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Strategic Petroleum Reserve. Final Environmental Impact Statement. West Hackberry Salt Dome

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16. Abstracts The Federal Energy Administration is considering implementation of the Strategic Petroleum Reserve (SPR), Title I, Part B of the Energy Policy and Conservation Act of 1975 (P.L. 94-163) through the development of a 60 million barrel crude oil storage facility at the West Hackberry salt dome. The purpose of the SPR is to mitigate the economic impacts of any future interruptions of the petroleum imports. Under the initial phase of the SPR, referred to as the Early Storage Reserve (ESR), one hundred fifty million barrels of oil will be stored by 1978. The West Hackberry site, a salt dome with existing cavities located in Cameron Parish, Louisiana, has been identified as a candidate site for the ESR because it offers the advantages of large storage capacity, easy access to the distribution network, and a relatively short preparation period. This site-specific EIS analyzes the environmental impacts caused by site preparation and operation.

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Strategic Petroleum Reserve
Early Storage Reserve
West Hackberry
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Louisiana

17c. COSATI Field Group

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SUMMARY

STATEMENT TYPE: ( ) Draft (X) Final Environmental Statement

PREPARED BY: The Strategic Petroleum Reserve Office, Federal Energy Administration, Washington, D.C. 20461

1. Type of Action: ( ) Legislative (X) Administrative

2. Brief Description of the Proposed Action:

The Federal Energy Administration is considering implementation of the Strategic Petroleum Reserve (SPR), Title I, Part B of the Energy Policy and Conservation Act of 1975 (P.L. 94-163) through the development of a 60 million barrel crude oil storage facility at the West Hackberry salt dome. The purpose of the SPR is to mitigate the economic impacts of any future interruptions of the petroleum imports. Under the initial phase of the SPR, referred to as the Early Storage Reserve (ESR), one hundred fifty million barrels of oil will be stored by 1978. Of the different types of storage facilities, existing solution-mined salt dome cavities are among the most attractive for petroleum storage because of the relative low cost of bulk storage and the extreme geological stability of rock salt masses. The West Hackberry site, a salt dome with existing cavities located in Cameron Parish, Louisiana, has been identified as a candidate site for the ESR because it offers the advantages of large storage capacity, easy access to the distribution network, and a relatively short preparation period.

3. Summary of Environmental Impacts and Adverse Environmental Effects:

This site-specific EIS analyzes the environmental impacts caused by site preparation and operation. Construction and preparation of the storage cavities, dock facilities and pipelines would degrade water quality by increasing the amount of suspended particulates, toxic sulfides, heavy metals, arsenic, pesticides and other toxic hydrocarbons. Marine operations (loading, unloading and transporting crude oil) create the risk of oil spills which have the potential to disrupt fish and shellfish production, destroy non-mobile aquatic organisms and birds, and damage marsh vegetation.

Brine disposal into subsurface aquifers and surface water bodies would increase the salinity of the water. The use of ground water for displacement of crude oil during drawdown operations could cause some surface subsidence over water storage areas, slow salt water encroachment and movement of near-surface geologic faults. Beneficial impacts include the economic gains associated with additional employment and income in the Gulf region, as well as protection from economic losses that result from petroleum supply interruptions.

4. <u>Alternatives Considered</u>:

Alternative Storage Sites

- Bayou Choctaw Salt Dome
- Bryan Mound Salt Dome
- Cote Blanche Island Mine
- Weeks Island Mine

Alternative Facility Components

- Alternative Distribution Facilities
  - Alternative Distribution Terminal
  - Alternative Pipeline Distribution
- Alternative Brine Disposal Facilities
- Alternative Displacement Water Supplies
- No Action

5. <u>Comments on the Draft Statement have been received from the following</u>:

Federal Agencies

- Advisory Council on Historic Preservation
- Department of the Army,
  New Orleans District,
  Corps of Engineers
- United States Environmental Protection Agency
- Federal Power Commission
- Department of Health, Education, and Welfare
- Nuclear Regulatory Commission
- Tennessee Valley Authority
- Department of Transportation
- Department of Treasury

State Agencies

Louisiana Air Control Commission

Louisiana State Soil and Water Conservation Committee

Individuals and Organizations

LOOP, Inc. (louisiana Offshore Oil Port)

6. Date made available to CEQ and the Public:

Draft statement was made available to the Council on Environmental Quality and the public in September, 1976. This statement was made available to the Council on Environmental Quality and the public on January 14, 1977.

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1. DESCRIPTION OF PROJECT

1.1 BACKGROUND

This document is a final site specific Environmental Impact Statement (EIS) for the proposed storage of crude oil at the West Hackberry salt dome located in Cameron Parish, Louisiana. This project is part of the Strategic Petroleum Reserve (SPR) program currently being planned by the Federal Energy Administration (FEA). Creation of the SPR was mandated by Congress in Title I, Part B of the Energy Policy and Conservation Act of 1975, P.L. 94-163 (the Act) for the purpose of providing the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. The Act requires that within seven years the SPR contain a reserve equal to the volume of crude oil imports during the three consecutive highest import months in the 24 months preceding December 22, 1975 (approximately 500 million barrels). The Act further requires the creation within three years of an Early Storage Reserve (ESR) of 150 million barrels as the initial phase of the SPR to provide early protection from near-term disruptions in the supply of petroleum products.

A draft programmatic EIS (DES 76-2) addressing the effects of the SPR program as a whole was filed with the Council on Environmental Quality and made available to the public on June 25, 1976. The final programmatic was filed on December 16, 1976. That statement considers several different types of storage facilities, including the use of existing solution-mined cavities in salt formations and conventional mines, the construction of new solution-mined cavities and conventional mines, the use of existing and the construction of new conventional surface tankage, and the use of surplus tanker ships. The draft programmatic EIS should be consulted for a description of each of these storage methods and the potential impacts which might result from its use. The programmatic EIS also assesses the cumulative impacts which could be expected from use of various combinations of the different facility types.

Because of the severe time constraints placed upon the ESR completion schedule by the Act, FEA will use sites which have existing capacity that may be converted to oil storage for this initial phase of the SPR (see Early Storage Reserve Plan, FEA, April 1976). Potential ESR sites include existing solution-mined cavities in salt domes, and existing conventional mines which can be converted into storage facilities in a realtively short time. A total of eight candidate ESR sites have been selected by means of a screening process involving the application of a series of six criteria.* Of these eight candidate sites, only five are alternatives to one another for the purpose of selecting ESR storage sites to supply oil to refineries on the Gulf Coast, on the East Coast, and in the Caribbean. The other three candidate sites can only supply the inland refineries.

In addition to the West Hackberry salt dome, the four other alternative candidate sites able to supply the Gulf Coast, East Coast and Caribbean market areas, include the Bayou Choctaw salt dome (Iberville Parish, Louisiana), the Bryan Mound salt dome (Brazoria County, Texas), the Cote Blanche salt mine (St. Mary Parish, Louisiana), and the Weeks Island salt mine (Iberia Parish, Louisiana). Section 7.1 includes a more detailed discussion of the rationale supporting the selection of the five alternative sites and a brief summary of the impacts associated with each of the other four sites besides the West Hackberry salt dome. Environmental Impact Statements on all five alternative candidate sites (DES 76-4 through DES 76-8, September 1976) have been filed with the Council on Environmental Quality and made available to the public on the same day so that the environmental impacts associated with the possible use of these sites may be compared with one another. EISs are also in preparation for the other three sites and will be made available prior to any subsequent site selection, as described in Section 7.1.

*These criteria are capacity, distribution accessibility, technical feasibility, potential environmental concerns, ease of acquisition and cost. Section II.E.1 of the programmatic EIS describes in detail how the criteria were applied to approximately 300 salt domes and approximately 300 existing mines to select 32 candidate SPR sites, including the eight candidate ESR sites.

1.2 Proposed Facilities

1.2.1 Concept of Storage in Salt Dome

The use of salt domes for petroleum storage is attractive because of both the relatively low cost of such bulk storage and the extreme geological stability of rock salt masses. In addition, being deep underground provides security from natural catastrophes or sabotage. In the Gulf Coast region, over 50 salt domes, both onshore and offshore, appear feasible for development (see Figure 1.1).

Salt domes are a major source of brine feedstock for chemical and salt industries in the gulf region. Cavities are formed by dissolving the salt with circulating water and pumping out the resulting brine (see Figure 1.2). The process requires a large volume of leach water (about 7 barrels fresh water or about 8 barrels seawater for every barrel of space created). Some of these cavities are currently used to store a number of petroleum products. In the U.S., the products stored are primarily LPG products such as propane, ethylene, etc., as well as some fuel oil. Although crude oil storage in solution cavities does not present particular technical problems, it has been done principally in other countries.

Both existing salt dome cavities and new cavities to be developed are being considered for the SPR. Salt domes with existing cavities have been identified as candidates for the ESR because they require less time to prepare for oil storage. Approximately 900 cavities with a total capacity of 300 million barrels are known to exist in salt domes and bedded salt formations. In some cases it is feasible to enlarge existing cavities or to leach additional cavities at selected sites.

1.2.2 Proposed Storage Site

The West Hackberry facility as currently designed would satisfy 60 million barrels of the SPR requirements in the Texoma/Lake Charles/ Beaumont storage region (see Section 1.1.1). The space would be adapted from five existing brine caverns operated by Olin Corporation to provide brine feedstock for manufacture of chemicals. These cavities are suitable for adaptation to petroleum storage and Olin is interested in the program as long as their brine obligations are met. The site is also desirable because of its size and potential for expansion, location with respect to leachwater supplies, and numerous options for nearby port facilities.

Because facility preparation would involve the conversion of existing cavities rather than the creation of new ones, it is anticipated that the planned capacity will be accomplished within a schedule such that all or nearly all of the stored oil could be credited as part of the 150 MMB goal of the ESR. However, the stringent time frame of the ESR would necessitate careful timing in the development of

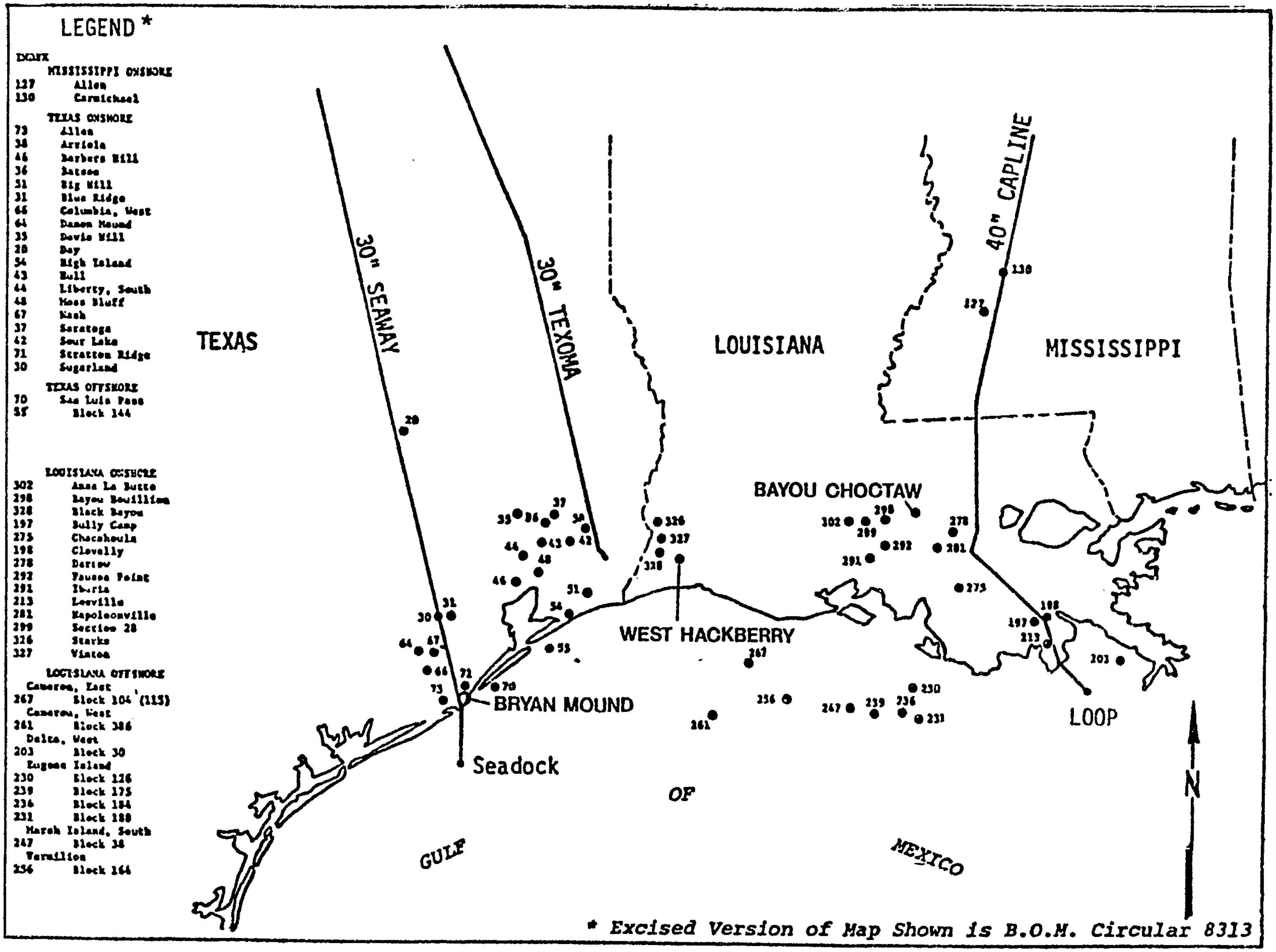

Figure 1.1, Gulf Coast Region Salt Domes

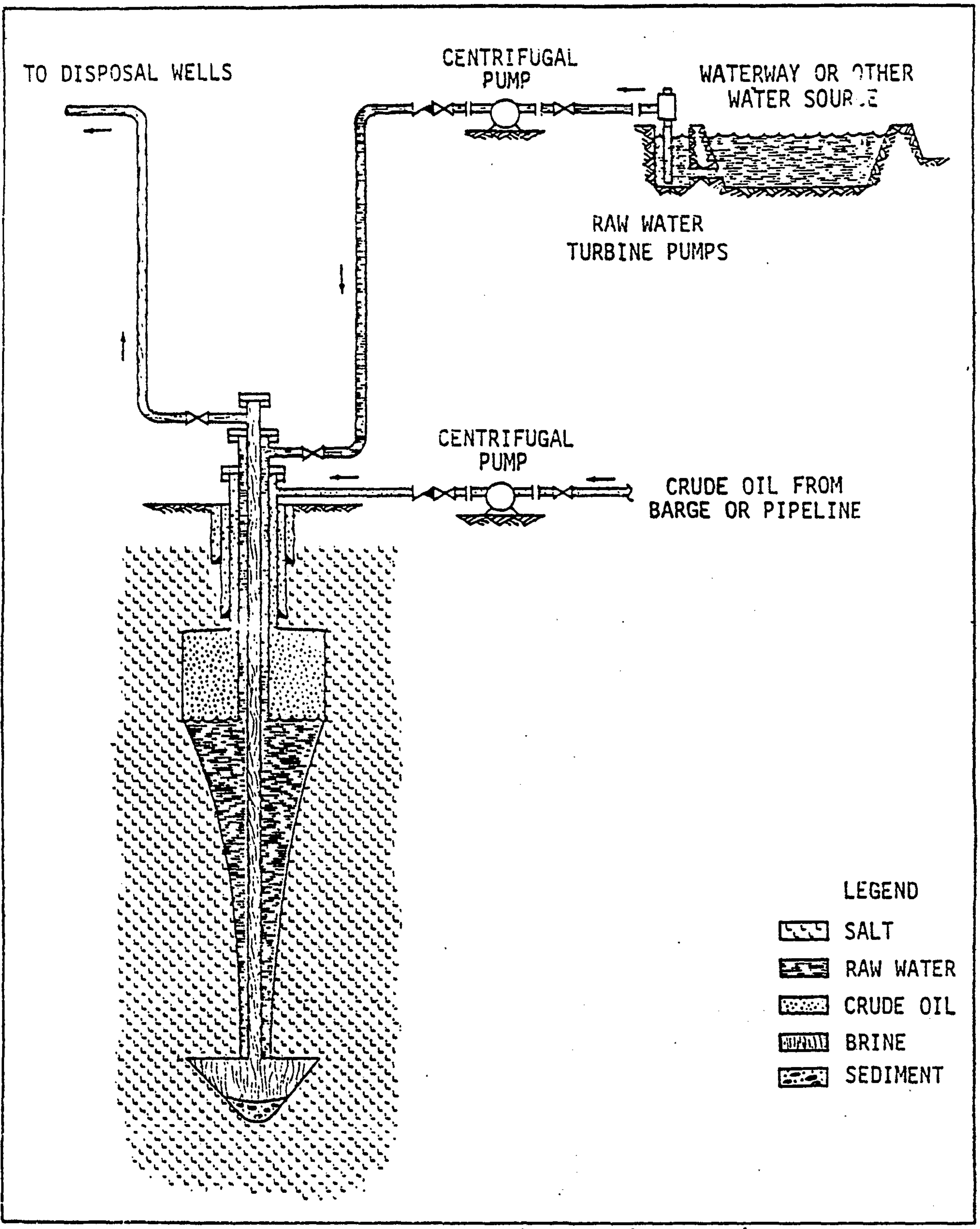

Figure 1.2. Typical Solution Cavity in Salt Formations

the West Hackberry site. As currently planned, temporary pumping facilities and crude oil supplies by barge would be used for early filling operations while the permanent facilities are being constructed. The full distribution system and many of the facilities needed for drawdown operations may not be complete until the end of the 3 year period.

1.2.3 Location

The West Hackberry salt dome is located in north-central Cameron Parish of southwestern Louisiana (See Figure 1.3). Portions of the dome are presently used by Olin Corporation for brine production and by Cities Services for hydrocarbon product storage. The dome area is extensively developed with hundreds of oil and gas wells located on its perimeter. It is among the largest salt domes in the Gulf Coast region with 11.5 cubic miles of salt above the depth of 10,560 feet. The depths to the caprock and salt are 1,234 and 1,960 feet, respectively. Little or no mining has taken place in the caprock.

Road access to the dome from Lake Charles is via State Highway No. 27. Hackberry, the local unincorporated town of 1,300 population, is approximately 4 miles east of the proposed site. Sabine National Wildlife Refuge lies approximately 2 miles to the south.

The salt dome exhibits two topographic expressions. The western portion of the dome is overlaid by a definite mounded area from 2 to 21 feet in elevation. It is the highest point in Cameron Parish with an area of about 890 acres elevated above 5 feet, (48.6% of the area above the 2,000 feet depth of salt contour). The eastern half of the dome area is covered by lakes and marsh.

A network of gravel roads serves the brining and storage facilities on the western portion of the dome. No difficulty is expected in the construction of additional roadways in this area. The eastern portion of the dome is served by canals allowing barge access to most of the area. Developing road access to the eastern portion of the dome will incur substantial cost.

Barge access to Black Lake from the Intracoastal Waterway is via an 80 to 150 wide canal 3.8 miles long. This canal is presently navigable by 6 to 7 foot draft barges.

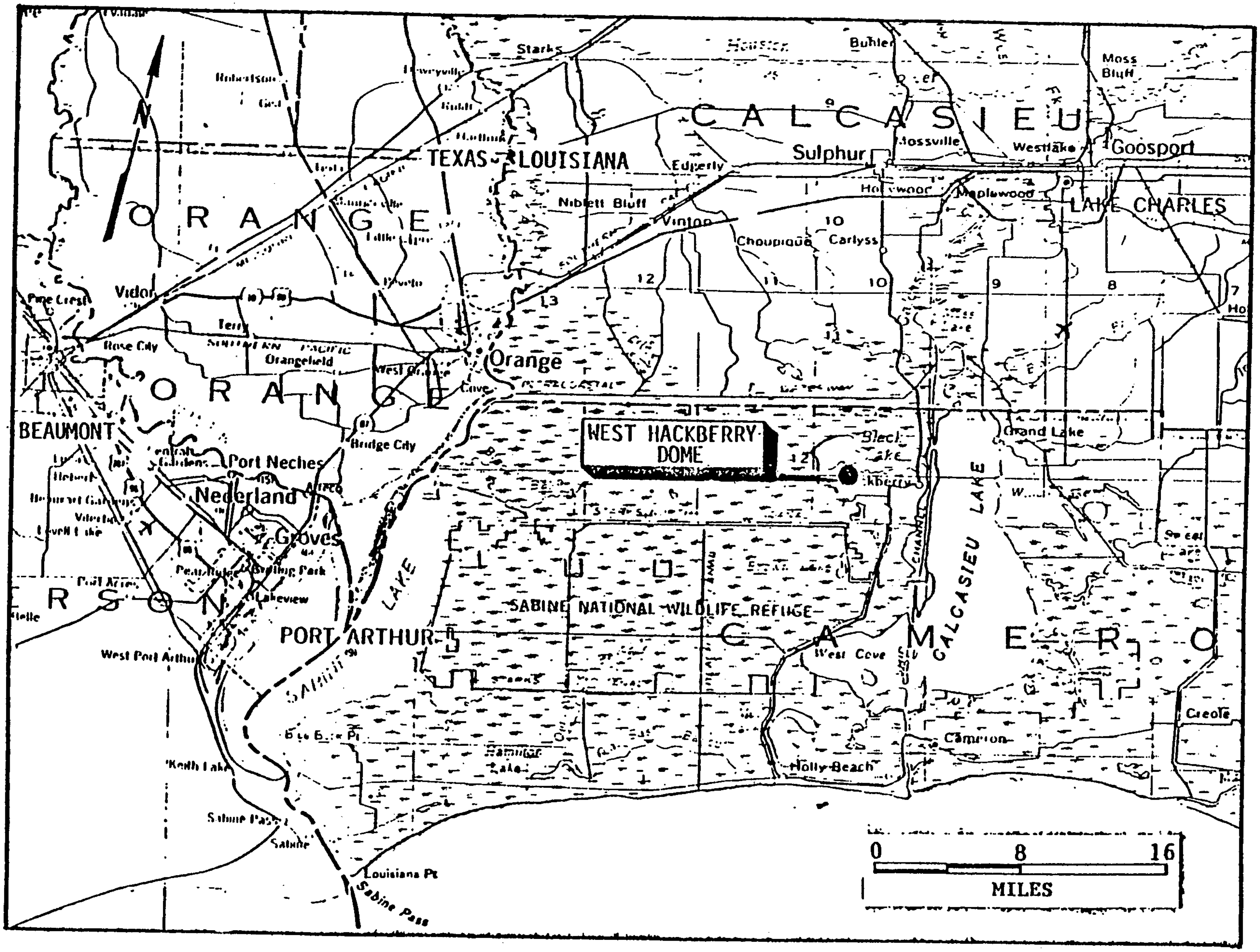

Figure 1.3 Location Map - West Hackberry Dome.

The site is favorably located with respect to ship terminals at Lake Charles about 30 miles away (see Figure 1.3). For the proposed facility, a new ship terminal is planned on the Calcasieu Shipping Channel within 4 miles of the site. Tankers serving the area would, however, be limited to the 40-foot draft capability of the channel.

West Hackberry is near existing pipelines. The Cities Services 20-inch pipeline serving their Lake Charles Refinery is 10 miles north of the site. The Texas 22-inch pipeline serving refineries at Beaumont and Port Arthur is 8 miles north of the site. The 26-inch Texoma pipeline terminal at Nederland, Texas is located about 50 miles to the west.

Both of the proposed superports, LOOP and Seadock, are located such that distribution through these facilities is not presently being considered.

The proposed facility is located within 50 miles of nine major refineries. Table 1.1 lists these refineries.

Development Capacities

The 5 caverns at West Hackberry developed by Olin Corporation and its predecessors provide a gross storage capacity of 64,025,000 barrels. Olin has officially informed FEA that all of the capacity can be made available under mutually agreeable terms providing its brine requirements and existing obligations are not affected.

Crude oil storage at West Hackberry has been considered on the basis of the net volume of initial cavern capacity available rather than the gross cavern volume.
In any salt storage cavern facility, allowances have to be made so that a cycling program can be conducted without repositioning the displacement casing. The net usable volume of cavern capacity, in the case of fresh water displacement, will increase after each cycle. The West Hackberry facility has been designed for 5 fill and withdrawal cycles, which will create a gross volume enlargement of about 77 percent. There must also be sufficient volume allowed below the displacement casing to store the insoluble material which will fall out as the salt is dissolved. The present sizing of surface wellheads, piping and pumps, however, is premised on the design rate associated with 150-day fill or recovery operations considering net initial capacity only. Based on these

Table 1.1. Beaumont/Port Arthur/Lake Charles Refineries

Company and Location	Capacity (BPD)	Distance (Mi.)
Cities Service - Lake Charles	268,000	14
Conoco - Lake Charles	83,000	18
American Petrofina - Port Arthur	26,000	45
Gulf - Port Arthur	312,100	45
Mobil - Beaumont	325,000	54
Texaco - Port Arthur	406,000	45
Texaco - Port Neches	47,000	44
Union - Nederland	127,000	48
Sun	N/A	54

considerations, the total net storage volume for the 5 caverns is approximately 60 million barrels (see Table 1.2).

The West Hackberry salt dome has a capacity for leaching additional caverns. It has a surface area of about 2,000 acres within the 2,000 foot salt contour. Olin Corporation controls about 500 acres with only 5 wells. Cities Service controls about 80 acres with 9 wells to the southeast of the Olin property. Assuming 20 acre spacing (933 foot well centers), and a minimum of 1,000 undeveloped acres, a total of 50 ten million barrel caverns could be developed there.

1.2.4 System Description

General Facilities

The presently planned SPR facility involves only the conversion of existing brine cavities to bulk crude storage. Hence no leaching of new cavities is considered within the preliminary designs described in this report. Crude oil supplies for filling the salt cavities are planned from 2 sources. Initially, a temporary dock would be built on an existing canal adjacent to the storage site (see Figure 1.4) and would be used in filling 2 of the cavities while the permanent facilities were being constructed. Then a new permanent tanker dock is planned on the Calcasieu Shipping Channel, some 4 miles east of the storage site (see Figure 1.4). Medium sized tankers (up to 50,000 DWT) could then supply the storage facility via a new pipeline connection.

The crude oil supplies would be injected into the salt caverns through the well tubings by pumps located at a central pump building on the storage site. The existing brine in the salt cavity is thus displaced, and the resulting brine (except that portion which can be marketed as feedstock for chemical industries) must be disposed of. The present plan for brine disposal is to drill a number of deep subsurface injection wells to be located off the southern flanks of the dome as shown in Figure 1.4 and to pump the waste brine into deep saline aquifers.

For withdrawal of the stored oil, displacement water taken from Black Lake Bayou (see Figure 1.4) would be injected into the storage cavity through the well tubing, pushing the crude oil out and through the pipeline to the distribution terminal at the shipping channel.

Table 1.2 Net Storage Capacity

Cavern No.	Gross Volume (Barrels)	Cavern Depth (Feet)	Sump Volume (Barrels)	Net Oil Storage Vol. (Barrels)
6	14,583,000	3,404	900,000	13,683,000
7	14,137,000	3,498	850,000	13,287,000
8	17,800,000	3,453	1,000,000	16,800,000
9	9,341,000	3,597	500,000	8,841,000
11	8,164,000	3,797	450,000	7,714,000
	64,025,000		3,700,000	60,325,000

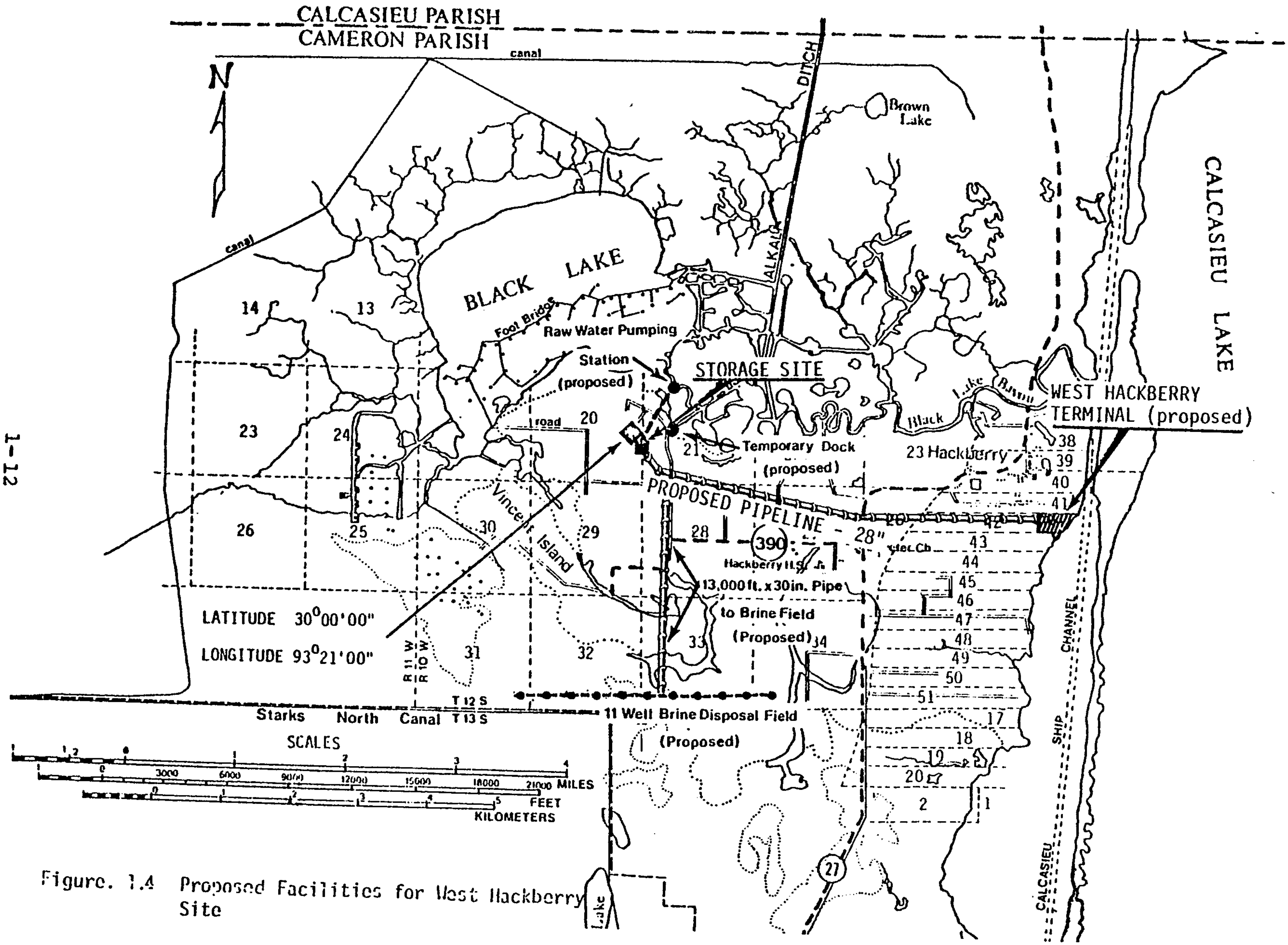

Figure. 1.4 Proposed Facilities for West Hackberry Site

As currently planned, the temporary dock would be used for initial fill operations only, and not for distribution.

1.3 SITE DEVELOPMENT AND CONSTRUCTION

1.3.1 Physical Facilities

The proposed facility would involve the conversion of the 5 existing brine cavities. The Olin facility layout as it now exists is shown in Figure 1.5. Conversion to a crude oil storage facility, as presently planned, entails the following developments:

Temporary Facilities

Initial crude oil fill operations are planned via a temporary barge dock to be located on the nearby Alkali Ditch from which supplies are unloaded through a temporary pipeline and custody transfer unit into caverns Nos. 9 and 11. It is assumed that an average of 20,000 barrels per day can be barged to the temporary facility; therefore, only one cavern and one disposal well would be required.

The temporary components planned are one 1,000 barrel oil surge tank, one 1,000 barrel brine tank, one diesel crude injection pump, and one diesel brine injection pump. The temporary pumps, located on skids, are sized to handle up to 1,000 gallons per minute. Initially, 150 gallons per minute of the displaced brine can be utilized by Olin, but the disposal system is designed to handle the full amount produced.

It is not anticipated that oil recovery facilities would be required during the temporary fill period.

Permanent Facilities

Cavity conversions planned for the storage facility call for the drilling of 3 new wells to allow additional penetration into caverns Nos. 6, 7, and 8. The existing wells in these caverns would be modified for oil injection or withdrawal and the new wells would handle brine displacement or raw water injection (see Appendix H).

At this particular site, the plan is to bury the various onsite pipeline connectors. This is standard procedure for plants located on high and dry land, especially when utilized for grazing. Some portions of the brine disposal

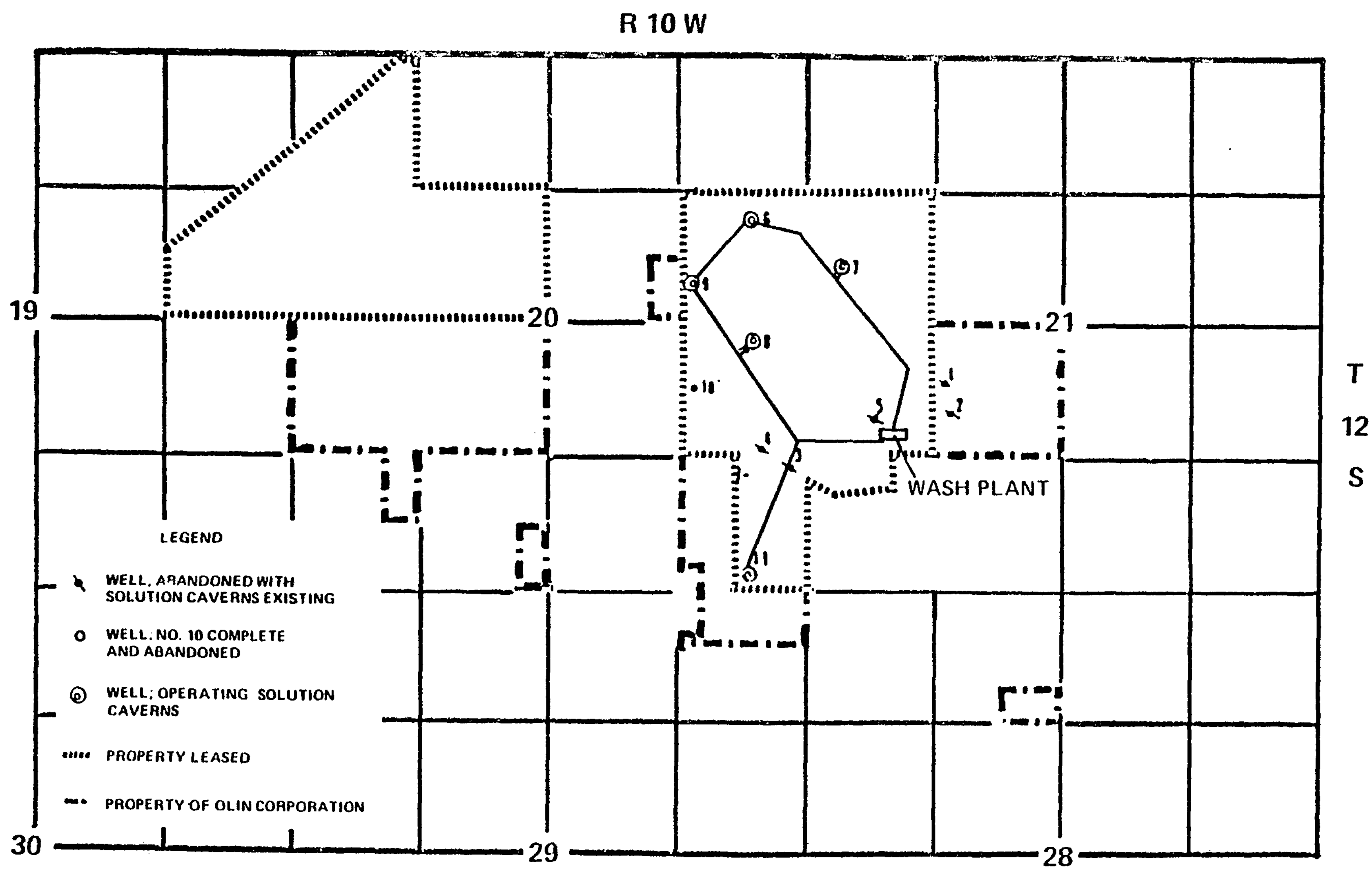

Figure 1.5. Plot Plan - Existing Brine Operations

line which extend over marsh areas may be supported on piles above the surface. A tentative pipeline flow diagram for the permanent facility is shown in Figure 1.6.

As shown in current designs for permanent systems component, all pumps and equipment are electric, the power being supplied by local utilities. No onsite backup generation is currently planned. Crude oil supplies and distribution would be handled by a new tanker terminal to be constructed on the Calcasieu Shipping Channel approximately 4 miles east of the site (see Figure 1.4). The tentative location for the brine disposal deep well injection system is about 2 miles directly south of the salt dome as indicated in Figure 1.4. The planned location of the raw water intake station for displacement operations is in a portion of Black Lake Bayou, some 2,000 feet north of the proposed central pump station (see Figure 1.4). The central pumping and control buildings are to be located at the site of the existing wash plant for the Olin brining plant at the end of the southwest leg of the Alkali Ditch (see Figure 1.4). More detail on each of the proposed system components is discussed in the following subsections.

Buildings and Other Structures

According to preliminary designs, all oil injection pumps, brine injection pumps, and raw water injection pumps would be housed in a central pump building located near the existing Olin wash plant (see Table 1.3 for pump specifications). Another building would be required to house the main office, all electrical control equipment, a repair shop, and a chemical lab. At this lab, brine samples would be analyzed to calculate the rate of new leaching (in the case of existing cavities, additional leaching is caused by the introduction of displacement water). Also, tests would be conducted on crude oil samples to determine their compatibility with other stored oils.

Buildings required for housing pumps, control equipment, laboratory, and repair shops would be built on concrete slabs. In cases of insufficient soil bearing strength, reinforced concrete piles would support beams upon which the floor is laid.

Two 10,000 barrel brine tanks (nominal 45 foot diameter, 40 foot height) would be needed to provide surge capability for the injection pumps and for settling some insolubles in order to protect the pumps and well screens from clogging.

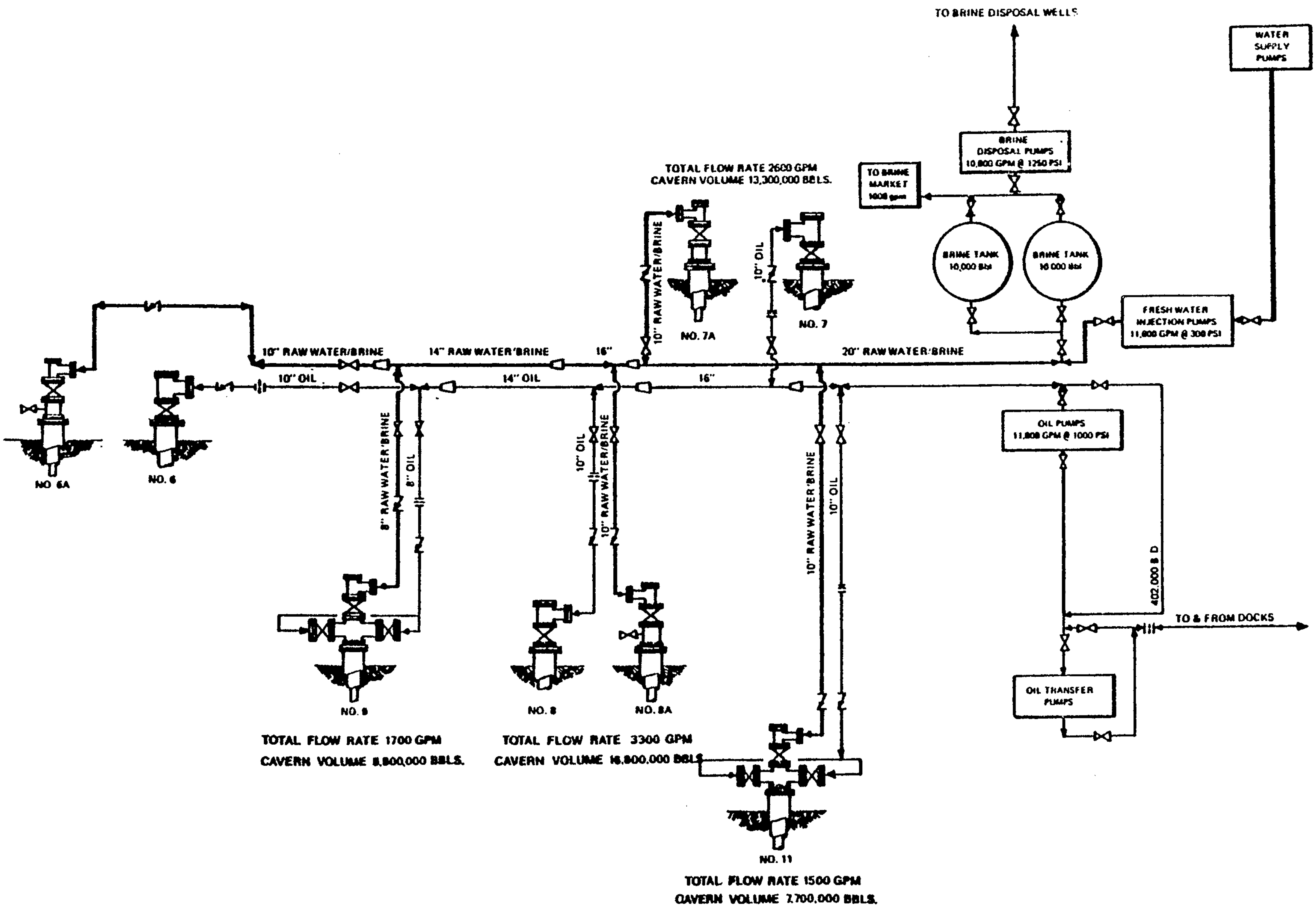

Figure 1.6, Flow Diagram - Permanent Facility

TABLE 1.3 PROPOSED PUMP SPECIFICATIONS

	Quantity	H.P.	R.P.M.	p.s.i.	Description	Total Design Rate (gpm)
Oil Injection	8	1250	3560	1000	8 Stage Horizontal Centrifugal	11,800
Displacement	8	600	3560	500	4 Stage Horizontal Centrifugal	11,800
Brine Disposal	8	1500	3560	1250	7 Stage Horizontal Centrifugal	11,800
Water Supply	8	75	1760	50	Single Stage Vertical Turbine	11,800
Tanker Loading	3	400		50	Single Stage Vertical Turbine	28,000
Pipeline Transfer	2	600		135	Single Stage Vertical Turbine (Series)	11,800

At West Hackberry, disposal is planned as a closed system, i.e., not exposed to air. Brine tanks would be of standard steel tank construction. The crude oil surge tanks would be of the standard plate steel floating roof type. Two 400,000 barrel oil surge tanks, as presently planned, are located at the distribution terminal. The required tanks are planned as floating roof structures, commonly used in the oil industry for this application and are approximately 250 feet in diameter and 48 feet in height.

In the case of all surface oil tankage, retention dikes are planned as required.. Dike enclosures are a standard engineering practice for compliance with this regulation.

On solid dry ground, such as exists at the West Hackberry site, the wellheads at the storage wells would not require special structures such as platforms, and in the case of multiple entry wells, the wellheads would be simplified and designed for operation without repositioning the displacement tubings. As currently planned, 3 of the storage caverns would require new wells equipped with wellheads designed for brine output and raw water injection only. The existing wells would be equipped with new wellheads for crude oil injection or withdrawal.

Brine Disposal

The proposed method of disposal for the saturated brine (about 265 ppt) displaced during crude oil fill operations is deep well injection into subsurface saline reservoirs off the southern flanks of the salt dome. At the required oil injection rates, an average of 11,800 gallons per minute (16,850 barrels per hour) would be produced. Olin Corporation plans to increase its brine requirements from the dome and may be able to take up to 1,000 gallons per minute of the brine for feedstock. The facility disposal system, however, would be sized to handle the worst case condition, or the full 11,800 gallons per minute.

A linear brine disposal field would be used for constructing the required disposal wells (see Figure 1.4). A right-of-way would be cleared and a roadway built the length of the system. A pad of fill would be required at each well where sufficient dry land is not available (see Section 1.3.1.2). As in the storage cavity wells, the brine injection wells would be drilled by standard oil well rigs.

Eleven disposal wells are planned. They would be drilled to between 5,000 and 7,000 feet and are spaced on 1,000 foot intervals. A 13,000 foot by 30 inch pipeline feeder would be constructed between the central pump building and the disposal line (see Figure 1.4). About half of the disposal well corridor, if located as shown, would be situated on dry land and half in marsh. Of the dry land portion, only the wellhead and a small fenced area (about 200 by 200 feet) at each well site would be left exposed. In the marsh portion, an access road (about 40 to 50 feet wide) on several feet of elevated fill would be constructed the length of the system, and a pad of fill (about 200 by 200 feet) would be required at each well location. The pipeline connectors may be supported on piles above the marsh along the edge of the roadways as an alternative to burial.

The other components of the brine disposal system are the two 10,000 barrel brine tanks and a battery of eight 1,500 horsepower injection pumps located in the central pump building. The proposed disposal system is to operate at a pressure of 1,250 psi (see Table 1.3).

Raw Water Supply

The first option for raw water supplies at the West Hackberry facility is to obtain water from Black Lake Bayou which connects Black Lake with Calcasieu Lake. The intake station would be built on a platform over the channel. Design has not been completed, but construction would involve the driving of piles and the erection of steel grating for the platform and walkway to shore (approximately 1,000 feet). The intake portal and screen design has not been completed, but according to standard engineering requirements, it would be sized to create a maximum velocity of 0.5 feet per second through the intake screen.

The tentative location for the intake structure is approximately 1,500 feet north of the central pump building in the channel of Black Lake Bayou, some 1,400 feet southeast of its lake entrance (see Figure 1.4). The entire area from around the Bayou to near the designated storage caverns Nos. 6 and 7 is currently flooded due to gradual increases in lake levels as reported in Section 2.2.1.1. A walkway connecting the intake structure to dry land would be required.

For total displacement of 60 million barrels of crude oil over a 150 day period, the rate of raw water required is an average of 11,800 gallons per minute. Although the design of the platform and intake portal have not been specified, it has been indicated that platform and walkway would be constructed of concrete piles and steel grating and that the portal would be designed according to standard engineering practice and in compliance with Hydraulic Institute Standards. Further discussion of factors pertaining to the intake structure and possible effects of withdrawal from Black Lake are found in Section 3.2.4 (p. 3-26).

The second option for a raw water source is to construct fresh water wells at a depth of 700 to 1,000 feet. These wells have been tentatively located south of the storage site over the 7,000 depth to salt contour. Details of this alternative may be found in Section 7.2.3.

Crude Oil Distribution

The West Hackberry dome has multiple options for the supply and distribution of crude oil. For initial filling of caverns Nos. 9 and 11, a temporary barge dock has been planned at the end of the southwest leg of the Alkali Ditch (see Figure 1.4). A timber dock similar to the existing docks at the nearby tank batteries would be used. This southwest trending leg of the Alkali Ditch must be cleaned out to its original 7.5 foot depth and 40 foot channel width to accommodate 5,000 barrel barges. Tangent to the canal and near the temporary dock facility, a tug turnaround approximately 200 feet in diameter is planned. The banks of the turnaround would be sloped at about 25 percent to minimize resilting. Due to the temporary nature of the facility, revetments, or bulwarks would not be required. Construction of the facility would involve roughly 35,000 cubic yards of dredge material. The dredging operation would be hydraulic and the spoil would be deposited on the original bank on the northwest side of the channel. Mooring dolphins would probably consist of 18 inch diameter, concrete piles driven to an approximate depth of 60 feet. The ensuing barge traffic at the temporary dock will be 4 to 5 barges per day for a total delivery of 20,000 barrels per day.

For the second phase of the fill operations and for later emergency distribution, a permanent dock would be built on the Calcasieu River Canal, approximately 4 miles east of the storage site. The permanent crude oil distribution terminal on the Calcasieu Shipping Channel is to be developed in such a way that intermediate barge fill from that location would be started as soon as the 4 mile pipeline connection is completed at month 24 (see Table 1.4). Then the tanker docks would be utilized as soon as each is completed. According to tentative schedules, dredging and site preparation would take 4 months; the completion of the first dock will require 15 months; and the completion of the second dock would take an additional 3 months. An estimated 2.5 million cubic yards of material would be dredged to create two 40 foot deep tanker berths at the terminal. As presently planned, the spoil would be deposited in designated confined spoil areas on either side of the ship channel. Because of periodic channel maintenance dredging, dredge spoil disposal has created levees on either side of the channel. The docks at the terminal location would provide mooring and loading/unloading systems for two 50,000 dwt (350,000 barrel) tankers or oil transport barges (see Figure 1.7). Designs are not available for the docks, but each would be approximately 1,000 feet long, requiring 2,500 feet to 3,000 feet of shoreline.

Based on net total existing capacity, 60 million barrels of crude oil would be handled by this facility. In designing to meet the stringent time requirements of the ESR, crude withdrawal is planned for a 150 day turnover. This requires an average withdrawal rate of 400 thousand barrels per day.

The dock facility design concepts provide for mooring, loading and unloading both tankers and barges, plus facilities for handling wastes and for the control of spills as required. The major construction activities at the terminal, besides dredging and dock construction, are the erection of the storage tanks, the containment dikes, and the installation of metering and pump station facilities, and security systems.

The construction of the 4 mile pipeline connection to the storage site would involve conventional dry land construction techniques. The pipeline must comply with Department of Transportation standards and applicable regulations.

At the terminal site, a chain link fence would enclose the tanks and other facilities. A 900 by 500 foot diked area would contain the 2 crude oil surge tanks, one for each dock. Each tank is sized to hold 400,000 barrels and would be approximately 260 feet in diameter and 48 feet in height. Another diked area, approximately 550 by 250 feet in size, would contain the ballast water tanks and treatment facilities. These include two 100,000 barrel ballast water tanks, one 15,000 barrel emulsion treatment tank, and one

Table 1.4 Timetable for Conversion and Fill

Month Period	Fill Rate (MB/D)	No. of Months	Cum. Storage (MMB)	Phase of Development
0-7	0	7	0	Site preparation
7-24	20.0	17	10.2	Early fill: Via temporary barge facility.
24-30	132.7	6	34.0	Intermediate fill via pipeline from partially completed terminal.
30-33	266.7	3	60.0	Completed fill: completed tanker terminal

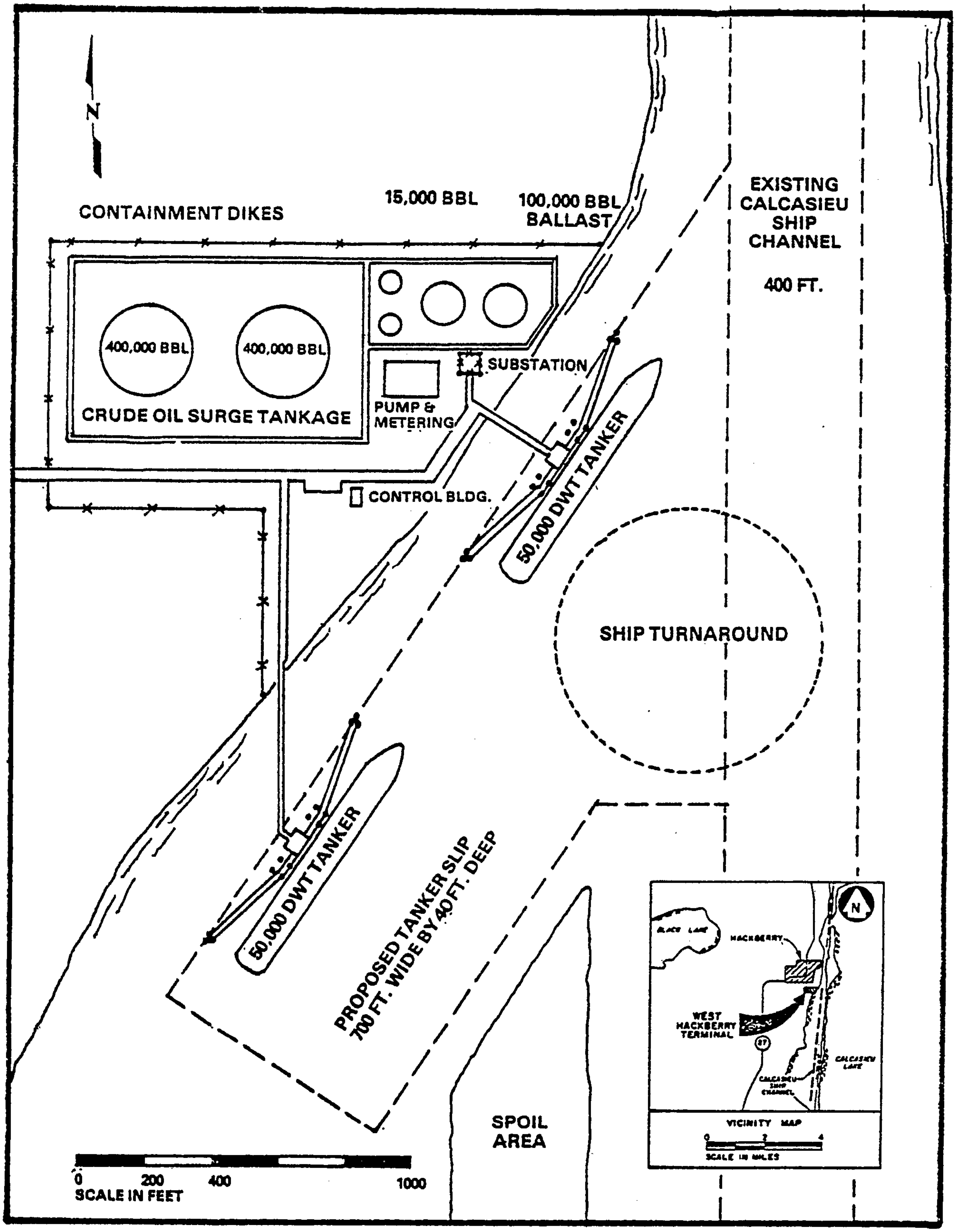

Figure 1.7 Proposed Distribution Terminal

15,000 barrel slop tank which would collect the waste oils that may be sold. The ballast treatment equipment consists of a mechanical oil/water separator and 2 small pumps. The ballast would be treated so that a maximum of 15 ppm oil in water would be discharged into the channel. Also to be treated by this facility is rain runoff from the dock areas and oily surface waters taken from minor routine spills around loading and unloading tankers. The potentials for these and more major spills are discussed in Section 3.7.2.

At the designed distribution rate of 400 thousand barrels per day, the ensuing tanker traffic during the 150 day withdrawal period would be one to two tankers per day. Tankers of up to 65,000 DWT (about 450,000 barrel loads) may be employed, at which time only one tanker per day would be required. But more likely, because of scheduling tankers for delivery, and the traffic problems created by tankers of great size in such a narrow channel, a combination of tanker sizes up to 50,000 DWT is planned.

Transfer of the oil to and from the storage site would be via a 4 mile single 24 inch pipeline. Main transfer pumps are two 600 horsepower pumps in series with an aim to deliver the required 400 thousand barrels per day (11,800 gallons per minute) to the manifold side of the injection pumps at the storage site. During oil withdrawal operations, the oil displaced from each cavern would have enough pressure at 150 psi minimum for delivery to the distribution terminal without transfer pumps at the storage site. Three 400 horse power tanker loading pumps are proposed for loading from the terminal surge tanks. Alternative distribution systems may be considered for longer term plans. These alternatives are discussed in Section 7.4.1.

The overall intention of the distribution system would be to eventually link all of the SPR sites in the Beaumont/Lake Charles area into a comprehensive system to provide maximum flexibility.

1.3.2 Land Requirements

Olin Corporation controls 500 acres of the approximately 2,000 acres over the West Hackberry dome. The storage site of existing well cavities amounts to approximately 240 acres.

Intake stations on Black Lake Bayou for leachwater supplies would require less than one acre (size depending primarily on the number of intakes needed), (See section 1.3.1).

The present design for a brine disposal field would require 13,000 foot by 50 foot right-of-way from the storage site to the field. Eleven disposal wells at 1,000 foot spacing would require an additional 10,000 foot by 50 foot right-of-way and eleven 200 by 200 foot well pads. This amounts to a total of approximately 36 acres (25 acres for rights-of-way and 11 acres for well pads) to be developed for a brine disposal system.

The 4 mile (21,000 ft) distribution pipeline to the Calcasieu terminal would require a 100 foot right-of-way for the dual pipeline requiring approximately 48.5 acres for right-of-way plus approximately 28 acres for onshore facilities at the terminal.

In total, approximately 352 acres are needed for the project as planned.

1.3.3 Road Construction and Other Grading

The western half of West Hackberry dome is situated on dry ground ranging in elevation from 2 to 21 feet, the highest point in Cameron Parish. The existing brine facility is located at the northern extremity of this mound, near the shoreline of Black Lake. Thus, roads and buildings would be situated on higher ground.

Additional road construction would be minimal and related primarily to the construction of the brine disposal field. Approximately 1 mile of the brine disposal line, as tentatively planned, would be situated on dry level terrain and would require minimum grading and graveling. Another mile of the line would be situated over marshland (see Figure 1.4) which would require a roadway to be constructed on elevated fill of 1/2 foot and 40 to 50 feet in width. In addition, 6 of the 11 disposal wells fall in marsh and would require raised fill for construction and operation pads, each covering an area of approximately 200 by 200 feet. Part of this area (approximately 50 by 50 by 5 feet), at each site would be used as a drilling mud pit. After completion of a well, the recoverable drilling fluid would be removed for reprocessing and the pit would be reclaimed.

Other grading would be required to construct a 5-foot levee to safely contain the volume of the oil surge tanks at the distribution terminal (see Section 1.3.1). The distribution terminal site, as shown in Figure 1.7, involves two dike enclosures, 1 of approximately 900 by 550 feet, and one of approximately 550 by 250 feet. The building of these dikes involves the moving of roughly 10,750 and 5,925 cubic yards of earth respectively over a total of 14.5 acres.

1.3.4 Pipeline Construction Techniques

Three basic methods may be used during the construction of the offsite pipelines: (1) flotation canal method, (2) push ditch method, and (3) conventional dry land method.

The flotation canal method of construction is required in the marsh portions of a pipeline route where the ground cannot support heavy construction equipment. Therefore, the work must be done on construction barges operating in a canal.

For the pipeline routes presently planned, flotation canals would not be required since marsh areas would not be involved. If alternate routes are chosen, however, as discussed in Section 7.4, marshlands to the north, south, and west of the site may be crossed. Portions of these marshes would undoubtedly require barge lay construction for the alternate pipelines, but the majority could be constructed using push ditch and conventional methods.

The push ditch method of construction would be used in the swampish portions of the pipeline route where the ground can support marsh buggy mounted excavating and backfilling equipment, but cannot support conventional dry land pipeline construction equipment. Experience has shown that the push ditch method greatly reduces potential environmental damage and it has been proven feasible for lines in excess of 40 inches in diameter.

Conventional construction would be used through the dry land portions of the route where heavy construction equipment can be supported. The proposed pipeline routes are situated on dry land except for a portion of the brine disposal line (see Section 1.3.1).

Flotation Canals

In the flotation canal method, a canal is dug along the route to accommodate construction barges. The canal would be dredged to provide a water depth of approximately 7 feet and a channel width 40 to 50 feet wide at the bottom and up to 75 feet wide at the top. The marine equipment needed for construction are a dredge, a pipe lay barge, materials barges, personnel boats, and special equipment barges required for tie-ins and work at pipeline crossings. The required right-of-way would range from 100 to 150 feet.

One or two pipe ditches would be dug in each flotation canal, as required, to accommodate the proposed pipeline(s). The spoil removed in dredging the flotation canal and pipe ditches would be stored along both sides of the flotation canal until after the pipelines have been installed.

The pipe lay barge, approximately 40 to 50 feet wide and 400 to 450 feet long, travels along the flotation canal while the joints of pipe are being welded together. The completed pipeline is then lowered off the stern of the barge into the pipe ditch(es).

Push Ditches

In the push ditch method, a right-of-way approximately 100 feet would be cleared, and the ditch(es) would be excavated with the centerlines of the ditches approximately 20 feet apart.

Four or five push sites would be selected at convenient locations along the proposed route. These sites would be used to assemble the pipe joints into a completed pipeline and to push it to its final location. The fabrication and assembly of the pipeline consists of welding together joints of pipe, each approximately 40 feet long, on the push site. 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 ditch with the front end of the pipeline to guide 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 pipe to sink to its final position. Draglines, mounted on marsh buggies, would travel along the right-of-way filling the ditch with the spoil which was stored along the sides.

Conventional Pipeline Laying

With the conventional dry land method, a right-of-way width of approximately 100 feet would be cleared. Excavation equipment will dig the pipe ditches. The pipe joints would then be strung along the pipe ditches, welded together, the required corrosion protection applied, and the pipe would be lowered into the ditch and backfilled in accordance with 49 CFR Part 195.

1.3.5 Preliminary Development Timetable

According to present plans, during the first 7 months of site preparation and facility conversion, the temporary barge dock would be constructed and the canal dredge operations conducted; the caverns planned for early fill would be tested and converted; one brine disposal well would be drilled; and temporary pumps and pipelines would be installed. Early fill via the temporary facility would take place over the next 17 months while the permanent facility components are being built. During this period, the brine disposal wells and additional cavern entry wells would be drilled; all pipelines would be constructed and tested; all pumps, metering, buildings, and security systems would be installed; and the distribution terminal facility would be constructed to allow intermediate barge fill from that location. During the 6 months of intermediate barge fill, the first tanker dock would be completed. After 3 months of intermediate tanker fill from the first dock, it is anticipated that the 60 million barrel design capacity would have been reached, at which time the second tanker terminal and all facilities required for emergency drawdown operations would be completed and in place (see Table 1.4). Present life expectancy for the project is 20 to 25 years.

1.4 OPERATION AND MAINTENANCE PROCEDURES

1.4.1 Operating Procedures

1.4.1.1 Storage Phase

When the storage facility has been completed and design capacity is reached, 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 operations personnel available.

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 West Hackberry facility design provides for oil return bypass valves to allow intermittent recovery of already stored oil.

Equipment Testing and Maintenance

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

1.4.1.2 Extraction Phase

The SPR program requirements plan for an emergency deliverability of stored oil over a 5 month period. Thus, delivery rates for a 60 million barrel facility are 400 thousand barrels per day. The facility's systems are designed to handle this maximum capacity.

Recovery Process

Crude oil stored in each salt cavity is recovered by pumping raw water into the bottom of the cavity, thus displacing the oil through the anular space at the top of the cavity. The oil leaves each wellhead at 150 psi, a pressure capable of transporting the oil via pipeline to the distribution facility.

Distribution

The new terminal to be built on the Calcasieu Shipping Channel is planned as the distribution point for the facility. During emergency distribution, both barge tows and 50,000 DWT tankers would transport the supplies to local refineries in Lake Charles, Port Arthur, and Beaumont; to the Texoma or Seaway terminals at Nederland and Freeport; and possibly to the East Coast and Carribean markets as well. The ensuing tanker traffic would be one to two tankers per 24 hour day (see Section 1.3.1).

1.4.1.3 Refill Phase

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 10 month period.

Refill Process

The refill process is the reverse of the recovery process. The crude oil is injected into the top of the storage cavity, thus displacing the brine, which in turn goes to the disposal wells. The brine disposal systems and distribution system is sized to handle a fill rate equal to the initial fill rate, i.e., 11,800 gallon per minute or 400 thousand barrels per day for a 5 month period.

Refill Capacity

Five fill and withdrawal cycles are designed for the SPR. Although for leached cavity facilities the cavern capacity enlarges during each cycle, due to the introduction of fresh water, only the original design capacity for each cavity would be refilled. The fact that a smaller percentage of fresh water would be introduced into the cavern during successive fill operation reduces somewhat the continued leaching process. Since caverns Nos. 6 and 9 are separated by only 50 feet of salt, even limited continued leaching is expected to cause coalescence after a few refill cycles, but as discussed in Section 3.1, the integrity of the caverns should not be adversely affected.

1.4.2 Safety Precautions

1.4.2.1 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 and would be visually inspected 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.

1.4.2.2 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 would be equipped with standard sprinklers and foam fire prevention systems.

1.4.2.3 Corrosion Protection

All buried portions of the pipelines would be externally coated with a cathodic protective coating and protected by impressed electrical currents. Sealed casings are required at highway or railway crossings, with insulators and spacers to electrically isolate the pipelines from the casing.

1.4.2.4 Protection from External Damage

All electrical equipment and control systems would be housed in buildings, elevated on fill where required for protection against most flooding.

Protection of the pipelines from external damage would be provided by burying them and by marking their location. Additional weight and mechanical protection for that portion of the pipeline in areas of swamp or marsh, and at waterway crossings, would be provided by the external coating of wire-mesh reinforced concrete.

1.4.2.5 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 piped into a central waste oil sump. Waste oil collected in this manner would be either returned periodically to the storage system or sold to local "slop oil" marketers.

All surface tanks are required to be enclosed in adequate retention dikes to protect the area environment from leakage of oil or brine (40 CFR 112.7).

1.4.2.6 Security

Main storage site facilities would be surrounded by fence to reduce any danger to the public and to prevent any interference with the facility by unauthorized persons or by animals. Since the facility operates on a 24-hour basis, personnel would be on duty at all times. Pump stations would be surrounded with chain link fences. All fenced facilities would have warning signs posted conspicuously to warn the public of the nature of the facility.

Security measures for the facility are standard for petroleum storage facilities. The main storage site is fenced and properly lighted. All wellheads have pneumatic gate valves on brine and crude lines to allow for remote control. These controls plus all electrical equipment are housed in a security building. Also, all pipelines are monitored with pressure switches plus visual inspection of the line for early detection of leaks. The facility maintains standard fire prevention systems and warning devices.

In event of a severe storm, power supply lines would most probably be affected and the various buildings or water supply and discharge lines might be damaged. All crude pipelines are buried, however, and the oil in underground storage cavities would be safe from conceivable disaster. Should a wellhead at a storage cavity be damaged, it is estimated that a maximum of 100 barrels of oil would escape.

2. DESCRIPTION OF THE ENVIRONMENT

2.1 LAND FEATURES AND USES

2.1.1 Evolution of Salt Domes

The West Hackberry salt dome is one of nearly 450 salt domes in the Gulf Coast region of the United States and Mexico. The salt in these domes was originally deposited in a broad shallow sea during Jurassic time (130 to 200 million years ago). Since then the salt basin was buried to depths of 15,000 to 35,000 feet by pelagic sediments of the Cenozic age. In general the salt was deposited in horizontal beds, but due to alternating periods of deposition and erosion the surface of the salt had topographically high areas. Since the mechanism of initiating and maintaining salt dome growth is one of isostatic adjustment, it was some of these topographic highs of the salt, that began to rise first and eventually formed the nucleus of present day salt domes.[1] The salt begins to rise because it has an average density that is lower than the average density of the overlying sediment, and that the column of sediment overlying the topographic high has a lower density than the sediment overlying the salt; consequently this causes the salt to flow laterally and up toward the areas of least resistance (namely the topographic high). Approximately 4000 feet of overburden is needed to exceed the density of the salt, and a sediment depth greater than that will cause upward movement of the salt.[2]

It was the size and shape of the original surface irregularities of the salt that controlled the early rates of vertical movement. This in part explains the differences in the present day size of salt domes.

As the salt rises, sediment stretching and normal block faulting occurs in the overlying sediments. The increasing permeability along the fault planes allows the relatively easy descent of meteoric water. This water combined with existing ground water leaches the upper leading edge of the salt dome leaving various insoluble residues: primarily anhydrite, with minor amounts of dolomite, calcites, barite, pyrite, quartz, and sulphur.[3] The continuing rise of the salt further fractures the caprock allowing deeper water percolation and additional salt leaching, and hydration of the upper anhydrite layers. The result is a thickening of the caprock and the formation of gypsum. These residues are the prime constituents of the salt dome caprock.

2.1.2 Regional Geology

The West Hackberry salt dome lies within the Gulf Coast geosyncline which, in the area of the dome, is characterized by about 9,500 feet of poorly consolidated Miocene and younger sands and shales. The dome is located north of the geosynclinal axis which during early Miocene time had a west southwest trend. The monoclinal strata of the geosyncline, through which the salt is rising, dip in a southeasterly direction. The Miocene sediments are faulted by normal dip slip faults that strike northeast and are down thrown on the basin side.

Seismic activity in the Gulf Coast region is very low. The National Oceanic and Atmospheric Administration (NOAA) has classified the United States into four zones with differing degrees of expected seismic risk. These subdivisions are based upon the recorded history of past seismic activity. Zone 0 covers areas having no reasonable expectancy of surface earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, possible major destructive earthquakes.

The West Hackberry dome project area lies within the boundary of seismic risk Zone 1. However, in order to acquire more specific information, an earthquake data search was requested from the NOAA seismic information service. This NOAA office has catalogued the records of all known tremors occurring since the mid 1800s. The data search was requested to cover the rectangle from 28°55' north to 30°19' north, and from 90°10' west to 95°45' west. The results of the search indicated that no earthquakes have been recorded in the West Hackberry area.

2.1.3 Local Geology

In plan view the West Hackberry salt dome is an elliptical piercement structure, having a broad nearly flat top at an average depth of 2,000 feet below sea level. The slope of the sides of the dome are from slightly less than 60° to steeper than 75° on the north side. On the southeast perimeter of the salt there is a significant re-entrant feature, often referred to as an overhang. The dome lies within the Texas Louisiana Coastal Salt Dome Belt, and is part of a larger salt mass which includes the East Hackberry salt dome (Figure 2.1). The overall length of this salt mass is more than 9 miles, with its width exceeding 2 miles. The long axis trends N73°E.

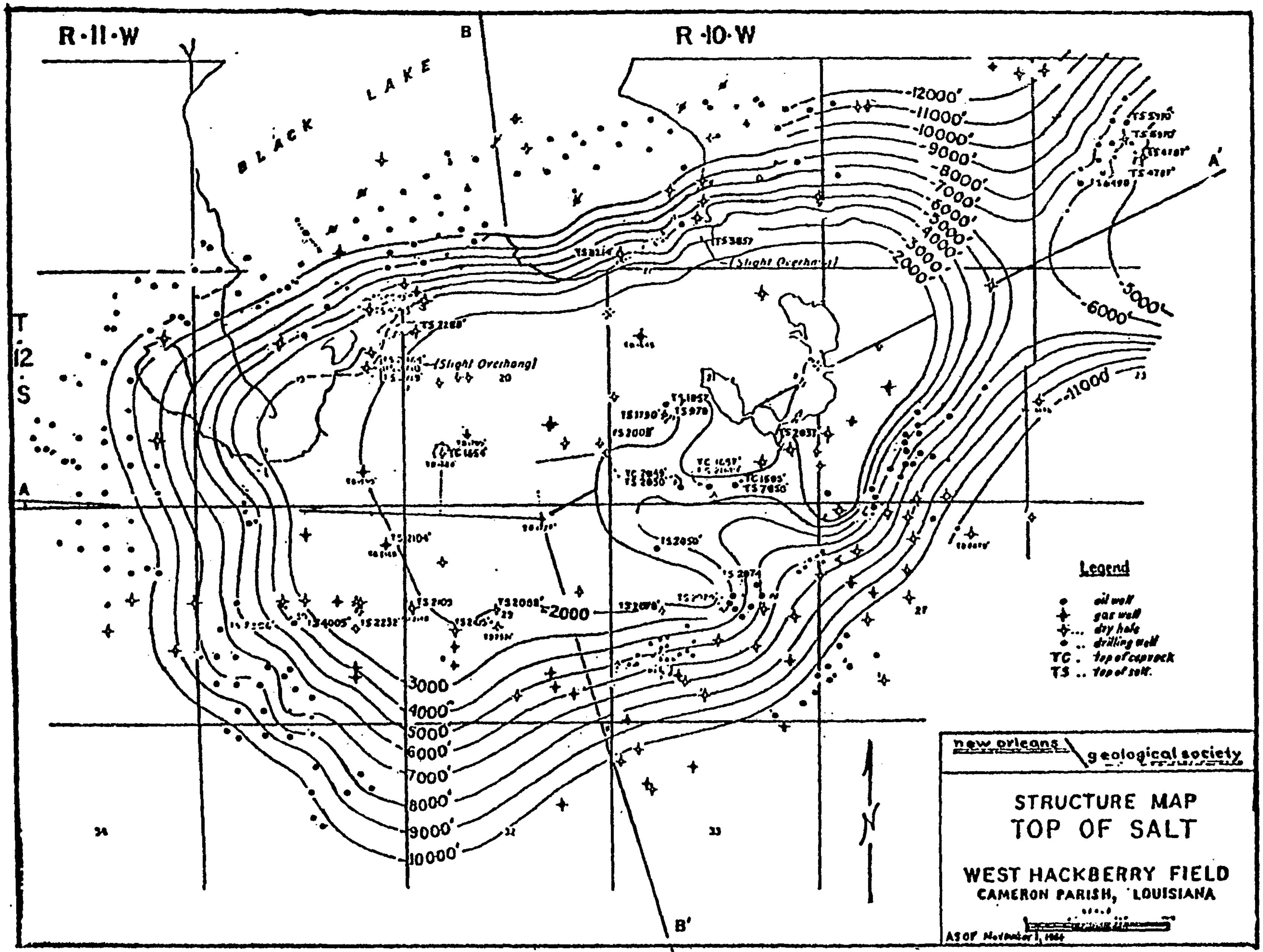

Figure 2.1 Structure Map - West Hackberry Field

Unconsolidated and partially consolidated muds, sands and shales of Recent, Pleistocene, and Pliocene age overlie the central portion of the dome, with thicknesses ranging from 1,500 to 2,000 feet. Unconsolidated and partially consolidated sands and shales of Pliocene and Miocene age extend to a depth of 9,500 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 19 feet above mean terrain.

An analysis of the records of more than 40 drill holes shows that a caprock covers the entire salt mass above the 3,000 foot depth contour. The caprock reaches a maximum thickness of 525 feet in the southwest quarter of Section 21 and gradually thins in all directions. A structural map and an isopach map of the caprock appear as Figures 2.2 and 2.3. Caprock depth ranges from less than 1,500 feet in the southwest quarter of the section to over 4,000 feet on the north and south perimeter. Geologic cross-sections A-A' and B-B', constructed from electric log data, (Figures 2.4 and 2.5) show the lateral extent of the caprock, the local sedimentary sequences and the relationship of these sediments to the salt structure.

The caprock is commonly intensely fractured, faulted, and brecciated due to the upward pressures exerted by the rising salt stock. During periods when the salt is stable or not rising as fast as the dissolution of the salt is occurring, the caprock may be partially unsupported and fall with adjustments occurring along new or pre-existing fault planes. This mechanism may be the cause of the slight topographic low above the east side of the West Hackberry dome. The faulting and fracturing in the caprock results in high permeability, but this is of no consequence with respect to potential oil storage capability. The salt surrounding the storage cavity provides the required containment.

Faulting within the Miocene and Pliocene formations overlying, and adjacent to the dome is extensive and complex. A structure map constructed on a Miocene marker bed, shows three major northeasterly trending faults, which may have influenced the orientation of the dome axis (Figure 2.6). These faults have created a zone of weakness through which the salt may have risen. A secondary series of radial faults is interpreted to occur on the northwest and southeast perimeter of the dome.

