishes, mackerals, bonito, amberjack, blue runner and several species of jack fish. Unique reef communities found offshore of the diffuser area play an important role in support of local fisheries. The red drum is known to spawn near reef communities. Both white and brown shrimp are fished commercially in the waters surrounding the diffuser site. White shrimp are known to spawn in the vicinity of the brine duffuser site, and the area is intensely used by local shrimpers. Sport fishing near the proposed site is often concentrated during summer months especially in the vicinity of the coral heads and rock outcropping in the vicinity known as the East Bank Area (Graham, 1977). A more detailed description of the aquatic species found in the vicinity of the proposed diffuser is presented in Appendix G.

B.3.5.3 Dock Sites

Estimated site acreage and land use requirements for the proposed new DOE docks are presented in Table B.3-6. The soils in cleared land areas consist mostly of sand, mud, and broken shell material. Some natural vegetation is present in scattered areas of the dock sites. No critical habitat or threatened or endangered species are located at the sites.

Brazos Harbor, because of its cul-de-sac configuration, is characterized by poor water quality and siltation problems. The harbor is subject to frequent (every 24 months) dredging activity. The harbor is not a particularly desirable habitat for most aquatic organisms because of the polluted water. Fish numbers in the harbor are low, and most of the species present are usually collected near the harbor breakwater.

Coleoptera (beetles) generally dominate samples collected from submerged logs and aquatic plants near Brazos Harbor, but amphipods (scuds) and Corixidae (water boatmen) are also common. Abundant macroinvertebrates in the deep water of the inner harbor area are the Chironomidae, Ceratopogonidae, oligochaeges, and bryozoans.

Fish common to the harbor include menhaden, mullet, and silversides (Table B.3-7).

B.3.6 Natural and Scenic Resources

The natural resources in the region surrounding the site are discussed in Section B.2.6.

The site is located primarily in undeveloped marsh and coastal prairie surrounding a small area which has already been developed. The marsh and prairie areas are typical of those found in this area of the Texas Gulf Coast and have no unique aesthetic features. Due to prior development, the area immediately surrounding the project site has a relatively low aesthetic value. The site itself is not easily reached from any major roads. It is visible from the road on the levee along the western edge of the site. Parts of the project may be visible to southern areas of Freeport.

There are four major beaches in the Freeport area: Bryan, Quintana, Surfside, and San Luis Pass beaches. Under the Texas Open Beach Act, all beaches fronting on the Gulf of Mexico are open to the public up to the line of first vegetation. Beach attendance in this area is estimated at 3.1 to 3.3 million persons annually.

B.3.7 Historical, Archaeological & Cultural Resources

The candidate site does not contain any known sites of archaeological, historical, or cultural significance. If this site is selected for SPR development, a qualified archaeologist will survey previously unsurveyed areas and coordinate with the State Historical Preservation officer.

B.3.8 Socioeconomic Environment

B.3.8.1 Land Use

The Bryan Mound site is located within the group of communities known collectively as Brazosport, which includes the town of Freeport (Figure B.3-3). As stated in Section B.2.8.2, this area is highly industrialized, with petroleum related facilities representing a significant share of the market.

The city of Freeport lies to the north and east of the site. The Environmental Geological Atlas, Texas Coastal Zone, shows the Freeport area as a residential-urban area containing commercial and residential development as well as industrial areas (McGowen and others, 1976).

To the east of the site is a filled area (classified as made-land), that is used for urban-residential and industrial expansion. This type of area is commonly developed over marsh and reclaimed land. Approximately one-half mile east of the site are facilities of Phillips Petroleum and Houston Natural Gas including small storage tanks and degassifying equipment to handle offshore operations. Farther to the east are the Brazosport (Freeport) Harbor facilities.

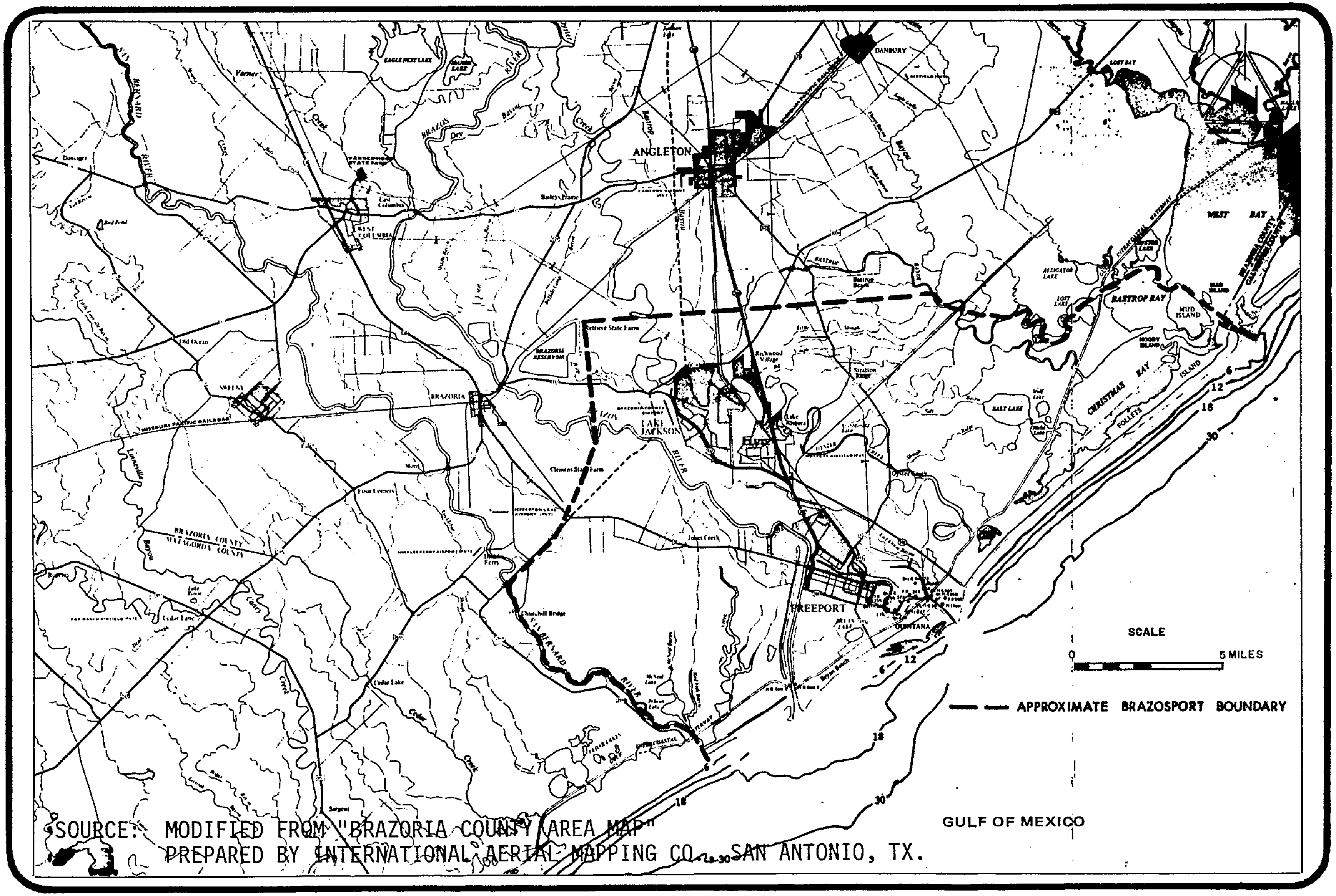
The southern perimeter of the Bryan Mound site has several types of land-use, including marsh areas, spoil areas, and the Intracoastal Waterway. Immediately adjacent to the site is a mud lake, used previously for the disposal of drilling mud. South of the site along the Gulf shore are beaches used for recreation. The Gulf in the vicinity of the brine pipeline and diffuser is used for recreation, fishing, and oil and gas extraction.

The industrial use of the Bryan Mound SPR site is compatable with the general land use patterns in the Freeport harbor area.

B.3.8.2 Transportation

Brazoria County transportation systems and planned future improvements are discussed in Section B.2.8.3.

Access to the dome from Freeport, Texas, is by the major highway Route 288 connecting with a road along the east edge of the Brazos River Diversion Channel, or by a gravel county road connecting with Route



SOURCE: MODIFIED FROM "BRAZORIA COUNTY AREA MAP"
PREPARED BY INTERNATIONAL AERIAL MAPPING CO., SAN ANTONIO, TX.

FIGURE B.3-3 Brazosport community

1495. Freeport is located about 2 miles from the Bryan Mound site by County Road 242 (Figure B.3-4).

The Intracoastal Water (ICWW) is less than a mile south of the Bryan Mound storage site and is crossed by the proposed brine disposal pipeline right-of-way. In this vicinity the waterway is fairly straight and 12 to 15 feet in depth, and is heavily traveled by commercial and pleasure vessels. The brine diffuser in the Gulf is located about 4000 feet west of a shipping anchorage area associated with Freeport Harbor. The shipping lanes in the Gulf are nine miles offshore from the proposed diffuser site. The pipeline to the diffuser would cross some existing pipelines in the area associated with oil and gas extraction.

B.3.8.3 Population Characteristics

Freeport is the port city of Brazoria County. It had an estimated 1976 population of 19,500.

The age distribution of the population in this area can be characterized as fairly youthful. Approximately half of the local population is between 20 and 55 years of age, while approximately 40 percent are 19 years or younger. Residents over 55 years of age represent approximately 15 percent of the local population. Freeport's population represented about 11 percent of the County total in 1970.

B.3.8.4 Housing

The vacancy rate for rental units in Brazoria County in 1970 was very high, but very low for sale units, as shown in Section B.2.8.5. (U.S.Dept. of Commerce, 1973a). In contrast, all types of housing are in short supply in the Brazosport area, the county's major urban complex. At least 700 new housing units are being constructed each year in the area but supply has not kept up with demand. Most mobile home parks are filled to capacity. A large percentage of the work force is forced to commute from other areas, some from as far as Houston (40 miles). This situation will probably continue for some time due to the rapid growth of the area.

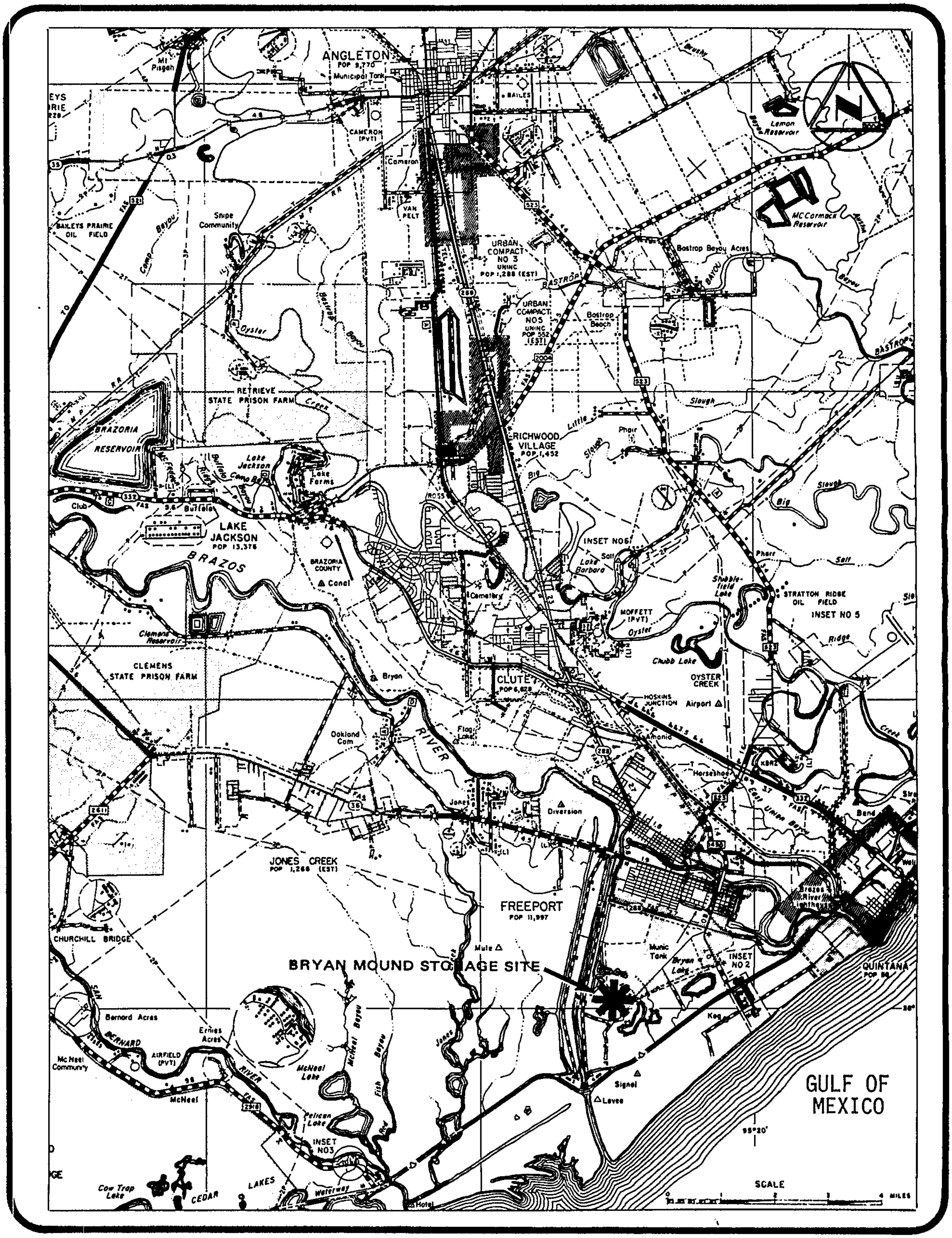


FIGURE B.3-4 Freeport area highway map

B.3.8.5 Economy

Chemicals

The largest basic chemical manufacturing complex in the world is in Brazosport, centered around the Texas Division of the Dow Chemical Company (over 5,000 employees). Other local manufacturers include Shell Oil Buccaneer Plant, Dow Badische, and Davis Oyster Creek Division (250 to 499 employees); Rhodia, Inc. (100 to 249 employees); ShinTech, Inc. and Nalco Chemicals (50 to 99 employees); Hoffman LaRoche, and Schenectady Chemicals, Inc. (25 to 49 employees); Red Barn Chemicals and Dow's new Brazosport plant (8 to 24 employees); all in the chemical field. A variety of diverse industries such as Rheem Manufacturing Company, Mallay Corporation, Maencor, Big Three Industries, and numerous small plants are also located in the area.

Fishing

The Brazosport area is a seasonal home to one of the world's largest shrimp fishing fleets, producing as much as 15 million pounds of shrimp annually. Many valuable fishing areas are nearby in the Gulf of Mexico.

Minerals and Agriculture

Mineral extraction and agriculture are also important contributors to the local economy (Section B.2.8.6).

B.3.8.6 Government

Education

The Brazosport Independent School District serves the entire Brazosport area, including the communities of Freeport, Clute, Jones Creek, Lake Barbara, Lake Jackson, Oyster Creek, Quintana, and Richwood. The present physical plant consists of two high schools, three intermediate schools, and nine elementary schools. At the present time, the district is planning the addition of a special education facility.

Since the district's enrollment has risen only slightly between 1969 and 1976, additional facilities (other than the special education facility mentioned above), are not planned. The district's staff is being constantly expanded in order to reduce class sizes and provide better services to the students (SEADOCK, 1975).

Hospitals

In addition to the Community Hospital, five small clinics serve the Freeport area. There is a shortage of medical personnel in the area, but an established system for emergency evacuation of seriously injured persons by helicopters and fixed wing aircraft exists.

Police and Fire Protection

Police and fire protection for the project would be provided by the Brazoria County Sheriff's Office and the city of Freeport. Several deputies from the Sheriff's Department regularly patrol areas outside municipalities. Freeport has 19 full time police officers, 5 dispatchers, and 7 police cars. Freeport has a paid full-time fire department with 7 firemen and a chief. The fire department has modern pumper trucks and a foam trailer for chemical fires. Additional fire fighting units and personnel are available from adjacent communities under an established and tested system for mutual assistance. A large number of trained volunteer firemen are available if needed.

B.4 SITE SPECIFIC ENVIRONMENT - ALLEN DOME

Allen dome is one of the four possible alternative sites of the Seaway Group for the SPR program. It is a small dome, whose geometry and size are not well defined. Further predevelopment exploratory work will be required if this site is to be developed.

B.4.1 Land Features

B.4.1.1 Physiography and Topography

The Allen dome storage site is a flat floodplain, sloping gently away from the natural levees of the San Bernard River. The maximum elevation on the levees is about 5 feet, while on the site the elevation is about 4 feet. The bathymetry of the area surrounding the proposed offshore diffuser is discussed in Section B.3.1.1.

B.4.1.2 Local Geology

Allen dome is a shallow salt dome, almost circular in plan. Its broad, nearly flat top lies about 1380 feet below sea level. Sides of the dome are steeply dipping contacts, with the north, west, and south sides dipping at about 78^{o} and the east side dipping at 84^{o}. Northsouth and eastwest crosssections through the dome are presented in Figures B.4-1 and B.4-2. The location of these sections is shown in Figure B.4-3. These sections show the relationship of the salt dome to the surrounding strata and also show the potential cavern interval and potential brine disposal strata.

A structure map contoured on top of the salt (Figure B.4-3) shows the shape of the top of the salt mass. Data for this figure is from 17 drill holes reported to penetrate the salt.

Structural interpretation based upon so few points is subject to change. However, three possible surface indentations (reentrants) are shown on the structure map. The reentrant feature on the south edge of the dome shows a significant salt embayment and overhang within the proposed storage cavern interval.

A detailed composition or quality of the salt mass in not known at this time. However, experience with other domes in the area suggests that the composition should be similar to that found at Bryan Mound (Section B.3.1).