2.1.4 Soil Characteristics

Insufficient data are available to describe in detail the soil series on the West Hackberry salt dome. However, based on the physiography, the fact that it is elevated

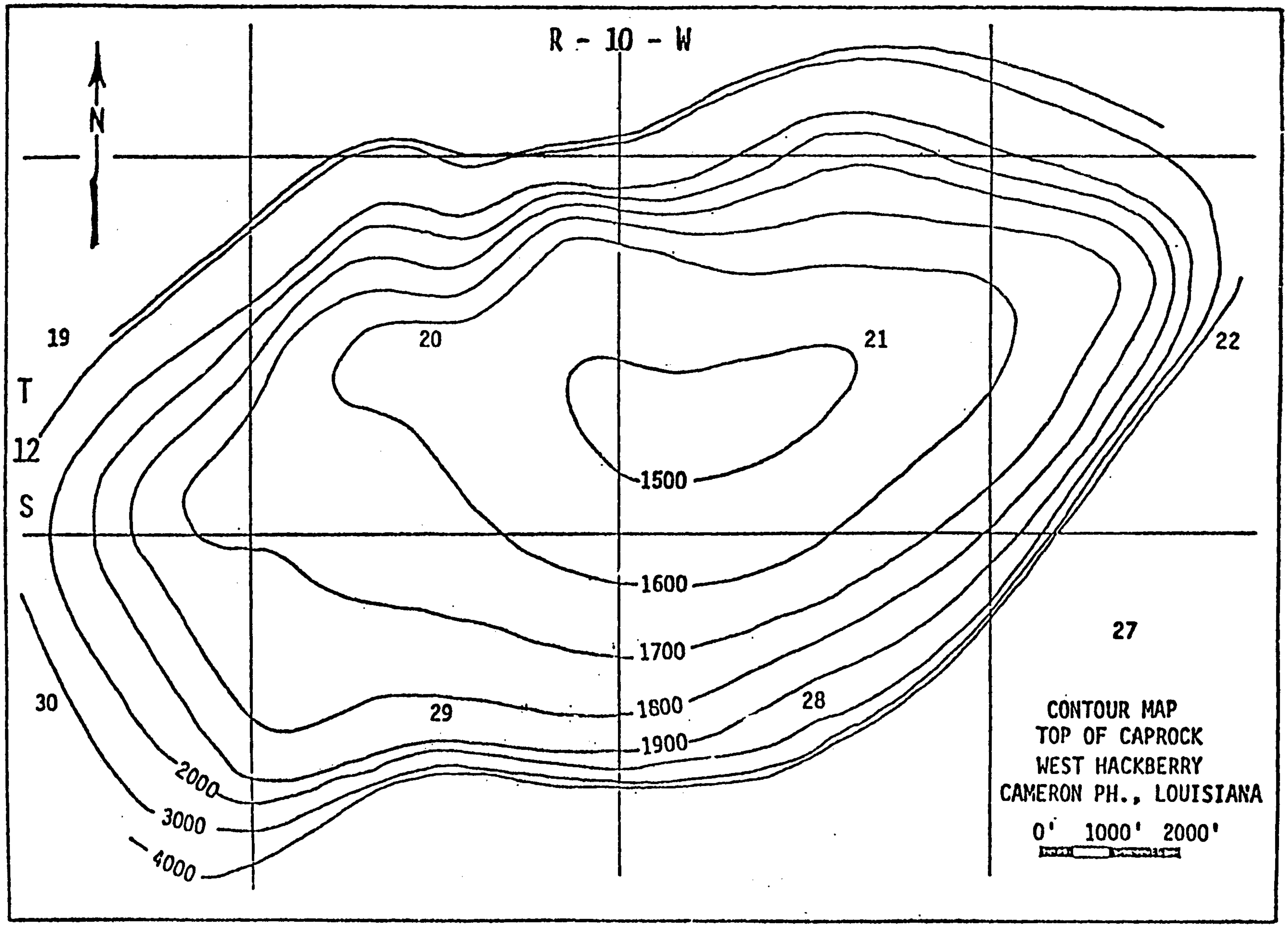

Figure 2.2. Contour Map - Top of Caprock

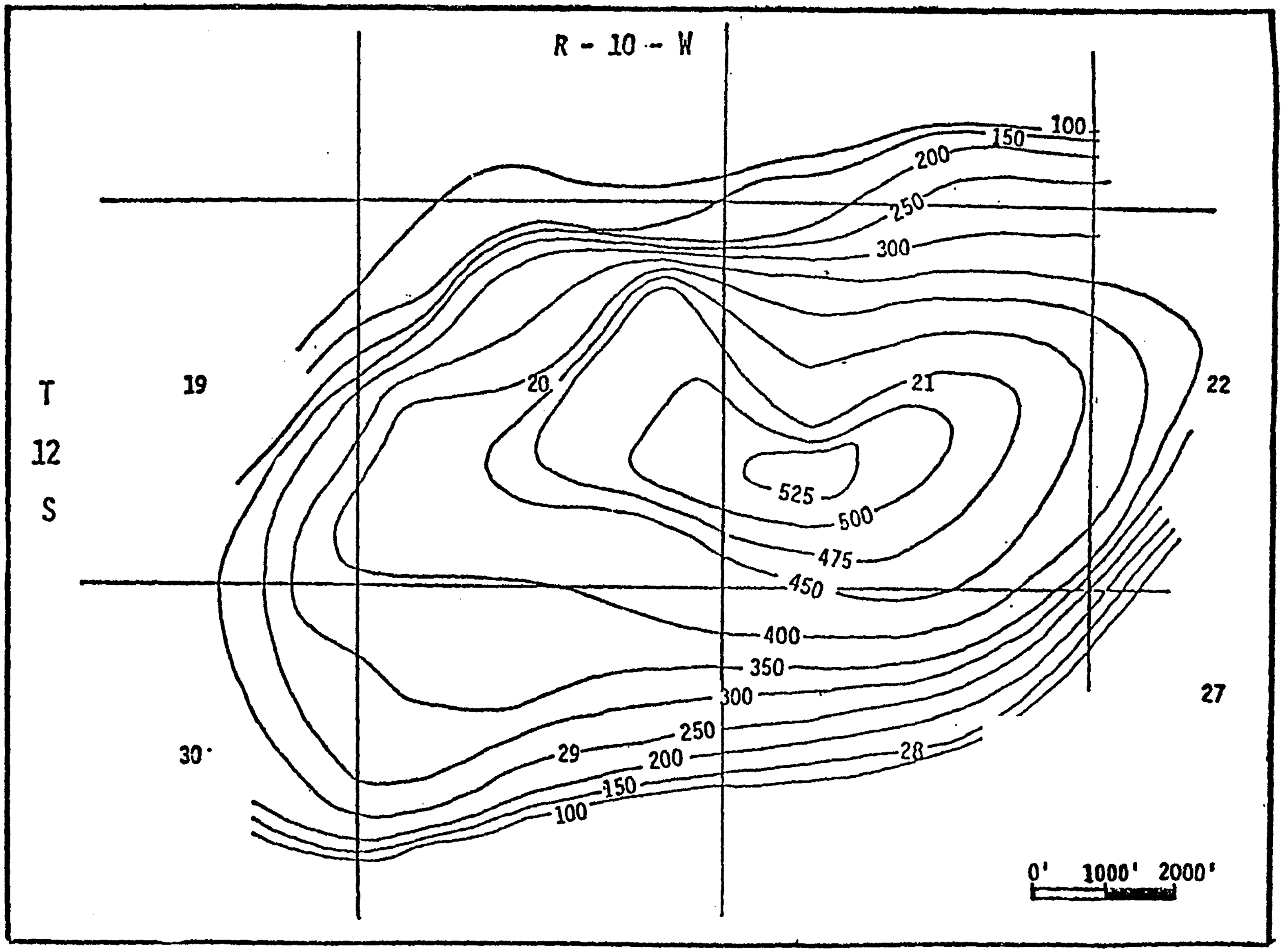

Figure 2.3. Isopach Map of Thickness of Caprock - West Hackberry, Cameron Parish, La.

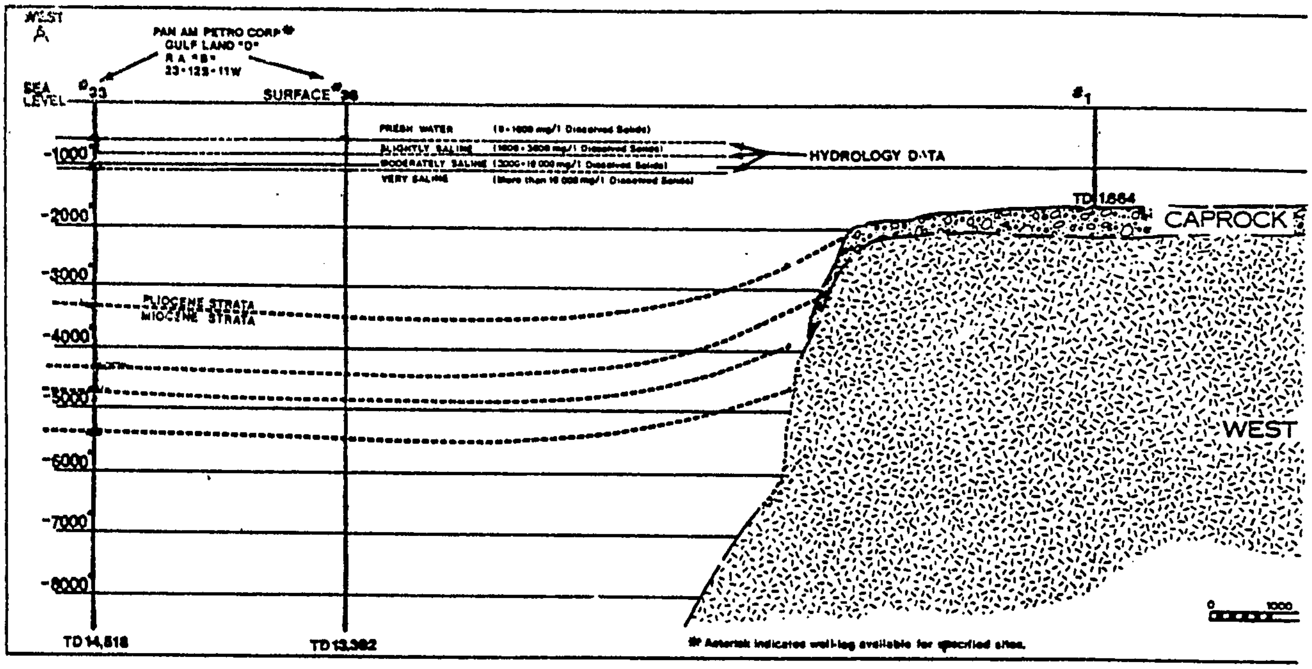

Figure 2.4 Geological East/West Cross Section

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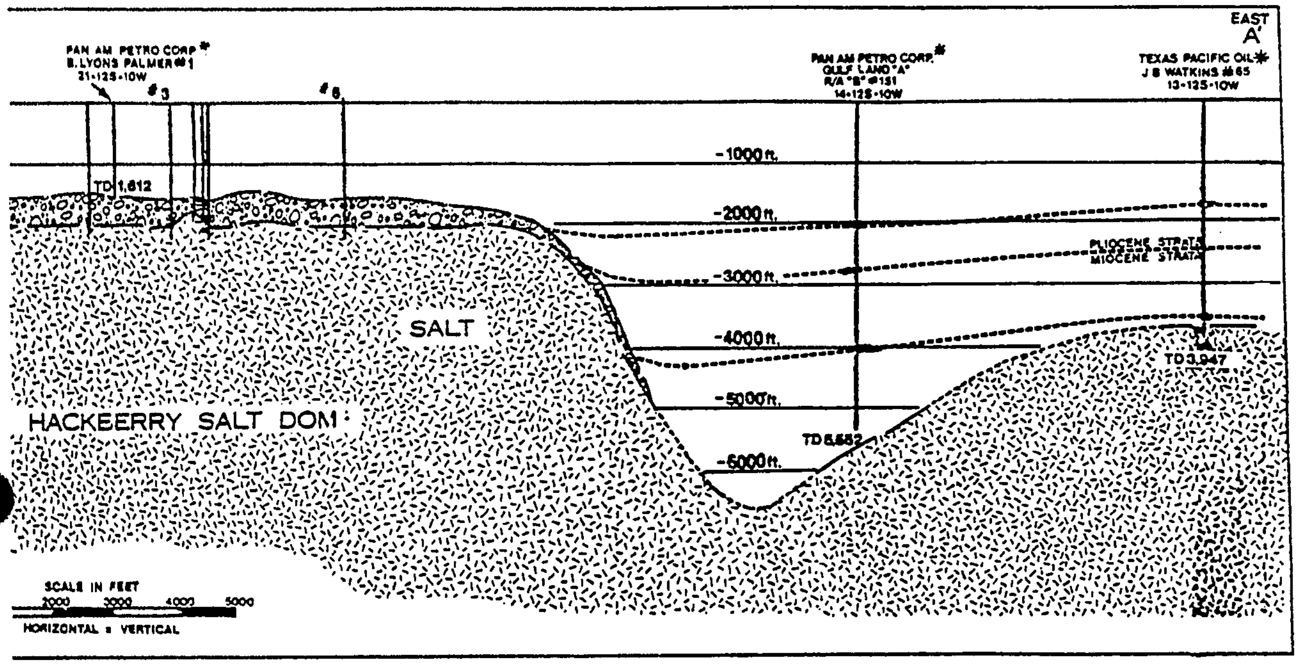

West Hackberry Dome A-A'

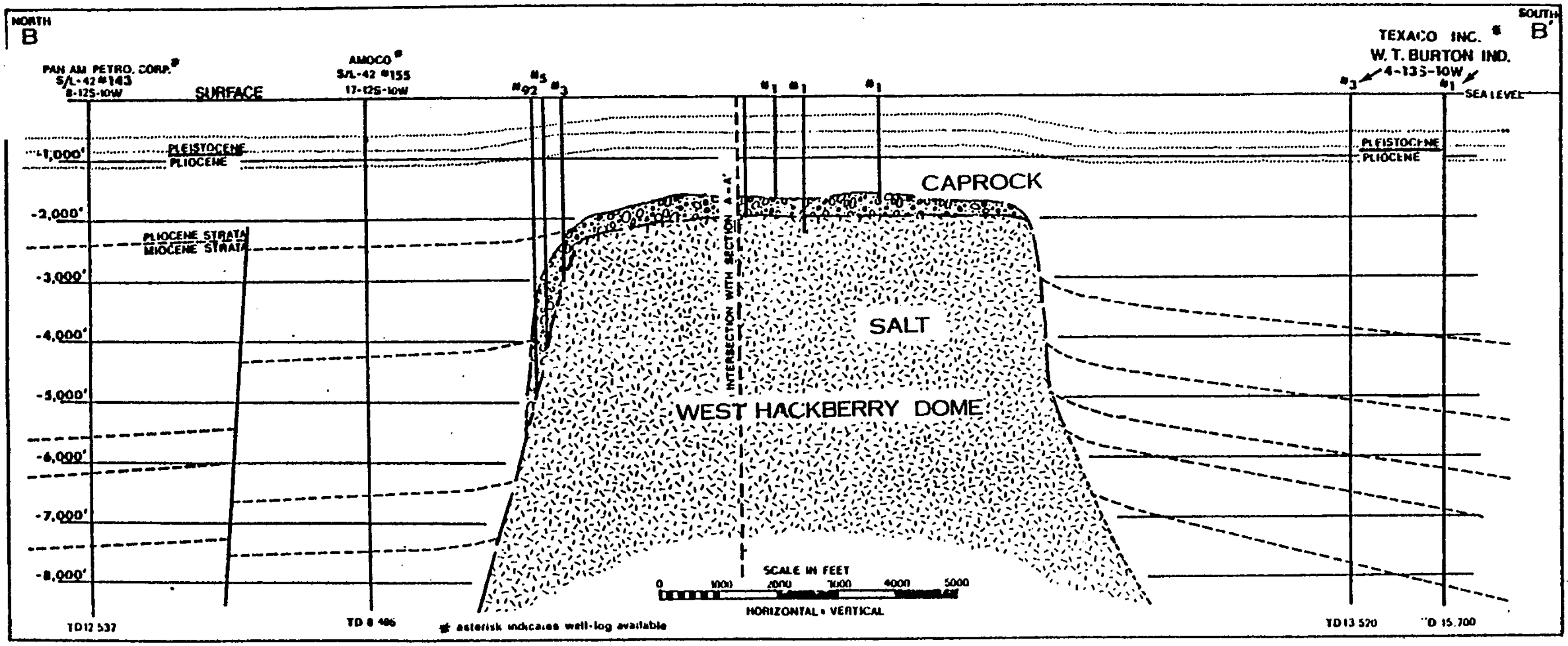

Figure 2.5 Geological Cross Section, West Hackberry Dome B-B'

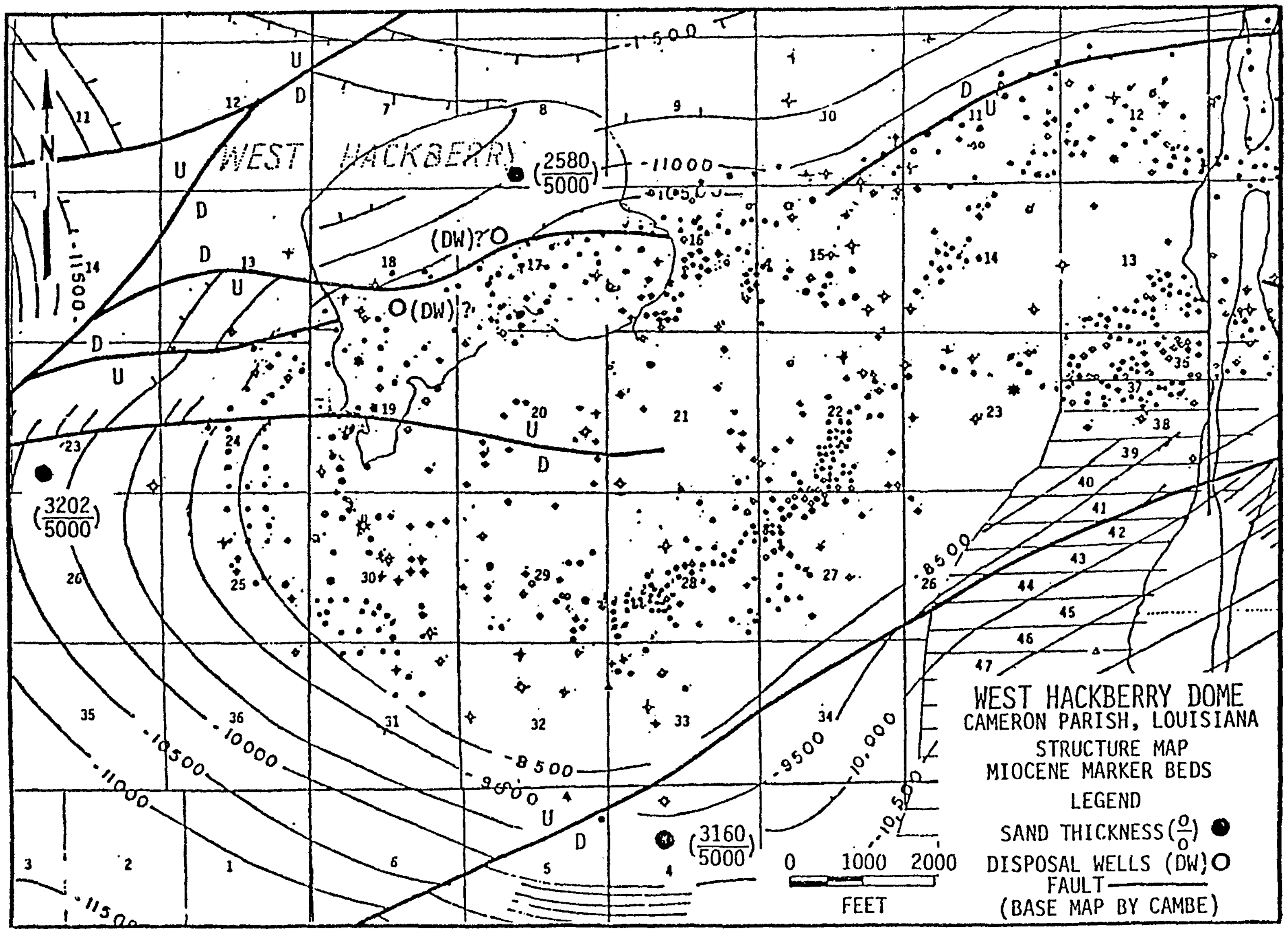

Figure 2.6 Structure Map - Miocene Marker Beds

above the surrounding environments, and the presence of relict "pimple-mounds,"* certain deductions regarding the origin and nature of the soil types that have developed there can be made.

An aerial survey of the delta suggests that these "pimple-mounds" originally developed in the marshlands and remain as relicts of that sedimentary environment. The sediment size of the marshes is in the clay/silt range. These "pimple-mounds" are not as well defined as in the marshlands, indicating they are relicts with their prominent morphology necessarily reduced by erosion. These mounds were probably exposed to increased erosion by the gradual uplifting of the surface of the piercement structure. The soils on the surface of the dome are occasionally inundated during floods, but the fact that they are generally well drained and provide good pasture land suggests that they are developing soils similar to those in the coastal prairies north of the Intracoastal Waterway. Soils developing in the marshlands are marsh peats, marsh clays, and Harris soils.

Due to the deficiency of detailed data on the soils at the West Hackberry site, chemical characterization will not be attempted. It is expected that the soils are closely related to the Midland series found on the coastal prairies 5 to 10 miles north. The Midland soil has a dark gray silty clay subsoil. The surface soil has a weak structure influenced by the high percentage of organics, but the subsoil has a moderate to strong compound subangular blocky and/or prismatic structure and a firm consistency when moist.⁴ The development of these structures is the result of considerable age. Since relict features of previous marsh environments still exist, it is doubtful that much time has elapsed since the uplift occurred; therefore, it is reasonable to assume that the soil structure and definition of horizons has not yet developed to the degree suggested above, since this description is of a mature soil in a similar environment on the coastal prairie.

The coastal marsh soils are generally classified as peats, mucks, and clays. The dominant morphological characteristics are the dark brown and black colors of the peats, muck, and organic clays. Gray colors are associated with waterlogged, reduced soil conditions where the organic

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*A term used to anthropomorphically describe relic soil features (in the aerial photograph of Figure 2.7 these "pimple mounds" appear as goose pimples on the surface.

fraction is small.[4] The soil building materials are silts, silty clays, and clays of recent alluvial origin, plus marine silts and clays, overlain at various locations by peat and muck. The depth of the peat or muck is determined by the amount of subsidence and the vegetative history of a particular area. The organic layer has been found at depths ranging from a few inches to 20 feet.[5]

The organic soils are classified on a basis of the stage of decomposition. Peat is a soil which has a brown or black color and contains plant parts only partially decomposed and generally with over 50 percent organic matter. Mucks are usually black or dark gray and contain organic material which is finely divided and well decomposed with none of the plant parts identifiable. The organic content of muck usually ranges from 15 to 20 percent; and soils with less than 15 percent organic matter are classified as mineral soil.[5]

The predominant material of the marsh is clay, with varying amounts of organic matter, peat, and silt which accumulated in these tidal areas around the roots of salicornia and spar+inia, which colonize the tidal flats. Poorly consolidated clays and peats are characteristically soft with very poor load bearing capacities. Drainage of surface water by the canalization of the area dries them and they shrink appreciably, with a volume reduction of 50 percent or more in the peats and 10 to 15 percent for clays. Clays have the additional disadvantage of swelling if water is added after drying. As a result of diking and draining areas, the organic fraction of the soil is exposed to oxidizing conditions which cause them to experience an additional loss of volume.[6]

2.1.5 Land Usage Characteristics

Minerals and Oil and Gas Production

Oil in the West Hackberry salt dome area was reportedly discovered by oil and gas surface seeps in 1902. Oil was first commercially extracted from the dome area in 1928 by the Cameron Oil Company. Initial production is reported to have been from Cameron Oil Company's Duhon No. 2 in 1928. Louisiana State Conservation Department records show that oil or gas is or has been produced from at least 15 different horizons as shallow as -3,920 feet and as deep as

-9,813 feet. Oil bearing production zones are found completely around the perimeter of the dome.

Interpretation of the salt structure indicates that the production occurs primarily from Miocene age sand formations faulted or pinched out against the sides of the salt stock. No known oil or gas production is located over the top of the dome in the area proposed for the solution mined storage cavern facility.

The first attempt at mineral mining of the dome was a sulphur exploration program conducted by the Freeport Sulphur Company in the late 1920s. Several holes were drilled into the caprock and salt to explore the potential for sulphur mining. No information regarding the results of this drilling program is available, and it appears that the dome was never mined for sulphur.

Olin Chemical Company is using portions of the West Hackberry salt dome for brine production and Cities Service Oil Company is using several cavities for subsurface storage of liquid petroleum gas. These operations represent only a partial development of the dome. The total acreage of the dome controlled by the Olin operation is 500 acres. Cities Service Oil Company has developed a total of nine caverns on 80 acres. The large rectangular pond visible on the aerial photograph (Figure 2.7) labeled as a brine pond is approximately 10 acres and is part of the Cities Service Oil Company operation. The bleached white boundary around the pond indicates that it occasionally overflows.

Associated with the developments on the dome and oil wells off the salt dome are a number of access roads, canals, and structures that can be seen in the aerial view (Figure 2.7). The pipeline rights-of-way are shown on a portion of the Oil and Gas Map of Louisiana, Figure 2.8. The roadways in the aerial photograph that depart from the main highway appear as white lines due to the use of shell fragments instead of gravel as the principal surfacing material of secondary roadways.

<u>Agriculture</u>

Agriculture in the West Hackberry salt dome area is restricted to the elevated area over the salt dome since the surrounding area is either marsh or lake. A large portion of available land is used for pasture. From an aerial

WEST HACKBERRY SALT DOME

Figure 2.7. Aerial Photograph of the Site and Vicinity

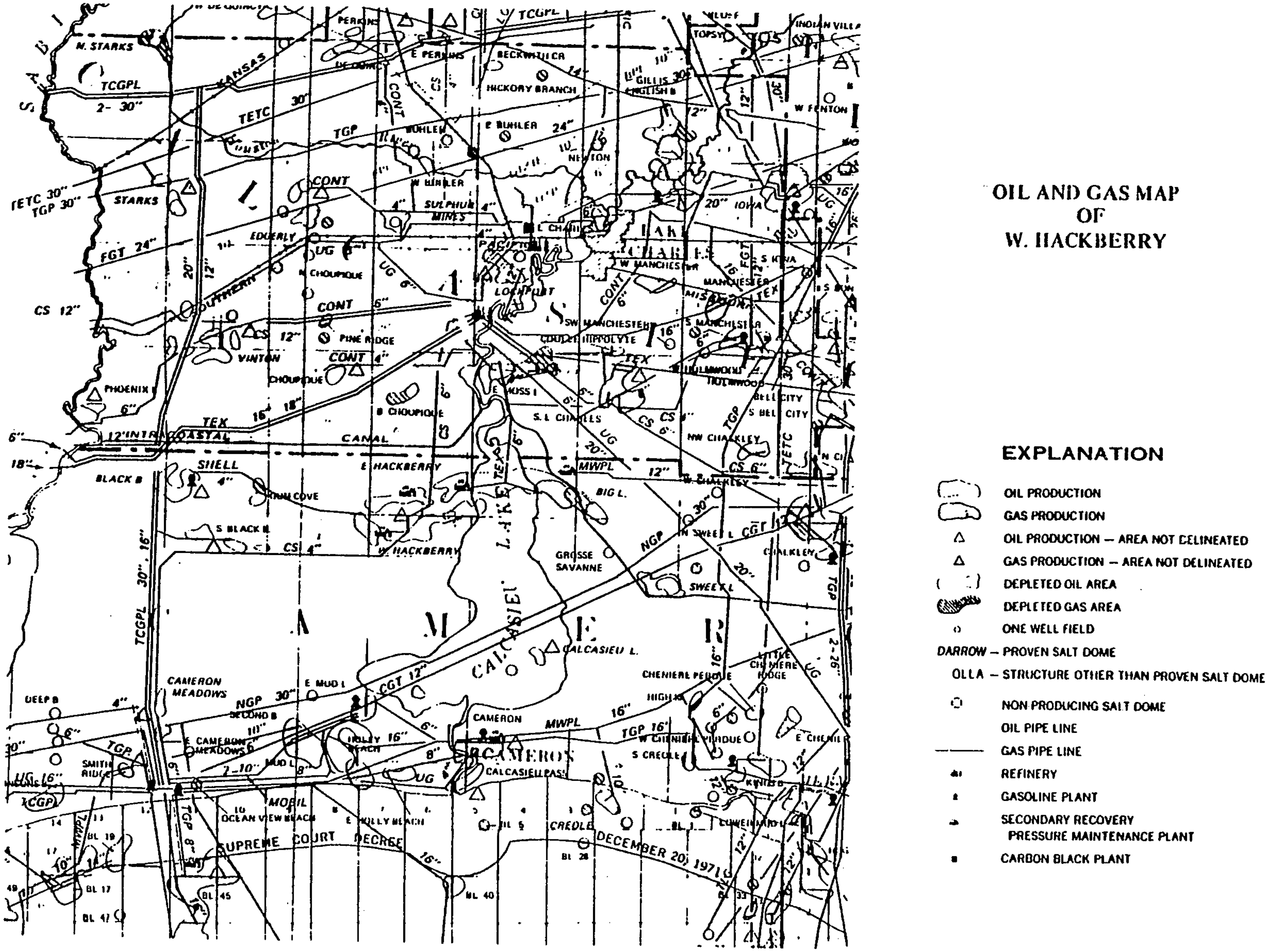

Figure 2.8. Oil and Gas Map of West Hackberry

survey, it appears that 75 percent of the dome surface is used for cattle grazing.

Residential/Commercial Development

The principal center of residential development in the area is Hackberry. Individual farms occur about the dome area, the one nearest the center of development is the house of Ernest Hamilton. For many of the residents, farming is a secondary source of income, whereas their primary source is the local oil industry. Fishing, fish processing, and several retail stores constitute the commercial development of the area and are located 2 to 3 miles east of the site.

Recreation and Wildlife Resources

The recreational and wildlife resources of the coastal marshlands and prairie are both vast and varied. However, the area to be impacted by the development of the West Hackberry salt dome is neither large nor particularly sensitive. The primary uses of the marshlands and coastal prairie are fishing, fowl hunting, trapping, and boating. Two miles to the south of West Hackberry salt dome is the Sabine National Wildlife Refuge. It is out of the area of potential impact since neither brine pipes nor oil pipes are planned to cross or pass near the refuge. However, it is the nearest designated area of wildlife resources.

2.2 WATER ENVIRONMENT

The West Hackberry salt dome is located in Hydrologic Unit 9 of southwestern Louisiana within the estuarine part of the Calcasieu River Basin.[5] The location of Hydrologic Unit 9 is indicated in Figure 2.9 while the Calcasieu River basin is presented in Figure 2.10. The northwestern rim of the dome lies beneath Black Lake, with the remaining portion covered by dry pasture land. To the south and west are marshes. Surface water in the general area is brackish with a salinity of 5 to 10 ppt, due to salt water intrusion (a major problem in this section of Louisiana). Surface levels in the region are underlaid by clays which are nearly impervious to water passage.[5] While the annual rainfall appears plentiful (55 inches), the area generally experiences a moisture shortage for vegetation during the growing season (from February through November). This precipitation deficit amounts to about 6 inches.[7]

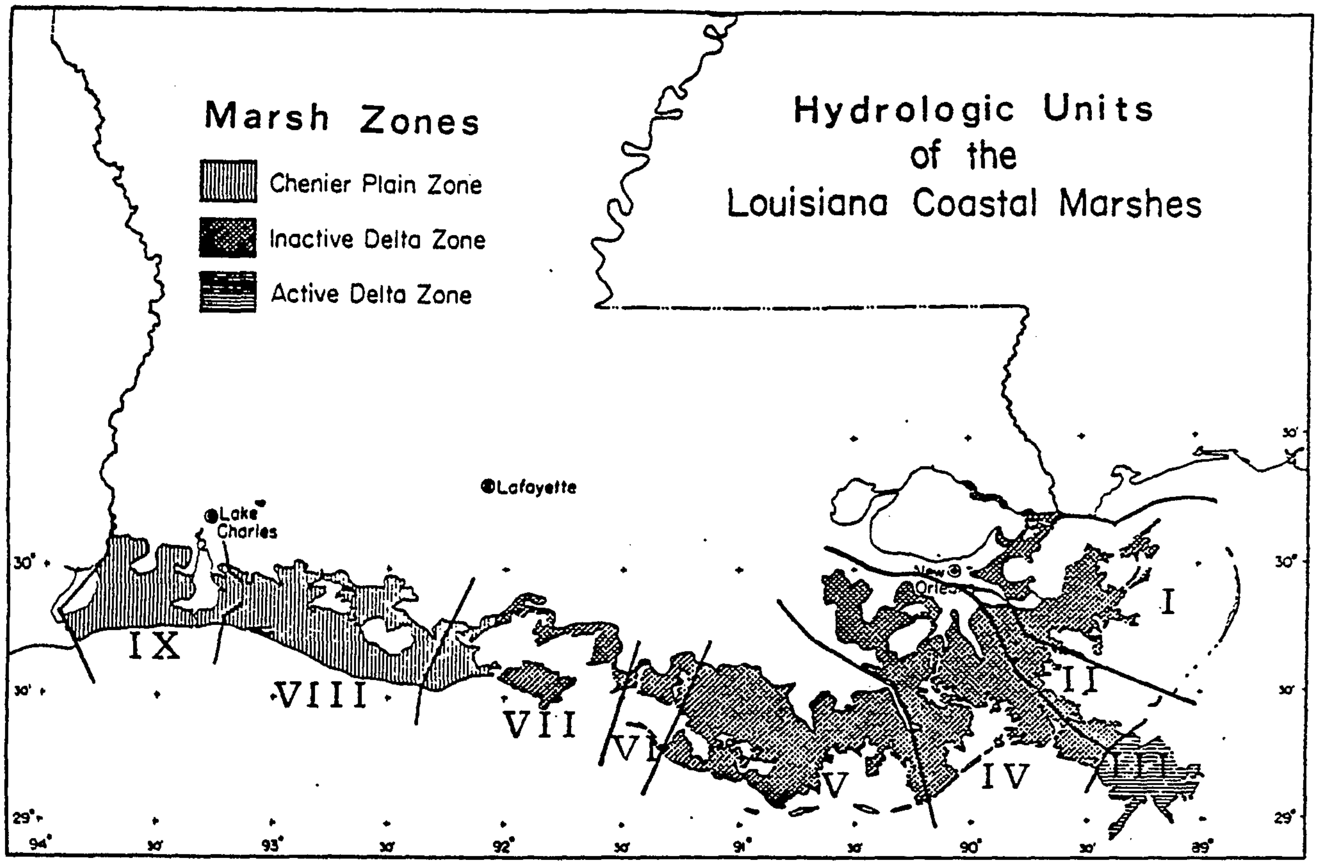

Figure 2.9 Hydrologic Units of the Louisiana Coastal Marshes

From Chabreck, R.H. 1972. Vegetation, Water and Soil Characteristics of the Louisiana Coastal Region. Louisiana State University Agri. Exper. Sta. Bull. No. 664.

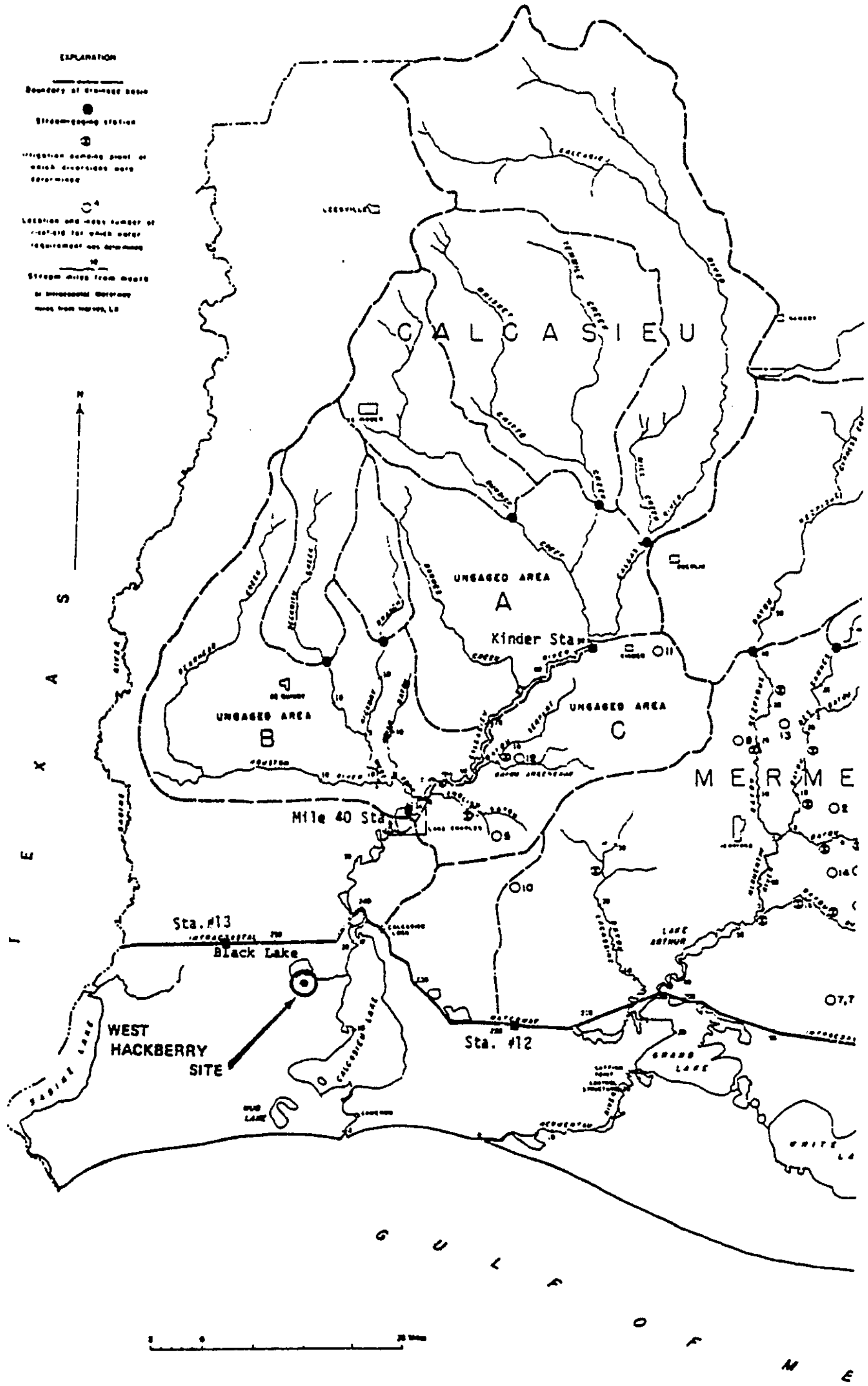

Figure 2.10 Calcasieu River Drainage Basin Areas

From Jones, P.H., Hendricks, E.L., Irelan, B., and others. 1956. Water Resources of Southwestern Louisiana. U.S. Geological Survey Water-Supply Paper 1364.

Enlargement of the barge dock and construction of the tanker dock would also affect these waters. For the disposal of brine, the primary site under consideration consists of the deeper subsurface aquifers in the vicinity of the dome. (Disposal in the shallow coastal waters of the Gulf of Mexico is, however, under consideration as an alternative.)

2.2.1 Surface Water Bodies

Hydrologic Unit 9, within which West Hackberry dome is located in southwestern Louisiana, consists largely of ponds, lakes, and marshes. As indicated in Table 2.1, less than 10 percent of the entire area is dry land. The southwestern Louisiana marshes are part of the Chenier Plain, which is characterized by natural barriers to north-south drainage, the cheniers, which are stranded former beach deposit zones.[8] In addition, man-made levees are present in numerous locations.

The surface water system in the vicinity of the dome consists of a brackish marsh interlaced by a network of bayous and canals which connect with Black Lake, Calcasieu Lake, Calcasieu River, and the Intracoastal Waterway. Pertinent characteristics of the surface water bodies nearest the dome are tabulated in Table 2.2, and the general arrangement of these water bodies is depicted in Figure 2.11.

As already noted, precipitation in the area is fairly heavy, amounting to 55 inches per year.[8] The average precipitation surplus for winter-spring and summer-fall amounts to 14 and 4 inches, respectively. However, during the growing season (from February through November) an average seasonal deficit of about 6 inches of precipitation is encountered in the vicinity of West Hackberry dome (see Appendix D.1). The water balance situation has been described as one of "feast or famine."[7]

Coupled with the seasonal deficit of precipitation, salt water intrusion is a significant environmental problem in the region surrounding the West Hackberry dome. In the immediate vicinity of the dome, salt water intrusion has produced brackish surface waters with salinities between 5.0 and 10.0 ppt as indicated in Figure 2.12.

Table 2.1. Acreages in Water for Hydrologic Unit 9* in Southwest Louisiana Coastal Area (Chabreck, 1968)[2]

Surface Feature	Acreage
Marshes	
Natural Marshes	212,362
De-Watered Marshes	39,858
Water Bodies	
Ponds and Lakes	228,552
Bays and Sounds	-
Bayous and Rivers	2,363
Canals and Ditches	3,855
Dry Land**	51,746
TOTALS	539,635

* The hydrologic unit used is the same as that used by the Corps of Engineers.

** Includes active beaches, cheniers, spoils deposits, ridges, elevated bayous, and lake banks.

From Chabreck, R. H., Joanen, T., and Palmisano, A. W., 1968. Vegetative Type Map of the Louisiana Coastal Marshes. La. Wildlife and Fisheries Commission, New Orleans.

Table 2.2 Surface Water Bodies in the Vicinity of West Hackberry Dome

Name	Location Distance(mi)	Location Direction	Length (miles)	Width (ft)	Depth (ft)	Area (sq.miles)
Black Lake	0.6	NW	-	-	4.0	3.40
Black Lake Bayou	0.5	NE	6.4	100	4.0	0.12
Browns Lake	3.9	SW	-	-	3.0	0.36
Calcasieu Lake	4.7	E	-	-	1.5	11.30
			-	-	4.5	34.90
			-	-	7.5	20.60
			-	-	10.5	0.03
Calcasieu River*	7.0	NE	24.9	850	22.0	6.10
Calcasieu Ship Channel*	4.0	E	26.0	250	35.0	1.20
Intracoastal Waterway*	4.1	N	104.5	300	8.0	5.90
Long Point Lake	6.0	SE	-	-	2.5	0.20
Mud Lake	6.5	NE	-	-	1.5	0.58
			-	-	4.5	0.29
			-	-	7.5	0.07
			-	-	10.5	0.06
			-	-	13.5	0.06
			-	-	20.0	0.10
Starks Canal	2.8	SE	21.6	40	2.5	0.16
Starks North Canal	2.6	SW	18.2	40	2.5	0.14
West Cove	8.0	S	-	-	1.5	9.80
			-	-	4.5	6.00
West Cove Canal	6.3	S	-	40	1.5	0.02

*Includes only portions within Hydrologic Area 9.

After Barney Barrett. 1970. Water Measurement of Coastal Louisiana. Louisiana Wildlife and Fisheries Commission and U. S. Dept. of Interior.

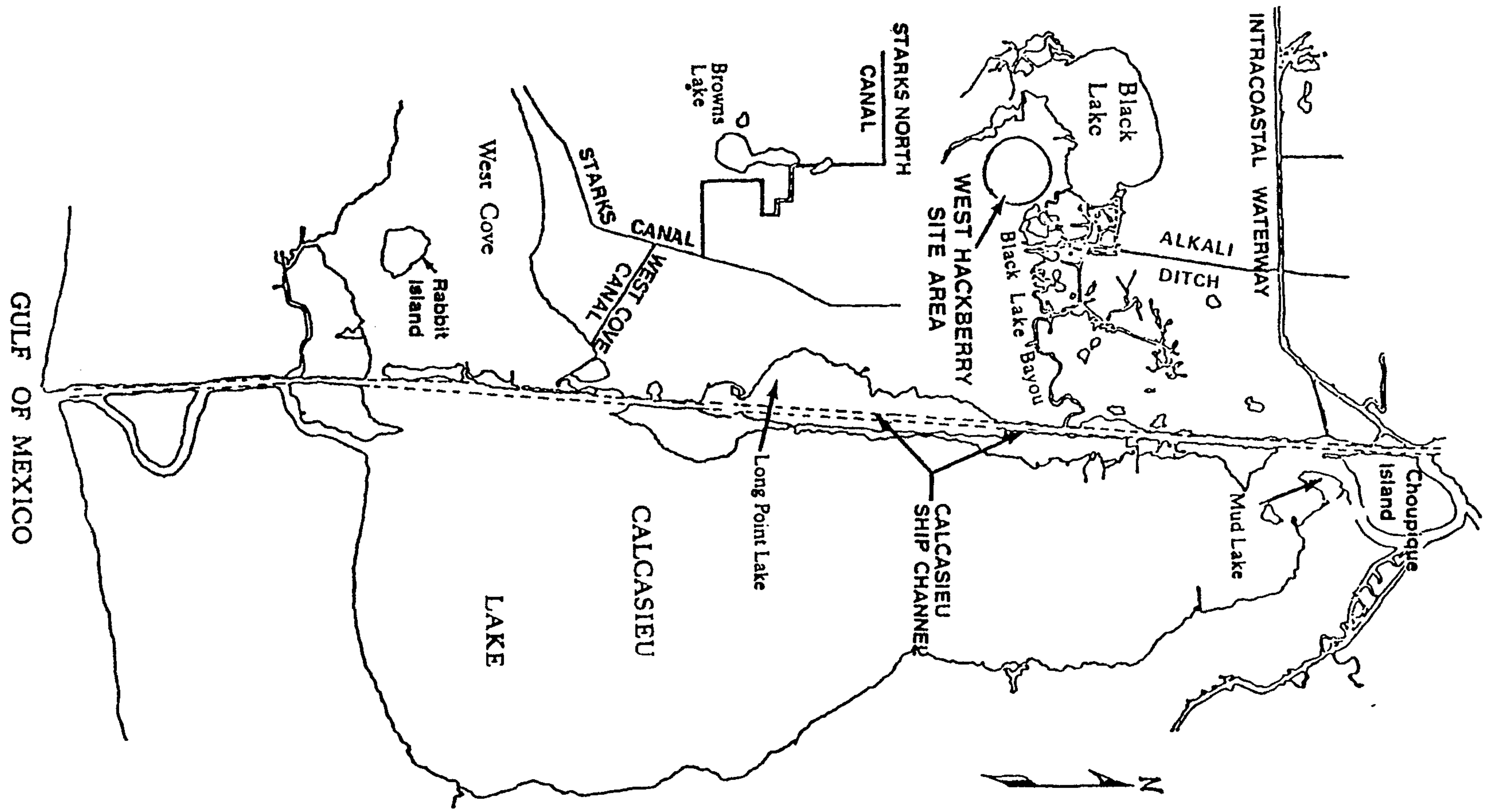

Figure 2.11 Surface Water System in the vicinity of the West Hackberry Site

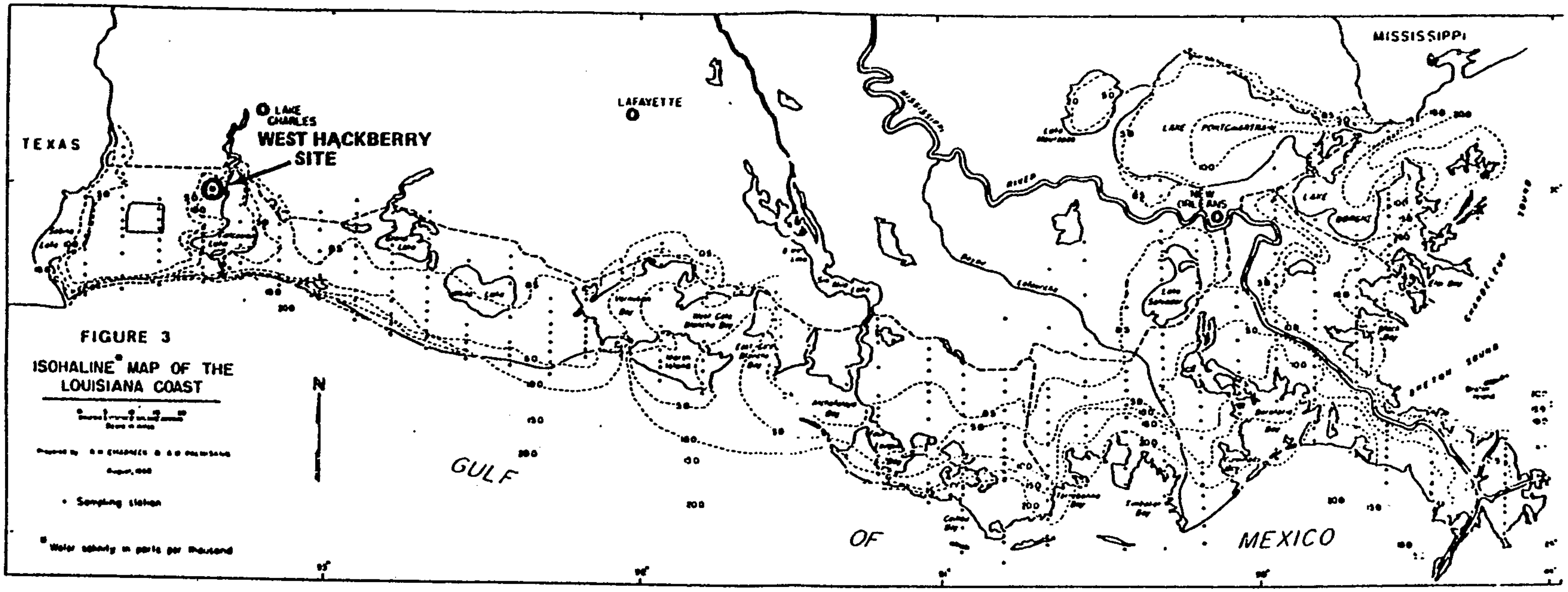

Figure 2.12 Isohaline Map of the Louisiana Coast

From Chabreck, R. H. 1972. Vegetation, Water and Soil Characteristics of the Louisiana Coastal Region. Louisiana State University Agriculture Experimental Sta. Bulletin No. 664.

Black Lake, Black Lake Bayou, and Alkali Ditch

As indicated on Table 2.2 and Figure 2.11, Black Lake is a small (3.4 square miles) shallow body of water located on the northwestern fringe of the dome. Minimal water quality data are currently available for this lake. The water is known to be saline with the salinity increasing in recent years. Current salinity values are dependent on tides and currents and vary from 0 to 12 ppt. The average salinity is on the order of 5 to 6 ppt.[9] Water in the vicinity may be subject to contamination from existing brine holding facilities.[10] The effect of brine releases upon dissolved solid content would be qualitative as well as quantitative since brine has a different composition than seawater. Contamination by brine as a concomitant of oil production is quite common in the area.[11] Black Lake has been increasing in surface area, probably as a consequence of erosion.[10] Wooden bridges, dredged channels, and oil wells are present in the lake and subsidiary canals connect the lake with the surrounding oil fields. No sediment quality data for Black Lake is available. Black Lake is naturally connected to Calcasieu Ship Channel via Black Lake Bayou, (4 feet deep, 100 feet wide), and is also linked to the Intracoastal Waterway by means of Alkali Ditch (6 feet deep, 100 feet wide) as shown in Figure 2.11. Thus, water quality in Black Lake is related to water quality in both the Intracoastal Waterway and Calcasieu Ship Channel as well as the water quality in Black Lake Bayou and Alkali Ditch. With respect to the last two, no water quality data or sediment quality data is available.

Calcasieu Lake, Calcasieu River, and Calcasieu Ship Channel

The dominant bodies of water in the dome area are Calcasieu Lake and the Calcasieu River which feeds the lake. Mud Lake, Long Point Lake, and West Cove are extensions of Calcasieu Lake. The Calcasieu Ship Channel extends northward from the Gulf in the vicinity of the original Calcasieu River bed and passes along the western side of the lake as shown in Figure 2.11. Further upstream, above the Intracoastal Waterway, the ship channel and the river bed essentially coincide. The lower portion of this channel provides direct connection between the Gulf and Lake Calcasieu and is largely responsible for the salt water intrusion problem which extends up the Calcasieu River to the vicinity of Lake Charles.

Due to the presence of the ship channel, the Calcasieu River is navigable from the Gulf to slightly north of Lake Charles for drafts up to 40 feet. The river and surrounding surface waters in the area are used for transportation, commercial fishing, occasional industrial water supply, rice farming, and dilution of industrial and domestic wastes. To prevent further flow of saltwater upstream, the Calcasieu River Salt Water Barrier was constructed at Westlake, just above Lake Charles.

Volumetric flow data for the Calcasieu River are presented in Appendix D.2 (see Table D.2.1 through D.2.6). As indicated in this Appendix, for the year 1974, the average flow rate at Kinder was 2,554 cfs. This station, however, is considerably upstream of the point at which the river empties into Calcasieu Lake. The flow at the latter point is significantly greater because of tributaries which feed into the river between Kinder and Calcasieu Lake. The flow rate of the entire river basin has averaged 4,900 cfs. Seasonal variation in the river's flow rate is quite pronounced; measurements taken at Kinder from October 1973 through September 1974 varied from 637 cfs in August to 12,670 cfs in January. The variation in flow rate in the river is closely linked with the variations in the level of precipitation for this part of Louisiana.

Currents in both Calcasieu Lake and the lower portion of Calcasieu River are strongly influenced by tidal conditions. The diurnal range of tides in both the river and the lake is 0.5 feet or less.[12] Winds frequently augment the tides in creating currents toward Black Lake. During winter, strong northerly winds tend to oppose incoming tides, sometimes depressing them 2 feet. With strong southerly winds, incoming tides are increased as much as one foot above the normal tidal fluctuations. Prolonged periods of such winds may flood the marshes. Tropical storms and hurricanes also push saline water far inland.[5]

Industry along the Calcasieu River Basin includes chemical, petroleum, natural gas, salt, fish oil, and seafood preparation. These industries and the municipal sewage treatment facilities of the area discharge considerable wastes into the basin, but only limited discharge data are available (provided in Appendix D.3).

The use of the surface waters for transportation, agriculture, and industrial development has clearly taken its toll on the water quality in this area. The most significant water quality problems are associated with: (1) saltwater intrusion into the freshwater marshes, lakes, rivers, and waterways; (2) contamination by agricultural fertilizers and pesticides; (3) industrial and municipal discharges; and (4) extensive engineering modification of surface water flow patterns for a period of many years.

The salinity of Calcasieu River and Calcasieu Lake is strongly affected by the flow rate in the river. Salinity increases have been empirically correlated with decreases in river flow rates.[13] Salinity measurements taken in the Sabine National Wildlife Refuge near the Calcasieu Ship Channel display a wide range of values (0.40 to 14.85 ppt) from month to month.

A comparison of data from five stations in Calcasieu Lake, Calcasieu River, and Calcasieu Pass, with the State of Louisiana water quality criteria and the maximum EPA recommended levels for pesticides provides some indication of the existing water quality problem in Calcasieu Lake and River (see Appendices D.4 and D.5). The salinity values obtained at all sites clearly indicate the severity of the salt water intrusion problem, with salinity values as high as 20 ppt being recorded at the northern end of Lake Calcasieu. However, the pertinent state criterion for total dissolved solids is not defined below Moss Lake (just north of Lake Calcasieu), and thus only at the mile 40 sampling station near Lake Charles is there any violation of State criteria due to salinity. At this same station, State criteria for dissolved oxygen and coliform bacteria are also clearly violated. The total coliform count at the St. John's Island station (at the southern end of Calcasieu Lake) exceeded the State criterion for 6 of the 8 dates on which measurements were taken. In terms of pesticides, the measured data appears acceptable, based on comparison with the EPA values. Also, pH values in the estuary were observed to be lower than the normal range several times in the period 1966-1967, with generally lower readings during the winter.[14] Other investigations have generally reported serious water pollution problems in the Calcasieu River.[15]

Water quality data from four sampling stations on Calcasieu Ship Channel are included in Appendix D.4. The locations of the four stations are indicated in Figure D 4.3 of the same appendix. Comparison of the data with State criteria reveals conformance for all parameters measured. However, it is worth noting that no measurements of fecal coliform were obtained at any of the stations and only at stations #10 and #11 were any measurements obtained of dissolved oxygen or pH. The State criteria indicate that the waters in this portion of the channel are tidal and thus the proposed EPA numerical criteria for water quality and marine water constituents, (aquatic life), appear most relevant. These criteria are included in Appendix D.5. Comparison between the measurements and these criteria indicates certain problem areas at stations #10 and #11. The level of mercury greatly exceeds the criteria at both stations while the levels for lead and cadmium may possibly be excessive. At stations #7 and #8, however, no excessive levels of any of the metals previously mentioned are encountered. The reason for this difference in results may possibly be the difference in the time of year when the samples were obtained. At stations #7 and #8, the samples were obtained in April 1974, while at stations #10 and #11, the samples were obtained in May and June 1975.

Gulf Intracoastal Waterway

The Gulf Intracoastal Waterway is another body of water of major significance in the vicinity of the West Hackberry dome. As indicated in Table 2.2, the waterway lies 4.1 miles north of the dome. It has a width of 300 feet with a dredged depth of 8.0 feet in this region. Currents in the waterway are variable and are primarily the result of tidal and wind effects. A limited amount of water quality data has been collected on the waterway 12.5 miles west of Calcasieu Lake (Station 13) and 18 miles to the east (station 12) is included in Appendix D.4. The location of these stations is indicated in Figure 2.10. A comparison of this information with Louisiana State water quality criteria indicates general conformance. The measurements of pesticide levels at Station 13, however, exceeded the maximum EPA recommended levels for lindane and O,P' - DDT. In addition, at Station 13, the levels of toxaphene, endrin, and P,P' - DDT may also exceed such levels. At Station 12, the pesticides already noted pose similar problems, and the levels of chlordane, dieldrin, P,P' - DDT and O,P' - DDD exceed the maximum EPA recommended levels.

Because of dredging operations which would occur during the site preparation and construction phase, bottom sediment data must also be considered. Such data are available for Station 12 on the Intracoastal Waterway, and are included in Appendix D.6. The bottom composition is 90 percent sand with the remaining 10 percent classified as finer than sand. The levels of chemical oxygen demand (COD), organic nitrogen (TKN), and grease and oil in the sediment are considerably higher than the corresponding levels in the water at Station 12. Hydrogen sulfide (H_2S), which can only exist in anaerobic sediments, is present with a concentration 1.65 ppm. The concentration of all metals in the sediment were also much greater than the corresponding levels in the water. A comparison of the concentrations in the sediment with recommended limiting values reveals that the sediments would be classified as polluted in terms of the levels of TKN, grease and oil, and mercury (see Appendix D.5). The concentration of pesticides in the sediment is much greater than the corresponding levels found in the water.

Also of importance is the standard elutriate* analysis of the sediment. (The results of such analysis for sediment from Station 12 are provided in Appendix D.6). Comparison of the chemical concentrations in the elutriate with the corresponding concentrations in the water reveals that the elutriate contained higher concentrations in all cases except for dissolved organic carbon, soluble zinc, and soluble lead. Comparison of pesticide levels in the elutriate with corresponding concentrations in the water indicates that the elutriate pesticide levels were generally of the same order of magnitude or less than the corresponding levels in the water. If the results of

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*The "standard elutriate" is the supernatant resulting from the vigorous 30 minute shaking of one part of bottom sediment with 4 parts water (on a volumetric basis) collected from the same sample site, followed by a 1 hour settling time and appropriate 0.45um filtration.

elutriate analysis are compared with the proposed EPA numerical criteria for water quality (fresh water aquatic life), the results indicate with respect to soluble metals the elutriate levels exceed the EPA criteria only for mercury. With respect to pesticides, the elutriate levels exceeded the EPA criteria for endrin and possibly for DDT.

The preceding description of the sediment at Station 12 suggests that water quality problems currently exist in this area of the Intracoastal Waterway. Although Station 12 was the closest station to the West Hackberry site at which sediment samples were obtained, there is the distinct possibility that the sediment in the vicinity of the site may differ somewhat from that noted.

2.2.2 Shallow Subsurface Aquifers

Southwestern Louisiana contains three shallow subsurface aquifers in the area of interest. Chicot aquifer lies closest to the surface and contains mostly fresh water north of Cameron Parish and all saline water in the coastal region. Evangeline aquifer lies under the Chicot aquifer; it contains fresh water north of Calcasieu Parish, and saline water from southern Calcasieu Parish to the coast. Jasper aquifer lies under the Evangeline aquifer and contains saline water from the middle of Beauregard Parish south to the coast.[16] Chicot aquifer is proposed as an alternative displacement water source if surface water supplies are insufficient.

The Chicot aquifer contains beds of clay, silt, sand, and gravel of Pleistocene age. The aquifer dips toward the south and southeast. It increases in thickness from less than 100 feet in Beauregard Parish to more than 7,000 feet under the Gulf of Mexico.[17] Near the West Hackberry site, the gulfward slope of the base is 18 feet per mile, though the slope may be distorted in the immediate vicinity of the dome. As shown in Figure 2.13, a well log approximately 10 miles from West Hackberry (sampling Station 23) indicates that the aquifer extends essentially from the surface to 1,120 feet. This figure also shows 6 thin sand layers between 100 and 500 feet and 5 sand layers between 500 and 1,350 feet deep with thickness from 100 to 250 feet. Individual sand beds often have fine sand at the top, changing to coarse sand and gravel at the bottom. The coefficient of permeability varies from 900 to 2,000 gallons per day per square foot, averaging 1,500 gallons per day per square foot. Coefficients of transmissibility for

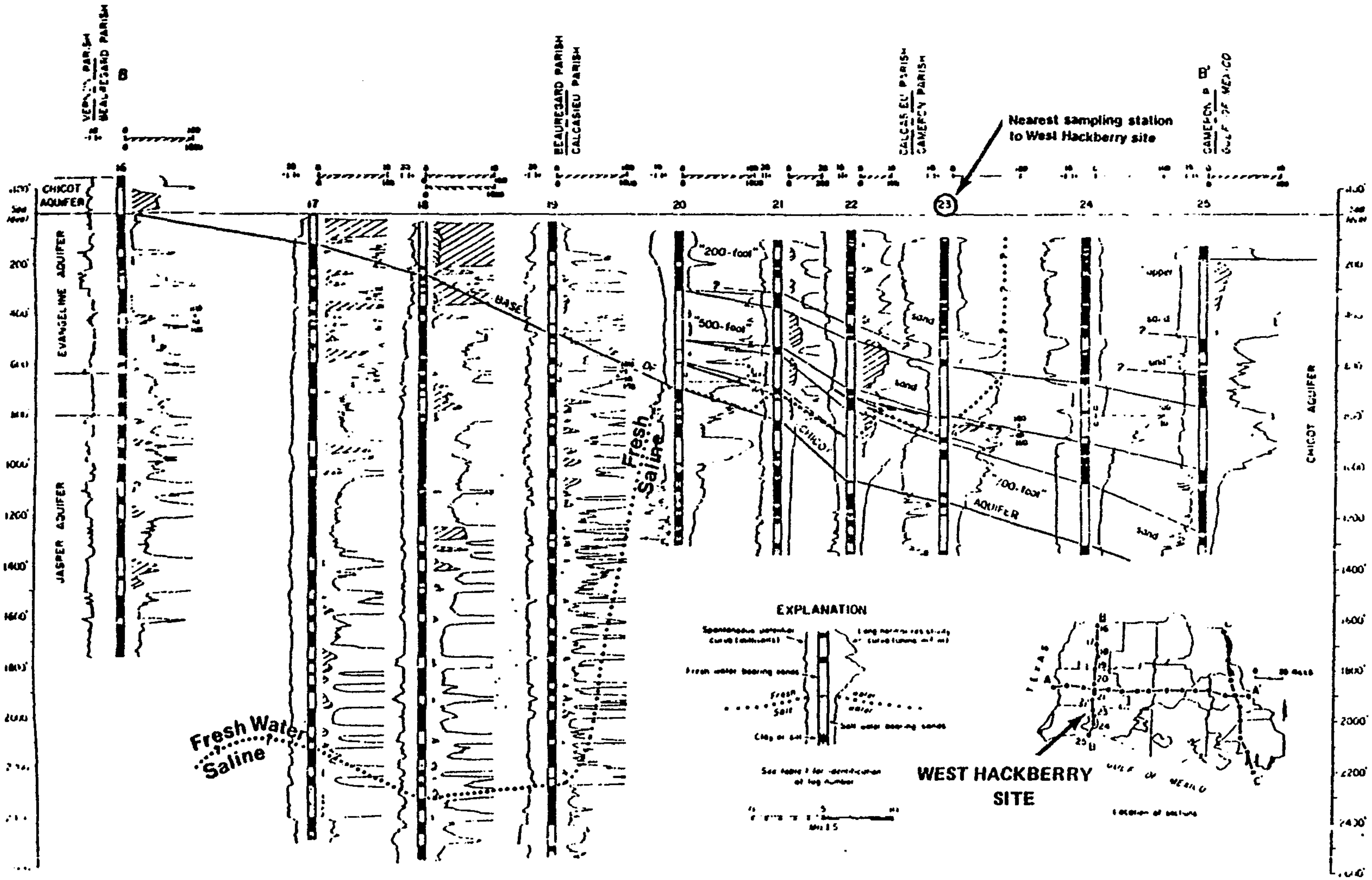

Figure 2.13 Geohydrologic Section from Northern Beauregard Parish to Southern Cameron Parish, Louisiana

individual sand beds range from 75,000 to 1,000,000 gallons per day per foot.[18]

Of special significance is the location of the interface between fresh and salt water. The dotted line rising vertically between wells 23 and 24 of Figure 2.13 indicates the .25 ppt salinity line, south of which no fresh water is found in the aquifer. Before large scale water pumping started, the general direction of water flow in the aquifer was southward. Heavy water use in the Lake Charles area for municipalities, industry, and agriculture has lowered the water level and reversed aquifer flow near West Hackberry as shown in the piezometric map* presented in Figure 2.14.

For this reason, 1967 data showed that the .25 ppt salinity line is moving northward at an estimated rate of 30 to 200 feet per year. This rate may have increased significantly in the last few years due to dredging in the area. In addition, because the aquifer sands are interconnected vertically as well as horizontally, the lowering of the water table may cause saline water to rise and contaminate less saline layers.

The major recharge for the Chicot aquifer occurs at the outcrop, more than 30 miles north of West Hackberry dome.[19] (See Appendix D.7.) The Chicot aquifer is not recharged from the surface in the West Hackberry area. Where pumping tests were performed, the Chicot responded as a confined

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*Piezometric maps can be explained as follows: The difference in head in the aquifer between 2 given points is generally expressed in feet of water, and the slope of the profile of head change between them is called the hydraulic gradient, generally expressed in feet per mile. The pressure gradient in an aquifer is determined by measuring the water level (in feet above or below a common datum) in wells tapping the aquifer. Contours, lines joining points of equal altitude on the potential surface of water in a given aquifer, enable a three-dimensional analysis of head distribution. Such water-level contour maps are known as piezometric maps. They show not only the distribution of pressure head in the aquifer, but also where the water is coming from, where it is going, and the route it is following. Piezometric maps can be used to determine the rate of ground water flow if the permeability and thickness of the aquifer are known.

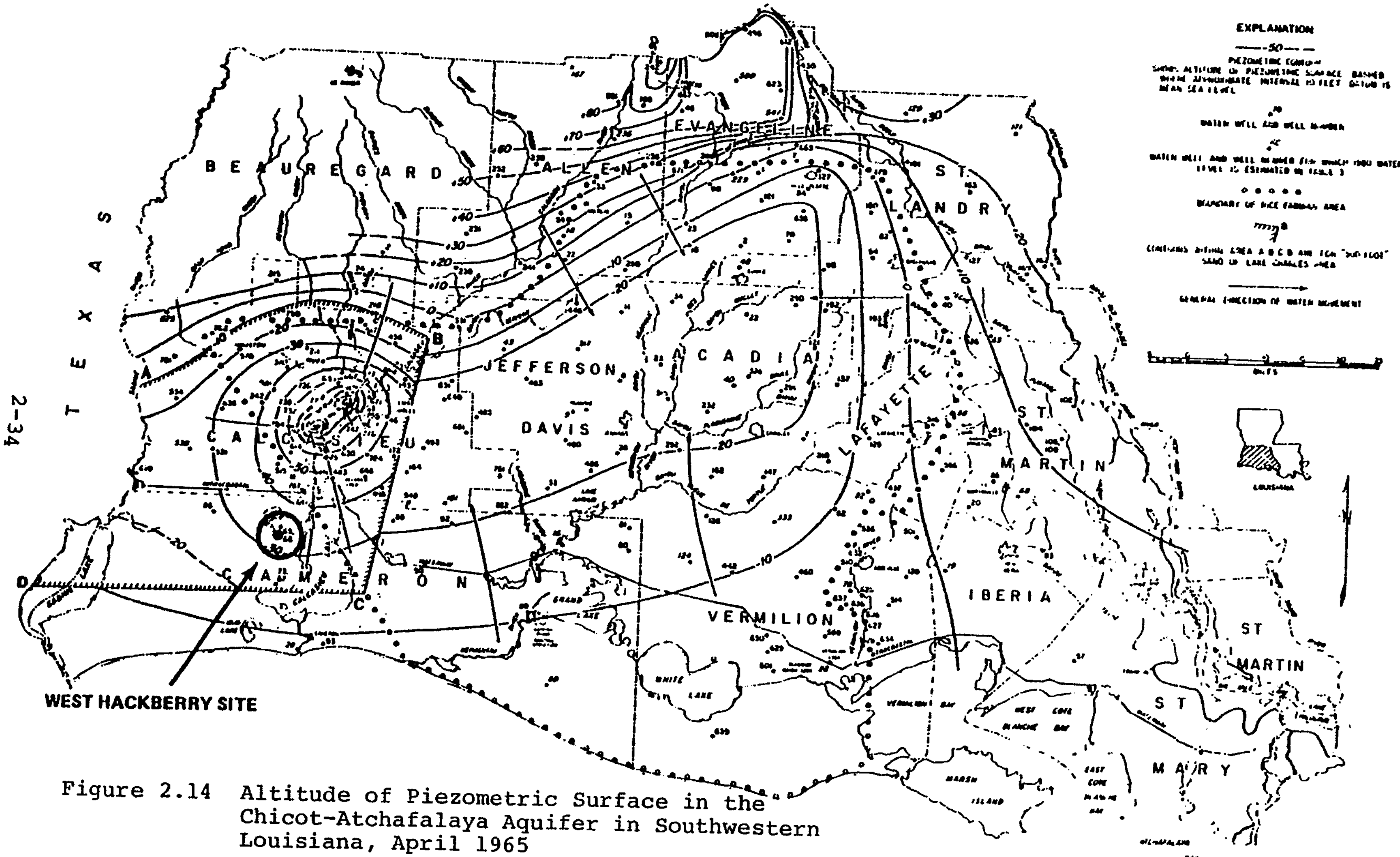


Figure 2.14 Altitude of Piezometric Surface in the Chicot-Atchafalaya Aquifer in Southwestern Louisiana, April 1965

aquifer, i.e., separate from surface recharged sources. Hundreds of feet[17] of impermeable clay overlie the Chicot near West Hackberry.

Because of the question of compatibility of water types which arises during brine injection, the characteristics of subsurface waters must be known.[20] (Data on the quantity of dissolved solids as a function of depth over this general area are given in Appendix H). The levels of dissolved solids corresponding to 1,000, 3,000, and 10,000 mg/l occur about 500, 850, and 1,100 feet respectively below mean sea level at the West Hackberry site. (Chemical and physical parameters for nearby wells in Cameron Parish at depths in the interval of interest are also presented in Appendix D.8.)

Estimates of the yield from wells in the shallow subsurface aquifers are based on a drawdown of 100 feet after 1 day of pumping and do not allow for the interference effects of pumping from other wells. The estimated potential yield for an individual well in both the slightly saline (1,000 to 3,000 mg/l) and moderately saline (3,000 to 10,000 mg/l) zones is in the 2,000 to 5,000 gallons per minute range.

In the immediate vicinity of the West Hackberry site, the principal user of shallow subsurface water is the town of Hackberry. Currently, the town's water supply consists of two wells. Well #1 has a total depth of 530 feet while well #2 has a total depth of 563 feet. The combined yield of the two wells is 200,000 gallons per day.[21]

The city of Sulphur, about 15 miles north of the site draws its water from 5 wells in the depth interval from 540 to 560 feet. The volumetric flow rate is about 4×10^6 gallons per minute.[22] Approximately 19 miles to the northeast, the city of Lake Charles also utilizes the shallow subsurface aquifers for its municipal water supply source. The water well depths range from 500 to 700 feet. The total yield is about 9×10^6 gallons per minute.[23]

2.2.3 Deep Subsurface Aquifers

The brine disposal method currently under consideration is injection into deep Pliocene-Miocene aquifers, at depths from 3,500 to 8,000 feet.

In the immediate vicinity of West Hackberry, deep well disposal of salt water was employed from 1949 to about 1972 with a cumulative disposal of 732,000 barrels. In 1974, no salt water disposal wells were being used in this area. However, throughout Cameron Parish in 1974, 37 deep wells were injected with 29.4 million barrels of salt water.[24] The cumulative amount in this parish through 1974 was 190.4 million barrels. Most of the salt water was injected at 2,500 to 3,500 feet. The minimum and maximum depths were 1,450 and 3,900 feet, respectively, except for one well at 20,314 feet. (Salt water disposal data for Cameron Parish are presented in Appendix H.)

Although no brine disposal is currently occurring at West Hackberry, in the past such operations have occurred. The brine involved originated at depths between 4,000 and 12,000 feet with a chloride content of about 100 ppt. In the initial operation of the disposal system, plugging of the wells was a problem. The cause of the plugging was not determined, but the problem was overcome by installation of a filtration plant and by periodically acidizing the wells. Due to a combination of corrosion and old age, the brine disposal lines are currently inoperative.[25]

The area south of West Hackberry dome is the proposed location for brine disposal wells. Only the 6 exploratory wells (indicated in Table 2.3) are located in this area. The location of each well is noted in Figure 2.15. As indicated in the Figure, three wells are located near the south boundary of the dome while the others lie on a north-east to south-west line which passes 5 miles south of the dome. The intervals between the latter 3 wells are 3 and 8 miles. Because the wells are few in number and widely spaced, correlations of major sand units are not possible. These reservoirs, however, are probably continuous for several miles east and west, but in the north-south direction their extent is probably less, due to salt structure and associated major east-west trending faults.

Massive sands (50 feet or thicker) were inventoried for wells numbered 1 and 4 in Table 2.3. These wells are presumed to be representative of the geologic section in which brine disposal wells will be completed. In each well, 6 sands 100 feet thick or thicker were present. In well #1, 24 percent of the section between 3,000 feet and 8,200 feet (bottom of sand section) or a total of 1,270 feet was massive sand beds (50 feet or thicker). In well #4, 18 percent or 1,100 feet of the interval between 3,000 feet and 9,000 feet (bottom of sand section) was massive sands. The sands, starting at a depth of 9,000 feet, slope southward

Table 2.3 Exploratory Wells in the Vicinity of the West Hackberry Dome

No.	Identity	Location	Total Depth (ft)
1.	Texaco, Burton #1	Sec.4-13S-10W	15700
2.	Texaco, Burton #2	Sec.5-13S-10W	13071
3.	Texaco, Burton #3	Sec.4-13S-10W	13520
4.	Texaco, Miani BR#1	Sec.25-13S-11W	12500
5.	Texaco, Miami - Starks #1	Sec.32-13S-11W	10300
6.	Hunt, State Lease 2397,#1	13S-9W	11001

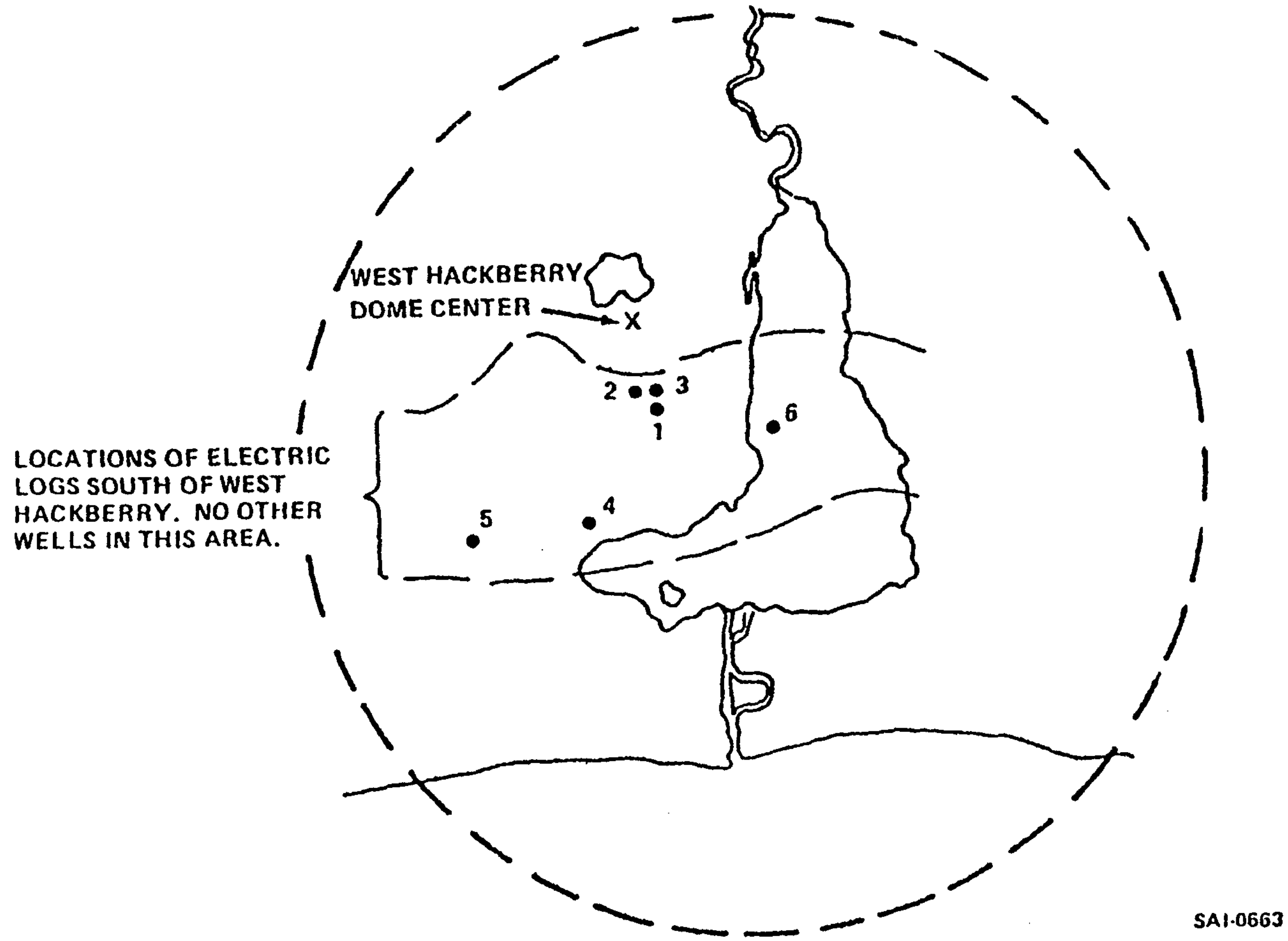


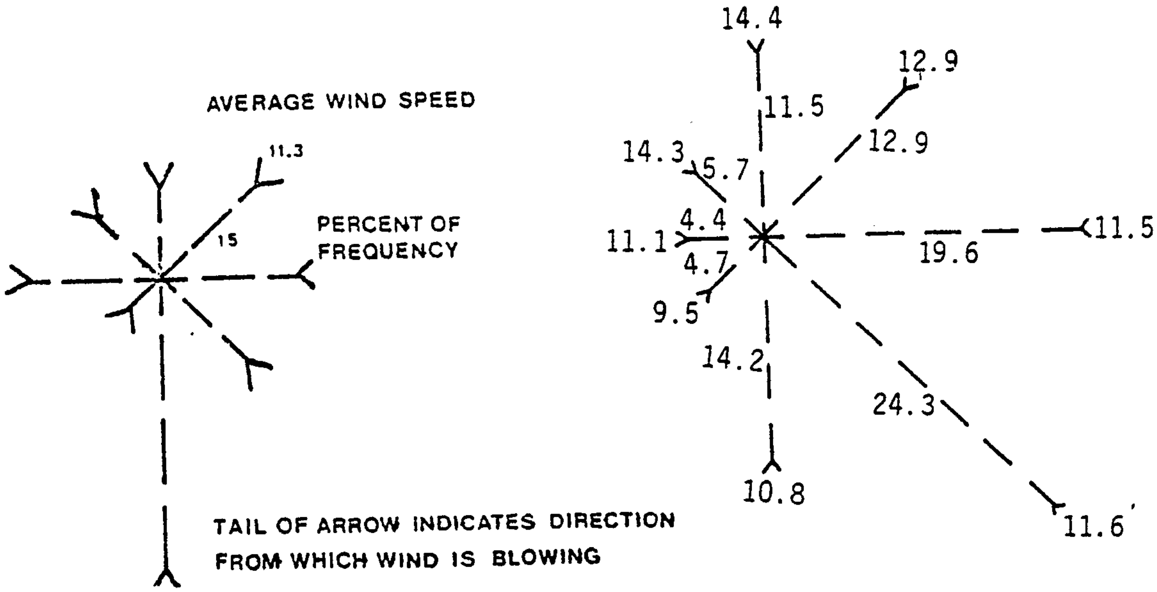
Figure 2.15 Location Map of Exploratory Wells in the Vicinity of the West Hackberry Dome

approximately 1,000 feet per mile for approximately 6 miles south of the dome. There the slope begins to reverse due to complex positive structures in the vicinity of East Mud Lake field.

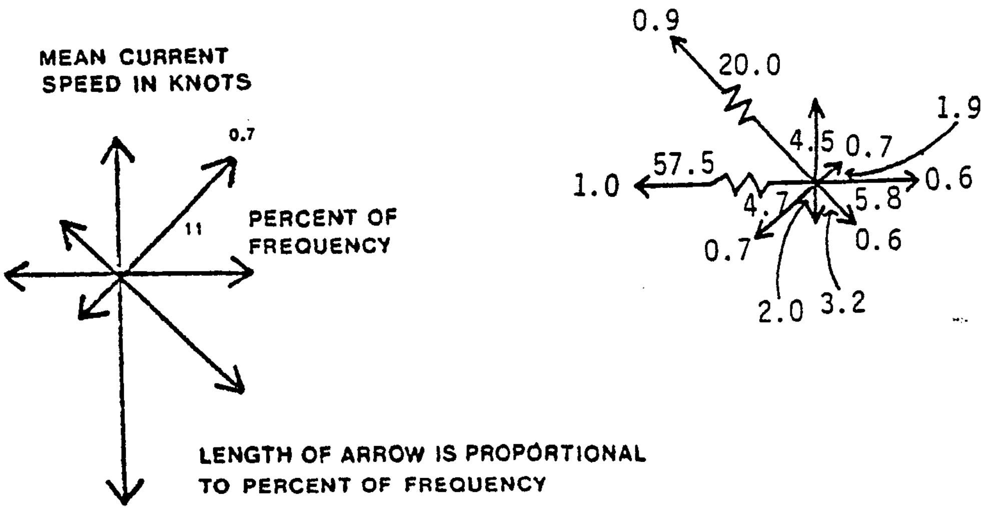
2.2.4 Coastal Waters of the Gulf of Mexico

The shallow coastal waters of the Gulf of Mexico south of West Hackberry constitute a brine disposal alternative. To attain the desired 20 to 25 foot depth for disposal, a site would be between 3 and 4 miles offshore.[26] The bottom composition in this area is mud.[27]

The salinity of the Gulf in the potential disposal area is affected by the discharge of rivers along the Louisiana coast, tides, precipitation, and other factors. No detailed salinity data for the immediate area are available. Salinity in Calcasieu Pass and the lower part of Calcasieu Lake is greater than 12 ppt.[28] The salinity at the entrance to Sabine Pass, 25 miles west is 28 ppt.[29] This relatively low salinity near the shore is evidently caused by west northwest currents carrying fresh water discharges from the rivers emptying into bays east of Calcasieu Pass (see Figure 2.10). It would appear that the salinity near a reasonable discharge point should be in the range of 15 to 10 ppt. Surface currents in the area are variable, being strongly affected by winds, tides, and other conditions. Mean surface currents 12 miles south of the potential discharge area are illustrated by the current rose in Figure 2.16. As indicated in this figure, the most likely current sets to the west (270°) with a drift of 1.0 knot . In the vicinity of Calcasieu Pass, the maximum drift is 2.3 knots.[30] The diurnal range of the tide here is 2 feet.[31] The wind rose shown in Figure 2.16 provides some indication of prevailing winds in the area. The most likely wind, as shown by the rose, is from the southeast (135°) at 11.6 knots.



Wind Rose off Calcasieu Pass



Current Rose off Calcasieu Pass

Figure 2.16 Wind Rose and Current Rose off Calcasieu Pass

2.3 METEOROLOGICAL CONDITIONS

2.3.1 Climatical Conditions*

The climate of the West Hackberry area is classified as "humid-subtropical with strong marine influences." Seasonal fluctuations are moderate. In winter the days vary from cool and clear to overcast. In summer the days are generally warm and humid, broken by afternoon showers or by thundershowers with little variety day-to-day.

The average freezing season at the Hackberry (8 SSW) weather station (approximately 6 miles south of the site on Calcasieu Lake) is between December 17 and February 17, with typically 4 to 8 days having temperatures of or below 32°F.[32] In Lake Charles, December and January are the foggiest months, with 8 to 9 days per month of heavy fog restricting visibility to less than a quarter mile.[33] November through May is usually the windiest, with mean wind speeds of 9 to 10 mph. The percent of winds less than 2 miles per hour at Lake Charles plotted per month is shown in Figure 2.17. The November through March period is typically the coldest with temperatures in the upper 50°'s; January to June is typically the driest with 4 to 4.5 inches of rain each month. The normal rainfall at Hackberry is plotted on a monthly basis in Figure 2.18. June, July, and August are usually the hottest, wettest, and most humid months with temperatures in the mid to low 80°'s, as seen in Figure 2.19; rainfall is 6.83 inches in July at Hackberry, and the humidity is greater than 80 percent in the morning, dropping to 70 percent in the afternoon and evening. Thunderstorm activity in the area is greatest in July and August with an average of 14 per month[34] and an approximate 70 mean annual days with thunderstorms.[35] The monthly distribution of thunderstorms for the Lake Charles area is shown in Figure 2.20. The annual rainfall in the area is approximately 54 inches at Hackberry and the annual lake evaporation losses are roughly 50 to 51 inches.[36]

Within the past twenty years, two storms passed through the area with winds 100 miles per hour or greater. These were Hurricane Audrey (25-29 June 1957), which passed west

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*The following data are not site specific in that the nearest weather monitoring stations are 6 to 20 miles away. Data presented is from the nearest station to West Hackberry.

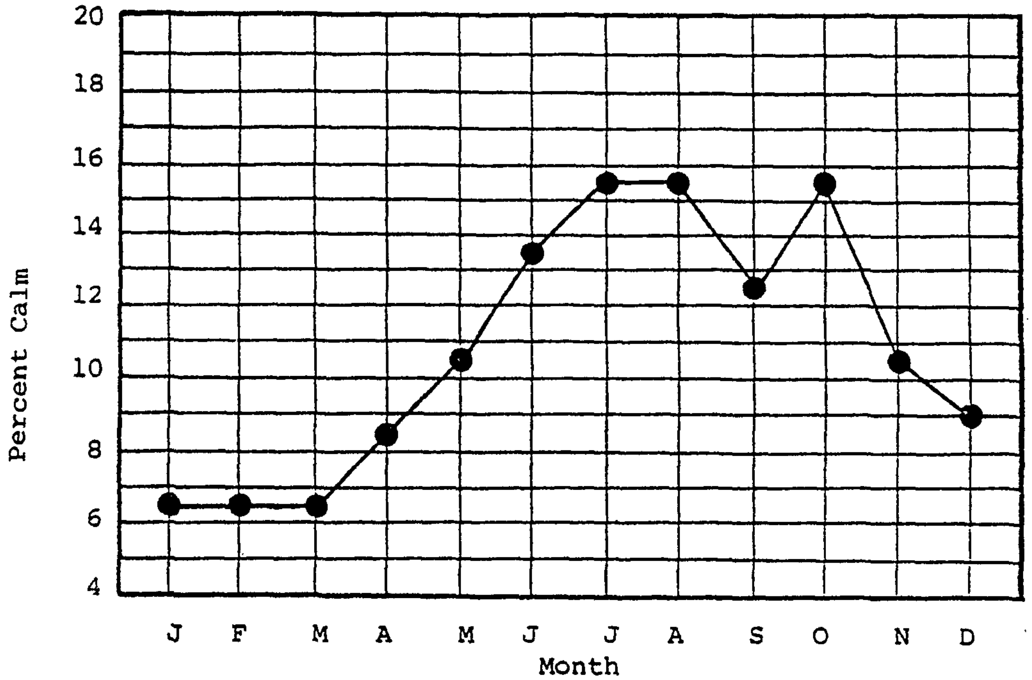

Figure 2.17 Monthly Percentage Calm at Lake Charles[43]
(Wind Speed ≤ 2 mph)

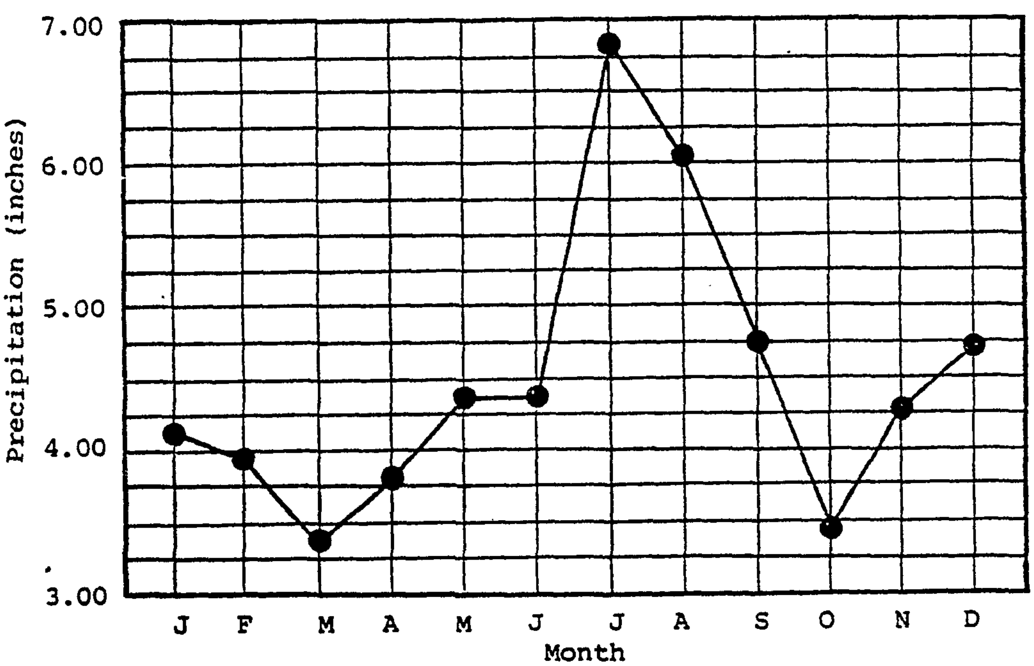

Figure 2.18 Monthly Normal Precipitation at Hackberry[39]
(8 SSW)

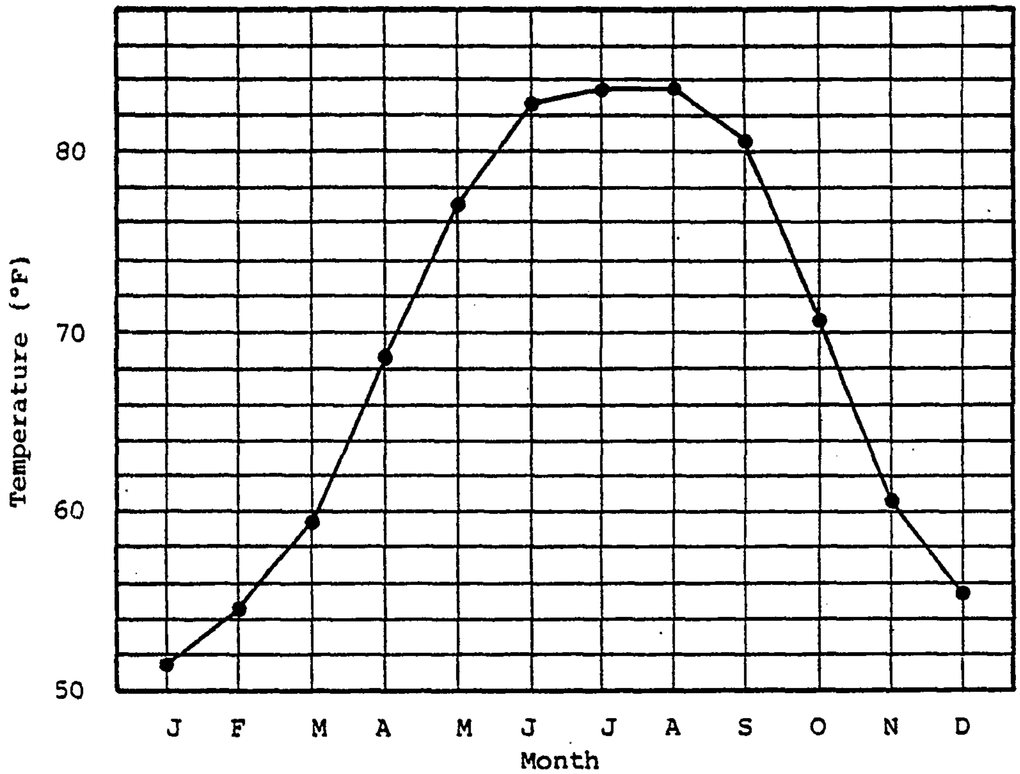

Figure 2.19 Monthly Normal Temperatures at Hackberry (8 SSW)
Source: Climatological Data-Louisiana, NOAA Vol. 78, No. 3, 1973 and Vol. 79, No. 13, 1974.

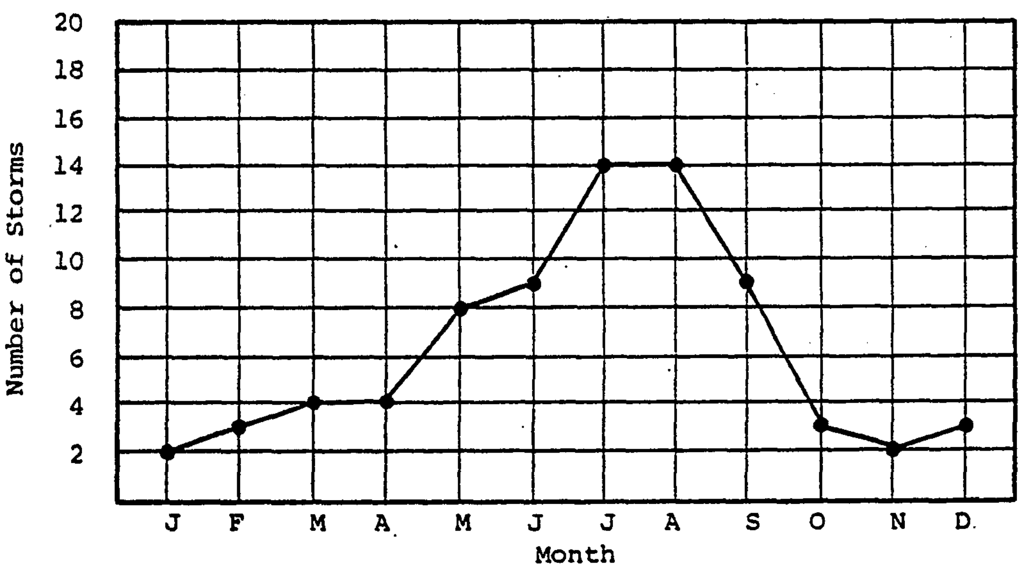

Figure 2.20 Average Number of Thunderstorms Per Month at Lake Charles (1967-1974)
Source: Local Climatological Data, National Climate Center, Asheville, N.C., 1967-1974.

of Lake Charles between Calcasieu Lake and Sabine Lake, and Hurricane Edith (5-18 September 1971), which passed southeast of the area.[38] Hurricane Bertha (8-12 August 1957) was a lesser storm (recorded winds less than 100 miles per hour through its path), and passed on a sweep from southeast of Hackberry to just north of Port Arthur.[38]

Severe storm statistics on the two 50 nautical mile strips (57.6 statute mile strips) of coastline in Louisiana surrounding West Hackberry reveal these details:[37]

Number of Tropical Cyclones Reaching the Mainland 1886-1970*

	West	East
All Tropical Cyclones	12	10
All Hurricanes	7	5
Great Hurricanes	3	1

Number of Years Between Tropical Cyclone Occurrences (Average for Period 1886-1970)

	West	East
All Tropical Cyclones	7	8
All Hurricanes	12	17
Great Hurricanes	28	85

Risk of Tropical Cyclones**

	West	East
All Tropical Cyclones	14%	12%
All Hurricanes	8%	6%
Great Hurricanes	4%	1%

*Dual numbers represent statistics for the western 50 miles and the eastern 50 miles in sequence, which surround West Hackberry on the west and east, respectively.

Definitions:

Tropical Cyclone	39-73 mph.
Hurricane	74-124 mph.
Great Hurricane	>125 mph.

**Risk equals the probability (%) that a tropical storm, hurricane or great hurricane will occur in any one year in a 50 nautical mile segment of coastline.

The nearest wind rose data are from Lake Charles. Figure 2.21 shows the pattern for the Lake Charles area, Figure 2.22 gives a general profile of the wind rose patterns for the Gulf Coast. The annual percent frequency of winds by speed groups for Lake Charles and Port Arthur, Texas show these characteristics:

Wind Speed Groups	Lake Charles[36]		Port Arthur[39]
0-3 mph	19%		6%
4-7 mph	31%		
8-12 mph	29%	60%	64%
13-18 mph	17%		
19-24 mph	4%	21%	29%
25-31 mph	1%		1%
32-46 mph	--		--
Mean Speed	8.5 mph		10.1 mph

Eighty percent of the winds in the Lake Charles area and seventy percent in the Port Arthur area are less than 12 mph. Extreme winds at 30 feet above ground with a 50-year recurrence interval are around 95 mph, and with a 100 year recurrence interval, around 100 mph.[40]

Atmospheric stagnation periods are minimal because of the Gulf Coast winds. The total number of forecast days of high meteorological potential for air pollution in a 5 year period ranges from approximately 5 to 10 days.[41]

The seasonal inversion frequency as percent of total hours is reported to be approximately 35 percent for winter, 25 percent for spring, 30 percent for summer, 40 percent for fall, with the annual inversion frequency of 30 percent.[42]

2.3.2 Existing Air Quality

In compliance with the Federal Clean Air Act, the State of Louisiana has initiated its Implementation Plan which provides for the implementation, maintenance, and enforcement of the Federal Air Quality Standards promulgated by the Environmental Protection Agency (EPA) on 30 April 1971 (36 FR 8186). The Louisiana Air Control Law requires any person intending to initiate new construction or modifications to file the appropriate applications and reports with the Louisiana Air Control Commission (LACC) stating plans, specifications, anticipated emissions and

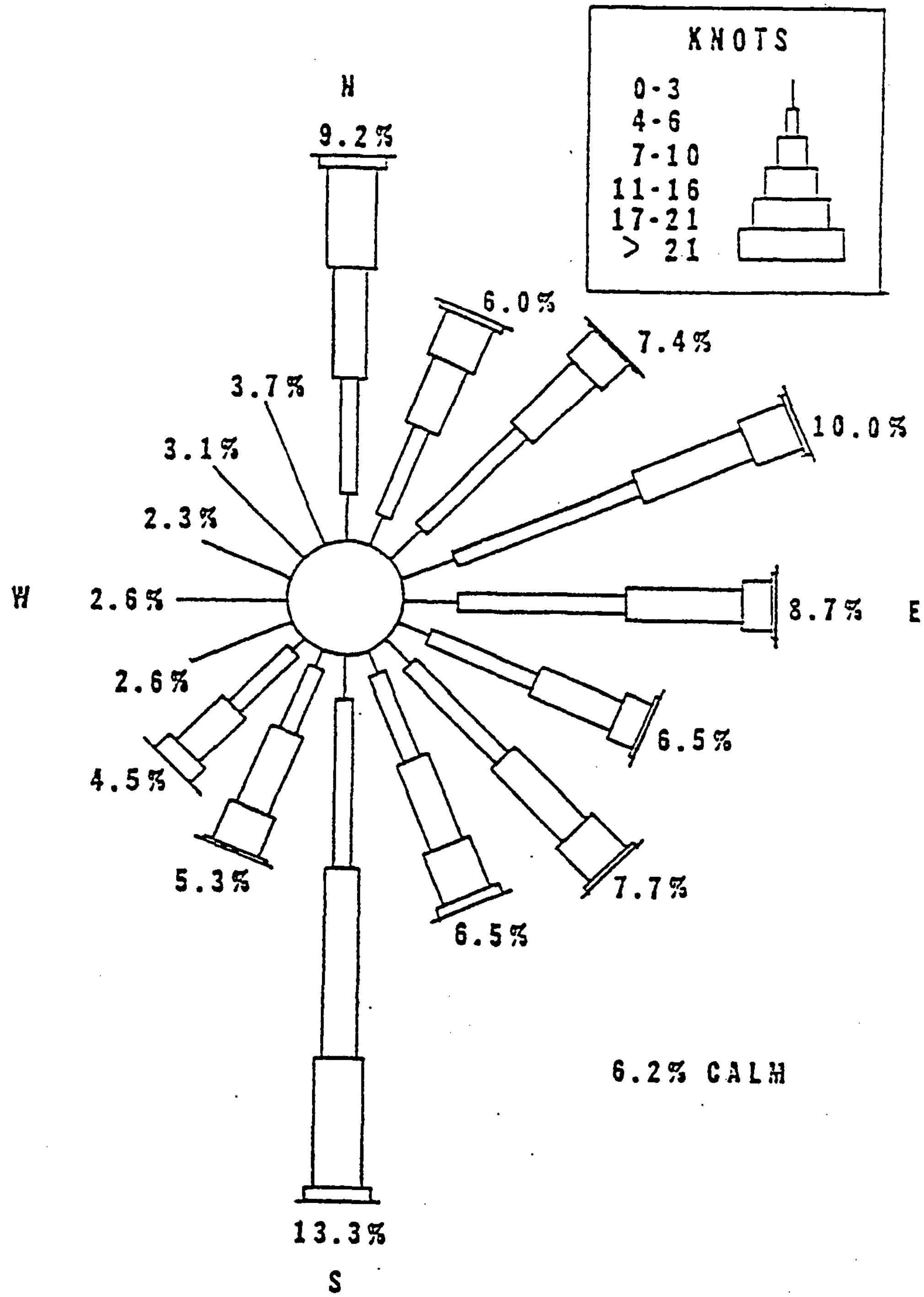

Figure 2.21 Annual Wind Rose, Lake Charles, Louisiana
(covers period 1966 - 1970)

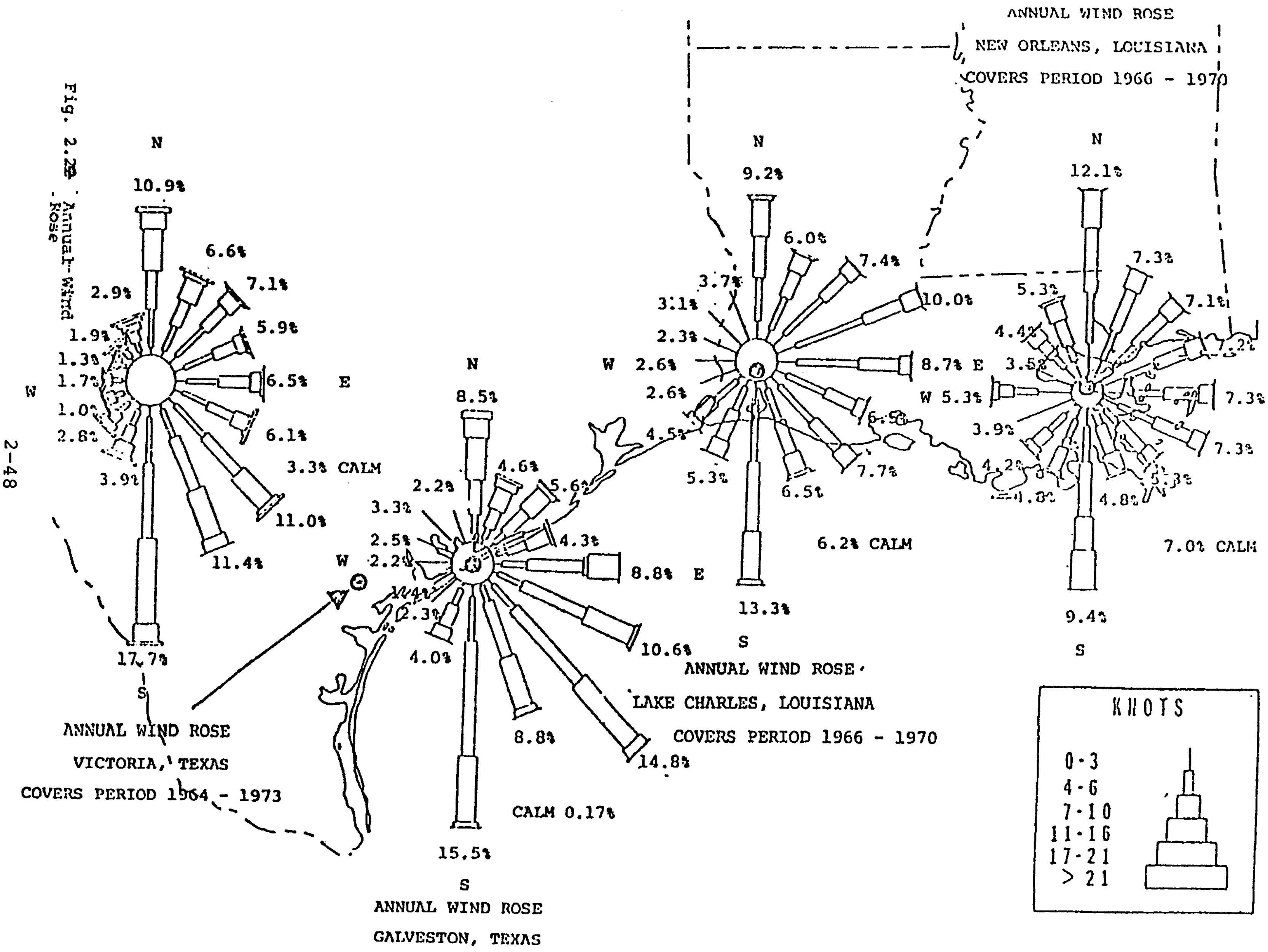

Fig. 2.2 Annual Wind Rose

and quantities, and plans for the abatement of emissions for the proposed construction or modification. Exemptions on emissions apply to volatile organics of these categories:

saturated halogenated hydrocarbons
perchloroethylene
benzene
acetone
C1-C5-n-paraffins
isobutane
methanol
crude oil and condensates

Exemptions can be made if economic hardship induced by the control of low photochemically reactive species can be shown for other volatile organics. Tables 2.4 and 2.5 show the Primary and Secondary Federal Ambient Air Quality Standards and the Louisiana Primary and Secondary Ambient Air Quality Standards. Discussions with the LACC indicate that it is the policy of the Commission to regulate pollutants at the source. Thus, Louisiana's first emphasis was directed toward monitoring highly industrialized areas of the state rather than the more remote areas such as West Hackberry. The nearest monitoring stations are in Lake Charles and West Lake (essentially a suburb of Lake Charles), 20 miles northeast. These stations have had many equipment problems and the resulting data are good for suspended particulates only, except in Lake Charles where sulfur dioxide concentration data have also been compiled.

Figures 2.23, 2.24, and 2.25 show the 1975 suspended particulate measurements for these two cities. The data received from the LACC are included in Appendix B. These data are for the monitoring stations within 25 miles of West Hackberry.

Lake Charles	20 miles, NE	Suspended Particulates
West Lake	22 miles, NE	Suspended Particulates
Lake Charles	20 miles, NE	Sulfur Dioxide

A review of these data show that March, April, and May are the periods when the highest levels of suspended particulates are encountered. Table 2.6 shows 1974 air pollution data for Lake Charles and Westlake. This table includes suspended particulates, sulfur dioxide, and nitrogen dioxide annual averages and daily or monthly maximum levels.

Table 2.4 Federal Ambient Air Quality Standards

Pollutant	Primary Standard	Secondary Standard
Particulates:		
Annual Geometric Mean	75ug/m^3	60ug/m^3
24-hour Maximum	260ug/m^3	150ug/m^3
Sulfur Oxides:		
Annual Arithmetic Mean	80ug/m^3 (0.03 ppm)	60ug/m^3 0.02 ppm
24-hour Maximum	365ug/m^3 (0.14 ppm)	260ug/m^3 0.10 ppm
3-hour Maximum	-	1300ug/m^3
Carbon Monoxide:		
8-hour Maximum	10mg/m^3 (9 ppm)	10mg/m^3 (9 ppm)
1-hour Maximum	40mg/m^3 (35 ppm)	40mg/m^3 (35 ppm)
Photochemical Oxidants:		
1-hour Maximum	160ug/m^3 (0.08 ppm)	160ug/m^3 (0.08 ppm)
4-hour Maximum	98ug/m^3 (0.05 ppm)	98ug/m^3 (0.05 ppm)
Hydrocarbons (bon-methane):		
3-hour Maximum	160ug/m^3 (0.24 ppm)	100ug/m^3 (0.05 ppm)
Nitrogen Dioxide (NO_2):		
Annual Arithmetic Mean	100ug/m^3 (0.05 ppm)	100ug/m^3 (0.05 ppm)

ug/m^3 = Micrograms per Cubic Meter

mg/m^3 = Milligrams per Cubic Meter

Table 2.5 Louisiana Ambient Air Quality Standards

POLLUTANTS	STANDARD (maximum permissible concentrations) PRIMARY	SECONDARY
Suspended Particulates:		
Annual Geometric Mean	75 μg/m^3	60 μg/m^3
Maximum 24-hour mean	260 μg/m^3	150 μg/m^3
Dust Fall	20 tons/mi^2/month	
Coefficient of Haze:		
Annual geometric mean	0.06 COH/1000 lin. ft.	
Annual arithmetic mean	0.75 COH/1000 lin. ft.	
Maximum 24-hr. mean	1.50 COH/1000 lin. ft.	
Sulfur Dioxide (SO_2)		
Annual Mean	80 μg/m^3	60 μg/m^3
Maximum 24-hour mean	365 μg/m^3	260 μg/m^3
Maximum 3-hour mean	---	1300 μg/m^3
Sulfur Acid Mist: (Sulfur Trioxide or any combination thereof)		
Maximum Annual Mean	4 μg/m^3	
24-hour Mean	12 μg/m^3 } not to be exceeded more than	
1-hour Mean	30 μg/m^3 } 1% of the time	
Carbon Monoxide (CO):		
8-hour Maximum	10 mg/m^3	10 mg/m^3
1-hour Maximum	40 mg/m^3	40 mg/m^3
Hydrocarbons (non-methane):		
3-hour Maximum between 6:00 and 9:00 a.m.	160 μg/m^3	160 μg/m^3
Total Oxidants:		
Annual Arithmetic Mean	58.8 μg/m^3	58.8 μg/m^3
4-hour Maximum	98.0 μg/m^3	98.0 μg/m^3
1-hour Maximum	160 μg/m^3	160 μg/m^3
Nitrogen Dioxide (NO_2):		
Annual Arithmetic Mean	100 μg/m^3	100 μg/m^3

Note: hourly means are not to be exceeded more than once per year

Source: Air Control Regulations, Louisiana Air Control Commission, New Orleans, Louisiana, August 1, 1974.

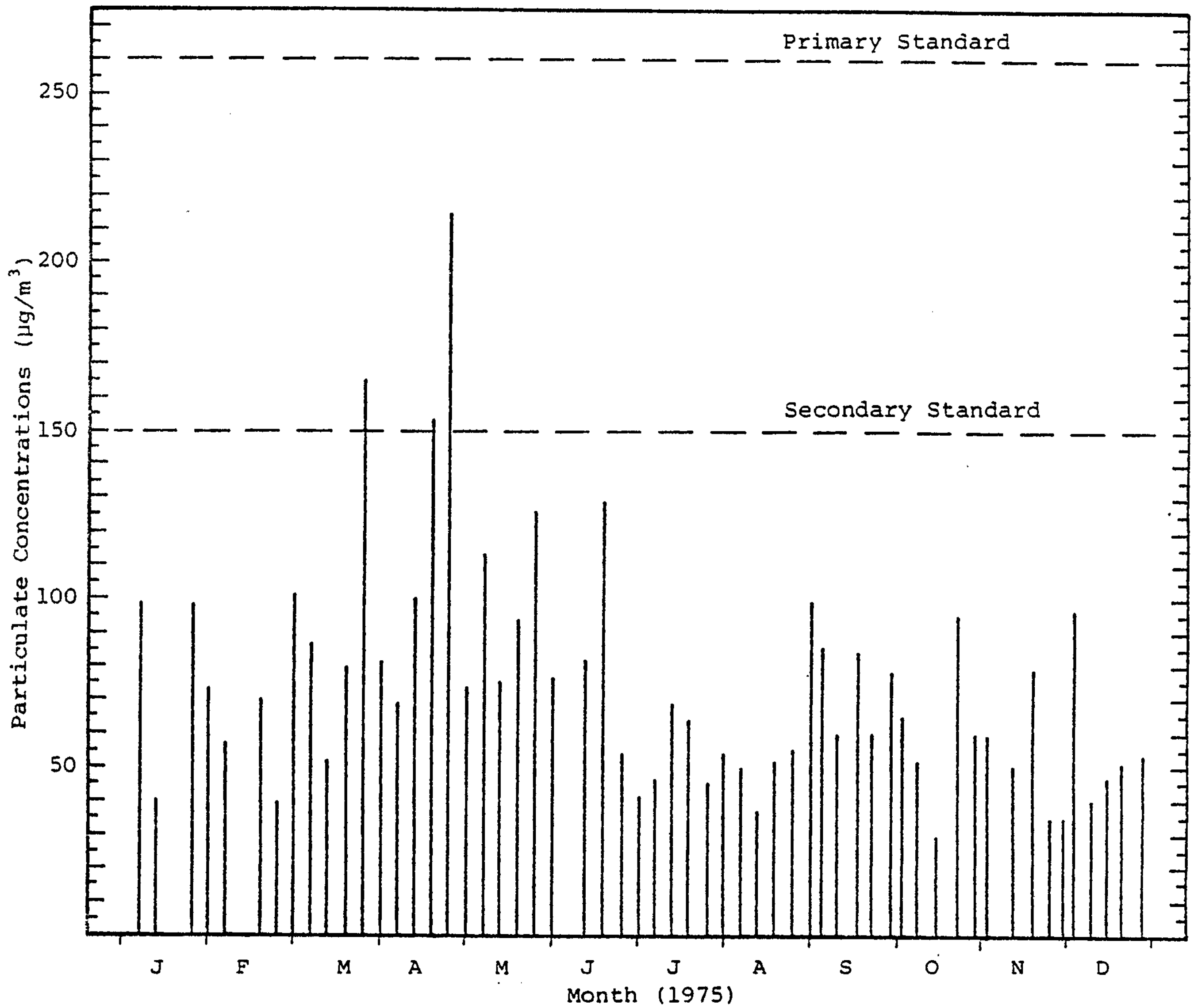

Figure 2.23 Louisiana Air Control Commission Suspended Particulate Air Data

City:	Lake Charles	Number of Samples:	57
Site:	721 Prien Lake Road	Geometric Mean:	68

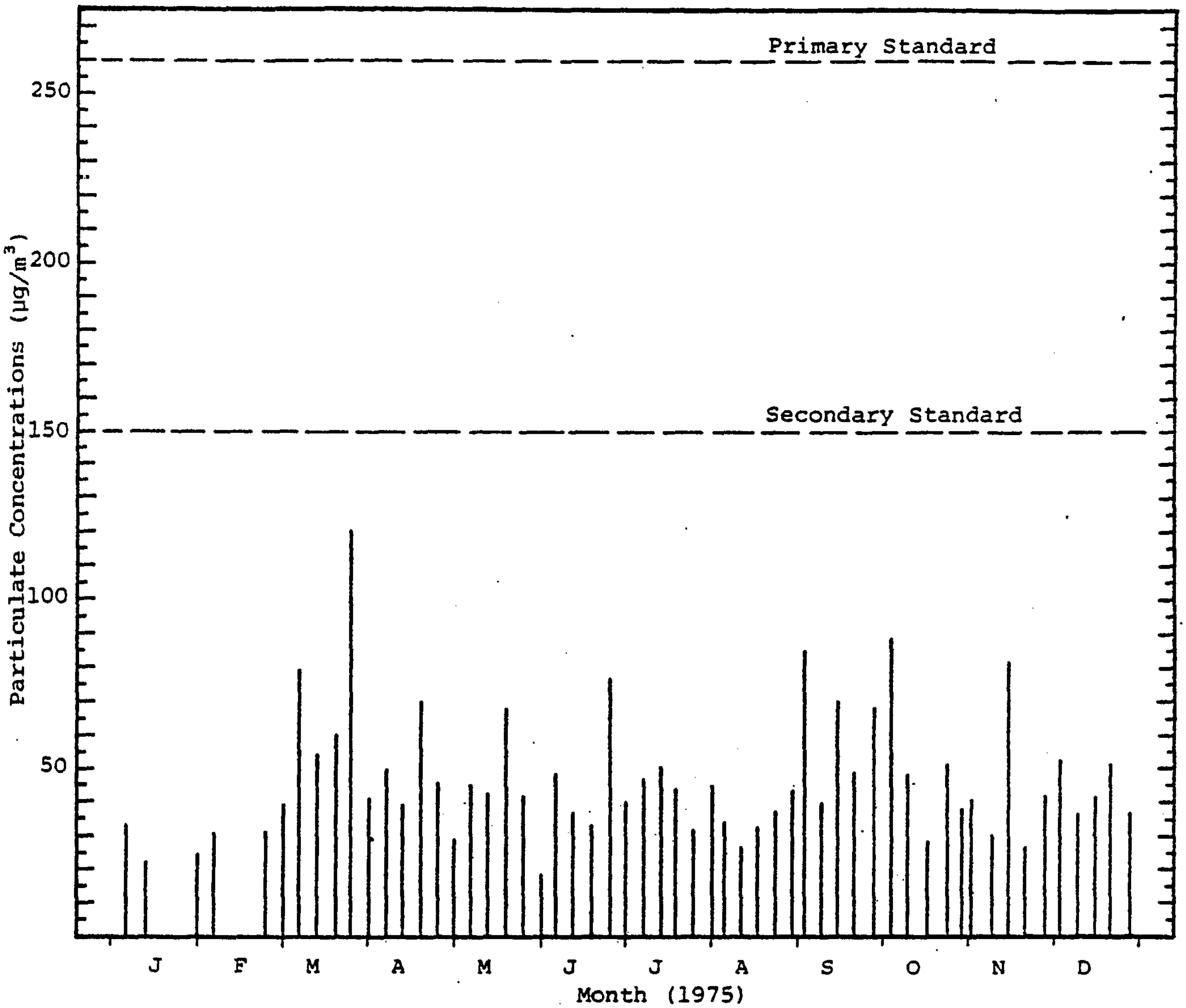

Figure 2.24 Louisiana Air Control Commission Suspended Particulate Air Data

City: Lake Charles — Number of Samples: 56
Site: Corner of Ryan and McNeese — Geometric Mean: 43

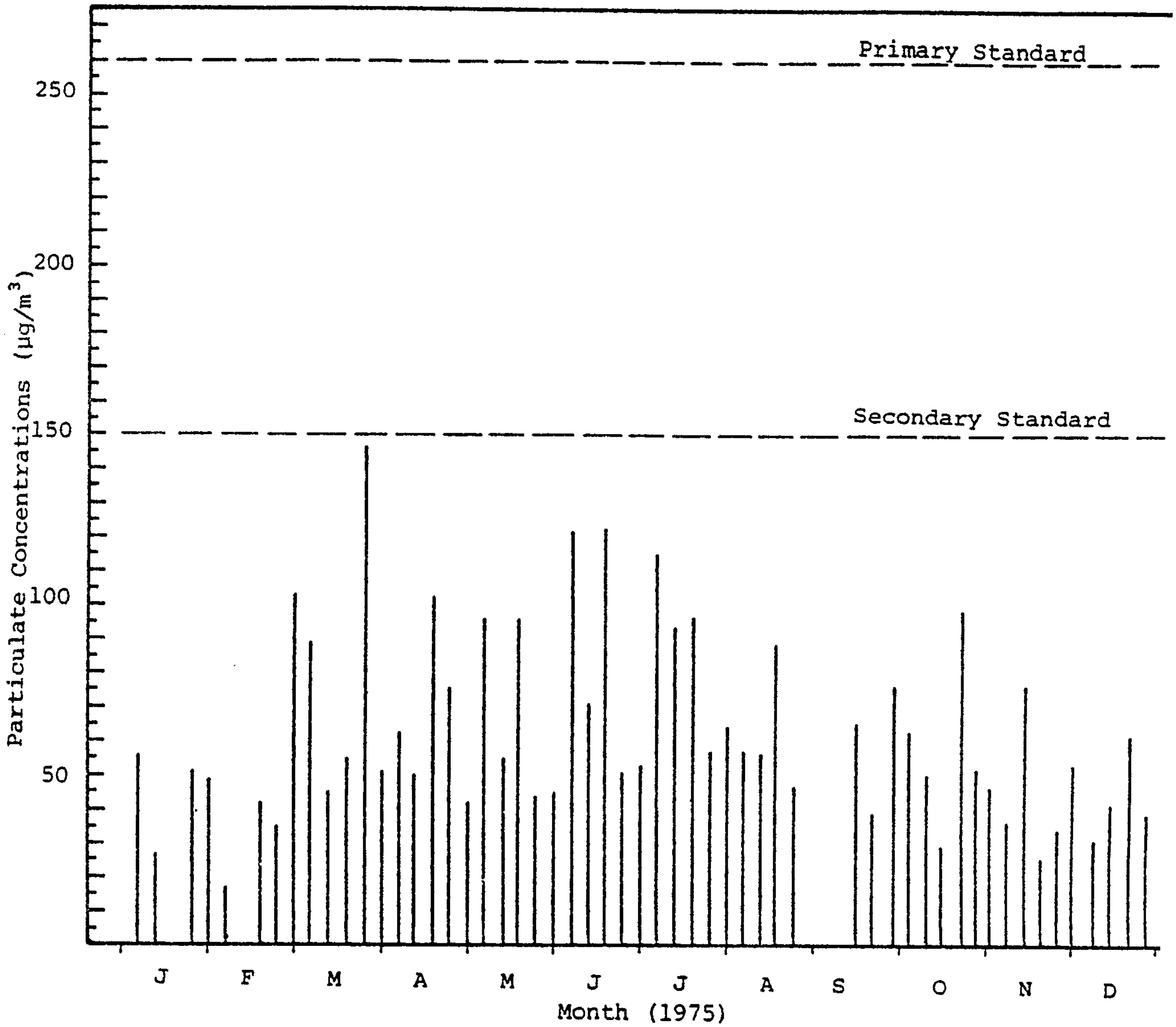

Figure 2.25 Louisiana Air Control Commission Suspended Particulate Air Data

City:	West Lake	Number of Samples:	55
Site:	701 Johnson St.	Geometric Mean:	57

TABLE 2.6 LOUISIANA AIR CONTROL COMMISSION AIR QUALITY DATA - 1974

given in micrograms per cubic meter

	Lake Charles	Westlake
Suspended Particulates		
Annual Average	65	60
Daily Maximum	12	150
SO_2		
Annual Average	5.5	1.3
Monthly Maximum	27	11
NO_2		
Annual Average	66	48
Monthly Maximum	160	72

In addition to LACC data on suspended particulates, other data collected by the Texas Air Control Board in the Beaumont-Port Arthur area (just west of West Hackberry) indicates that hydrocarbon and oxidant standards were violated during 1973 through 1975.*

This data indicates that the three-hour hydrocarbon standard was consistently violated during the three years of recording. This is not uncommon, however, as the subject standard is fairly consistently exceeded in most parts of the United States. The key issue in a discussion of hydrocarbon emissions is the reactive fraction, the type of gaseous hydrocarbons felt to contribute to smog formation. The fraction of reactive species was not quanitfied in the TACB monitoring program; however, elevated oxidant levels as observed in the area by the LACC during 1975 attest to the presence of reactive hydrocarbons and oxides of nitrogen. During 1975 in the Louisiana portion of the Southern Louisiana-Southeast Texas AQCR, second-highest hourly oxidant readings in excess of the national standard were recorded at Baton Rouge (340 $\mu g/m^3$), New Orleans (188 $\mu g/m^3$), and Lake Charles 348 $\mu g/m^3$). These data indicate that sufficient amounts of reactive species are present in the atmosphere to result in significant photochemical activity. However, the primary sources of the reactive species are difficult to discern as regional transport mechanisms are involved.

A synopsis of the available air quality data from local and regional sources indicates that existing pollutant levels at West Hackberry are below the applicable State and Federal air quality standards with the exception of hydrocarbons and photochemical oxidants. The latter contaminant will violate the applicable standards on occasion while hydrocarbon levels will often be in excess of the three-hour national standard. However, the local average fraction of reactive hydrocarbons has not been established.

*Texas Air Control Board, Ambient Air Monitoring Data Summaries for Nederland and West Orange, Texas, 1973-1975.

In order to represent the West Hackberry salt dome area more appropriately, the best profile comes from the LACC and their compilation of annual emissions of particulates, hydrocarbons, and sulfur oxides by parish. The West Hackberry salt dome is in Cameron Parish, and is 3 miles south of the border of Calcasieu Parish. Cameron Parish is a marsh dominated area. Since Calcasieu Parish is essentially dry land, it is more industrialized and urbanized than Cameron Parish. The measure of emissions in tons/year[43] is not convenient for comparison, so these numbers were reduced to a roughly common form of pounds per square mile per hour. Table 2.7 shows these adjusted emissions for Cameron and Calcasieu Parishes. Included is the predominant industry of each parish, based on census statistics of the total work force and the distribution among the various industry and commerce operations in each parish. In Calcasieu Parish, high emissions come from petroleum refineries, and petrochemical plants alone contribute greater than 95 percent of the total parish sulfur oxide emissions. The combination of petroleum refineries, and petrochemical and chemical plants accounts for greater than 70 percent of the total Calcasieu Parish point source emissions of hydrocarbons and particulates.

Cameron Parish is shown to be a very "clean" parish with regard to air quality, and perhaps this is the best characterization which can be given to the general area.

2.3.3 Noise.

Noise at the site and in the near vicinity of the West Hackberry salt dome is typical of a secluded, essentially flat area. In the winter and spring, the contributing noise sources are wind in the trees, periodic bird calls and the rustle of the grasses and brush. The day-night weighted levels are around 48 dBA on reasonably calm days (winds less than 10 mph). In the summer, due to the high humidity and warmth, the marshland noise is dominated by the buzz of mosquitoes and other insects, frogs, crickets, and bird calls, and the noise of the foliage on the trees and brush, as winds blow through. On a normal summer evening, the noise levels can be as much as 10 to 15 dBA higher than winter levels because of activities of native creatures and insects.

The West Hackberry site is characterized by remote area noise patterns, and local activity nearby on public roads

Table 2.7 Emissions and Industry Profiles for Calcasieu and Cameron Parishes (1970)

Parish	Area Sq. Mi.	Pop. Density	SO_x lb/mi^2-hr	Hydrocarbons lb/mi^2-hr	Particulates lb/mi^2-hr	Predominant (% of Total Work Force) Industry: Mining	Manufacturing	Industry as % of Manufacturing Work Force: Chemical	Transportation Equipment
Cameron	1444	5.7	0.08	0.004	0.006	16%	11.8%	9%	11%
						13%	= Agriculture, Forestry and Fisheries (% of Total Work Force)		
Calcasieu	1105	131.6	11.4	11.8	1.6	3.6%	19%	37%	5%
% Petroleum Refinery and Petrochemical Operations Point Source Contribution			98%	35%	63%	2.3%	= Agriculture, Forestry and Fisheries (% of Total Work Force)		
						11%	= Construction (% of Total Work Force)		
% Chemical Industry Point Source Contribution				43%	8%				

Source: Public Affairs Research Council of Louisiana, Inc., "Parish Profiles," Baton Rouge, Louisiana, 1973.

Emissions from LACC Implementation Plan.

barely penetrates to the site due to the sound attenuation of scattered clusters of trees.

In preparation of the environmental impact report for the proposed offshore superport, Seadock, Inc. performed a brief ambient noise survey in the area of Jones Creek (a small community southwest of Freeport, Texas) where the onshore facilities will be located. While this study is not site specific for West Hackberry, the area is very similar and the ambient levels and spectra can be assumed to be representative of noise sensitive areas around the site. Figures 2.26 and 2.27 show the daytime, evening, and nighttime octave band spectra for two sites chosen by Seadock, Inc. on the basis of their sensitivity to interruption by noise. The first is approximately 2,000 feet from a running creek, the second is at a small community roadside. These spectra were taken in early March when deciduous trees are still barren and the insect population is relatively low. Figure 2.28 is the ambient spectrum taken from a Department of Transportation noise survey of the Florida Everglades.[45] This spectrum is a little "quieter" than the Jones Creek area daytime spectrum, which can be attributed to the lack of human activity (road traffic in particular) in the everglades.

The A-weighted* levels range from a low of 40 dBA (nighttime) to a high of 48 dBA (daytime). In the summer, these ambient levels may be as high as 50 dBA in the evening.

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*The A-Weighting is a method of adjusting the sound pressure level (dB re:0.0002 ubar) at each center octave band frequency in much the same way that the human ear does in attenuating incident sounds. Essentially, a young, normal human ear is much more sensitive to sounds between 500 Hz and 8000Hz than it is to low and high frequency sounds. This apparent "attenuation" is very closely matched by the A-weighted scale used in sound measurements.

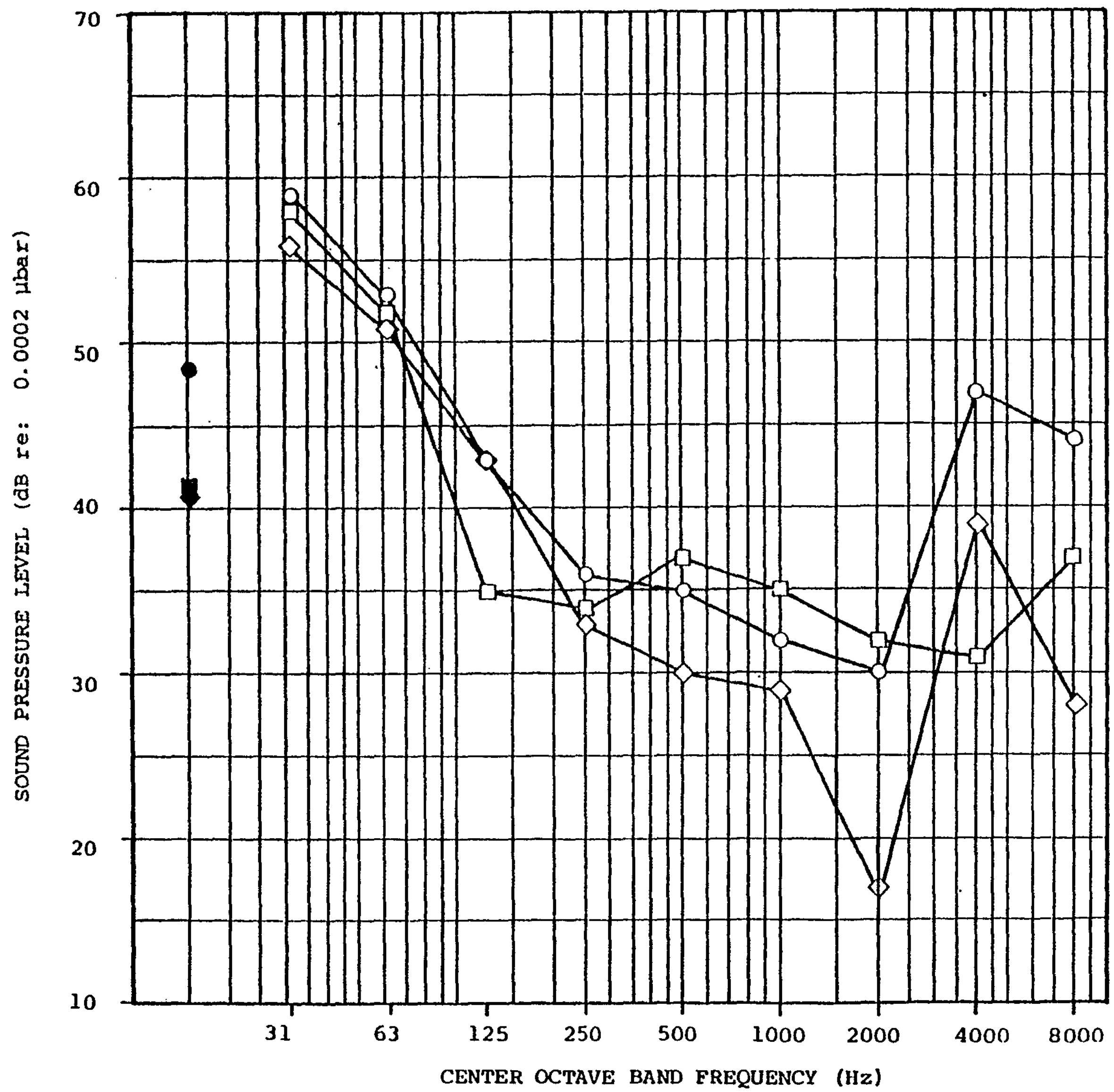

Figure 2.26

Ambient Levels, SPL, 2000 feet from a Small Creek at a Roadside Park near Jones Creek (Seadock, Inc.)

L_{dn} = 49 dBA

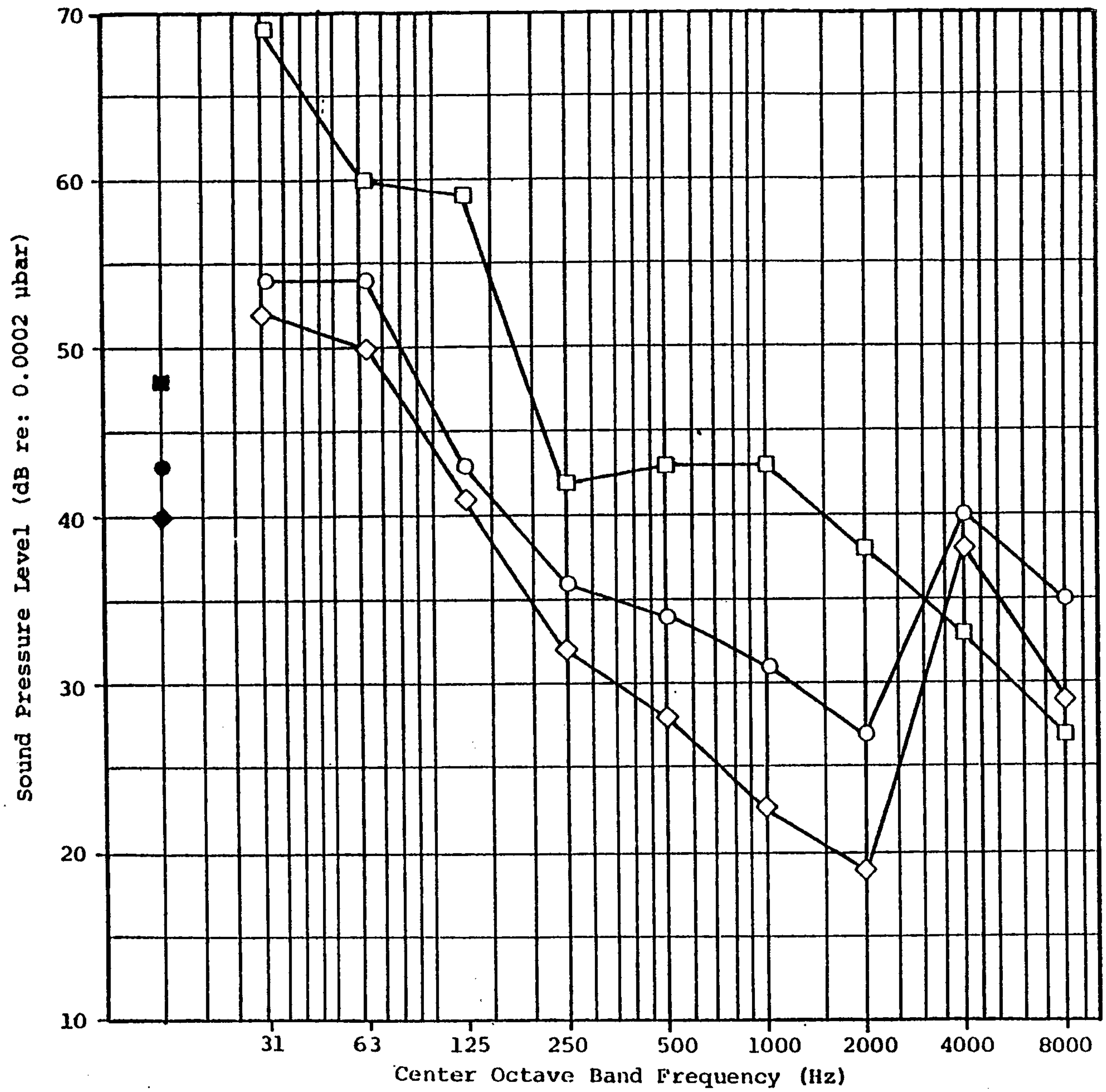

Figure 2.27

Ambient Levels, SPL, in Small Community Roadside near Jones Creek (Seadock, Inc.)

L_{dn} = 48 dBA

○ Evening SPL (dB)

□ Daytime SPL (dB)

◇ Nighttime SPL (dB)

● Evening SPL (dBA)

■ Daytime SPL (dBA)

◆ Nighttime SPL (dBA)

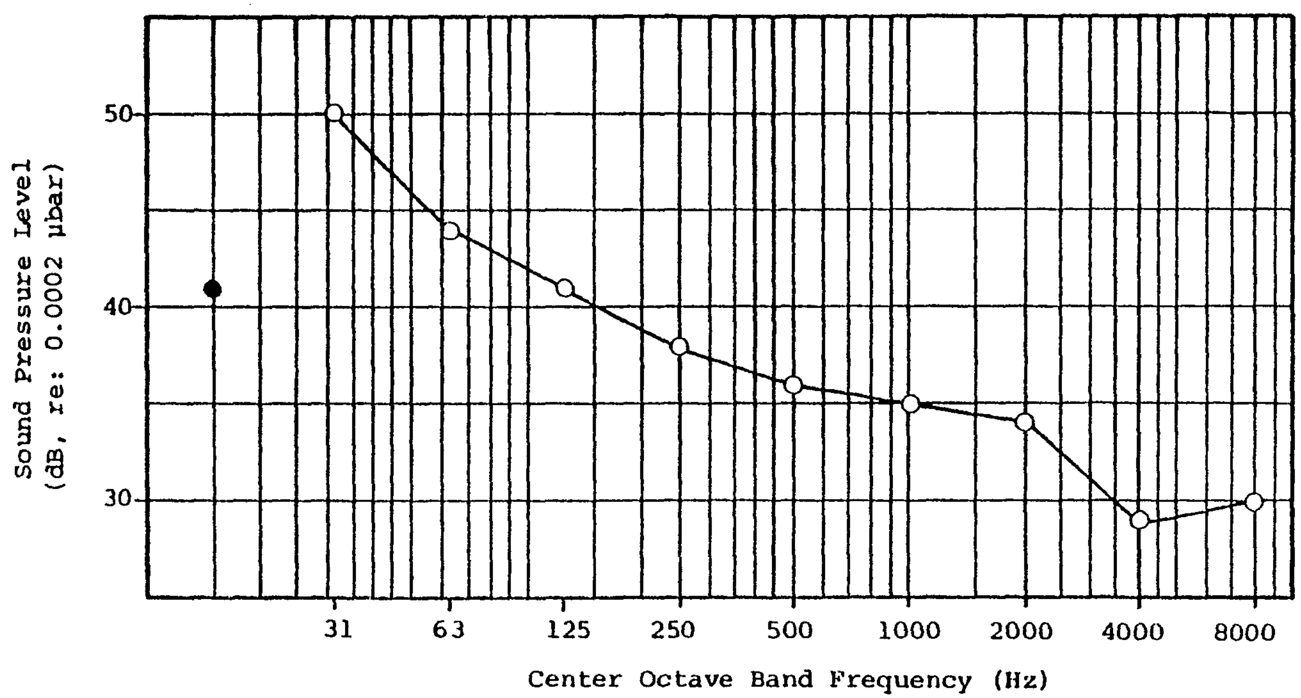

Figure 2.28

Ambient Levels, SPL, Florida Everglades, Early March, Daytime

2.4 SPECIES AND ECOSYSTEMS

Major ecological areas surrounding the site are shown on Figure 2.29. The dominant species of these ecosystems are displayed on Table 2.8. Present design of the storage facility indicates that three types of ecosystems will be affected as shown in the following matrix:

	Prairie Land (pasture)	Brackish Marsh	Inland and Estuarine Waters
Storage Site	x		
Brine Disposal Field	x		
Displacement Water Source			x
Pipeline Rights-of-way	x		
Temporary Barge Dock		x	x
Permanent Tanker Dock	x		x

2.4.1 Prairie Ecology

The western half of the dome is a slightly elevated area within the brackish marsh and historically probably contained prairie vegetation. However, today the prairie region of southwestern Louisiana is mainly an agricultural area and in the vicinity of the site is improved pastureland. Natural vegetation found at the site is predominantly switch grass (*Panicum virgatum*), big bluestem (*Andropogon* spp.), Indian grass (*Sorghastrum avenaceum*), and prairie wildgrass (*Spenopholis obtusata*). Also found are typical pasture species: signal grass (*Brachiaria platyphylla*) and goatweed (*Croton capitatus*). Trees are found in scattered areas and around residences. These trees are a mixture of oaks, ash, American elm, and sweetgum.

Dominant species of mammals located in the prairie environment within the study area are mice and rats, (*Peromsycus gossypinus* and *Sigmodon hispidus*), and domestic livestock.

Avian wildlife within this environment primarily consists of small birds, field birds and migratory waterfowl. The

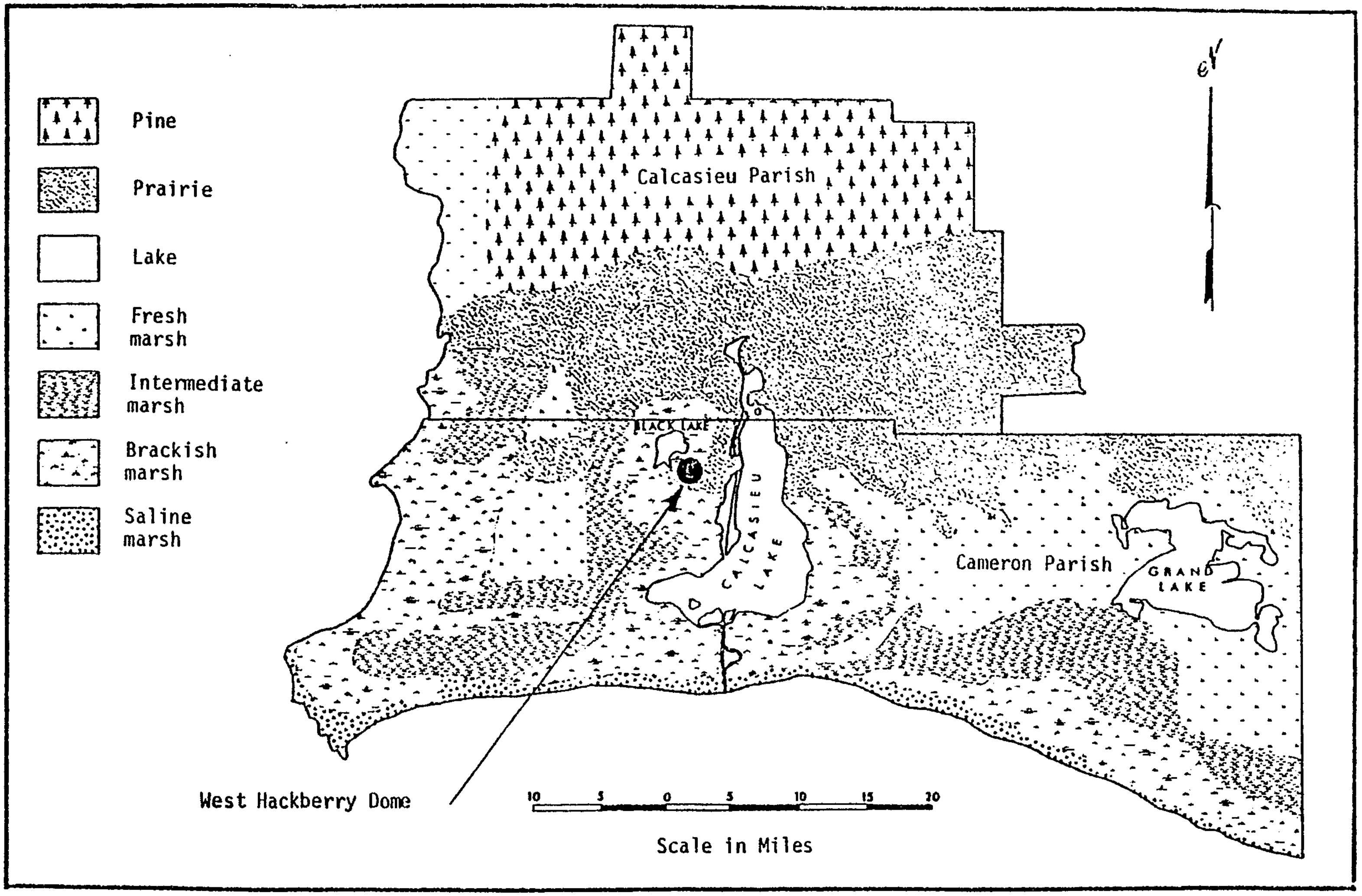

Figure 2.29 Distribution of vegetation types in two parish study area of the West Hackberry salt dome.

Table 2.8 Dominant Flora and Fauna of the Ecosystems of the Affected Area

Ecosystems	Prairie Lands	Cleared Lands	Marshlands	Inland and Estuarine Waters
Environmental Subcategory	Prairie	Cropland, Suburban, and Urban	Fresh, Intermediate Brackish, and Saline	Lakes, Rivers and Intracoastal Waterway
Typical herbs, grasses and trees	Bluestem, switch grass indian grass prairie wild-grass	rice	Oystergrass maiden cane alligatorweed wiregrass widgeongrass bulltongue	N/A
Typical mollusks and crustaceans	Snails	Snails	Clams snails shrimp, crab	Oysters, shrimp clams, snails, crabs
Typical amphibians and reptiles	Grass snakes turtles	N/A	Water snakes alligators	Frogs alligators
Typical mammals	Eastern Cottontail rabbit, mice, striped skunk	Domesticated mammals Norway rat housemouse	Nutria, muskrat raccoon, mink striped skunk	Dolphins
Typical fish	N/A	N/A	Gar killifish crappie sunfish catfish	Mullet, catfish, cyprinids, flounder drum, shad, menhaden
Typical birds	Marsh hawk, Eastern Meadowlark	American Robin, Starling, House sparrow, Brown headed cowbird	Red-winged black-bird, egrets ibises, shore birds, Marsh Hawk Ducks	Ducks gulls tern

Bobwhite (*Colinus virginianus*), Killdeer (*Charadrius vociferus*),
Common Crow (*Corvus brachyrhynchos*), various thrushes, Starling (*Sturnus vulgaris*), Savannah Sparrow (*Passerculus sandwichensis*), and Field Sparrow (*Spizella pusilla*) are only a few common birds known to inhabit the region.

2.4.2 Brackish Marsh Ecology

Brackish marsh almost surrounds the West Hackberry dome and Black Lake. The eastern half of the dome is partially under brackish marsh. Vegetation of the brackish marsh is more diverse than a saline marsh and is made up of less salt-tolerant species. Salinities usually average between 10-20 ppt.[46] Chabreck lists forty species of plants from the brackish marshes of Louisiana of which the site is typical.[47] The dominant species is wiregrass,which comprises 55 percent of the vegetation. Saltgrass makes up 13.3 percent, and of the remaining 38 species, only five are listed as secondary species (2 to 5 percent of the vegetative type). These species are three-cornered grass, oystergrass, black rush, wigeongrass, and dwarf spikerush.

The value of *Spartina*-*Distichlis* dominated marshes to wildlife is relatively low. These species tend to form dense stands to the exclusion of more important wildlife food plants. However, two valuable species found in scattered associations are *Scirpus olneyi* and *S. robustus*. Both species occur in localized but distinct situations in the brackish marsh. *S. robustus* is more often associated with more salt tolerant species. *S. olneyi* is generally located in the interior of marshes removed from tidal activity and usually in low, wet situations. At present these sedges occupy only a small portion of the total brackish marsh, but they are important wildlife food plants in these areas.[48],[49] Brackish marshes, like saline marshes, serve as important nursery and rearing areas for many species of fishes and shellfishes. However, productivity is generally considered less than the oystergrass dominated saline marshes.

The value of coastal marshes to waterfowl is great. Table 2.9 shows the estimated number of puddle ducks (dabblers) and diving ducks in the Louisiana Coastal Marsh and ricelands during December 1972. The southwest region is probably indicative of the site's waterfowl inhabitants. Mallards are almost twice as abundant in the southwest region as compared to the southeast area. Northern

Table 2.9. Estimates of waterfowl in southwest and southeast Louisiana marshes* during December, 1972. (information courtesy H. Bateman, Louisiana Wild Life and Fish. Comm.)

SPECIES**	SOUTHWEST	SOUTHEAST	TOTALS
Mallard	224,000	117,000	341,000
Gadwall	521,000	582,000	1,103,000
Baldpate	296,000	341,000	637,000
Green W. Teal	455,000	253,000	708,000
Blue W. Teal	66,000	94,000	160,000
Shoveler	118,000	81,000	199,000
Pintail	212,000	246,000	458,000
Mottled Duck	32,000	26,000	58,000
TOTAL DABBLERS	1,924,000	1,740,000	3,664,000
Redhead	NO ESTIMATE	NO ESTIMATE	-
Canvasback	NO ESTIMATE (150,000 offshore)	NO ESTIMATE (500,000 offshore)	- (partial estimate
Scaup	4,000	4,000	658,000
Ringnecked	31,000	11,000	42,000
Ruddy	TRACE	TRACE	TRACE
Hooded Merganser	4,000	6,000	10,000
TOTAL DIVERS	189,000	521,000	710,000
TOTAL DUCKS	2,113,000	2,261,000	4,374,000
Coots	599,000	1,017,000	1,616,000

* Below U.S. Hwy. 90

** Wood ducks and geese not censused and black ducks are included with Mottled ducks.

Shovelers and Green-winged Teal are particularly more abundant in the southwestern area. The most abundant dabbling duck is the Gadwall. Other abundant dabblers are Baldpate and Pintail.

Besides their importance for waterfowl, the marshes also serve as habitat for many shore and wading birds and resident passerine species. The Common Snipe is an abundant winter resident of the marshes and lake shores. Other common winter birds of the marsh are the Marsh Hawk, Sora, Gull-billed Tern, Tree Swallow, Short-billed Marsh Wren, and Sharp-tailed Sparrow. Some birds such as the Greater and Lesser Yellowlegs and the Bank Swallow are migrants through the marshes.

Many birds are year around residents of the marshes. The Willet is an abundant permanent resident as are the Great-tailed Grackle, Red-winged Blackbird, and Fish Crow. Other common residents include the Great Blue Heron, Great Egret, Snowy Egret, Louisiana Heron, Black-crowned Night Heron, Yellow-crowned Night Heron, American Bittern, King Rail, Clapper Rail, Caspian Tern, Long-billed Marsh Wren, Yellowthroat, and Seaside Sparrow.[46]

The prairies, rice fields, and marshes of southwestern Louisiana have many of the same birds as the other coastal areas, but some species are found there far more often than in the marshes. Many dabbling ducks and geese feed in the prairie and rice fields. The Fulvous Tree Duck is a long-legged goose-like bird which commonly breeds in rice fields. The Canada Goose winters in southwestern Louisiana. The number of Canada Geese wintering in Louisiana has dropped from 100,000 in the 1930s to less than 2,000 by 1974.[46]

The Snow Goose is abundant in southwestern Louisiana and probably at the site during the winter. Other birds that winter in the area are the Sandhill Crane, Sprague's Pipit, and LeConte's Sparrow. Some birds, such as the Buff-breasted Sandpiper, the Marbled Goodwit, and the Whimbrel, migrate through this area.