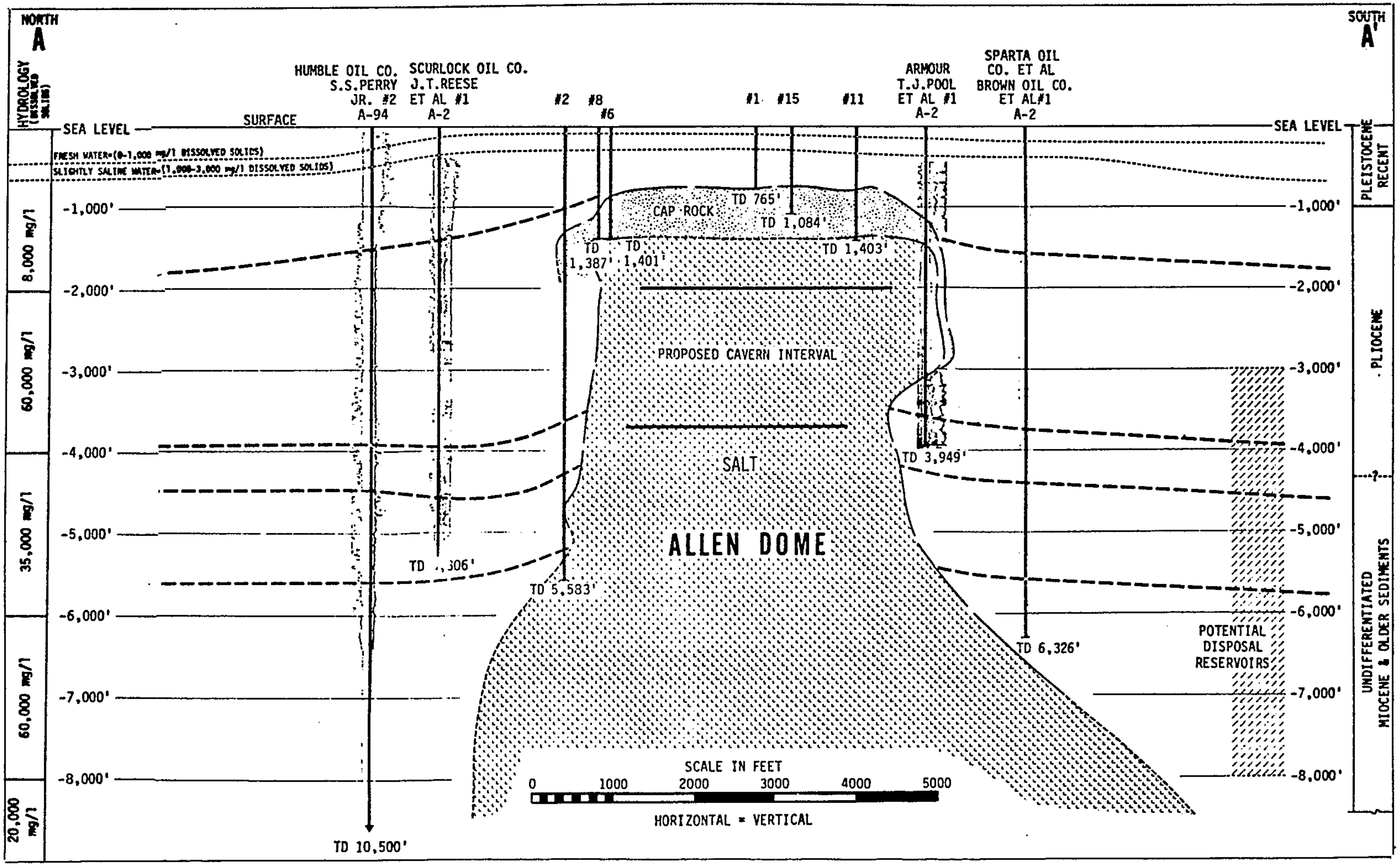


FIGURE B.4-1 Geologic cross-section (North-South) Allen Dome candidate SPR storage site (alternative site)

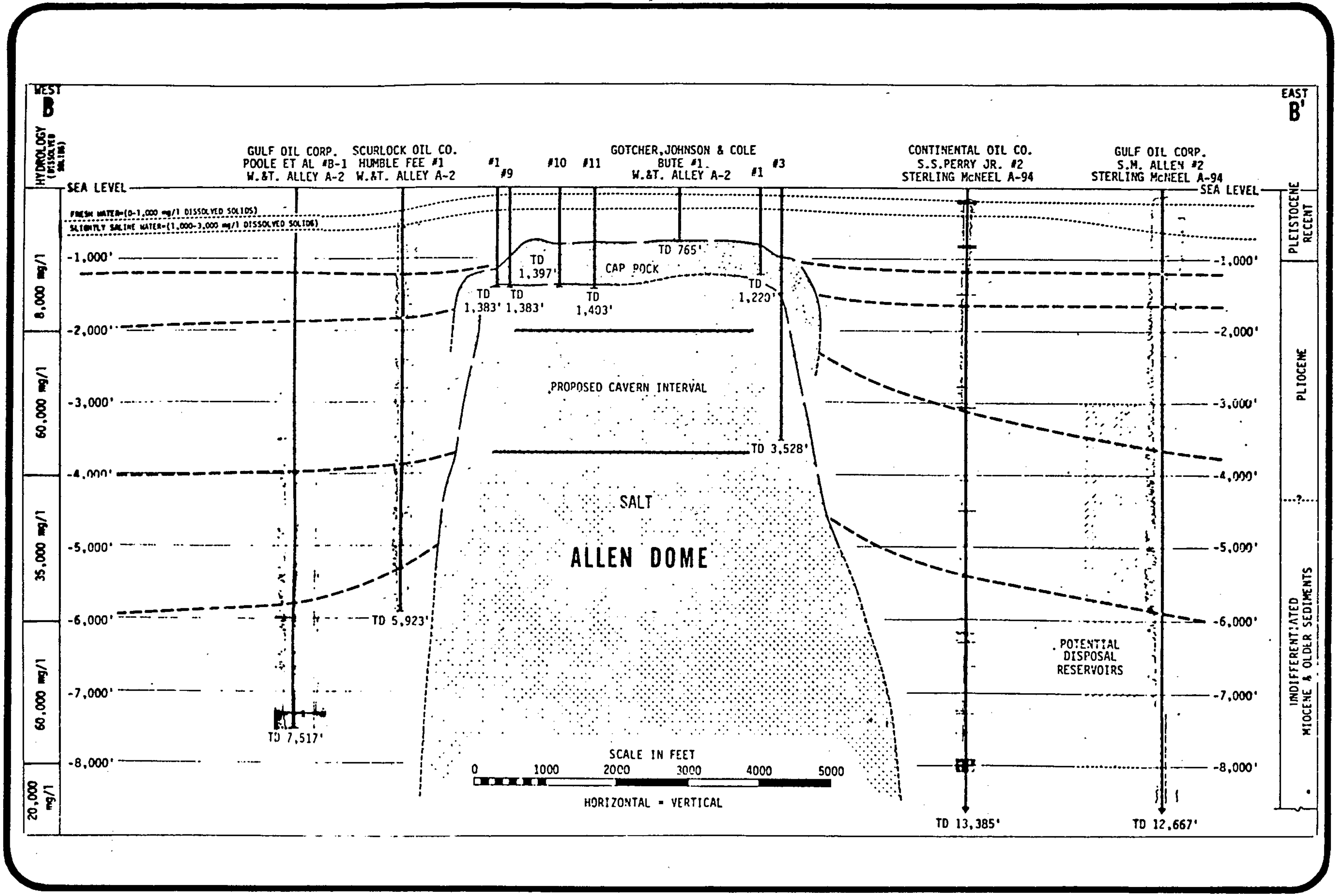


FIGURE B.4-2 Geologic cross-section (East-West) Allen Dome candidate SPR storage site (alternative site)

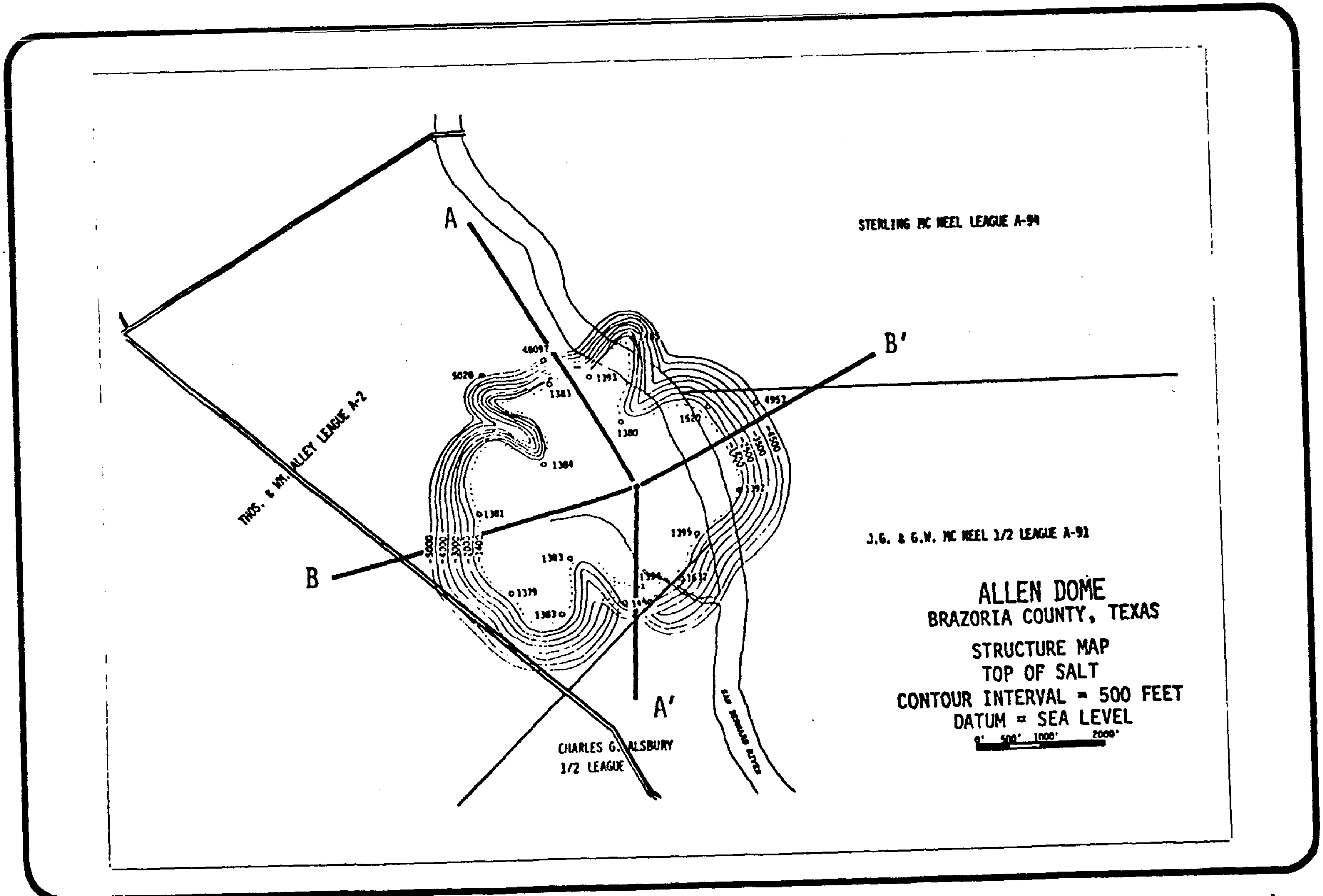


FIGURE B.4-3 Structure Map - top of salt - Allen Dome candidate SPR storage site (alternative site)

Records of drillholes penetrating caprock and salt show an average caprock thickness of about 490 feet, ranging from 302 to 592 feet. The caprock appears to completely overlie the salt dome. From top to bottom, the caprock of the Allen dome is composed of an average of 51 feet of calcite, 247 feet of gypsum, and 166 feet of anhydrite. It also contains about 18 feet of sand and shale sediments. Lenses of sandy clay up to 111 feet thick are reported throughout most of the limey portion of the caprock. Sulfur is a minor constituent.

Approximately 1000 feet of Pleistocene and Recent age unconsolidated sediments composed of muds, shales and sands overlie the caprock. Unconsolidated and partially consolidated sands and shales of Pliocene and Miocene age extend downward alongside the dome to between 4500 and 7000 feet and below. The thickness of the Miocene section in the vicinity of the dome is approximately 6500 feet. In the immediate vicinity of the dome these sediments have been forced upward by the salt piercement. Faulting within the Miocene and overlying Pliocene formations immediately adjacent to the dome is probably extensive and complex.

B.4.1.3 Economic Geology

First oil production at Allen dome was from the Shell No. 1 Allen in May 1927. A search of available records shows that the area's most recent drilling activity was in 1962. Oil and gas occur primarily on the southeast and east flanks of the dome in Miocene age sediments which are faulted or pinched out against the sides of the dome. No known oil or gas production is located over the top of the dome in the area proposed for the storage facility.

Sulfur is a minor constitutent of the caprock, but could be a commercial resource. Freeport Sulphur Company drilled 15 holes into the caprock and salt in an exploratory program during 1926 and 1927. They are reported to have found as much as 11 feet of sulfur in some of their test wells, but never produced it commercially.

B.4.1.4 Soils

The Moreland-Pledger-Norwood association occurs along the San Bernard River. Soils in this association are calcareous, clayey, and loamy in texture. They were derived from recent flood plain alluvium. These soils also are mixed with a considerable amount of montmorillonite and are moderately alkaline and calcareous to neutral in the surface layer, or present a moderate surface salinity hazard to plants, while subsoils are much higher in salinity.

Marine sediments located in the vicinity of the proposed brine disposal system in the Gulf are discussed in Section B.3.1.4.

B.4.2 Water Environment

B.4.2.1 Surface Water Systems

The San Bernard River runs to the east of the Allen dome alternative storage site. This reach of the San Bernard, from the Gulf of Mexico to Brazoria, is an estuary. Adjacent to the site, a dredged channel 50 feet wide by 9 feet deep is available for river traffic.

Jones Creek and the Brazos River Diversion Channel are crossed between Freeport Harbor and the Allen dome site. Jones Creek is a small, intermittent stream which drains a very small coastal basin. Several small ponds are found in the Jones Creek bed. The Brazos River Diversion Channel near the Bryan Mound site was discussed in Section B.3.2. It is an estuary in this reach, but suffers from high salinities due to fresh water mixing with water from the Gulf of Mexico. A large number of agricultural and industrial users are also located upstream of the subject area.

South of the Allen dome site, the coastal marshes of the San Bernard Wildlife Refuge drain into the Intracoastal Waterway. Some of the marsh east of the San Bernard River drains into the San Bernard in small tributaries such as Redfish Bayou. The rest of the marsh east of the San Bernard drains into the Intracoastal Waterway.

The Intracoastal Waterway drains to the Gulf of Mexico through the San Bernard and Brazos estuary mouths. The waterway is used extensively by dry bulk cargo barges and pleasure craft. Because the entrances to the San Bernard and Brazos Rivers are very shallow (3 to 4 feet at MLW), most barge traffic exits from the Intracoastal Waterway into Freeport Harbor or the Gulf of Mexico through the Freeport Harbor Entrance Channel.

Freeport Harbor has been discussed in Section B.2.2 and B.3.2. It is a closed water body with circulation restricted by the damming of the Brazos and creation of the Brazos River Diversion Channel. The Gulf of Mexico lies just about four miles south of Allen dome.

The site is subject to periodic flooding. The Corps of Engineers computes that the 100 year flood from the San Bernard River would rise to elevation +9.5 feet. The 100 year flood at the site due to hurricane surges has been estimated at 14 to 18 feet (Trahan, personal communication, 1977).

The marine conditions in the area of the proposed brine diffuser are discussed in Section B.3.2.1.

B.4.2.2 Subsurface Water Systems

Because of the proximity of Allen dome to Bryan Mound, the occurrence and characteristics of the ground water are similar to those described in Section B.3.2 for Bryan Mound. Structure maps and cross-sections of the shallow aquifers are shown in Figures B.4-1, B.4-2 and B.4-3.

Ground water use in the vicinity of the Allen dome does not appear to be extensive. The hydraulic gradient is essentially flat in the upper unit of the Chicot aquifer at the site. Local use of ground water is probably limited to rural domestic pumpage and stock watering.

Bernard Acres subdivision, just south of the site, uses shallow fresh aquifers for individual domestic wells. The town of Brazoria, about 10 miles north of the site, pumps water from the lower unit of the Chicot aquifer with an average municipal usage of 156,000 mgd in 1967 (Sandeen and Wesselman, 1973). The cone of drawdown in the surface aquifer from that pumping extends to the site, but the hydraulic gradient is relatively flat, at about 1.5 feet per mile.

Land subsidence resulting from large ground water withdrawals is minimal in the site vicinity, as shown in Figure B.2-26.

B.4.3 Climatology and Air Quality

Existing air quality levels at Bryan Mound are very good with the exception that non-methane hydrocarbon and oxident concentrations sometimes exceed the NAAQS. Like Bryan Mound, the Allen site experiences a predominantly marine climate characterized in Section B.3.3.1 with prevailing south to southeasterly winds.

B.4.4 Background Ambient Sound Levels

A wildlife refuge lies southwest of the Allen dome site and grazing land lies northeast and south of the site. A small development of about 35 singlefamily dwellings lies approximately 1000 feet south of the site and is the principal noisesensitive land use area. Streets have been laid out in an area 1/2 mile north of the site, but at present few houses have been built. Unlike Bryan Mound, the Allen dome site is an appreciable distance from the Intracoastal Waterway or industrial or drilling activities. Principal sound sources anticipated include insect and animal activity, recreational activity on the river, and wind. Average day/night sound levels of up to 54 dB are estimated for the area. Sound levels are expected to be somewhat quieter here than at the Bryan Mound site. Sound levels at the Bryan Mound site and the brine diffuser pipeline right-of-way are discussed in Section B.3.4.

B.4.5 Species and Ecosystems

B.4.5.1 Site Area

The Allen dome is flat, with elevations of generally less than 5 feet above mean sea level. On the southeastern flank of the dome, a residential neighborhood is developed around a manmade canal system. Within the Allen dome site area, the ecosystems are characterized mainly as coastal prairie, fluvial woodland, and estuary. Estimated site acreages are summarized in Table B.4-1.

The San Bernard National Wildlife Refuge is located two miles to the southwest of the Allen dome site. The refuge is located in coastal marshland which is dotted with numerous lakes and ponds, and contains abundant and diverse wildlife communities.

TABLE B.4-1 Estimated site acreage analysis for Allen dome candidate SPR storage site (alternative site).