Amphibians and reptiles are abundant in the general southern Louisiana area. Typical herpetofauna of the site include water snakes (<u>Natrix</u> spp.), many species of turtles (<u>Graptemys</u> spp., <u>Malaclemys</u> spp., <u>Pseudemys</u> spp., and <u>Terrapene</u> spp.), the Western Cottonmouth (<u>Agkistrodon piscivorus leucostoma</u>), and several species of toads and frogs (<u>Bufo</u> spp., <u>Hyla</u> spp., and <u>Rana</u> spp.).

In general, little is known about the actual population levels of mammals along the Louisiana coastal zone other than the commercial and sport species. Locally, populations of species such as rats and mice may undergo drastic changes. These species are important constituents of the food chain and are necessary for a viable faunal community. However, when populations of commercial species such as furbearers fluctuate, it is apparent, especially to those individuals such as trappers who derive part of their livelihood from them. Typical mammals of the site are muskrat, nutria, raccoon, cottontail rabbit, swamp rabbit, and white-tailed deer, along with several species of rats and mice.

2.4.3 Aquatic Ecology

Three major aquatic environments are encountered in the area of the proposed West Hackberry site. Black Lake lies adjacent to the north of the site, Calcasieu Lake is about 5 miles east of the site, and a vast brackish marsh lies mostly to the south of the site.

Calcasieu Lake is a large brackish lake having 42,792 surface acres and containing 210,482 acre-feet.[50] Collections utilizing monthly seine hauls were made from April 1968 through March 1969 in Calcasieu Lake and surrounding bodies of water.[51] The results of this study, given in Table 2.10, show that the most common vertebrates species are Menhaden (*Brevoortia patronus*), Bay anchovy (*Anchoa mitchilli*), and Atlantic croaker (*Micropogon undulatus*). The most common invertebrates taken were blue crabs (*Callinectes sapidus*) and white shrimp (*Penaeus setiferus*). Trawl samples which were also taken as part of the study showed that spot (*Leiostomus xanthurus*), Atlantic threadfin (*Polydactylus octonemus*), and brown shrimp (*Penaeus aztecus*) were also common around Calcasieu Lake.

A study was conducted of the zooplankton in the Calcasieu Lake area. The results of this study are summarized in Table 2.11. As expected, the dominant zooplankter encountered was *Acartia* sp. Other commonly encountered zooplankton were coelenterates, ctenophores, decopod larvae, and other copepods. Many of the zooplankters taken from Calcasieu Lake are eurythermal and euryhaline, traits which are very desirable in organisms inhabiting waters such as Calcasieu Lake with wide salinity and temperature ranges.

Table 2.10. Monthly average salinity, temperature, and catch per unit effort in the Calcasieu Lake area from April 1968 through March 1969.

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Number of seine samples	2	2	2	2	2		2	1	2	2	1	2	20
Salinity ppt	11.1	1.9	1.5	6.7	14.4		17.6	3.8	3.8	6.8	19	2.8	9.9
Temperature C°	24.1	24.9	31.9	34.5	31.4		21.3	13.5	13.5	15.7	14	17.7	21.6
Commercial Species													
Vertebrate													
Lepisosteus spatula												1	.1
Brevoortia patronus	53	52	607	109	28		64	3	2	46	11	8	122
Dorosoma cepedianum	.5						.5			3		2	.6
Bagre marinus					5								.5
Galeichthys felis			.5	.5									.1
Ictalurus furcatus									.5				.1
Caranx hippos			7		3								1
Trachinotus carolinus			9	3			2						1
Bairdiella chrysura			1	1									.2
Cynoscion arenarius		2	11										1
Leiostomus xanthurus		1	2	3	4		6	1	5	1		2	2
Menticirrhus americanus		.5	.5	.5									.2
Micropogon undulatus	4	2	10		8		1	66	65	272	21	68	47
Archosargus probatocephalus							.5						.1
Lagodon rhombiodes			.5										.1
Trichiurus lepturus												.5	.1
Scomberomorus maculatus			.5	.5	2		.5						.4
Mugil cephalus	5	2	16	11			15	15	3	4	1	6	7
Menidia beryllina	20	53	2	28	6			2	1	37		9	15
Invertebrate													
Penaeus setiferus								136	18				9
Callinectes sapidus	13	2	31	26	1		3	4	4		1	2	9

Table 2.10. (Cont'd)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Other Species													
Vertebrate													
Alosa chrysochloris							.5	1	.5				.2
Dorosoma petenense	2	.5	50		13		.5	5	6	1		5	8
Harengula pensacolae				23	6								3
Anchoa hepsetus					12								1
Anchoa mitchilli	12	47	107	9	2		199	28	74	116	5	76	65
Strongylura marina			4				2						.6
Cyprinodon variegatus								1	1	13	1	21	4
Fundulus grandis	1	3	2	1	3		1						1
Chloroscombrus chrysurus			13	13	22		1						4
Oligoplites saurus			.5	3	.5		.5						.5
Peprilus paru					.5								.1
Polydactylus octonemus	96	156	69	8	12		6						34
Sphaeroides nephelus		3	6	7									2
Invertebrate													
Lolliguncula brevis							.5						.1
Livoneca ovalis		1		1				1				.5	.4
Acetes americanus	2												.2
Palemonetes vulgaris										2		2	.4
Pagurus longicarpus							1						.1

Source: Perret, 1971

TABLE 2.11. SPECIES COMPOSITION AND RELATIVE ABUNDANCE OF MAJOR PLANKTERS IN MONTHLY PLANKTON ALIQUOTS WITH SETTLED VOLUME PER 100m^3, SALINITY (PPT), AND WATER TEMPERATURE (C^o) AS COLLECTED APRIL 1, 1968, THROUGH MARCH 31, 1969, IN THE CALCASIEU LAKE AREA.

	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Settled Vol. cc	98.6	9.6	51.0	8.0	4.6	6.3	5.0	4.6	4.6	12.0	20.7	10.2
Salinity ppt	10.8	12.2	18.1	17.3	16.4	11.9	20.5	24.2	21.3	13.9	--	--
Temperature C^o	22.0	24.9	31.2	34.4	31.6	26.2	24.4	14.8	12.5	8.0	--	--
Taxon												
PROTOZOA												
Dinoflagellida												
Noctiluca scintillans	5154									105	2500	192
COELENTERATA	P	P				P		P	P	P	P	P
CTENOPHORA	P	P			P	P	P	P		P	P	P
ANNELIDA												
Polychaeta Immatures												25
ARTHROPODA												
Crustacea Nauplii	2099	233			70	503	81	85		54	85	37
Cladocera												
Evadne tergestina									81		27	160
Penilia auirostris	391		91			1692						85
Copepoda Copepodite	T	T	T			T	T	T	T	T	T	T
Acartia sp.	3070	997	236	56	105	3373	2333	9378	500	157	236	2253
Caligus sp.								2				
Centropages sp.	520					2693	20	136	136	26	174	75
Corycaeus sp.		296					86					
Eurytemora hirundoides		100				1215						
Labidocera aestiva	556	324	48	20	57	1485	290	134	22			43
Sapphirina nigromaculata							25	60				

TABLE 2.11 (Cont'd)

	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Temora sp.			91			523	430	72	15			25
Tortanus sp.							47	45				
Undinula vulgaris						128	104	165	174		120	69
Halicyclops fosteri							80	198	121	25	20	59
ISOPADA												
Aegathoa aculata					3		40		1			
DECAPODA IMMATURES	1056	480	116	80	93	2240	623	289			20	50
Caridea												
Leander tenuicornis	9	18	110									
Brachyura Immatures										2		
Callinectes Immatures												
CHAETOGNATHA												
Sagitta hispida	143					125	728	410				25
CHORDATA												
Urochordata												
Oikopleura sp.		200					104	120			20	250
DOLIOLIDA						5						
Osteichthyes EGG	295	2200					10					
Osteichthyes Immatures	36	16				60	36	2	2	49	50	1

P - Present in large numbers
T - Trace

Source: Gillespie, 1971

Salinity appears to be the chief controlling factor in the number of species present, while temperature, ecological competition, and predation also control the number of species present.[50] Zooplankton biomass appears to be highest in April and September and lowest in mid-summer and mid-winter.[50]

The phytoplankton community in Calcasieu Lake, as in any other large estuary, is dependent on its source, in this case the Calcasieu River. The mount of flow from this river determines the salinity of the lake and therefore the constituency of the phytoplankton community. The diatom community at mid-salinity ranges in Calcasieu Lake should be dominated by Cyclotella comta, C. meneghiniana, Melosira distans, M. granulata, Navicula graciles, N. rhyncocephala, Nitzschia closterium. Major diatom species in more saline lakes are Nitzschia seriata, Thalassiothrix fravenfeldii, Thalassionema nitzschioides, Skeletonema costatum, Asterionella japonica, Chaetoceros affinis, and C. diversus. Coscinodiscus sp., the dominant diatom reported by Stern (1968) in Lake Pontchartrain (a brackish lake near New Orleans), may also be present and possibly abundant. Dinoflagellates in Calcasieu Lake include the genera Ceratium, Glenodinium, Goniodoma, and Pyrocystis. The blue-green genera Microcystis and Anabaena are also common inhabitants of brackish and saline lakes.[15] The major algae genera of benthic, sediment, epiphytic, and periphytic species in Calcasieu Lake includes Nitzshia, Amphora, Melosira, Cocconeis, Enteromorpha, Ecotocarpus, Bostrychia, Polysiphonia, and Gracillaria.

The brackish water clam (Rangia cuneata) and the American oyster (Crassostrea virginica) are the commercially important members of the benthic invertebrate fauna in Calcasieu Lake. Other important members of the benthic invertebrate community in Calcasieu Lake include the nematode Diplolaimelloides brucei, the harpacticoid copepod genera Canuella, Nitocra, Paralaophonte, and Tachidius, the amphipods Coraphium lacustre and Ampilesea, and the polychaete Neanthes succines.[15]

Black Lake, which is adjacent to the north flank of the dome, is biologically similar to Calcasieu Lake due to increases in salinity from brine discharge of oil and gas fields, and salt water influences from the Intracoastal Waterway, Calcasieu Lake, and a system of interconnecting canals. The biology of Black Lake is expected to be quite similar to that of Calcasieu Lake.

2.4.4 Marsh and Lake Confluent Ecology

The vast marsh system surrounding the West Hackberry dome has become more saline since the Calcasieu Ship Channel was first constructed in the early 1940's. This ship channel enlarged the deep channel to 40 feet and was the main factor influencing salinity levels in the marsh area. Presently, other factors contributing to the increasing salinity are: (1) the Intracoastal Waterway has a 12-foot channel; (2) brine is released into the area from oil production activities; and (3) there is a reduction in the Calcasieu River flow stemming from increased industrial and agricultural uses.

Aquatic plants are the prominant primary producers of the aquatic marsh system. These can be grouped into three types: phytoplankton (freefloating microscopic algae), periphyton (epiphytic, benthic, or attached algae), and macrophytes (larger algae and other reeds, marsh grasses, pondweeds, sedges, and wetland plants).

The majority of phytoplankton found in the standing waters of the marshes, ponds, and lakes consists of green algae, blue-green algae, and diatoms. Among the common algae reported in salinities from 0.0 to 7.2 ppt for four algal groups are the following: green algae (Scenedesmus brasiliensis, Pediastrum spp., Staurastrum spp.), blue-green algae (Anabaena spp., Oscillatoria spp., Spirulina sp., Microcystis sp.), diatoms (Coscinodiscus spp., Melosira spp., Pleurosigma sp.), and flagellates (Trachelomonas spp., Synura spp., Pandorina sp., Eudorina sp., Chlamydomonas spp., Euglena sp.).[15]

Diatoms are the most abundant type of phytoplankton in the marsh areas of Louisiana where saline to brackish conditions exist.[15] Dinoflagellates are the second most common phytoplankton group in saline and brackish waters. Green and blue-green algae are minor constituents of the phytoplankton communities.

Benthic algae (periphyton) which are most commonly encountered in the varying salinities of the coastal marshes include Lyngbya, Cladophoropsis, Vaucheria, Ulothrix, Cladophora, Spirogyra, Melosira, Amphora, Cocconeis, Denticula, Nitzschia, and Diploneis. Species composition and density of benthic algae varies with salinity and many other physiochemical conditions and, as with phytoplankton, specific densities of periphyton in the marshes are not presently known.

Net annual primary production for phytoplankton plus benthic algae in Louisiana marshes is 906 g dry wt/m^2/yr.[53] In brackish and saline marshes, zooplankton populations are usually dominated by copepods which represent 52 to 97 percent (averaging 79 percent) of the monthly totals.[15,46]

The most common copepod in the area is Acartia tonsa with densities ranging from 1,000 to 10,000 org/m^3.[50] Decapod larvae are a large part of the zooplankton community in brackish waters, particularly in the spring when spawning occurs. Larval decapods of importance include the netclinger (Acetus americanus), mud crab (Rhithropanopeus harrisii), and Leander tenuicornis. Zooplankton communities in brackish water also include many decopod larvae, ctenophores, polycheate larvae, arrow worms, tunicates, amphipods, and some rotifers. Rotifers are rare in brackish water compared to their fresh water distribution. Of the 1,700 species described, less than 5 percent of these are restricted to marine or brackish water.[54] The zooplankton community in Louisiana coastal marshes of all salinity produces an average of 25 grams of organic material/m^2/yr.[53]

Of the benthic fauna, shellfish and crayfish are of considerable economic importance to southern Louisiana. The large zone of brackish water and marsh with salinity above approximately 5 ppt is extremely productive for oysters, shrimp, and crabs. The Eastern or Atlantic oyster, Crassostrea virginica, is the only species of oyster with commercial value in Louisiana.[55] It inhabits estuaries with virtually all degrees of salinity levels, but permanent communities flourish between 10 and 30 ppt.

Another brackish water clam, Rangia cuneata, forms the great bulk of shell accumulations in Louisiana deposits.[55] Other less abundant genera found in the brackish marshes of the study area include Littoridina, Mulinia, Tellina, Vioscalba, and Tagelus.[56]

One species of crab, the blue crab (Callinectes sapidus), is of significant economic importance in the West Hackberry area. Blue crabs spawn in the Gulf of Mexico and lower bays near tidal inlets and large waves of larvae enter the estuaries from January through March. Among other common genera of crabs found in Louisiana estuaries and tidal areas are the hermit crab (Eupagurus spp.), ghost crab (Ocypode spp.), fiddler crab (Uca spp.) and Callinectes donae (a smaller relative of the blue crab). The horseshoe crab (Limulus polyphemus) also common in these areas, is not really a crab because of their chelicerate mouth parts.

Many species of crayfish inhabit the marshes of Louisiana; however, they are of little commercial importance in the West Hackberry area.

In brackish marsh areas other organisms commonly found are nematodes, copepods, ostracods, and rotifers. Nematodes represented 61 percent of a total sample.[57] Minor components of the samples were large protozoans, foraminifera, and cumaceans. Brackish marshes seem to have the lowest diversity of mollusks with greater diversity occurring in both saline and fresh areas.[58]

As marshes become more saline, the benthic invertebrate population may become dominated by nematodes, harpacticoid copepods, amphipods, ostracods, chironomid larvae, and polychaetes. Tanidaceans and cumaceans are occasionally numerous.[57] Marsh periwinkle (Littorina irrorata) is a common mollusk in the salt marsh region. Other mollusks include the oyster drill (Thais haemostoma), the Atlantic moon snail (Polinices duplicatus), and the Atlantic ribbed mussel (Modiolus demissus).

Anthropods collected from saline marshes include the mantis shrimp (Squilla sp.), Cymadusa compta, Grandidierela sp., Cerapus tabularis, Gammarus mucronatus, and Hyalella azteca.[57] Salt marsh decapods include the stone crab (Menippe mercenaria) and a mud crab (Panopeus herbstii).[58]

The ichthyofauna of the marsh areas in the West Hackberry area is dependent on the salinity in the marshes. The species present in the marshes are similar to those discussed for Calcasieu Lake. The dominant species present in the marsh are Gulf killifish, (Fundulus grandis), longnose killifish (F. similis), variegated cyprinodon (Cyprinodon variegatus), common mosquitofish (Gambusia affinis), and sailfin molly (Mollienesia letipinna).

2.4.5 Rare and Endangered Species of the Study Area

There are four species of plants in Louisiana proposed as threatened under the Rare and Endangered Species Act.[59] None of the species are known to occur in either Cameron or Calcasieu parishes, although one species, Castilleja ludoviciana, has been reported from Jefferson parish which borders Calcasieu on the east.

Wildlife species or subspecies considered "endangered" by the United States Department of the Interior, Fish and Wildlife Service, total twelve in Louisiana. Three species of turtles are listed as "endangered" for the coastal region of Louisiana.[60] These are the Atlantic ridley, the hawksbill, and the leatherback. In addition, two species of turtles, the green sea turtle and the loggerhead are considered as threatened species of the area under the "similarity of appearance" clause of the Endangered Species Act of 1973. Common throughout Louisiana and within the study area is the American alligator. Once in danger of extinction, this species is currently abundant and at times a nuisance. Although protected, recent trends toward harvesting this alligator have begun. The Southern Bald Eagle has been spotted in Southern Louisiana and may exist in the study area. Nesting habits of the Southern Bald Eagle require close proximity to open water. Such suitable sites may be found near Calcasieu Lake. The Arctic Peregrine Falcon is known to migrate through the area. Reduced reproductive rates caused by pesticide utilization have resulted in reduced numbers of Southern Bald Eagle and Arctic Peregrine Falcon populations. The red wolf has been extirpated from its former range and now occurs in southeastern Texas and Cameron Parish in Louisiana. In 1975, two red wolves were trapped in the Sabine National Wildlife Refuge and transported to Washington for breeding. Later in that same year, two were released in the refuge.

2.4.6 Commercially Important Species

Vegetation

The vegetation of primary commercial interest is found in the prairie region of the study area and consists of agricultural products, in particular rice, and secondarily, soybeans. Of those farms registered with the U.S. Department of Commerce, Bureau of the Census, Calcasieu Parish has 283 acres of corn, 294 acres of sorghum, 41 acres of wheat, 29,100 acres of soybeans, 5,029 acres of hay, and 75,316 acres of rice.[60] Cameron Parish, which is covered mostly by marshland, has 214 acres of corn, 2,998 acres of soybeans, 2,890 acres of hay, and 14,214 acres of rice.[60] The majority of Cameron and Calcasieu Parishes is now marshland and prairie. The former long leaf pine area has for the most part been logged out or cleared and very little timber production exists in the area.

Wildlife

The most significant wildlife in the area which are of commercial importance are the furbearers and the American alligator. Louisiana leads all other states in fur production. Most of the fur industry is confined to the coastal swamps and marshes. The nutria, muskrat, mink, otter, and raccoon are sources of the fur industry in Louisiana. The marshland along the coast in

Cameron Parish is the preferred habitat of furbearers. Value of the marshes to the fur industry is shown in Table2.12. Fresh and intermediate marsh types are more valuable for nutria harvest while brackish vegetative types are important for muskrat production. In 1975 and 1976, there were limited (state controlled) harvests of the American alligator for its hide in parts of Cameron, Calcasieu, and Vermillion parishes.

The Sabine National Wildlife Refuge is located within the study area and is divided into three lease areas for trapping: Back Ridge, Gate Camp, and West Cove. Table 2.13 is a breakdown of harvest for each of these areas. These data should be indicative of the marshlands within the study area due to the enormous size of the refuge.

Aquatic Organisms

The Louisiana Coastal zone is an exceedingly productive fisheries and wildlife resource as it contains an extensive amount of estuarine habitat. Louisiana leads all states in volume of catch of commercial fisheries products. Over 1.2 billion pounds were harvested in 1975.[63] In 1974, the catch was 1.2 billion pounds valued at $86 million. In 1973, over 1.0 billion pounds of commercial fishery products valued at over $98 million were taken in Louisiana waters. The record catch for Louisiana was in 1971 when total catch was over 1.4 billion pounds.[64]

The lakes and bayous of Cameron Parish, especially Calcasieu Lake, are extremely important for oyster production and as a shrimp nursery area. Oyster production in Calcasieu Lake has historically been good. Because water conditions in the southern portion of the lake are more conducive to oyster productivity, oysters are most abundant and generally harvested in those areas. Based on seasonal productivity of oyster beds, harvest is at times restricted at specific oyster reefs to allow regeneration of oyster populations. Unlike many other coastal bays and lakes within the Gulf Coast, oyster harvest at Calcasieu Lake has not been restricted for health reasons as a result of contamination from industrial or municipal sources.[65] However, the productivity of the northern and eastern portions of the lake has declined in recent years, possibly from an altered circulation pattern as a result of channel levees created from the disposal of dredged material. In an effort to re-establish oyster population in these areas, the Corps of Engineers and the Louisiana Wildlife and Fisheries Commission have modified the levees and worked to improve the oyster habitat within the region. These efforts appear to have met with moderate success.[66] The commercial catch for

Table 2.12. Estimated annual value of fur catch, per 1,000 acres of coastal marsh.

	Saline		Brackish		Intermediate		Fresh	
	mean*	maximum	mean	maximum	mean	maximum	mean	maximum
Muskrat	**	**	$127	$9717	$146	$ 771	$118	$ 970
Nutria	**	**	194	430	641	1125	1154	1991
Mink	**	**	6	64	5	60	11	71
Raccoon	**	**	**	16	**	6	**	31
Otter	**	**	5	18	10	33	13	33
TOTAL Value			332	10,245	802	1995	1296	3096

* Value of pelts to the trapper 1970-71 season in dollars

** Inadequate records

Table 2.13. Furbearer Harvest in Sabine National Wildlife Refuge

	1972-1973	1973-1974	1974-1975	1975-1976	Value for 1975-1976 Harvest (dollars)
Muskrat					
Back Ridge	391	51	84	202	844.80
Gate Camp	0	0	0	16	67.00
West Cove	159	18	23	33	131.75
Mink					
Back Ridge	40	69	33	18	88.50
Gate Camp	2	2	5	25	128.90
West Cove	50	28	21	14	56.80
Otter					
Back Ridge	6	6	6	5	103.10
Gate Camp	4	1	4	2	36.00
West Cove	4	5	4	3	68.50
Nutria					
Back Ridge	4,915	3,400	2,767	2,489	11,116.00
Gate Camp	1,347	693	597	1,068	4,805.76
West Cove	2,946	1,886	2,013	1,073	4,756.00
Raccoon					
Back Ridge	88	107	118	44	164.00
Gate Camp	0	33	53	40	149.90
West Cove	99	90	51	89	376.25

Cameron Parish in 1971 was 438 million pounds valued at $11.0 million while in 1973, the catch was 339 million pounds valued at $19.2 million.[67]

The most important commercial species in Cameron Parish as well as throughout Louisiana are menhaden (Brevoortia spp.), shrimp, and Atlantic Croaker (Micropogon undulatus) (see Table 2.14). The marsh ecosystem is commercially important because it provides breeding grounds for fish and shrimp. White and brown shrimp (Penaeus setiferus and P. aztecus) production within Cameron Parish near Calcasieu Lake is extensive. During peak harvest periods as much as 100,000 pounds have been collected in a single night.[68]

A detailed breakdown of the commercial fishery industry in Louisiana onshore and offshore waters as well as Calcasieu Lake appears in Table 2.15. From these data it can be seen that the shellfish harvest (pounds) far exceeds the finfish harvest for Calcasieu Lake, while the opposite is true for other onshore-offshore waters.

2.5 SOCIOECONOMIC CHARACTERISTICS

2.5.1 Population Density and Growth

The project site is located in Cameron Parish, the largest parish in the state and the least populous. Because of the low availability of manpower in Cameron Parish, Calcasieu Parish will also be considered in the area of study. Table 2.16 shows the population density of these two parishes and of the State of Louisiana, and the extent of their urban and rural development. Cameron Parish is shown as being entirely rural because it has no communities with populations of 2,500 or more. The project site is in a rural area where much of the land is wetland or pasture.

Towns and Urban Areas

There are three small communities within a 10 mile radius of the site: Hackberry, Grand Lake, and Moss Lake. Hackberry is 4 miles east of the storage site and will be affected by the construction of the tanker dock and pipelines to that dock. Commercial businesses servicing the area are located in Lake Charles, about 26 miles northeast of the site via Louisiana Highway 27 and Interstate 10. Figure 2.30 shows these centers of population in relation to the site.

Table 2.14. Average annual harvest and value of major commercial fishes and shellfish for Louisiana during period 1963-67.

Species	Eastern Cameron Parish	Western Cameron Parish	Louisiana
Menhaden			
Production [1]	12.40	41.10	713.06
Value [2]	0.18	0.58	10.12
Shrimp			
Production	0.50	2.90	73.51
Value	0.19	1.05	26.68
Croaker			
Production	0.30	2.11	23.71
Value	0.01	0.04	0.42
Oyster			
Production	0.00	0.29	9.97
Value	0.00	0.13	4.39
Blue Crab			
Production	0.04	0.62	8.27
Value	0.004	0.05	0.73
Spot			
Production	0.11	0.53	4.62
Value	0.002	0.01	0.08
Catfish and Bullheads			
Production	0.22	0.003	4.59
Value	0.04	0.001	0.78
Seatrout			
Production	0.08	0.42	4.11
Value	0.003	0.02	0.19
Red Drum			
Production	0.00	0.02	0.53
Value	0.00	0.003	0.09
Total			
Production [1]	13.65	47.99	842.37
Value [2]	0.43	1.88	43.48
Estuarine water [3]	13	134	3,283
Production, pounds/acre	1,050.0	358.1	256.6
Value dollars/acre	33.1	14.0	13.2

1 Millions of pounds

2 Millions of dollars

3 Thousands of acres

Source: Lindall et.al., 1972

Table 2.15. Average annual fisheries harvest from Louisiana coastal waters, (1966-1970)

	Calcasieu Lake lbs	Inshore Waters lbs	Offshore Waters lbs	Offshore-Inshore TOTALS lbs
Amberjack			14,466	14,466
Bluefish		2,867	8,033	10,900
Bluerunner		100		100
Buffalo		51,600		51,600
Cobia			8,167	8,169
Carp		2,533		2,533
Catfish & Bullheads		959,601		959,601
Croaker		110,400	1,716,767	1,827,167
Drum, Black	533	405,732	75,100	480,832
Drum, Red	3,433	726,566	136,167	862,733
Flounders	12,567	84,832	433,233	518,065
Gar	1,633	362,662		362,662
Groupers			263,133	362,133
Jewfish			5,666	5,666
King Whiting (Kingfish)		93,432	554,800	648,232
Menhaden		130,540,533	797,457,067	927,997,600
Mullet		116,766	10,567	127,333
Pompano		200	32,900	33,100
Sawfish		800	1,467	2,267
Scup			16,201	16,201
Sea Catfish		36,401	100,933	137,334
Seatrout, Spotted	1,034	793,735	122,166	915,901
Seatrout, Sand		90,632	271,166	361,798
Sharks		433	3,801	4,234
Sheepshead, Freshwater (FW Drum)		21,833		21,833
Sheepshead		240,064	74,366	314,430
Snapper, Mangrove			3,200	3,200
Snapper, Red		533	2,914,933	2,915,466
Snapper, Vermilion			36,566	36,566
Snapper, Yellowtail			67	67
Spanish Mackerel		3,733	54,866	58,599
Spot		4,233	23,566	27,799
Swordfish			6,067	6,067
Triggerfish			6,599	6,599
Tripletail		433	5,400	5,833
Warsaw			35,734	35,734
Unclassified Food Fish			8,366	8,366
Unclassified Industrial Fish			37,742,433	37,742,433
Total Finfish	19,200	134,650,654	842,143,965	976,794,619
Crabs	577,866	9,802,930	360,231	10,163,161
Crawfish			66,666	66,666
Shrimp	1,361,567	41,359,330	46,732,765	88,092,095
Oysters	41,667	10,856,462		10,856,462
Total Shellfish	1,981,100	62,018,722	47,159,662	109,178,384
Squid			1,998	1,998
Terrapin		800	33	833
Turtles, Baby		133		133
Turtles, Green			1,465	1,465
Turtles, Snapper		767		767
Total, Non-Finfish	1,981,100	62,020,422	47,163,158	109,183,580
Total, Harvest	2,000,300	196,671,076	889,307,123	1,085,978,199

Source: U. S. Army Corps of Engiueers, Lower Mississippi Valley Division, 1973[16]

Table 2.16. Population Density of Surrounding Parishes (1970)

	Cameron	Calcasieu	Louisiana
Population			
total	8,194	145,415	3,643,180
per square mile	5.7	131.6	81.1
Rural Population			
farm	894	1,171	113,757
non-farm	7,300	35,816	1,118,627
Urban Population			
% rural	100.	25.2	23.9
% urban	0	74.8	66.1

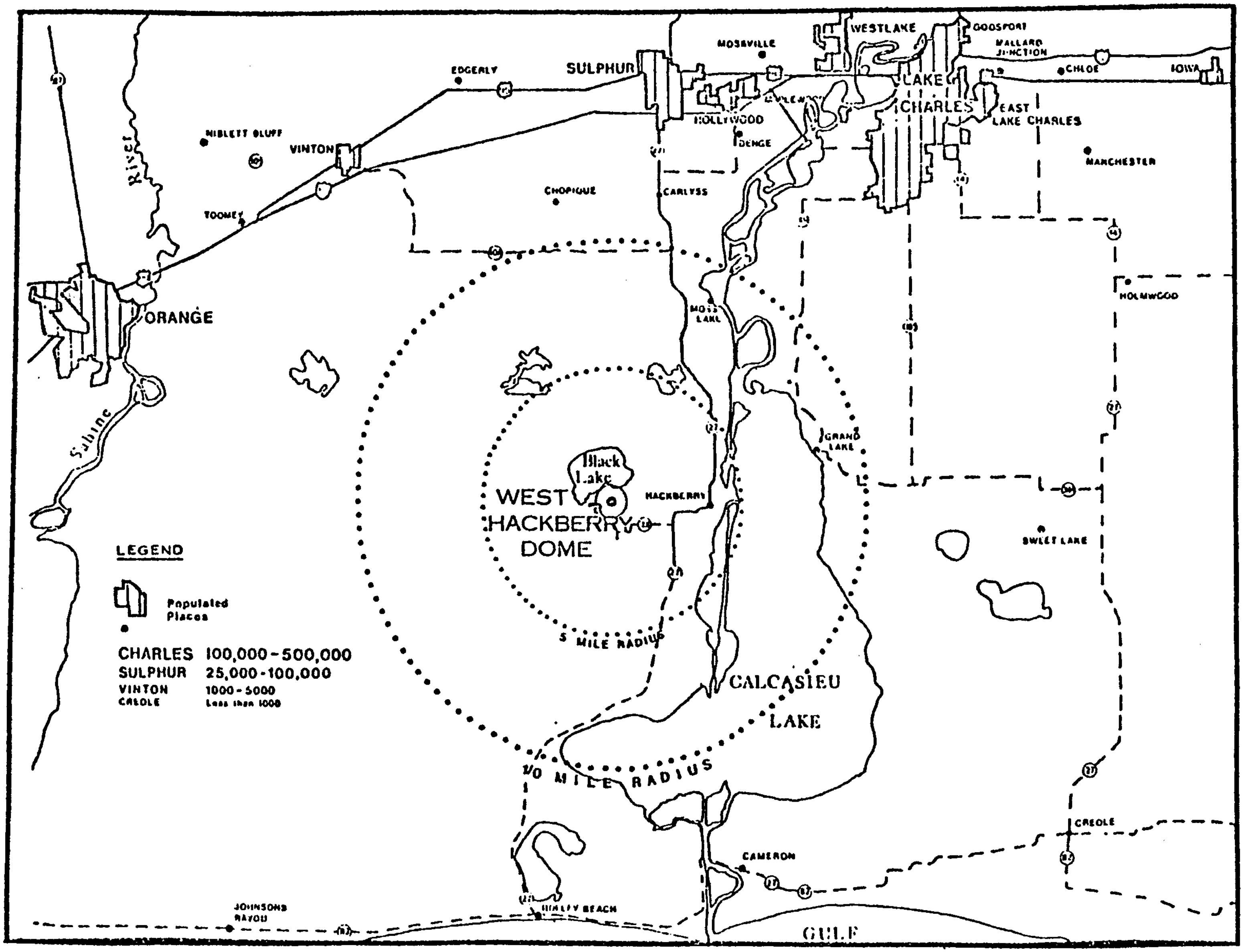

Figure 2.30 Population Centers

Hackberry

This is an unincorporated community with about 1,300 people living in a 10 square mile area. There are 400 to 500 buildings clustered in a small area with a post office, school, about 5 grocery stores, 3 fish packing houses, and several other commercial buildings that service residents and oil companies in the area. The local economy is centered on fishing and fish processing, raising cattle, and producing oil and gas.

Lake Charles

The population of Lake Charles was about 78,000 in 1970 and dropped to about 74,000 in 1975.[69] It is a major manufacturing center, particularly for the chemical industry, and an important port for the region. The area around the lake itself was originally inhabited by Indians. Settlers from France arrived in 1771. The lake and city are named for one of these early French colonists, Charles Sallier. Lake Charles became the parish seat for Calcasieu Parish in 1852.

Historical Growth and Trends

Population growth and projections for the area are shown in Table 2.17. The population of Cameron Parish increased by 10.7 percent between 1950 and 1960, and by 18.6% between 1960 and 1970. Hackberry is expected to reach a population of nearly 1,500 by 1980 and exceed 1,600 by 1990. Calcasieu Parish population increased by 62.3 percent between 1950 and 1960, but marginally declined between 1960 and 1970. During the past 5 years, the population of the city of Lake Charles declined slightly.

Population projections for Calcasieu Parish vary greatly because of uncertainties as to whether the decline noted between 1960 and 1970 will continue. Recent estimates by the Louisiana Technical College of Administration and Business, in cooperation with the U.S. Census Bureau indicate a 3.5 percent increase for Calcasieu Parish in the 5 years since the 1970 census, and a population of about 150,520 in 1975. This compares with a 3.5 percent increase for the Southwest Louisiana Planning District as a whole, and a 4.1 percent increase for the state during the same 5 year span.[70]

Table 2.17. Population and Population Projections, by Parish

	Cameron	Calcasieu
1950		
Population	6,244	89,635
1960		
Population	6,909	145,475
% change	10.7	62.3
1970		
Population	8,194	145,415
% change	18.6	(-0.1)
1978		
Series E*	7,600	135,000
Series C*	8,600	153,000
Statistical Abstract	9,304	163.382
1990		
Series E*	7,800	138,000
Series C*	9,000	160,000
Statistical Abstract	10,617	181,647

*Figures are based on Bureau of Economic Analysis Areas for Southern Louisiana and provide only the first three significant figures.

Sources: Dept. of Commerce, Bureau of the Census, Characteristics of the Population, 1960 and 1970; U.S. Water Resources Council, OBERS Projections, Regional Economic Activity in the U.S. Series C, 1970; U.S. Water Resources Council, OBERS Projections, Regional Economic Activity in the U.S., Series E, 1972; Louisiana State University, Division of Business and Economic Research, 1974 Statistical Abstract of Louisiana, 5th Edition.

2.5.2 Cultural Patterns

There were Indians living on the cheniers of Cameron Parish before settlers came to the area, as evidenced by artifacts that have been unearthed. The Attakapa tribe lived here during the time that Louisiana was being explored. The first colonists were Americans of Scotch-Irish descent. They bought land grants after the War of 1812 and settled in the lower section of the parish near the Gulf. French settlers moved into the area mainly by the waterways that drain the land northeast of the parish. The census of 1860 revealed that a large percentage of the population at that time was foreign-born, and from a variety of European countries. Inhabitants of the area were at different times ruled by Spain and France. The predominant cultural influence in the area now is French.

Calcasieu Parish was the home of several tribes of Indians. The early settlers were a mixture of English, French, Spanish, and Dutch. The river that flows through Lake Charles was once known as Rio Hondo. Titles to the Rio Hondo lands were based on Spanish grants in return for services to Spain. When the city of Lake Charles was primarily a lumber port, the citizens were predominately Anglo-Saxon. A later influx of French people from the east and central parts of the state has resulted in the city becoming almost an equal mixture of Anglo-Saxon and French cultural influence.

The proportion of nonwhites in the total population of these two parishes is lower than in the state as a whole, as shown on Table 2.18. While the percentage of net migration of nonwhites out of Calcasieu Parish is greater than that for the state, it is about equal to the percentage of net migration of whites from the parish. The influx of nonwhites to Cameron Parish may be attributed to the jobs available in the Menhaden fishing industry, which operates out of the town of Cameron.

2.5.3 Community Services

Housing

The number of housing units, occupancy, and availability of housing are shown on Tables 2.19 and 2.20. The vacancy rates shown on these tables include a number of housing units that do not have all the standard plumbing facilities, i.e., hot and cold water faucets in the structure, flush

Table 2.18. Racial Distribution and Migration, by Parish

	Cameron	Calcasieu	Louisiana
Nonwhite			
total number	567	31,725	1,099,808
% of population	6.9	21.8	30.2
net migration	26	-5,196	-148,359
% migration	4.8	-14.1	-11.9
White			
total number	7,627	113,690	2,541,498
% of population	93.1	78.2	69.8
net migration	161	-18,816	37,569
% migration	2.2	-14.2	1.5

Table 2.19. Housing Units and Occupancy, by Parish

	Cameron	Calcasieu
Year-round Housing Units	3,098	45,461
Occupancy and Tenure		
Occupied Dwelling Units	2,310	42,065
Owner-Occupied	1,774	29,922
Renter-Occupied	536	12,143
Lacking Some or All Plumbing Facilities	476	2,865
Vacant For Sale or Rent	121	2,007
% Vacant For Sale or Rent	4.0	4.4
Median Value (Owner Occupied)	$8,800	$12,900

Source: 1970 Census of Housing

Table 2.20. Housing Units and Occupancy in Lake Charles

	Lake Charles
Year-Round Housing Units	24,893
Owner-Occupied	14,887
Renter-Occupied	8,186
For Sale	337
Homeowner Vacancy Rate	2.2
For Rent	1,014
Rental Vacancy Rate	11.0
With All Plumbing Facilities	948
Mobile Homes or Trailers	235
Owner-Occupied	192
Renter-Occupied	43

toilet, and bathtub or shower. The vacancy rate would be reduced if it excluded substandard housing units.

The median value of owner-occupied units in Cameron Parish is substantially below that of the state: $8,800 compared to $14,600.* A comparison of the percentages of increase in housing value between 1960 and 1970 shows that values are rising slightly faster in Cameron Parish than in the state. Also, the growth in the number of year-round housing units in Cameron Parish is 35.4 percent in that same time period, and is comparable to the 36.4 percent growth rate for the state.

The housing situation in Calcasieu Parish reflects its population pattern. There was a sharp increase in population and housing between 1950 and 1960 followed by a period during which the parish grew far more slowly than neighboring parishes and the state. During the decade of 1960 to 1970, the number of year-round housing units in Calcasieu Parish increased only 4.6 percent, and its median value of housing (which is just under the state median) increased by 16.22 percent, or less than half the increase experienced in the state.

Education

The educational levels of the population 25 years of age and over in the two parishes under study and in the state are shown on Table 2.21. Louisiana ranks fairly low among the fifty states in the educational level of its residents. It has the highest percentage of persons with no schooling, and Cameron Parish's percentage of persons in this category is greater than that of the state. A marked increase occurred between 1960 and 1970 in the number of persons in the parish who had completed at least 4 years of high school. There is one school in Hackberry with 12 grades and an enrollment of 362 students.

Calcasieu Parish residents have a higher general level of education than those in Cameron Parish, and those in the State as a whole. The public school system in Calcasieu

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*Based on one-family houses on less than 10 acres and excluding mobile homes.

Table 2.21 Years of School Completed, for Persons 25 Years Old and Over, by Parish

	Cameron		Calcasieu		Louisiana
	No.	Percent	No.	Percent	
Total	4,103	100.0	71,438	100.0	100.0
No Schooling	197	4.8	2,446	3.4	3.9
Grade School					
1-4 years	410	10.0	5,976	8.4	9.2
5-8 years	1,322	32.2	16,411	23.0	25.4
High School					
1-3 years	846	20.6	12,100	16.9	19.2
4 years	1,022	24.9	21,227	29.7	24.7
College					
1-3 years	151	3.7	6,812	9.5	8.5
4 or more years	155	3.8	6,466	9.1	9.1

Source: Public Affairs Research Council of Louisiana, Inc. Figures are for 1970.

Parish is the fifth largest in the State. The number of public and parochial schools in the Parish is as follows:

	Public	Parochial*
Elementary	37	7
Jr. High School	16	
Sr. High School	14	1
Pupil Enrollment	38,300	3,000

There is also a private academy for grades 1-12 with an enrollment of about 200 students.

Student-teacher ratio in the public elementary schools is 23.2 on the elementary level and 19.4 on the secondary level.[71]

There are about 5 industrial and technical schools in the Lake Charles area, including proprietary institutions and public vocational centers.

McNeese State University offers a variety of higher education programs. It is located in South Lake Charles, and has an enrollment of about 5,700 students. The university started in 1939 as a junior college affiliated with Louisiana State University. Two-year degree programs are available in the Department of Technology and the School of Continuing Studies. Higher degree programs include: bachelors degrees in both arts and sciences, a variety of masters programs, and doctorates in education.

Police and Fire Protection

Cameron Parish has a sheriff's department with a staff of deputies that hold full-time jobs in addition to their law enforcement duties. Three deputies and one parish special investigator live in the Hackberry area. Calcasieu Parish has a full-time sheriff's department. In Lake Charles, there is a force of 75 uniformed police officers, with

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*Includes grades 1 through 8 in elementary schools and 9 to 12 in high school.

additional guards for night security patrol, school crossings, and shoplifting detail.[72]

Fire protection would have to be provided at the site for all buildings and equipment. Auxiliary fire-fighting assistance will be available from the fire station at Hackberry. The municipal fire department at Lake Charles has a staff of 111 paid firemen to serve the community.

Hospitals and Medical Personnel

There is one hospital in Cameron Parish, in the town of Cameron about 33 miles southeast of the project site via Route 27. This is the South Cameron Memorial Hospital, with 27 beds and a staff of 49 personnel. It does have an emergency unit.

The hospital facilities nearest the site are located at Sulphur, about 22 miles north via Route 27. Here, the West Calcasieu-Cameron Hospital offers operating facilities and an intensive care unit as well as an emergency department. It has 111 beds and a 262 member staff. There is an ambulance service affiliated with it.

Lake Charles has three hospitals: Lake Charles Charity Hospital with 110 beds; Lake Charles Memorial Hospital with 227 beds; and St. Patrick Hospital of Lake Charles with 246 beds.[73] An independent ambulance service operates out of Lake Charles.

There is a doctor at Hackberry and two more in Cameron. This area is part of the Lake Charles Health Service Planning Region, which includes Beauregard and Jefferson Davis Parishes as well as Cameron and Calcasieu. Medical services for this region are concentrated in the Lake Charles metropolitan area, which is centrally located in the region. A study of health services relative to population shows this region to be below the national norm in availability of medical and health practitioners, but it compares well with other regions of Louisiana.[74]

Civic and Recreational Facilities

There are a number of community-sponsored cultural activities in Lake Charles, such as a civic orchestra, choir, drama groups, and associations to promote concerts, exhibits, and art educational programs in the city. McNeese

State University also sponsors cultural activities and sports events.

In addition to boating and swimming, major forms of recreation include hunting and fishing. Statistics for the 1970-1971 hunting and fishing season show that well over 1,600 resident hunting licenses were issued in Cameron Parish, or about one for every five persons, while in Calcasieu Parish, the ratio was slightly less than one license for every eight persons. Calcasieu Parish issued over 4,700 big game licenses that year, more than were issued in any other coastal parish. The two parishes together issued over 2,000 licenses for nonresident hunting trips, more than a quarter of all such licenses issued in the state.[75]

Fishing is especially important in Cameron Parish, where over 4,000 resident fishing licenses were sold (although the population of the parish is only about twice that number). While Calcasieu Parish sold over 9,000 fishing licenses, the ratio of licenses to population is only 1 to 16. A large number of licenses are also granted for nonresident fishing trips.[75]

2.5.4 Economic Characteristics

Basic Economy of the Area

Minerals

Louisiana is a major oil producing state and has almost one-third of the total U.S. reserves of natural gas. For the state as a whole, onshore levels of oil and gas exploration and production are gradually dropping while offshore levels increase. Its natural gas reserves and number of new gas wells completed per year have remained fairly constant, while oil reserves have begun to show a decline. The importance of this industry to the state is revealed by the fact that during the 6 year period from 1964 to 1970, the State of Louisiana received about 27 percent of its total revenues from severance taxes on mineral production and from mineral leases.[76]

The extraction of petroleum and natural gas ranks as the primary income-producing industry in Cameron Parish. Over $10,000,000 in severance taxes were collected each year in the 5 year span from fiscal year 1966-67 through 1970-1971, and over 90 percent of this was derived from oil and gas production. Revenue from gas extraction is about twice that derived from oil.[76] Cameron Parish far exceeds Calcasieu in the production of petroleum and gas, as shown on Table 2.22, and its economy is much less diversified. The value of all mineral production in the two parishes for the years 1969 through 1971 is shown on Table 2.23. Cameron Parish is one of the ten leading parishes in production of oil and gas in Louisiana, but the reserves of these commodities are greater in the coastal parishes farther east.

In addition to direct employment in the oil and gas fields, a substantial number of persons are employed in those industries that service the actual production.

Manufacturing

In 1946, Louisiana passed a law to exempt new industries from direct taxation for a period of 10 years. Gas fields led to the growth of industry in the state. The greatest single source of employment in Calcasieu Parish is manufacturing, which accounts for about 10,000 jobs in the parish, and a payroll of about $27 million. The manufacture of chemicals and allied products comprises more than one third of this employment.[77] Among the local industries that each employ over 500 people are: Cities Service Oil Company, Continental Oil Company, Firestone Synthetic Rubber and Latex Co., Conaco, Olin Corporation, and PPG Industries.

Other manufacturing companies in Calcasieu Parish are in such industries as: lumber and wood products, fabricated metal products and machinery, building materials, and food products, especially dairy goods. The primary manufacturing industry in Cameron Parish is the processing of fish. There are two firms producing packaged fish, fish oil, and fishmeal fertilizer.

Fishing

Louisiana is the leading state in the nation in terms of the volume of commercial landings of fish and shellfish, though it ranks third (after Alaska and California) in the dollar value of these products. In 1973 and 1974, the commercial catch exceeded one billion pounds* and netted over $98 million and $86 million in each year respectively. A record landing for the state occurred in 1971 when slightly over one billion four hundred million pounds of fish were harvested.

* This indicates hire weight for all items except univalve and bivalve mollusks such as clams, oysters, and scallops which are shown in weight of meats excluding the shell.

Table 2.22. Production of Crude Oil, Condensate, Casinghead Gas & Natural Gas

	Cameron		Calcasieu	
	1971	1972	1971	1972
Crude Oil (barrels)	15,648,933	12,766,896	6,599,966	7,117,785
Condensate (barrels)	6,642,130	4,267,184	3,102,304	2,710,327
Casinghead Gas (Mcf, 15.025#Abs.)	19,234,167	16,247,238	4,961,691	4,369,532
Natural Gas (Mcf. 15.025#Abs.)	553,602,819	393,403,690	64,370,789	54,636,536

Table 2.23 Value of Mineral Production

	Cameron Natural Gas Petroleum Natural Gas Liquids Salt Shell	Calcasieu Petroleum Natural Gas Natural Gas Liquids Lime Salt Sand & Gravel	State
1969*	$270,883,000	$61,156,000	4,685,326,000
1970**	$289,105,000	$66,168,000	5,102,321,000
1971**	$312,357,000	$63,506,000	5,553,009,000

* U.S. Dept. of Interior, Bureau of Mines. Minerals Yearbook, 1969, Vol. II, Area Reports: Domestic, "The Mineral Industry of Louisiana, Washington, D.C.

** Area Reports: Domestic, p. 337-354. U.S. Dept. of the Interior, Bureau of Mines. Minerals Yearbook, 1971, Vol. II, "The Mineral Industry at Louisiana" by David A. Carleton and Leo W. Hough, Washington, D.C. 1973.

Source: Corps of Engineers - Baton Rouge - New Orleans Inventory

The menhaden catch accounts for the major volume of fish: over one billion pounds were landed in 1974. The Louisiana menhaden industry is the largest in the nation and supplies 55 percent of the total domestic catch.

Cameron ranked second among the nation's ports in terms of the volume of commercial fish landings in 1974. Over 405 million pounds of fish were harvested, for a total value of $18,724,000. The large catch of manhaden landed at Cameron accounts for the high volume and relatively low value of fish. Most of it is processed into fishmeal, menhaden oil, and menhaden solubles; the rest is used for bait.

The season for menhaden is from April to October, and the heaviest harvest is during June, July, and August. The fish are caught in purse seines (large nets with floats along the top and weights on the bottom) which are strung in a large circle and enclose the fish. This manner of fishing does not employ great numbers of people relative to the volume of fish caught.

Contract Construction

Contract construction is another major source of employment in Lake Charles. A 1973 report showed that about 4,000 people were employed by this industry in mid-March, and that the payroll for that quarter totaled nearly $9 million.[77] Within this industry, there is a nearly equal distribution of employment among heavy construction contractors, general building contractors, and special trades.

The work forces in both manufacturing and construction are heavily unionized. Union membership in Lake Charles has been estimated to be about 11,000 persons, producing a situation whereby about one-third of the city's population is in a union or union-supported.[78] About three or four years ago, the Committee of Contractors and Union Representatives was established to arbitrate jurisdictional disputes between individual trade unions.

Lake Charles Port Facilities

In tonnage of goods handled, the port at Lake Charles ranks twentieth in the nation, tenth among the Gulf ports, and third in Louisiana. Total tonnage handled for selected years is as follows:[76]

Year	Tonnage
1955	15,396,366
1960	17,433,441
1965	14,469,783
1967	16,697,672
1969	16,154,684
1970	17,600,000

In 1970, the tonnage at Lake Charles was 38.7 percent of what was handled at Baton Rouge and 14.2 percent of that at New Orleans. The overwhelming proportion of goods handled at Lake Charles was in the domestic market. Crude petroleum was the largest single item, followed by gasoline. Rice was the largest foreign export in 1970: a total of 503,000 tons were shipped out. Other exports include paper and lumber. Automobiles, fertilizer, and coke are major bulk items that are imported to the area.

Barge traffic provides low-cost transport of such commodities as: petroleum and petroleum products, grain, soy beans, sand, gravel, and other bulk products. The Intracoastal Waterway near the project site is a major link between the industrial centers of Beaumont and Port Arthur, Texas, and Lake Charles.

Agriculture

Agricultural income in this region of Louisiana is derived mainly from growing rice and raising cattle. The quantities of land, labor, and income from agricultural pursuits in the two parishes is as follows:[15]

	Cameron	Calcasieu
Acres	22,700	102,600
Paid Farm Workers	177	731
Value of Goods Sold	$3,193,000	$13,332,000

There has been a trend in Cameron Parish to convert rice acreage to pastureland. Growing rice requires large quantities of fresh water, and since the dredging in ship channels along Calcasieu Lake and the Intracoastal Waterway, fresh water bodies have become contaminated with salt water from the Gulf of Mexico. A second factor encouraging this trend is the recent national legislation to lift the acreage limitation on rice farming. If this legislation is made law, marginally productive rice lands in the study area may not be able to compete with larger farms in Texas and Arkansas.

Employment Distribution

The unemployment rate in this area is low as can be seen from Table 2.24, Employment Status. The table also shows that few workers are available in Cameron Parish, and it can be expected that the majority of the project labor force will commute from Calcasieu. The percentage of unemployed persons in 1970 was substantially lower than what was recorded in 1960, when Cameron Parish had 10 percent of its men unemployed, and Calcasieu had 8 percent.

The number of men in the labor force in Lake Charles in 1970 was nearly 17,900. Of these, 1,037 were listed as unemployed, or 5.8 percent. It should be noted that contract construction and oil and gas field explorations, which form a substantial number of employment resources, fluctuate widely in the number of jobs available for semi-skilled and unskilled workers.

The relative importance of standard industries in the employment of personnel in these two parishes is shown on Table 2.25. Primary sources of job opportunities are: manufacturing and construction in Calcasieu Parish, and mining and fisheries in Cameron Parish. The occupational distribution of men and women employed by all industries is shown on Table 2.26. Those occupational groups most heavily drawn upon by the proposed project will be: (1) craftsmen, foremen and kindred; (2) operators and kindred; and (3) laborers. Calcasieu Parish offers a substantial number of workers in these categories. A study of the commuting patterns for persons living in Lake Charles and in the surrounding standard metropolitan statistical area (SMSA) shows that a large proportion of workers in these occupational groups go to jobs outside the city.[60]

Table 2.24. Employment Status, by Parish

	Cameron		Calcasieu	
	Male	Female	Male	Female
In Labor Force*	2,062	672	33,863	16,682
Employed	1,984	617	32,033	15,615
Unemployed	78	55	1,830	1,067
% Unemployed	3.8%	8.2%	5.4%	6.4%

* Excludes military personnel.

Source: Public Affairs Research Council of Louisiana, Inc., based on 1970 census data.

Table 2.25. Employment in Major Industries

	Cameron		Calcasieu	
	Number	Percent	Number	Percent
Total	2,601	100.0	47,648	100.0
Agriculture, forestry & fisheries	336	12.9	1,084	2.3
Mining	416	16.0	1,693	3.6
Construction	219	8.4	5,168	10.9
Manufacturing	306	11.8	9,052	19.0
Furniture*	0		127	
Primary and fabricated metal	0		276	
Machinery	12		177	
Elec. machinery	0		19	
Motor vehicles	0		0	
Transport equip.	34		430	
Other durables	9		497	
Food & kindred	144		552	
Textile mill and apparel	3		12	
Printing, publishing	10		317	
Chemical	27		3,334	
Other nondurable	67		3,302	
Railroad	6	0.2	417	0.9
Trucking service	9	0.3	532	1.1
Other transport.	164	6.3	945	2.0
Communications	17	0.7	580	1.2
Utilities & sanitary	84	3.2	957	2.0
Wholesale trade	95	3.7	2,526	5.3
Food & dairy	22	0.8	1,310	2.8
Eating & drinking	122	4.7	1,403	2.9
Other retail	45	1.7	2,872	6.0
Finance, ins. & real est.	29	1.1	1,202	2.5
Business and repair service	101	3.9	1,382	2.9
Private households	38	1.5	1,391	2.9
Other personal service	33	1.3	1,574	3.3
Entertainment	15	0.6	324	0.7
Hospitals	50	1.9	1,429	3.0
Education	136	5.2	4,351	9.1
Other prof. service	63	2.4	1,001	2.1
Public administration	111	4.3	1,592	3.3
Other	184	7.1	4,863	10.2

*Includes lumber and wood products.

Source: Public Affairs Research Council of Louisiana, Inc., based on 1970 census data.

Table 2.26. Employment in Major Occupation Groups

Employment in Major Occupation Groups

	Cameron		Calcasieu	
	Male	Female	Male	Female
Total	1,984	617	32,033	15,615
Prof., tech. & kindred	122	83	3,744	3,137
Farmers & farm mgrs.	108	6	331	5
Mgrs., officials & props.	281	47	3,321	725
Clerical & kindred	66	139	2,049	5,061
Sales workers	25	38	1,722	1,300
Craftsmen, foremen & kindred	380	0	8,492	162
Operatives & kindred	443	32	4,869	370
Private household	0	29	33	1,419
Service workers except private household	137	201	2,036	3,162
Farm laborers	58	5	382	13
Laborers	256	5	2,965	136
Other	108	32	2,089	125

Source: Public Affairs Research Council of Louisiana, Inc., based on 1970 census data.

Income Distribution Patterns

The income of workers in various occupational groups is shown in Table 2.27. It should be noted that in the groups that the project would draw from, median earnings for workers in Cameron and Calcasieu Parishes are higher than those for the state. The relatively high income levels can be attributed to: (1) the strength of unions in obtaining wage gains for these workers, and (2) a relatively constant demand for workers in these occupational groups despite the employment fluctuations natural to the primary industries (particularly in contract construction).

Family income levels are shown on Table 2.28. Comparison of income levels in these two parishes with those of the state show that this area has a relatively strong economy. Median family income in both parishes is above that of the State, and the percentage of families below the poverty level is less than that of the state.

2.6 UNIQUE FEATURES

2.6.1 Archaeological and Historical Sites

As is true for almost every major deltaic and estuarine complex in the mid-latitudes, the Louisiana coastal region was an attractive habitat for prehistoric man due to an abundance and variety of resources available to sustain primitive economies. Choctaw and Attacapa Indians occupied the area through which the pipeline will pass. The latter was a nomadic group having a fairly large community in the Black Bayou area 11 miles west of Black Lake.[79] Evidence of their presence is in the form of shell middens, which represent refuse discarded by the Indians near their dwellings. They are valuable archaeologically in that they contain bits of pottery, arrowheads, and implements indicating the lifestyle of the inhabitants of the region. Most of the early sites can be dated at between 300 and 400 A.D. The oldest site known in the area was from the Precambrian Period around 1000 B.C., and the most recent was in the Historic Period around 1500 A.D.[79]

Areas officially designated by the government as having historic value are listed in the National Register of Historic Places. In compliance with Section 106 of the National Historic Preservation Act of 1966, a search of the National Register and monthly supplements has been made for Cameron Parish and Calcasieu Parish. This search revealed no national historical sites in these areas. The Louisiana State Historic Preservation Officer was asked to locate areas of historical

Table 2.27. Median Earnings of Selected Occupation Groups

	Cameron	Calcasieu	Louisiana
Male, total with earnings	$6,546	$7,551	$6,536
Prof., mgrs., & kindred	7,840	9,792	9,511
Craftsmen, foreman & kindred	8,635	8,237	7,294
Operatives & kindred	6,400	7,396	5,786
Laborers, except farm	4,776	4,238	3,714
Female, total with earnings	$1,748	$3,040	$3,003
Clerical & kindred	2,774	3,702	3,808
Operatives, including transport	1,450	2,611	2,915

Source: Public Affairs Research Council of Louisiana, Inc., based on 1969 income figures.

Table 2.28. Family Income Levels, by Parish

	Cameron		Calcasieu		Louisiana	
	Number	% of Total	Number	% of Total	Number	% of Total
All families	2,027	100.0	35,891	100.0	872,772	100.0
Under $1,000	76	3.7	1,295	3.6	41,960	4.8
$1,000-$1,999	100	4.9	1,929	5.4	60,401	6.9
$2,000-$2,999	104	5.1	1,843	5.1	62,494	7.2
$3,000-$3,999	143	7.1	2,077	5.8	60,920	7.0
$4,000-$4,999	116	5.7	2,034	5.7	58,364	6.7
$5,000-$5,999	216	10.7	2,472	6.9	60,065	6.9
$6,000-$6,999	135	6.7	2,442	6.8	60,099	6.9
$7,000-$9,999	541	26.7	8,193	22.8	174,897	20.0
$10,000 and over	596	29.4	13,606	37.9	293,572	33.6
Income not reported	---	---	---	---	---	---
Below poverty level*	339	16.7	5,919	16.5	187,955	21.5
Median family income	$7,726		$8,404		$7,530	

*The U.S. Bureau of the Census established the poverty level for all families at $3,388 annually.

Source: Public Affairs Research Council of Louisiana, Inc., based on 1969 income figures.

significance as listed in the State Registers. Louisiana has three historic marker locations in Calcasieu Parish and none in Cameron. There are no locations in the area of potential impact.

In compliance with Section 2(a) of Executive Order 11593, "Protection and Enhancement of the Cultural Environment," May 13, 1971, a survey has been carried out to locate, inventory, and nominate eligible historic, architectural, and archaeological properties to the National Register of Historic Places. The results of this survey showed that the proposed undertaking will not result in the transfer, sale, demolition, or substantial alteration of eligible National Register Properties. Additionally, as the project progresses, additional surveys will be carried out to determine that additional eligible properties have been covered.

In compliance with Section 1(3) of 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 archaeological significance.

2.6.2 Wildlife Refuges

Sabine National Wildlife Refuge south of the pipeline route is the largest waterfowl refuge on the Gulf Coast covering 142,846 acres. Four of the brine disposal wells will be located within 750 feet of the north boundary of the refuge, while the oil pipeline to the West Hackberry Terminal will be approximately 2.5 miles from the refuge. The original intent in establishing the refuge was to provide protection to marsh habitat important to wintering snow geese and ducks. Coastal marshes in southwest Louisiana were formally one of the most famous fur-producing areas of the country. Access canals dug through this area have since changed the ecological situation considerably by blocking the drainage of fresh water and allowing the intrusion of salt water. One of the management goals of Sabine Refuge is the re-establishment of a high quality marsh habitat over a large area through proper manipulation of water levels.

2.6.3 State and National Recreational Parks

No parks or recreational areas are in the area of potential impact.

2.6.4 Scenic Areas and Unusual Features

No scenic areas or unusual features of the landscape are within the area of potential impact.

2.6.5 Biologically Sensitive Areas

The estuarine tidal marsh, the brackish marsh, and the fresh water marsh are all very sensitive biological areas Conceptually, two principal gradients strongly influence the ecology and zonation of the marshlands. One is the water salinity which increases from the fresh (less than 0.5% salt) water table of the coastal prairies toward the coast line of the Gulf of Mexico. The other gradient is that which represents the degree of soil saturation which is a function of elevation in the marshlands. It is the response to these two gradients that causes the general zonation of the plant communities parallel to the coastline.

The tidal marsh is an estuarine environment that serves as a nursery ground for commercially important fish and shellfish. It was estimated that two-thirds of the cash value of species harvested on the gulf coasts are "estuarine dependent." Even gulf coast species which do not breed their young in the estuaries or tidal marshes are still dependent upon the food chain which is at least partially based on the productivity of the tidal marshes as a source of mineral and organic nutrients.

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3. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

3.1 LAND FEATURES AND USES

Impacts of the project on land features and uses would occur almost exclusively during site preparation and the construction of facilities. They would result primarily from building the docks, laying the pipelines, and creating the required levees around tank areas. Minor soil erosion would result from exposing the soil during these construction activities, the tendency of the soil to break loose, and heavy rainfall in the area.

Erosion will be a temporary adverse effect, however, and permanent changes to land features are not considered detrimental. These changes include: additional roadways, enlargement of Alkali Ditch and part of the Calcasieu River Channel, providing access to the permanent dock, and construction of levees around the oil storage tank and brine settling tanks.

The terrain over a portion of the site, including disposal wells and water wells, if used, would be elevated for roadbeds and buildings. These features would be maintained over the operational life of the project and surface water flow paths would be affected near these elevations. Drainage pipes may be required in some areas so that trapped stagnant pools do not form.

3.1.1 Geologic Impacts

Construction

Subsurface geologic impacts that may occur during construction are: (1) the suspension of sediment during dredging, and (2) potential fracture of rock as a result of injecting a large quantity of brine into Miocene sandstone at a depth of 7,000 feet. Sufficient salt structure exists, however, around the cavities to prevent collapse of the overlying caprock during the displacement process. The volume and porosity of sandstone aquifers in the area designated for brine disposal indicate that injection at a rate of 10,800 gallons per minute would not fracture the overlying rock or cause contamination of overlying fresh water aquifers. (See Section 3.2.5)

Dredging would be required to create a temporary barge terminal on the Alkali Ditch, and spoil would be distributed along the northwest bank. Further dredging in the Calcasieu River Channel during construction of the permanent dock facilities would remove approximately 2,500,000 cubic yards of spoil which would be deposited in designated areas and revegetated to minimize erosion. In any dredging operation a certain amount of turbidity would result. Since the proposed dredging would be done hydraulically and the spoil would be deposited on the bank, the amount of material put into suspension would be negligible and would not constitute a significant geologic impact. Water quality impacts are discussed in Section 3.2.

Operation

Two potential impacts of geologic significance resulting from the operation of the petroleum storage facility are: channel erosion due to increased barge traffic in Alkali Ditch, and cavern collapse and subsidence.

Deepening and widening a 1500 foot section of Alkali Ditch would initially cause some turbidity during construction and early operation. However, after the larger suspended sediment particles have settled and the extremely fine clay and silt particles have lodged between larger particles, the amount of erosion or turbidity that subsequently results would be low.[1] Tidal currents would not be a factor in the resuspension of sediments because the currents are so small. This is based on the results of tidal current measurements made by the Army Corps of Engineers in the Intracoastal Waterway 5 miles west of the entrance to Alkali Ditch.[2] Although the site of the proposed dredging is 2 miles closer to ocean access, the tidal currents would be negligible because the proposed channel is not only at a right angle to whatever flow there is in the Intracoastal Waterway, but the channel is narrower and shallower than the Waterway, thereby reducing flow velocity.

Dredge spoil will be deposited in confined areas behind levees along the Alkali Ditch and Calcasieu Ship Channel, therefore the potential for surface erosion and return to the waterway is minimal.

Another factor that would limit the amount of stream bed erosion is colloidal cementation of sediment in the channel. The sediments in this area are sand, silt, and clay with high organic content. Clay minerals commonly form colloidal suspensions which are capable of forming bonds between sediment particles regardless of size. The high organic content of these sediments would generate humic acid which in some cases would also form bonds between particles thereby increasing the sediment coherence.[3]

An impact of increased barge traffic along the newly dredged leg of Alkali Ditch is erosion on the channel bottom and shore caused by the movement of the barges. The barges may generate wakes capable of transporting some material from the sides of the channel, but natural development of marsh vegetation (Spartina patens primarily) would eventually act as a wave baffle and dissipate wave energy.

Turbulence along the bottom of the channel caused by the passage of barges will initiate sediment motion. The turbidity increase in the channel will depend on vessel size, speed, draft, depth of channel, and grain size of bed material.[4] The geologic significance of resuspended sediment and any bank erosion that might occur will be minimal. In Alkali Ditch, the suspended sediment will settle during the time between the passage of barges but will not move out of the area. Transport of sediment out of the area is unlikely because ambient currents in Alkali Ditch are nearly indeterminable.

The general conclusion regarding bottom scour and channel bank erosion in Alkali Ditch is that geologic impacts would be minimal for the duration of the proposed activities.

The other potential geologic impact of operation is cavity collapse and subsidence.* It is believed that cavity collapse was responsible for the subsidence that occurred at the Bayou Choctaw Dome over the number 7 well in 1954.[5] A roughly circular lake formed at the site with a diameter of about 200 yards. Sonar probing in 1975 showed the maximum depth of the lake to be 85 feet. Few other such collapses have been reported.

Subsidence of the ground surface above a cavern is a potential geologic impact that could occur either with or without cavern collapse (a more detailed discussion of subsidence appears in Appendix J). Without cavern collapse, the amount of subsidence that occurs depends

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*Appendix I contains a cavern design analysis.

on the amount of cavern closure, and the elasticity of all salt and sediments overlying the cavern. Caverns 6, 8, and 9 will coalesce during the design life of the project if fresh water is used for displacement. This is based on the following: it is estimated that seven parts of water will dissolve 1 part of salt, this would allow a 14.2% volume increase if the water has enough time to become saturated. The assumption is made that the cavern floor does not dissolve because it is protected by insoluable residues in the salt that rain to the bottom during cavern formation; and the roof is protected by the floating oil blanket. It was further assumed that the cavern wall dissolution proceeded as if the caverns were cylindrical. Table 3.1 presents the increase in diameter after each cycle. The geometric arrangement of the cavities may be visualized with the aid of Figures 3.1, 3.2 and 3.3. Figure 3.2 shows the relative location of the five cavities in plan view.* Figure 3.2 and 3.3 shows vertical cross sections through the three caverns expected to coalesce.

Based on available sonar profile data the configuration, depth, and proximity of caverns 6 and 9 are such that they will coalesce during the first cycle.** If the oil-water interface in cavern 6 is higher than the oil-water interface in cavern 9, the brine in cavern 6 will pour into cavern 9, displacing the oil into cavern 6 and filling it completely. See Figure 3.2. As the brine from cavern 6 pours into 9, it will carry residues from the floor which will become suspended in the oil in cavern 9. Also agitation could cause the formation of an emulsion of oil and water. When oil from cavern 6 is withdrawn an oil blanket in cavern 9 cannot be maintained, upward dissolution of the roof in cavern 9 will continue as long as there is a difference in elevation between the oil water interface in cavern 6 and the roof of cavern 9 below.

When cavern 8 coalesces with 9 and 6 during the fourth cycl. Figure 3.3, oil stored in cavern 6 will in part be controlled by the level of the oil in the interface in cavern 8. When the oil-water interface in cavern 8 is

*The plan view of each cavern in reality is nearly circular at its maximum width. See Appendix H.

**Cavern 6 is an active brining operation and may have already coalesced with cavern 9.

Table 3.1 West Hackberry Cavern - Diameter After Each Cycle

Cavern Number	Cavern Diameter (feet)	Cavern Height (feet)	Diameter after each Cycle* (feet)				
			1	2	3	4	5
6	800	164	854	912	973	1,038	1,100
7	420	958	448	480	513	548	586
8	425	1,024	453	484	516	551	588
9	565	220	604	645	690	737	788
11	270	852	288	308	329	352	377

*In theory the dissolution at any wall is equal to half the difference between the diameter of the cavern after each cycle and the original cavern diameter.

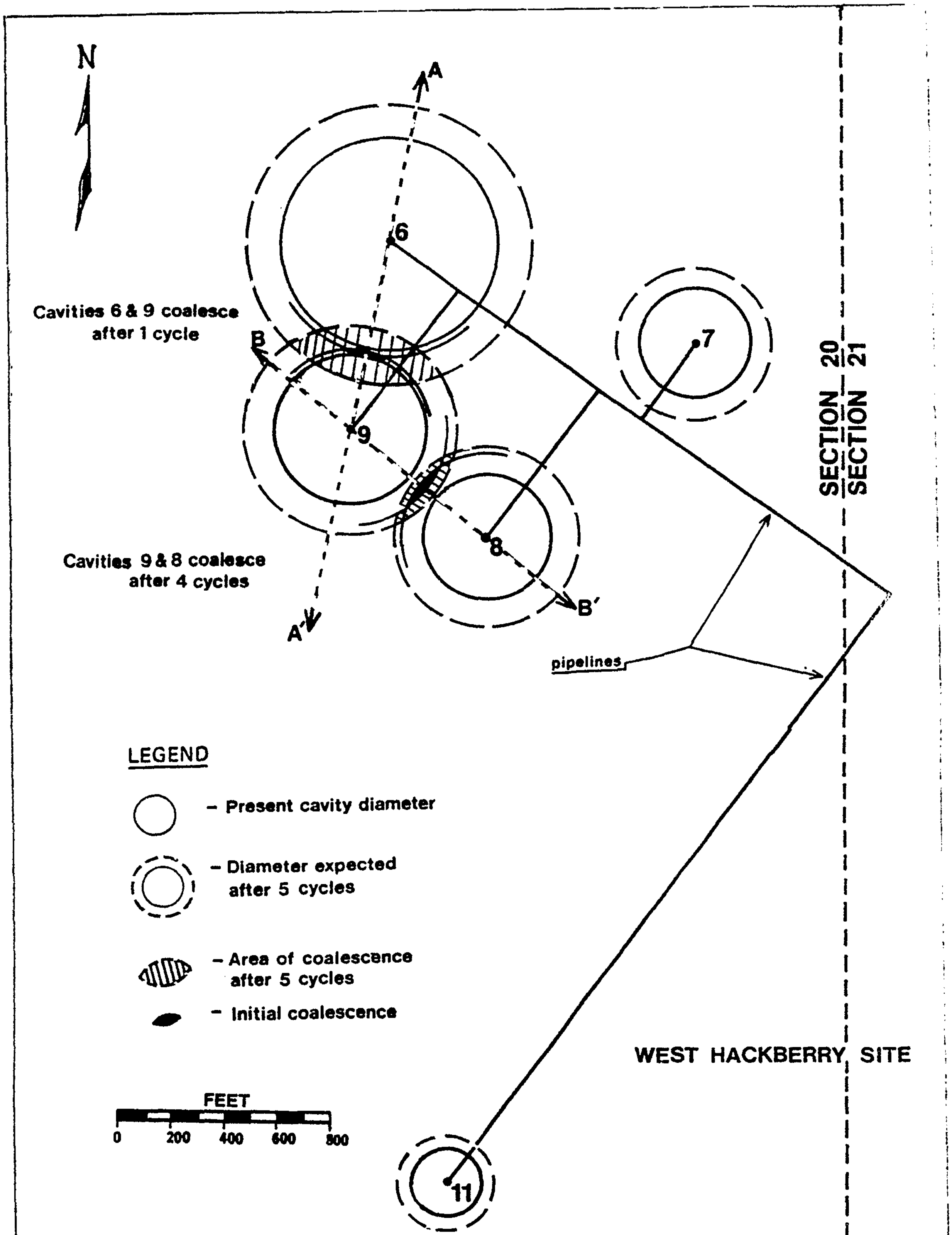

Figure 3.1 Plan View of Caverns at West Hackberry Showing the Present Diameter Du... Coalescence, and the Diameter After Five Cycles. Also Illustrated Is the Pipeline ... Between Cavern Wells. The Caverns Are Located In the Northeast Quadrant of Sectio...

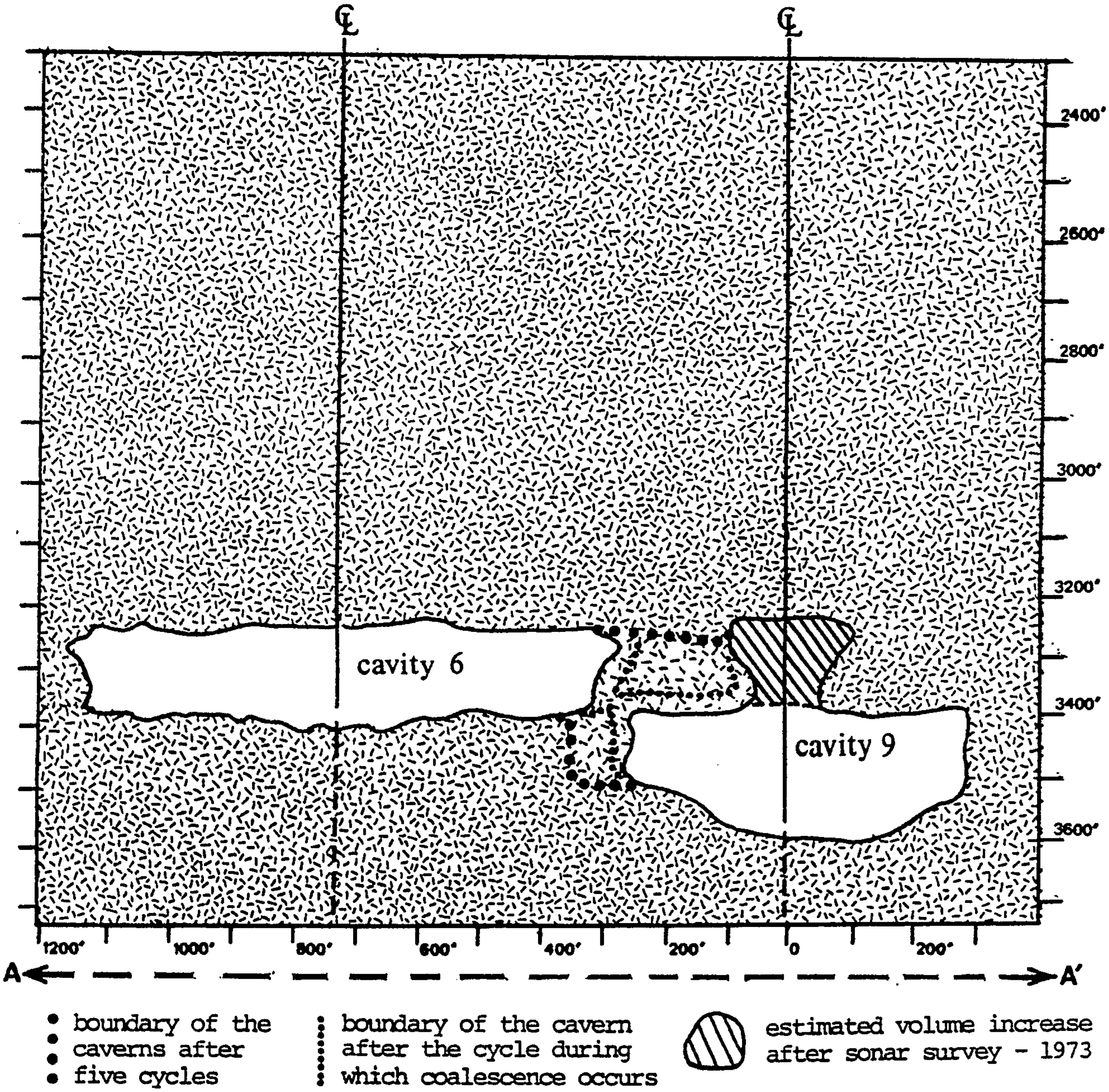

Figure 3.2 Illustration of Caverns 6 and 9 Coalescing After One Cycle and the Area of Salt Removed by Dissolution After Five Cycles (this is indicated in the area between the caverns only for simplicity. In reality, the caverns will increase in both directions laterally).

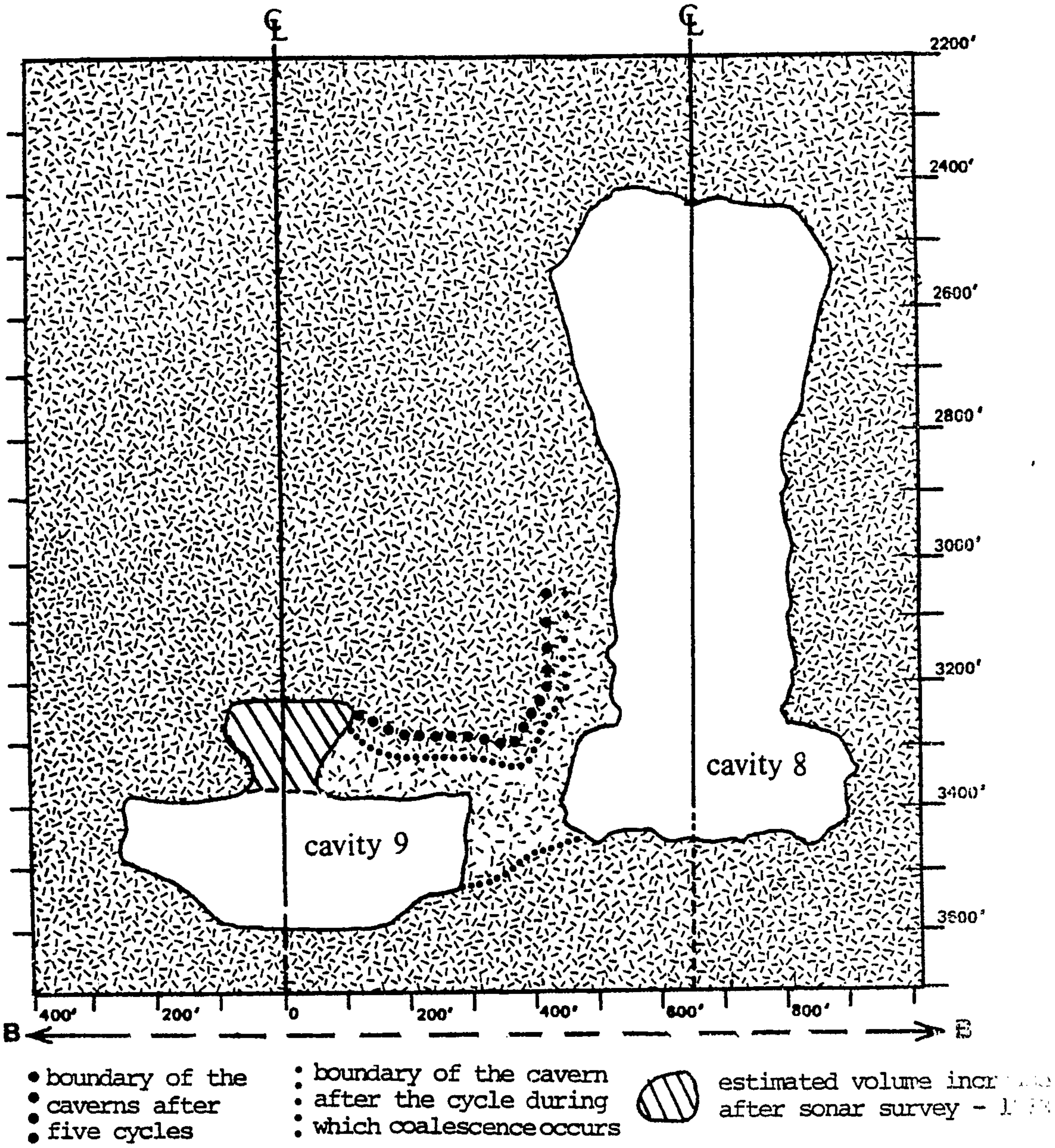

Figure 3.3 Illustration of Caverns 8 and 9 Coalescing After Four Cycles and the Area of Salt Removed by Dissolution After Five Cycles (this is indicated in the area between the caverns only for simplicity. In reality, the caverns will increase in both directions laterally).

above the roof in cavern 9, oil cannot be stored in cavern 9 because the brine in 8 will fill 9 and a part of 6 below the roof of 9. In addition upward dissolution of the salt will occur in cavern 9 until the brine is saturated, or until the dissolution of the roof reaches the level of the oil-water interface in cavern 8. Coalesence of caverns 6 and 9 is unavoidable even if one or the other is not used for storage of oil. They are extremely close together (few tens of feet maximum) if not already coalesced. If cavern 9 is full of brine when coalescence occurs, there will be no suspension of insolubles in oil or emulsification when the interface of the two caverns, either 6 or 8, attempt to equalize their levels. The consequence of coalescence is the removal of roof support and the potential increase in the rate of cavern closure.

If cavity collapse occurs, brine and/or oil could be forced out into the caprock and adjacent strata. It is unlikely, however, that fluid would escape to the surface through the cement casing of present wells. The injection of brine and the soluble components of oil into slightly saline or very saline aquifers is possible. As a result of cavity collapse, a localized surface depression could form and fill with surface water, in which case one or more wells would be damaged along with surface buildings and equipment.

Effects on Soils

Routine operating conditions are not expected to effect soil conditions significantly. Small amounts of fill dirt and shells would migrate to immediately adjacent areas. During floods, larger quantities of fill dirt might migrate to surrounding areas. The amounts and types of fill dirt should not significantly change the character of nearby soils.

3.1.2 Land Use Impacts

Land usage patterns would be affected at the storage facility site, along pipeline routes, and at the dock sites. About 240 acres surrounding the five cavities to be used in the initial phase of the project would be enclosed by a fence. Presently two settling tanks, a brine pond, and several buildings on the site are used in the brine production operations conducted by the Olin Chemical Corporation. The land is also being used for cattle grazing and a determination has not yet been made as to whether this use can be continued during the project.

The pipeline right-of-way from the storage site to the brine disposal field would be 50 feet wide and about 10,000 feet long. Additional rights-of-way within this disposal area leading to the individual wells would use a total area 50 feet wide and 12,000 feet long. Total right-of-way area for brine disposal will amount to about 25 acres. This land is currently being used as pasture area. These rights-of-way will be temporarily taken out of use while the pipeline is being constructed, a period of no more than 4 months. The land would then be restored to its present use with the required wellheads in place.

The pipeline right-of-way leading to permanent dock facilities on the Calcasieu River Channel would be approximately 4 miles long and would cross Louisiana Highway 27. It would pass through Hackberry (which is an unincorporated community and has no established boundaries). The pipeline would cross oil and gas fields southeast of the site and could cross other existing pipelines.

During construction of the pipeline on dry land, a temporary right-of-way 75 feet wide would be required. This land is primarily being used as pasture. At the completion of backfill operations on each segment of the pipeline, this right-of-way will be reduced to a width of 20 to 25 feet and can be restored to previous use. The permanent right-of-way to be maintained during the project would amount to about 12 acres, based on a maximum 25-foot width extending the 4 miles from the storage site to the dock.

Several acres of land adjacent to the Calcasieu River Channel wouldbe required for the construction of a permanent dock and an access road leading from Route 27. Activities at this site wouldpreclude its use as a hunting and fishing area. The resulting land impacted by the project is summarized in Table 3.2.

3.2 WATER QUALITY

Site preparation and construction activities would involve a significant amount of dredging, first in the construction of the temporary barge dock on the Alkali Ditch, and later in the construction of the permanent dock on the Calcasieu Ship Channel. These dredging operations wouldhave a significant impact on the water environment. In addition, a considerable amount of earth-moving wouldoccur at the site during construction of dikes, roads, and pipelines. Such activity would also have some impact on the water environment, and a limited amount of chemical and biological pollutants wouldbe generated.

The operation of the facility wouldaffect water quality in the vicinity of the dome in three ways. The first effect deals with the withdrawal of water from the environment in order to displace oil from the caverns. The second effect results from the disposal of brine displaced from the caverns by oil during each filling cycle. The third effect is concerned with maintenance dredging operations.

3.2.1 Impacts of Dredging

The dredging operations wouldoccur primarily in two areas: (1) the Alkali Ditch and (2) the Calcasieu Ship Channel. In each case, the impact on water quality can be divided into two parts: (1) the impact of dredging on water quality at the dredging site and (2) the impact on water quality at the site of the spoil disposal. The locations of the sites for dredging and disposal for both areas are indicated in Figure 3.4.

Dredging at Alkali Ditch

The dredging operations in the southern most part of the Alkali Ditch, associated with restoring the ditch to a depth of 7½ feet and constructing the temporary dock on the southwestern branch, wouldinvolve removal of 35,000 cubic yards of sediment from the ditch. The dredged material wouldbe discharged into the marsh located in the vicinity of the northwestern bank of the branch of the ditch.

Table 3.2. Land Impacted by Pipeline Systems During Construction and Operation of the Storage Facility.

	Pipeline Distance	Construction Phase: Width of Right-of-way	Construction Phase: Acreage Affected	Operation Phase: Width of Right-of-way	Operation Phase: Acreage Affected
Storage Site to Brine Disposal Field	10,000 ft.	75 ft.	17.2	50 ft.	11.5
Brine Disposal Field Connections to Individual Wells	12,000 ft.	75 ft.	20.7	50 ft.	13.8
Oil Distribution System	21,000 ft.	75 ft.	26.2	25 ft.	12

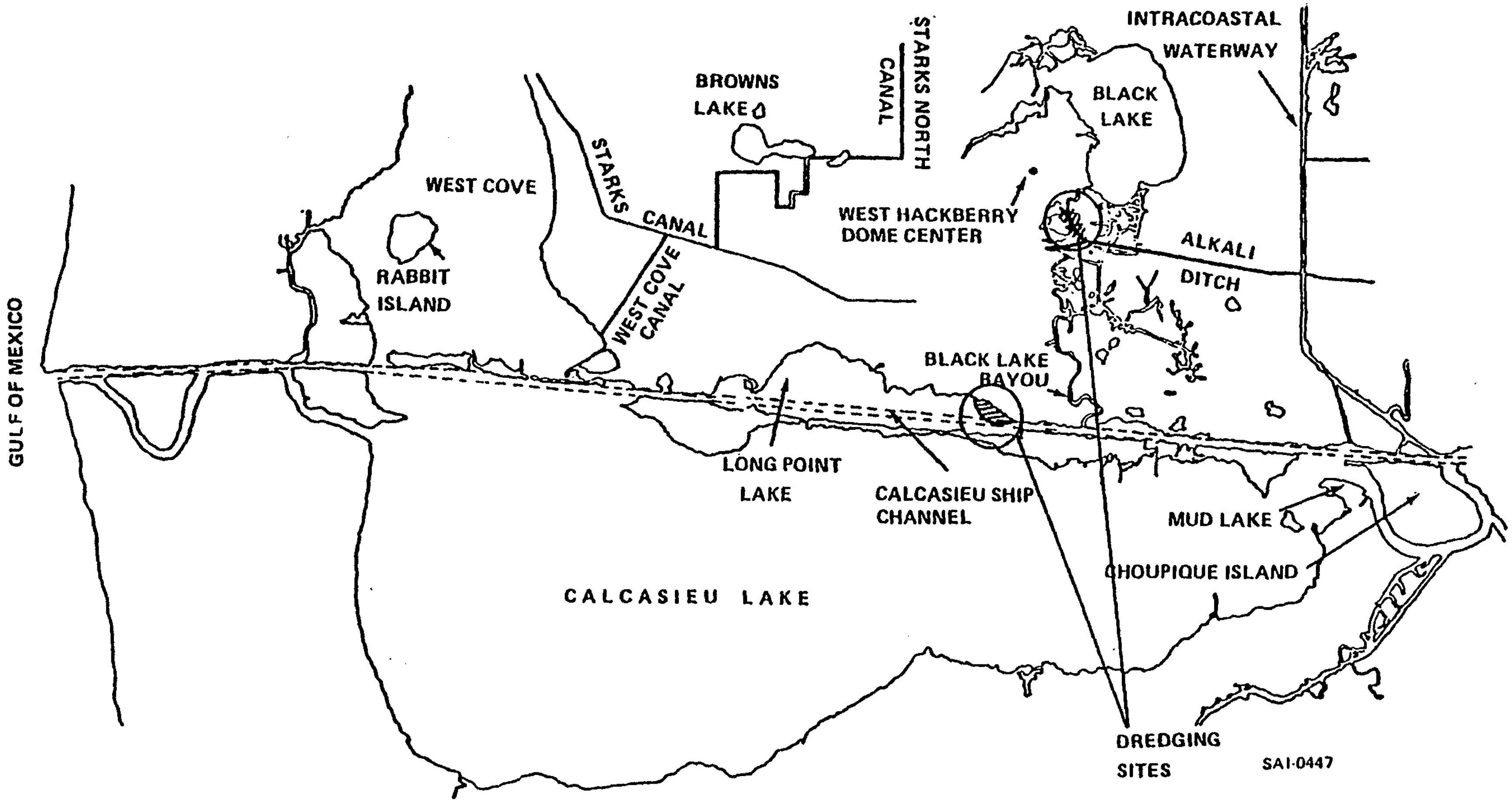

Figure 3.4 Location of Dredging Sites

Because of the absence of strong persisting currents, dredging should not have any appreciable impact on water quality in any other body of water. Some impact would occur at the southern end of the ditch where it connects with Black Lake Bayou and at the northern end where it joins with the main Alkali Ditch. Because neither Black Lake Bayou nor the main ditch have strong prevailing currents, this impact should be minimal. Within the Alkali Ditch, water quality degradation may result from (1) an increase in turbidity* of the water; (2) the release of toxic sulfides; (3) the release of toxic heavy metals or arsenic; or (4) the release of pesticides or other toxic hydrocarbons trapped within the bottom sediments.

At the site of the dredging activity, there would be an inevitable increase in turbidity created by the dredge. If the bottom sediments are polluted, the release of a fraction of these pollutants during dredging cannot be avoided. Thus the probable severity of the impact must be established. Most researchers have concluded that the dredging operation, using modern techniques, has little local effect on the water overlying the sediments.[6,7,8,9,10] This appears to be the case even when the sediments are highly polluted. These investigations report that some dredging activities increase water turbidity and other parameters to a very minor degree up to a mile from the dredge site under certain conditions. A significant increase in any parameter has been reported only within 200 feet of the dredge.

Sediments sampled in the ICWW are comprised of a large fraction of sand*. Sediments comprised predominantly of sand should create little turbidity problem at the dredge site because their settling rate is rapid in comparison with silt or clay particles. Generally, suspended solid increases are localized near the dredge and exert little stress on

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*Turbidity is a measure of the amount of light that will pass through a liquid and describes the degree of opaqueness produced by suspended particulate material. In contrast to turbidity, suspended solids is a direct measurement quantifying the actual amount of particulate material in the water.

*In the absence of other data it is assumed that the sediment in Alkali Ditch is the same as that in the Gulf Intracoastal Waterway.

surrounding aquatic organisms. Clam shell and bucket dredges, which are used in cast and stack methods, allow little water-sediment contact while being removed and disruption of the sediments near the dredge is minimal. Hydraulic dredges with revolving cutterheads cause some localized turbidity. However, a large percentage of the sediment-laden water near the operating cutterhead is sucked into the dredge and discharged with the dredge material into the disposal area.

Although the effect of dredging should be localized within the Alkali Ditch, some considerations must be given to pollutants which might be released from the bottom sediments. The sulfide content of bottom sediment samples taken from the ICWW was low,[2] and no significant impact is anticipated as a result of the release of hydrogen sulfide during dredging. The results of the elutriate test on the bottom sediments (Appendix D.6) indicate there should be no problem with release of heavy metals from the sediments into overlying waters. In fact, the sediments show a tendency to absorb metals from the water. A certain amount of arsenic will be released from some of the sediments. A concentration of 70 μg/l was obtained in the elutriate test, and this is only slightly higher than the concentration in the water (63 μg/l). (See Appendix D.4). Thus, the release of arsenic should have minimal effect.

Pesticides have been used heavily in the Louisiana wetlands and were found in the bottom sediments of the ICWW. The release of pesticides and other toxic hydrocarbons during dredging can result in water quality degradation and a severe impact on aquatic life. An analysis of pesticides in the water, the sediment, and sediment elutriate indicates that although the levels of pesticides in the sediment were much higher than the corresponding levels in the water, the levels in the elutriate were of the same order of magnitude or less than such levels in the water. Thus, the release of pesticides from bottom sediment to the water during the dredging operation should not change the current levels of pesticides in the water by any appreciable amount.

Studies along the southeastern coast indicate that large amounts of ammonia are released from polluted sediments when they are dredged.[8] This may also be the case with sediments from the ICWW. Analyses were not conducted for ammonia in the sediment but appreciable amounts of ammonia were present in the water samples (Appendix D.4), which suggests that ammonia is also present in the sediment.

The intrusion of saline waters into freshwater areas is a recognized problem throughout the coastal zone. Dredging the southwestern branch of the Alkali Ditch may contribute to this problem in that the increased depth may facilitate the flow of salt water into the general area. Because of the lack of a direct passage between the ditch and the Gulf of Mexico combined with the relatively shallow final depth of the ditch (7 1/2 feet), this problem should be small. The dredging operations would only restore the ditch to its original depth.

In summary, the impact of dredging <u>at the dredging site</u> in Alkali Ditch, during site preparation and construction should be confined primarily to the ditch itself. Within that water body, all available data indicates that a temporary, localized increase in turbidity would be the most severe environmental impact. No significant increase in any other water quality is anticipated.

<u>Disposal of Dredged Material From Alkali Ditch</u>

The impact of the disposal of dredged material (spoil) from Alkali Ditch represents a separate but related problem to the impact of the dredging operation itself. Of major concern in the disposal area are the possibilities for (1) an increase in turbidity of the water in the disposal area; (2) a significant release of aquatic nutrients; (3) the depression of dissolved oxygen levels; (4) the release of toxic sulfides; (5) the release of toxic heavy metals or arsenic; (6) the release of pesticides or other toxic hydrocarbons mixed in the bottom sediments and (7) the loss of wetland habitat.

The greatest impact from increased turbidity and suspended solids on the aquatic ressources would be realized in the disposal of the dredged material. The relative impact of the suspended solids on the aquatic system is in part determined by the method of disposal. Current design for the Alkali Ditch operation calls for bucket dredging with confined disposal areas. Although the material dredged from the waterways will be a mixture of sands, clays, silt, and organic debris, some portion (<10 percent of the disposal material will be fine silt, which in still water requires many hours to settle. Wind action and drainage flow tend to keep this material in suspension. The majority of sediment should be sand which tends to settle out fairly rapidly.

The potential for the release of water quality degrading pollutants to the water during disposal of the dredged material may be assessed by reviewing the sediment elutriate test results (Appendix D.6). The soluble orthophosphate concentration measured during the elutriate test on bottom sediments was 0.02 mg P/l which was approximately twice the concentration in the water. In general, phosphorus is released from the sediments to the water only in very small quantities. The concentration of phosphorus in the elutriate is, however, just adequate to support a large aquatic biomass, typical of eutrophic conditions, if the waters were confined without dilution. TKN in the elutriate is 4 times higher than that in the corresponding water. TKN is comprised of organic nitrogen plus ammonia. Based on a comparison of the organic nitrogen release to the relatively small release of dissolved organic carbon from the sediments, it appears that most of the TKN released is in the form of particulate detrital material and ammonia, since only a fraction is released as dissolved carbonaceous matter. The TKN values measured in the sediments strongly suggest the presence of a considerable amount of detrital plant matter.

The release of nutrients, particularly nitrogen, in confined disposal areas is a matter of concern. Within a confined disposal area, these nutrients may encourage the growth of excessive populations of algae and the consequent degradation of water quality. In a confined area with insufficient retention capability, the rapid return of enriched sediment transport water may be viewed as undesirable in certain areas. On the other hand, the Louisiana Advisory Commission believes the enrichment of coastal and marsh waters in the area would be beneficial.[11] In either case, it is likely that released nutrients would be rapidly assimilated into the marsh system.

The elutriate test (Appendix D.6) indicates that the sediments have a significant potential for the release of oxygen demanding substances. COD of the elutriate is greatly increased over that of the water while TKN and dissolved organic carbon levels, which are a measure of the organic material, are not increased to nearly the same extent. It may be concluded from these data that much of the COD released from the sediments is in the form of reduced iron, manganese, and possibly other reduced metals. Although iron analysis was not conducted on the sediments, it is reasonable to speculate that iron concentrations in the sediments may be quite high, since concentrations reported in the overlying waters were as high as 5 mg/l.[2]

The disposal of dredged materials in a confined area with an adequate transport water retention time may be used to reduce this potential problem. If the oxygen demanding sediments are dispersed adequately into a shallow retention area where the overlying water may undergo atmospheric reoxygenation, the net effect would be to satisfy the oxygen demand without risking a water quality problem. The growth of algae in the confined area, stimulated by the release of nutrients from the sediments, will further aid in satisfying oxygen demand since algae produce oxygen during photosynthesis. A significant increase in DO has been observed in confined disposal areas.[8] If care is taken in design of the confinement area so that the sediment transport water is returned to the waterway after sufficient time for suspended solids to be deposited and nutrients to be removed by algae, but before the algae population becomes senescent and dies, then the returning transport water may be of good quality with high oxygen and low nutrient content. Under these circumstances, the confined disposal area would serve much like an oxidation pond similar to those used for many years to treat municipal and industrial organic wastes.

As noted in the discussion of the impact of dredging, the level of sulfide in the bottom sediments is low. Thus the release of hydrogen sulfide during the disposal process should not represent a significant effect.

The release of toxic heavy metals has been discussed previously and it was noted that no problem should be encountered. The observation was made that the sediments show a tendency to absorb the metals from the water. This tendency appears most evident for the case of zinc.

Zinc concentration was fairly high in the sediments analyzed (22 mg/kg). The concentration of dissolved zinc in elutriate water, however, was 7.7 μg/l. This is less than the concentration in the water before the elutriate test (39 μg/l). Similarly, mercury contamination amounts to 3.1 mg/kg of the sediment, but the level in the elutriate waters (15 μg/l), is only slightly greater than the level in the original water sample (13.4 μg/l). This level is, however, greatly in excess of the proposed EPA numerical criteria value of 0.1 μg/l for freshwater aquatic life. Notice should be taken that at a number of other sampling stations along the ICWW, adsorption of mercury from the water is more commonly observed.[2] This adsorption of metals from the water (rather than their release) by the sediments has been ascribed to oxidation of ferrous iron sulfides to ferric oxides, which trap the other metals. Ferric oxides are insoluble and retain the occluded metals as long as the oxides are not reduced again to sulfides.

The release of arsenic from the dredged material to the water system in the disposal area should not pose a problem because (as discussed earlier) the level of arsenic in the elutriate sample was only slightly higher than that in the corresponding water sample.

The question of pesticide release was discussed earlier in connection with the impact of dredging on the dredging site. As noted in that discussion, the levels of pesticides in the elutriate were of the same order of magnitude or less than the levels in the corresponding water sample. Thus, although the current levels of pesticides exceed EPA standards, in some cases, the disposal of dredged sediments should not appreciably change the current levels in the disposal area.

The orientation of the disposal area must also be considered. Large, continuous disposal areas running perpendicular to the general flow of surface or tidal waters may halt, impede, or redirect the flow of such waters. This in turn may produce alterations in periods of inundation, salinity, and sediment deposition. Because the exact arrangement of the disposal area has not been defined, the resulting impact cannot be assessed at this time.

Because a contained disposal area is used, during the fill years most of the containment structure will hold turbid water and a turbid aqueous solution of dredged solids from the dredging site. This water must be discharged from the disposal areas, since in most cases it represents 80 to 95 percent of the total volume of materials pumped into the containment structure. The impact of this excess water on the receiving water body will vary according to the quality and volume of the receiving water and the quality and quantity of the dike effluent. In general, the impact should take the same form as that related to dredging.

The confined disposal area must be capable of containing 35,000 cubic yards of dredging spoil. Based on the assumption that the spoil can be stacked to a mean height of two feet, this volume of spoil would require approximately 11 acres of disposal area. This area would generally be in the vicinity of Alkali Ditch and is currently brackish marshland. Thus, the loss of wetland habitat would amount to approximately 11 acres.

The soil underlying the disposal sites is primarily Pleistoce clay. Such soil represents the upper layer of an impermeabl clay aquitard from 100 to 400 feet thick, which is immediatel above the Chicot aquifer in the West Hackberry area. This layer of clay may be interlaced with a few thin aquifers, but such aquifers contain brackish waters and are not suited for use as water sources. Because the water table is within one or two feet of the surface, the clay should be water-satu Contaminants from the dredged spoil could possibly permeate into the clay, but only a short distance. No aquifers of any value could be contaminated by such permeation.

In summary, the impact of the dredged material on the disposal site should consist of an increase in turbidity, TKN (in the form of detrital matter and ammonia), and COD combined with a possible decrease in DO. The flow of surface water in the marsh may also be affected. Approximately 11 acres of wetland habitat would be lost. The impact of the dredging disposal operation can be localized and minimized by employing the most recent technology in dredge disposal.[12,13,14,15]

Dredging at the Calcasieu Ship Channel Dock Site

The construction of the permanent dock facility on the Calcasieu Ship Channel will involve dredging approximately 2.5 million cubic yards of material during a period of several years. The dredging operation should be confined to a region located approximately 1 mile south of the mouth of Black Lake Bayou and extending 3,000 feet further to the southwest. The disposal site for the dredged material would be the spoil areas located on either side of the Calcasieu Ship Channel in the vicinity of the dredging operation as shown in Figure 3.4.

At the ship channel, the dredging and disposal operations may be close enough together to cause a combined impact on certain regions. Such combined impacts can be identified only when a more complete description of the dredging operations in the Calcasieu Ship Channel is made available.

The impact on water quality at the dredging site in the channel would be generally similar to that experienced in Alkali Ditch (except that the effects may be distributed over a larger area due to the larger size of the body of water involved). The major concern is a degradation of water quality resulting from (1) an increase in turbidity; (2) the release of toxic sulfides; (3) the release of toxic heavy metals or arsenic; or (4) the release of pesticides or other toxic hydrocarbons contained in the bottom sediments.

A number of specific considerations regarding these 4 problem areas have already been stated for Alkali Ditch and many of these comments are equally applicable to the ship channel. For the sake of brevity, these comments will not be repeated. Only significant differences will be discussed in the paragraphs which follow.

The bottom sediment in the region to be dredged is largely located in relatively shallow spoil area (2-6 feet deep) on the western side of the ship channel proper (40 feet deep). It is possible that much of this sediment may have originally been dredged from the ship channel and then deposited in the proposed dredging area. The sediments in this shallow water are largely silts and clays* which may increase turbidity in Calcasieu Lake during dredging and disposal.

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*Barney B. Barrett, Louisiana Wildlife and Fisheries Commission, 1971, Cooperative Gulf of Mexico Estuarine Inventory and Study, LA, Phase II, Hydrology and Phase III Sedimenology.

In considering the possibility of increased turbidity, the description given for Alkali Ditch is generally applicable Because of the likely presence of stronger currents and wave action in the channel region, however, the turbidity plume may extend over a larger region. The size and duration of this plume will depend upon the number and size of the dredges operating in the area and the length of time during which dredging occurs. It is reasonable to expect a moderate (less than 5 percent) increase in turbidity at distances as great as 1 mile from the dredging site.

Available sediment and elutriate data for the Calcasieu Ship Channel, as provided in Appendix D.4, do not include measurement of sulfides and thus the potential for the release of toxic sulfides cannot be established.

With respect to toxic heavy metals, it is indicated that zinc and mercury in sediment samples and lead, zinc, and nickel in elutriate samples will exceed the proposed EPA water quality criteria for marine water constituents (aquatic life). Thus some problem with the release of heavy metals at the dredging site in Calcasieu Ship Channel may be encountered.

With respect to the release of pesticides or other toxic hydrocarbons, the available data (which are very limited) generally indicate no problem.

Because the Calcasieu Ship Channel is directly connected with the Gulf of Mexico, the dredging process would have some effect on the salt water intrusion problem already present in this region. The area which is to be deepened does not connect with any other body of water besides the ship channel itself. Thus, the only change in the salt water intrusion situation would be an increase of salt water entering the dredged area, where the salinity should be approximately the same as that in the channel proper (15-20 ppt).

In summary, <u>at the dredging site</u>, the impact of the dredging operations would be similar to that experienced in Alkali Ditch, except the size and duration of the disturbed area would be larger, and some problems with heavy metal may be encountered. Salt water would have direct access into the dredged area from the Gulf of Mexico via the ship channel.

Disposal of Dredged Material From the Calcasieu Ship Channel Dock Site

The impact of the disposal of the dredged material on water quality in the Calcasieu Ship Channel would differ in many respects from that encountered in the marsh near Alkali Ditch. There is a basic difference in that the disposal area for the Calcasieu Ship Channel would be the spoil area alongside the channel. This spoil area is largely under water on the western side, but is partly dry land on the eastern side. The basic concerns, however, remain the same: (1) an increase in turbidity of the water; (2) a significant release of aquatic nutrients; (3) the depression of dissolved oxygen levels; (4) the release of toxic sulfides; (5) the release of toxic heavy metals or arsenic; or (6) the release of pesticides or other toxic hydrocarbons trapped within the bottom sediments.

Probably the most significant difference in the impact observed will be the turbidity plume generated by the sediment discharged into the spoil area under water. Previous studies of canal dredging in Louisiana have indicated that silt can be carried as far as 1,300 feet from a dredge discharge. However, at distances greater than a few hundred feet, turbidities did not exceed those often attained under natural conditions.[16] The amount of material drifting away from the dredge discharges was estimated to be only 1 percent of the total dredged material, and evidence of fine material in suspension was lost in the natural turbidities over distances of 1,000 feet. Turbidities and suspended solids can often reach very high levels, as indicated by hydraulic maintenance dredging studies in Alabama where suspended solids along the bottom of the disposal area often exceeded 10,000 mg/l within 400 feet of the dredge discharge.[9]

The turbidity plume from the disposal operation extended 400 to 1,200 feet depending on wind and current conditions during dredging. Suspended solids data illustrate that some transport of discharged solids does occur; however, the Alabama studies indicate that suspended solids concentrations were less than 100 mg/l at distances greater than 400 feet from the source. Average suspended solids values for Louisiana marshes normally range from 20 to 200 mg/l.[16]

In terms of all other effects, the impact should be similar to that noted for the marsh near Alkali Ditch. Because the spoil areas are parallel to the general direction of current flow, no appreciable change in the water flow pattern should occur.

In summary, the impact of the distance of the dredged material on the disposal area will consist primarily of increased turbidity over a region extending approximately 1 mile from the disposal site. Because the dredged sediments are largely sand the turbidity should dissipate fairly rapidly due to settling. Due to the fact that the dredging operation may occur over a period of several years, however, turbidity plumes will be present in the region for a similar period of time. The undesirable effects of the disposal process can be minimized by conforming to the latest disposal technology.[12,13,14,15]

Maintenance Dredging

The life expectancy of the facility is estimated to be 20 to 25 years. For the first 17 months, the temporary dock on the Alkali Ditch would be used for crude oil distribution, then the permanent dock on Calcasieu Ship Channel would be used. Maintenance dredging of Alkali Ditch during the early fill period may be needed to keep the ditch deep enough to permit the necessary barge traffic. Such dredging would probably be required to maintain the necessary depth near the permanent dock on the Calcasieu Ship Channel.

The impact of maintenance dredging on both Alkali Ditch and the Calcasieu Ship Channel would be quite similar to that incurred during the original dredging for site preparation and construction. The impact would include (1) increased turbidity and suspended solids; (2) increased oxygen demand due to the decomposition of disturbed organic sediments; (3) the release of hydrogen sulfide into the waters from anaerobic sediments; and (4) the release of nutrients, heavy metals, oil and grease, and pesticides. The amount of material to be dredged during maintenance, however, should be significantly less than the amount initially dredged, and at both sites the impact on the water system, due to the dredging and due to the disposal of dredged material, should be reduced. However, maintenance dredging operations are inherently cyclic in nature. At Alkali Ditch, it would be unlikely for more than one maintenance dredging operation to be needed in the 17-month period, but at the permanent dock on Calcasieu Ship Channel, over a period of 20 years or more, a number of dredging cycles would be involved. Therefore, the cumulative effects of such cycles must be taken into account.

In one respect, maintenance dredging should have a cumulative favorable impact on the water system at the dredging site. The removal and proper disposal of polluted bottom sediments may improve the overlying water quality. A fraction of the bottom sediments are suspended into the water column each time a deep-draft vessel passes. This mixing permits the release of pollutants from the bottom sediments into the water column and the subsequent degradation of water quality. Since efforts are underway to reduce the discharge of polluting substances to surface waters, it may be expected that sediments, which are subsequently deposited in place of those that have been removed, would be less likely to contain pollutants that would adversely affect water quality. The net effect, then, would be the removal of a source of water pollution from the channel. Mercury, for example, is concentrated in most of the bottom sediments sampled along the region. Concentrations in the water are also of concern. Removal of the sediments polluted with mercury may permit both the establishment of a more healthy aquatic life and improved water quality. Continued maintenance of the channel depths would minimize the suspension of bottom sediments by the passage of ships and, hence, minimize the adverse effects of increased turbidity and the release of pollutants trapped in the bottom sedim[illegible]

3.2.2 Impacts of Earth Movement

Sediment represents the major non-point source of water pollution on most construction sites, especially on those which require extensive grading. Sediment includes solids and organic materials detached from the ground surface by erosion and carried into the drainage system principally by runoff. The introduction of sediment into various natural bodies of water and the associated turbidity and solids deposition result in numerous adverse physical, chemical, and biological effects. Suspended sediment ultimately reduces the storage capacity of waterways, increases flooding hazards, fouls and destroys aquatic habitats, impedes navigation, increases water treatment costs, diminishes recreational and property values and enhances the transport of other harmful pollutants such as human and animal sanitary wastes, pesticides, and petrochemicals.

The site preparation and construction activity would involve a significant amount of earth movement. Approximately 60,000 cubic yards of earth would be displaced during this process, excluding the dredging operations. Associated with this movement of earth, approximately 34 acres of land would be disturbed. Based on the analysis presented in Appendix [illegible] approximately 5,028 cubic yards of sediment would be washed into the surface water system annually as a result of erosion of this disturbed land by rainfall. This discharge of sediment should produce an increase in the ambient suspended solid level of approximately 2.35 percent.

3.2.3 Chemical and Biological Pollutants

Numerous solid and liquid products, both organic and inorganic, used in construction are a source of water pollution. The major sources of contruction-related chemical pollution can be broadly grouped under the following headings:

- Petroleum products
- Herbicides and pesticides
- Fertilizers
- Metals
- Soil additives
- Construction chemicals
- Miscellaneous wastes

Of these, petroleum products, herbicides and pesticides, and fertilizers appear to be the best-known and the best-documented sources of chemical pollution:

a. Pollution from petroleum products generally occurs from improper disposal of waste materials such as crankcase oil and various cleaning solvents, leakage of fuels and oil from storage facilities, and damaged or improperly maintained vehicles; fuel spills during equipment refueling operations; and the use of oils for dust control on roadways.

b. Herbicides and/or pesticides are used on some construction sites to control undesirable vegetation, insects, and rodents. The primary causes of pollution from the use of these chemicals are in the improper use, handling, and disposal of waste materials.

c. Fertilizers are extensively utilized in the revegetation of areas affected by grading operations. Like herbicides and pesticides, the primary causes of damaging pollution are improper use, i.e., applying too much fertilizer or improper preparation of the ground surface prior to application.

The biological pollutants which generally enter receiving streams and other water bodies as a result of construction activities are bacteria, fungi, worms, viruses, and other less prevalent organisms. Biological pollution is primarily a result of poor sanitary conditions at a construction site - generally improper disposal of human wastes, garbage, and other organic material. The disturbance, exposure, and subsequent erosion of surface soils that contain bacteria and other organisms are contributing factors. Regardless of their origin, biological pollutants have an adverse effect on water and the nature of the biological organisms. The pollutants of major concern are the pathogenic organisms associated with human wastes.

Prediction of the impact of such chemical and biological contaminants is quite difficult because of the human element involved, and the current incompleteness of facility design. This type of pollution, however, can be minimized by proper instruction of personnel coupled with good housekeeping practies.

3.2.4 Withdrawal of Surface Water

Current design calls for displacing the oil at a rate of 10,650 gpm for a period of 150 days. All displacement water is to be drawn from Black Lake Bayou, at a point approximately 1500 feet from the junction of the bayou with Black Lake, as shown in Figure 3.5. Because of the proximity of Black Lake to the withdrawal point, the lake is generally considered the primary source of displacement water. If Black Lake served as the sole source of displacement water, and if the lake were completely isolated from other water bodies, a withdrawal rate of 10,650 gpm (23.7 cfs) would lower the water level of the lake at a rate of .0215 ft/day (as explained in Appendix F). Because the lake is not isolated, however, the actual rate of fall of the water level in the lake would be much less than the value noted. The withdrawal of water from Black Lake Bayou would induce a current from Black Lake to the withdrawal point, which would indeed tend to lower the level of the lake. At the same time, however, as shown in Figure 3.5 currents would be induced in other portions of the bayou and also in Alkali Ditch, which would have two effects. First, the actual amount of water withdrawn directly from the lake would be reduced because of the induced flows along Black Lake Bayou from the Calcasieu Ship Channel and along Alkali Ditch from the Gulf

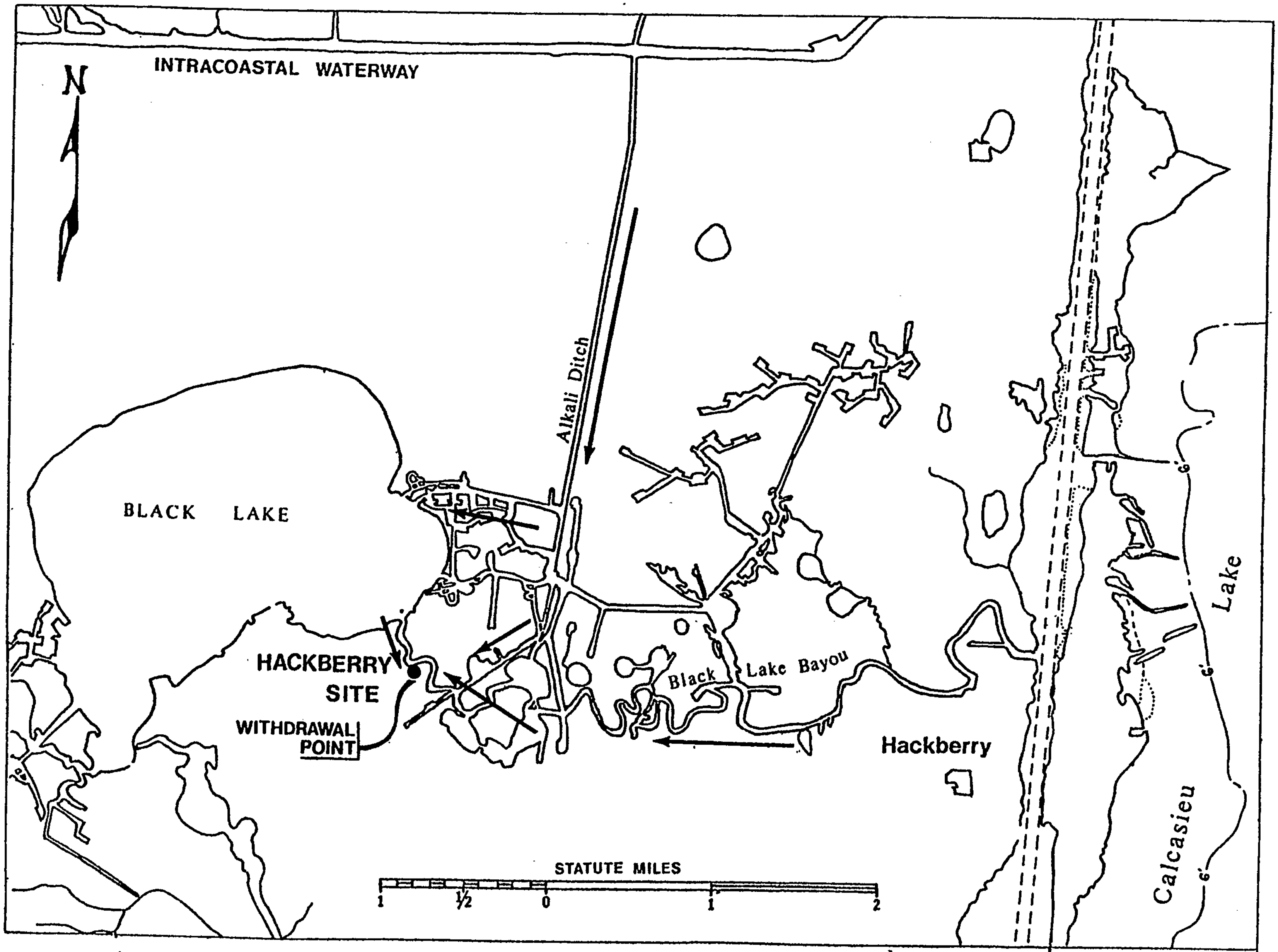

Figure 3.5 Induced Currents in Surface Water System Due to Withdrawal of Displacement Water

Intracoastal Waterway (ICWW). The second effect would be the replenishment of Black Lake by means of the network of canals which connect it with Alkali Ditch and Black Lake Bayou (independent of that portion of the bayou between the withdrawal point and Black Lake). Thus it can be seen that much of the replenishment water would actually come directly from the Calcasieu Ship Channel or the ICWW.

It is not clear which of the two neighboring water bodies would be the principal replenishment source. The two extreme cases would involve each source alone supplying the total water removed from the lake. The variation of surface height of Black Lake with time, with Calcasieu Ship Channel as the sole replenishment source, via Black Lake Bayou, is presented in Figure 3.6. As indicated in the figure the withdrawal of water will cause Black Lake's surface height to drop approximately .006 feet, with equilibrium occurring in about 3 days. The corresponding variations of induced velocity in Black Lake Bayou are presented in Figure 3.7. The maximum induced velocity would be about 0.6 ft/sec.

If the water is supplied solely from the Intracoastal Waterway via Alkali Ditch, the variation of the surface height of Black Lake with time would be quite similar, as shown in Figure 3.8. In this case a slightly shorter time period would be involved (about 0.5 day) and the maximum decrease in the surface level of the lake would be somewhat less (about .001 ft). The variation of induced velocity in Alkali Ditch with time for this case is shown in Figure 3.9. The maximum induced velocity in the ditch would be about .04 ft/sec.

Based on the preceding analysis it would appear that the surface level of Black Lake would experience a very small decrease (<0.1 feet) regardless of which water body provides replenishment water. Likewise, the induced velocities in either Black Bayou or Alkali Ditch would be small (<0.1 ft/sec) in comparison with existing currents in the bayou and ditch (as discussed in Appendix F). These computations are based on the assumption of steady-state conditions existing in the two replenishment sources. In reality, steady-state is not maintained due to winds, tides, and other related effects. The tidal range in Calcasieu Lake is 0.5 feet with an equal value reported in Calcasieu River,[17] so similar variations in the Calcasieu Ship Channel and the Intracoastal Waterway can be expected. Such a range is

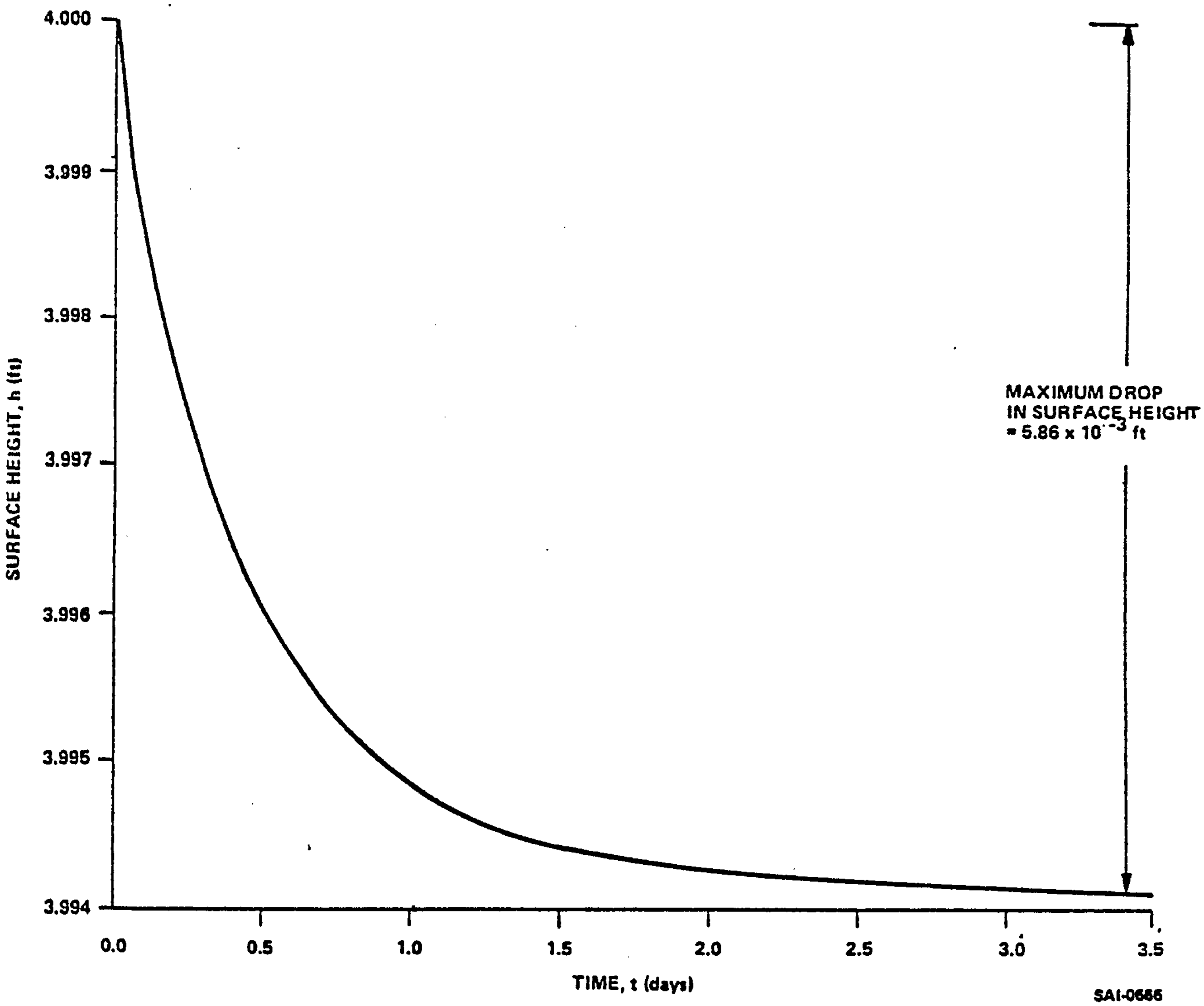

Figure 3.6 Variation of Black Lake Surface Height with Time (Black Lake Bayou Serving as Replenishment Channel)

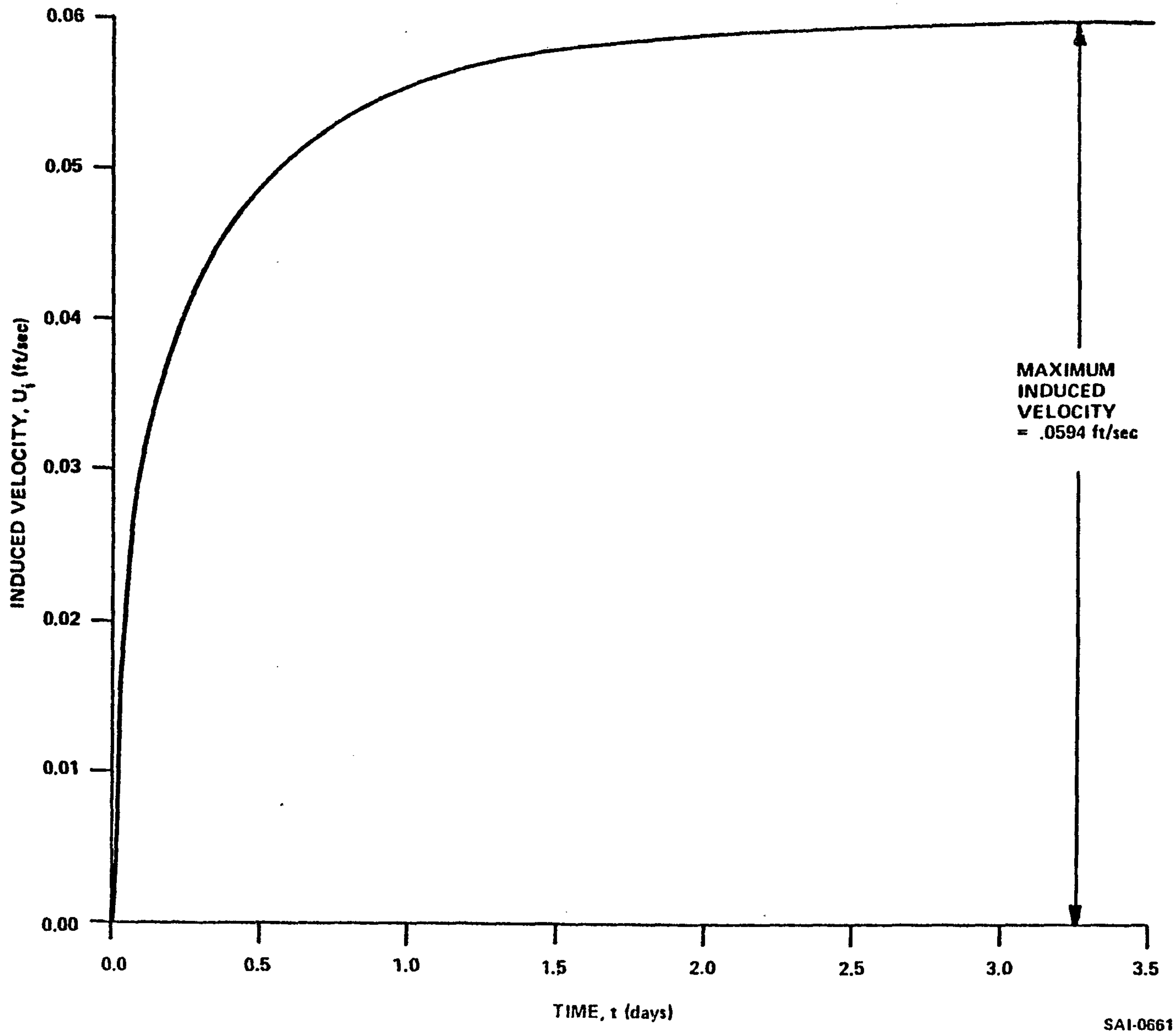

Figure 3.7 Variation of Induced Velocity in [illegible] Bayou with time

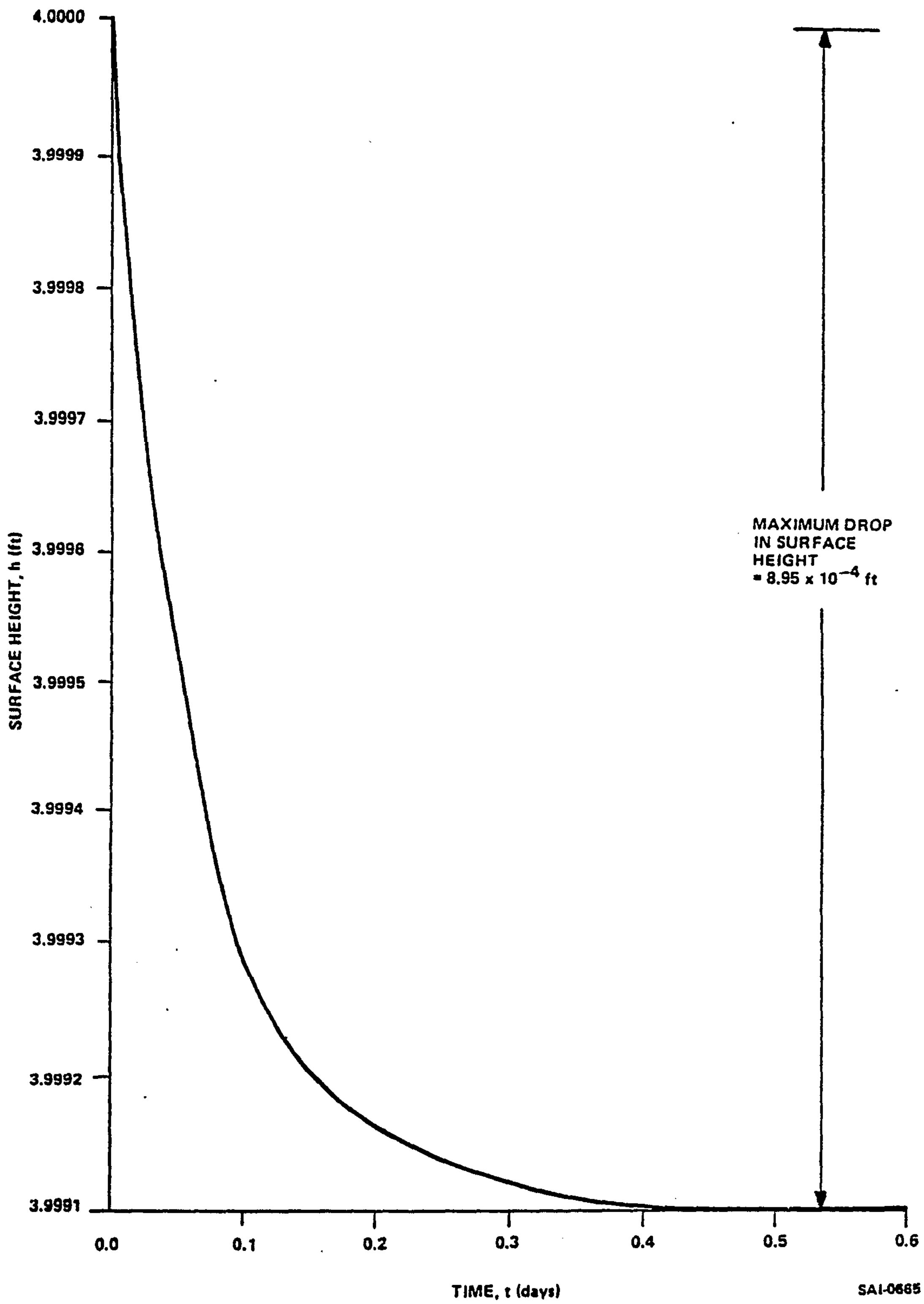

Figure 3.8 Variation of Black Lake Surface Height with Time (Alkali Ditch Serving as Replenishment Channel).

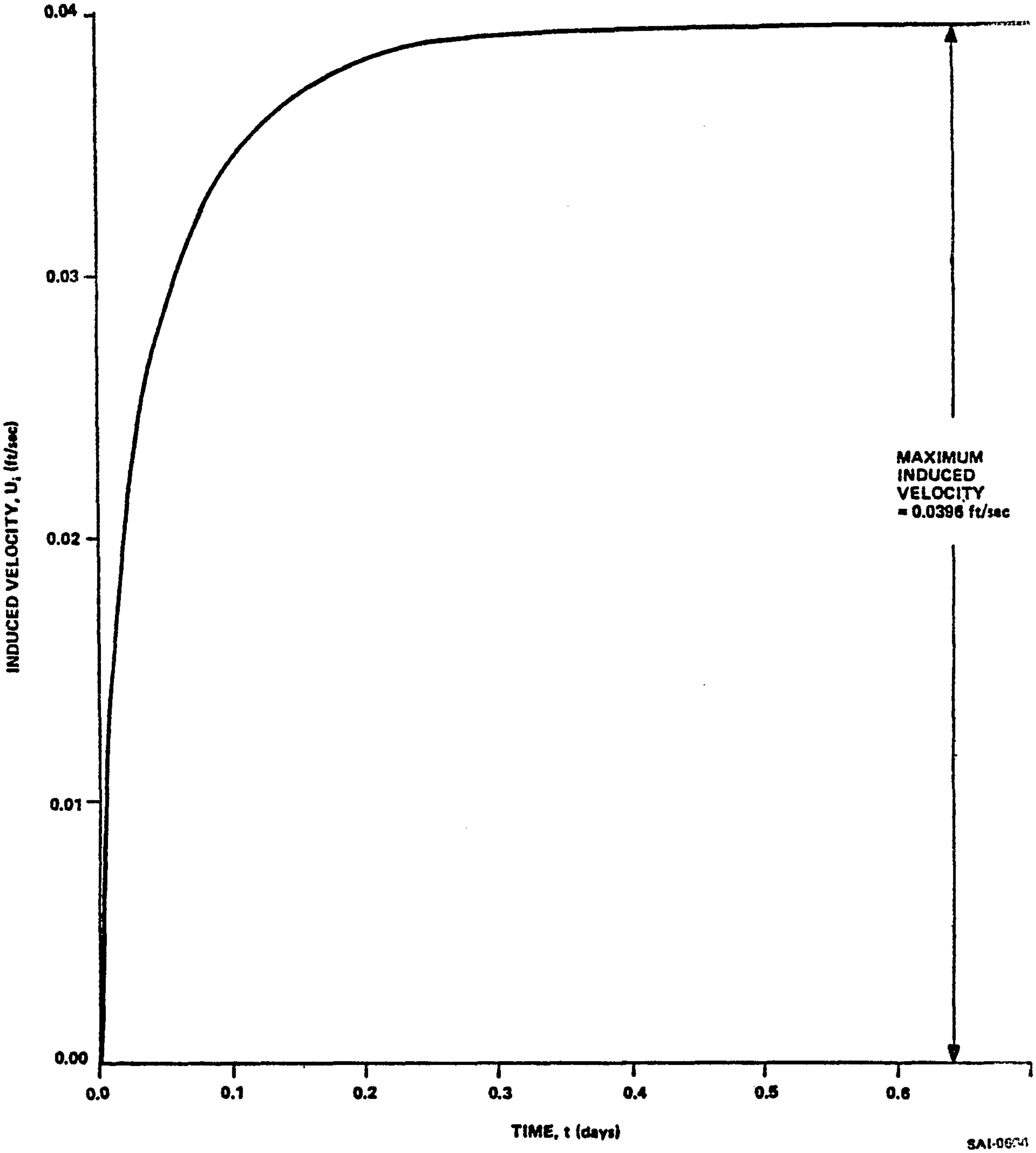

Figure 3.9 Variation of Induced Velocity in Alkali Ditch with Time

considerably greater than the height differentials previously noted for maintaining the necessary replenishment flow. This suggests that the flows in both Black Lake Bayou and Alkali Ditch are actually periodic, with the water level in Black Lake also fluctuating with the tidal cycle. Although no calculations have been carried out for this more complex case, the fact that the tidal range is so much greater than the required height differential still means that the present periodic variation of the water level in Black Lake will change very little due to the removal of the displacement water.

The water quality within Black Lake is clearly dependent upon the quality of the water entering from the two replenishment sources. Water quality data for the Calcasieu Ship Channel have been discussed in Section 2.2.1. No salinity data for the channel is available, but for Calcasieu Lake the salinity ranges from 0 to 26 ppt. Because the channel is the major passageway for salt water from the Gulf, salinity in the channel will generally be higher than in Calcasieu Lake.

Values of 20 ppt are quite likely in the vicinity of the mouth of Black Lake Bayou. Water quality data at Station 13 of the Intracoastal Waterway indicates that salinity in the Intracoastal Waterway is low (.17 ppt). It is important to note that the water sampling station on the waterway was located about 11 miles west of the river, so the salinity at the mouth of the ditch, which lies within the salt water intrusion zone, is likely to be higher (1-10 ppt).

A simple model has been constructed to predict the change in salinity in Black Lake resulting from the flow of water into the lake from either the Calcasieu Ship Channel or the Intracoastal Waterway (see Appendix F). Because of uncertainties associated with the actual salinity of the two sources, the change in salinity predicted by the model during the 150-day displacement process is best expressed in the form of a dimensionless ratio $(C-C_o)/C_i-C_o)$ where

C = Salinity of Black Lake as a function of time

C_o = Initial salinity of Black Lake

C_i = Salinity of replenishment source

The variation of the dimensionless ratio with time is shown in Figure 3.10. As indicated by the figure, after 150 days, the change in the salinity of Black Lake will be about 55 percent of the initial difference between the salinity of the replenishment source and the lake. If the initial salinity of Black Lake is assumed to be 5 ppt, the final concentration after 150 days becomes a simple linear function of the salinity of the replenishment source as shown in Figure 3.11 Thus, for example, if the replenishment water is fresh (<.25 ppt), the salinity of Black Lake would drop to 2.2 ppt after 150 days. On the other hand, if the replenishment source is saline, for example, 20 ppt, the salinity of the lake would increase to about 13.3 ppt after 150 days.

The preceding results are based upon using a constant salinity for the replenishment source combined with a constant flow rate into Black Lake. The actual salinities would vary during the displacement process, and the actual flow between Black Lake and the replenishment sources would be periodic due to tidal action, with the flow proceeding from Black Lake towards

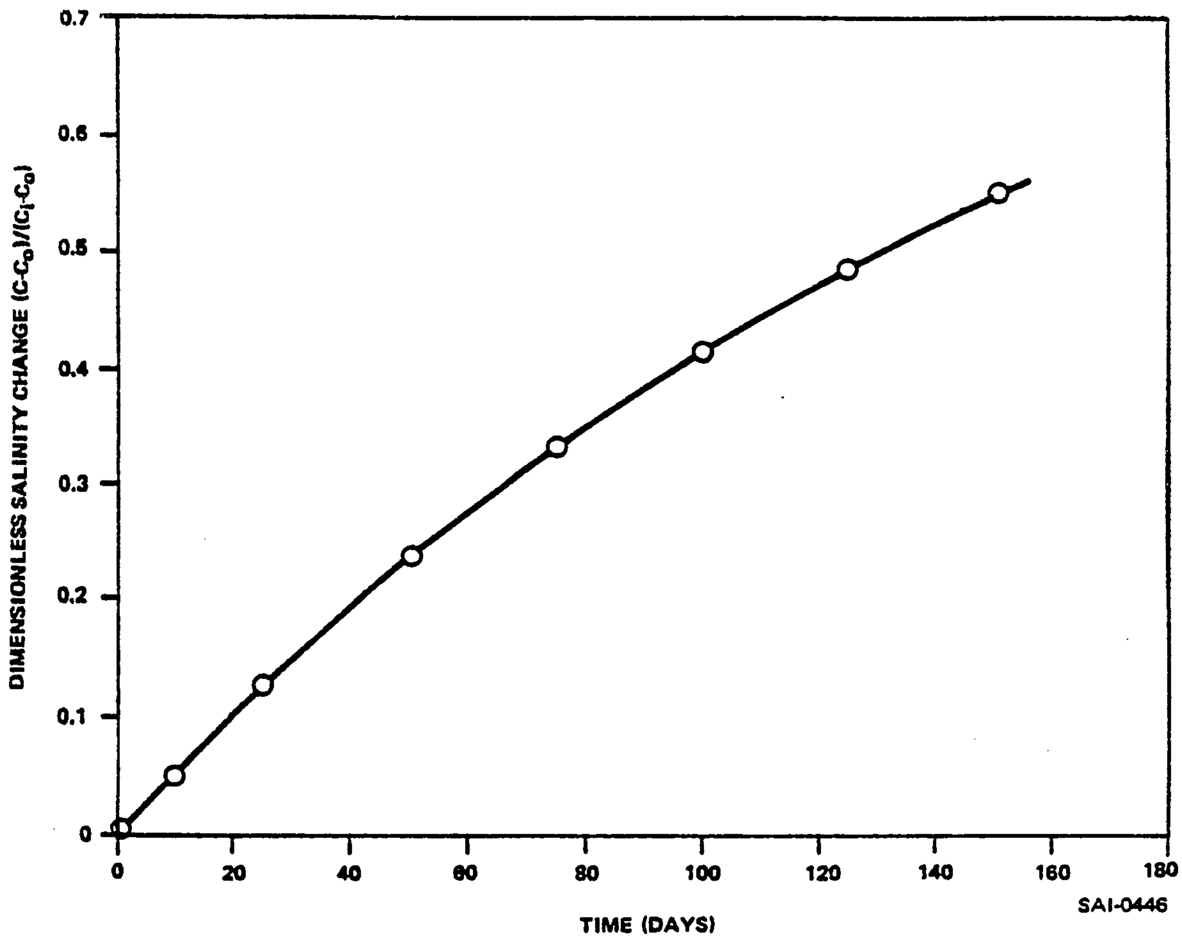

Figure 3.10 Variation of Salinity in Black Lake with Time

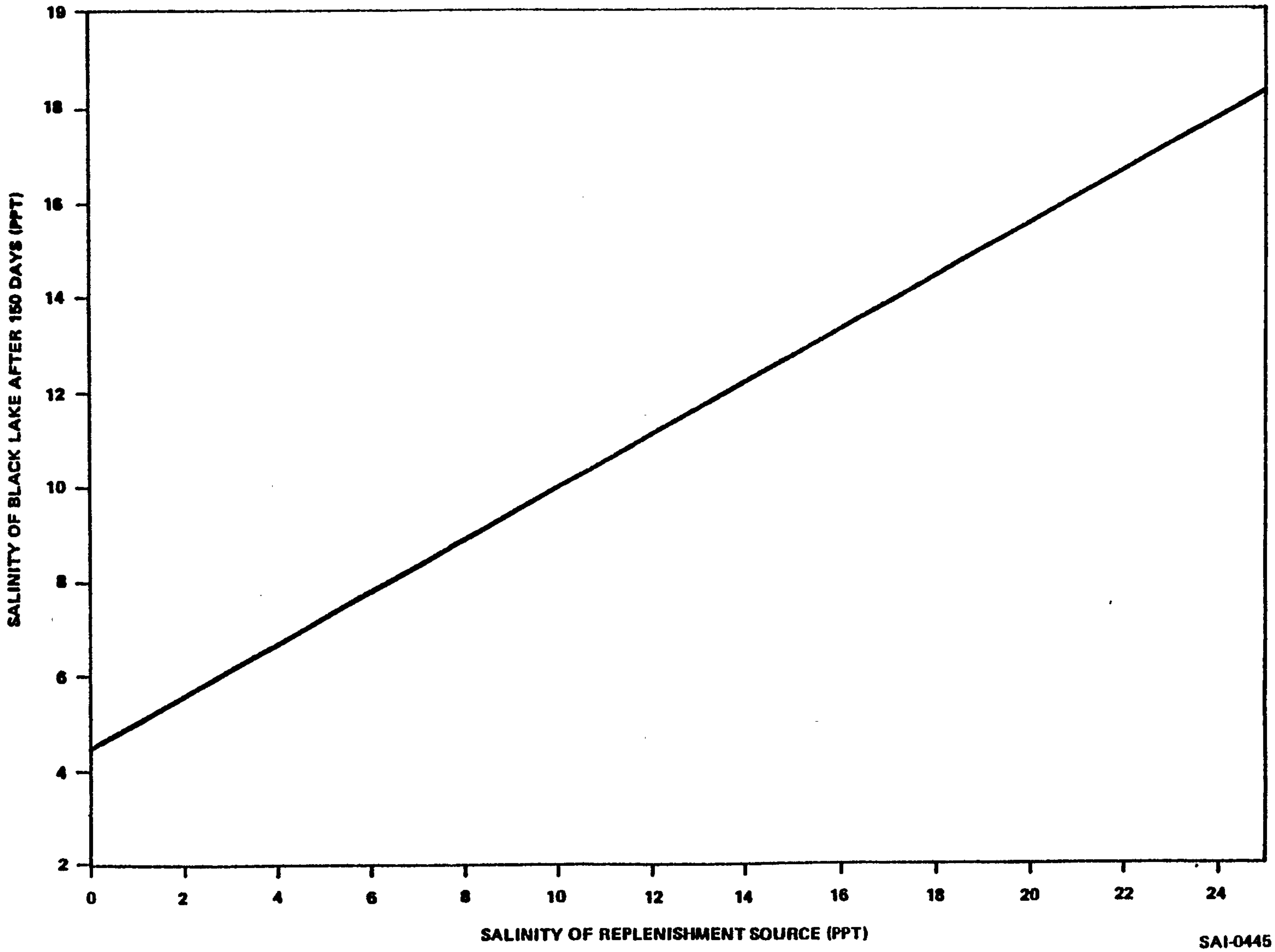

Figure 3.11 Final Salinity of Black Lake as a Function of Salinity of Replenishment Source

the replenishment sources at certain times. These effects would generally reduce the overall change in salinity in Black Lake during the displacement operation. It appears, however, that the salinity increase produced by flow from the Intracoastal Waterway would be less than that produced by flow from the Calcasieu Ship Channel.

Black Lake Bayou connects Black Lake with the Calcasieu Ship Channel, which lies along the western side of Calcasieu Lake. The presence of a spoil bank along the eastern side of the channel separates it to a large extent from Calcasieu Lake proper. Because the channel is relatively deep (about 40 feet) and connected directly to the Gulf of Mexico (to the south) as well as with the Calcasieu River (to the north), much of the water drawn into the Black Lake Bayou from the channel should be replaced by water either from the Gulf or from the river. Some fraction of this replacement water, however, will be drawn from Calcasieu Lake. This water in turn will be replaced by water either from the Gulf of Mexico or Calcasieu River. The worst case envisioned involves all of the water for a single displacement cycle being drawn ultimately from Calcasieu Lake and only water from the Gulf, replacing that drawn from the lake. As shown in Appendix F.2, the resulting increase in salinity of Calcasieu Lake would be about .33 ppt.

3.2.5 Brine Disposal

During the filling process at the West Hackberry site, 265 ppt brine will be displaced at a rate of 11,800 gpm for a period of 150 days.* Current design calls for the disposal of the brine by means of 12 brine-injection wells spaced 1,000 feet apart with each well capable of an injection rate of about 1,000 gpm. Injection depths would range from 2,000 to 8,000 feet.

The disposal of the brine from the displacement process at the West Hackberry site would involve 34,285 bbls/day per well. This injection rate is approximately 6 times the reinjection rates for the East Texas oil field.[18] The proposed injection rate is more than 3 times as great as the current maximum rate of 10.241 bbls/day/well achieved in Cameron Parish (at Cameron field).

* Current plans call for disposal of 10,800 gpm into deep wells, and supply of 1,000 gpm to Olin Chemical Company (see page 1-18)

Because of the scarcity of data, it is not possible to achieve a correlation of the sand beds between 2,000 and 8,000 feet. Thus, the thickness and lateral extent of these beds are not precisely known at this time. In order to carry out any analysis of the effect of brine injection on the deeper aquifers, conservative assumptions have been made, as discussed in Appendix D.7. Based on such assumptions, calculations of reservoir capacity and pressure buildup can be carried out in accordance with the basic equations governing the flow of slightly compressible fluids through porous media.[19]

The assumed characteristics of the individual reservoirs are summarized in Table 3.3. In Table 3.4, the assumed total dimensions of the entire disposal site are presented along with the resulting computed brine disposal capacity. The later figure, 1.06×10^9 barrels, is approximately 16-17 times the volume of brine to be injected during an individual filling cycle (60.7×10^6 barrels). Therefore, in terms of total capacity, the aquifer appears capable of holding the total volume of brine discharged during the lifetime of the facility (5 filling cycles). Pressure buildup during injection must also be taken into account. The variation of surface pressure and bottom hole pressure with time is presented in Table 3.5. As shown in these tables, after 5 months of injection, the bottom hole pressure would reach 3,259 psig, which is well below the fracture pressure of 4,500 psig. When the injection process stops at the end of the filling cycle, the pressure throughout the aquiferwould begin to equalize, causing a drop in the bottom hole pressure. After 1 day, the pressure would be essentially uniform throughout the reservoir with a value of 3,090 psig (Appendix D.7). Because the reservoir is probably not totally isolated from other aquifers in the area, as time progresses, the pressure will tend to return to its original value of 3,000 psig. In the worst case, the pressure would remain at 3,090 psig and this would represent the starting pressure for the second injection cycle. The pressure variation with time during the second cycle would be essentially identical to the first cycle except for the overall 90 psi increase, as shown in Cycle #2 in Table 3.5. As before, at the end of the injection process, the pressures throughout the reservoir would begin to equalize and after 1 day would be essentially uniform at 3,180 psig. This sequence of pressure variation

Table 3.3 Characteristics of Pliocene-Miocene Aquifers in the Vicinity of West Hackberry

Total Thickness of Disposal Sands	600 feet
Individual Reservoir Characteristics	
Diameter	31,680 feet
Depth	6,000 feet
Thickness	152 feet
Initial Pressure	3,000 psig
Normal Pressure Gradient	.5 psi/ft
Fracture Pressure Gradient	.75 psi/ft
Temperature	54° C (130° F)
Porosity	33%
Permeability	1.00 darcies
Well Conditions	
Diameter	10 inches
Surface Flow Rate	34,286 BPD
Maximum Surface Flowing Pressure	3,000 psig*
Fluid Properties	
Viscosity	.550 centipoises
Compressibility	10^{-5}/psi
Density	10.0 ppg

*This is the maximum allowable surface pressure. The actual surface pressure never exceeded 515 psig (Table 3.5)

Table 3.4 Brine Storage Capacity at West Hackberry

Length of Disposal Site	12 miles
Width of Disposal Site	6 miles
Area of Disposal Site	72 $miles^2$
Thickness of Disposal Sands	600 feet
Gross Volume of Disposal Sands	1.2×10^{12} ft^3
Net Volume of Disposal Sands	70.6×10^9 bbls
Average Pressure Increase	1500 psi
Brine Disposal Capacity	1.06×10^9 bbls

Table 3..5 Reservoir Pressure Build-Up History at West Hackberry

	Month	Surface Pressure (psig)	Bottom Hole Pressure (psig)
a. Cycle #1			
	0	0	3000
	1	81	3184
	3	125	3229
	4	140	3244
	5	155	3259
	5 (+ 1 day)	90	3090
b. Cycle #2			
	0	90	3090
	1	171	3274
	3	215	3319
	4	230	3334
	5	245	3349
	5 (+ 1 day)	180	3180
c. Cycle #3			
	0	180	3180
	1	261	3364
	3	305	3409
	4	320	3424
	5	335	3439
	5 (+ 1 day)	270	3270
d. Cycle #4			
	0	270	3270
	1	351	3454
	3	395	3499
	4	410	3514
	5	425	3529
	5 (+ 1 day)	360	3360
e. Cycle #5			
	0	360	3360
	1	441	3544
	3	485	3589
	4	500	3604
	5	515	3619
	5 (+ day)	450	3450

would be repeated for each of the remaining cycles #3, 4, and 5 as shown in the table. At the end of the fifth month of the fifth cycle, the bottom hole pressure would reach a maximum value of 3,619 psig, well below the fracture pressure of 4,500 psig. This pressure would drop down to a final value of 3,450 psig after 1 day.

The preceding computations are based on certain additional assumptions. First, no deposit of slightly insoluble material in the brine is present to clog up the porous formations about the well bottoms. (The brine settling tank may eliminate this problem.) It is also assumed that no biological growth will render the porous sands impermeable.

The assumptions noted were necessary because of the current lack of data to permit more detailed computations. Such computations cannot be performed until complete chemical and biological analyses have been conducted on the brine to be injected and also on the water within the aquifer. Such analyses are necessary because of 3 potential problem areas:

(1) Incompatibility of waters

(2) Water-sensitive formations

(3) Water quality considerations

With respect to incompatibility of waters, Ostroff[20] notes "Waters that are compatible can be mixed without producing any undesirable chemical reactions between components dissolved in the individual waters. Undesirable reactions are those that produce insoluble products such as calcium and carbonate ions, forming barium sulfate. Insoluble products produced from these reactions can decrease flow in lines, plug injection wells, or reduce permeability."

Potential problems with water compatibility exist at several different points in the brine disposal problem.[21,22] Of primary concern in the current case is the compatibility of the brine to be injected with the waters of the aquifer where injection is to occur. When brine is injected into a resevoir containing waters incompatible with the brine, deposits will form only where the brine and resevoir water make contact and mix. Deposits will form only in a small volume of water if there is a small degree of mixing, but deposits will form in a large volume of water if a large degree of mixing occurs.