Total For Fenced Site Area -- 184 Acres
Total Within -2000 Foot Salt Contour ---------------------------- 333 Acres
Total for Cleared Land ---------------------------------- 3 Acres
Total for Fluvial Woodlands ------------------------------ 70 Acres
Total for Coastal Prairie -------------------------------- 232 Acres
Total for Open Water ------------------------------------- 28 Acres

SYSTEM	Total Miles of Pipeline	Acreage for Construction	Acreage for Operation
Proposed Brine Disposal System (5.8 mile Bryan Mound Gulf Diffuser & Injection Wells)	21.5	335.2	144.6
Fluvial Woodlands		2.0	2.0
Coastal Prairie		130.0	97.0
Shell Ramp Barrier Flat		1.0	0.5
Marsh		12.2	9.1
Open Water		143.0	0.0
(total water crossings 8)			
Proposed Raw Water System (Brazos River Diversion Channel)	12.1	99.0	74.0
Fluvial Woodlands		2.0	2.0
Coastal Prairies		84.0	63.0
Marsh		12.0	9.0
Open Water		1.0	0.0
(total water crossings 6)			
Proposed Oil Distribution System (New Tanker Docks)	12.7	121.0	94.0
Cleared Land		18.0	17.0
Marsh		16.0	12.0
Fluvial Woodlands		2.0	2.0
Coastal Prairies		84.0	63.0
Open Water		1.0	0.0
(total water crossings 6)			
Alternate Brine Disposal System (wells)	3.2	19.0	19.0
Coastal Prairies		19.0	19.0
Alternative Brine Disposal System (5 mile Gulf Diffuser Directly Offshore)	13.4	234.0	70.0
Coastal Prairies		17.0	13.0
Marsh		76.0	57.0
Open Water		141.0	0.0
(total water crossings 2)			
Alternative Brine Disposal System (12.5 mile Diffuser from Bryan Mound)	26.3	425.0	89.0
Fluvial Woodlands		2.0	2.0
Coastal Prairies		104.0	77.0
Marsh		12.0	9.0
Shell Ramp Berrier Flat		1.0	1.0
Open Water		306.0	0.0
(total water crossings 10)			
Alternate Raw Water System (Brazos River)	5.0	106.0	80.0
Fluvial Woodlands		45.0	34.0
Coastal Prairies		61.0	46.0
Alternate Raw Water System (San Bernard River)	---	6.0	4.0
Fluvial Woodlands		1.0	1.0
Coastal Prairies		5.0	3.0

TABLE B.4-1 continued.

SYSTEM	Total Miles of Pipeline	Acreage for Construction	Acreage for Operation
Alternate Raw Water System (Ground Water Wells)	5.5	22.0	22.0
Coastal Prairies		22.0	22.0
Alternate Raw Water System (Gulf)	13.4	234.0	70.0
Coastal Prairies		17.0	13.0
Marsh		76.0	57.0
Open Water		141.0	0.0
(total water crossings _2_)			

[a]Based on features of USGS topographic maps (15 minute series).

[b]Cleared land includes agricultural, industrial, and rural, and disturbed land.

Coastal Prairie

Vegetation

The coastal prairie on which Allen dome is situated is used predominantly for grazing land. Within the coastal prairie, the vegetation consists of medium tall to tall grasses. The principal species include seacoast bluestem, coastal sacahuista and big bluestem. Specific subdominant plant species include Indiangrass, eastern gammagrass, Gulf muhly, western ragweed, turtlegrass, little bluestem, buffalo grass and smut grass. Additional floral components which are normally associated with the coastal prairie include mesquite, oaks, prickly pear and huisatch.

Wildlife

The coastline at the site provides suitable habitat for a large number of avian species. During the spring when the prairie is wet, the site attracts herons, egrets, ibises, and other wading wetland birds. The most common bird species likely to be found in coastal prairie habitat at Allen dome include:

Eastern meadowlark	Green heron
Dickcissel	Great egret
Redwinged blackbird	Turkey vulture
Killdeer	Marsh hawk
Upland plover	Mourning dove
Horned lark	Savannah sparrow
Common grackle	Vesper sparrow

At least 12 species of mammals are expected to occur in the Allen dome vicinity (Dames & Moore, 1973). Species commonly associated with coastal prairie are presented in Table B.4-2.

The hispid cotton rat and rice rat are the two small rodent species most likely to occur on the site. Studies at similar habitat yielded 6.5 cotton rats per hectare (Dames & Moore, 1973b). Rice rats favor wet areas, therefore, these rodents are probably restricted in their abundance and distribution at the site.

TABLE B.4-2 Ecosystems and typical flora and fauna of the Allen dome site candidate SPR storage site (alternative site)

	Ecosystem									
	Marshlands			Coastal Prairies	Fluvial and Oak Woodlands	Cleared Lands		Coastal and Inland Waters		Beaches, Shell Ramp-Barrier Flat
	Freshwater Marsh	Brackish Marsh	Salt Marsh			Urban and Suburban	Crops and Future Lands	Freshwater	Saline	
Key to Fig. B.2-28	5	5	4	5	8	7	6	2	1	3
Plants, herbs, grasses and trees	Maiden cane cordgrass sedges water hyacinth pennywort	smooth cordgrass soilbind morning glory fiddle leaf morning glory sea purslane	smooth cordgrass salt grass lazy daisy shortgrass glasswort salt matrimonyvine batis sea myrtle Carolina wolfberry bulrush marstem bulrush	Gulf cordgrass bunchgrass Indian grass switchgrass bluestem live oak huisache ragweed prairie pleatleaf smut grass turtle grass muhly coastal sacahuista Eastern gammagrass buffalo grass mesquite prickly pear	live oak pecan sugar berry pignut hickory bluestem cordgrass water oak elm	Various residential species	rice soybeans prairie grass	NA	NA	sea oats cordgrass mesquite morning glory seacoast bluestem
Mollusks and crustaceans	snails mussels clams crayfish	snails crabs crayfish clams shrimp oysters	fiddler crabs mud crabs clams oysters snails shrimp	snails	NA	NA	NA	clams snails oysters	clams oysters shrimp crabs snails	snails clams ghost crabs
Water snakes, amphibians, and reptiles	turtles western cottonmouth toads frogs	Western cottonmouth Gulf salt marsh snake Western diamondback rattlesnake	Gulf salt marsh snake Western cottonmouth	ornate box turtle leopard frogs Western diamondback rattlesnake Eastern garter-snake Gulf Coast toad cottonmouth	ornate box turtle five-lined skink Eastern garter-snake	NA	NA	turtles frogs water snakes	NA	sea turtles
Fish	minnows crappie sunfish catfish gar	killifish	killifish cyprinids immature mullet spot	NA	NA	NA	NA	crappie catfish black bass gar shad buffalo-fish	mullet anchovy silver-sides cyprinids menhaden red drum sea trout tarpon flounder Atlantic croaker	NA
Mammals	muskrat raccoon nutria	muskrat rabbits rice rat Canid sp.	Canid sp raccoon rice rat cattle	Canid sp. cattle hispid cotton rat rice rat rabbits striped skunk	gray and fox squirrel opossum armadillo raccoon cottontail rabbit white-footed mouse bobcat coyote	opossum domesticated animals bats rabbits striped skunk	cattle rabbits hispid cotton rat	muskrat nutria.	whales porpoises	small rodents mice
Birds	gulls terns black skimmer red-winged blackbird willet black duck mottled duck blue-winged teal Great Blue heron Snowy egret	American coot yellowlegs terns Seaside sparrow yellow-crowned night heron mottled duck blue-winged teal Great Blue heron Great egret Green heron Louisiana heron snow goose	plovers geese Great Blue heron Little Blue heron egrets Least bittern ibis Roseate spoonbill ducks clapper rail sandpipers	sparrows marsh hawk Eastern meadow-lark egrets vultures kites upland plover killdeer bobwhite quail sandhill crane dickcissel red-winged blackbird horned lark common grackle green heron mourning dove	turkey vulture Coopers hawk great horned owl red-bellied woodpecker gray catbird tufted titmouse prothonotary warbler brown thrasher chestnut-sided warbler scarlet tanager cardinal indigo bunting Northern oriole white-eyed vireo	blackbirds robins starlings	blackbirds hawks killdeer Eastern meadowlark mourning dove sparrows	ducks gulls coots geese	frigate bird gulls terns ducks	waterfowl terns seagull geese ducks

Opossum, cottontail rabbits, armadillo, raccoon, striped skunk, and coyote are typical site area residents. All of these species were common in the coastal prairie habitat east of the dome site.

Population densities of 1 rabbit per 4 to 5 acres of coastal prairie is not unusual for cottontails (Davis, 1966); coyote densities may vary between 1 and 4 animals per square mile (Knowlton, 1972).

Fourteen species of herpetofauna are likely to be found encountered in coastal prairie habitat similar to that at the site, namely:

Ornate box turtle	Corn snake
Slender grass lizard	Texas rat snake
Eastern garter snake	Western Diamondback Rattlesnake
Western ribbon snake	Western cottonmouth
Rough earth snake	Speckled kingsnake
Western mud snake	Rio Grande leopard frog
Rough green snake	Gulf coast toad

Of these animals the most common species are the box turtle, garter snake, cottonmouth, rattlesnake, and Gulf coast toad.

Fluvial Woodlands

Vegetation

The fluvial woodlands consist primarily of tree species located at the eastern portion of the site along the west bank of San Bernard River. The major tree species of this ecosystem include live oak, water oak, American elm, sugarberry, pignut hickory, and pecan.

Wildlife

At least 60 species of birds are likely to occur throughout the year in the fluvial woodlands. Bird species commonly encountered at the Allen dome are presented in Table B.4-2. The woodlands at the site are grazed by cattle, and consequently the growth of the understory is reduced; this reduction may preclude the occurrence of some species which would normally inhabit a similar but undisturbed forest layer.

The presence of the woodland at Allen dome enhances the likelihood of occurrence of woodland species of wildlife such as the opossum, whitefooted mouse, gray and fox squirrels, raccoon, and armadillo. The open woodland understory habitat is most suitable for the fox squirrel, but the gray squirrel is more common in the project area. Portions of the fluvial woodlands are poorly drained and these areas provide suitable habitat for the swamp rabbit.

One section of the fluvial woodland along the San Bernard River is low and wet, and during the rainy season of the year this section provides suitable habitat for the cottonmouth snake and several species of frogs.

San Bernard River

The major aquatic habitat at Allen dome is the San Bernard River. The mouth of the river is 8 miles downstream from the site. The only other aquatic habitat in the area is one small intermittent creek which drains the center of the site and several drainage ditches along the access roads. This creek is not expected to contain any significant fisheries habitat; however, small invertebrates such as crawfish would be expected to populate this area, at least during the rainy season.

Salinity of the estuarine portion of the San Bernard River at the site ranges from 0 to 19 parts per thousand depending upon the amount of freshwater runoff (Section B.2.2.1). The estuary is usually stratified.

It is not uncommon to collect blue catfish near the mouth of the river during periods of high river flow. On the other hand, during low river flow, blue crabs, Atlantic croakers, and Gulf menhaden have been taken more than 8 miles upstream from the site. The lower San Bernard River provides an important nursery for many species of fish and some of the more important invertebrates such as blue crab and shrimp (Texas Parks and Wildlife, 1974).

Common invertebrates collected from the San Bernard River include oysters, white and brown shrimp, seabobs (shrimp), crayfish, and blue crabs. Seabobs, caught near the mouth of the San Bernard River, accounted for more than 50 percent of the 1974 commercial catch in Texas. White and brown shrimp are also considered to be abundant in the San Bernard River as far upstream as the Allen dome. Commercial harvest of oysters is undertaken at Cow Trap Lake (located 4 miles to the south) but the potential for increased oyster harvest in the area is limited (Texas Parks and Wildlife, 1974). Polychaete worms, snails, clams, mussels, and crustacea (in addition to those mentioned above) are other invertebrate groups which are expected to inhabit the aquatic habitat in the vicinity of the site.

The most abundant fish collected in the San Bernard River in the vicinity of the proposed site are seatrout and Atlantic croaker. Other species common to be found in the coastal area include sharks, gar, carp, catfish, eels, menhaden, and flounder (Texas Parks and Wildlife, 1974).

Gulf of Mexico

The biologic environment surrounding the proposed brine diffuser location is described in Section B.3.5.2.

B.4.5.2 Pipeline System Route

The 23.9 mile pipeline system route passes through 21 acres of cleared land, 2 acres of woodlands, 158 acres of prairies, 16 acres of marsh and 1 acre of ramp barrier flat for a total of 198 acres on land. Acreages of each of the habitats affected by proposed and alternative pipelines are summarized in Table B.4-1.

Coastal prairie is generally flat to gently rolling land and has a mud and/or sand substrate. Prairie grasses, such as bluestem and Indiangrass predominate in the prairie, but scattered bushes such as mesquite, huisatch, and sugarberry are also found. Marshlands consist of saltwater and brackish marsh types. The saltwater areas consist of primarily waterlogged soils in which haloproytic grasses and forbs are dominant. Brackish water marshes include low, perennially wet areas in which saltgrass and rushes are the major vegetation elements. Fluvial woodlands consist of areas in close proximity to estuaries, creeks, rivers, or other water bodies. These areas are dominated by water tolerant hardwood tree species such as pecan, hickory, live oak, water oak, blackjack oak, and sugarberry. Cleared land consists of areas where human activities have significantly altered the natural environment and include agricultural cultivation, urban development, industrial facilities, pipelines, roadways, channels, and other land uses. Open water bodies is a generic category including ponds, rivers, streams, as well as swamp and marshland locales.

The ecosystems along the brine diffuser pipeline from Bryan Mound to the Gulf are discussed in Section B.3.5.2.

Wildlife species which inhabit these areas and may be affected by construction and operations of the lines are presented in Table B.4-2.

B.4.6 Natural and Scenic Resources

B.4.6.1 Natural Resources

The natural resources and recreational opportunities to be found in the vicinity of the Allen dome are similar to those found in the vicinity of the Bryan Mound site as discussed in Section B.3.6. These two sites are located approximately 11 miles apart.

The Allen dome site, however, is closer to two rather unique natural features not as readily available to the Bryan Mound vicinity. The first of these is the San Bernard National Wildlife Refuge, located to the southwest of the site. The second is the San Bernard River, located adjacent to the Allen site. This river has been dredged to a navigable depth of nine feet and affords such activities as recreational boating and fishing.

The natural and scenic resources in the vicinity of the brine diffuser are discussed in Section B.3.6.

B.4.6.2 Scenic Resources

The project site is predominantly undeveloped coastal prairie and marsh. A small area in the northeast corner of the site contains a few oil wells and related buildings. To the southeast of the site, on the San Bernard River, a small residential subdivision, Bernard Acres, has been built. Subdivision roads north of the site indicate the probability of future development there also.

Part of the site is currently in use as pasture and is well grazed. The natural levees of the river are wooded. The site has no aesthetic characteristics that are unique to that area. The "natural" qualities of the surrounding area are considered valuable.

B.4.7 Archaeological, Historical, and Cultural Resources

The candidate site does not contain any known sites of archaeological, historical, or cultural significance. If this site is selected for SPR development, a qualified archaeologist will survey it for DOE and coordinate with the State Historical Preservation Officer.

B.4.8 Socioeconomic Environment

B.4.8.1 Land Use

Land uses surrounding the site include residential development, pastures, marshes, and wetlands. Some industrial uses exist in the area between the San Bernard River and Freeport. The San Bernard National Wildlife Refuge is southwest of the site. The site is in an area of the San Bernard River Basin designated as critical habitat.

No buildings remain on the site from the earlier oil production activity. A small subdivision of permanent homes has been built southeast of the site, near the San Bernard River, and land to the north has been partitioned for residential development. Most of the dome has been cleared of trees and is used to graze cattle.

The land uses in the vicinity of the brine diffuser off Bryan Mound are discussed in Section B.3.8.

B.4.8.2 Transportation

The general transportation systems and planned future improvements are discussed in Section B.2.8.2.

The Allen dome site can be reached by Texas State Highway 36, a northwesterly trending road between Freeport and Brazoria, which runs about six miles east of the site. Route 2918, a paved county highway, passes within 3500 feet of the western edge of the 2,000 foot salt contour. Improved gravel roads serve the northern and southern portions of the dome.

B.4.8.3 Population Characteristics

The area immediately surrounding Allen dome is predominantly undeveloped and, therefore, has a very small population. This population is found in the small subdivision near the site and in the small community of Churchill Bridge north of the site. Partitioned land north of the site is essentially undeveloped, but has potential for a moderate number of families. Freeport, Lake Jackson, and Brazoria are all part of the Brazosport community and are all approximately equidistant from the Allen dome site. These areas comprise the urbanized portion of southern Brazoria County (Section B.2.8.3).

B.4.8.4 Housing

As stated previously, there is a small, permanent subdivision of homes located at the southeastern corner of the dome. This appears to be the greatest concentration of houses in the area of the dome. Churchill Bridge and Jones Creek are within a five-mile radius of the site and may provide limited housing. A housing shortage is being experienced throughout southern Brazoria County as population growth continues (Section B.2.8.5).

B.4.8.5 Economy

The small subdivision near the Allen dome SPR site consists of approximately 35 homes. As there are few employment opportunities in the immediate vicinity of the project many residents of this area work in the Brazosport area, or farther away. Sections B.2.8.6 and B.3.8 discuss the structure of the regional and Brazosport economy.

The availability of retail facilities in either Jones Creek or Churchill Bridge is extremely limited and most shopping occurs in the Brazosport area.

B.4.8.6 Government

Education

The Allen dome area is served by the Brazosport Independent School District discussed in Section B.3.8.

Hospitals

Allen dome is served by the Brazosport area hospitals (Section B.3.8).

Police and Fire Protection

The Brazoria County Sheriff's Department provides police protection for the Allen dome area. Fire services come from the River's End Fire Department and the Brazoria Fire Department.

B.5 SITE SPECIFIC ENVIRONMENT - WEST COLUMBIA DOME

The West Columbia dome alternative SPR storage site is located just north of the town of West Columbia (Figure A.5-1). West Columbia is a small dome, and additional predevelopment exploratory work will be required if this site is to be developed.

B.5.1 Land Features

B.5.1.1 Physiography and Topography

The proposed West Columbia site is located on the prairie terrace of the Gulf Coastal Plain. The center of the site is a freshwater swamp due to poor surface drainage conditions. General surface elevation of the area is +35 feet. A slight topographic depression occurs over the center of the dome, with elevations below +25 feet. The highest elevation in the vicinity of the site is on a small hill to the west, which is slightly above +45 feet (Figure A.5-2). The topography and bathymetry of the proposed brine diffuser right-of-way is described in Section B.3.1.1.

B.5.1.2 Local Geology

West Columbia salt dome is an elliptical structure in plan, with steep sides and a fairly flat top. A structure map of the top of salt (Figure B.5-1) shows that at -2000 feet elevation, the east-west axis is about 5100 feet and the north-south axis is about 3500 feet. The area of salt enclosed by the -2000 foot contour is approximately 320 acres. The highest point at which salt was encountered in a boring was about -700 feet in Texaco's No. 1 West Columbia. Where there is a lack of information regarding the elevation of the salt on the dome's south and west flanks, the salt outline is generalized and subject to revision.

A cross-section of the salt dome and adjacent strata (Figure B.5-2) shows the flanks of the dome dipping steeply to the north and south sides at about 70^{o}. Dips to the east and west sides are shallower, dipping at 45^{o} to 50^{o}.

A characteristic pattern of faulting associated with the dome is shown in Figure B.5-3. It is also shown in the cross section. The faults exhibit a very strong east-west pattern, possibly controlling or resulting from the east-west trend of the salt stock's long axis. A series of radial faults is also known along the north and south sides of the dome.

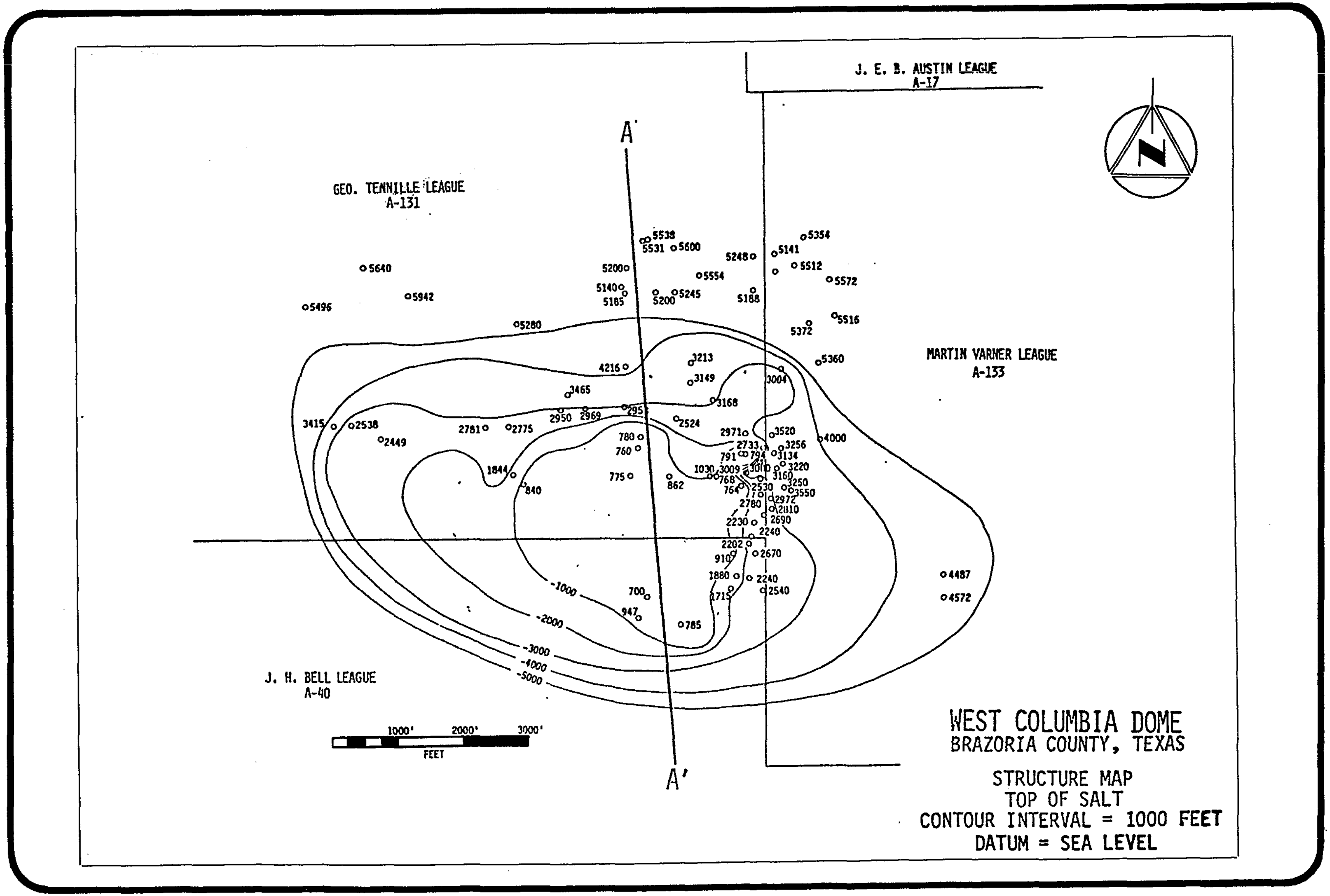


FIGURE B.5-1 Structure Map - top of salt - West Columbia dome candidate SPR storage site (alternative site)

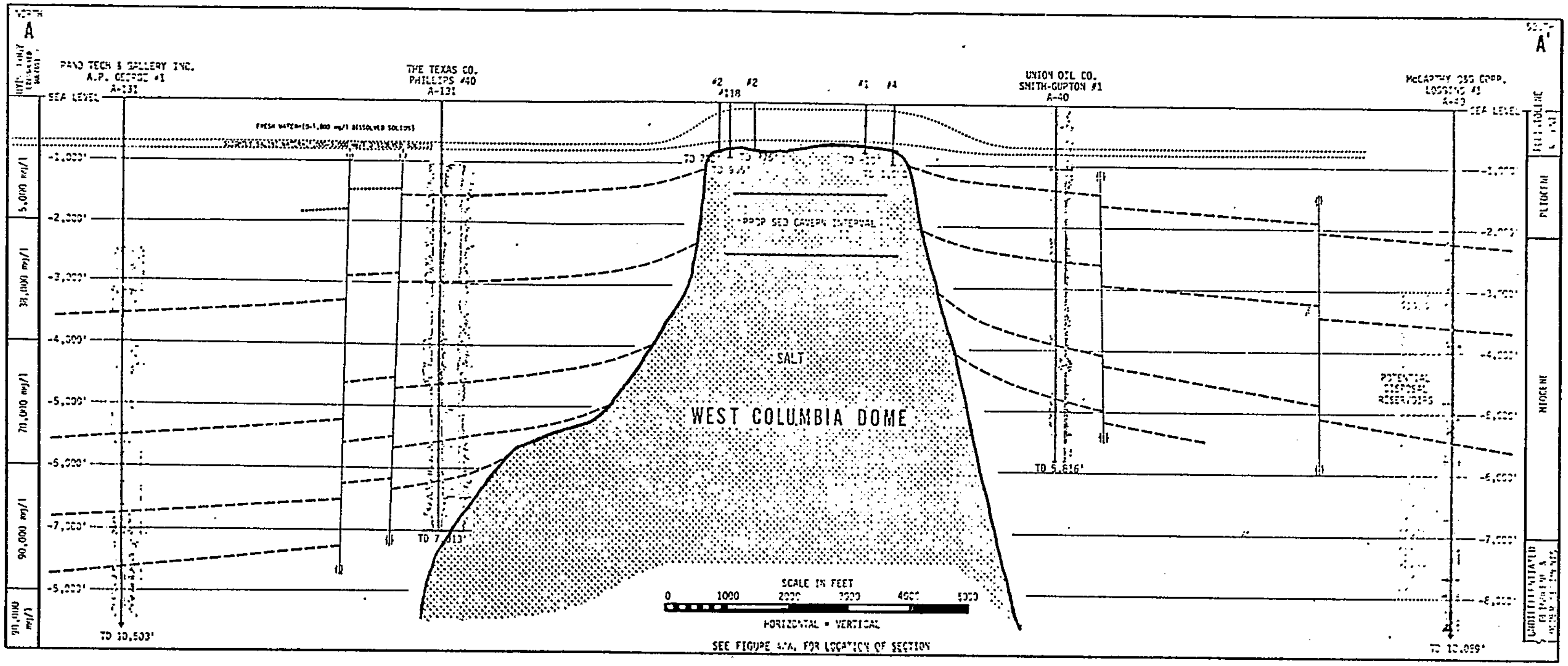


FIGURE B.5-2 Geologic cross-section West Columbia dome candidate SPR storage site (alternative site)

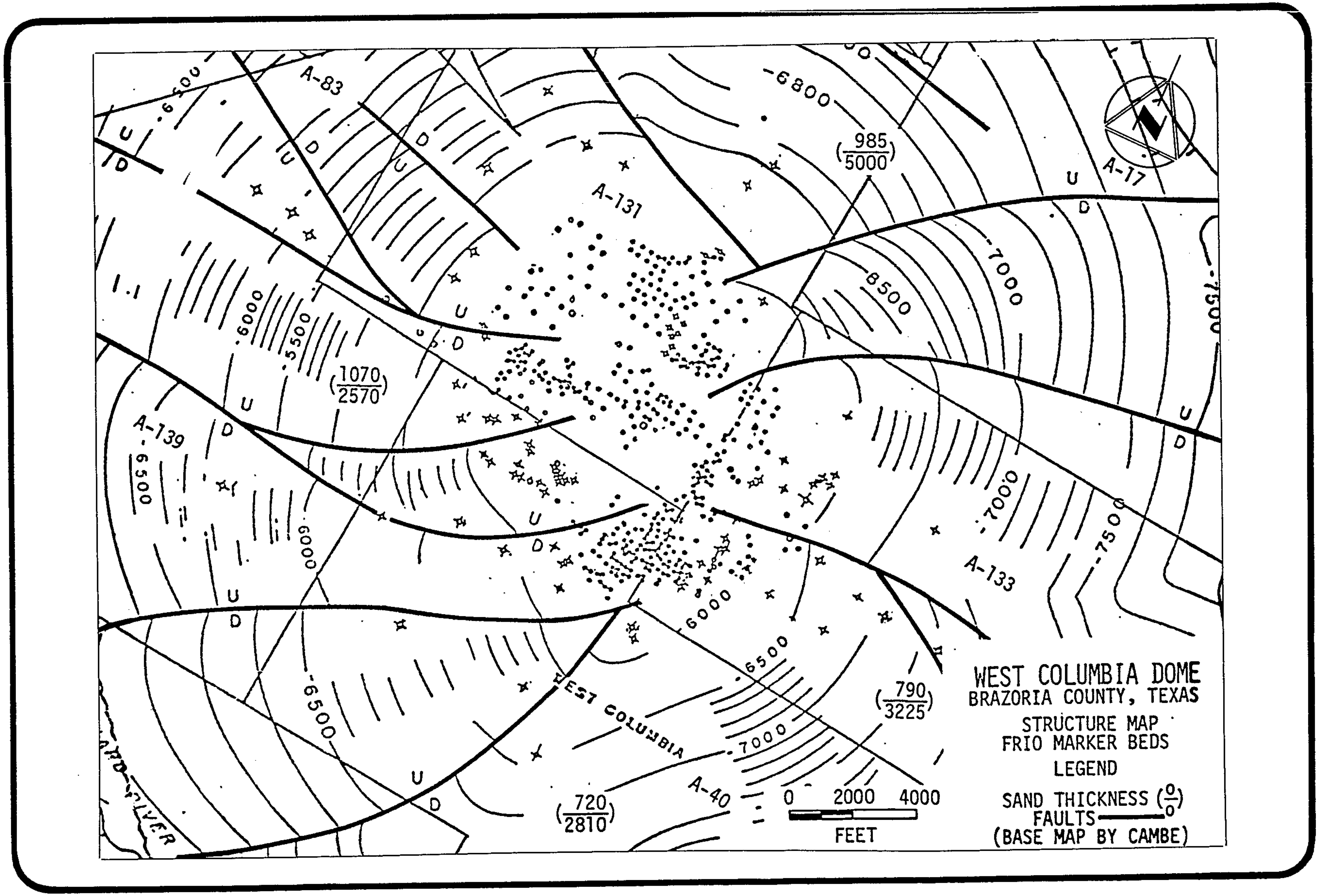


FIGURE B.5-3 Structure map, Frio marker beds - West Columbia dome candidate SPR storage site (alternative site)

Quality of the salt mass is unknown at this time; it is, however, probably similar to that found at Bryan Mound (Section B.3.1).

The caprock at West Columbia dome ranges from 100 to 150 feet thick over the northern portion of the dome. It thins out to the south, and is missing altogether on the south side of the dome. It is reported to be a mixture of gypsum and anhydrite (Barton, 1921).

Up to 600 feet of unconsolidated and partially consolidated muds and clays, sands, gravels and shales of Recent and Pleistocene age overlie the central portion of the dome. Unconsolidated and partially consolidated sands and shales of Pliocene, Miocene and Oligocene age extend downward along the flanks to depths of 8000 feet and below.

B.5.1.3 Economic Geology

Initial petroleum production from the West Columbia dome was in 1904 when gas was produced in Equitable Mining Company's no. 2 well, but commercial production did not begin until 1917 (Hackbarth, 1953). Drilling intensity has been greatest on the southeast and north flanks of the dome. Oil and gas occur on the flanks of the dome in Oligocene and Miocene sediments that are faulted or pinched out against the sides of the dome.

No oil or gas production is located over the top of the dome in the area proposed for the storage facility.

B.5.1.4 Soils

The soils in the West Columbia site area are assigned to the Moreland-Pledger-Norwood association discussed in Section B.3.1. They are characteristically calcareous, clayey, and loamy, having developed on recent flood plain alluvium. These soils have an appreciable fraction of montmorillonite which imparts a high shrink-swell potential. They are moderately alkaline and calcareous to neutral in the surface layer, and moderately alkaline and calcareous below. They are subject to occasional flooding and present a high corrosion potential. Marine sediments located in the vicinity of the proposed brine disposal system in the Gulf are discussed in Section B.3.1.4.

B.5.2 Water Environment

B.5.2.1 Surface Water Systems

The West Columbia dome is situated between two major river channels, the Brazos and the San Bernard. The town of East Columbia lies on the Brazos River about 2.7 miles east of the site. East Columbia lies about 15 miles south of the USGS Brazos River gauging station at Rosharon, Texas (Section B.2.2). The Brazos River is about 250 to 300 feet wide in the reach through East Columbia. Varner Creek is located about one-half mile to the east of the West Columbia dome, and joins the Brazos River approximately three miles southeast of the site. No streamflow measurements are available for Varner Creek, but it is indicated to be an intermittent stream on USGS topographic maps of the area.

The San Bernard River passes closest to the dome about 3 miles to the southwest, where it is about 100 feet wide. Bell Creek, located about one mile west of the site, flows southerly to the San Bernard River. The confluence of Bell Creek and the San Bernard River is approximately 3 miles south-southwest of the site.

Bell Creek, Redfish Bayou, Jones Creek, and the Brazos River Diversion Channel are crossed by proposed pipelines between Freeport Harbor and the West Columbia dome site. Bell Creek, a tributary of the San Bernard River, is a small stream. No flow data are available for Bell Creek. Redfish Bayou is intermittent near the proposed pipeline crossing. Downstream, Redfish Bayou is a tidal stream which drains some of the coastal wetlands, and finally feeds the San Bernard River. Jones Creek is a small, intermittent stream which drains a small coastal basin. Several small ponds are found in the Jones Creek bed. The Brazos River Diversion Channel near Bryan Mound was discussed in Section B.3.2. It is an estuary in this reach, having high salinities due to fresh water mixing with water from the Gulf of Mexico. A large number of agricultural uses are located upstream of Bryan Mound.

According to preliminary U.S. Army Corps of Engineers' studies, flooding of the Brazos River may reach elevation +33.0 feet (Trahan, 1977). This 100-year flood could potentially flood the site.

The marine conditions in the area of the proposed brine diffuser are discussed in Section B.3.2.1.

B.5.2.2 <u>Subsurface Water Systems</u>

West Columbia Dome is one of seven salt domes that penetrate through the Evangeline aquifer and into the Chicot aquifer in Brazoria County. The base of the Chicot aquifer is about 900 feet below sea level in the vicinity of the dome (Sandeen and Wesselman, 1973) and the top of the caprock is at a depth of 615 feet. The depth to salt is about 715 feet. Fresh water occurs in about the upper 70 feet of material over the dome and slightly saline water (1,000 to 3,000 mgl dissolved solids) in about the upper 600 feet (Ibid). The base of the slightly saline water extends to a depth of 800 feet about one mile from the center of the dome.

The water in the formations adjacent to the dome and the caprock is highly mineralized with a dissolved solids concentration on the order of 9,000 milligrams per liter or greater. At some distance from the dome, however, the water can be expected to be similar to the sea water in which the formations were deposited, or about 35,000 milligrams per liter dissolved solids below a depth of about 2,000 feet.

Aquifers in the vicinity of West Columbia dome are capable of delivering large quantities of slightly to moderately saline water to properly completed wells. Aquifer porosities are on the order of 40 percent with permeabilities in the range of 600 to 1,000 gpd per square foot. Permeabilities decrease with depth to an estimated 250 gpd per square foot in the Evangeline aquifer below a depth of about 1000 feet.

Ground water use in the vicinity of West Columbia dome does not appear to be extensive. The hydraulic gradient is essentially flat in the upper unit of the Chicot aquifer at the site. The town of West Columbia located on the dome pumps water from the lower unit of the Chicot aquifer with an average municipal usage of .312 mgd in 1967 (Sandeen and Wesselman, 1973). The site is within the cone of drawdown from that pumping.

B.5.3 Climatology and Air Quality

B.5.3.1 Climatology

The climatic conditions discussed in Section B.2.3.1 are generally applicable to West Columbia. The data from Hobby Field, Houston are considered more representative than those from Galveston since the site is located about 25 miles inland where coastal effects are less pronounced. Compared to the coastal sites, described in Section B.3.3.3.1, this site is expected to experience lighter winds and more frequent south and south-southeast winds, larger diurnal ranges of temperature, slightly lower humidity, and a higher frequency of stable conditions than the coastal sites.

Tropical storm effects, while more pronounced than further inland, will be significantly less than near and along the coast.

B.5.3.2 Air Quality

The conclusions reached in Section B.2.3.3 based on data in the Freeport area are considered to be representative of existing air quality conditions at West Columbia; i.e., low levels with the exception of hydrocarbon and oxidant concentrations. Slight differences are expected due to local influences and the occasional influx of air from heavy industrialized areas northeast of the site.

B.5.4 Background Ambient Sound Levels

An oil field is located approximately one mile north of the West Columbia site. A number of drill rigs are active at the field and are principal sound sources in this area. The principal noise-sensitive land uses are residential and educational areas and are located in and around West Columbia. Sound levels of 56 dB are estimated for these areas based on ambient sound level surveys made at similar sites under earlier studies. The principal sound source is the activity of residents of West Columbia. Sound levels along the brine diffuser pipeline are discussed in Section B.3.4.

B.5.5 Species and Ecosystems

B.5.5.1 Site Area

During the construction of the West Columbia site facilities and grading and filling, the disturbed areas within the 232-acre site would involve 30 acres (Table B.5-1).

Ecological habitat types found at the West Columbia site (Table B.5-2) include coastal prairie, scattered oak woods, freshwater wetlands, and cleared land (developed oil well field).

The West Columbia dome site is located on land which consists mostly of grassland used primarily for grazing. Scattered woodland groves and a marshland area are also located directly over the dome.

Coastal Prairie

Vegetation

The dominant vegetation at the site consists of coastal prairie grasses but cattle grazing areas contain introduced cultivated grass species. Within the grassland areas the primary species include bluestem, coastal sacahuista, and big bluestem. The subdominant species include Indiangrass, eastern gammagrass, Gulf muhly, western ragweed, turtlegrass, little bluestem, buffalo grass and smut grass. In addition, component vegetation normally associated with the coastal prairie include mesquite, oaks, prickly pear and huisache.