The problem of water-sensitive formations has been considered by a number of investigators.[20,21,23] Certain types of rocks are susceptible to permeability damage when infiltrated by fresh or slightly saline water. Damage of this type is related to rock properties and is caused by swelling of indigenous clays and the dispersion of indigenous nonswelling particles during fluid flow.

The swelling (hydration) of clays is a function of the salinity of the water being injected. Clays which are prone to swell are more sensitive to fresh water than saline water with a minimum salinity of 20 to 50 ppt. Because the brine salinity will be considerably above this level, clay swelling appears unlikely.

The third problem concerning water quality in general is clearly related to the 2 already discussed. As noted by Ostroff[20], "Water quality includes the amount of suspended solids in the water, number of bacteria present, and the corrosivity of the water. All of these solids could plug the pore spaces in the formation or build up an impermeable filter cake on the face of the reservoir rock that would impede water injection. Bacteria may contribute to corrosion and corrosion products, resulting in plugging of the injection well. Bacterial growths themselves can sometimes result in plugging. Corrosive water not only damages the system but may produce corrosion products which can plug the well. A common example of this is iron sulfide formed from corrosion by hydrogen sulfide."

"The character of the reservoir rock largely influences the quality of water than can be injected. A reservoir rock with small pore sizes and low porosity requires water of very low suspended solids or high-quality water. Conversely, a high-porosity reservoir having large pores and voids would take water containing a considerable amount of suspended solids."

For evaluating water quality for injection purposes a rating system has been devised[24] as shown in Table 3.6. At the present time, no results from these types of tests are available for water samples from the West Hackberry site.

A major water quality problem is concerned with suspended solids. "Suspended solids carried by water may be sand grains from the water-sand, corrosion products such as iron sulfide

Table 3.6

WATER QUALITY RATING CHART

	Rating					
	1	2	3	5	10	20
Membrane filter test (0.45 μ filter) slope	0-0.09 excellent	0.10-0.29 very good	0.30-0.49 good	0.50-0.99 acceptable	1.00-1.79 fair	1.80+ excessive
Filtered solids mg liter	0.-0.04 negligible	0.5-0.9 very low	1.0-2.4 low	2.5-4.9 moderate	5.0-9.9 large	10.0+ excessive
Tot. sulfide increases lb day 1,000 sq ft	0 none	0.001 very low	0.002-4 low	0.005-9 moderate	0.01-0.019 large	0.02+ excessive
Iron count increases lb day 1,000 sq ft	0 none	0.001-0.011 very low	0.012-0.11 low	0.12-0.59 moderate	0.60-1.1 large	1.2+ excessive
Sulfate-reducing bac- teria colonies ml	0 none	1-5 very low	6-9 low	10-20 moderate	30-90 large	100+ excessive
Total bacteria count colonies ml	0 none	1-99 very low	100-999 low	1,000-9,999 moderate	10,000-99,999 large	100,000+ excessive
Corrosion rate (30 days) (insulated coupon) mils year	0 none	0.01-0.09 very low	0.10-0.99 low	1.00-4.9 moderate	5.0-9.9 high	10.0+ excessive
Pit depth (30 days) (insulated coupon) mils	0 none	1 shallow	2-3 minor	4-5 moderate	6-10 deep	10+ excessive
Pit frequency (30 days) (insulated coupon) pits sq in	0 none	1 very low	2 low	3 moderate	4 high	5+ excessive

or iron oxide, free sulfur, or bacterial growths. If allowed to enter the injection wells, these materials will either plug the wells completely or cause increases in injection pressures These materials are often present in water in a finely divided state and in amounts small enough so that their presence is not easily detected by looking at the water. Yet, when large volumes of water are injected, even small amounts of suspended solids can form an appreciable filter cake or deposit in an injection well bore."[20]

A second water quality problem arises from the corrosive qualities of the water. The brine to be injected should not be corrosive to the metals used in the disposal system. Such corrosion would not only be destructive to the disposal equipment but might also produce corrosion products that would plug the injection well.

A third major water quality problem results from the presence of bacteria.[20,25] "The number and type of bacteria present in injection water affect the quality of the water. Bacteria can contribute to corrosion or produce plugging. Desulfovibrio or sulfate-reducing bacteria utilize oxygen in sulfate ions to oxidize organic compounds. Corrosive hydrogen sulfide is produced in the process. Increases in sulfide content of water within the water-handling system are caused by sulfate reducers. Desulfovibrio are nearly always present, but, when conditions are not right for their growth, they are not a serious problem."

"The total bacterial count is indicative of the number of all varieties of bacteria in the water. Large growths of bacteria can result in colonies of the microorganisms plugging the injection well or otherwise fouling equipment."[20]

It is important to note that plugging problems have been encountered in brine disposal operations at West Hackberry in the past. These problems were associated with the <u>reinjection</u> of brine which originally came from aquifers in the West Hackberry area. The type of plugging experienced and the methods used to eliminate it in that situation are not necessarily applicable to the brine <u>injection</u> process under consideration. For the current process the brine will be produced by passing water from Black Lake through the West Hackberry salt dome. The chemical composition of such brine is very likely quite different from the brine involved in the reinjection process. Additional discussion of the potential problems resulting from chemical and biological reactions occurring during injection is provided in Appendix D.7.

The injection process would increase the salinity of the aquifers involved to a small degree. Salinity in these aquifers is estimated to range from 10-35 ppt.[26] The injection of 309×10^6 bbls of brine with a salinity of 265 ppt would cause an increase of approximately 1 ppt over the present level. This increase appears insignificant.

Brine injection could cause pollution of shallow fresh ground water if abandoned wells at West Hackberry permit flow between these shallow aquifers and the brine injection zone. This could occur if the old well casings are corroded and are therefore open in both the fresh water aquifers and brine injection zones.

Oil and gas maps of the Louisiana Department of Conservation show that approximately 30 wells (mostly abandoned) exist in an area 1 mile on either side (north and south) of the proposed east-west line of brine disposal wells.

The worst case assumption is that 10 of these wells, each 1,000 feet from the line of disposal wells, were inadequately plugged and operate as open pipes connecting the Chicot sands and the brine disposal resevoirs. According to the Theis nonequibilrium formula, the maximum total discharge of these wells should be less than 50 gal/min into the Chicot sands immediately after the pressure buildup from 5 brine injection cycles. This rate of saline water intrusion should not significantly affect future water supply development from Chicot Aquifer because naturally occurring saline water in the base of the Chicot Aquifer in this region is a much more serious water quality problem.

Brine disposal at West Hackberry is not expected to adversely affect existing oil and gas production. Those areas with the greatest density of producing wells are generally a mile or more from the proposed line of disposal wells. It is possible that pressure buildup in the disposal sands would be accompanied by slight pressure increases in oil and gas strata. This could benefit hydrocarbon production by reducing the effect of pressure loss due to oil and gas depletion.

The proposed zone of brine injection, from 2,000 to 8,000 feet, overlap the oil and gas producing interval (4,000-12,000 feet). Louisiana rules and regulations prevent brine injection into oil and gas reservoirs except when prescribed procedures are followed. In such cases, the brine serves as a water drive for the reservoir. In general, disposal wells must be designed to avoid inadvertant injection into oil and gas sands unless prior clearance is obtained. (See Appendix D.7)

Based on available data, combined with the assumptions noted in the preceding paragraphs, the Pliocene-Miocene aquifers appear capable of containing the brine discharged during the lifetime of the facility without risk of fracture, and without significantly altering the current environment in the aquifers. The question of well plugging or clogging cannot be rigorously answered until the necessary chemical and biological analyses have been completed.

3.3 AIR QUALITY AND NOISE

3.3.1 Construction of Dome Facilities

Prior to the operational phase of the program, construction would take place for about one year at the site and for about 30 months at the tanker terminal.

The quality of the air near the West Hackberry site would be slightly affected during site preparation and construction. The sources of emissions in general will be short-lived and transient in nature. It is anticipated that the emissions will be less than in oil and gas field explorations because the drilling operation will involve geological formations where there are no pockets of oil or gas.

Prior to site preparation and construction, plans and specifications for the proposed facility must be submitted to the Louisiana Air Control Commission[27], and all sources of potential emissions and estimates of quantity must be listed.

Emissions due to construction machines, paint, and oil transfer will degrade the air with dust, CO, SO_2, NO_2, HC, H_2S, and particulates. An estimate of the emissions may be made based upon assumptions concerning number and types of sources. The impact of these emissions depends on ambient air quality and the dispersal characteristics of the atmosphere. Ambient air quality has been discussed in Chapter 2. Atmospheric dispersion calculations are based on methods recommended by the Environmental Protection Agency[28] and averaged over appropriate time intervals as outlined in Appendix A.

General Construction Vehicles and Drill Rig Equipment

During the site preparation phase, there would be tree clearing operations, land fill, and road construction. This phase would last several months. A number of machines and heavy vehicles would be used. The gas and diesel engines would emit: Hydrocarbons, SO_2, CO, NO_x, aldehydes, and particulates.

The prediction of quantities of pollutants is difficult because it depends upon many factors including: number of vehicles, type of vehicles, model year, duty cycle, speed, cold operation fraction, and ambient temperature. Average emission levels for light- and heavy-duty, gasoline and diesel vehicles are shown in Table 3.7.

Drill rig equipment include two caterpillar D-353-TA diesel engines rated at 750 continuous horsepower each, two GMC 6-71 twin engines rated at 500 continuous horsepower each, and other smaller engines. These motors are considered to total 3,000 horsepower and to be heavy-duty diesels of miscellaneous construction type. The pollutant yield is listed in Table 3.8.

The on-site vehicle sources are assumed to be 10 heavy-duty gasoline vehicles plus 10 heavy-duty diesel vehicles with a conservative duty factor of 2,000 hours/year[29] and speed of 10 miles (58.2 meters) per hour. The emission data are given in Table 3.9. In addition, the drill rig equipment would require about 1,500 horsepower of diesel industrial equipment for about 7,000 hours/year, as shown in Table 3.9. It is apparent that the estimated vehicles emissions are much smaller than the drill rig equipment emissions.

The pollutant concentrations for the drill rig equipment are shown in Table 3.10. Note that all primary standards are met except for the hydrocarbon concentration at 0.5 km. Recalculation for a distributed source rather than a point source shows that the standard will not be exceeded at this distance.

The concentration levels shown in Table 3.10 do not include ambient levels due to sources outside the project. Data is not available describing ambient levels at the site but is assumed to be similar to ambient levels in industrialized Lake Charles and Westlake which are given in Chapter 2 for suspended particulates (60-65 μgm^3 annual average, 120-150 $\mu gm/m^3$ 24 hour maximum), SO_2 (5 $\mu gm/m^3$ annual average, 27 $\mu gm/m^3$ 24 hour maximum), and NO_2 (60 $\mu gm/m^3$ annual average). It is conservative to apply the Lake Charles and Westlake

Table 3.7. Average Emission Factors for Vehicles

Pollutant	Gasoline Light Duty 1970 gm/mi	Gasoline Heavy Duty 1970 gm/mi	Diesel Light Duty Pre-1973 gm/mi	Diesel Heavy Duty Pre-1973 gm/mi
CO	33.2	188.	1.7	28.7
HC	4.8	13.8	0.46	4.6
NO_x as NO_2	5.2	12.6	1.6	20.9
Particulate	.54	1.3	0.73	1.3
SO_x as SO_2	.18	.36	0.54	2.8

NOTE: Low speed operation may increase emission levels by a factor of 2 to 4.

SOURCE: Compilation of Air Pollutant Emission Factors. Second Edition, Supplement No. 5, U.S. Environmental Protection Agency, Dec. 1975.

Table 3.8. Pollutant Yield From Drill Rig Equipment (3000 hp, 50% duty factor)

Pollutant	gm/sec
CO	2.35
HC	.867
NO_X and NO_2	12.3
SO_X as SO_2	.777
Particulate	.752

SOURCE: Compilation of Air Pollutant Emission Factors, Second Edition, U.S. Environmental Protection Agency, March 1975.

Table 3.9 Vehicle and Drilling Rig Equipment Emission Sources During Construction

	Construction* Vehicles gm/sec	Drilling Rig** gm/sec
CO	0.138	0.979
HC	0.0117	0.389
NO_2	0.0211	5.14
SO_2	0.0020	0.324
Particulate	0.0019	0.313

*Assumes 10 heavy duty gasoline and 10 heavy duty diesel vehicles, operating 2000 hours/year.

**Assumes 3000 horsepower diesel-powered industrial equipment operating at 50 percent load, 20 hour/day.

Table 3.10. Pollutant Concentrations for Drill Rig Equipment

Pollutant	Federal and State Primary Standards ugm/m^3		Calculated Downwind Concentrated - ugm/m^3 .5km	1km	2km	5km
CO	8 hr max	10,000	535	176	45	16
	1 hr max	40,000	760	250	64	22
HC	3 hr max	160	249*	83	28	8
NO_2	Annual Mean	100	52.	15	4.7	1.0
SO_2	Annual Mean	80	3.3	.95	.29	.07
	24 hr max	365	150	50.	17.	5.
Particulates	Annual Mean	75	3.2	.92	.28	.06
	24 hr max	260	145	48.	16.	4.

*Standard exceed due to the point source assumption.

ambient levels to the rural West Hackberry site. If this is done, primary standards are not exceeded at 1 kilometer or more. The standards would not be exceeded at 0.5 kilometers if an area source assumption is used instead of a point source assumption.

The impact of the drill rigs on air quality is expected to last 1 year. Work during this period of time would include new wells drilled into existing caverns and approximately 2 new brine disposal wells.

The source strength of emissions from construction vehicles is also listed in Table 3.9. The intensities are negligible compared to the drill rig sources.

Paint Solvent on Storage and Surge Tanks

There would be 6 tanks located near the docks; 2 are 400 MB surge tanks; 2 are 100 MB ballast holding tanks; and 2 are 15 MB tanks for emulsion treatment and slops. There would be 2 10-MB brine surge tanks located at the site; and 2, 1,000 barrel oil and brine surge tanks located at the temporary dock on Alkali Ditch.

These tanks would probably be spray painted with solvent-based paints. Guideline No. 4 of the Louisiana Regulations[1] states that the solvent must not contain more than 20 percent of its volume of photochemically reactive material or the painting operation is subject to requirements of Section 22.9 and A22.9 of those regulations. The quantity of paint required depends on several variables. Here, it is assumed that 1 gallon will cover 100 square feet (the average of 2 estimates), 1 gallon will weigh 15 pounds (the range is 10 to 15 pounds (4.5 to 6.8 kg) per gallon), and that half the weight is solvent (50 to 55 percent is normal).

The 6 tanks at the dock have a total of about 270,000 square feet (0.248 sq km) of external surface area. The 2 tanks at the site have 14,600 square feet (1,322.3 sq m) and, the 2 tanks at the Alkali Ditch have 8,000 square feet (734.6 sq m). Therefore, 1 coat of paint would release into the atmosphere 20,000 pounds (9,080 kg) of solvent at the dock, 1,100 pounds (499.4 kg) at the site, and 600 pounds (272.4 kg) at the Ditch. The emission rate depends upon the time required for painting. It is assumed that the 6 tanks at the dock would be painted in 90 days, and the other tanks would require proportionately less time. The source strength at the dock would average 1.17 gm/sec., or 3 times the intensity of the drill rig HC source in Table 3.9. Therefore, the HC concentration would be triple that shown in Table 3.10. The centerline concentration would exceed primary standards out to nearly 2 km on a stable day; even if ambient levels were zero. The use of abrasives during surface preparation will result in small levels of particulate emissions. The impact of these emissions on ambient air quality is expected to be minimal.

Fugitive Dust

Dust emissions would result from construction activities at the site. The dust would be associated with land clearing, blasting, excavation, cut and fill operations, and construction. The amount of dust would vary from day to day depending on activity and the weather. A large portion of the dust is due to equipment traffic over temporary roads.

Field measurements at apartment and shopping center construction sites yield an estimate of 1,2 tons (1,089.6 kg) of dust per acre of construction per month of activity. This estimate is high for the West Hackberry site because it is intended for a semiarid climate. Dust emission is inversely proportional to the square of ground moisture, and ground moisture is twice the semiarid level in Louisiana.[30] Therefore, the dust emission during construction at West Hackberry is estimated to be 0.3 tons (272.4 kg) of dust per acre of construction per month of activity. This amount of dust would cause no serious air quality problem in the area. Present ambient dust levels are unknown, but are estimated to be low due to high ground moisture levels.

Oil Transport During Construction

The temporary dock at the Alkali Ditch would be used for oil transport during construction. The surge tank working loss is estimated to be 588 pounds per day on a worst case basis, or 3.1 gm/sec. The HC concentration levels would be 8 times higher than those shown in Table 3.10 for the 10-month loading period during construction. The centerline concentration would exceed primary standards out to 3 km on a stable day, even if the ambient levels were zero. The ambient levels at the dock location are unknown.

3.3.2 Operation of the Dome Facility

During the operational phase of the facility, air quality would be impacted by hydrocarbon emissions from valves, pump seals, gauges, surge tanks and vessel loading and unloading because of crude oil handling. In addition, an insignificant amount of combustion emissions from vehicular traffic would occur.

Valves, Pump Seals, and Gauges

There would be a wide variety of valves, seals, and gauges associated with the pumping of crude oil through the pipelines between the dock facility and the individual cavities. Pipe flanges may be ignored because they are insignificant leakage sources. Valves may be classified in 2 categories: flow control or pressure relief valves. Several types (gate, globe, angle, plug, etc.) exist in each category. A study of refineries in Los Angeles County showed that the leakage of flow control valves in liquid service averaged 0.108 pounds (49 gms) per day per valve. The upper limit for 1 refinery was 3 times higher or 0.32 pounds (145 gms) per day per valve. The average leakage of hydrocarbons from pressure relief valves was 2.9 pounds (1,396 gms) per day per valve for all refineries. The maximum average for an individual refinery was about 3 times higher, or 9.0 pounds (4,131 gms) per day per valve. [31]

Pump leakage generally occurs through seals, which may be either of a mechanical or a packed type. A study[31] found that centrifugal pumps with mechanical seals lose about 0.6 pound (272 gms) per day while those with packed seals average 5.9 pounds (2,779 gms) per day. Reciprocating pumps with packed seals lose about 4.0 pounds (1,816 gms) per day. An upper limit on average leakage of 6 pounds (2,724 gms) per day per pump will be assumed. A fraction of this leakage would evaporate into the atmosphere.

The leakage rate of gauges is not known. In the absence of pertinent data, the average leakage rate of flow control valves is assigned to gauges and other instrumentation.

Site schematics show 19 oil valves, 20 pressure indicators, and about 20 other gauges at the site. Assuming that 15 valves are flow control and 4 are for pressure relief, the upper limit on leakage should be:

15 x 0.32	flow control valves
4 x 9.1	pressure relief valves
40 x 0.108	gauges
8 x 6.0	pumps
94 pounds per day or 0.49 gm/sec	

Most of this leakage would be collected but some, perhaps 10 pounds per day or .053 gm/sec, would enter the atmosphere. This quantity of hydrocarbon emissions is considered negligible. A maximum of 3.8 percent of the emission could be hydrogen sulphide if sour crude is being transferred.

Crude Oil Storage Tanks

A temporary oil surge tank would be located at the Alkali Ditch dock. The capacity is 1,000 barrels. Assuming this tank would be of fixed roof construction in order to get "worst case" conditions, the daily breathing loss due to thermal expansion and contraction, barometric pressure change, and added vaporization would be 6.3 pounds (0.03 gm/sec) per day. Working loss is the exhaust of vapor while filling and emptying. A conservative estimate for a surge tank might be 10 percent of what the working loss would be with the tank filled and emptied completely for each 1,000 barrels processed. This assumption leads to an estimate of 588 pounds per day or 3.09 gm/sec.

Two floating roof surge tanks with capacities of 400,000 barrels are located at the permanent dock. These tanks would not suffer breathing loss or working loss, but would have a standing storage loss due to the space between the seal and shoe of the tank. Collected data estimates this loss at 500 pounds per day or 2.63 gm/sec, each.[29] Other tanks would have smaller losses. This rate is equivalent to 5.25 gm/sec. The 3-hour maximum concentration is 378 $\mu gm/m^3$ at 2 km and 108 $\mu gm/m^3$ at 5 km. A maximum of 3.8 percent of the hydrocarbon emissions may be hydrogen sulfide depending on source and treatment. Floating roof storage/surge tanks are specified for the West Hackberry site, and are considered by EPA to be the best available control technology.

Vessel Loading and Unloading

Hydrocarbon vapors will be emitted during the tanker or barge loading and unloading of crude oil. During loading, the hydrocarbon vapors will be forcibly expelled into the atmosphere unless it is collected by a vapor recovery system. Vapors generated during unloading will be partially vented to the atmosphere as ballast water is taken in. Estimates* of these losses are 0.94 pounds per thousand gallons unloaded and 1.07 pounds per thousand gallons loaded.[29] Calculations for worst case weather conditions* of very stable atmospheric conditions and a low wind speed occurring about 9.2 percent at Lake Charles indicate that the extent of hydrocarbon vapor plume downwind from vessels would exceed the Federal 3-hour standard of 160 micrograms per cubic meter for considerable distances.

Tanker unloading operations would provide a plume greater than 30 miles long and about a mile wide within which hydrocarbon concentrations are above the Federal standard. If two tankers are unloading concurrently, the extent of such a plume could be more than 45 miles. Loading operations during the 150-day drawdown period under these atmospheric conditions would result in plumes as wide as one and a half miles and up to 45 miles long. The plume from barge unloading at the Alkali Ditch would be about 6 miles long and 2/10 mile wide, within which the Federal standard is exceeded. Crude oil emissions are not currently regulated in the State of Louisiana.

During initial fill operations at the Alkali Ditch barge dock and the Calcasieu shipping channel tanker dock, emission rates are estimated to be 8,286 pounds per day (43.5 grams per second) for each tanker unloading and 781 pounds per day (4.1 grams per second) for each 5,000 barrel barge unloading at Alkali Ditch. During the 150 day drawdown period, emission rates from tankers loading at the Calcasieu Dock are estimated to be as high as 20,953 pounds per day (110 grams per second).

Electric Power Generation

Electricity for facility operations would be supplied by the local utility. Should the utility be unable to provide this power due to an unforeseen contingency, electric power would be generated on site. The amount of power required is uncertain at this time. The oil injection pumps and brine injection pumps would require about 30 KW at full load. Other requirements may bring the total up to 50 KW or 67 horsepower. Allowing for generator efficiency, it appears that 1,300 horsepower diesel unit would be adequate. It may be advantageous to divide the Ioad into several units totaling 300 horsepower to minimize power line length.

The pollution source strengths would be about 1/10 the intensity listed in Table 3.8 for drill rig equipment.

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*Estimates are based on crude properties of: Reid vapor pressure 3 psia, 27^{o} API (7.43 lb/gal), and annual temperature of 68^{o}F.

Fugitive Dust

Dust emissions during facility operation would be due to vehicle travel over unpaved roads for the most part. Assuming an average vehicle speed of 40 mph and a road surface silt content of 30 percent, the estimated dust emission is 0.05 pounds (22.7 grams) per mile of vehicle travel.[30]

3.3.3 Current Regulations

The Louisiana State Implementation Plan (SIP), revised in 1972, had exempted from regulation the hydrocarbon emission from crude oil storage and handling. At that time, the SIP had not been developed to detail projected levels of air quality by region but predicted that all primary standards would be met by 1976. However, because of the high 1 hour photochemical oxidant levels which have been tabulated from 1975 data, the EPA has disapproved the control strategy for attainment and maintenance of the national primary and secondary air quality standards for photochemical oxidants in the Southern Louisiana - Southeast Texas AQCR.*

The State has been ordered to prepare and submit by July 1, 1977, a revision containing:

a. All achievable emission limitations that are needed to provide for the attainment of the national standard for photochemical oxidants, and

b. A demonstration of the effect on air quality concentrations of such measures.

If additional control measures such as land use and transportation measures are needed for attainment of the national standard, the State will submit by July 1, 1978:

a. Such measures for attainment of the standard for photochemical oxidants, and

b. A demonstration that the control strategy will attain the standard for photochemical oxidants.

The foregoing revision requirements are currently under review by the Louisiana Air Control Commission; a hearing will be held in March of 1977 to provide its response to the new requirements.

*41 Federal Register, No. 138, July 16, 1976.

As a result of the current status of the Louisiana SIP, neither vapor emissions from crude oil storage nor those from crude oil transfer operations are regulated at this time. Although it is impossible to predict with certainty if any control measures will be required when the final EPA-approved SIP is promulgated, it is possible to gain an insight into the probable approach which may be taken toward crude oil storage and transfer operations by examining the recently proposed EPA revision to the Texas SIP for the Houston-Galveston AQCR.*

Like Louisiana, the Texas SIP is currently in a state of disapproval because of the inability to meet the primary standard for photochemical oxidant. Furthermore, parts of the Houston-Galveston AQCR have experienced much more severe violations of the one hour standard (both with regard to level and duration) than have been experienced generally in the Southern Louisiana-Southeast Texas AQCR. The new proposal would require controls for previously exempt emissions from crude oil storage tanks. Floating roof tanks are considered by EPA to be the best available control technology. However, regulation of emissions resulting from vessel loading and unloading of crude oil was not specified in the proposed SIP revision.

Another requirement for SIPs to meet the National Ambient Air Quality Standards (NAAQS) is new source review. The most recent ruling from EPA regarding new source review has established the tradeoff system.** Under this proposed provision, new sources would be required to show that emissions proposed 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 AQCRs. The effects, if any, of this ruling on the SPR program remain uncertain at this time.

3.3.4 Noise Impacts

Construction activity associated with the conversion of the existing space at West Hackberry and ancillary facilities may cause some noise impacts for residential, recreational farming, and other land use areas in the Hackberry and West Hackberry areas. The construction is planned to take place over a period of approximately 17 months and will occur at the following locations (see Figure 3.12).

* "Proposed EPA Revision to the Texas State Implementation Plan", Environmental Reporter, Current Developments, Volume 7, Number 29, November 19, 1976, pp. 1065-1083.

** "EPA Draft Preamble to Interpretive Ruling on New Source Review Requirements", Environmental Reporter, Current Developments, Volume 7, Number 29, November 19, 1976, pp. 1091-1094.

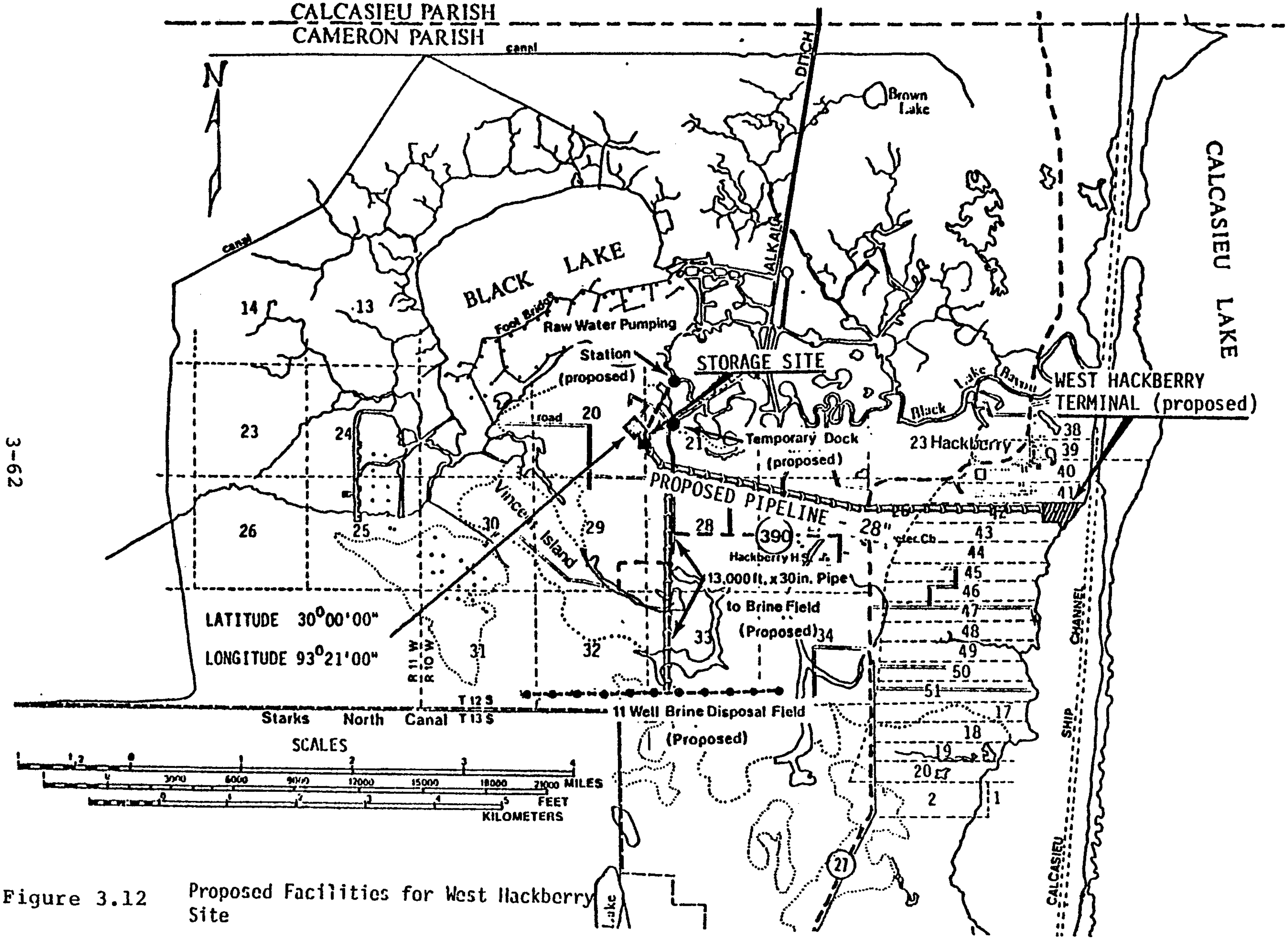

Figure 3.12 Proposed Facilities for West Hackberry Site

Storage Site Area

Contributing noise sources at the storage site area during site preparation would be air compressors, trucks, diesel engines, pumps, drilling rigs, impact equipment, concrete mixers, and general construction related equipment. Noise levels typical of this equipment are given in Table 3.11. An evaluation of the construction noise sources indicates that diesel engines would provide the most consistent source of noise and that impact and drilling equipment would create the peak sound levels. The areas adjacent to the storage site are mostly marshlands and are sparsely populated. The nearest residence (J. C. Ellender residence) is believed to be approximately 2,000 feet from the center of the site.

During operations at the storage facility, the primary noise generation would be from pumps associated with fill and discharge operations. Early fill operation (20,000 barrels per day) would commence during the construction period and would continue for 10 months. During this period, a temporary injection system would pump oil into caverns No. 9 or 11. Barges would be in operation at the temporary barge dock on the Alkali Canal. The diesel engines and pumps associated with this operation would be a contributing source to the overall construction noise at the site.

After completion of the docking facilities on the Calcasieu Shipping Channel, fill operation would require the operation of 8 oil injection pumps with 1,250 horsepower motors and 8 brine disposal pumps with 1,500 horsepower motors. These pumps together with other lower horsepower pumps which would be used for oil discharge operations, would be sheltered in a pumphouse at the storage facility. Although noise levels within the pump house could be expected to exceed 90 dBA, typical pump house construction should reduce exterior noise from this source to less than 70 dBA at 50 feet from the structure.

Additional noise at and near the storage facility would be caused by the increased vehicle traffic due from maintenance and operating personnel. Present plans provide for the utilization of 34 personnel during fill and discharge operations and 12 personnel during standby operation. It is estimated that noise from all sources associated with fill/discharge operations would increase the noise levels 3 dB at the site perimeter.

Table 3.11. Construction Equipment Noise Levels

Equipment	A-weighted sound level at 50 feet
Air Compressor	81
Backhoe	85
Concrete Mixer	85
Crane Mobile	83
Dozer	87
Generator	78
Grader	85
Pile Driver	101
Pump	76
Rock drill	98
Truck	88

SOURCE: "Noise Emission Standards for Construction Equipment Background Document for Portable Air Compressors," U.S. Environmental Protection Agency, EPA 550/9 - 76 - 004.

Based upon the existing land use and the remoteness of the site from residential and other noise sensitive use areas, it is not anticipated that noise from storage facility operations will interfere with either outdoor or indoor activities near the storage area.

Pipeline Corridors

Two pipeline systems will be built in the West Hackberry area. One of approximately 2 miles length will extend directly south from the storage site to the brine disposal area; the other will extend east approximately 4 miles to the terminal at the Calcasieu dock. The pipeline construction consists of (1) excavation, (2) laying of pipe, (3) welding, and (4) finishing operations. As can be seen on Figure 3.1 , the proposed pipeline construction passes near by residences on Route 390 in Section 28 and several residences in Section 41. Noise levels associated with typical pipeline construction equipment are shown in Table 3.12. The Hackberry High School and St. Peter's Church are located approximately 2,000 feet and 3,000 feet south of the proposed oil pipeline. These noise sensitive areas are well beyond the noise impact boundary from pipeline construction which is estimated to be Leq = 55 dB at 500 feet from the pipeline construction.

Terminal and Dock Area

Major noise sources from the terminal and dock construction Figure 3.13 are expected to be pile driving for the dock construction and diesel engine noise in the terminal area construction. Trucks, concrete mixers, compressors, and general construction equipment would all contribute to increased ambient levels. For construction activity at the dock and terminal site, the daytime Leq during the period of construction is estimated to be 70 dB at the center of the site. It is probable that residents in Section 41 will experience an increase in ambient noise levels during the period of construction activity. Nighttime construction activity is not anticipated in the terminal area.

When tanker unloading and loading occur, the major noise associated with the operations would be from tanker traffic, tanker pumps discharging crude oil, tanker loading pumps, and pipe transfer pumps.

Table 3.12. Summary of Sound Level Contribution (dB) from Construction Activities.

Construction Site	L_{eq}	L_{dn}	Distance from Center of Site
Storage Site Area	< 55	< 55	2,000' (nearest residence)
Pipeline Corridors	55	< 55	500'
Terminal and Dock area	64	< 55	2,000' (nearest residence)
Brine Disposal Area	55	55	1,800'

* No nighttime activity planned.

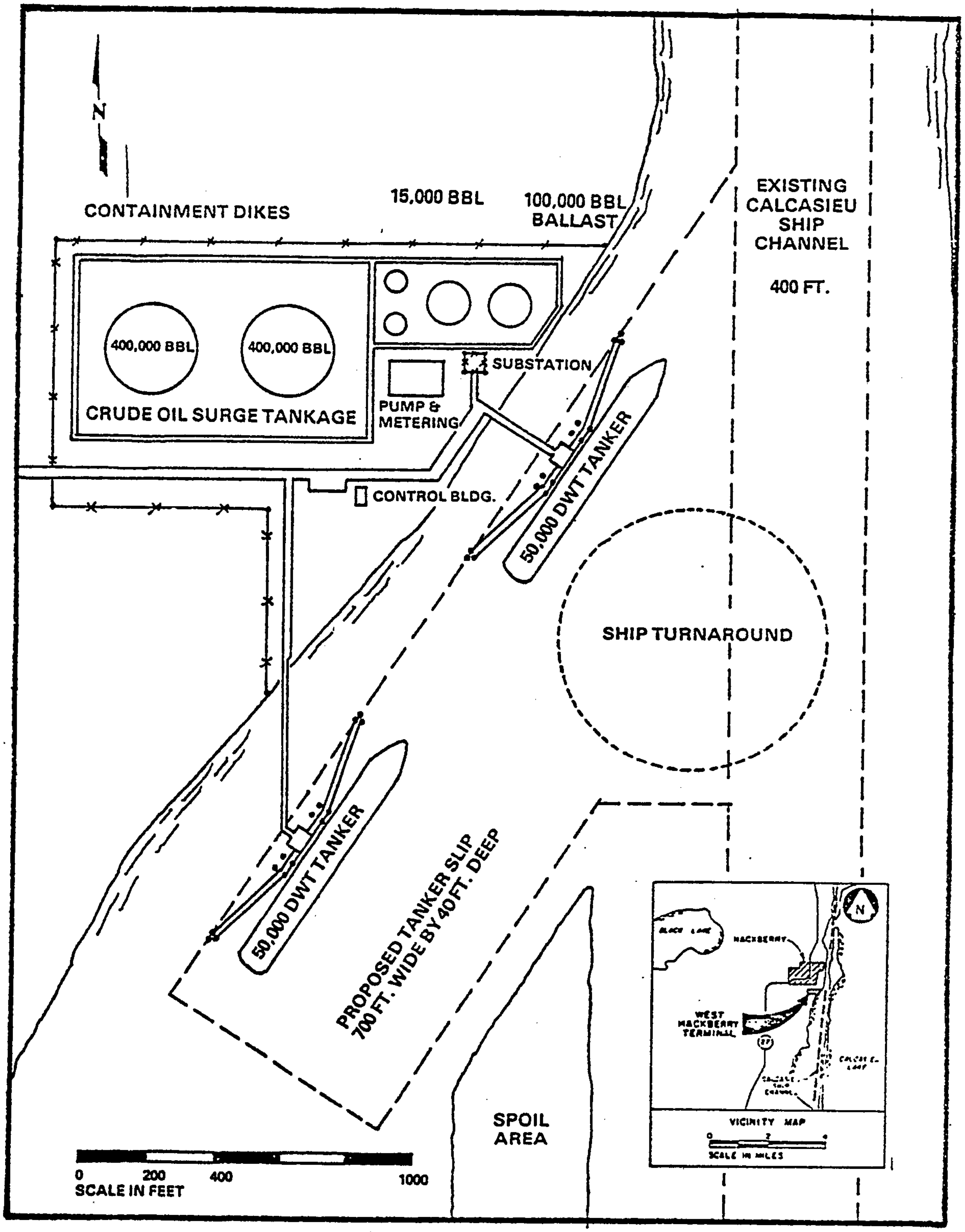

Figure 3.13 Proposed Distribution Terminal

The pumps for both tanker loading and pipeline transfer to the storage area will be electrically powered and would be housed in a pump house on the terminal site. Noise from the diesel engines powering the tankers and tanker discharge pumps would contribute negligibly to daytime ambient levels. It is estimated that nighttime levels would be increased by approximately 4 dB along the perimeter of the terminal area. It is not anticipated that noise from the terminal operation will affect residential land use approximately 2,000 feet from the terminal site.

Brine Disposal Area

Noise from drilling operations is expected at both the storage facility and the brine injection wells 2 miles south of the storage facility. It is anticipated that conventional oil drill-rig equipment will be used for work over and drilling of wells at the storage site and at the 11 brine disposal wells in Sections 32, 33, and 34. Drilling rigs are planned to be in continuous day/night operation for approximately 30 days. Noise from conventional oil drilling equipment reaches levels of 95 to 100 dBA at 50 feet from the drill rig. The noise impact zone (Leq <55 dB) is estimated to extend approximately 1,800 feet from the drilling sites; however, all drilling sites are in remote areas and noise from these sites should have little effect on residences.

Summary of Noise Impacts

Noise impacts from the construction associated with the West Hackberry site preparation are summarized in Table 3.11.

During fill and/or discharge operations, there would be noise generated from the continuous operation of pumps at both the storage and terminal facilities. The noise is expected to be continuous day and night for approximately 5 months, however, since the pumps at both the storage and terminal facility would be enclosed in pumphouses, it is anticipated that there would be negligible noise impacts (see Appendix C for Federal guidelines) on the nearest residential areas in the vicinity of these facilities.

3.4 SPECIES and ECOSYSTEMS

3.4.1 Impacts on Prairie Ecology

The 240 acre tract designated for the storage site would be directly affected by project activities. Since this area has been in use for some time as a storage facility, new impacts to coastal prairie vegetation and local fauna would be minimal. Small areas of coastal prairie vegetation which would be destroyed are comprised predominantly of switch grass (*Panicum virgatum*), big bluestem (*Andropogon* spp.), Indian grass (*Sorghastrum avenaceum*), and prairie wildgrass (*Sphenopholis obtusata*). Noise, construction activity, and the overall increase of human activity in the area would discourage use of the site by wildlife and possibly destroy a very small number of nests and individual animals.

The permanent oil distribution terminal on Calcasieu Lake would take about 28 acres to construct the dock for loading and unloading tankers, oil and ballast treatment tanks, waste facilities, and retention dikes. Terrestrial impacts would be slight since the dock would be placed on already highly disturbed land designated for commercial development. Approximately 55 acres of predominantly agricultural land would be disturbed. Organisms that occur in this area are introduced or migrant species from surrounding natural ecosystems. Pipelines for the 5 cavern storage layout, the brine settling tanks and the displacement water would be buried in an area which is already disturbed. This community generally supports migratory or introduced species, and impacts would be slight. Construction activities would inhibit use of the area for bird feeding or nesting and small mammals would move into surrounding areas during construction. A total of 15 acres of native grasses would be eliminated within the 50 foot rights-of-way of the pipeline which would connect the brine disposal wells with the other components. A total of about 15 acres of native grasses would be eliminated within the 50 foot pipeline rights-of-way which would connect the brine disposal wells with the other components.

The brine disposal components which would be located on dry land would effectively remove 7 acres of primarily grazing land during construction. At an average productivity for these grasses of 2,500 $Kcal/m^2/yr$, this loss of acreage represents a loss of primary production of 7.08×10^7 Kcal/yr[32]. Relative to the extent of pastureland in the vicinity of the dome this loss of 0.7 percent of the present productivity is negligible.

Furthermore, construction areas on coastal prairie may be partially usable again as grazing land after drilling and other construction has been completed. Coastal prairie vegetation should return to about 5 acres of the 7-acre total and would be usable for grazing in about a year.

Oil distribution would require a 4-mile pipeline to the Calcasieu River terminal with a 100 foot dry land right-of-way during construction. This pipeline will cross agricultural lands and affect a total of 48 acres. Ecological impacts to the agricultural or disturbed lands would be minimal.

During the facility operation phase, only the wellheads of the storage cavities and brine injection wells would be exposed. Pipeline rights-of-way will be kept accessible by mowing. Mowing equipment and well maintenance operations would disturb wildlife and hinder growth of prairie grasses. Bird feeding and nesting would be interrupted during inspection times. Human activity can be expected to increase during the 150-day displacement and withdrawal operations. Noise, reduced air quality and other human activity impacts are expected to occur each time oil is required from the system. Maintenance, displacement and withdrawal operations would cause wildlife to temporarily abandon habitats around the facilities.

3.4.2 Impacts on Brackish Marsh Ecology

Landfill

Land fill would be required for an access road to the brine disposal wells in the marsh and for 200 foot square pads at each wellhead. Also at each wellhead, 50 foot by 50 foot mud pits will be constructed for use during drilling. Filling of marshland will directly eliminate small acreages of grass and produce some siltation and increased turbidity in the vicinity of the roads. Although such construction activity will destroy both marsh grass and benthic organisms, the biological communities alongside the road and walls would recover relatively rapidly, while only a limited area would be permanently lost as wetlands.

A total area of about 36 acres would be utilized for the brine disposal system; of this 1 acre is permanently committed to the 2-tank settling system, 10 acres are permanently committed to fill around wellheads, and approximately 11 acres are permanently committed to pump station construction and access roads. Of the total 36 acres involved in the brine disposal system, approximately 11 acres are brackish marsh and 25 acres are coastal prairie.

Conversion of 11 acres of brackish marsh to dry land fill would eliminate marsh community productivity of 1,518 g dry wt/m^2/yr (equivalent to loss of about 74 tons of dry vegetation annually for the entire 11 acres). This loss of vegetation is small in relation to the overall marsh acreage in the dome vicinity. Filling of the marsh acreage will also eliminate potential breeding area for fish and shrimp as well as for benthic macroinvertebrates and plankton. The Gulf estuaries have been estimated to produce an average of 230 pounds per acre in commercial catches of fish and shellfish. If a somewhat lower annual production of 150 pounds per acre can be assumed for the brackish marsh for various fish and shellfish, a total loss of 1,650 pounds annual production or less would result. This is a relatively minor loss in comparison to the estimated annual harvest for fish, shrimp, oysters and crabs from Calcasieu Lake of over 2,000,000 pounds.

Dredging

Initial crude oil fill operations would require construction of a temporary dock on Alkali Ditch which connects with the Intracoastal Waterway. Site preparation and construction would entail dredging this channel to its original 7.5 foot depth and 40 foot width to accommodate 5,500 barrel barges. Dredge spoil equalling 35,000 cu. yds. would be removed along the 1½ mile canal) deposited on the original bank on the northwest side of the channel. Mooring piles would be driven into the bottom near the canal terminus adjacent to the site and a timber dock and walkway would also be constructed. A 200 foot circular, 7½ deep, barge turning basin also would be dredged (11,500 cu. yds.). About 3-4 acres of marshy land would be required for the dock construction and for the turning basin.

The Alkali Ditch is adjacent to the site on the east. Eastern portions of the dome over which Alkali Ditch traverses are under water in the brackish marsh ecosystem. The remainder of the canal up to the Intracoastal Waterway crosses the intermediate marsh ecosystem.

Impacts on terrestrial and aquatic communities as a result of construction of the temporary docking facility would generally be short term. Dredging would disturb the marshland bottom sediments and temporarily eliminate benthic forms and increase turbidity, thus reducing plankton productivity. Dredge spoil would smother vegetation and soil organisms on the northwest bank. The exact size of the area to be covered by dredged material is not known, but would not exceed 90 acres (assuming that the spoil is distributed along the entire 1 1/2 mile section). The productivity of the marsh is about 1,518 g. dry wt./m^2/yr. That area covered by dredge material which is marsh would be permanently destroyed. Assuming that all is marsh, approximately 554,000 kg/yr of productivity would be lost if vegetation were not re-established. Noise and increased human activity will force mobile wildlife, especially birds, to evacuate the area temporarily. Rapid recovery of the benthic organisms where dredging occurs is anticipated. Phytoplankton and zooplankton productivity would increase after settling occurs and mobile animals should return soon after construction is complete (within 2 to 3 months).

Construction of permanent dock facilities on the Calcasieu Ship Channel would involve dredging of 2.5 million cu. yds., driving piles, and erecting docks. Benthic organisms would be destroyed by siltation during dredging and spoil deposition. Deposition of spoil material in a continuous band along the ship channel disrupts the normal circulation patterns of Calcasieu Lake and has been implicated in the collapse of the oyster industry there in the 1960s (see Section 3.7.2.4). Recent resurgence of oyster populations in the southern portion of the lake is attributable to washouts and selective cuts made in the spoil bank of Calcasieu Ship Channel. If spoil is deposited such that cuts are maintained, impacts on oyster populations would be transient (oysters are not present at proposed spoil deposition site).

Turbidity would decrease phytoplankton and zooplankton productivity. Phytoplankton and benthic algae productivity in the area is approximately 906 g. dry wt./m^2/yr. and zooplankton productivity is approximately 25 g. dry wt./m^2/yr.[33] Also, nekton would emigrate until turbidity decreases, especially those species such as sunfish which feed mostly by sight. Sump dredging in Black Lake Bayou for the water withdrawal system would increase the local turbidity temporarily (thereby reducing plankton production), and would eliminate benthic organisms in the dredged area.

Water quality would adversely affect organisms due to 3 major categories of impacts: turbidity, nutrient release and pesticide release. Photosynthesis by primary producers in the brackish marsh and lake areas where dredging or spoil deposition is done would be limited by turbidity. Generally, primary production is greatest in summer months and would be most limited during those months. However, diatom (periphyton) growth is often most noticeable in colder months and would be inhibited by dredging at those times.

The primary consumers of the aquatic system include insect larvae, crustaceans, polychaete worms, amphipods, copepods, ostracods, and mollusks (which are also filter feeders and also consume detritus). Sediments settling out will suffocate mollusks and other shellfish (crabs) or will cause gill abrasion. Most benthic macroinvertebrates will be buried or killed during dredging. Mobile forms (notably shrimp and fish) will emigrate from turbid areas and will return shortly after clearing of the turbidity by settling. Re-establishment of preconstruction crab and oyster populations would take several years while crayfish repopulation would probably require less than 1 year after construction.

Although Spartina spp. and other marsh grasses act as nutrient pumps and release phosphorus and other elements from the sediments, dredging has a much greater effect over a shorter time span by stirring sediment-bound nutrients into the water. The release of sediment-bound nitrogen, phosphorus and carbon compounds (plus detritus) can have an almost immediate positive effect on primary production of algae (phytoplankton and periphyton) and on both submerged and floating macrophytes. Results of testing Intracoastal Waterway samples have shown that release of phosphorus is just adequate to support a large aquatic biomass, typical of eutrophic conditions, if the waters were confined without dilution.[2] Dilution due to inflows, rainfall and tidal movements will decrease potentially heavy eutrophic growths. In addition to any additional phytoplankton production, suspended detritus in turn enhances secondary production by zooplankton, benthic organisms and filter-feeding fish. The growth rate of these organisms does not always change substantially, but the absolute numbers or biomass which the system produces can be multiplied many times depending on the species present which can adapt and take special advantage of the environmental conditions. On the other hand, stirring of sediments can release unusual quantities of pesticides and their degradation products. Release of these materials can greatly inhibit, or in some cases, stop primary production (e.g. mercury compounds can halt phytoplankton production). In addition, many biocides are accumulated by various organisms in the aquatic environment and are passed up the food chain. However, some ortho-phosphorus pesticides are degraded within 1 to 2 months and pose less threat than do chlorinated hydrocarbons.

3.4.3 Impacts on Aquatic Ecology

During facility operation, displacement water would be drawn from Black Lake Bayou 1,500 feet downstream from the 2,500 acre Black Lake which overlies the northern flank of the dome. This shallow, brackish body of water is linked via canals and bayous to Calcasieu Lake and to the Intracoastal Waterway. Therefore, water quality and biology are related to that of the Intracoastal Waterway and Calcasieu Lake. Water would be drawn into the displacement system through intake stations which would require that a sump be dredged in the channel (design and size not defined). Intake velocities will be less than 0.5 ft/sec.

When the Black Lake water level is equalized from surrounding areas such as Calcasieu Lake, salt water inflow could be induced in the southern reaches of Calcasieu Lake. The southern end of Calcasieu Lake varied in salinity from 17.3 ppt to 26.7 ppt in 1971.[34] Therefore, salt water is not expected to present problems to aquatic species in this portion of the lake as the salinity is already high. In the water column, individual organisms will be sacrificed because of entrainment in the intake structures. Organisms that would be entrained would be the plankton (e.g., diatoms, other algae, copepods), larval fishes, benthos, and small aquatic plants. Assuming that all 60 million barrels of crude oil are displaced for 1 withdrawal and assuming 3,000 organisms per 100 m^3* of intake water, 3.57×10^{11} planktonic organisms would be entrained during withdrawal operations. Considering the immense volume of the aquatic system and rapid turnover rate of planktonic species, this number is inconsequential in regard to productivity of the system.

The number of impinged organisms will depend on the size of the screen apparatus. Most intake systems are fitted with ½ inch mesh screens. It is doubtful that any severe impingement problem will occur since intake velocity will be less than 0.5 ft/sec. Large organisms incapable of passing through the screen presumably will be mobile enough to escape since intakes are designed to minimize inflow velocity and thus prevent impingement. Frequent clearing will prevent clogging which can create stronger currents across the screen.

Operations at the temporary Alkali Ditch dock and the permanent Calcasieu Lake dock would primarily involve barge and oil tanker movements. Sediments would be resuspended as barges traverse the 7½ foot deep Alkali Ditch, thereby disrupting benthic organisms, fish, shellfish and retarding plankton growth. Sediment resuspension would occur during 10 months for every fill cycle and would strongly inhibit aquatic production in the immediate vicinity and in waters receiving turbid inflows. Spillage of oil during operations is calculated to be less than 1 percent probability. Further discussion of accidental spills is found in Section 3.7.

3.4.4 Commercially Important Species

With respect to wildlife in the area, the impact of construction activities (particularly land fill and dredging) will vary in intensity depending upon the season during which the activity takes place and the degree of change produced in the environment. Table 3.13 indicates these sensitive times for each of the commercially important species, and the reasons for this sensitivity.

*This number is based on larger plankton forms only.

Table 3.13 Important organisms and related sensitivities.

Organisms	Sensitive Time	Reasons for Sensitivity
BIRDS		
Ducks, Geese, Waterfowl	November through March	Abundant at nearby Sabine Wildlife Refuge, Moss Lake, Black Lake and in surrounding marshes. Areas used for feeding
Wading birds, shorebirds	All year, primarily in spring	Wading bird rookeries are abundant in areas for feeding, and nesting in spring months
MAMMALS		
Muskrat	All year	Several litters produced annually
Mink	January through March	Mating season, 39-76 days gestation period
Otter, River	March and April	Breeding season, gestation period is 12 months
Nutria	All year	Breed throughout year, gestation 127-132 days
(NOTE: Trapping season for mammals is during winter months.)		
REPTILES		
Alligator	May through June	Mating season, eggs hatch in about 9 weeks
FISH		
Channel Catfish	When salinity above 1.8 ppt	Reproduction will not occur in water above 1.8 ppt.
Sunfishes	When salinity above 2 ppt	Tolerance for living in brackish waters is low, never above 12 ppt

Table 3.13 (cont'd)

Organisms	Sensitive Time	Reasons for Sensitivity
Shad (Dorosoma cepedianum and D. petenense) and Alligator gar (Lepisosteus spatula)	When salinity above 10-15 ppt	Tolerance for living in brackish waters high
Bay anchovy (Anchoa mitchelli)	Summer and fall	Can tolerate salinity of 0.4-33.9 ppt, but spawn primarily in summer and fall. Most abundant in estuaries February-June
Menhaden (Brevoortia spp.)	October through February - December through April	Spawning occurs Larvae present
Croaker (Micropogon undulatus)	January through May	Prominent months of appearance in estuaries
	May through November	Emigration of yearling fish back to the sea from the estuarine areas
Spot (Leiostomus xanthurus)	October through March November through June	Spawning in bays Present in bays and estuaries as juveniles
SHELLFISH		
Blue crab (Callinectes sapidus)	March through August; or when salinity less than 20 ppt or very high (above 35 ppt)	Spawning season, can tolerate salinity from 0 to 35 ppt (20 ppt optional for spawning) Young often found throughout the year within 2 months of spawning
Oyster (Crassostrea virginica)	When salinity below 10 ppt or above 35 ppt	Intolerant to wide salinity changes, abnormal larval development
	When turbidity high	Suffocation due to gill clogging and abrasion
	May through November	Primary time of oyster larval "spat setting" (several years required for establishing oyster bed)

Table 3.13 (cont'd)

Organisms	Sensitive Time	Reasons for Sensitivity
Brown shrimp (*Penaeus aztecus*)	February through April	Postlarval shrimp appear at inshore areas after offshore spawning. Slightly in more eastern areas of Louisiana with later trend in west
White shrimp (*Penaeus setiferus*)	September through November	Some white shrimp can be found on inshore nursery grounds during all months, but highest density occurs in late summer and early fall, just prior to offshore migration

NOTE: Shrimp spawn in offshore areas and the fall inshore population depends on the spawn, abundance, and survival of postlarval and juvenile populations in upper marshes; whereas, the spring inshore population is dependent on the abundance and survival of the overwintering juvenile populations.

NOTE: Shrimp inshore catch season usually begins in mid to late May and remains open for a minimum of 50 consecutive days from opening date.

3.5 WASTE DISPOSAL

A formal waste disposal program has not been established; however, discussions with Olin Corporation personnel have led to potential disposal techniques for the various types of wastes that correspond to acceptable practice. During the site preparation and construction phase, generated wastes include surplus lumber and metal goods, paper, waste concrete, earth excavations, personnel sewage, and possibly formation water during the drilling process.

All construction wastes are handled by the construction contractor, who is required to leave the site clear of wastes. Surplus lumber and scrap metal are normally sold to local dealers who handle such materials. On the other hand, disposal of waste paper, concrete, and other non-marketable goods is usually in local land fill sites. Probably no more than a few thousand cubic feet of each of these types of materials would be generated during the entire project.

One land fill site is located on state highway 27, about 5 miles south of Hackberry. Several land fill sites are located at Cameron on the other side of Lake Calcasieu.[34] The Hackberry site is one year old and is estimated to have a 7 to 8 year life expectancy. The land fill area is 7 acres. The Police Juryman in charge of solid waste disposal anticipates no problems in opening a new land fill site when the present one is full.

The earth material excavated during project construction would be used within the project, for example, as dike material around various tanks or as fill to raise buildings or equipment above flooding levels. Dredgings from the temporary barge dock construction would be deposited on the original northwest bank of the channel. Similarly, the dredgings for the permanent dock site would be deposited in areas presently used for spoil dredged from the Calcasieu Ship Channel.

Sewage treatment and disposal would probably be through the common portable septic tank system that can be rented from various contractors or through a more permanent septic tank system that would have to be constructed in compliance with State regulations.

Any formation water produced during the well-drilling process would probably be reinjected into the well hole with the drilling mud or collected by drilling support tank trucks supplied by the drilling contractor to handle such wastes. Once the drilling has been completed, the drilling contractor would haul away all the drilling mud to be processed and re-used on another project. The mud pit where drilling mud is prepared and stored would be cleaned and re-covered with topsoil.

3.6 SOCIOECONOMIC EFFECTS

3.6.1 Manpower Requirements

Onsite Construction and Drilling

An estimate of the manpower requirements for work on the site is shown on Figure 3.14 Construction operations will be the major component of the work and will employ about 37 skilled craftsmen and laborers for a period of 4 months. This includes construction of temporary dock facilities, storage tanks, wellheads, connecting pipelines onsite, and installation of equipment for (1) the disposal of brine presently occupying the caverns, and (2) the displacement of oil with raw water during oil recovery procedures. Construction operations will proceed concurrently with the drilling of wells for brine disposal and additional access to the cavities. Current plans call for the use of one conventional drill rig and one workover rig. The drill rig will be operated by about 16 men working in shifts, and the workover rig by 6 men.

The number of men working onsite during the day is not expected to exceed 60 during the 4 months of construction. Drilling operations will continue for an additional 12 month period, during which the number of men onsite will drop to about 20. This includes employees to monitor the storage facilities and maintain equipment.

Construction of Permanent Dock and Pipelines

The preparation of the site and construction of the dock on the Calcasieu River Canal is expected to take 14 months. Construction here will begin at the same time that work begins on the storage site and will employ about 25 men during the initial 4 months. The number of workers at the dock will rise to about 50 during the ensuing 6 month peak period.

Two 30-inch pipelines are to be laid between this dock and the storage site, a distance of 3 to 4 miles. Construction of these pipelines will be delayed until 7 months of work on the dock have been completed. Laying of the pipeline and related tasks will employ about 25 men for a period of 11 months.

Summary of Construction Labor Force

Construction of facilities at West Hackberry, dock construction on the Calcasieu River Canal, and pipelaying operations will involve about 150 workers. Due to the short

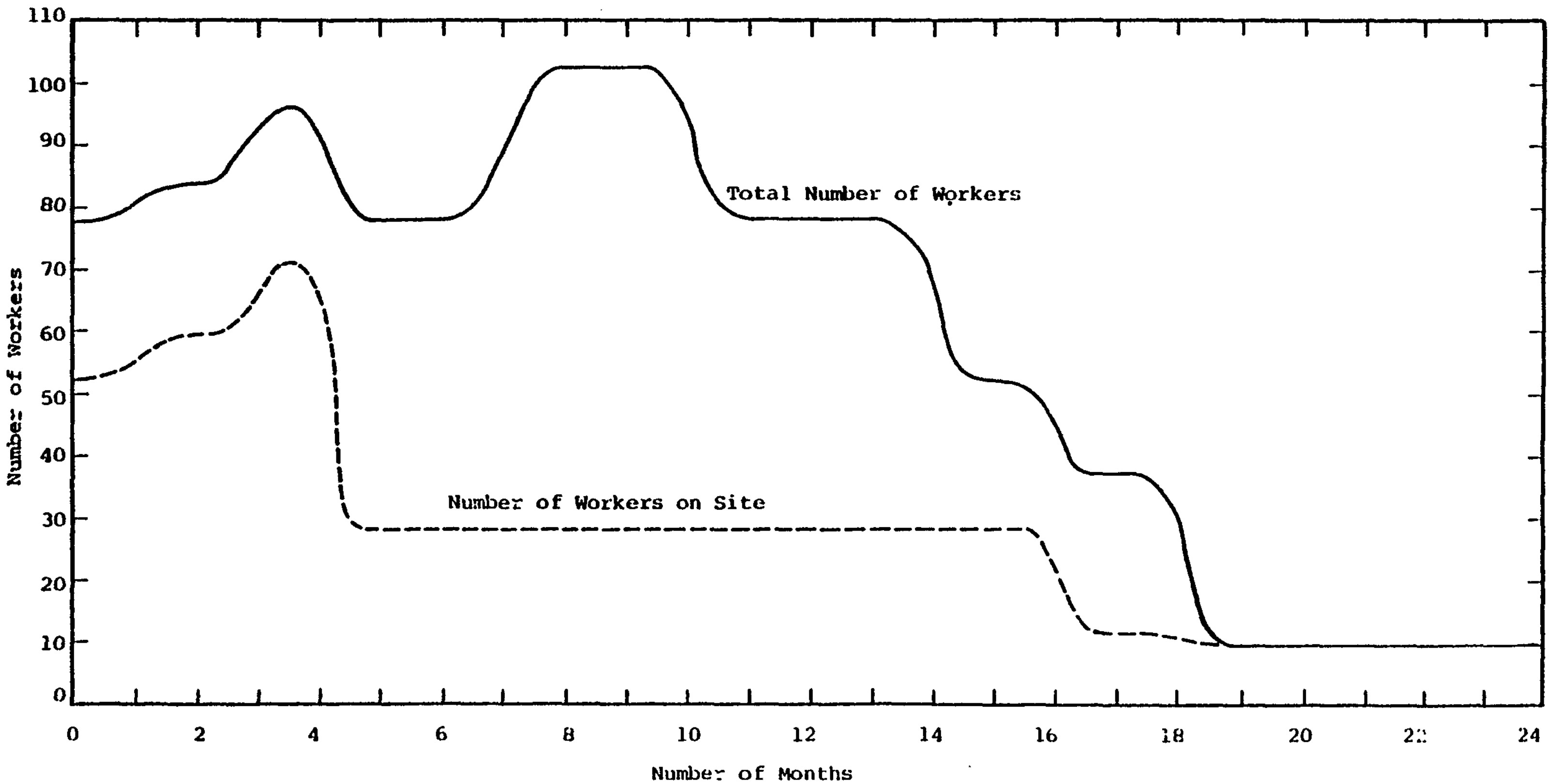

Figure 3.14 Manpower Requirements For Site Preparation and Construction

duration of onsite construction, and the delayed starting date of the major pipelaying work, peak manpower requirements are not expected to exceed 105 persons. This employment peak is anticipated to occur about 7 months after construction starts, and last for about 3 months.

Sources of Construction Labor and Supplies

Construction is a major industry in the Lake Charles area, and it is anticipated that contractors will be available from Sulphur, Westlake, and Lake Charles, itself. Work similar to that required for the proposed project has been performed by local firms involved in the development of oil fields, and the construction of facilities for large chemical plants.

The work requires primarily skilled workers who would be permanent employees of the contractors, and would be living in the Lake Charles area. They will commute to their jobs at the West Hackberry site and at the dock site on the Calcasieu River Canal.

Many of the supplies can be purchased from local firms in the Lake Charles area. Specialized equipment, pipe, and wellheads may be brought in from regional suppliers in New Orleans, Baton Rouge, the Beaumont-Port Arthur Area, and Houston.

Operation of Facilities

Approximately 10 personnel would be required to maintain the facilities and to monitor operations at the storage site, at the permanent dock, in the brine disposal field, and along the pipeline rights-of-way. It is anticipated that 6 skilled workers and technicians would be needed, 3 general laborers, and one person for clerical work. Efforts would be made to fill these positions with qualified persons from the local area in Cameron Parish. Payroll for these workers will total about $18,000 per month.

During oil recovery procedures, a work force of 20 to 30 skilled laborers will be required for a period of 5 months. This estimate includes personnel to operate and monitor pumps and valves, and dock workers to load tankers with oil from the storage site. Based on an average wage rate of $1,750 per month, total payroll for these workers during the recovery period will be approximately $43,750 per month. A similar level of manpower would be necessary when the cavities are refilled at the end of the petroleum shortage period. These workers would be drawn from the greater Lake Charles area (which includes Westlake, Sulphur and towns in the intermediate area), and from Cameron Parish residents who augment their farm income with short-term employment in the oil and gas business and related industries.

Workers who had been employed by the project during the construction phase, a maximum of 150 persons, will probably seek replacement work in the Lake Charles area. This number is insignificant compared to a total civilian labor force projected to be in the range of 60,000 persons at the time of completion of the project.

3.6.2 Impacts on Community Services

Construction Effects

No significant migration of workers to the area is anticipated to result from the project. The major impact will be increased traffic on Highway 27 leading from Lake Charles to Hackberry, and on parish roads leading to the storage site and the dock.

The housing situation in Cameron Parish does not allow for workers to move into small communities there. Rental units are available in the Lake Charles area to accommodate the small number of workers and worker's families that may be drawn to the project from other parts of the region.

School systems are not expected to be affected by the project since it would not draw significant numbers of new families with school age children to the area.

Security guards would be stationed at the storage facility site and at the dock to prevent theft of equipment and materials. They would cooperate in their activities with sheriff's department of Cameron Parish, which has jurisdiction over these areas. Fire fighting equipment would be on hand at the site and the dock. Auxiliary aid in containing fires that may spread into the surrounding fields is available from Hackberry.

Medical facilities in Sulphur and Lake Charles would be used to provide emergency care to workers injured at the site and at the dock. Since workers and their families would primarily be established residents of the area, no additional stress on health services is expected to result from the project.

Operation Effects

The project will not produce a need for additional housing in the region if local residents are employed. Housing at Hackberry is limited, and it is expected that any workers hired from outside the immediate locality would commute to their jobs. The additional activity in the area and installation of equipment can be expected to contribute to the demand for expansion of police and fire protection services. Continued use of the site wouldrequire expenditures to be made to upgrade access roads to the area.

3.6.3 Economic Impacts

Employment and Payroll

The major local benefits from construction of the project would be the direct employment and payroll. It is anticipated that a number of local contractors will be hired for various phases of construction. Including the personnel detailed to the project by these contractors, the payroll during site preparation and construction would be approximately as follows:*

1st through 7th month:	$140,000 per month
8th through 10th month:	$184,000 per month
11th through 14th month:	$140,000 per month
15th through 18th month:	$ 79,000 per month

*Based on an average wage rate of $1,750 per month.

Income received by workers would tend to circulate in the Lake Charles area.

Local Business and Industry

The construction phase of the project would benefit local firms engaged in the following businesses: building contractors, construction material suppliers, pump and pipe manufacturers and distributors, metal fabricators and suppliers, and drilling companies. There are also a number of firms in the area that specialize in the repair of the kinds of equipment that would be used.

To avoid adverse effects on the area, it is expected that these local contractors would be used as much as possible. This secondary business generated by the project would not create a significant number of new jobs, but would be an important source of income for these industries. Because the duration of construction for the project is confined to 18 months, it is anticipated that no new businesses would be induced by it.

The operation of the storage facility would, by itself, contribute only a small part to the overall growth of the predominantly rural area of Cameron Parish. If the dock facilities built on the Calcasieu River Channel are permitted to be used by private industry when they are not needed by the federal government, this could encourage incidental growth at Hackberry.

Tax Benefits

Sources of tax revenue for Louisiana and the parishes are: (1) severance taxes (and royalties) from the extraction of oil and gas, (2) property taxes, and (3) sales tax (3% State tax on general goods and services). Severance tax will not apply to this operation. If the site, rights-of-way, materials and equipment are federally owned, then these items will be exempt from property and sales taxes.

In the event that the oil is withdrawn from the salt cavities, the companies that purchase the oil will be exempt from State sales tax if they are registered wholesalers (most oil companies are registered). Tax benefit from the project will accrue indirectly from the income and from purchases made by the workers.

Costs

Costs to the community would be primarily those paid for public services: electrical, water and sewerage connection, trash collections, police and fire protection, schools, and health facilities. These would be costs attributable to the general growth of the communities, and not incurred because of this specific project. There would be added costs of road maintenance in the vicinity of the site that would be directly attributable to the project.

The present and projected growth rate of general construction, heavy industry and the oil and gas industry in the area indicates that opportunities for replacement jobs at the end of the project's construction period would be available.

3.7 ACCIDENTS AND NATURAL DISASTERS

The potential for accidents and natural disasters is discussed in this section with particular emphasis on the possible occurrence of crude oil or brine spills.

The probabilities of occurrence were generated from historical accident or natural disaster data. Care has been taken to use probabilities generated for circumstances and environments similar to those existing in this project.

3.7.1 Pipeline Accidents

The available pipeline accident or failure data gathered by the Department of Transportation covering the years 1968 through 1973 show fairly consistent statistics.[35] Analyses of these data performed in conjunction with the submission of the Louisiana Offshore Oil Port (LOOP) Project environmental impact assessment indicated that an accident rate of 0.00136 incidents occurred per mile/year. However, taking into account the improvements in pipeline materials, manufacturing processes, construction, and testing procedures, reasonable accident/failure frequency was projected to be 5×10^{-4} per mile/year. These probabilities include spills caused by external forces including natural disasters, corrosion, operational reliability, and better than a 10 percent contingency category.[36]

Using this accident/failure frequency, the probability of an incident per year for the various types of pipelines in this SPR project is given in Table 3.14.
Also present in this table are the lengths of each of the pipeline systems and the number of operational years associated with a program of five fill/withdraw cycles. In this context, the number of operational years is computed by adding the time of each period of active operations for each pipeline system; for example, one crude pipeline configuration will be operational from the temporary dock facility for the 10-month ESP fill period, then the crude line associated with the permanent facilities will be operational for 14 months to complete the initial fill, 5 month withdrawal periods, and four 10 month refill periods. Note that although the system is presently scheduled for a 10-month plus 14-month initial fill period and is designed for a 5 month refill period, for purposes of these calculations, longer periods were assumed based on possible lower crude availability. These longer periods give conservative results.

Employing these data from Table 3.14, the probability of a given number of spills from each of the types of pipelines

Table 3.14 Accident/Failure Frequency

Type of Pipelines	Approximate Length(mi)[1]	Accident/Failure Frequency (Events/Year)	Approximate Number of Operational Years[2]
Crude Oil			
Barge Fill Only	1.2	.0006	1.0
Normal Operation	9.0	.0045	25.0
Brine			
Barge Fill Only[3]	3.6	.0018	1.0
Normal Operation	6.0	.003	4.5
Raw Water	2.0	.001	2.1

1. Includes approximately 1.1 miles of line on the dome site for each type.
2. Assumes approximately 1 year of barge dock operation and 14 months of permanent dock operation to complete initial fill, 5 five-month withdrawals, and 4 ten-month refill periods. The pipeline to the dock will remain full.
3. One or two brine injection wells will be adequate during the barge fill phase.

during the life of the project may be computed. These probabilities are presented in Table 3.15. Note that in each case by far the most probable number of pipeline spills is zero. In fact, only about a 3 percent chance of a crude spill is projected and less than a 2 percent chance of a brine spill. Even this very low probability of a spill must be tempered by the fact that the probability data are based upon higher pressure oil lines. Even the crude spill probability must be tempered somewhat because the operating pressures for most of the crude pipelines at this SPR site are relatively low (less than 500 psi).

The same data base that was used to compute an accident frequency rate projects the mean spill size to be about 1,000 barrels. Using this mean spill size, the annual crude spill volume expectation is only 4.5 barrels during peak operations, or the total crude spill volume expected over the life of the project is only about 30 barrels.

A large pipeline accident spill is unlikely because the pipeline is protected by burial along the entire route. The lines being buried also enhance the probability that a bad break can be detected and the lines can be cleared before a large amount of crude is released. Crude leaking from a buried line will be somewhat contained by the surrounding earth; therefore, the damaged area would be limited and cleanup could proceed effectively. Similarly, pipeline spills in the dock area reaching the waters of Alkali Ditch or Calcasieu Shipping Channel should be contained by the proper operation of the dock site spill equipment and other accident equipment in the area.

Table 3.15 Probability of Pipeline Failure During Project*

Number of Crude Spills	Probability (%)
Barge Fill Period:	
None	99.94
1	.06
More than 1	nil
Normal Operation:	
None	87.4
1	11.3
More than 1	1.3
Number of Brine Spills	**Probability (%)**
Barge Fill Period:	
None	99.8
1	0.2
More than 1	nil
Normal Operation:	
None	98.6
1	1.3
More than 1	0.1
Number of Raw Water Spills	**Probability (%)**
None	99.8
1	0.2
More than 1	nil

* Assumes that pipeline integrity is tested prior to initiation of each withdrawal/refill cycle.

3.7.2. Risk of Oil Spills During Marine Transportation

3.7.2.1 Introduction and Summary

This section presents estimates of both the probability and the size of oil spills arising from accidents during marine operations and transport. Marine operations considered include the voyage of the tankship or barge tow along the Calcasieu Ship Channel and associated waterways from the Gulf to the terminal, and loading and offloading operations at the terminal. Accidents include vessel casualities such as collisions and groundings, and mishaps at the marine terminal such as failure of a hose connector, overfilling a tank, opening the wrong valve, etc.

A detailed description of the estimated risk of oil spills from accidents is presented in the following two subsections. A summary is provided in the following paragraphs.

The estimates are based primarily on statistical analyses. The number of vessel casualties, which would result in the spill of oil, were derived from the Coast Guard's listing of Commercial Vessel Casualties for fiscal years 1969 through 1974. The count of ship traffic was obtained from Waterborne Commerce of the United States, U. S. Army Corps of Engineers. Combined, these data yielded the expected frequency of spills per transit of a tankship or tankbarge from the Gulf to the terminal. Similarly, the frequency of spills for loading and offloading oil at the terminal was obtained from incidents reported by the Coast Guard's Pollution Incident Reporting System and Corps of Engineer traffic data, both covering the entire United States. The distribution of the quantity of oil spilled, with the number of spills, was developed from the Coast Guard Commercial Vessel Casualty data for losses from tank barges in Western Rivers* and the inland Gulf region. The quantities spilled are distributed log normally versus number fraction of spills. This relationship was modified for application to tankship casualties and accidental spills during loading and offloading at the marine terminal.

The above methodology is based on the assumptions that the planned crude oil transport operation is essentially the same as that for which the accident experience has accrued

*Primarily the Mississippi River system.

and that the added ship traffic along the Calcasieu Channel does not in itself increase the likelihood of accidents. These assumptions seem justifiable and, indeed, may be conservative in the sense of over estimating accident frequency. For the first assumption, the facilities, tankships and barges to be used will be nearly the same as those now used in the area. For the second assumption, it may be noted that traffic along the Calcasieu is one way[37], movements in one direction at a time. Hence ship collisions have not been observed and the increased traffic caused by the movements of crude oil should have no effect on the accident rate of a ship or barge tow.

The estimates of risk of accidental oil spills is summarized in Table 3.16. The expectation quantity of crude oil spilled per trip from vessel accidents, such as groundings, rammings (striking fixed objects, submerged or on or above the water surface), structural failure, fires and explosions, etc , is 0.15 barrels per trip for the barges (21,000 barrels capacity), and 0.89 barrels per trip for the tankships (400,000 barrels capacity). Accidents at the marine terminal, such as overfilling a tank, opening the wrong valve, etc., have an expectation quantity spilled of 0.93 barrels per trip for either barges or tankships. The total expected quantity of oil spilled during the transport of 60 x 10^6 barrels is 3,058 barrels for transport by barges and 273 barrels for transport by tankship. The large difference between these quantities arises from the large difference between the number of trips required, 2,953 barge trips versus 150 tankship trips. This difference more than compensates for the sevenfold difference between the expected quantities spilled from tankship casualties and barge casualties.

Figures 3.15 and 3.16 show the frequency distribution of spill sizes for tankship and barge transportation accidents.

As is well known, oil spilled onto water produces a very extensive slick. The following relationship between spill quantity and slick area or radius, assumes unhindered (no wind, currents, or surface obstacles) spreading and a circular-shaped slick:[38]

$$A = \pi r^2 = 2.52 \times 10^4 \ (V)^{3/4}$$

Table 3.16

Risk of Spills of Crude Oil from Marine Transport Accidents at the West Hackberry Site

	Temporary Fill System-Barges	Permanent System Tankships
Frequency of oil spills from vessel casualties[c], spills/trip	5.4×10^{-5}	3.3×10^{-5}
Median qualtity of oil spilled from vessel casualties[c], bbls/spill	1100	8300
Expectation quantity of oil spilled from vessel casualties[c], bbls/trip	0.15	0.89
Frequency of oil spills from accidents at the marine terminal, spills/trip	8.4×10^{-3}	8.4×10^{-3}
Median quantity of oil spilled from accidents at the marine terminal, bbls/spill	18	18
Expectation quantity of oil spilled from accidents at the marine terminal, bbls/trip	0.93	0.93
Total expectation quantity of oil spilled for transport of 60×10^{6} bbls, bbls	3087[a]	273[b]

a 2858 barge trips
b 150 tankship trips
c Groundings, rammings, structual failure of vessel, etc.

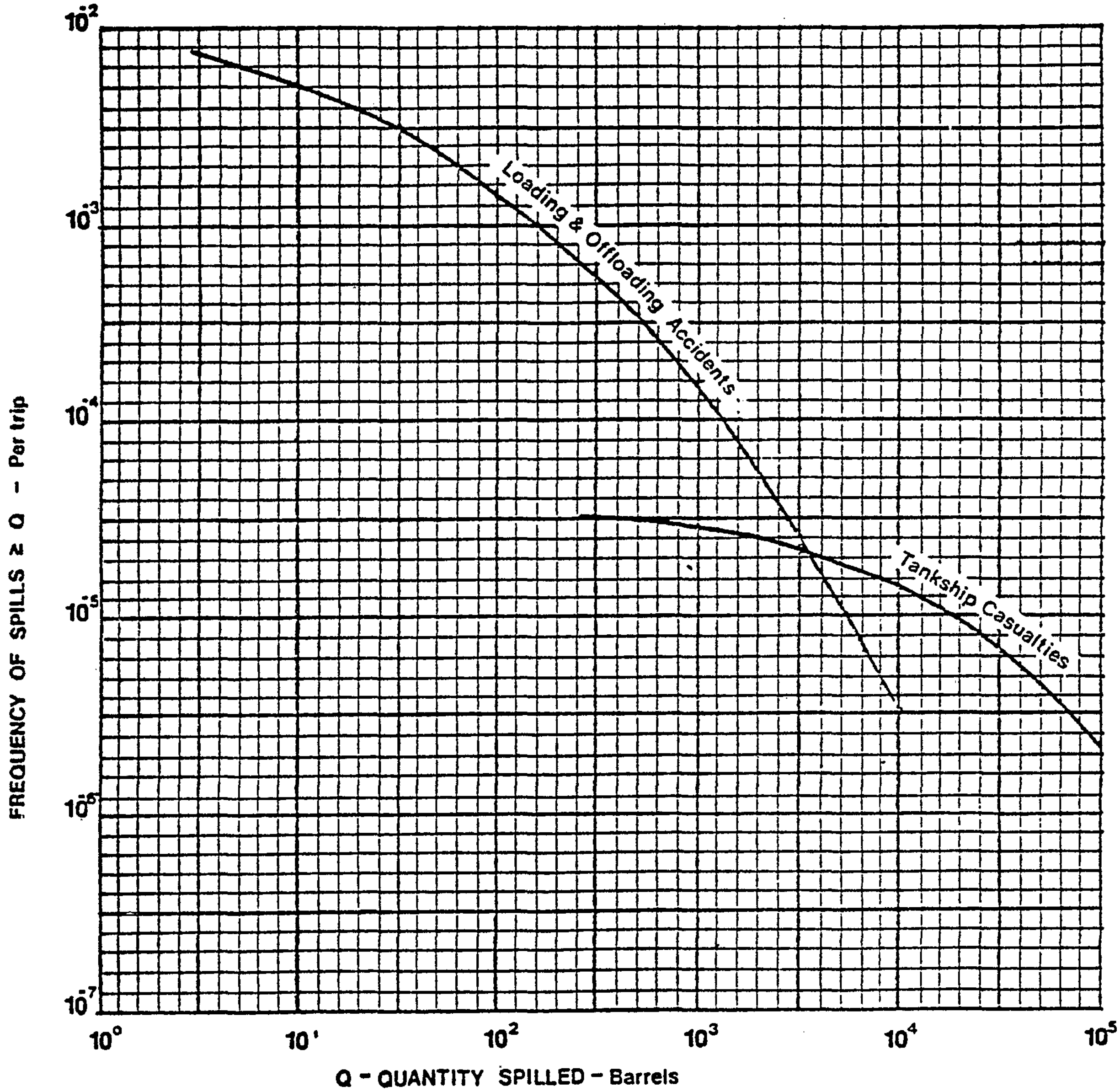

Figure 3.15 Estimated Frequency Per Trip of Crude Oil Spilled from Accidents During Transport by Tankship

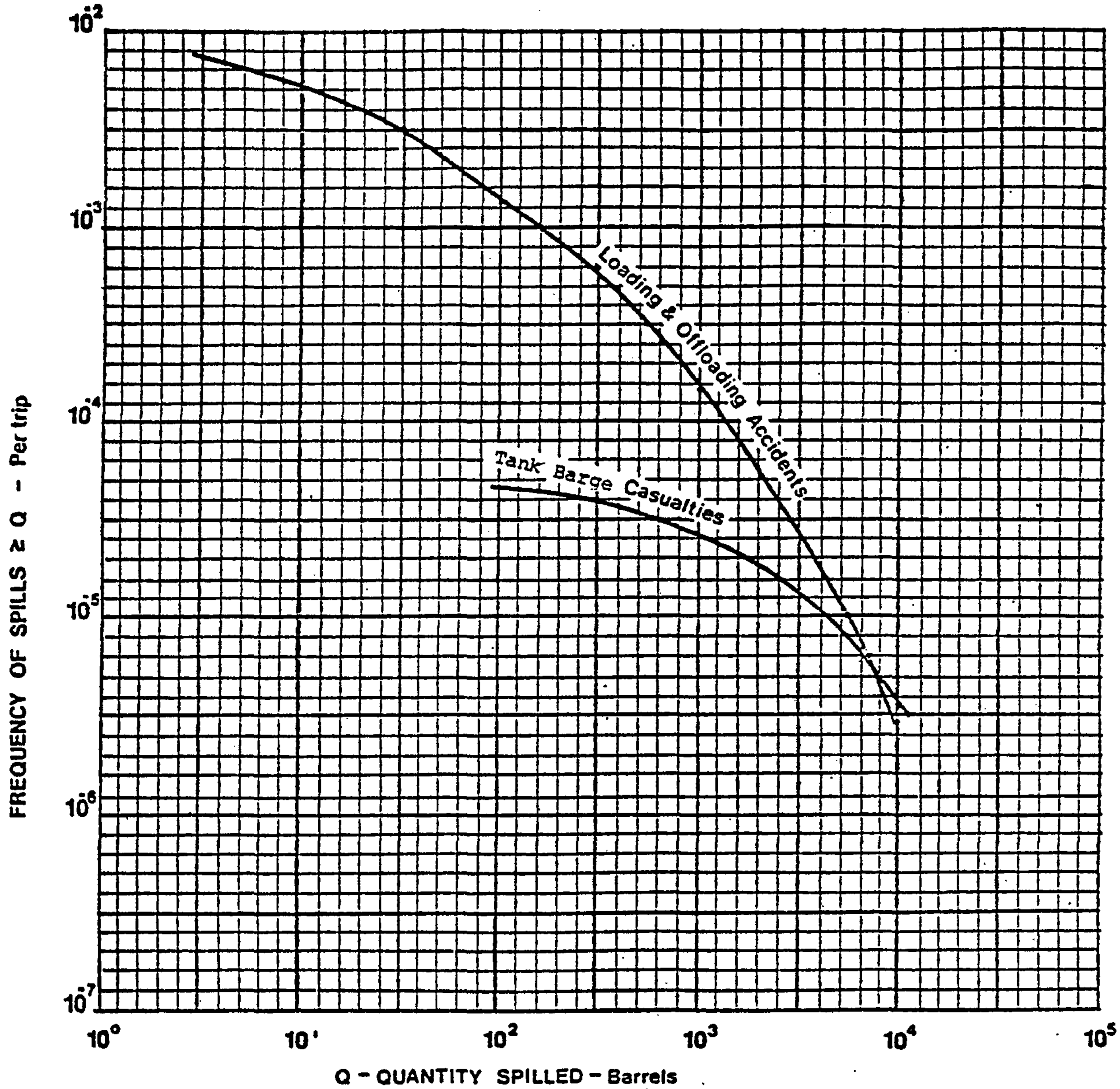

Figure 3.16 Estimated Frequency Per Trip of Crude Oil Spilled from Accidents During Transport by Tankbarge

Where A is square meters, r is the radius of the slick in meters, and V the volume spilled in barrels.

These dimensions are achieved 24 to 48 hours after the spill. For the median spill quantities listed in Table 3.16, the ultimate slick dimensions were computed:

	Quantity Spilled (barrels)		
	18	1,100	8,300
Slick area (m^2)	0.22×10^6	4.81×10^6	21.9×10^6
Slick radius (m)	469	1,237	2,640

With respect to the temporary barge-fill system, spills at the West Hackberry terminal are expected to remain at the site, and in the absence of booms or other containment measures, they would spread into the surrounding marsh areas rather evenly. There are no known major water currents in the area and the vegetation above the water surface in the marshes would greatly limit the effect of wind on the movement of the slicks. Spills in the Alkali Ditch and the Intracoastal Waterway would be expected to behave similarly during periods of light winds (occurring 19 percent of the time). However, during periods of higher winds, the slick will be blown along these waterways at about 2 to 3 percent of the wind velocity.[38] Thus since east winds occur about 25 percent of the time (see Figure 2.21), slicks in the Intracoastal Waterway will move in a westerly direction this percentage of the time. However, the edges of the slick which have penetrated into the bordering marshes will tend to remain in place, unaffected by the wind.

Currents in the Calcasieu Channel, also are negligible except in the portion between the Calcasieu Pass and St. Johns Island (see Figure D4-2). Here the currents may be of the order of one knot, driven by the tides. Except in the portion which passes by West Cove the Calcasieu Channel is constrained by dredged spoil or natural banks. Thus oil spills occurring in that West Cove portion would produce a slick which could cover extensive portions of Calcasieu Lake (area 173×10^6 m^2)*, and West Cove (area 41×10^6 m^2)* depending on the direction of the wind. Spills at the ship terminal at Hackberry or in the channel between Hackberry and Long Point (see Figure D.4-2) would remain primarily in the Channel because of the spoil banks and natural land

*Table 2.2

boundaries. Spills in the Channel in the vicinity of Cameron could be swept into Calcasieu Lake during a flooding tide.

3.7.2.2 Risk of Spills from Vessel Casualties

The estimation of the frequency of shipping accidents and spills of oil was based on the number of reported accidents to tankships and tankbarges compared with the number of trips these vessels made into U.S. ports along the Gulf Coast (Brownsville, Texas to Key West, Florida). The accident data was obtained from the U.S. Coast Guard Commercial Vessel Casualty Reporting System in which pertinent items of information have been recorded on magnetic tape. The data for the Gulf Coast area are summarized in Tables 3.17 and 3.18 for tank ships and tank barges respectively.

Only casualties which resulted in loss of cargo, i.e., rupture of at least one of the cargo tanks, were counted for the estimate of spill frequency. From the tables, only 1.4 percent of the reported tank ship casualties and 3.9 percent of the reported tank barge casualties were sufficiently severe to result in a spill of the cargo.

This data base is believed to be accurate and complete. The reporting system has been in effect for over 10 years, and by law, all vessel casualties with more than $1,500 total damages must be reported. Casualties sufficiently severe to cause the loss of cargo invariably involve total damages much greater than $1,500.

For all U.S. ports along the Gulf Coast, there were a total of 9,830 inbound tank ship trips and 76,856 inbound barge trips during calendar year 1974.[39] For a 6 year period corresponding to FY 1969 through FY 1974, it was estimated that there were 60,000 tank ship trips into Gulf Coast harbor during which liquid cargo was carried. Similarly for tank barges, the estimated 6 year count was 460,000 trips. These estimates are believed to be correct to within at least a factor of 2. The reason for this is that the count of outbound ships and barges very nearly equals the inbound count and it is likely that many, if not most, carry a liquid cargo.

In estimating the frequency of vessel casualties with cargo loss, the category "collisions" in Tables 3.17 and 3.18 were excluded from the accident count. According to the Captain

Table 3.17 Tankship Accidents In Inland Gulf Waters During Fiscal Years 1969-1974

Cause	Number of Vessel Casualties	Number of Vessel Casualties with Cargo Loss
Collisions (with other vessels)	81	1
Rammings (collisions with fixed, floating and submerged objects)	75	1
Groundings	14	1
Fires and Explosions	3	0
Structual Failures	24	0
Other (flounderings, capsizing, flooding, undetermined)	11	0
Total	208	3
Total (less collisions)	127	2

Table 3.18 Tank Barge Accidents In Inland Gulf Waters During Fiscal Years 1969-1974

Cause	Number of Vessel Casualties	Number of Vessel Casualties with Cargo Loss
Collisions (with other vessels)	712	25
Rammings (collisions with fixed, floating and submerged objects)	383	9
Groundings	122	8
Fires and Explosions	19	0
Structual Failures	25	4
Other (flounderings, capsizing, flooding, undetermined)	35	4
Total	1,296	50
Total (less collisions)	584	25

Of The Port (U.S. Coast Guard) for the area, the traffic in the Calcasieu Pass and Channel is one way because it is so narrow. Vessels traversing the channel in one direction must complete their passage before vessels can commence a passage in the opposite direction.[37] The same is true of the Alkali Ditch. In the Intracoastal Waterway, the traffic is two way, but one barge tow usually yields to the other, pulling well over to one side to let the other pass. This is arranged ahead of time between the pilots of the tugs on radio telephones.

Accordingly, the frequency of casualties of cargo loss for tank ships becomes:

$$\frac{2 \text{ (losses in 6 years)}}{60{,}000 \text{ (transits in 6 years)}} = 3.3\text{x}10^{-5} \text{ spills/transit.}$$

For tank barges, the same estimate becomes:

$$\frac{25 \text{ (losses in 6 years)}}{460{,}000 \text{ (transits in 6 years)}} = 5.4\text{x}10^{-5} \text{ spills/transit.}$$

It should be noted that these frequencies of spills are an average for the entire inland Gulf Coast area. On the other hand, in the specific segment of the Intracoastal Waterway of interest, there have been no vessel casualty spills during the 6 year period. Similarly, for the Calcasieu Channel, there have been no spills from tank ship casualties. For the entire coastal region of Louisiana, west of the Mississippi, which includes the Calcasieu Channel, there have been only 2 spills from barge casualties of all types.

The Coast Guard Vessel Casualty data reports the dollar value of the cargo loss. These data for tank barge casualties in both the Gulf Coast region and on Western Rivers (mainly the Mississippi-Ohio River system) have been plotted in Figure 3.17. The cost of the material spilled in each incident is distributed log normally with the number of spills. The cumulative distribution curve in Figure 3.17 should be interpreted for any given percent of all spills as having cargo value equal to or less than the indicated value. Most of the spilled cargoes consisted of crude oil and petroleum fuels, and at the time most of the spills occurred, it is assumed that the average value of these materials was $3.00 per barrel. Using this value, the data in Figure 3.17 were converted to a frequency distribution of quantity spill as shown in Figure 3.18. The curve in Figure 3.17 begins to bend over at spill quantities of 8,000 to

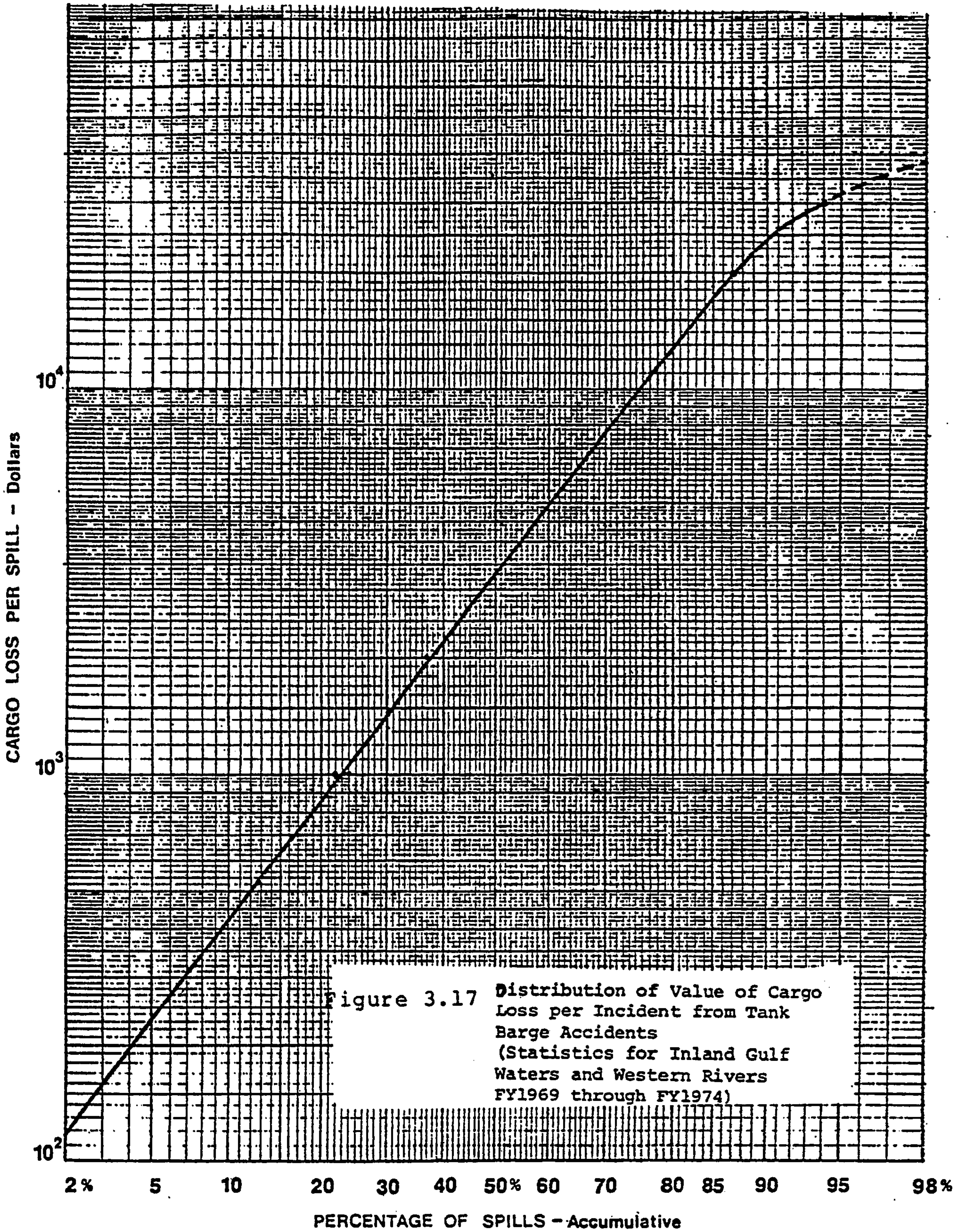

Figure 3.17 Distribution of Value of Cargo Loss per Incident from Tank Barge Accidents (Statistics for Inland Gulf Waters and Western Rivers FY1969 through FY1974)

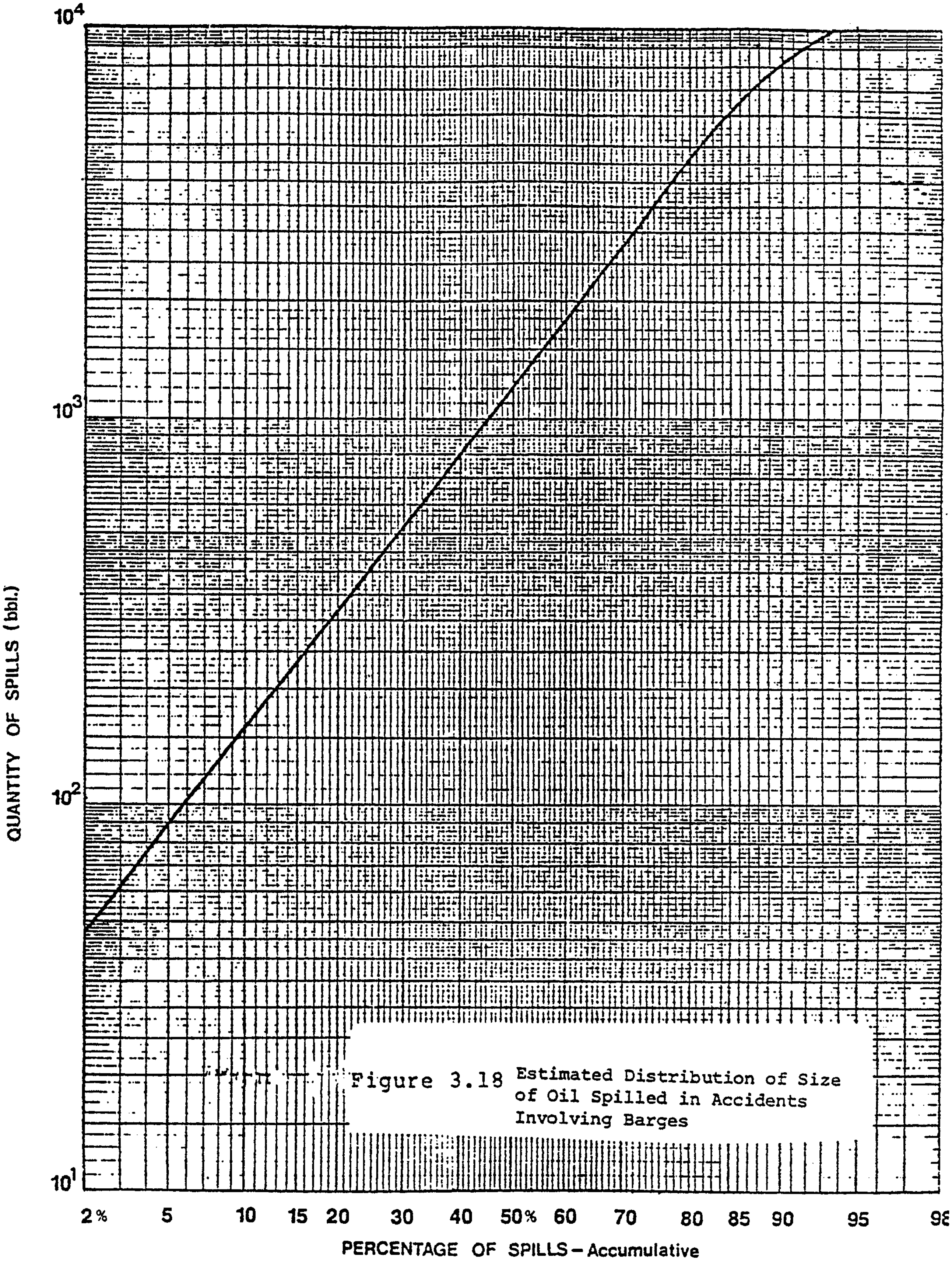

Figure 3.18 Estimated Distribution of Size of Oil Spilled in Accidents Involving Barges

10,000 barrels and this reflects the fact that the capacity of many barges is between 10,000 to 20,000 barrels.

The median quantity spilled is approximately 1,100 barrels. From Table 3.19, the most common tank barge sizes are 1,500 2,750, and 3,000 tons. The two larger sizes are those planned for use in the temporary phase to fill the West Hackberry salt dome cavities. These barges will hold 15,000 to 21,000 barrels of oil in 6 tanks of 2,500 to 3,500 barrel capacity each. Hence the median spill represents approximately 1/3 the capacity of a typical barge cargo tank.

This is indicative of the fact that the damage in a casualty is such that all the cargo cannot leak out, and that the outflows often are sufficiently slow to permit taking measures, such as transfer of the cargo to another vessel or tank, to limit the amount lost.

Since the comparable statistics are unavailable for tank ship casualties, the barge spill distribution curve was modified to estimate the spill size distribution for tankship casualties. For this, it was assumed that the loss of 1/3 the volume of a single tank would be equivalent to the median spill from a tankship casualty. Table 3.20 shows the characteristics of a tankship that is slightly larger (greater draft) than would be used in the Calcasieu Channel. Using these data, it was estimated that a wing tank on a slightly smaller vessel would contain 25,000 barrels, and that the median spill would be 8,300 barrels for the tankship. Assuming the same slope as for the tank barge spill distribution, the spill size distribution for tankships, shown in Figure 3.19 is obtained. The available data indicate that the prediction gives a conservative estimate (tend to overestimate the consequences).

Estimates of the expected spill size frequency from tank ship and barge casualties are presented in Tables 3.21 and 3.22, respectively. The per trip frequencies are simply the product of the spill frequency and the fraction of spills in the given size range from Figures 18 and 19. These data were used to help derive the estimates presented in Table 3.16 and Figures 3.15 and 3.16 discussed above. The expectation quantity of crude oil spilled is the sum of the products of frequency and quantity spilled (average of the ranges in Tables 3.21 and 3.22) for all spill sizes.

3.7.2.3 <u>Spills at the Marine Terminal</u>

Spill frequency and size during operations at the barge and tank ship terminals were estimated in a manner similar to

Table 3.19 Barge Size Distribution, Tank

Representative Barge Size (Dimensions in ft)	Draft Empty (ft)	Draft Loaded (ft)	Nominal Tons/Barge	Number of Barges
508 x 90	4.0	34.0	32425	1
340 x 54	2.5	11.0	4680	13
290 x 53	1.5	11.0	3000	520
240 x 50	2.0	9.0	2750	427
185 x 54	1.5	9.6	2100	154
220 x 40	1.5	9.0	2000	65
148 x 54	1.5	9.0	2000	99
195 x 35	1.5	9.0	1500	662
180 x 35	1.5	9.0	1300	105
135 x 40	1.5	6.0	1000	276
215 x 25	1.5	9.0	1200	3
175 x 26	2.0	9.0	1000	38
140 x 26	1.0	6.0	626	91
110 x 30	1.5	6.0	345	191

(Source: U.S. Army Corps of Engineers Waterborne Commerce Statistics Center, Transportation Lines on the Mississippi River System and the Gulf Intracoastal Waterway 1974 (Transportation Series 4)).

Table 3.20

Characteristics of a 60,000 DWT Tankship[4]

Length Overall	731 feet
Beam	105 feet
Draft	43 feet
Gross Tonage	32,000
Net Tonage	23,000
Number of Wing Tanks	8
Approximate Capacity of the Wing Tanks	27,500 bbls
Number of Center Tanks	5
Approximate Capacity of the Center Tanks	46,000 bbls

Source: "Offshore Petroleum Transfer Systems for Washington State," Oceanographic Institute of Washington, December 16, 1974, p. III-54.

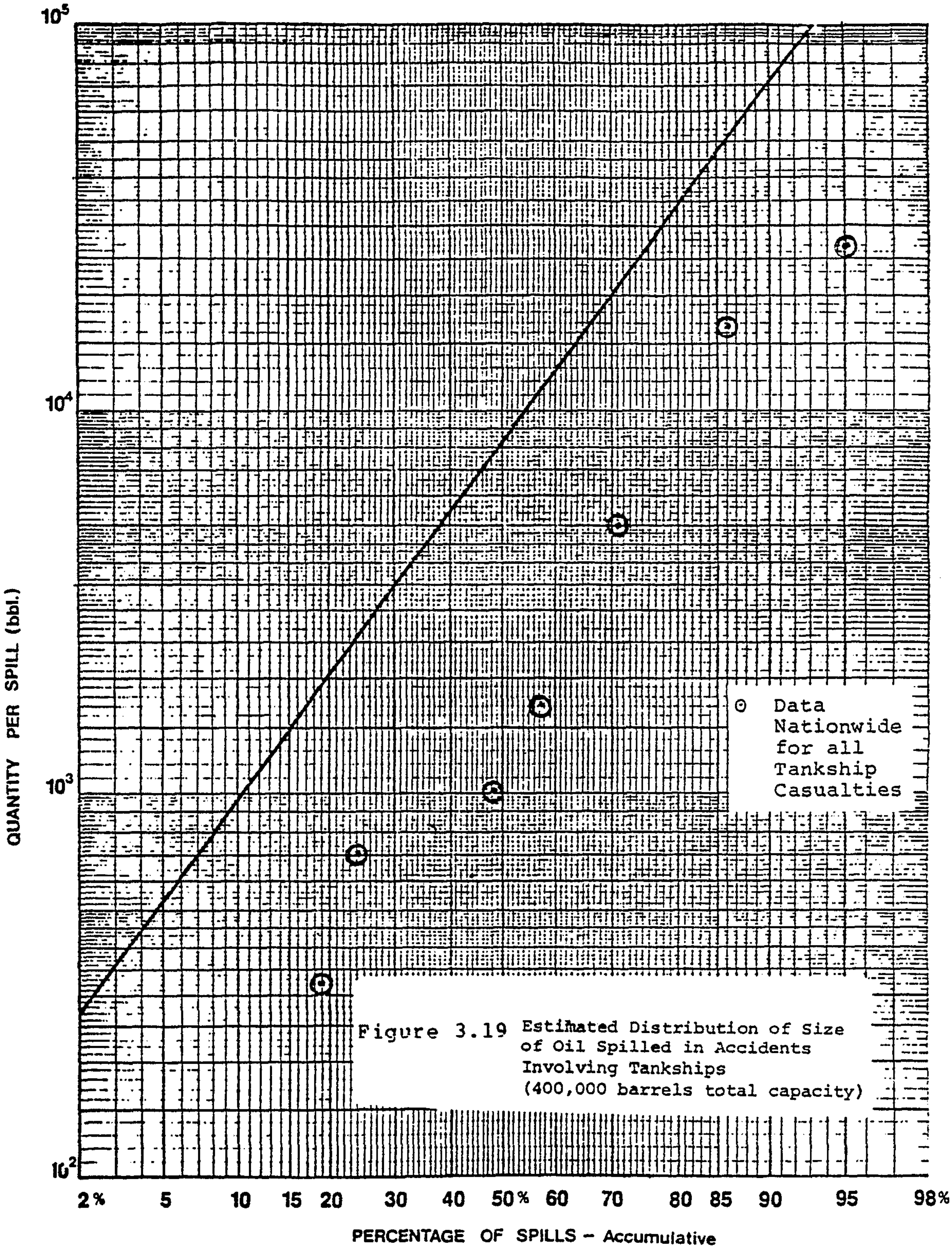

Figure 3.19 Estimated Distribution of Size of Oil Spilled in Accidents Involving Tankships (400,000 barrels total capacity)

Table 3.21

Estimated Spill Size Frequency
From Tankship Accidents
(Permanent Fill and Distribution System)

Spill Size (BBLS)	Frequency (Per Tankship Trip)	Frequency per Transport of $60x10^6$ bbls[a]
<300	$7.59x10^{-7}$	$1.14x10^{-4}$
300-1000	$2.61x10^{-6}$	$3.92x10^{-4}$
1000-3000	$5.61x10^{-6}$	$8.42x10^{-4}$
3000-10,000	$9.04x10^{-6}$	$1.36x10^{-3}$
10,000-30,000	$7.66x10^{-6}$	$1.15x10^{-3}$
30,000-100,000	$4.75x10^{-6}$	$7.13x10^{-4}$
>100,000[b]	$2.18x10^{-6}$	$3.27x10^{-4}$

a 150 Trips
b Maximum quantity spilled is 400,000 bbls, the capacity of the tankship.

Table 3.22

Estimated Spill Size Frequency

From Barge Accidents

(Intermediate Fill System)

Spill Size (BBLS)	Frequency (Per Barge Trip)	Frequency per Transport of $60x10^6$ BBLS[a]
<100	$3.83x10^{-6}$	0.011
100-300	$7.61x10^{-6}$	0.022
300-1000	$1.41x10^{-5}$	0.040
1000-3000	$1.34x10^{-5}$	0.038
3000-10,000	$1.16x10^{-5}$	0.033
>10,000[b]	$3.62x10^{-6}$	0.010

a 2858 Barge Trips

b The maximum quantity spilled is 21,000 bbls, the capacity of the barge.

that used for vessel casualties. A count was made of the total number of spills and quantity spilled at marine terminals during a single year, 1974. Next, an estimate was made for the total number of barges and tankships loaded or unloaded at these terminals. Spill frequency was obtained simply from the quotient of the number of incidents and the number of loading and offloading operations. A spill size distribution was estimated by adjusting the distribution in Figure 3.18 such that the median equalled the size of the average spill. Data on the individual incidents were not examined and the actual size distribution could not be developed.

The data base for the number of spill incidents was the U.S. Coast Guard's Pollution Incident Reporting System (PIRS).[40] Data for the year 1974 are reported in summary form by the Coast Guard.[35] The number of spills and the total amount spilled in the entire United States at marine terminals from the shore facility and from tankship and tank barges at the terminal have been accumulated and broken down by type of cause. These are reproduced in Table 3.23. It is not clear from this source if all these spills were associated with loading and unloading operations. However, from the nature of the causes listed, they could have been. The assumption made here is that they were. This is conservative in the sense that the number of spill incidents associated with loading and offloading may be overestimated. In this vein, a question arises concerning the completeness of the data. The requirements according to law are that all spills of polluting substances must be reported.[40] U. S. Coast Guard personnel feel that all of the larger spills eventually are reported, and therefore, the data base is adequate.

The manner in which the number of loading and offloading operations were counted also tends to overestimate the frequency of spills. During recent years, there are approximately 33,000 tank ship trips into all U.S. ports annually.[41] A major fraction of tank barge traffic into U.S. ports occurs in Gulf Coast ports, approximately 80,000 trips inbound annually.[39] Also, during 1974, there were 34,000 east bound tank barge trips along the Intracoastal Waterway.[39] It is assumed that for each inbound trip into a port, a tank ship or tank barge makes at least one stop to load or offload a bulk liquid cargo. On the Intracoastal Waterway,, the assumption is made that the number of trips in one direction (only) corresponds to at least 2 loading/offloading operations (one at the origin and one at the destination). This adds to a total of 181,000 loading

Table 3.23

Spills Loading and Offloading Bulk Cargo

At a Marine Terminal

Cause	Shore Facility		Tankships and Tank Barges	
	Number of Incidents	Total Barrels Spilled	Number of Incidents	Total Barrels Spilled
Tank Ruptures, Leaks	7	477	-	-
Pipe and Hose Ruptures and Leaks	82	921	117	296
Valve Failure	21	191	120	722
Pump Failures	9	1,742	18	19
Other Leaks and Equipment Failure	81	250	182	957
Tank Overflow	30	24,179	366	2,916
Personnel Errors	85	2,340	278	1,994
Intentional Discharges Including Bilge Pumping	6	73	112	1,016
Natural or Chronic Phenomenon	22	420	4	0
Unknown	21	28	116	7,647
Total	364	30,621	1,313	15,567
Average Spill	84 bbls/spill		12 bbls/spill	

and offloading operations. Not included in this count is an appreciable tank barge traffic along the Mississippi River system and tank barge trips into U.S. ports other than those along the Gulf Coast. Therefore, a total of 2×10^5 loadings and unloadings of bulk liquid cargo are assumed to occur annually at marine terminals in the United States. Because of the count of operations left out, it is believed that the value 2×10^5 may be low by a factor of 2.

Combining this value with the number of spill incidents listed in Table 3.23, the following spill frequencies are obtained:

$$\frac{364}{2\text{x}10^5} = 1.8\text{x}10^{-3} \text{ spills/trip}$$

from the terminal, and

$$\frac{1313}{2\text{x}10^5} = 6.6\text{x}10^{-3} \text{ spills/trip}$$

for loadings and offloadings at the marine terminal.

The estimated log normal distributions of the quantity of oil spilled are shown in Figure 3.20. As before, these were derived from the distribution in Figure 3.18 using the average spill sizes listed in Table 3.23 as the median values.* Finally, the frequency of spills in a given size range was calculated as the product of the spill frequency and the percent of spills in the size range. These are listed in Table 3.24 and were used to help construct Figures 3.15 and 3.16 discussed above. The data listed in Table 3.24 also were used to calculate the median spill size and expected spill quantities listed in Table 3.16 above.

*This tends to overestimate the size of the spills in the distribution since the median in a log normal distribution is always less than the average.

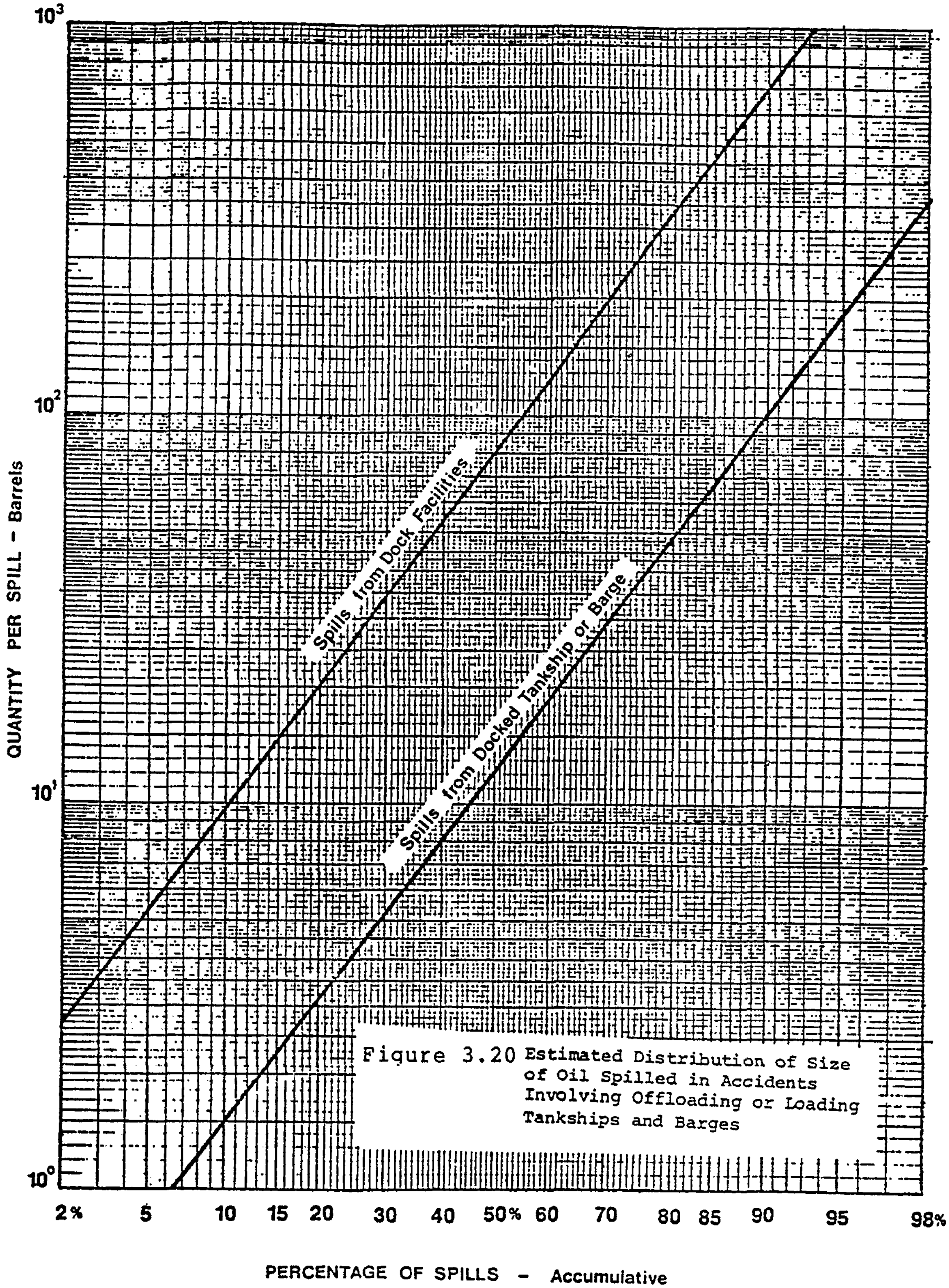

Figure 3.20 Estimated Distribution of Size of Oil Spilled in Accidents Involving Offloading or Loading Tankships and Barges

Table 3.24

Estimated Spill Size Frequency
From Accidents During Loading
or Offloading at the Dock

SPILL SIZE (BBLS)	FREQUENCY (PER OPERATION)	PROBABILITY FOR TRANSPORT OF $60x10^6$ bbls	
		BARGES[a]	TANKSHIPS[b]
< 3	$1.4x10^{-3}$	4.0	.23
3-10	$1.8x10^{-3}$	5.1	.27
10-30	$2.0x10^{-3}$	5.7	.30
30-100	$1.8x10^{-3}$	5.1	.27
100-300	$9.0x10^{-4}$	2.6	.14
300-1,000	$4.2x10^{-4}$	1.2	.06
> 1,000	$1.5x10^{-4}$	0.4	.02

a 2858 barge trips
b 150 tankship trips

3.7.2.4 Ecological Impact of Oil Spills

Oil related risks associated with oil storage in the West Hackberry salt dome facility involve accidental releases from barges, tanker spills, pipeline ruptures, terminal facility storage accidents and ballast water discharges. Such releases pose potentially adverse impacts to Calcasieu Lake and bordering marsh and prairie environs. The extent of such impacts depends primarily on (1) the amount and type of oil released; (2) the time of year; (3) how long the oil "weathers"; (4) whether releases are chronic or acute, i.e. 1 or multiple spillages; and (5) type and efficiency of cleanup operations.[42] In addition, the levels of background oil pollution from industrial drilling and transportation operations, spills not associated with the Strategic Petroleum Reserve Program, and industrial effluents into Calcasieu Lake are stresses to the integrity of this ecosystem.

Background Pollution

Pollution and other man-related activities have stressed and presumably continue to stress certain species in Calcasieu Lake. Perret, et al.[43] indicate that 15 separate plants discharge industrial wastes into the Calcasieu River system. Such discharges have been implicated in oyster kills along the northern margin of the lake.[44] The EPA[45], in 1971, cited several companies in the Lake Charles area in violation of Section 407, Rivers and Harbors Act of 1899. Measures to bring companies into compliance have been ordered in most instances.

Sediments in the northern Calcasieu estuary contain petrochemicals and volatile compounds[45] and water samples contain a variety of chemical wastes. Due to the relatively shallow nature (6 foot mean depth of Calcasieu Lake[44]) and occasionally turbid conditions[46] which cause oil to settle, some crude oil fractions will probably submerge and reach the bottom. This, combined with the background load of hydrocarbons already in the sediments, will determine impact on benthic and sediment-dwelling organisms.

Potentially Impacted Organisms and Habitats

The diversity of organisms and habitats in and surrounding Calcasieu Lake is substantial. The likelihood of oil significantly impacting particular habitats varies with location and size of spill, season and other factors. Organisms, for a variety of reasons (physiology, behavior, etc.), vary in their susceptibility to oil pollution Plankton and mobile organisms such as fish, shrimp and birds are the groups most likely to first contact an oil spill in Calcasieu Lake. Benthic and sediment dwelling forms may be affected if oil sinks to the bottom. Intertidal and marsh areas can be affected if oil reaches shore. Breeding areas of birds and mammals occur in marsh areas.

Plankton

Plankton, attached algae, and detrital inputs collectively form the basis of the estuarine food web in the Calcasieu region as well as offshore Gulf waters, with detritus the major component.

Phytoplankton and zooplankton are comprised of very small organisms whose movements are greatly influenced by currents producted by tides, winds and other factors. Some vertical movement is exhibited by some forms but the capacity for avoiding an oil spill by plankton is very limited. Fish eggs and larvae of many benthic organisms (including oysters) are major components of the temporary zooplankton. Many forms are planktonic throughout their life cycles.

Available field evidence indicates that plankton populations are not adversely affected by oil; however, since these species are readily transported by water currents it is difficult to discern effects in the field.[42] Further, oil may be ingested by some species and toxic fractions can be transmitted to higher tropic levels. There is little evidence that oil transmitted in this fashion will be concentrated in higher forms, i.e. food chain magnification effects are not likely.[42]

Phytoplankton are generally characterized by high growth rates and populations can rapidly replace losses. Also migration of these forms from unaffected areas can repopulate affected areas. Physiological effects of oil include accelerated phytosynthesis at low concentrations (10 to 30 ppb) and reduced photosynthesis at higher concentrations (60 to 200 ppb).[42]

Since many temporary zooplankton species have longer life cycles and larval and juvenile stages are more sensitive than adult stages, oil can affect these groups to a greater extent. This is particularly important in that heavy mortality of these forms can affect density and population structure of these populations for one to several years beyond the initial kill.

Mobile Forms

Fish, crabs and shrimp comprise a major portion of the large mobile species in Calcasieu Lake. This lake constitutes an important "staging" area for brown, (*Penaeus aztecus*) and white (*P. setiferus*) shrimp before their offshore migrations and they are actively harvested during this staging period.[47] Brown shrimp apparently migrate from Rockefeller Refuge into Calcasieu Lake from June through July of each year.[47] Thus a major oil spill (>1,000 bbls) immediately prior to or during this period can be expected to especially impact shrimp populations. This extent of mortality is difficult to estimate due to the mobile nature of these species. There is a potential for a a reduction of food supply and habitats in addition to direct effects.

The response of mobile forms to oil is varied; many species of fish can avoid oil and oil related fish kills which have been reported for the area generally occurred in restricted bodies of water. The avoidance behavior of most mobile groups to oil is poorly known, and different age classes and species have different abilities to avoid oil. Some bottom dwelling forms (crabs and some fish) are less mobile due to dependence on the bottom for food, cover, and breeding grounds. Submerged oil which covers the bottom can reduce these resources, but impacts can be expected to localize. Direct oil effects of most mobile forms is not considered likely.

Oysters

Natural oyster reefs exist in certain areas of Calcasieu Lake but are greatly reduced in size when compared to former oyster stocks.[44] Oyster reefs were apparently destroyed by activities associated with construction and maintenance of the ship channel in the early 1960s[44], especially disruption of the natural circulation pattern of the lake. Production declined from 80,000 barrels of oysters in 1962 to 3,000 barrels in 1964 and the lake was closed to commercial oyster tonging.[44] Recent efforts to re-establish viable oyster reefs have been successful, however, re-establishment is hampered in the northern portions by chemical effluents.[44, 48]

Crude oil can suffocate oysters and/or stress oysters such that they become more susceptible to diseases and other mortality factors. Oil can be incorporated directly into body tissues and may render the substrate unsuitable for larval settlement.

Large and concentrated quantities of submerged crude oil are apparently required to produce direct mortality. Mackin and Sparks[49] indicate that a continuous 2-week release of crude oil from a well in coastal Louisiana did not significantly affect oyster survivorship. Although evidence suggesting the absence of synergistic effects of oil and disease incidence exists, it appears inconclusive due to problems associated with the testing situation. The roles of oil stress and disease incidence are complicated and the relationship between these factors is probably best viewed as unresolved.

Oysters take in oil from water suspensions by filter feeding and store it in lipids.[50] These hydrocarbons, once in lipids, may remain essentially unchanged for months.[50,51] Such stored products can result in oily tasting oysters.[52] A commercially important food resource of Calcasieu Lake may be contaminated and unusable for an undetermined period after oil uptake.

The duration of edibility effects obviously depends on many factors such as the initial amounts of oil consumed and stored in body tissues and whether the sources of recontamination (new spills, seepage from sediments, etc.) exist.

Influences on reproduction and/or larval survival from contaminated adults is unknown; however, the high reproductive potential of oysters and the probability of immigration of larval oysters from other areas are mitigating factors. Direct fouling of the suitable oyster substrate by crude oil can be expected to be a short-lived phenomenon.

Other Benthos

Most other benthic organisms, whether occurring on the substrate or in the muds, are susceptible to oil due to their generally low mobility and dependency on the substrate for cover and/or attachment.

Mortality of sea urchins, starfish and other subtidal and intertidal benthic invertebrates due to oil spills as been recorded[42] and short-term changes in community structure can be expected in the event of larger spills. Recovery of communities can occur by immigrating individuals reestablishing populations. Bottom sediments can act as reservoirs of oil contaminants which occasionally release oil to the lake waters and serve as a source of chronic pollution. Although degradation of crude petroleum in Louisiana muds is reported to be rapid,[49] background levels are relatively high and additional releases can be expected to increase those levels. The degree to which they will be increased cannot be accurately predicted, however.

Marshes: Vegetation

Calcasieu Lake is bordered by extensive areas of intermediate and brackish marshes [53] including substantial areas of Sabine National Wildlife Refuge which borders on both the western and eastern margins of the lake. Marshes are the inland aquatic communities likely to be impacted by an oil spill.

Damage to plants occurs when oil penetrates. Cell membranes are damaged and oil may enter the cell.[54] Blockage of stomata and intercellular spaces can occur and transpiration rates be reduced. Photosynthesis can also be inhibited.[54] The extent of the actual impact depends on several factors. Many studies have shown that marsh plants survive light to moderate oilings in a single application.[42, 55, 56] Adverse but short-term effects are death of oiled shoots, reduced germination of contaminated seeds, and a reduction of annual species.[56] Recovery by marsh vegetation can be expected to be rapid (less than 2 years) under these conditions. Successive spillages within a few months of one another, however, can produce longer lasting effects. Using the calculated frequency of spillages from barges and tankers (Section 3.7.2.1) the probability of the extensive sections of marsh bordering Calcasieu Lake receiving in excess of 4 oilings in any 2 to 3 year period of the project is small. In this time period, 4 or more oilings have been shown to produce substantial mortality of marsh vegetation to the point that recovery was retarded.[57, 58]

The degree of weathering of crude oil directly affects its toxic content and several studies[55, 59] have indicated that several days of weathering, i.e. period at sea before beaching, reduces the deleterious effects of oil on plants. The more toxic, aromatic compounds have time to evaporate and disperse during this period. The shape, size (52,878 acres)[60] and enclosed nature of Calcasieu Lake means that oil that is not cleaned up or which quickly sinks to the bottom will be deposited along the shoreline before a great deal of weathering can take place. This, of course, depends on the location of any such spill, its size, the prevailing wind and water circulation patterns and the efficiency of cleanup operations.

The timing of an oil spill has differential effects on marsh vegetation. Oiling during the active, growing stages causes more damage than at other times.[42] Annual plants suffer more than perennials when oiled during the growing season;[42] the opposite appears to be true at other times.[59]

Birds

Mortality of birds due to oil spillage is well documented from a number of major tanker and oil platform spills[42] and it is a highly visible impact. Mortality can occur when feathers lose their insulating properties, birds lose body heat and subsequently die of pneumonia. Destruction of water-proofing can result in drowning. Diving sea birds suffer substantially greater mortality than other groups[42] since then can emerge from under an oil slick and be covered. The probability of an oiled bird surviving has been calculated at 20 percent or less and oiled birds may not lay eggs and/or eggs may not hatch.[42] Accidental consumption via preening of crude oil (12.5 to 50.0 ppm in water) interferes with certain physiological processes and results in dehydration.[61] Roosting and nesting sites which are contaminated by oil are uninhabitable.

The area around Calcasieu Lake is an important overwintering ground for a tremendous variety of migratory bird species (Chapter 2). Sabine National Wildlife Refuge which contains extensive wintering grounds borders both the eastern and western margins of the lake. This refuge, which is at the southern end of the Mississippi Flyway, is an important national resource and harbors large populations of Gadwall, Northern Shoveler, Widgeon, and Green-Winged Teal. The Southern Bald Eagle, an endangered species, may occur near Calcasieu Lake and Peregrine Falcon migrate through the area. For these reasons, oil spills in Calcasieu Lake, which may be deposited in the Refuge's marshes, may be of potential significance. Oil spills in the lake to date have had little apparent impact on bird populations.

Ecological Impacts of Oil Pipeline Spills

Oil pipeline ruptures occurring along the 4.0 mile pipeline from the dock facilities in Calcasieu Lake to the Hackberry dome can be expected to vary in impact depending on the amount degradation can change the oil's physical characteristics and influence the rate of movement. The oil is affected after release and/or during transport by separating processes of evaporation, dissolution, emulsification, sedimentation, and chemical oxidation, as well as biological degradation. The lighter, more toxic oil components are lost by evaporation. This creates a heavier surface residue which may become heavy enough to sink. Particles in suspension (silt, clay, organic material) may combine with the oil so that sedimentation is increased. Conditions of increased turbidity, such as during periods of high surface water runoff or water turbulence would increase this effect. Bacterial masses in the slicks can increase sedimentation also. Emulsification results in suspended globules which, it is believed, eventually settle out after contact with suspended particulates.

Related Effects on Recreational Activity

The wide variety of fish, birds, and mammals found in this region are largely responsible for the high level of fishing and hunting as recreational activities. Large oil spills, as we have seen, are capable of causing bird and fish mortalities that are large if the oil is able to spread considerably. The settling of oil to the bottom can further disrupt the ecosystem, and prevent recovery of the affected region for some time. It follows that such a large spill would result in decreased recreational fishing and hunting in the affected area; the economic impact would vary with the size of this area.

Chronic smaller spills may similarly cause mortalities over a longer period of time, and possibly over larger areas, resulting in overall decreases in wildlife population. As has been discussed, certain species are more vulnerable to these effects. Decreases in wildlife population due to such chronic spillage might lead to an overall reduction in recreational hunting and fishing; these recreational activities might or might not be displaced to other areas.

Effects of Cleanup Operations

Containment and cleanup operations of oil spills from barges, tankers and at dock facilities into Calcasieu Lake and spills from oil pipeline ruptures are the overall responsibility of the U.S. Coast Guard. They must be notified whenever a spill occurs and an On-scene Coordinator oversees cleanup operations and takes whatever steps necessary to assure appropriate cleanup procedures are implemented. Biological effects of cleanup operations are minimal. Emulsifiers and other chemical agents have been virtually discontinued and the requirement that use of such agents must be Coast Guard approved on scene[62] suggests that cleanup operations will not adversely impact the environment. Mechanical removal procedures (booming, skimming and pumping) can be expected to ameliorate the potentially harmful effects of an oil spill and should not be a source of negative biological impact.

Cleanup operations in marshes and on beaches could involve removal of damaged vegetation and dead animals. Burial can have an impact on the specific site used to dispose of such material. It is assumed that chemical cleansing agents will not be used in these situations.

3.7.2.5 Effects of Oil Spills on Shallow Aquifers

The soil underlying the beaches and shore deposits near West Hackberry is primarily Pleistocene clay. Such soil represents the upper layer of an impermeable clay aquitard from 100 to 400 feet thick, which is immediately above the Chicot aquifer in the West Hackberry area. This layer of clay may be interlaced with a few thin aquifers, but such aquifers contain brackish waters, and are not suited for use as water sources. Because the water table is within one or two feet of the surface, the clay should be water saturated. Contaminants from oil spills could possibly permeate into the clay, but only a short distance. No aquifers of any value could be contaminated by such permeation.

of oil leakage and when it occurs. The immediate area through which this pipeline is to be laid is primarily agricultural pasture lands. With the exception of ruptures at the dock facilities or very close to Calcasieu Lake all pipeline spills would occur on dry land.

Effects on soil organisms (collembola, mites, nematodes, earthworms, etc.) and plants can be expected to be severe but very localized in the immediate area of the leakage. The oil would be degraded and/or leached away eventually (over a period of years). Based on a projected mean spill size of 1,000 bbls and initial infiltration of the oil into the ground to a depth of 1 decimeter about 1,600 m^2 or approximately 0.4 acres would be immediately affected in an average spill. The exact coverage depends on soil types, viscosity of oil, pipeline pressure, soil moisture and other factors. It can be expected that oil will reach the water table which along the pipeline route is 2 to 3 feet deep. Slow discharge of oil into a body of water (probably Calcasieu Lake, Black Lake or the bordering marshes) via water table transport can eventually be expected to occur. Thus, a spill of approximately 1,000 bbl can act as a source of low level contamination for periods exceeding several years. The U.S. Coast Guard can take steps to prevent releases into navigable bodies of water. A trench is usually dug near the point of entry into such a water body and when oil collects (generally after rains) it can be pumped off.

The alternative pipeline routes extend through marshland, over dryland, and across open water (e.g., the Intracoastal Waterway and the Sabine River). The impacts on organisms would be as described above for the dryland situation and as given in subsections 3.3.2.2 through 3.3.2.7 for the aquatic habitats. Small spills (up to 300 bbls) tend to spread to a density of 6 to 12 bbls per acre of water surface by surface tension alone. Thus, a spill of 200 bbls could produce a slick of from 33 to about 67 acres if there was no water movement. A greater retention of oil per acre would occur with larger spills.

Oil will spread at the water's surface under the influence of forces of gravity, surface tension, viscosity, surface currents and surface winds. Weathering and other degradation can change the oil's physical characteristics and influence the rate of movement. The oil is affected after release and/or during transport by separating processes of evaporation, dissolution, emulsification, sedimentation, and chemical oxidation, as well as biological degradation. The lighter, more toxic oil components are lost by evaporation. This creates a heavier surface residue which may become heavy enough to sink. Particles in suspension (silt, clay, organic material) may combine with the oil so that sedimentation is increased. Conditions of increased turbidity, such as during periods of high surface water runoff or water turbulance would increase this effect. Bacterial masses in the slicks can increase sedimentation also. Emulsification results in suspended globules which, it is believed, eventually settle out after contact with suspended particles.

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3.7.3 Fires and Explosion on Site

An analysis of the available fire and explosion data associated with petroleum production, storage and transportation (for example, USGC data) indicates that almost all major fires and explosions are in conjunction with high pressure situations or blowouts.[63] Only during the core hole drilling phase does the possibility exist in the SPR Program, and during this phase it is only a remote possibility. The more probable occurrence is for minor fires caused during repairs or maintenance, or caused by overheated engines or leaks onto hot surfaces.

The impact on the environment of such fires will generally be a temporary release of smoke to the atmosphere. It is unlikely that any crude or brine spill would occur because of the protective measures such as levees. Even in conjunction with OCS production, where the risk of environmental release is greater, from 1968 to 1975 only two fires or explosions (not associated with blowouts or high pressure operations) resulted in oil spills (one of 100 barrels and one less than a barrel). The maximum spill associated with a well head failure would be approximately 100 barrels on the storage site within the dikes. Although it is rare for crude spills to catch fire, if a 100-barrel spill did occur, the following emissions would occur:

CO_2: 34,000 to 34,700 pounds
SO_2: 6 pounds (emissions depending on emitted H_2S Conc.)
NO : 66 to 1,000 pounds

Actually, since combustion is incomplete, certain quantities of petroleum would vaporize, and carbon particulates, carbon monoxide, nitruous oxide, and sulfur monoxide would be formed. The weather conditions at the time of the accident would influence the exact amounts. This would degrade the air quality for a short time.

3.7.4 Accidental Injury

In incidents recorded by USGC from 1968 through 1975, a total of 15 people were killed (9 in a single explosion) and 42 injured in some twenty injury-or-fatality-causing OCS accidents that did not entail high pressure or "blowout" circumstances.[63] (Ship specific incidents are not included). Again, offshore operations are more dangerous because the compact work area on a platform results in activities being performed near one another that from a safety standpoint should not be. Considering these factors and the number of

OCS operations during the 8 years of recorded data, the probability of accidental injury or death appears to be minimal with respect to the Strategic Petroleum Reserve at this salt dome site.

3.7.5 Natural Disasters

Natural disasters that may cause a problem in conjunction with this project include seismic disturbances, hurricanes, tornadoes, lightning, and floods. Of these, a strong seismic event would have the greatest potential impact on the storage cavity. The probability, however, of such an occurrence is extremely low. The National Oceanic and Atmospheric Administration (NOAA) describes the West Hackberry dome area as a Zone 1 seismic risk area. This classification means that if a quake did occur, only minor damage to surface structures would be expected and there would be no damage to the cavern itself. Further, a record search conducted by NOAA indicates that no earthquake has ever been recorded for the immediate West Hackberry area.

The current frequency of occurrence of hurricanes in the Gulf Coast area is approximately one every four years. It is anticipated that little damage to the onsite facilities will occur during a hurricane. However, in the event that significant damage did occur to the facilities, it would cause no permanent environmental impact. To prevent damage to the facility and subsequently to the environment, certain precautions should be followed as a hurricane approaches, such as:

1. Empty crude and brine from all pipelines, settling tanks, surge and temporary storage tanks, then weight these tanks to preclude damage that would be caused by the tanks floating.

2. Place all down-hole safety devices in a safe position.

3. Have a standby electrical system (batteries) to keep monitoring equipment in operation.

4. Have a manually operated control, remote from the facility to disconnect all electrical power at the facility.

In general, the impact of floods on the storage facility would be very little. Buildings, electrical equipment, and pumps would be damaged, but flood water would not damage, nor even enter, the storage caverns as the system design protects against flood water entry.

High winds should not affect any critical components of the project, since these structures are designed to withstand a "100-year storm." Any damage to buildings would have little environmental impact as long as waste disposal procedures are followed for the damaged components. Any resultant power failure will cause no adverse environmental impact because the system fails in a safe manner.

Although lightening can cause fires when striking some system components, these are considered of low probability in the first place, and most likely of little environmental consequence if they do occur. Tornadoes are a low probability occurrence at any given location, except perhaps during a hurricane which is addressed above.

3.7.6 Cavity Collapse

The inherent characteristics of solution mined caverns make them one of the safest possible means for crude oil storage. The plastic nature of salt at the temperatures and pressures present permit the caverns to withstand shock forces far in excess of any earthquake known to have occurred in the Gulf Coast region. Although cavity collapses have occurred in this region, these collapses seem to have occurred as a result of factors such as uncontrolled leaching adjacent to the caprock, with subsequent subsidence of the unsupported overburden. [65]

A number or factors affect the stability of cavities in salt domes including: cavity depth, diameter, and temperature; dissolution; and proximity of the salt dome boundary or other cavities. These factors were considered in selecting the cavities proposed for development in the SPR Program.

For existing cavities, the major factor is changes in proximity to salt dome boundaries or multiple cavities. Since cavities used for oil storage grow approximately 15 percent during each cycle of fill and withdrawal due to dissolution of salt, it may be necessary to control growth of the cavity in some cases. This may be accomplished in the upward direction by maintaining a blanket of oil near the cavity ceiling and may be controlled in all directions by using saturated brine rather than fresh water as the displacement fluid.

The proposed storage caverns use a blanket of crude oil to control growth in the upward directions, (see Figure 3.21). The location of the oil-brine interface may be monitored by any one of several available instruments such as sonic interface detection, nuclear logging, and oil column pressure gauging. One or more of these devices would be utilized to monitor the oil-brine interface. Thus the level of the oil-brine interface can be controlled to preclude upward leaching. However, as may be noted from Figure 3.21, the physical arrangement of the well casings prohibits withdrawal of oil above the location of the annulus through which the oil is withdrawn. Thus an oil blanket would always be present in any leached spaced above the location of the annulus. This provides a fail-safe design not subject to operator error. Casing cement failures at upper levels (for example the 16" at 2500' in Figure 3.21) would be easily detected and repaired using standard techniques.

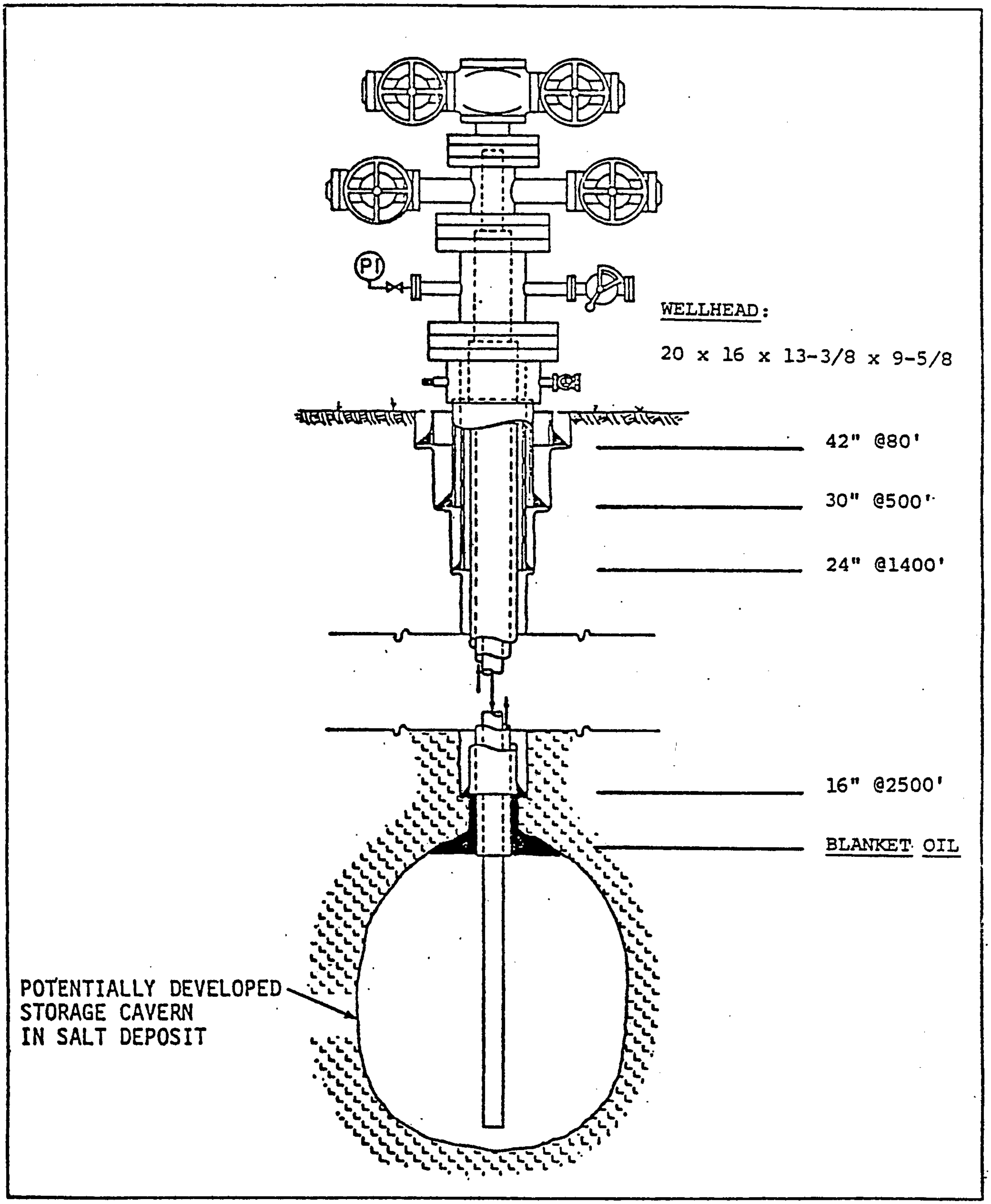

Fig. 3.21 Typical Storage Well

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4. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED AFTER APPLICATION OF MITIGATING MEASURES

4.1 SUMMARY

Abstracted from the preceding discussions and shown in Table 4.1 are the anticipated environmental impacts of the construction and operation of the proposed Strategic Petroleum Reserve storage program at the West Hackberry salt dome. Also listed are the causes of the impacts, the mitigative measures available to lessen their effect, and the unavoidable impacts which would still result even if the mitigative measures were employed. Although environmental impacts of extreme severity are not present, several unavoidable disturbances would result. The most significant effects are discussed briefly in this summary.

Construction Impacts

Construction operations would be the most disruptive, inducing soil erosion, increased turbidity and sediment-resuspension in Alkali Ditch and Calcasieu Lake. The construction of new roads, pipelines and further development of the storage site itself will involve the temporary disturbance of existing grazing and agricultural land as well as forcing resident wildlife to emigrate to more tranquil settings until human disruption ceases. The permanent dock facilities, settling, ballast and surge tank sites and dikes will remove from existing use all acreage within the fenced and/or diked areas for the lifetime of the project.

The surrounding surface water system would experience very localized, temporary increases in turbidity, resuspension of sediments and/or biocides from dredging operations and erosion. The resultant impacts on the aquatic community will primarily involve the elimination of minor amounts of benthic organisms and reduced plankton production in the dredged area. During drawdown operations, the use of Black Lake Bayou for the water supply would result in a minor water level drop of Black Lake and possibly could enhance the salt water intrusion already experienced in the Calcasieu Lake shipping channel. The southern end of Calcasieu Lake where it is directly connected to the Gulf, supports aquatic life tolerant of elevated salinity levels and the potential increases in these levels are expected to have a negligible impact upon this environment.

The injection of brine into deep saline aquifers off the southern flanks of the salt dome would increase the down-hole pressure of the aquifer temporarily. The magnitude of these deep aquifers tends to allow rapid pressure equalization provided the injected brine does not clog the aquifer and essentially seal the local injection area off from lateral communication with the rest of the aquifer. Brine settling tanks are to be employed to assure this does not happen. Additional treatment of the brine may be required if it is determined that it is chemically and biologically incompatible with the saline water in the aquifer.

Operational Air Quality Impacts

The handling of crude oil in general results in temporary, localized increases in hydrocarbon concentrations at the dock facilities. As discussed in Section 3.3, these concentrations may be very high during loading and unloading operations. However, these worst-case concentrations would be reduced if vapor recovery systems for tanker loading and unloading were installed. Emission control technology for marine terminals require three systems: (1) a ship-side vapor collection system, (2) a shore-side collection system, and (3) a vapor control unit. The vapor control unit represents the key consideration in emission control technologies, and there are several units which are currently used in the petroleum industry, although they are not generally used for marine terminal and oil transfer operations. Incineration and refrigeration would be the most appropriate methods for the West Hackberry Marine Terminal.

The shipboard vapor collection system would convey the hydrocarbon vapors to the shore-side system, with both systems having collection efficiencies between 90 and 95 percent. These vapors would be incinerated via an elevated, smokeless flare. Smokeless flares convert the hydrocarbons to carbon dioxide and water with better than 99 percent efficiency. Flaring these gases can create sulfur dioxide and nitrogen oxides if sufficient sulfur and nitrogen are present in the vapors. These combustion by-products can be removed with at least 90 percent recovery by scrubbing the gas with water. The overall efficiency of a collection-incineration emissions control system is greater than 95 percent.

Refrigeration of the collected hydrocarbon vapors results in the liquification of the vapors which can then be reinjected into the crude oil at the marine terminal. This recovery has been shown to be greater than 90 percent efficient. Should reinjection not be feasible, the recovered vapors can be used for fuel or sold to petrochemical industries. The overall efficiency of such a vapor recovery system is about 86 percent.

These vapor control systems and the indicated efficiencies are representative of the technologies available in the petroleum industry. Gasoline vapor control technology has been applied in some cases for vessel transferring operations where the liquid and vapor spaces are closed. These systems have not been applied to marine terminal operations for large tankers carrying either crude oil or gasoline. The principles involved in marine vapor collection and control are well understood. Applicable vapor control technology and explosive vapor processing technology have been developed in other fields; however, these technologies need to be refined with respect to marine loading of gasoline. Hydrogen sulfide levels are expected to be minimal since most crude expected to be delivered would have weathered sufficiently during transit to substantially reduce these emissions.

Pipeline Accidents

Crude oil spills along the buried pipeline routes, of a median volume of 1000 barrels would result in an initial infiltration of ten centimeters into the surrounding soil. This infiltration will result in approximately 0.4 acres of land area being effected. Over a period of years the oil contamination of this area will decrease due to degradation of the crude and dissolution due to the heavy annual rainfall in the area. Because the water table in the West Hackberry area is so near the surface (-2 to -3 feet), some quantity of any oil spilled from a pipeline failure will reach the water table and consequently migrate with the natural water migration. This can result in a low level contamination of nearby water bodies for a duration of several years. The U.S. Coast Guard recommends steps to minimize the magnitude of this contamination by digging trenches at the point of entry into the nearby waterbody (Black Lake and Calcasieu Lake). The oil is then collected from these trenches as it migrates towards the larger lakes. Oil migration is enhanced by heavy rainfalls and thus the location of the point of entry into either Black Lake, Black Lake Bayou or Calcasieu Lake will have to be determined fairly rapidly after spills of a significant size, so that this technique can be employed.

The effect of such an underground pipeline spill on soil organisms in the immediate vicinity would be drastic. Organisms such as mites, collembola, nematodes, earthworms etc., would be killed locally. It is not anticipated that the soil organisms in the path of the oil migration in the water table will be as drastically effected since the concentrations of crude oil fractions would be increasingly diluted with time, rainfall and distance the oil is from the spill site.

The only above ground pipelines would be at the storage site and at the dock on Calcasieu Lake and the Alkali Ditch. Should a spill occur above ground it is readily detectible by inspection and the magnitude of such a spill is on the order of barrels (rather than thousands of barrels). These spills are readily contained and cleaned up, leaving negligible environmental damage behind.

Tankships and Barge Oil Spills

The probability of tankship spills ranging from less than 300 barrels to greater than 10,000 barrels (for 150 trips to transport 60 x 10^6 barrels) is estimated to be from 1.14 x 10^{-4} to 3.27 x 10^{-4}, respectively. The total expectation quantity of crude spilled is 273 barrels for the fill of the cavity to 60 x 10^6 barrels, with 150 tankship trips. During the initial barge fill operations (involving approximately 510 barge trips up Alkali Ditch) the probability of barge spills ranging from less than 100 barrels to greater than 10,000 barrels is estimated to range from 1.95 x 10^{-3} to 1.84 x 10^{-3} respectively. The total expectation quantity of crude spilled is 551 barrels for these 510 trips. This number is higher than that expected from tankship deliveries to completely fill the storage capacity, partly due to the greater number of trips the barges will make during the initial fill phase of the program. Over the life time of the program, assuming five fill and drawdown cycles the total expected quantity of oil spilled is 3,008 barrels. The total spill volume expected over the lifetime of the project reflects the low probability of such spills but does not reflect the anticipated median quantity of such a spill, should it occur (eg. 1,100 barrels/spill-barges, and 8,300 barrels/spill-tankships).

Should a spill of median expected volume occur on open water, an oil slick, uncontained, could range (in 24-48 hours) from 1,200 acres to 5,400 acres (1,100 barrels to

8,300 barrels) assuming no currents, wind or obstacles. Depending on the weather conditions and the rapidity of containment and clean-up operations, oil slicks could cover a significant portion of Calcasieu Lake. Any spill in the West Cove portion of Calcasieu Lake would be of particular concern since this region is subject to strong tidal currents and these would enhance the spread of the oil slick, possibly covering extensive portions of the lake and West Cove. Spills at the temporary dock facility at Alkali Ditch would primarily be contained by marsh grasses and the banks of the ditch. Spills in the Ship Channel proper between Long Point and West Hackberry would be expected to be contained in the channel by the dredge spoil banks.

The ecological impacts of a major oil spill (1,000 barrels or more) would probably be most significant to the oyster population. Large, concentrated quantities of submerged crude oil are necessary to produce direct mortality, and this situation is unlikely. What is more likely is the direct ingestion of submerged crude fractions into body tissues by the oyster. This greatly decreases the taste and hence the commerical value of the oyster. Direct fouling of suitable oyster substrate for larval settlement is expected to be short term in the event of a spill.

During the period from June to July, a major spill (1,000 barrels) could impact shrimp populations in Calcasieu Lake since this is the active breeding season. Direct contact of benthic organisms with oil may occur, and there may be the secondary effect of a poorer or reduced quality of food supply.

A general increase in the background level of oil contamination in the bottom sediments would result as well as a disruption of the community structure in the benthic communities affected by an oil spill. Organisms would immigrate after an oil spill and establish new populations.

Marsh vegetation appears to withstand light to moderate oil contamination. Short term effects are generally the death of oiled roots, reduced germination of contaminated seeds and consequently the reduction in annual species. Recovery is relatively rapid, taking less than two years. If more than four oil spills (1,000 barrels) occur within a two to three year period, substantial marsh vegetation mortality is sustained and recovery is retarded. The occurance of spills of this magnitude and frequency is unlikely as witnessed by the low frequency of spills on the Calcasieu Ship Channel to date and the expected fill and refill frequency of the SPR program.

Oil spills in this area have had little apparent impact on the bird populations. However, Sabine National Wildlife Refuge borders Calcasieu Lake and extensive breeding grounds are on the east and west margins of the lake. This wildlife refuge harbors large populations of Mallard, Mottled Duck and Green-winged Teal. The Peregrine Falcon is known to migrate through the area and the Southern Bald Eagle (an endangered species) may occur near Calcasieu Lake. The impact of a large oil spill upon these birds is not known; however the effect on aquatic birds which come into contact with the oil is known to result in a loss of the insulating properties of their feathers, resulting in pneumonia and consequently death.