Wildlife

Coastal prairie and cleared lands normally provide habitat for a diverse fauna but the extensive development and human activity near the West Columbia site discourages the presence of many animal species. Common species which are expected to occur in prairie and cleared lands include: cattle egret, turkey vulture, marsh hawk, sparrow hawk, bobwhite quail, killdeer, upland plover, mourning dove, horned lark, eastern meadowlark, brown-headed cowbird, dickcissel, Savannah sparrow, vesper sparrow, and Lincoln's sparrow. Game species expected to occur at the site in open habitats include bobwhite quail and doves.

TABLE B.5-1 Estimated site acreage analysis for West Columbia dome candidate SPR storage site (alternative site).

Total For Fenced Site Area	232 Acres
Total Within -2000 Foot Salt Contour	360 Acres
Total for Cleared Land	30 Acres
Total for Coastal Prairie	257 Acres
Total for Freshwater Marsh	83 Acres

SYSTEM	Total Miles of Pipeline	Acreage for Construction	Acreage for Operation
Proposed Brine Disposal System (5.8 Mile Bryan Mound Gulf Diffuser & Injection Wells)	36.9	445.2	227.6
Fluvial Woodlands		149.0	112.0
Coastal Prairies		153.0	115.0
Marsh		0.2	0.1
Shell Ramp Barrier Flat		1.0	0.5
Open Water		142.0	0.0
(total water crossings 2)			
Proposed Raw Water System (Brazos River Diversion Channel)	27.1	279.0	210.0
Coastal Prairies		130.0	98.0
Fluvial Woodlands		149.0	112.0
Proposed Oil Distribution System (New Tanker Docks)	27.7	301.0	230.0
Cleared Land		18.0	17.0
Fluvial Woodlands		149.0	112.0
Coastal Prairies		130.0	98.0
Marsh		4.0	3.0
Alternate Brine Disposal System (Wells)	3.2	19.0	19.0
Fluvial Woodlands		17.0	17.0
Coastal Prairies		2.0	2.0
Alternate Brine Disposal System (12.5 Mile Bryan Mound Gulf Diffuser)	41.3	605.2	224.6
Coastal Prairies		150.0	112.0
Fluvial Woodlands		149.0	112.0
Marsh		0.2	0.1
Shell Ramp Barrier Flat		1.0	0.5
Open Water		305.0	0.0
(total water crossings 2)			
Alternate Raw Water System (Wells)	5.9	22.0	22.0
Fluvial Woodlands		19.0	19.0
Coastal Prairies		3.0	3.0
Alternate Raw Water System (Brazos River)	3.0	39.0	28.0
Fluvial Woodlands		34.0	25.0
Coastal Prairies		4.0	3.0
Open Water		1.0	0.0
(total water crossings 1)			

[a]Based on features of USGS topographic maps (15 minute series).

[b]Cleared land includes agricultural, industrial and rural, and land already disturbed.

TABLE B.5-2 Ecosystems and typical flora and fauna of the West Columbia dome site candidate SPR storage site (alternative site)

Typical or Important Organisms	Ecosystem: Marshlands	Coastal Prairies	Woodlands	Cleared Lands: Urban and Suburban	Cleared Lands: Crops and Future Lands	Inland Waters: Freshwater
Plants, herbs, grasses and trees	Maiden cane cordgrass sedges water hyacinth pennywort	Gulf cordgrass bunchgrass Indian grass switchgrass bluestem live oak huisache ragweed prairie pleatleaf smut grass buffalo grass Gulf Muhly gamma grass coastal sacahuista	live oak pecan sugar berry pignut hickory bluestem cordgrass	Various residential species	rice soybeans prairie grass	
Mollusks and crustaceans	snails mussels clams crayfish	snails	NA	NA	NA	clams snails oysters
Water snakes, amphibians, and reptiles	turtles Western cotton-mouth Yellow bellied watersnake Diamond backed watersnake Bullfrog Southern leopard frog Central newt small mouthed salamander	ornate box turtle leopard frogs Western diamondback rattlesnake Eastern gartersnake Gulf Coast toad Texas toad Spotted chorus frog Texas rat snake Racerunner	ornate box turtle five-lined skink Eastern gartersnake Gray tree frog broad headed skink Ground skink Hunter's spadefoot northern spring peeper	Eastern garter-snake Gulf Coast toad	ornate box turtle Texas rat snake	turtles Western cotton-mouth Yellow bellied watersnake Diamond backed watersnake Bullfrog Southern leopard frog Central newt small mouthed salamander
Fish	minnows crappie sunfish catfish gar	NA	NA	NA	NA	crappie catfish black bass gar shad buffalo fish sunfish carp
Mammals	muskrat raccoon nutria mink opossum	Canid sp. cattle hispid cotton rat rice rat striped skunk opossum armadillo cottontail rabbit coyote lost shrew	gray and fox squirrel opossum armadillo raccoon gray fox white-tailed deer white-footed mouse bobcat coyote striped skunk	opossum domesticated animals bats striped skunk cottontail rabbit Eastern mole	cattle cottontail rabbit striped skunk opossum	nutria bats raccoon
Birds	red-winged blackbird mottled duck blue-winged teal Great Blue heron Snowy egret Green heron	sparrows marsh hawks Eastern meadowlark cattle egret vultures upland plover killdeer bobwhite quail sandhill crane mourning dove cow bird dickcissel horned lark	turkey vulture Coopers hawk great horned owl gray catbird tufted titmouse Carolina chickadee vireos warblers woodpecker wrens blackbirds finches	blackbirds starlings songbirds sparrow	blackbirds hawks killdeer Eastern meadowlark mourning dove sparrows	waterfowl herons egrets

Small animals which normally are residents in prairie and cleared land habitats include opossum, small rodents, skunks, cottontail rabbits, armadillo, and coyote. The extent of development and human activity also affects the distribution abundance of some of these species. The cottontail rabbit is the only game species which is likely to occur at West Columbia. Because of the over-grazed conditions at the site the prairie is not suitable to support abundant cottontail populations.

Prairie and cleared land herpetofauna species include the ornate box turtle, six-lined racerunner, eastern garter snake, Texas rat snake, Gulf coast toad, and upland chorus frog.

Scattered Woodlands

Vegetation

The fluvial woodlands of the West Columbia site are characterized as isolated, scattered overstory species in which live oak and other oak are the dominant tree species. Additional components of the woodlands are water oak, elm, hickory, and sugarberry. Industrial development and cultivation of the area have removed the forest cover from the site.

Wildlife

Woodland habitat is very limited at the dome site and most of this area is heavily grazed. Bird species which would be expected to occur in the woods include woodpeckers, chickadees, wrens, vireos, warblers, blackbirds, and finches.

The scattered woodland provides habitat for ground skink, five-lined skink, Hurter's spadefoot, and northern spring peeper.

Wildlife expected to occur in the scattered woodlands include opossum, small rodents, gray and fox squirrels, armadillo, and raccoon. Gray and fox squirrels are of economic importance in areas where abundant populations exists. The opossum and raccoon are important furbearers in the area.

Wetlands

Vegetation

The marshland on the West Columbia site consist primarily of fresh-water wetlands which are characterized by stumps and snags contained in a shallow depressional water body which lies directly over the dome. The impeded drainage on the site is related to the clayey soils which are common throughout the area. These clays are light colored, and have a slightly sandy surface. The surface clay overlies a mottled fine textured grey clay. As a result of this composition, the site is poorly drained, and the soils are acidic, low in humic content, and have an overall low productivity (USDA, 1957).

Wildlife

The only significant aquatic habitat at the site is a small intermittent creek which drains the marsh at the center of the site. This creek joins Varner Creek about one-half mile northeast of the site and would be expected to be inhabited intermittently by any of those species of fish included in the regional setting (Section B.2.5).

Wetland habitats (swamp and creek) at the site provide habitat for a number of bird species. The shallow water, snag and stump infested area situated in the center of the site provide habitat for herons, egrets, plovers, and sandpipers. The numerous producing oil wells in the area would tend to reduce the number of bird species below that which would otherwise be expected to occur there.

The swamp and creek provide habitat for turtles, water snakes, western cottonmouth, salamanders, and frogs. The low water levels in the wetlands on the dome limit the presence and abundance of most turtles that might otherwise normally occur there.

The swamp and creek provide habitat for raccoon and perhaps, nutria, however, the low water conditions may adversely affect the presence of the nutria on site.

Gulf of Mexico

The biologic environment surrounding the proposed brine diffuser location is described in Section B.3.5.2.

B.5.5.2 Pipeline System Route

The 39.7-mile brine-raw water-oil pipeline right-of-way will pass through 149 acres of fluvial and oak woodlands, and 153 acres of prairie grassland, 34 acres of marsh, 18 acres of cleared land and 1 acre of ramp barrier flat for a total of 355 acres on land.

The major wildlife habitat types found along the pipeline right-of-way between the West Columbia site and the SEAWAY Tank Farm include: Fluvial and oak woodlands; coastal prairie; fresh and brackish marsh; cropland and pasture; and cleared land. Wildlife habitat types between the SEAWAY Terminal and Bryan Mound site, through which the brine and raw water lines will pass, include coastal prairie, coastal marsh, and open water habitats. The general ecological characteristics of both of these pipeline rights-of-way have been described previously in Section B.3.2 for the Allen dome pipeline system. The ecosystems found in the vicinity of the brine diffuser pipeline are described in Section B.3.5.2.

B.5.6 Natural and Scenic Resources

The West Columbia site is located in coastal prairies and marshlands, as described in Section B.2.6. The central portion of the site itself is freshwater marshland that is lower than the surrounding prairie. There are scattered woodlands surrounding the site, but the site itself is primarily flat grasslands.

There are no recreational facilities on the site, but the Varner-Hogg Plantation State Park is located about one-half mile east of the eastern boundary of the project site. This park is an important historic area containing buildings constructed during the early settlement of Texas, and a museum showing artifacts from that era. There are several urban recreation facilities in the town of West Columbia, approximately one mile southeast of the site. East of the Varner-Hogg State Park is a golf course which straddles Varner Creek.

The project site has no unique scenic resources. It is typical of coastal prairies and rangeland found throughout the county. The area surrounding the site has been extensively developed with oil fields and associated pipelines and buildings. The area along Varner Creek east of the site is partially wooded and has greater aesthetic appeal than the site itself.

The natural and scenic resources in the vicinity of the brine diffuser pipeline are described in Section B.3.6.

B.5.7 Archaeological, Historical, and Cultural Resources

The candidate site does not contain any known sites of archaeological, historical, or cultural significance. If this site is selected for SPR development, a qualified archaeologist will survey it for DOE, and coordinate with the State Historical Preservation Officer.

B.5.8 Socioeconomic Environment

B.5.8.1 Land Use

The West Columbia site is located approximately one mile north of the town of West Columbia. The lands surrounding the site are used predominantly for range and pasture, and mineral and resources extraction. The industrial land uses in the town of West Columbia are those associated with the petroleum industry and include tank farms and pipelines.

As stated above, the West Columbia salt dome has experienced oil and natural gas production activity on the northern and eastern flanks of the dome. To the northwest, there are several small artificial ponds associated with the oil and gas production to the north. This resource production is the current land use to the north and east of the dome.

The Varner-Hogg State Park, a wildlife refuge, is located one-half mile to the east of the site. An area of freshwater marsh is also to the east of the site.

To the west, south, and southeast of the site, the land uses are range-pasture and residential-urban. The range-pasture lands are characterized as land uncultivated or permanently removed from crop production or silage fields. The residential-urban area is the town of West Columbia, which has both commercial and residential development and may include some minor industrial areas.

The land use along the brine diffuser pipeline right-of-way is discussed in Section B.3.8.1.

B.5.8.2 Transportation

The site is located approximately one mile north of West Columbia just east of Route 36, and has easy access to surrounding population centers in the county. Angleton is located 15 miles east via State Highway 35. The Rosenberg-Richmond area is approximately 30 miles north via Route 36.

A well-maintained shell road connects the site with Route 36. There are few roads within the boundaries of the site itself, but roads used for the existing oil development nearly encircle the site just outside its perimeter. These roads are lightly traveled.

B.5.8.3 Population

There are currently no residences within the boundaries of the site. There are a few residences along the gravel road just south of the site and along Route 36 about a quarter of a mile southeast of the site. The closest urbanized area is the town of West Columbia, which had a population of 3335 in 1970, within an area of 2.5 square miles. The population of this town increased by 13 percent between 1960 and 1970 (U.S. Department of Commerce, 1972a), and continues to show steady growth since 1970. This trend is consistent with population trends throughout Brazoria County, as discussed in Sections B.2.8.4 and B.3.8.

B.5.8.4 Housing

The housing availability in Brazoria County varies significantly depending on location, as discussed in Section 3.2.8.5. Like Brazosport, West Columbia has a severe shortage of housing, and many wishing to move to the area must wait for units to be constructed to accommodate them. This area is expected to double its population within the next decade.

B.5.8.5 Economy

Most of the residents of West Columbia are dependent on the petrochemical industries for their living. Many residents commute to the

Freeport area to work for Dow Chemical or Phillips Petroleum, or to work on various construction projects. There is an active retail trade in the city providing a wide variety of products and services. Agriculture in the surrounding prairies also provides income to some local residents.

The West Columbia area economy is closely tied with that of the county as a whole, as described in Section B.2.8.6.

B.5.8.6 Urban Services

Police and Fire

The site will be served by the West Columbia volunteer fire department, which has mutual assistance agreements with other volunteer brigades in the county (Phillips, 1977). Police services would be provided by the Brazoria County Sheriff's Office, in conjunction with the Texas Department of Public Safety, which patrols state highways and handles traffic-related calls (Wood, 1977).

Education

The Columbia-Brazoria School District serves the area surrounding the project site. In 1975-76, the school district had a total enrollment of 2779, a slight decrease from the 1969-70 enrollment of 2785. As housing in the area continues to expand, school enrollment may begin to rise over the next ten years. The school district has relatively new high school facilities.

Hospitals and Medical Services

Major health services for the area are provided primarily through facilities in the Brazosport area, as discussed in Section B.2.8.7.

B.6 SITE SPECIFIC ENVIRONMENT - DAMON MOUND

The town of Damon lies on the eastern flank of Damon Mound dome. The Damon Mound alternative SPR storage site would occupy a portion of the large dome, west of the town.

B.6.1 Land Features

B.6.1.1 Physiography and Topography

Damon Mound salt dome is one of the most conspicuous topographic features of the Texas Gulf Coastal Plain. It rises more than 80 feet above the surrounding countryside to a maximum elevation of 145 feet. The dome is broad and surface slopes on its flanks are consequently low. The topography and bathymetry of the proposed brine diffuser right-of-way is described in Section B.3.1.1.

B.6.1.2 Local Geology

Damon Mound salt dome is elliptical in plan view, with a broad, fairly flat top (Figure B.6-1). The highest elevation of the top of the salt mass ranges from 527 to 600 feet below sea level. At the -2000 foot contour, the dome encompasses about 1700 acres. The southeast-northeast axis (major axis) of the -2000 foot contour is about 12,000 feet, and the southwest-northeast axis (minor axis) is about 8500 feet. Sides of the dome have steeply dipping contacts. A cross section through Damon Mound salt dome is shown in Figure B.6-2.

A pattern of faulting associated with the dome is shown on a structure map drawn of the top of one of the surrounding sedimentary stratum (Figure B.6-3). This map shows a major northwesterly trending fault zone which parallels the trend of the salt dome's major axis. In addition, at least eight radial faults have been interpreted along the southern perimeter of the dome.

The quality of the salt in the dome is unknown at this time. Due to its close proximity to Bryan Mound, and their postulated similar origin, it is probable that the salt in Damon Mound is similar in composition to that found at Bryan Mound.

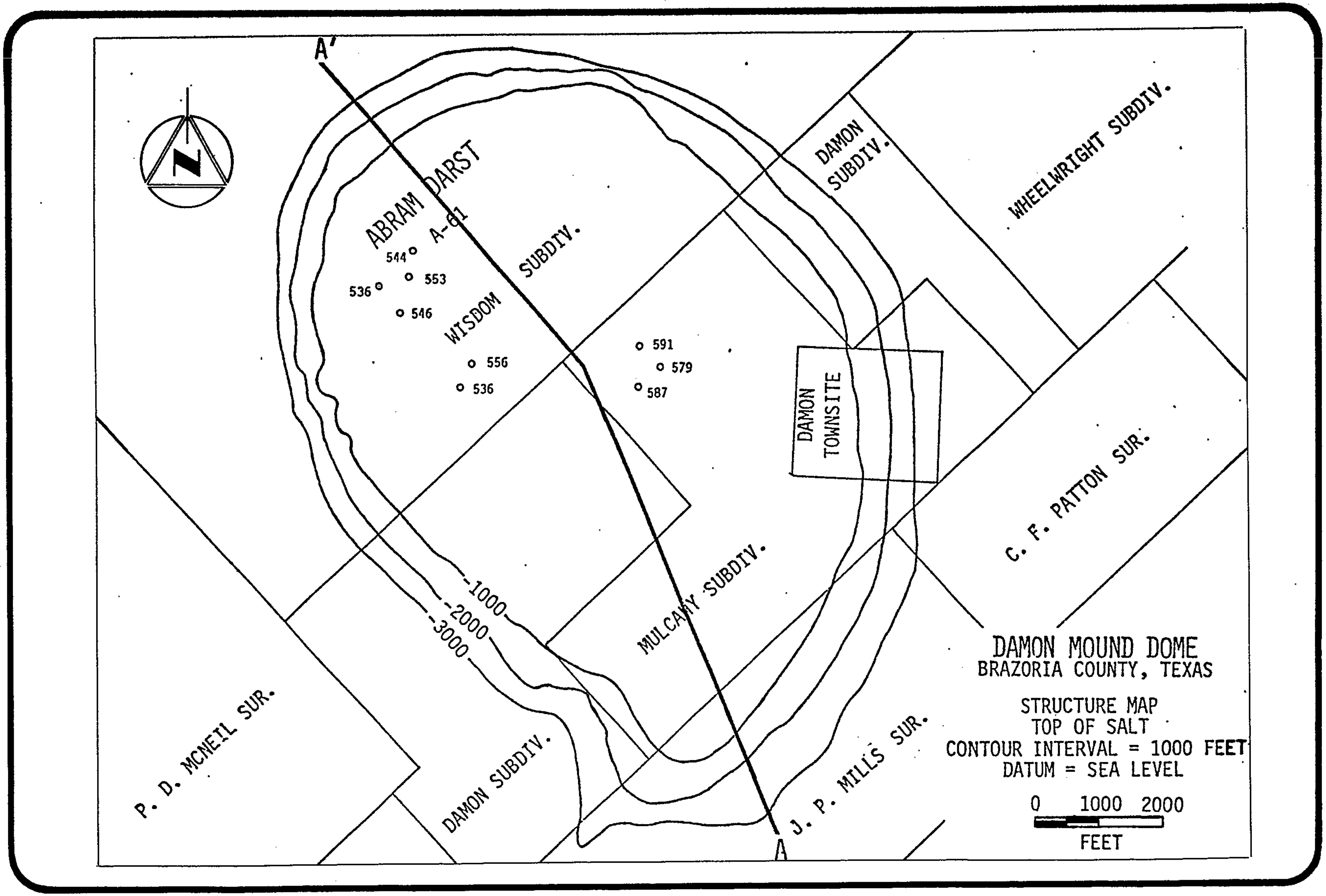


FIGURE B.6-1 Structure map - top of salt - Damon Mound dome candidate SPR storage site (alternative site)

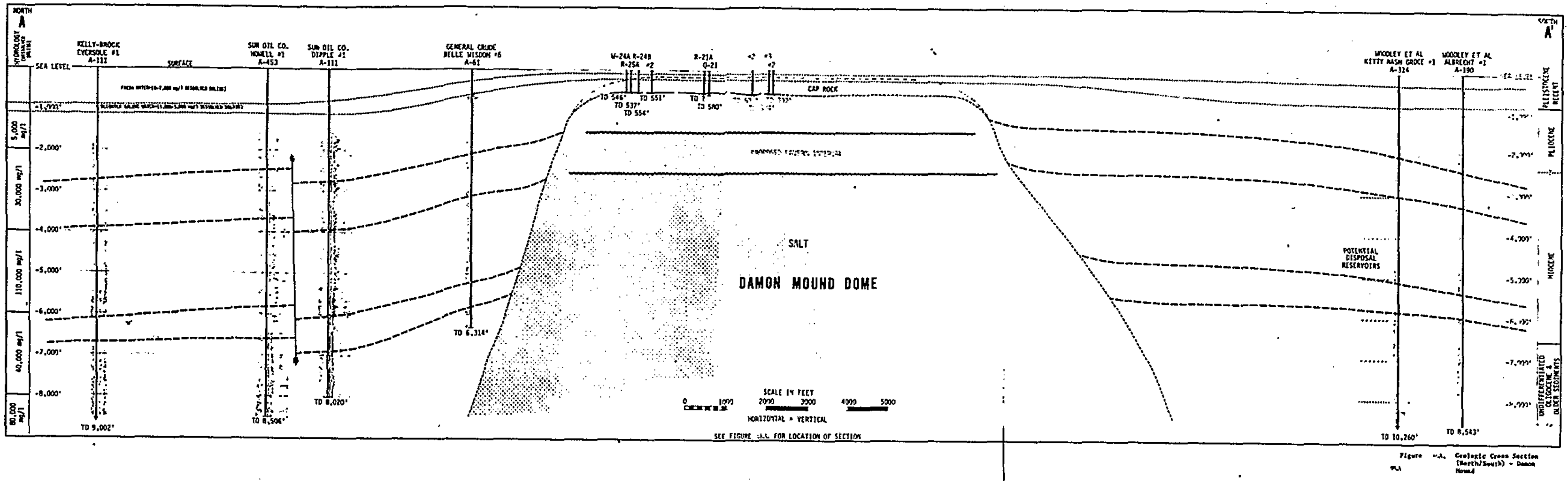


FIGURE B.6-2 Geologic cross-section - Damon Mound dome candidate SPR storage site (alternative site)

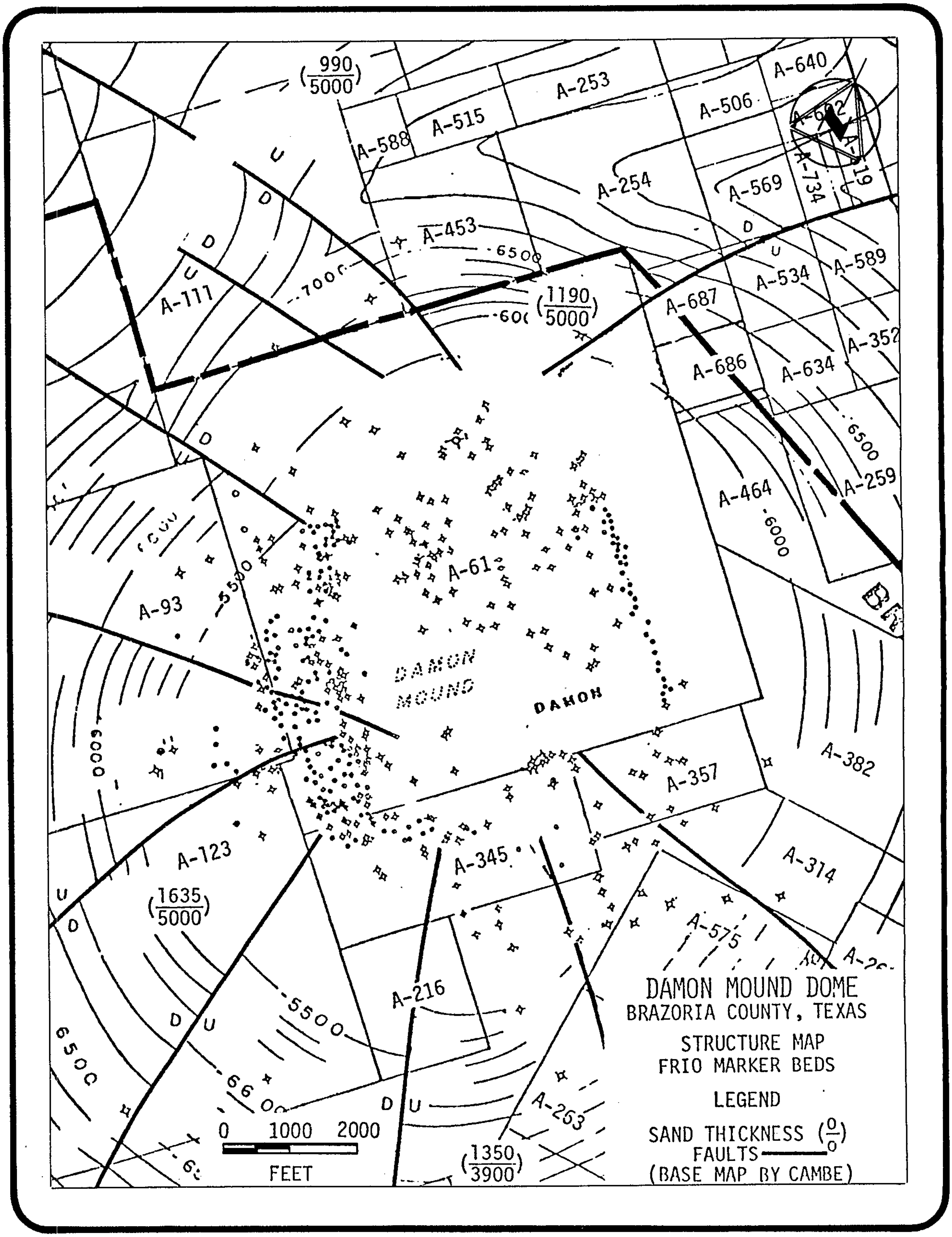


FIGURE B.6-3 Structure map - Frio marker beds - Damon Mound dome candidate SPR storage site (alternative site)

Data from 28 wells indicate that caprock at Damon Mound averages about 380 feet thick. The major constituents include gypsum and limestone. A thin, discontinuous horizon of anhydrite-rich gypsum often is found between the limestone and gypsum. Sulfur is found in concentrations of 2 to 50 percent scattered in thin horizons through the gypsum and anhydrite-rich gypsum horizons.

Well records show that caprock reaches to within 68 feet of the surface. However, it is believed that caprock may actually extend to the surface on the northwest and east sides of the dome, where limestone and gypsum similar to caprock materials have been mined and quarried.

Although it is unclear whether the caprock extends to the surface at Damon Mound, it is known that the sedimentary rock sequence over the dome is very thin. Sedimentary rocks extend to great depths all around the dome. Local disturbance around the dome includes tilting and faulting of the sedimentary strata, which decreases rapidly with increasing distance from the dome.

B.6.1.3 Economic Geology

First oil production from the Damon Mound salt dome came in 1915 from the Texas Exploration Company No. 1 Wisdom. Later production has been largely confined to the east and west rim of the salt dome. However, the greatest density of drilling has taken place on the dome's west flank. Interpretation of the salt structure map and geologic cross section suggests that oil and gas occur on the flanks of the dome in Oligocene and Miocene sediments which are faulted or pinched out against the sides of the dome. No known oil or gas production is located over the top of the dome in the area proposed for the storage facility.

Dresser Minerals, Inc. has opened a limestone quarry on Damon Mound adjacent to the proposed crude oil storage site. The limestone, used for road fill, is of poor quality and Dresser is doubtful that they will open the entire proposed quarry (Figure A.6-2).

B.6.1.4 Soils

Soils at the Damon Mound site are assigned to the Lake Charles-Edna-Bernard association. These soils consist of clayey and loamy deltaic deposits. They have a significant portion of montmorillonite clay and are strongly acid to moderately alkaline at the surface. Alkalinity increases with depth. It has a high shrink-swell potential and very low permeability. It is highly corrosive, and presents severe residential foundation problems. Marine sediments and soils located in the vicinity of the proposed brine disposal system in the Gulf are described in Section B.3.1.4.

B.6.2 Water Environment

B.6.2.1 Surface Water Systems

The Damon Mound alternative SPR site is located between the Brazos and San Bernard Rivers, in the San Bernard River drainage basin. Site drainage is to Mound Creek, one mile to the north. Mound Creek flows south-southeasterly to join the San Bernard River about four miles west of the town of West Columbia (Figure B.2-9). No streamflow measurements are available for Mound Creek.

Approximately 7 miles north of West Columbia the proposed pipeline route crosses near the source of Varner Creek. Varner Creek flows generally southeasterly at this location, and is an intermittent stream. It joins the Brazos River approximately 1.5 miles east of West Columbia. The pipeline also crosses Bell Creek, approximately 1.5 miles south-southwest of the town of West Columbia. Bell Creek flows generally westerly at this location, and merges with the San Bernard River approximately one mile further downstream. No streamflow measurements or water quality data are available for Bell Creek or Varner Creek. Between Bryan Mound and the SEAWAY Tank Farm, the proposed pipeline route crosses the Brazos River Diversion Channel and Jones Creek. Both of these water bodies were discussed in Section B.2.2.1 as part of the regional surface water system.

The marine conditions in the area of the proposed brine diffuser are discussed in Section B.3.2.1.

B.6.2.2 Subsurface Water Systems

The base of the Chicot aquifer is about 800 feet below sea level in the vicinity of the dome (Sandeen and Wesselman, 1973). Fresh water does not occur in the material over the dome, and slightly saline water (1000 to 3000 mgl dissolved solids) occurs to an elevation about 100 feet below sea level (Ibid). The base of the slightly saline water extends to a depth of 900 feet about one mile from the dome.

The water in the formations adjacent to the dome and the caprock are highly mineralized with a dissolved solids concentration on the order of 110,000 milligrams per liter or greater. At some distance from the dome, however, the formation water can be expected to be similar to sea water, or about 35,000 milligrams per liter dissolved solids below a depth of about 2000 feet.

Aquifers in the vicinity of Damon Mound are capable of delivering large quantities of slightly to moderately saline water to properly completed wells. Aquifer porosities are on the order of 40 percent with permeabilities in the range of 600 to 1000 gpd per square foot. Permeabilities decrease with depth to an estimated 250 gpd per square foot in the Evangeline aquifer below a depth of about 800 feet.

Water Use

Ground water use in the vicinity of Damon Mound does not appear to be extensive. The hydraulic gradient is essentially flat in both the upper and lower units of the Chicot aquifer at the site. Local use of ground water is probably currently limited to rural domestic pumpage and stock watering.

B.6.3 Climatology and Air Quality

B.6.3.1 Climatology

Due to the proximity of Damon Mound to West Columbia, refer to Sections B.2.3 and B.4.3 for site-specific data applicable to this site. The site is considered an inland site, where the coastal effects are attenuated.

B.6.3.2 <u>Air Quality</u>

Damon Mound site is situated near the town of Damon, a small, primarily residential community. Oil production activity around the dome is the primary local source of pollutants, while the occasional influx of air from heavily industrialized areas northeast of the site may occasionally contribute to concentrations of pollutants. The existing air quality conditions are considered to be equivalent to those at Freeport (i.e., low levels with the exception of hydrocarbons and oxidant concentrations).

B.6.4 <u>Background Ambient Sound Levels</u>

The small town of Damon overlies a portion of Bryan Mound, on the east. A limestone quarry, active since 1975, lies on the western portion of the mound. Associated with the quarry are blasting and digging activities plus truck movements on an access road skirting the north portion of the site. These activities influence sound levels in the area. Background ambient sound levels of 54-56 dB are estimated for the town of Damon where principal noise sensitive land uses lie. Sound levels along the brine diffuser pipeline are discussed in Section B.3.4.

B.6.5 <u>Species and Ecosystems</u>

B.6.5.1 <u>Site Area</u>

The Damon Mound dome site includes pasture land, and also industrial, and residential development. Coastal prairie makes up a major portion of the dome site (Table B.6-1). Scattered oak woodlands consisting of scrubby, immature hardwood species are found on the site.

Site soils include light colored, acidic, sandy loams and sand. The soils of adjacent lowland areas are light brown to dark gray, acidic, sandy loam and clay. Significant industrial and residential development on and near the dome site have brought about changes in the native cover primarily for agricultural and/or industrial uses. The available surface habitat is largely urban (the town of Damon) and already disturbed.

TABLE B.6-1 Estimated site acreage analysis for Damon Mound candidate SPR storage site (alternative site).

Total For Fenced Site Area -- 232 Acres
Total Within -2000 Foot Salt Contour ------------------------------ 1742 Acres
Total for Cleared Land -- 150 Acres
Total for Quarry -- 100 Acres
Total for Coastal Prairie ------------------------------------ 1503 Acres

SYSTEM	Total Miles of Pipeline	Acreage for Construction	Acreage for Operation
Proposed Brine Disposal System	46.8	563.2	315.6
(5.8 mile Bryan Mound Gulf Diffuser & Injection Wells)			
Cleared Land		5.0	4.0
Fluvial Woodlands		182.0	136.0
Coastal Prairies		233.0	175.0
Marsh		0.2	0.1
Shell Ramp Barrier Flat		1.0	0.5
Open Water		142.0	0.0
(total water crossings 15)			
Proposed Raw Water System	36.4	397.0	298.0
(Brazos River Diversion Channel)			
Cleared Land		5.0	4.0
Fluvial Woodlands		182.0	136.0
Coastal Prairies		210.0	158.0
Proposed Oil Distribution System	37.0	419.0	318.0
(New Tanker Docks)			
Cleared Land		23.0	21.0
Fluvial Woodlands		182.0	136.0
Coastal Prairies		310.0	158.0
Marsh		4.0	3.0
Alternate Brine Disposal System (wells)	3.2	19.0	19.0
Coastal Prairies		19.0	19.0
Alternate Brine Disposal System	50.6	723.2	312.6
(12.5 Mile Bryan Mound Gulf Diffuser)			
Cleared Land		5.0	4.0
Fluvial Woodland		182.0	136.0
Coastal Prairies		230.0	172.0
Marsh		0.2	0.1
Shell Ramp Barrier Flat		1.0	0.5
Open Water		305.0	0.0
(total water crossings 2)			
Alternate Raw Water System (wells)	6.1	22.0	22.0
Coastal Prairies		22.0	22.0
Alternate Raw Water System	10.0	122.0	92.0
(Brazos River)			
Fluvial Woodlands		4.0	3.0
Coastal Prairies		115.0	86.0
Open Water		3.0	3.0
(total ater crossings 4)			

[a]Based on features of USGS topographic maps (15 minute series).

[b]Cleared land includes agricultural, industrial and rural, and land already disturbed.

The only aquatic habitats on the mound are a few very small ponds and several intermittent creeks. During the spring these creeks are drained by Mound Creek, about one mile north of the site.

Coastal Prairie

Vegetation

In the grassland areas of the site, the primary species include bluestem, coastal sacahuista, and big bluestem. Subdominant species include Indiangrass, eastern gammagrass, Gulf muhly, western ragweed, turtlegrass, little bluestem, buffalo grass, and smutgrass (Table B.6-2).

Wildlife

The coastal prairie habitat at the site is heavily grazed by cattle. The urban setting has affected the number and kinds of species of birds found there. Species expected to occur at the dome include cattle egret, turkey vulture, sparrow hawk, bobwhite quail, killdeer, mourning dove, eastern meadowlark, cowbird, savannah sparrow, and vesper sparrow. Although quail and dove are game species, they are probably not hunted extensively in this urban setting. Cleared land bird species include doves, goatsuckers, swallows, thrushes, vireos, warblers, blackbirds, finches, and sparrows. Mammals likely to inhabit the prairie and cleared land habitats include opossum, small rodents, skunks, cottontail rabbits, and armadillo.

Amphibians and reptiles expected to inhabit the coastal prairie and cleared land onsite include the ornate box turtle, eastern garter snake, Texas rat snake, Gulf coast toad, Texas toad, and spotted chorus frog.

Oak Woodlands

Vegetation

In the oak woodlands the dominant species include live oak, post oak, blackjack oak, and hickories. The subdominants include white oak, red oak, black oak, red lovegrass, broomsedge bluestem, splitbeard bluestem, Indiangrass, and switchgrass.

TABLE B.6-2 Ecosystems and typical flora and fauna of the Damon Mound dome site candidate SPR storage site (alternative site)

	Ecosystem							
	Marshlands			Coastal Prairies	Oak Woodlands	Cleared Lands		Coastal and Inland Waters
Typical or Important Organisms	Freshwater Marsh	Brackish Marsh	Salt Marsh			Urban and Suburban	Crops and Future Lands	Freshwater
Plants, herbs, grasses and trees	Maiden cane cordgrass sedges water hyacinth pennywort	smooth crodgrass soilbind morning glory fiddle leaf morning glory sea purslane	smooth cordgrass salt grass lazy daisy glasswort salt matrimonyvine batis Carolina wolfberry bulrush Harstem bulrush shore grass	Gulf cordgrass bunchgrass Indian grass switchgrass bluestem live oak huisache ragweed prairie pleatleaf coastal sacahuista Eastern gammagrass Gulf Muhly buffalo grass smut grass	live oak sugar berry pignut hickory bluestem cordgrass post oak blackjack oak hickory	Various residential species	rice soybeans prairie grass	NA
Mollusks and crustaceans	snails mussels clams	snails crabs clams shrimp oysters	fiddler crabs mud crabs clams snails shrimp	snails	NA	NA	NA	clams snails crayfish
Water snakes, amphibians, and reptiles	Western diamondback rattlesnake	Gulf salt marsh snake Western diamondback rattlesnake	Gulf salt marsh snake	spotted chorus frog ornate box turtle Southern leopard frog Western diamondback rattlesnake Eastern garter-snake Gulf coast toad Texas rat snake Texas toad	ornate box turtle broad-headed skink Eastern garter-snake gray tree frog Hurter's spadefoot five-lined skink ground skink	Eastern garter-snake Gulf coast toad Texas toad	ornate box turtle Texas rat snake	turtles frogs water snakes salamander
Fish	minnows crappie sunfish catfish gar	killifish	killifish cyprinids immature mullet spot	NA	NA	NA	NA	crappie catfish sunfish gar shad carp buffalo bass
Mammals	raccoon opossum rabbit	rabbits hispid cotton rat	hispid cotton rat rabbits	cottontail rabbit cattle striped skunk raccoon armadillo coyote opossum	gray and fox squirrel opossum small rodents white-tailed deer gray fox raccoon striped skunk coyote bat armadillo	opossum domesticated animals bats cottontail rabbit	cattle opossum armadillo cottontail rabbit	muskrat nutria raccoon
Birds	gulls terns black skimmer red-winged blackbird willet barn owl Eastern meadowlark killdeer sanderling	American coot yellowlegs terns Seaside sparrow sandpiper boat-tailed grackle Eastern meadow-lark common gallinule	plovers geese Great Blue heron Little blue heron egrets Least bittern ibis Roseate spoonbill ducks clapper rail	sparrows marsh hawks Eastern meadow-lark vultures killdeer cattle egret bobwhite quail mourning dove cowbird upland plover sparrow hawk	hawks crows woodpeckers chickadees wrens vireos warblers thrushes blackbirds finches sparrows	blackbirds starlings songbirds goatsuckers swallows finches sparrows doves	blackbirds hawks killdeer Eastern meadow-lark mourning dove sparrows horned lark geese	waterfowl herons egrets

Wildlife

Bird species expected to occur in this habitat include crows, woodpeckers, chickadees, wrens, vireos, warblers, blackbirds, and finches.

Wildlife species inhabiting the woodland include opossum, small rodents, gray and fox squirrels, armadillo, and raccoon. The box turtle, broadheaded skink, eastern garter snake, Hurter's spadefoot and gray treefrog also may be found in the woodlands. The wooded areas on the site are not large enough to support large populations of animals.

Gulf of Mexico

The biologic environment surrounding the proposed brine diffuser location is described in Section B.3.5.2.

B.6.5.2 Pipeline System Route

The 53.4 mile pipeline right-of-way will pass through 263 acres of coastal prairie, 182 acres of fluvial and oak woodland, 4 acres of marsh, 1 acre of ramp barrier flat and 23 acres of cleared lands, affecting a total of 473 acres of land. The ecosystems found in the vicinity of the brine diffuser pipeline right-of-way are described in Section B.2.5.2.

B.6.6 Natural and Scenic Resources

The area surrounding the Damon Mound site has few natural or scenic resources. Most of the mound itself is in use as pastureland or for mineral extraction, neither of which provides unique, valuable scenic resources. The southern and southeastern areas near the town of Damon have greater aesthetic appeal due to gentle, wooded slopes of the dome. The surrounding countryside is very flat, but contains wooded areas interspersed with pastureland and land cultivated for agriculture. The San Bernard River is located approximately one mile west of Damon Mound.

On the project site, pastureland predominates; however, the ground on the southwestern edge of the site has been stripped during previous sulphur mining, reducing the aesthetic appeal. Dresser Minerals' quarry is an open pit operation, reducing the aesthetic appeal to the northwest.

There are no major recreation areas located near the storage site.

The natural and scenic resources in the vicinity of the brine duffuser pipeline are described in Section B.3.6.

B.6.7 Archaeological, Historical, and Cultural Resources

The candidate site does not contain any known site of archaeological, historical, or cultural significance. If this site is selected for SPR development, a qualified archaeologist will survey it for DOE, and coordinate with the State Historical Preservation Officer.

B.6.8 Socioeconomic Environment

B.6.8.1 Land Use

The Damon Mound site is located near the western edge of Brazoria County, approximately one mile from the Fort BendBrazoria County line. Land uses in the vicinity of the site include mineral extraction, agricultural and residential uses, and forest (Houston-Galveston Area Council, 1972).

Sulfur production from the dome caprock has been abandoned. The land overlying the dome is used primarily for cattle grazing. The town of Damon (estimated population 750) overlies a portion of the dome. The south and southeast sides of the domes have some tree cover. Land adjoining the candidate storage site to the north is primarily in agricultural use, which includes cultivated fields and range and pasturelands (McGowen and others, 1976). The land immediately adjacent to the west of the site is presently being used by Dresser Minerals for resource extraction.

B.6.8.2 Transportation

The Damon site is easily accessible from the major transportation systems in the region, described in Section B.2.8.3. Route 36 is the major highway leading close to the site, just east of Damon. From this highway, access to the proposed site is provided via two roads, both of which pass through residential areas in Damon.

B.6.8.3 Population Characteristics

The Damon Mound candidate site is located just west of the small town of Damon, which had a 1977 population of approximately 750 (Hardcastle, 1977). The Damon site is located within commuting distance of the major population centers in the region discussed in Sections B.2.8.4 and B.3.8.

B.6.8.4 Housing

Damon is the residential area closest to the site; however, the available housing there is limited. Other nearby residential areas include Needville in Fort Bend County and West Columbia. As stated in Sections B.2.8.5 and B.3.8, housing in the northern portion of Brazoria County has a higher vacancy rate than the southern portion.

B.6.8.5 Economy

There are few employment opportunities within the area immediately surrounding the site. Nearby industries include agricultural production, mineral extraction, and retail sales. The Damon area is not expected to experience significant economic growth within the foreseeable future.

B.6.8.6 Government

Police and Fire Protection

Supplementary police services for the candidate site can be provided by the Brazoria County Sheriff's Office. Several deputies from this department regularly patrol the area. Calls for police services involving traffic or accidents on state highways are handled by the Texas Department of Public Safety (Wood, 1977).

Fire protection can be provided by the Damon Fire Department. This volunteer force handles all fires within a 10-mile radius of the town. In case of a large disaster, assistance can be obtained from surrounding volunteer fire departments under mutual assistance agreements (Hardcastle, 1977).

Hospitals and Medical Personnel

There are four hospitals located within 20 miles of this site: the Polly Ryan Memorial Hospital in Richmond; the Texas Gulf Sulphur Company Hospital in Wharton County; the Angleton-Danbury General Hospital; and the Sweeny Community Hospital. The Damon area is dependent upon these facilities and those discussed in Section B.3.8 for its major medical services.

Education

The Damon Independent School District serves the area immediately surrounding Damon Mound. Its enrollment increased by 10 percent between the 1969-70 and the 1975-76 school years. Actual enrollment in these years was 147 and 162 students, respectively.

B.7 SITE SPECIFIC ENVIRONMENT - NASH DOME

The Nash dome alternative SPR site is located in Fort Bend County, Texas, and extends slightly into Brazoria County. It is in a rural, agricultural setting.

B.7.1 Land Features

B.7.1.1 Physiography and Topography

Nash Dome is in the prairie terrace of the Gulf Coastal Plain physiographic province. Average elevation in the area is about +50 feet. A slight mound over the dome rises to a maximum elevation of 58 feet. The topography and bathymetry of the proposed brine diffuser right-of-way is described in Section B.3.1.1.

B.7.1.2 Local Geology

Nash salt dome is an elliptical, shallow-lying structure with a relatively flat top and steep sides. The broad, almost flat top lies at about 950 feet below sea level (Figure B.7-1). The -2000 foot contour encloses about 760 acres; its east-west and north-south axes are 5500 and 7000 feet long, respectively. An estimated 600 to 900 feet of Pleistocene and Recent age sediments overlie the dome. The sides of the dome have steeply dipping contacts (Figure B.7-2).

Faulting associated with the dome (Figure B.7-3) is shown in the structure contour map on top of one of the sedimentary strata which surround the dome. The major fault pattern seen here is a typical radial pattern.

The quality and composition of the salt mass is probably similar to that at Bryan Mound. Composition of caprock overlying the Nash dome is unknown. Studies of other domes suggest that gypsum and anhydrite comprise most of the caprock.

B.7.1.3 Economic Geology

Nash dome was the first salt dome with petroleum deposits found in the United States by geophysical methods. Oil was first produced from the dome on January 4, 1926, from the Rycade Petroleum Corp. No. 5 W. R.

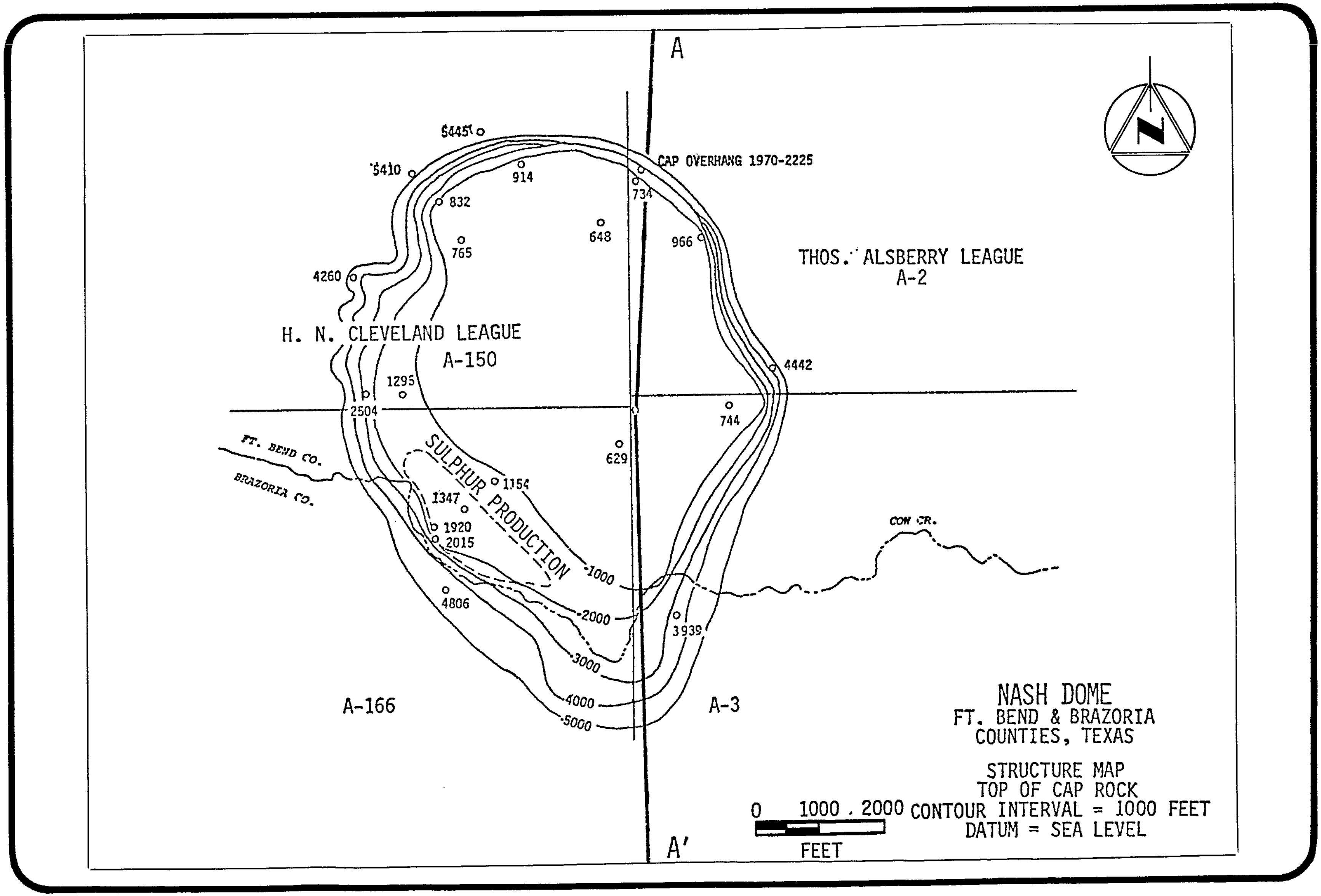


FIGURE B.7-1 Structure map - top of Caprock - Nash Dome candidate SPR storage site (alternative site)

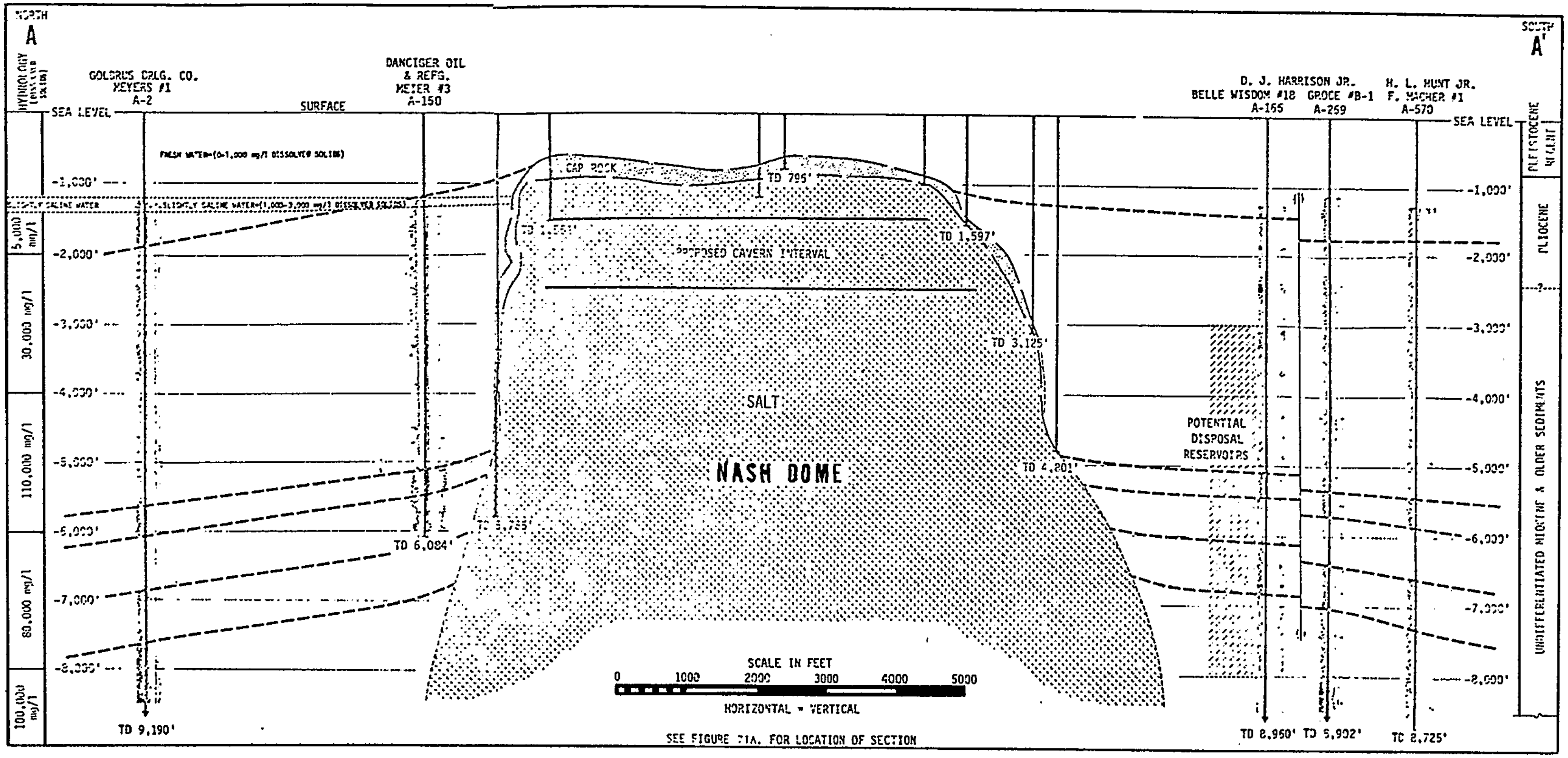


FIGURE B.7-2 Geologic cross-section, Nash dome candidate SPR storage site (alternative site)

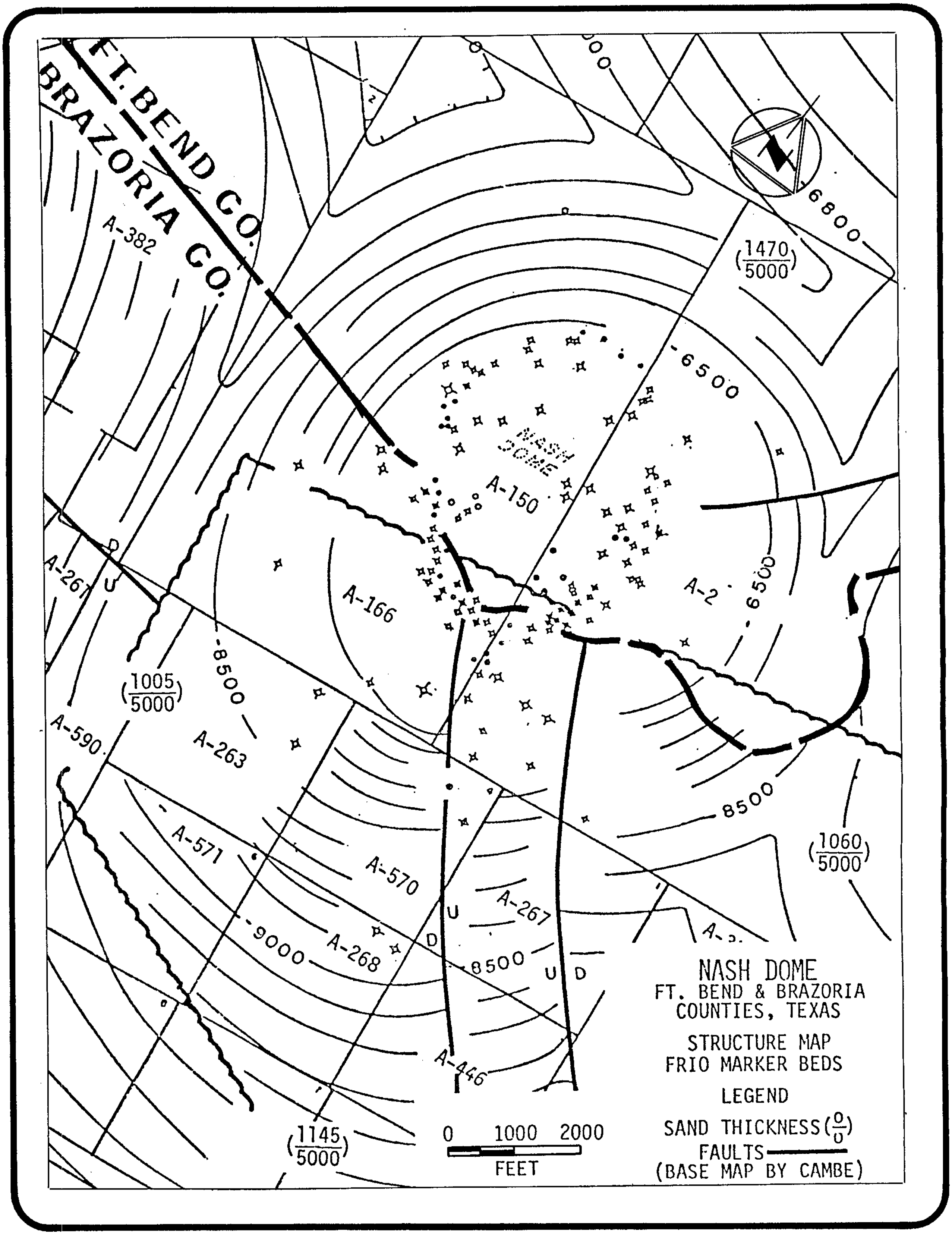


FIGURE B.7-3 Structure map - Frio marker beds - Nash dome candidate SPR storage site (alternative site)

Nash well. Interpretation of the salt structure indicates that the oil occurs primarily on the southern flank of the dome. Deposits are concentrated in Miocene age sands and limestones which are faulted or pinched out against the sides of the dome. No known oil or gas production is located over the top of the dome in the area proposed for the storage facility.

Freeport Sulphur Company, using the Frasch process, has recovered sulfur from some 50 acres on the southwest rim of the caprock (Figure A.7-3). The thickness of the sulfur zone appears to average about 13 feet.

B.7.1.4 Soils

Soils in the vicinity of the Nash dome belong to the Lake Charles-Edna-Bernard association. They consist of poorly drained clayey and loamy soils. These soils consist of clayey and loamy deltaic deposits. They have a significant portion of montmorillonite clay and are strongly acid to moderately alkaline at the surface. Alkalinity increases with depth. It has a high shrink-swell potential and very low permeability. It is highly corrosive, and presents severe residential foundation problems. Marine sediments and soils located in the vicinity of the proposed brine disposal system in the Gulf are described in Section B.3.1.4.

B.7.2 Water Environment

B.7.2.1 Surface Water Systems

Surface water runoff from the Nash dome storage site is to Cow Creek, one mile to the south; and Turkey Creek, one mile to the north (Figure A.7-3). No streamflow data is available for either stream. They are both classified as intermittent streams on the U.S. Geological Survey topographic maps of the area. Turkey Creek merges with Cow Creek about one mile east of the site, and the combined flow reaches the Brazos River about 3-1/2 miles east of the site.

The pipeline access route to Nash dome crosses the water bodies discussed for the West Columbia dome site (Section B.5.2), including

Varner Creek, Redfish Bayou, Jones Creek, and the brazos River Diversion Channel. It also crosses the intermittent Cow Creek and Varner Creek, where it is listed as an intermittent stream, between West Columbia and Nash dome.

The marine conditions in the area of the brine diffuser are discussed in Section B.3.2.1.

B.7.2.2 Subsurface Water Systems

Nash dome penetrates through the Evangeline aquifer and into the Chicot aquifer. The base of the Chicot aquifer is about 700 feet below sea level in the vicinity of the dome (Sandeen and Wesselman, 1973). The top of the caprock is at a depth of about 620 feet. Fresh water occurs in about the upper 600 feet of material over the dome. Slightly saline water (1000 to 3000 mg/l dissolved solids) occurs from about 600 to 1000 feet.

About one mile from the dome, the base of the slightly saline water extends to a depth of 1200 feet. The water in the formations adjacent to the dome and the caprock is highly mineralized, with a dissolved solids concentration on the order of 110,000 milligrams per liter or greater. At some distance from the dome, however, the water can be expected to be similar to sea water or about 35,000 milligrams per liter dissolved solids.

Aquifers in the vicinity of Nash dome are capable of supplying large quantities of slightly to moderately saline water to properly completed wells. Aquifer porosities are on the order of 40 percent with permeabilities in the range of 600 to 1000 gpd per square foot. Permeabilities decrease with depth to an estimated 250 gpd per square foot in the Evangeline aquifer below a depth of about 900 feet.

Ground water use in the vicinity of the Nash dome does not appear to be extensive. Local use of ground water is probably limited to rural domestic pumpage and stock watering.

B.7.3 Climatology and Air Quality

B.7.3.1 Climatology

Due to the proximity of Nash dome to West Columbia, refer to Sections B.2.3 and B.4.3 for site-specific data applicable to this site. The site is considered an inland site, where the coastal effects are attenuated.

B.7.3.2 Air Quality

Oil production activity around the dome is the primary local source of pollutants, while the occasional influx of air from heavily industrialized areas northeast of the site may occasionally contribute to concentrations of pollutants. The existing air quality conditions are considered to be equivalent to those at Freeport (i.e., low levels with the exception of hydrocarbon and oxidant concentrations).

B.7.4 Background Ambient Sound Levels

The Nash dome is virtually unpopulated. Aside from a small number of oil wells, principal noise sources are insect and animal activity and wind. Based on this land use and on previous studies on similar sites, average day/night sound levels of less than 50 dB are estimated for the area. Sound levels along the brine diffuser pipeline are discussed in Section B.3.4.

B.7.5 Species and Ecosystems

B.7.5.1 Site Area

The Nash dome site is situated on land which can be characterized as cleared agricultural land, which is used primarily for crop and pastureland. However, around the site area the petroleum industry accounts for a large proportion of the land use. Prairie and woodlands make up the remaining portion of the dome site (Table B.7-1).

Soils of the site area include light-colored, acidic, sandy loams and sand. The soils of lowland areas are light brown to dark gray, acidic sandy loam and clay. Impoundments and industrial development on and in the immediate vicinity of the dome have markedly changed the soil and vegetation which were originally present.

TABLE B.7-1 Estimated site acreage analysis for Nash dome candidate SPR storage site (alternative site).

Total For Fenced Site Area -- 206 Acres
Total Within -2000 Foot Salt Contour -------------------------------- 800 Acres
Total for Coastal Prairie -------------------------------------- 800 Acres

SYSTEM	Total Miles of Pipelines	Acreage for Construction	Acreage for Operation
Proposed Brine Disposal System (5.8 mile Bryan Mound Gulf Diffuser & injection wells)	46.7	595.2	340.6
Fluvial Woodlands		210.0	158.0
Coastal Prairies		242.0	182.0
Shell Ramp Barrier Flat		1.0	0.5
Marsh		0.2	0.1
Open Water (total water crossings 16)		142.0	0.0
Proposed Raw Water System (Brazos River Diversion Channel)	36.7	429.0	323.0
Fluvial Woodlands		210.0	158.0
Coastal Prairies		219.0	165.0
Proposed Oil Distribution System (New tanker docks)	37.3	454.0	346.0
Cleared Land		18.0	17.0
Fluvial Woodlands		210.0	158.0
Coastal Prairies		222.0	168.0
Marsh		4.0	3.0
Alternate Brine Disposal System (wells)	3.2	19.0	19.0
Coastal Prairies		19.0	19.0
Alternate Brine Disposal System (12.5 mile Bryan Mound Gulf Diffuser)	50.9	766.0	346.0
Fluvial Woodlands		210.0	158.0
Coastal Prairies		239.0	179.0
Marsh		11.0	8.0
Shell Ramp Barrier Flat		1.0	1.0
Open Water (total water crossings 2)		308.0	0.0
Alternate Raw Water System (wells)	6.1	22.0	22.0
Coastal Prairies		22.0	22.0
Alternate Raw Water System (Brazos River)	6.1	73.0	55.0
Fluvial Woodlands		4.0	3.0
Coastal Prairies		69.0	52.0
Open Water (total water corssings 2)		0.0	0.0

[a]Based on features of USGS topographic maps (15 minute series).

[b]Cleared land includes agricultural, industrial and rural, and land already disturbed.

Agricultural Land

Except for the southern flank of the site, nearly all of the Nash dome is agricultural land. The agricultural land provides limited resources for birds such as geese, blackbirds, doves, eastern meadowlark, killdeer, horned lark, and sparrows. Wintering flocks of snow and white-fronted geese were seen feeding in the local fields (February 1977 site visit) and are also likely transients at the site (Table B.7-2).

Few mammal species are likely to inhabit the cleared agricultural areas found on Nash dome.

Woodlands and Pastureland

The southern area of the dome has a small wooded streambank habitat, several small man-made ponds, and cleared land.

Vegetation In the woodland areas, the dominant tree species include live oak, post oak, blackjack oak, and hickories. The subdominant trees include white oak, red oak, and black oak.

In the prairie, the principal plant species include bluestem, coastal sacahuista, and big bluestem. Less common are Indiangrass, eastern gammagrass, Gulf muhly, western ragweed, turtle grass, little bluestem, buffalo grass, and smut grass.

The small onsite ponds are steep-banked and have no emergent aquatic vegetation.

Wildlife The wooded streambank provides habitat for a large number of small birds, particularly woodpeckers, flycatchers, titmice, nuthatches, kingfishers, thrushes, vireos, warblers, finches, blackbirds, and sparrows.

Mammals inhabiting the surrounding woodlands cross the fields but seldom make use of the area, since little food or cover is available. Mammal species likely to be encountered in or near the fields include opossum, cottontail rabbits, raccoon, deer, skunks, coyote, and armadillo.

Mammals which inhabit streambanks include opossum, cottontail rabbits, squirrels, striped skunks, coyotes, raccoons, and armadillos. The cottontail and squirrel are important game species; the opossum and raccoon are major furbearers of the area.

TABLE B.7-2 Ecosystems and typical flora and fauna of the Nash dome site candidate SPR storage site (alternative site)

	Ecosystem							
	Marshlands			Coastal Prairies	Oak Woodlands	Cleared Lands		Coastal and Inland Waters
Typical or Important Organisms[a]	Freshwater Marsh	Brackish Marsh	Salt Marsh			Urban and Suburban	Crops and Future Lands	Freshwater
Plants, herbs, grasses and trees	Maiden cane cordgrass sedges water hyacinth pennywort	smooth cordgrass soilbind morning glory fiddle leaf morning glory sea purslane	smooth cordgrass salt grass lazy daisy shortgrass glasswort salt matrimonyvine batis sea myrtle Carolina wolfberry bulrush Harstem bulrush	Gulf cordgrass bunchgrass Indian grass switchgrass bluestem live oak huisatch ragweed prairie pleatleaf	NA	Various residential species	rice soybeans prairie grass	NA
Mollusks and crustaceans	snails mussels clams crayfish	snails crabs crayfish clams shrimp oysters	fiddler crabs mud crabs clams snails shrimp	snails	NA	NA	NA	clams snails crayfish
Water snakes, amphibians, and reptiles	turtles Western cottonmouth bullfrog Southern leopard frog Western diamond-back rattlesnake Yellow bellied watersnake	Gulf salt marsh snake Western diamondback rattlesnake	Gulf salt marsh snake	ornate box turtle Southern leopard frog Western diamondback rattlesnake Eastern garter-snake	ornate box turtle five-lined skink Eastern garter-snake gray tree frog Hurter's spadefoot broad-headed skink ground skink	Eastern garter-snake Gulf coast toad	ornate box turtle Texas rat snake	turtles frogs watersnakes salamander
Fish	minnows crappie sunfish catfish gar	killifish	killifish cyprinids immature mullet spot	NA	NA	NA	NA	crappie catfish black bass gar shad buffalo fish sunfish bass carp
Mammals	muskrat raccoon nutria mink opossum	rabbits hispid cotton rat	hispid cotton rat rabbits	cattle hispid cotton rat rice rat rabbits	gray and fox squirrel opossum armadillo raccoon white-tailed deer white-footed mouse gray fox coyote striped skunk	opossum domesticated animals cottontail rabbit Eastern mole	cattle opossum cottontail rabbit striped skunk armadillo	muskrat nutria
Birds	gulls terns red-winged blackbird killdeer sandpipers white pelican mottled duck blue-winged teal Great Blue heron Snowy egret Green heron Great egret	American coot yellowlegs terns Seaside sparrow sandpiper boat-tailed grackle Eastern meadow-lark common gallinule	plovers geese Great Blue heron Little Blue heron egrets Least bittern ibis Roseate spoonbill ducks clapper rail sandpipers	sparrows marsh hawks Eastern meadow-lark egrets vultures kites	turkey vulture Coopers hawk great horned owl woodpeckers tufted titmouse Carolina chickadee thrushes vireos warblers sparrows	blackbirds starlings songbirds sparrows swallows finches doves	blackbirds hawks killdeer Eastern meadow-lark mourning dove sparrows geese	waterfowl herons egrets

Some of the ponds and Cow Creek may support a small population of fish. The small ponds provide a shallow water habitat for herons, egrets, and kingfishers. The brushy banks of the ponds contained finches, blackbirds, and sparrows. The ponds appear unsuitable for muskrat and nutria. The edges of the pond are probably utilized by raccoon.

The pasture land is heavily grazed by cattle and provides little useful habitat for birds. Expected inhabitants in the pasture land include cattle egret, killdeer, blackbird, and sparrow.

Few amphibians and reptiles are expected to occur at the site since they are not likely inhabitants of the sparsely vegetated cropland and pasture. Species normally found on cleared land include the ornate box turtle and Texas rat snake.

Gulf of Mexico

The biologic environment surrounding the proposed brine diffuser location is described in Section B.3.5.2.

B.7.5.2 Dock Site

For a discussion of the species and ecosystems found at the dock site, see Section B.3.5.

B.7.5.3 Pipeline System Route

The 53.0 miles of pipeline for the Nash dome SPR facilities would pass through 242 acres of prairie grasslands, 210 acres of fluvial and oak woodland, 48 acres of cleared land, 4 acres of marsh and 1 acre of ramp barrier flat, including the right-of-way for the brine pipeline from the SEAWAY Tank Farm to Bryan Mound and a return raw water line from Bryan Mound to the tank farm site, a distance of eight miles. The habitats crossed by these pipeline rights-of-way have been generally discussed in Section B.4.5 for the Allen dome alternative. The ecosystems found in the vicinity of the brine diffuser pipeline right-of-way are described in Section B.2.5.2.

B.7.6 Natural and Scenic Resources

The natural and scenic resources in the area surrounding Nash dome are similar to those found near Damon Mound (Section B.6.6). The area south of the site, along Cow Creek contains some wooded areas. The site itself and much of the surrounding land is in use for agricultural production in cropland and pastureland. The site is very flat and contains few trees.

The natural and scenic resources in the vicinity of the brine diffuser pipeline are described in Section B.3.6.

B.7.7 Archeological, Historical, and Cultural Resources

The candidate site does not contain any known sites of archaeological, historical, or cultural significance. If this site is selected for SPR development, a qualified archaeologist will survey it for DOE, and coordinate with the State Historical Preservation Officer.

B.7.8 Socioeconomic Environment

B.7.8.1 Land Use

The Nash dome candidate site is located in Fort Bend County, approximately one-half mile from the Brazoria County border, and east of the town of Damon. Land uses in the vicinity of the site include pastureland, agricultural cropland, residential development, forests, and mineral resource extraction.

The northern and eastern perimeters of the site are classified as cultivated land and orchards with signficant acreage presently out of cultivation. Farther north and east of the site are oil and gas fields. Also to the east of the site is a woodland-timber area located on the floodplains of several small streams. The area to the south of the dome is primarily used for resource extraction. Sulfur production by Freeport Sulfur Company has occurred on the southwestern flank of the dome. Also south of the site are located gas and oil wells. To the west of the site, the land is primarily cultivated agricultural land (McGowen and others, 1976).

B.7.8.2 Transportation

The transportation systems in the Nash dome area are the same as those discussed for Damon Mound (Section B.6.8). Access to the site from Highway 36 is provided via county roads that are not heavily traveled.

B.7.8.3 Population

The closest area of concentrated population is Damon, (Section B.6.8). There are a few widely spaced residences in the vicinity of the project site.

B.7.8.4 Housing

The available housing for this area is discussed in Section B.6.8. Open areas are available should new housing be required.

B.7.8.5 Economy

The economic activity near Nash dome is the same as discussed for Damon Mound in Section B.6.8.

B.7.8.6 Government

Police and Fire Protection

Supplementary police services to the site could be provided through the Fort Bend Sheriff's Department, headquartered in Richmond. Fire services could be provided by the Damon Fire Department (Section B.6.8).

Hospitals and Medical Personnel

Provision of medical services would be the same as for Damon Mound.

Education

Educational services for the area surrounding Nash dome are provided by the Damon Independent School District (Section B.6.8).

B.8 SUMMARY

The Seaway Group of SPR sites includes 5 shallow salt domes where existing cavities and/or new solution mined cavities could feasibly be used to store crude oil. They are all within a 35 mile radius of the port facilities at Freeport Harbor and the oil distribution facilities associated with the port and the SEAWAY, Inc. Pipeline

The SEAWAY sites are located on the seaward margin of the Texas Gulf Coastal Plain. Surface relief is subtle, with a general slope toward the Gulf of Mexico. Elevations within the region range from sea level to 146 feet. The origin of the SEAWAY salt domes is in the Lovann (Gulf Coast) Salt, an extensive evaporite deposit which extends throughout the Gulf Coastal region from western Florida to Texas. At least 500 salt domes are known to occur in the Lovann Basin. Oil and gas, salt, and sulfur are the main economic minerals associated with gulf coast salt domes.

Surface water in the region consists of two major rivers, the Brazos and the San Bernard, and coastal areas inundated with the 1.8 foot local tides. Circulation in the nearshore Gulf of Mexico is predominantly wind-driven, with a significant probability of stagnation during all seasons.

Ground water is heavily exploited by major metropolitan centers in southeat Texas, and the resulting surface subsidence from the large withdrawals extends into the vicinity of some of the proposed storage sites. Sufficient water is available in deeper saline water bearing sands to meet the requirements of this project. Brine disposal to deeper saline water bearing sands is a possibility in this region. Available data suggest that there is an extensive thickness of suitable saline water bearing sands at depths in excess of 5000 feet.

Air quality in the region is generally good, with the exception of non-methane hydrocarbons and photochemical oxidant concentrations. The intense development of petroleum extraction and petrochemical industries is probably the chief cause of these excesses. Occasionally, wind conditions will introduce pollutants from the heavily industrialized areas to the north and northwest.

Noise sources in the area vary from site to site and range from the industrialized sources near Bryan Mound to the rural, agricultural sources near Nash dome.

The ecosystems at the sites are typical of the Texas Coastal Plain and include Coastal Prairies and marshes, fluvial and oak woodlands, and cleared lands. Inland waters, coastal waters and all terrestrial ecosystems are also productive.

Natural and scenic resources in the area include major wildlife management areas, and extensive public beaches open for recreation. The San Bernard Wildlife and Brazoria Refuges are major refuges in the area.

The Brazosport, Houston, and the Texas City-Galveston areas are the socioeconomic units directly affected by the project. All of these areas are experiencing relatively low unemployment and recent economic growth, especially in the petrochemical industries.

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