Table 4.1

SUMMARY OF PRIMARY ENVIRONMENTAL IMPACTS, MITIGATION PROCEDURES AND UNAVOIDABLE ENVIRONMENTAL EFFECTS

ACTION	PRIMARY IMPACT	MITIGATION	UNAVIODABLE IMPACT
Dredging			
Alkali Ditch	$\sim$3-4 acres of marshland will be disturbed during construction of the dock and barge turnaround	none	same as primary impact
	-mobile animals (especially birds) will leave the area; they may return within 2-3 months of completion	none	same as primary impact
	-temporary, localized increase in turbidity -temporary flow impedence	-follow most recent advances in dredging technology to minimize turbidity dispersion	-turbidity localized to within 200 feet
Disposal of Spoil Dredged from Alkali Ditch	-slight temporary localized increase in turbidity, TKN (detrital matter and ammonia), COD	-follow most recent dredge disposal technology	same as primary impact
	-possible slight decrease in total dissolved oxygen	none	same as primary impact
	-temporarily eliminate benthic forms in areas dredged	none	same as primary impact
	-temporarily reduce plankton productivity due to increased turbidity	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Disposal of Spoil Dredged from Alkali Ditch (continued)	-dredge spoil will smother soil organisms and vegetation where disposed on site < 90 acres	-reduce the area covered by spoil	-smothering of soil organisms and vegetation
Displacement Water Intake Station on Black Lake Bayou	-benthic organisms destroyed and decreased plankton production from dredging-induced turbidity	none	same as primary impact
Calcasieu Ship Channel	-moderate increase in turbidity	-follow most recent advances in dredging technology to minimize turbidity	same as primary impact
	-shrimp, crayfish, fish & other mobile forms will emigrate from turbid areas	-avoid dredging during shrimp migration season	-negligible impact on shrimp
	-possible increase in salinity of the dredged out region due to direct connection between ship channel and the Gulf of Mexico	none	same as primary impact
	-release of sediment-bound nutrients	none	same as primary impact
	-induced increase in primary production of algae (phytoplankton and peri-plankton) from release of bound nitrogen, phosphorous and carbon compounds plus detritus	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Calcasieu Ship Channel (continued)	-increased secondary production by zooplankton benthic organisms and filter feeding fish	none	same as primary impact
	-potential inhibition or stoppage of primary production in localized areas where unusual quantities of pesticides and their degradation products are re-suspended	none	same as primary impact
Disposal of Spoil Dredged from Calcasieu Ship Channel	-moderate increase in turbidity, TKN, COD within 1300 ft.	none	same as primary impact
	-sediment settling will suffocate oysters, mollusks & other shellfish (crabs) and/or cause gill abrasion	-may use spoil banks previously created from deposition of spoil dredged in maintaining the ship channel depending on compatibility between dredged material and existing spoil bank	-some shellfish, oysters and mollusks impacted; low mortality
	-benthic micro-invertebrates will be buried or killed	-use spoil banks previously created	same as primary impact
Withdrawal of Displacement Water from Black Lake Bayou	-surface level on Black Lake drop less than 0.01 foot	none	same as primary impact
	-change in salinity depending upon the source of replinishment water	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Withdrawal of Displacement Water from Black Lake Bayou (continued)	-salt water intrusion in the southern reaches of Calcasieu Lake	none	same as primary impact
	-potential increase in salinity is estimated to be less than 0.33 ppt.	none	same as primary impact
	-entrainment in intake structures of about 3.57×10^{11} planktonic organisms	-clear screen to minimize higher velocities of water through screens	reduced number of planktonic organisms entrained
	-impingement of fish against intake structures	-clear screens -design intake structure to avoid creation of intake velocity greater than fish's ability to escape	none
Dissolution of Salt by Successive Drawdown-Refill Cycling	-potential collapse of cavity causing surface subsidence and damage to buildings and equipment	-use of permanent oil blanket to avoid cavity leaking above safe depth and to avoid damage to the integrity of the well casing.	none
	-potential leakage of oil and/or brine through flanks and caprock of salt dome, causing contamination of water and soil	-use saturated brine for displacement water to limit enlargement of cavities	same as primary impact given cavity collapses
	-loss of useful volume for storage	-use sonar device for testing the shape of cavities which may coalesce to assure maintenance of structural support	same as primary impact given cavity collapses

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Dissolution of Salt by Successive Drawdown-Refill Cycling (continued)	-potential coalescence of cavities #6 & #9.	-use of saturated brine for displacement water in cavities -reduce number of draw-down refill cycles	none
Brine Injection	-well head blowouts if wells are drilled through pressure zones and excessive pressure buildup occurs	-careful evaluation of aquifer capacity, extent and pressure gradients	same as primary impact in the event that pressure zones are violated
	-possible strata fracture and contamination of fresh-water aquifers	-use conservative spac-ing of injection wells; ∿1000 feet; discontinue injection	same as primary impact
	-interference with existing oil production operations	-secure wellhead plugs on all abandoned oil wells	
	-temporary increase in pressure equalized over short period at end of injection	-monitoring to detect loss of pressure indicat-ing loss of pressure con-tainment -brine cleanup treatment prior to injection	same as primary impact
	-increase in salinity (∿ 1 ppt) in the aquifer	-none	-same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Enclosure of the Storage Site	-~240 acres removed from pasture	-permit grazing of cattle on portions of the site	-removal of fenced area from grazing use for lifetime of project
	-~48 acres of land disturbed	none	same as primary impact
	-possible destruction of a very small number of nests and individual animals	none	same as primary impact
	-some coastal prairie vegetation will be destroyed and regrowth will not be allowed	none	same as primary impact
	-noise will cause mobile wildlife to temporarily leave the site	none	same as primary impact
Pipelines			
-pipeline connections to 5 storage cavities, to brine settling tanks	-approximately 15 acres disturbed (11.5 acres-operation) (28.7 acres-construction)	-lay pipelines during winter which is a low growth period and is the local dry season (ground does not freeze hard)	same as primary impact
-oil distribution pipeline	~48 acres permanently disturbed (48.5 during operation) (60.3 during construction)	none	-48 acres disturbed for pipeline right of way
-displacement water (brine) disposal system construction	~11 acres of brackish marshland permanently committed	-install culverts to maintain natural drainage patterns through landfill areas	-11 acres committed, natural drainage minimally disturbed.

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
-displacement water (brine) disposal system construction (continued)	-loss of marsh community productivity of $\sim$1518 g dry wt./M^2/yr (equivalent to 54 tons/yr of dry vegetation	-plant grasses on banks of landfill area to prevent soil runoff into marsh	-same as parimary impact with enhanced re-vegetation
	-7 acres of dry land temporarily committed, 2 acres permanently committed	-bury pipelines, and return to pasture usage	-temporary disturbance until pasture regrowth is complete
	-removes pasture land w/net productivity of $\sim$7.08 x 10^7k cal/yr	-bury pipeline and return to pasture usage	-temporary disturbance until pasture regrowth is complete
<u>Additional Barge and Tankship Traffic</u>	-erosion from increased wave action on the banks of the Alkali Ditch	-seed and plant banks with native brush and underbrush to waterline	-minor erosion from wave action
	-bottom scour from increased turbulence	none	-increase in bottom scour due to turbulence
	-increased chance of oil spill at docks or in transit	-construction of spill retention device at docks	-increased chance of oil spill; minimize extent of spill
<u>Additional Barge Traffic</u>			
Alkali Ditch	-emissions of hydrocarbons, sulfur oxides, carbon monoxide, nitrogen oxides and particulates	none	-slight increase in hydrocarbons, sulfur oxides, carbon monoxide, nitrogen oxides, and particulates

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Additional Barge Traffic			
Alkali Ditch (continued)	-increased noise levels from vessel operations and from pumping of crude oil	-enclose pumps in acoustically insulated pump houses	-slight increase in noise levels close to dock facilities; levels below 55 db at nearest residence
Oil Spilled from Vessel in Transit	-potential oil spill of 1100 to 8300 bbl will spread to cover 1200 to 5400 acres of Calcasieu Lake (critical if it occurs in West Cove or in bad weather)	-rapid containment with booms, absorbents to minimize spread of slick with the tides and winds	-reduced area covered by slick depending on volume contained in 48 hours
	-temporary contamination of sediment	rapid cleanup	same as primary impact
	-oil may affect taste of oysters and decrease oyster larval development	none	same as primary impact
	- moderate oil contamination of marsh vegetation will cause death of roots, reduced germination of contaminated seeds and a reduction in annual species (recovery relatively rapid in <2 yrs.)	rapid clean-up	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Oil Spilled from Vessel in Transit (continued)	-possible hazard to wildlife using the Sabine National Wildlife Refuge for breeding grounds	none	same as primary impact
	-potential threat to the Southern Bald Eagle (endangered species) thought to be in the area	none	same as primary impact
Above Ground Oil Pipeline Spill	-contamination of soil and vegetation in small area near spill	clean up promptly	-minor surface soil and vegetation contamination
Underground Oil Pipeline Spill	-contamination of soil to 10 cm depth from spill ($\sim$1000 bbl) covering $\sim$0.4 acres	none	-minor contamination of soil surrounding pipeline until degradation and migration dilute oil concentration
	-migration of oil via water table into water bodies	-dig trenches at point of entrance into water body and collect and dispose of oil	-minimal contamination of water bodies from oil not collected
Road Construction, Building Foundations, Wellhead Pads	-$\sim$34 acres disturbed	none	$\sim$34 acres disturbed
	-erosion	-plant or seed with native vegetation	-erosion and runoff occur prior to successful establishment of vegetation
	-$\sim$5028 cu.yd./yr. sediment washed into water from erosion due to rainfall on 34 disturbed acres	-plant or seed with native vegetation -avoid landfill work during rainy season	

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Drill Rig Operations	-at .5 km, centerline concentrations of emissions CO (8 hr): 535 $\mu g/m^3$ *HC (3 hr): 249 $\mu g/m^3$ NO_2 (Annual): 52 $\mu g/m^3$ SO_2 (24 hr): 150 $\mu g/m^3$ Particulates (24 hr): 145 $\mu g/m^3$ *only concentration exceeding standards; due to point source assumption (See Table 3.10)	none	same as primary impact
	-noise levels less then 55 dB at nearest residence	none	negligible
Vessel Loading and Unloading	-maximum of 230 g/sec hydrocarbon emissions during unloading at rate of 400 MB/day	-use of a vapor recovery system at dock	negligible hydrocarbon emissions
Alkali Ditch	-surge tank working loss hydrocarbon emissions of 3.1 g/sec. primary standards exceeded to 3 km (for 10 mos)	-use of a vapor recovery system on tank	negligible hydrocarbon emissions
	-at 2 km, centerline concentrations of emissions *HC (3 hr): 224 $\mu g/m^3$ *hydrocarbon levels exceed primary standard due to point source assumption	-use of a vapor recovery system	-reduced hydrocarbon emissions
Terminal and Dock Construction Alkali Ditch	-daytime ambient noise levels increased for residents in section 41 (see Figure 3.11) to Leq $\sim$ 64 dB at 2000'	none	same as primary impact

ACTION	PRIMARY IMPACT	MITIGATION	UNAVOIDABLE IMPACT
Calcasieu Dock	-floating roof storage tanks standing storage loss of 2.6 g/sec of hydrocarbons	-use of a vapor recovery system	negligible hydrocarbon emissions
	-at 2 km, the 3 hr maximum centerline concentration of hydrocarbons will be *378 g/m^3, and 108 g/m^3 at 5 km *exceeds primary standard	-use of a vapor recovery system	reduced hydrocarbon emissions
Employment of Skilled Laborers	-possible delay in reemployment of these laborers at the completion of construction operations	none	same as primary impact
	-increase in local traffic load	none	same as primary impact
	-increased demand for local maintenance operations	none	same as primary impact
Operation of Facility	-increased responsibility to assure security and respond to fire hazards	-SPR employment of dedicated security and fire fighting capabilities	minimal demand on local police and fire fighting capabilities

4.2 CONSIDERATIONS OFFSETTING ADVERSE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTIVITY

The United States possesses abundant natural resources and yet is dependent upon the importation of large quantities of fuels. It has become increasingly dependent upon petroleum imports, which now constitute approximately 35 to 45 percent of the nation's oil consumption and account for 20 percent of the total domestic energy usage. In 1974 the annual cost of these imports was over $25 billion.

In the past twenty-five years, the United States has experienced four sudden denials of oil imports for various reasons by oil-exporting countries. Not, however, until the oil embargo of 1973-74 did the nation find itself without the capacity and resources to offset the interruption of oil imports. This embargo reduced the quantities of petroleum exported to the United States by approximately 2 million barrels per day for 19 weeks and caused world prices for crude oil to escalate.

Although the economic impacts of these events on the United States economy are still under study and debate, most of the macroeconomic study estimates of the repercussions of supply denial and simultaneous price increases tend to indicate a Gross National Product (GNP) loss of approximately $35-45 billion.[1,2] Although not all of this GNP loss can be ascribed to the embargo, the interruption contributed significantly to increases in the consumer and wholesale price indices. In addition, the GNP loss was reflected in higher unemployment and stagnation in several sectors, including automobile sales and housing starts, which exacerbated the economic downturn believed to have started in late 1973. During this period, the embargo prevented real growth that probably would have stabilized unemployment and provided a stronger base for eventual economic recovery.

The United States is now more vulnerable to a petroleum supply interruption than it was in the fall of 1973. In responding to that interruption, many relatively easy steps to conserve energy were taken, and significant improvements in energy efficiency have been achieved. Higher energy prices, natural gas shortfalls, and continued uncertainty about the availability and prices of alternative forms of energy have induced many energy users to restrict their energy consumption and emphasize more effective energy management practices. However, additional improvements will require substantial investment, longer lead times, and even more intensive energy management. Moreover, the program to convert oil- and gas-fired utilities and industrial plants to coal will have converted many plants to coal, which will largely preclude further conversion to coal during a future supply interruption. Some estimates have shown that a future supply interruption of the magnitude of the one in 1973-74 could cause a reduction in GNP that, in terms of employment impact, would be equivalent to the loss of jobs for 2 million workers. Economic effects would not be limited to some geographical areas or industries but would affect the entire nation.

Standby supplies of petroleum have been proposed repeatedly as a way to buffer the impact of future supply interruptions. The National Petroleum Council (NPC)[3], Ford Foundation,[4] and the Energy Laboratory at the Massachusetts Institute of Technology MIT)[5] have all recommended this action. In addition, the International Energy Program (IEP) agreement, which the United States has entered into with 17 other energy importing countries, provides for the establishment of this type of reserve. Although the western European countries and Japan have developed stockpiles, the only appreciable stocks in the United States are working inventories.

The concern voiced by these organizations as well as the public, in addition to the nation's formal commitments to the IEP, provided strong impetus for passage of the Energy Policy and Conservation Act of 1975 (P.L. 94-163), which provides for the creation of the Strategic Petroleum Reserve. The West Hackberry ESR storage facility provides 96 million barrels of the SPR requirement.

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3. Petroleum Storage for National Security; National Petroleum Council; Aug. 1975.

4. Time To Choose America's Energy Future; Ford Foundation; 1974.

5. Energy Self-Sufficiency: An Economic Evaluation; Massachusetts Institute of Technology, Energy Laboratory Study Group; 1974.

5. RELATIONSHIP BETWEEN SHORT TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG TERM PRODUCTIVITY

The short term use of the land and minerals would have little effect on the long term productivity of this land.

The short term use of part of the dome for the SPR program would dedicate some underground space to use as a storage facility for the life of the project. The use of the salt dome for brine extraction is not prevented by the use of the dome for petroleum storage. The subsurface disposal of brine would render some salt irretrievable. This quantity is small in relation to the net amount available, thus the long term consequences from this loss of salt are insignificant.

The disposal of up to 300 million barrels of brine in the saline aquifers would increase the salinity slightly. Because the brine would be injected at depths of approximately -2,000 to -8,000 feet, the depths overlap the oil and gas producing interval. Therefore, care would have to be exercised to assure that brine is not inadvertently injected into oil and gas sands in a manner which would reduce oil and gas production. It is possible that the injection would offset losses in formation pressure due to oil and gas depletion.

Presently the land on the dome that has not been developed for brine extraction or for petroleum storage is used as grazing land. The short term use of the site for petroleum storage at this location should not prevent most of the land from being used for agriculture in the future since the facilities and pipelines would remove only a small amount of land from agricultral use. At the close of the project, the land could be returned to its present usage.

There would be short-term adverse effects on the vegetation and wildlife on the site and along the pipeline rights-of way (described in detail in Section 3). However, for the most part, the oil pipeline will pass through pastures and other cleared former prairie areas, which should cause no particular impairment to the hunting and fishing resources.

The availability of crude oil from this project would mitigate the effects of an interruption in supply of foreign oil. Therefore, it would serve to enhance productivity that would otherwise be reduced by lack of supply of fossil (oil) energy sources and petrochemicals.

6. IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES

During the developmental and operational phases of the Strategic Petroleum Reserve facilities at West Hackberry salt dome, a number of resources will be committed to the project. Only a few of these commitments are irreversible or irretrievable.

Salt

The solution mining of the salt dome is an irreversible commitment of a solid salt resource. However, because salt domes, beds, and deposits are present throughout many parts of the United States, and since the West Hackberry site cavities have been created during mineral extraction, this is not a new commitment of resources.

Energy

This energy consumption analysis includes the energy required to supply materials, prepare and operate the site, as well as transport the crude during fill and withdrawal operations.

Materials utilized in the construction of the West Hackberry facility include estimated maximum amounts of 11,000 tons of steel and 23,000 tons of concrete. Assuming 40 million BTU are required to supply a ton of steel and 6 million BTU per ton of concrete, the energy required to supply materials is about 580,000 million BTU.

Equipment operations for site preparation and operations will consume approximately 202,000 million BTU. In addition, the energy required for crude transportation for each fill/withdrawal cycle amounts to about 560,000 million BTU for pipeline transport and about 209,000 million BTU for barge and tanker transport. In the above, it has been assumed that short haul barge and tanker transport consumes about 350 and 750 BTU per ton-mile, respectively.

In terms of crude oil equivalence content (5.5 million BTU/barrel), the potential oil resource utilization for the proposed 5 cycle SPR program at West Hackberry is about 0.84 million barrels. Since during the 5 cycle program 300 million barrels of crude will be handled by this site, the energy resource utilization amounts to less than 0.3 percent of the potential energy storage capacity.

Land Area, Vegetation, and Wildlife

During pipeline route construction, a short-term irretrievable loss of production would be sustained from a maximum of 350 acres. Vegetation and wildlife in this area would be sacrificed or displaced between the interval of construction and revegetation.

During construction, there would be a temporary loss of productivity in the marsh adjacent to the Alkali Ditch, and in the Calcasieu River. This loss of productivity is considered very small when compared to the total productivity of the area (see Section 3.4).

During operation, some organisms would be entrained with the displacement water and would be lost from the population. Because the number or organisms is small when compared to the normal population, the effects would be less than from natural mortality.

Water Resources

During each withdrawal cycle of the project, approximately 7820 acre feet of water would be taken from the surface water system of Black Lake and ultimately injected into the deep saline aquifers. This water would be irretrievable in its original low salinity form since the salt in the dome would dissolve to saturate the brine during periods when water is in the cavity.

It should be noted that this volume would not appreciably lower the lake level. The maximum withdrawal rate of 26.29 cfs is less than 4% of the low flow for the Calcasieu River, less than 0.2% of the high flow, and is approximately equal to 1% of the average flow rate.

*The lifetime of the facility is assumed to be in excess of 10 years.

Construction Materials

Most of the concrete, steel, and other materials used in construction must be considered as an irretrievable commitment of resources since no valid estimate of salvage can be made at this point. Approximately 6,400 tons of steel would be required for pipe, wells, and other components.

Labor

To construct and operate the facility for twenty years, approximately 313 man-years of effort is required. This involves approximately 1134 man-years of construction effort and approximately 200 man-years of operational effort.

Investment

The cost of constructing the project at this site is estimated to be approximately 52 million dollars. Operating costs will range from one million dollars/ year to three million dollars/year. These costs do not include the value of the stored oil.

Oil

Some of the stored oil may not be recoverable due to loss on the cavern walls and from solution in the brine. Assuming that loss is approximately one percent, (based on crude adhesion to cavity walls), a total of 60,000 barrels might not be recoverable from the caverns.

7. ALTERNATIVES TO THE PROPOSED ACTION

Several alternatives to the proposed action have been examined. These include alternative storage sites, alternative facility components and no action.

7.1 ALTERNATIVE STORAGE SITES

During any future oil import interruption, SPR crude oil will have to be distributed to refineries in each of three major markets: East Coast and Caribbean via tanker ship; inland via the Seaway, Texoma and Capline pipelines; and the Gulf Coast refinery complexes (Freeport, Port Neches and St. James). The West Hackberry salt dome storage site is one of a group of five sites within the eight candidate ESR sites which can service all three markets, including each of the three pipelines (see Figure 7.1). Of the eight sites there are only five candidate sites which can supply both the Gulf Coast, and the Caribbean and East Coast markets. Based on current demand, these two markets combined would, in the event of a supply interruption, require approximately 75 percent of the 150 million barrels in the ESR, or about 110 million barrels. Together the five sites have an existing capacity of approximately 330 million barrels--well above the 110 million barrels needed for the two markets.

Site selection, therefore, will involve a two-step decision-making process. The first decision in the site selection process will be to choose two or three of the five sites for the purpose of satisfying the ESR needs of the Gulf Coast, the East Coast and the Caribbean. These five candidate sites are thus alternatives for accomplishing this purpose. Site specific EISs have been prepared for all five alternative candidate sites. The impacts which would result from development of each of the other four candidate sites are described briefly in Sections 7.1.1 - 7.1.4. The individual statements should be consulted for a detailed assessment of these impacts.

The second step of the site selection process will involve choosing sites to satisfy the ESR requirement for the inland refineries. The remaining three of the eight candidate ESR sites are unique in that oil from them could be distributed only to the inland market area because they are "downstream" on major crude oil transmission pipelines. One would connect with the Seaway pipeline market area, while the other two would service the same part of the inland market area served by the Capline pipeline. Because of their ability to supply this inland market, those of the five candidate sites which are considered in the first step of site selection, but are not selected in that process, would be considered again as alternatives to the three inland market sites during the second step in the site selection process. EISs are now in preparation for the additional three inland sites which will be considered.

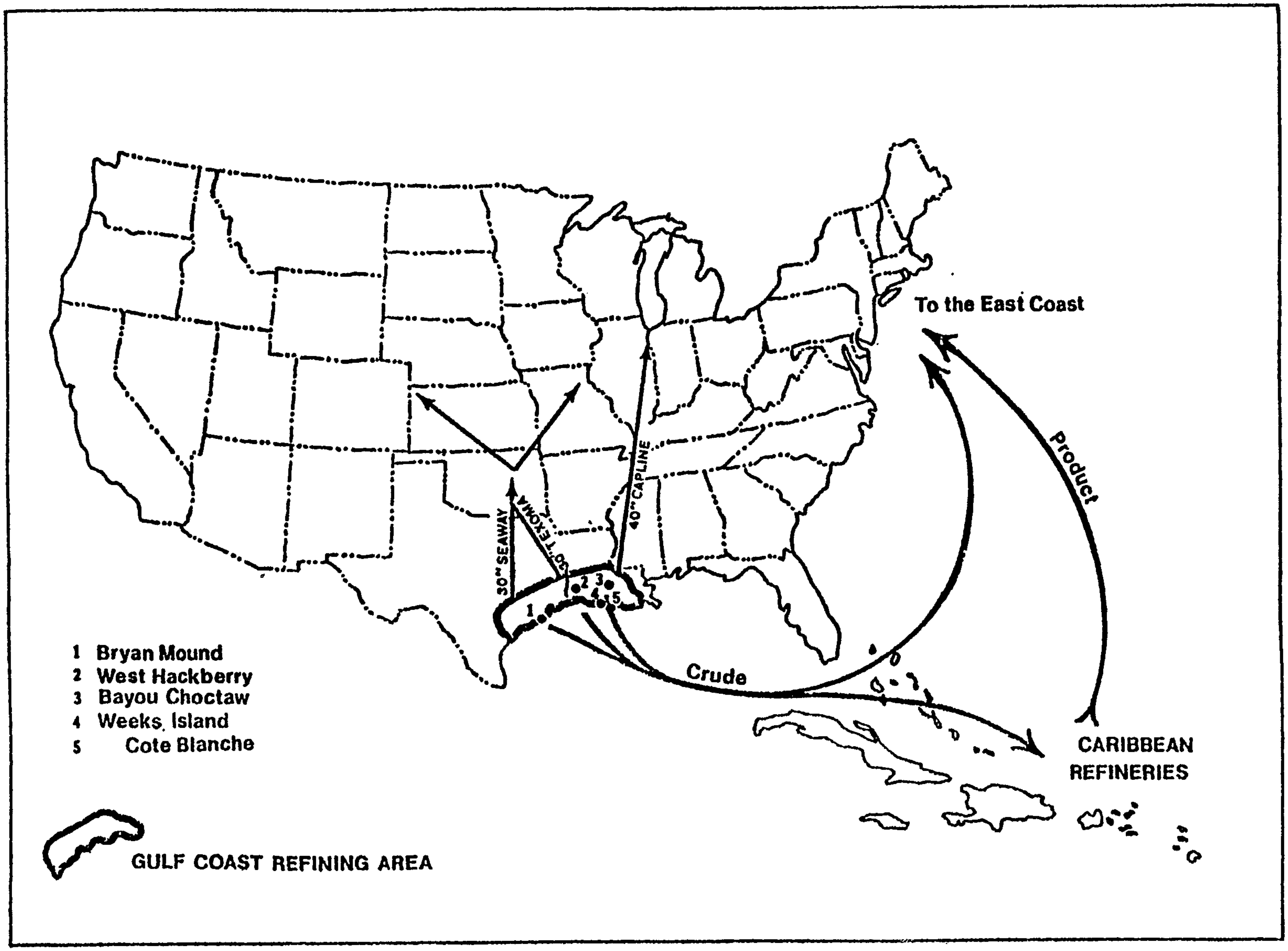


Fig.7.1 SPR Distribution Network

The future site selection for the longer-range portion of the SPR program will be very similar to the process described above for the ESR. Candidate sites will be grouped geographically according to market and distribution requirements. Each group will comprise a set of alternative sites, and EISs will be prepared which compare the impacts of developing each site. Those among the first eight which are not selected for the ESR will be considered as alternative storage sites for the longer-term phase of the SPR if they were rejected as ESR sites for reasons other than unsuitability for oil storage; e.g., if they were found to be unavailable for the ESR within the required time frame.

7.1.1 Bayou Choctaw

Converting existing solution-mined cavities in the Bayou Choctaw salt dome into a 94-million barrel oil storage facility would require drilling 28 brine disposal wells, constructing related brine handling facilities, expanding an existing dock and storage tank facility on Bull Bay, constructing a new tanker terminal at Addis on the Mississippi River, and constructing an oil pipeline between the dock at Addis and the storage site. Water for displacement of oil during withdrawal operations would come from a small on-site lake. Although the oil storage reserve at the Bayou Choctaw salt dome would not likely cause long term adverse environmental impacts, it would alter the local environment in significant ways. These effects are displayed in Table 7.1 and discussed below for storage site construction, brine disposal, dock facilities and pipelines displacement, marine operations, and facility operation.

Storage Site Construction

Construction of dikes, roadways, well-heads, and buildings at the storage site would require about 15 months and would disturb farm and swamp land and induce soil erosion, which will, in turn, increase turbidity and suspended solids in nearby waters. Resident wildlife will be forced to emigrate to a more tranquil setting until the construction activities cease.

Construction equipment would temporarily degrade on-site air quality with CO, SO_2, NO_2, HC, and particulates. However, resulting levels of these pollutants, with the possible exception of the hydrocarbon concentrations from drilling rigs within a downwind distance of 0.5 kilometers, would meet federal and state primary standards. Point solvent emissions would be high, but do not exceed Federal three-hour standards and are not regulated in Louisiana.

Brine Disposal

The brine disposal system would consist of 28 disposal wells evenly spaced in a rectangular field of 1,150 acres. Brine would be collected in a 500,000-barrel holding pond for temporary storage and settling, and then piped 6,500 feet to the disposal area. Since the brine disposal area

Bayou Choctaw

ENVIRONMENTAL IMPACT SUMMARY

Table 7.1

ACTIVITY	IMPACTS DUE TO ACTIVITIES: GEOLOGY AND SOILS	LAND USE	WATER QUALITY AND SUPPLY	AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
STORAGE SITE CONSTRUCTION	Short-term erosion from dikes, roads, and other earthmoving; [illegible] cubic yards of sediment.	134 acres enclosed, industrial use unchanged. [illegible] cubic yards of construction waste in 1 of 9 landfill sites	Small increase in turbidity from grease and oil, 7% increase in suspended solids in local waters.	Temporary degradation from construction equipment and paint solvents not in excess of standards. Increase of 19.1 tons/yr of suspended particulates, 7% increase for parish overall.	Noise impact zone (greater than 55 dBA) within 2,[illegible] feet. no residences within 1 mile	Minor disturbance to wildlife, alteration of vegetation	386 man-months of construction employment on site, $675,500 in payroll, slightly increased traffic and resulting maintenance costs for public facilities.
BRINE DISPOSAL							
28 Injection Wells 500,000-Barrel Holding Pond 6,500-Foot Pipeline (P)	No rock fracture under average pressure, possible rock fracture of 50-foot sand layers during fifth cycle	[illegible] acres of swamp forest changed to industrial use	Increase in salinity in saline aquifers, possible contamination of fresh aquifers if old wells unplugged.	Slight impact from drilling operations.	95-100 dBA at 50 feet; noise impact zone at 1,800 feet, no residences within 1 mile.	Loss of wildlife habitat and production. <1% probability of brine spill that could destroy some marshland over 128 acres.	Included in storage site construction.
116-Mile Pipeline to Gulf (A)	Temporary surface disruption.	182 acres of sugar cane and 350 acres of wetlands lost.	0.1-ppt salinity increase in Gulf waters over 450 acres, increase of 1.5 ppt over 1 acre; no increase more than 1.5 ppt.	Slight impact.	Noise impact zone within 500 feet; no residences within one quarter mile.	Temporary loss of benthic organisms and fish. <1% probability of brine spill that could destroy marsh.	Loss of $62,500 in sugar cane (one harvest; requires 3 yrs growth).
DOCK FACILITY CONSTRUCTION							
Expansion of Bull Bay, Tanker Dock at Addis; Storage and Ballast Tanks (P)	Suspension of sediment	250-acre tract, including 30 agricultural acres, disturbed.	Local increases in turbidity, toxic sulfides, heavy metals, hydrocarbons, ammonia, TKN, COD from dredging, and dredge disposal of 86,000 cubic yards and 1.5 million cubic yards for permanent dock.	Same as site construction.	70 dBA at dock during construction.	No impact at Bull Bay; loss of aquatic species at new dock site.	500 man-months of construction labor at dock sites, $875,500 in payroll.
Expansion of St. James Terminal Pipeline to St. James (A)	Suspension of sediment.	30 acres disturbed. [illegible] acres of sugar cane production possibly precluded	Same as proposal, but larger turbidity plumes that will dissipate more rapidly; river sediment less polluted; less dredging impact.	Same impact as proposal.	Same impact as proposal.	Less impact than proposal.	Possible loss of $43,000 in sugar cane (one harvest)
PIPELINE							
Oil Line 5 Miles from Addis to Site (P)	Temporary surface disruption.	55 acres disturbed (30 in sugar cane, 25 in backwater swamps).	Temporarily increased turbidity in swamp.	Slight hydrocarbon emissions.	Noise impact zone at 500 feet; few residences within one quarter mile.	Minimal impact during construction only; vegetation will return.	450 man-months of construction employment; loss of $7,500 in sugar cane production (one harvest).
Pipeline Accidents	Soil fouled in vicinity of pipeline.	Land unsuitable for farming until oil dispersion through soil complete.	Local degradation of water quality.	Slight hydrocarbon emissions.	Slight impact during cleanup operations.	16 barrels spilled oil would destroy local soil organisms (if underground) and vegetation (if above ground).	Temporary loss of farm and swamp production over small area.
OIL DISPLACEMENT WATER SOURCE							
12-Acre On-Site Lake (P)	No impact	No impact.	No significant impact on lake or replenishing water sources; 3 ppt decrease in lake salinity.	Slight hydrocarbon emissions.	Slight impact; pumps and motors.	Temporary migration during displacement; entrapment of plankton, larval fishes, vertically migrating benthics, small aquatic plants.	No impact.
Mississippi River (A)	No impact	No impact.	32,000 gpm, representing 0.035% of river flow; no adverse impact.	Slight hydrocarbon emissions.	Slight impact; pumps and motors.	Impact same as on-site lake.	No impact.
Ground Wells (A)	Surface disruption due to drilling	5.7 acre-well area	10-foot reduction in water table level at 0.5 miles from pumping station.	Slight hydrocarbon emissions.	Slight impact; pumps and drilling rigs.	4.2-ton loss of biological swamp production for 1 year plus impacts of on-site lake.	No impact
MARINE OPERATIONS	Small amount of erosion on channel bottom	No impact	Expected spill of 536 barrels from tankers or 7,857 from barges per fill/withdrawal cycle. Disposal of 47,500 barrels of ballast water per tanker in brine well; no adverse impact to aquifer.	Worst case hydrocarbon emissions from storage tanks could exceed 160 $\mu gm/m^3$ as far as 10 km downwind; maximum concentrations of 7500 $\mu gm/m^3$ at 0.5 km.	Noise impact zone at 200 feet; no residences within ½ mile.	Destruction of non-mobile species and residual oily taste in fish if oil spills occur.	Reduced marketability of fish fouled if oil spills occur.
FACILITY OPERATION	No impact.	No additional impact.	Small quantities of solid and sanitary waste; no adverse impact.	Vessel loading and unloading could produce 2,000 tons hydrocarbon emissions for each fill or withdrawal; worst case emissions could exceed 160 $\mu gm/m^3$ for considerable distance downwind (5-10 km); maximum concentration at 0.5 km of 6,125 $\mu gm/m^3$.	Noise impact zone at 200 feet; no residences within ½ mile.	No additional impact.	10 full-time personnel: 6 skilled, 3 laborers, 1 clerical; 20-30 skilled workers for oil recovery.

(P) Proposed system design.

(A) Alternative to the proposed system design.

is located in a backwater swamp forest, 128 acres of which would be converted to industrial use, construction would result in a loss of wildlife habitat..

The major environmental risk in brine disposal is the danger of acquifer fracture, which could cause contamination of fresh water or interference with oil and gas production. During the filling process at the Bayou Choctaw site, 267 ppt brine would be injected at a maximum rate of 19,450 gallons per minute at depths of -5,000 to -7,000 feet. After 150 days of brine injection under average conditions, the bottom hole pressure would increase but remain well below the fracture pressure. Pressure throughout the well would tend to equalize when injection is stopped and so cause the bottom hole pressure to decrease. After several fill and withdrawal cycles, the bottom hole pressure would steadily increase again but still remain below the fracturing point. However, in thin (50-foot) sand layers, where the average pressure build-up is greater, the bottom hole pressure would probably exceed the fracturing point during the fifth cycle. The likelihood of actual fracture varies with the potential for well clogging, which in turn depends on the chemical and biological compatibility of the injected brine and the saline water in the aquifer.

Some risk of fresh ground water contamination also exists where abandoned oil and gas wells provide passageways between a fresh water aquifer and the saline acquifer used for brine disposal. Two such wells, the conditions of which are unknown, lie within the brine disposal area. In the worst case, 15 million barrels of saline water could leak to the Plaquemine aquifer (a nearby fresh water supply) over 20 years. Relative to the capacity of the Plaquemine aquifer, such leakage is small, and careful inspection and replugging of the 2 abandoned on-site wells can avoid any negative impact.

As an alternative to deep-well injection, a 116-mile pipeline would carry the brine 20 miles into the Gulf of Mexico. Since it would follow an existing right-of-way, this pipeline would avoid many impacts associated with pipelines in general. Nevertheless, the pipeline would eliminate 182 acres of suger cane (one harvest valued at $62,500) and a total of 350 acres of wetlands, an amount considerably more than that affected by the deep well injection of brine. Disposal of brine in the Gulf would increase salinity 0.1 parts per thousand over a 250 acre area and 2.5 ppt over one acre. Although bottom organisms would be destroyed in the diffuser area, they would repopulate shortly after disposal stopped.

Dock Facilities and Pipelines

Barges serving the Bayou Choctaw site would use an existing barge dock on Bull Bay for the initial fill of the first storage cavern. The existing dock facility would be expanded by a new barge mooring ship and a new dock. In addition, a new tanker facility with mooring for two tankers would be constructed on the Mississippi River, southeast of Addis and 5 miles east of Bayou Choctaw. Six surge tanks and two ballast tanks would also be constructed at the tanker terminal.

Expansion of the Bull Bay dock would have little impact; however, construction of the new tanker dock would require a 250-acre tract of already disturbed land and 30 acres of property planted in sugar cane. Dredging 86,000 cubic yards of bottom material in the Mississippi would moderately increase turbidity, toxic sulfides, heavy metals, hydrocarbons, ammonia, TKN, and COD at both the dredging and disposal sites. The dredging operations would destroy bottom organisms, and sediment settling would suffocate local mollusks and shellfish.

Oil for storage or distribution would be carried by a 5-mile pipeline between the docks and the storage site. The pipeline would temporarily disturb 30 acres of sugar cane and 25 acres of backwater swamp and thus cause temporary increases turbidity. Ecological impacts would also be temporary since the pipelines would be buried and vegetation expected to return. Although a pipeline accident is very unlikely, an expected spill would release 16 barrels of oil, which would destroy local soil organisms.

An alternative to constructing a new tanker dock at Addis is to install a pipeline to an existing tank farm at St. James and expand the tanker terminal there. Most effects would be the same, but because it would require less dredging, this alternative would have less impact on water quality and aquatic ecology. In addition, since the river sediment is less polluted at St. James, the effects of dredge disposal would be further reduced. The pipeline itself, along an existing right-of-way, would have little impact on the environment. However, this alternative could prevent 127 acres of sugar cane production, valued at $43,000 (one harvest, requiring three years' growth).

Oil Displacement

Water to displace the stored oil would be taken from a 12-acre on-site lake, connected by canal to the Choctaw Bayou and the Intercoastal Waterway, that could accommodate displacement (115 million barrels per cycle) because of connection with these two waterways. No adverse effects to water quality are expected in any of the waters. However, some aquatic species would become trapped during the pumping process, and more mobile species would emigrate from the area. Both types of species would return after displacement is completed.

An alternative to thelake as a water supplv source is the Mississippi River. The ecological impacts of using this water source would be the same, and no adverse effects on river flow would occur.

A third alternative, to use ground water pumped from drilled wells, would have the greatest adverse impact. The water table would be lowered approximately 10 feet wtihin a half mile of this well area, accompanied by loss of swamp productivity.

Marine Operations

The major potential impacts from the operations of tankers and barges is the risk of oil spillage from accidents and the hydrocarbon emissions from the various oil transfer operations. Marine operations include both the temporary arrangement of transporting the oil along the Mississippi River by tankship to Port Allen and by barge to Bull Bay, and the permanent use of only tankships docking at Addis.

Vessels loading and unloading would produce estimated total hydrocarbon emissions of about 2,000 tons occuring over about 2.8 years of initial fill operations or about 2,000 tons for each 150 day withdrawal operation. Although hydrocarbon emissions from vessel loading and unloading are not regulated in Louisiana, the downwind associated with these emissions would greatly exceed the three-hour Federal standard of 160 $\mu gm/m^3$ for considerable distance downwind (5-10 Km) during worst case atmospheric conditions.

Statistical analysis of accidents and spillage indicates that expected spills from tankers alone would total 536 barrels, and the temporary combination of tankers and barges, 7,857 barrels in a single fill and withdrawal cycle. The large difference between the two systems arises solely from the need for barges at the temporary Bull Bay dock; the risk from the tankship phase of the operation is the same for both the temporary and permanent phases.

Oil spilled from vessels in transit would temporarily contaminate sediment and might affect the taste of fish in the area. Vegetation contaminated by oil would die, but the area would revegetate within a couple of years.

The potential impact of oil spills would be essentially the same for permanent docks located at Addis or St. James. The shorter travel distance up the Mississippi to St. James is offset by the greater congestion at that terminal.

Facility Operations

Operations of the Bayou Choctaw storage site would have no significant impacts other than those associated with oil fill and withdrawal and related employment. Vapor losses from the oil storage tanks at the tanker and barge docks would exceed Federal three-hour standards up to 10 Km downwind from the tanks. The Bayou Choctaw storage facility would employ 20 to 30 skilled workers during oil recovery operations (150 days) and 10 full-time employees for maintenance and site security during the storage phase.

7.1.2 Bryan Mound

Converting existing solution-mined cavities in the Bryan Mound salt dome into a 58-million barrel oil storage facility would require on-site construction; construction of pipelines between the site and the Seaway dock, the Seaway tank farm (both under construction), and the displacement of sources of water (Brazoria and Harris Reservoirs). Although the oil storage facility at the Bryan Mound salt dome would not likely cause long term adverse impacts, it would alter the local environment in several significant ways. The most significant effects are discussed below and displayed in Table 7.2 for storage site construction, brine disposal, storage tanks, dock facilities, pipelines, displacement, marine operations, and facility operations.

Storage Site Construction

Construction of dikes, roadways, well-heads, and buildings at the storage site would affect some already disturbed land within the existing site. Turbidity and suspended solids would be increased, but since little resident wildlife is on the site, impact would be minimal.

Construction equipment would temporarily degrade on-site air quality with hydrocarbons, SO_2, CO and NO_2; approximately 0.5 tons per acre of dust per month would be generated from construction activity. Since the area surrounding Bryan Mound is industrially developed, air quality is often degraded and pollutant levels may exceed Primary Air Quality Standards by factors of 3-15.

Brine Disposal

The Dow Chemical Company would process the brine displaced during fill through two close-by chemical plants. If Dow could not take the brine, a 4-mile pipeline would carry it to the Gulf for disposal. The two miles of pipeline along a 100-ft. wide corridor would affect 24 acres of coastal prairie, beach, marsh and developed land. The installation of two miles of pipeline in the Gulf would destroy 24 acres of benthic habitat temporarily. Although the increased salinity from brine disposal in the Gulf would destroy bottom organisms in the diffusion area, they would repopulate shortly after disposal stopped.

A second alternative brine disposal method, deep well injection, would require ten wells spaced at 1000-foot intervals one mile outside the perimeter of the site and would require 20 acres of

Bryan Mound

Table 7.2

ENVIRONMENTAL IMPACT SUMMARY

ACTIVITY	IMPACTS DUE TO ACTIVITIES: GEOLOGY AND SOILS	LAND USE	WATER QUALITY AND SUPPLY	AIR QUALITY	[illegible] NOISE	ECOLOGY	SOCIOECONOMIC
STORAGE SITE CONSTRUCTION							
50 million-barrel capacity involving 216 acres (P)	Short-term erosion from dikes, roads, and pipelines; 64,500 cubic yards of material involved.	216 acres previously used for production of sulphur; 20 acres involved in new construction; one new 65x100-foot building. 3,000 to 12,000 cubic feet of surplus lumber, paper waste, concrete and formation water for entire project to landfill sites.	Small increase in turbidity and levels of petroleum products, herbicides and pesticides, metals, salt additives, and construction chemicals.	Temporary degradation by construction vehicles and drill rig equipment, resulting in hydrocarbons, SO_x, NO_x; about 0.5 tons/acre of dust given off per month of activity.	Noise impact zone (greater than 55 dBA) at 2,500 feet; no nearby residences.	Minor additional disruption of wildlife habitat	≈ 750 man-months of total construction employment on site, $250,000 per month payroll; 90 men involved in general site construction and drilling; slightly increased traffic and resulting maintenance costs for public facilities.
BRINE DISPOSAL							
Disposal of brine to chemical plants via existing pipeline (P).	No impact.	Brine disposed of in existing ponds at rate of 9,333 gallons per minute.	No impact.	No impact.	No additional impact.	No impact	No impact
Disposal of brine to Gulf via 4-mile pipeline (A)	Temporary surface disruption.	24 acres (100-foot right-of-way through 8 acres of coastal prairie, 2 acres of beach, 4 acres of marsh, and 10 acres of cleared land).	Crossing of Gulf Intracoastal Waterway (ICWW) near Brazos River; destruction of nonproductive benthic habitat.	Slight hydrocarbon and dust emissions during construction.	Temporary annoyance to beach visitors from construction equipment	24 acres of benthic habitat destroyed temporarily along 100-foot corridor for 2 miles into Gulf; entrainment of low mobility unattached organisms near the intake.	No impact
Deep well injection using 10 wells spaced at 1,000 feet on the perimeter of the site (A)	Temporary surface disruption.	20 additional acres required outside site boundaries.	Less than 1% chance of brine spill due to pipeline or wellhead failure; possibility that overpressurization could fracture aquiclude to cause freshwater contamination.	Slight hydrocarbon emissions during drilling.	Drilling noise for 12 months	Minor additional disruption of wildlife habitat	No impact
STORAGE TANK CONSTRUCTION							
Four 400,000-barrel above-ground floating roof storage tanks on site (P)	Permanent surface disruption.	30 acres of cleared land to be modified for tanks.	During construction, some petroleum products, herbicides, pesticides, and sediment.	Vapors from solvents during spray painting of tanks 1 km downwind for several of 90 days, depending on wind.	Noise impact zone up to 2,500 feet; no nearby residences	Minor additional disruption of wildlife habitat.	25 welders and pipefitters for all pipeline and tank construction
DOCK FACILITY CONSTRUCTION							
Use of Seaway, Inc. dock facilities under construction, 100,000 barrel ballast treatment system and pump building (P)	Suspension of some sediment from channel	3 acres of cleared and already disturbed land for Ballast Treatment System.	Same as storage tanks.	Paint solvent emissions from spraying 1.10 gram per second during initial painting.	70 dBA at dock facilities.	3 acres of land for ballast treatment tanks; no critical wildlife habitat; no impact	No impact
New barge docks in ICWW (A)	Temporary surface disruption.	Precise location not determined but approximately 1 mile southeast of storage site.	Dredged materials to be placed on 100-acre disposal area 3 miles east; oil spills from associated barge traffic to be contained in the ICWW.	Slight hydrocarbon emissions.	Slight impact from construction.	Marshland, the waterway, a sand dune (disposal site) affected by dredged material, stagnant ICWW water; increased barge traffic.	Construction payroll less than that for storage site construction.
PIPELINES							
30-inch pipeline from site to dock at Freeport, 3.7 miles east (P)	Temporary surface disruptions	45 acres, 100-foot right-of-way (ROW) through disturbed land.	Local and temporary increase in turbidity and levels of toxic heavy metals and hydrocarbons, and pesticides from dredging and dredge disposal for Brazos River crossing.	Slight hydrocarbon emissions.	Noise impact zone up to 500 feet, no nearby residences.	Little effect except temporary displacement of transient species like waterfowl and small mammals.	50-man labor force for all pipeline construction
30-inch pipeline from site to Seaway storage tank facility, 4.5 miles west (P)	Temporary surface disruptions.	53 acres, 100-foot ROW through 18 acres of marsh, 9 acres of developed land, and 26 acres of coastal prairie		Slight hydrocarbon emissions	Noise impact zone up to 500 feet; no nearby residences.	Temporary disturbance of marsh and coastal prairie to displace wildlife until vegetation reestablished; dredging on Brazos River crossing to eliminate 0.5 acres of benthic habitat, but with repopulation after 1 to 2 months	
Pipeline accidents	Soil fouled to 10 cm depth in buried pipeline for 1,000 barrel spill, covering 0.4 acres.	Local land unsuitable for current use until oil dispersion through soil complete.	Only local and minor degradation of water quality.	Slight hydrocarbon emissions.	Slight impact during cleanup.	6.3 barrels; annual spill expected with mean spill size approximately 1,000 barrels; would destroy local soil organisms (if underground) and vegetation (if aboveground)	Small area involved not commercially productive; no impact.
OIL DISPLACEMENT WATER SOURCE							
Water supply from Brazoria and Harris reservoirs via Dow plant and 5-mile pipeline (P)	Temporary surface disruption.	15 acres, 50-foot ROW through 6 acres of coastal prairie, 4 acres of developed land.	Displacement at maximum rate of 14,000 gallons per minute; no significant impact on reservoirs or Brazos River replenishment source; reservoir volume 10 times projected displacement water requirement during one cycle.	Slight hydrocarbon emissions.	Noise impact zone up to 500 feet; slight temporary impact on residences and businesses. Slight impact from pumps during operations.	Plankton affected primarily during withdrawal phase due to impingement and entrainment in intake structure	50-man labor force for all pipeline construction
Gulf of Mexico water transported by 2-mile pipeline (A)	Temporary surface disruption.	1 to 2 acres onshore for pumping station; 14 acres of coastal prairie and marsh.	Crossing of ICWW; disturbance of land areas with possible turbidity due to runoff during construction.	Slight hydrocarbon emissions.	Temporary annoyance to beach visitors due to construction	Benthic habitat along corridor temporarily destroyed, entrainment of low mobility unattached organisms at the intake	50-man labor force as above for all pipeline construction.
Water from Brazos diversion channel adjacent to site (A)	Temporary surface disruption.	Less than 1 acre of disturbed industrial land involved	Temporary increase in turbidity in diversion channel.	Slight hydrocarbon emissions.	Slight impact from construction and pumps.	Entrainment of low mobility, unattached organisms near intake, dredging for the intake would destroy small area of benthic habitat.	50-man labor force for all pipeline construction.
MARINE OPERATIONS	Small amount of erosion on harbor bottom.	No impact.	Increased turbidity due to tanker traffic; possibility that median oil spill of 5,500 barrels could affect 3,850 acres of surface water if spill not contained to harbor and entrance channel; 331 barrels total expected spillage during complete withdrawal cycle for tankers; for barges, 2,980 barrels total expected spillage during one fill/withdrawal cycle (higher than tankers because of number of trips required).	Tanker hydrocarbon emissions of 70,500 lb/day during loading and 48,180 lb/day during unloading; concentrations in excess of 160 $\mu gm/m^3$ for considerable distances (≈10 km) downwind; maximum concentration of 57,000 $\mu gm/m^3$ at 0.5 km.	Slight impact.	Destruction of non-mobile species and residual oily taste in fish from spill.	Reduced marketability of fish fouled by oil.
FACILITY OPERATIONS	Possible compaction of aquifers and unconsolidated material in immediate vicinity of tanks.	No impact.	7 ppm oil from ballast water treatment to Freeport Harbor at onshore facility; small quantities of sanitary waste.	Evaporative hydrocarbon losses of ~1,800 lb/day for surge and storage tanks combined; storage tank emissions exceed 160 $\mu gm/m^3$ for ~0.5 km downwind; small quantities of emissions from pumps.	Slight impact.	No additional impact.	Crew of 10 during storage phase, 46 during loading and withdrawal phases.

(P) Proposed system design

(A) Alternative to the proposed system design

additional land. The adverse effects of this alternative include drilling noise for a 12-month period, a one percent chance of brine spill from pipeline or well-head failure, and the possibility that overpressurization would contaminate the freshwater aquifers.

Dock Facilities, Storage Tanks, and Pipelines

Oil supply and distribution would involve on-site storage tanks, a pipeline system, and dock facilities (including a 20,000 barrel surge tank). Thirty acres of land would be cleared. During construction, runoff would carry some petroleum, herbicides, pesticides, and sediment into adjacent waters. The painting of the four 400,000-barrel floating-roof storage tanks would cause a vapor plume one kilometer long and 200 meters wide on several days during a 90-day period, depending on winds.

The proposed method of crude oil supply and distribution is designed to utilize, under a common carrier contract, the Seaway dock facilities now being constructed east of Bryan Mound, and the Seaway tank farm facilities west of Bryan Mound. Initially, the facility would consist of three tanker docks, to moor tankers from 35,000 to 85,000 dead weight tons (DWT), and a 15,000,000-barrel tank farm, located 7 miles west-northwest of the harbor. Ultimately, the dock facility could be expanded to four docks and the tank farm to a 27,000,000-barrel capacity with pipelines for inland distribution to northwestern and mid-western United States markets. Constructing the 100,000-barrel ballast treatment facility at the dock would require the clearing of three acres of already disturbed land. The painting of the tanks would release solvent emissions downwind. Treated ballast water released to Freeport harbor would contain 7 ppm of oil (maximum monthly average). Oil recovered from the ballast treatment process would be injected into the cavities at Bryan Mound.

Construction of new barge docks in the ICW approximately one mile southeast of the storage site is an alternative to the proposed facilities. The most significant impacts would be those associated with dredging. Dredged materials would be deposited in a 184-acre disposal area 3 miles east of the dredging site.

Oil distribution would require two 30-inch pipelines, both along 100-foot rights-of-way. A 3.7-mile pipeline connecting the site with the Seaway dock at Freeport would be routed along the protected side of an existing levee and would cause minimal damage to the already disturbed land involved. A 4.5-mile pipeline would link the site to the Seaway Storage Tank Facility to the west. This pipeline would affect 18 acres of marsh and 26 acres of coastal prairie as well as 9 acres of disturbed land. In addition, the pipeline would cross the Brazos River and the necessary dredging would increase turbidity up to one mile downstream and increase levels of toxic heavy metals, hydrocarbons, and pesticides. One-half acre of Benthic habitat would be eliminated, but repopulation would occur after one to two months following completion of construction.

The pipeline spill expectation for the entire project is 106 barrels. Spills associated with pipelines would be discovered quickly as a result of constant monitoring. On land areas contamination of soil would occur to a 10-centimeter depth and cover 0.4 acres for a 1,000-barrel spill. If rupture occurred at the Brazos River crossing, that section of the pipeline could be quickly isolated by valves on both sides.

Oil Displacement

Water to displace the stored oil would be taken from Brazoria and Harris Reservoirs via Dow Plant B at a maximum rate of 14,000 gallons per minute. No significant impact on the reservoirs or the Brazos River replenishment sources is expected since the reservoir volume is ten times the projected volume of displacement water required for one cycle.

A 24-inch concrete pipeline, requiring 15 acres for a 25 foot right-of-way, would be constructed for carrying water to the site from the Dow Chemical plant located five miles away. Construction would have little effect on the use of nine acres of previously developed land. Six acres of coastal prairie, although destroyed temporarily, should return to its previous condition during the next growing season.

Water from an alternative source of supply for displacement, the Gulf of Mexico, would be transported by a two-mile pipeline. Construction of a pumping station would affect one to two acres permanently and would temporarily affect up to 14 acres of coastal prairie and marsh. Unattached organisms of low mobility would be entrained at the intake during the five-month withdrawal phase, although intake velocities are relatively low.

A second alternative source for displacement water is the Brazos River, adjacent to the site. Less than one mile of disturbed industrial land would be involved, and dredging for the intake would destroy a small area of benthic habitat. Entraining and entrapping organisms of low mobility at the intake would be a minor problem.

Marine Operations

One of the most significant impacts from the operation of tankers and barges is the risk of accidental spillage in and approaching Freeport Harbor. Tanker traffic would reach a maximum during an emergency withdrawal of stored oil, with a worst case condition of 1.5 tankers per day (32,000 DWT) unloading 58 million barrels in 150 days. The total spillage expected during the lifetime of the program is 1,655 barrels, including terminal spills and vessel accidents. Should a maximum credible vessel accident occur in a given cycle, a median spill size of 5,300 barrels is estimated, which could involve about 3,850 acres of water surface in 48 hours if the spill is uncontained by the harbor and entrance channel.

If the alternative of constructing barge docks on the ICW is implemented, a total spillage of 14,500 barrels (versus 1,655 for tankers) could be expected for the fill or withdrawal project cycles because the number of barge trips is higher than that for tankers.

During the life of the project, offshore spills, more than spills in the harbor, would affect a diverse and productive habitat, causing destruction of immobile species and a residual oily taste in fish.

Vessel loading and unloading at the Seaway dock would result in significant hydrocarbon emissions. It is estimated that vapor losses would occur at rates of 46,100 pounds per day during unloading and 70,500 pounds per day during loading at the respective proposed fill and withdrawal rates of 254,000 and 385,000 barrels per day. Under worst case atmospheric conditions, these operations would cause hydrocarbon concentrations to greatly exceed the 3-hour Federal standard of 160 ugm/m^3 for a considerable distance (greater than 10 kilometers) downwind. The maximum concentration at .5 kilometers is estimated at 57,700 ug/m^3 (total hydrocarbons). The State of Louisiana currently exempts from regulation emissions from crude oil transfers.

Facility Operations

During fill and withdrawal, hydrocarbon vapors would be emitted from the surge tank and the four storage tanks at rates of 12.2 and 986 pounds per day respectively. Under worst case atmospheric conditions, the vapors from the storage tanks would cause concentration to slightly exceed the 3-hour Federal standard of 160 ugm/m^3 for approximately .5 kilometer downwind.

The weight of the filled tanks may cause some minor subsidence due to compaction of aquifers, unconsolidated material, and caprock.

The crew of ten, present at the site during the storage phase primarily for security and monitoring purposes, would expand to 46 during the loading and withdrawal phases.

7.1.3 Cote Blanche

Converting the Cote Blanche salt mine into a 27-million barrel oil storage facility would require relocation of existing mining operations, construction of a new pump shaft at the existing mine, enlargement of a barge slip, and construction of four barge loading platforms and associated pipelines to the site. Although they are not likely to cause long term adverse impacts, construction and operation of this facility would alter the local environment in several significant ways. These effects are shown in Table 7.3 and discussed below for storage site acquisition and construction, dock facilities and pipelines, marine operations, and facility operations.

Storage Site Aquisition and Construction

The major construction activity at the storage site itself, sinking a new 12-foot pump shaft and pump station, would require minimum surface grading over 1 acre and therefore create only small, localized increases in dust, and of vehicle exhaust from construction equipment. Ecological effects would be limited to minor accumulations of dust on foliage in the immediate vicinity of the construction. Proposed freezing of the area surrounding the pump shaft would prevent any construction disturbance to the groundwater.

Development of a replacement mine would require considerably more construction activity. Approximately 20 acres of land now in pasture and forest would be needed for new mine development. Grading at the new mine site would increase soil erosion and runoff and lower surface water quality in the local area. The use of drilling mud around the walls of the hole to prevent water inflow would protect groundwater.

Although government acquisition of the mine site would eliminate the annual property tax of $26,000, construction of the storage facilities, including docks and pipelines, would provide 20,000 man-weeks of labor for 83 weeks and total annual earnings of $6.3 million for two years. Economic gain resulting from an interruption in mining to accelerate the storage schedule would be offset by unemployment or underemployment of 120 mine workers and a loss of $1.7 million in earnings. If Domtar decided not

Cote Blanche

E N V I R O N M E N T A L   I M P A C T   S U M M A R Y

Table 7.3

ACTIVITY	IMPACTS DUE TO ACTIVITIES: GEOLOGY AND SOILS	LAND USE	WATER QUALITY AND SUPPLY	AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
STORAGE SITE CONSTRUCTION							
12 ft Pump Shaft and Associated Aboveground Equipment (P)	Surface grading of 1 acre. no impact on mine structure; excavation of 15,000 cu. yds. of material for landfill disposal. loss of salt resource due to absorption. fracture unlikely due to absence of faulting.	No impact.	Impermeability of salt offsets potential impacts on groundwater system; no impacts	Small quantities of dust and NO_x, SO_2 from construction vehicle exhaust; no violation of standards.	Less than 6 dB increase in nighttime ambient sound levels in nearby undeveloped areas during construction; no increase in nearby towns.	No impact.	Loss of $26,000 property tax per year; no adverse impact to archaeological sites.
NEW MINE DEVELOPMENT	Expanded access to salt deposits; increased gradings and soil erosion.	20 acres of pasture and forest for development of new mine.	Slight decrease from soil erosion and runoff.	Slightly increased dust and construction vehicle exhaust.	37 to 70 dB at 500 feet for ground refrigeration on equipment and service shaft construction, explosives; no impact on nearby towns, however	No impacts; site of new mine already highly disturbed.	20,000 man-weeks of construction over 83 weeks with earnings of $3,300,000 per year for 2 years; if mining interrupted, unemployment or underemployment of 60 mine workers for 74 weeks and earnings loss of $1.7 million; if mining not interrupted, continuation of 25,000 man-weeks of labor over 103 weeks and earnings of $4,000,000 per year for 2 years.
Permanent Shutdown of Dumtar Mine (A)	50% reduction in site excavation and grading.	Surface acreage required for mine site would be unaltered.	Reduction erosion and siltation associated with grading.	Slight reduction in air emissions during construction from those of mine relocation option.	Noise levels reduced over mine relocation option.	No impact.	Elimination of $1.2 million annually in gross wages; local loss of 120 jobs; induced loss of 200 service jobs in region.
DOCK FACILITIES							
Barge Slip and 4 Barge Loading Platforms (P)	250,000 cu. yds. soil dredged. slightly increased runoff (barge slip now dredged biannually).	Alteration of 9 acres from marsh to open water; 30 acres required for aboveground storage, of which 15 acres are marshland and upland forest	Small decrease at site of excavation and dredge disposal; increase in BOD, decrease in DO, reduction in pH, increase in nutrients, possible increase in heavy metals, suspended solids in access canals.	Increased dust, NO_x, SO_2 from construction vehicle exhaust.	71 dB 10 hours each day at 500 feet from pile drivers for barge dock construction; no impact to nearby towns due to distance.	Removal of 50 x 10^6 grams dry weight of oyster grass; adverse impact to 6 x 10^6 grams of organisms, mostly blue crab.	Included above.
PIPELINES							
Four 0.5-mi Pipelines Between Doc and Site (P)	Disturbance of sand, silt, and clay soils; increased runoff.	About 3 acres affected by representative 500-bbl spill; seepage and movement to barge slip where it would be contained.	No significant impact on ground or surface water.	Slight hydrocarbon emissions.	68 dB at 500 feet.	Spills reaching marsh beyond barge slip probably would affect less than 5 acres and would be allowed to weather and degrade naturally.	Included above; protection of potential for archaeological finds by presence of state archaeologist.
Pipeline to St. James via Bayou Teche (80 mi) (A)	Temporary disruption of soils along right-of-way, resulting in runoff.	Alteration of 1201 acres, of which 60% are undisturbed swamp.	Possible lowering of pH and DO and increase in nutrient concentrations and BOD from deposit of excavated soils; no impact on ground water; oil spill impacts less than with barge system.	Slight hydrocarbon emissions.	As above.	More adverse impacts on ecology of of unmodified swamp forest than on Atchafalaya route and of dock construction.	Less operation expense than for barge transport; construction employment of 150 persons for one year.
Pipeline to St. James via Atchafalaya (60 mi) (A)	Temporary disruption of soils along right-of-way, resulting in runoff	Disturbance of 923 acres, of which 42% are undisturbed swamp.	Same as first alternative.	Slight hydrocarbon emissions.	As above.	Less impact than Bayou Teche route.	Less operation expense than for barge transport; construction employment of 120 persons for one year.
MARINE OPERATIONS							
Barges (P)	Increased erosion on banks of ICW and access canal.	No impact.	Slightly increased turbidity in ICW and access canal from barge operations; minimal impact from spilled oil (2724 barrels expected; 60,000 maximum) due to limited potential for lateral spreading.	Hydrocarbon emissions during transit at an annual rate of 244 tons/yr, and during vessel-to-vessel transfers at an annual rate of 1200-1300 tons/yr. Tanker-barge transfers would cause hydrocarbon concentrations in excess of 160 $\mu g/m^3$ as far as 6.0 mi. downwind.	55 dB at 500 feet for one barge passby; frequency of occurrence to increase by less than one additional passby per hour over present rate for 28-month fill, 5-month withdrawal period; noise levels occurring over 12 months if weeks also developed and barges used for transfer.	Small risk to all fauna and wildlife inhabiting coastal marshes from spilled oil; temporary disruption of vegetation where oil spilled.	Significant increased demand for barges, tug boats, crews with resultant expanded employment and income in region; need for priorities in equipment use during emergency; possible impact to recreational use of water nearby from oil spill; significant cleanup costs.
Seagoing Barges (A)	Greater disruption of soils due to need for larger barge facilities and pipeline across island.	More land required for dock facilities.	Fewer water impacts due to expected spillage of 42% less oil.	Hydrocarbon emissions 37% lower than from smaller barges.	Slightly less impact than smaller barges.	Less impact due to lower expected volume of spilled oil.	Slightly greater than dock operation
FACILITY OPERATIONS	No impact.	No impact	No impact.	Hydrocarbon emissions during barge loading at an annual rate of 731 tons/yr, causing concentrations in excess of 160 $\mu g/m^3$ as far as 4 mi. downwind. Minor hydrocarbon and hydrogen sulfide emissions from system leakage during pumping and minor sulfur dioxide emissions from flaring of vapors during fill.	Loading and unloading barges result in 55 dB at 500 feet (at least 12 dB lower than existing background).	No additional impact.	2-3 permanent employees to monitor equipment and provide security; 15 people for 5 months during withdrawal; 15 people for 10 months during refill.

(P) Proposed system design

(A) Alternative to the proposed system design

to construct a new mine, the 120 jobs permanently lost would eliminate annual earnings of $1.2 million. The multiplier effect of this decision would entail the loss of another 200 service jobs and associated incomes within the region.

Dock Facilities and Pipelines

Enlargement of the barge slip and construction of four barge loading platforms would require excavation and disposal of 250,000 cubic yards of soil materials to create 9 acres of open water from marshland and involve another 20 acres of marsh and forest. Construction of four half-mile pipelines between the docks and the storage site would also disturb soils on the island.

Surface water quality would decrease in the access canal near the excavation and disposal sites with increases in biological oxygen demand (BOD) and nutrients and decreases in dissolved oxygen (DO) and ph. Since the existing barge slip is now dredged bi-annually, the additional excavation associated with enlargement of the dock facility would be less significant than in an otherwise undisturbed area.

The dock construction would not affect any rare species but would remove a small quantity of vegetation (e.g., oyster grass), and bottom organisms (e.g., blue crab).

As an alternative to enlarging the dock, the construction of a pipeline from Cote Blanche to St. James, following a route along either Bayou Teche (80 miles) or the Atchafalaya River (60 miles), is more likely if both Cote Blanche and Weeks Island are developed for storage. The Bayou Teche route would affect a larger number of acres (1,201 as opposed to 923), of which a greater percentage is now undisturbed. Both routes would degrade the quality of surface water by lowering pH and DO and increasing nutrient concentrations and BOD from deposits of excavated soils. However, by supplanting the barges, the pipeline would cause less impact from oil spills. The pipeline would be more expensive to construct but less expensive to operate than the barge facilities.

Marine Operations

The use of barges for transporting oil to and from the storage facility would increase erosion along the banks of the Intracoastal Waterway (ICW) and would in turn increase turbidity. Over the lifetime of the project, it is expected that about 2,700 barrels of oil would be spilled and that the maximum credible spill (Gulf shore) would be 60,000 barrels from a 45,000 DWT tanker. Although slow water currents and minimal wave action would inhibit the oil from spreading, the oil reaching shore would destroy many sensitive marsh species, which would regenerate after two years.

Transporting the oil to and from the dock at the storage site would result in significant hydrocarbon emissions, both during transit and at the transfer points in the Mississippi River and in the Gulf of Mexico. System leakage ("breathing") losses from tankers and barges would occur at a maximum annual atmospheric loading rate of 244 tons/year during fill and withdrawal. These emissions would be dispersed along the Mississippi River - Intracoastal Waterway route from the Gulf to the storage site. VLCC-tanker transfers in the Gulf and tanker-barge transfers in the Mississippi River would cause emissions at maximum annual rates of 1,220 tons/year and 1,300 tons/year respectively. Under worst case atmospheric conditions, transfers at the Mississippi River transfer point would cause hydrocarbon concentration in excess of the three-hour Federal standard of 160 ugm/m^3 as far as 6.8 miles downwind. The State of Louisiana currently exempts from regulation emissions from crude oil transfers.

An an alternative to small barges, large, seagoing barges might be used to transport part of the oil directly between the tankers in the Gulf and the site. This system would require larger dock facilities and a pipeline across the island creating a greater impact on the ecology of the island. However, their use could result in a 42 percent reduction in spilled oil and a 37 percent reduction in hydrocarbon emissions.

Facility Operations

Transferring the oil from the storage cavern to the barges at the dock would result in significant hydrocarbon emissions as the barge tanks are filled with oil and the vapors contained therein are vented to the atmosphere. These venting losses would occur at a maximum annual atmospheric loading rate of 731 tons/year. Under worst case atmospheric conditions, this operation would cause hydrocarbon concentrations in excess of the three-hour

Federal standard of 160 ugm/m^3 as far as 4 miles downwind. Because of unavailable system leaks, minor amounts of hydrocarbons and hydrogen sulfide would be emitted during filling of the storage cavern as a result of flaring of the vapors that would be vented during that operation.

Fifteen employees would be needed during the 150-day withdrawal and the 300-day refill periods. Only two to three permanent employees would be needed to maintain security on the site during the storage phase of the program.

7.1.4 Weeks Island

Conversion of an existing salt mine to an 89-million barrel oil storage facility at Weeks Island would involve the construction of a new replacement salt mine, enlargement of an existing barge slip, and construction of abutment barge docks and six and one-half-mile pipelines between the barge slip and storage facility. Although the oil storage reserve at Weeks Island is not likely to cause long term adverse impacts, construction and operation of this facility would alter the local environment in several significant ways. These effects are discussed below and in Table 7.4 for the construction of the storage site as well as for a new replacement mine, dock facilities, pipelines, marine operations, and facility operations.

Storage Site Construction and Aquisition

Conversion of an existing salt mine to an 89 million-barrel oil storage site would entail only temporary, local increases in the levels of hydrocarbons, NO_x and SO_2, as well as dust, which results from the grading needed for the above-ground pump station and small electric substation.

Construction of a new salt mine to replace that converted for oil storage would involve about 20 acres of land used currently as a landfill site. The socioeconomic impact of such construction would depend on whether (1) Cote Blanche followed a construction schedule similar to Weeks Island. and (2) salt production was interrupted.

Development of the new mine at Weeks Island with no interruption in salt production would require 18,500 man-weeks of labor over 93 weeks and provide an estimated $6 million in salaries. If mining operations continue uninterrupted at Weeks Island as well as at Cote Blanche, production at both sites would yield a total of $13.9 million.

With a 64-week cessation in salt production at Weeks Island, designed to expedite the completion of the storage facility, 16,800 man-weeks over 73 weeks could be required, and the resulting loss in salt production would decrease state revenue, through severance taxes, by $92,000 and local

Weeks Island

ENVIRONMENTAL IMPACT SUMMARY

Table 7.4

ACTIVITY	IMPACTS DUE TO ACTIVITIES: GEOLOGY AND SOILS	LAND USE	WATER QUALITY AND SUPPLY	AIR QUALITY	NOISE	ECOLOGY	SOCIOECONOMIC
STORAGE SITE CONSTRUCTION							
Conversion of existing salt mine to 89 million barrels oil storage facility (P)	Minimal regrading of soil.	Only temporary increase in vehicular traffic likely	Impermeability of salt offsets potential impacts on groundwater system; no impacts.	Temporary local increase in hydrocarbons, NO_x, SO_x, particulates, and dust from construction (not measurable beyond several hundred yards from site)	Less than 6 dB increase in nighttime ambient sound levels in nearby undeveloped areas during construction, no increase in nearby towns	Removal of total 45 acres for entire site of low-quality habitat but creation of new "edge" along site perimeter for possible increase in wildlife diversity	Slight loss of recoverable salt due to minor oil absorption, minor temporary increase in construction-related transportation employment
CONSTRUCTION OF REPLACEMENT MINE (P)	Expanded access to salt deposits, increased drainage and soil erosion	Approximately 20 acres of land affected on site currently used for landfill. Waste overburden disposed of in 1 acre landfill on site.	No impacts to ground or surface water systems, no flooding risk because of high surface elevation of facilities	Impacts as above	33 to 70 dB at 500 feet for ground refrigeration equipment and service shaft construction, explosives; no impact on nearby towns, however	No impact; new mine on site of landfill.	Increased accessibility to salt deposits due to relocation of operation to new mine; 19,500 man-weeks labor, involving 110 non-local workers, over 93 weeks to generate $6 million ($13.9 million combined with Cote Blanche), with interruption in mining, 14,000 man-weeks labor, involving 80 non-local workers, over 73 weeks to generate $3.9 million ($11.7 million combined with Cote Blanche), loss from interruption of 64 weeks' salt output, $93,000 in severance tax, $210,000 combined sites), $50,000 to local ($150,000 combined sites).
DOCK FACILITIES							
Enlargement of existing slip to 650 x 650 feet and construction of 6 abutment-type barge docks (P)	Estimated 500,000 cubic yards excavated to enlarge southerly portion of existing slip.	Total of 20 acres affected; 9 acres of marsh and spoil deposit to be altered to open water; 10 acres of land adjacent to slip to be used for ancillary equipment (manifold, pumps, meters), excavated material to be disposed of in an approved site.	Temporary impact to water quality before bank stabilization complete from increased runoff, small increases in turbidity, nutrient, BOD, DO, decreased pH, possible increase in heavy metals; major impact on Spartina.	Impacts as above.	*71 dB 10 hours each day at 500 feet from pile drivers for barge dock construction, no impact to nearby towns due to distance	Temporary displacement of local aquatic life by enlargement of slip; approximate loss of 50×10^4 grams dry weight marsh grass due to barge slip development and 8×10^6 grams of benthic organisms (9×10^3 of which would be blue crabs)	Included above.
PIPELINES							
6 0.5-mile pipelines between barge slip and storage facility (P)	Several thousand cubic feet of soil disturbed by excavation and refilling of pipeline trenches.	About 3 acres affected by representative 500-bbl spill, seepage and movement to barge slip where it would be contained.	Sediment runoff to Waterway, barge slip and marsh to west of site.	Slight hydrocarbon emissions.	58 dB at 500 feet.	Spills reaching marsh beyond barge slip probably would affect less than 5 acres and would be allowed to weather and degrade naturally.	Included above
1 80-mile pipeline to St. James via Bayou Teche (A)	Temporary disruption of soils along right-of-way resulting in runoff and sedimentation.	Alteration of 1,201 acres, of which 60% are undisturbed wetlands.	Possible lowering of pH and DO increase in nutrient concentrations and BOD from deposition of excavated soils; no impact on groundwater; oil spill impacts less than with barge system.	Slight hydrocarbon emissions.	As above.	More adverse impact on ecology of unmodified wetland forest than Atchafalaya route or dock construction.	Less operating expense than for barge transport. construction employment 150 persons for 1 year.
1 60-mile pipeline to St. James via Atchafalaya (A)	Temporary disruption of soils along right-of-way resulting in runoff and sedimentation.	Disturbance of 923 acres, of which 42% are undisturbed wetlands.	Same as first alternative.	Slight hydrocarbon emissions.	As above	Less impact than Bayou Teche route.	Less operating expense than for barge transport, construction employment 140 persons for 1 year.
MARINE OPERATIONS							
Barges (P)	Some erosion of banks generated by tugs and barges moving along waterway	Very small possibility of large oil spill reaching developed water recreation areas; increases in barge traffic 11% daily during filling period; increases in traffic 36% over shorter 5-month withdrawal period, all in addition to Cote Blanche.	Slight increase in bank erosion during 28-month fill, 5- to 9-month emptying periods from increased barge traffic. minimal impact from spilled oil in ICW (1827 barrels expected, 20,000 barrels maximum) or Gulf (60,000 barrels maximum)	Hydrocarbon emissions during transit at an annual rate of 830 tons/yr, and during vessel-to-vessel transfers at an annual rate of 2140-4015 tons/yr. Tanker-barge transfers would cause hydrocarbon concentrations in excess of 160 μg/m³ as far as 7.5 mi downwind	55 dB at 500 feet for one barge passby. Frequency of occurrence to increase by less than one additional passby per hour over present rate for 28-month fill, 5-month withdrawal period. Noise levels occurring over 12 months if Cote Blanche also developed and barges used for transfer, if both Weeks and Cote Blanche, probable use of pipelines.	Oil spilled in Gulf could significantly affect habitat and populations; from 840 to 1680 acres of marsh could be lost from productivity for 2 years (1.5% of total marsh in area) if tanker spill occurred inland from Gulf, maximum credible spill in ICW could contaminate up to 320 acres for 2 years if it reached wet marsh	Significant increased demand for barges, tug boats, crews with resultant expanded employment and income in region. Need for priorities in equipment use during emergency. possible impact to recreational use of water nearby from oil spill. significant leasing costs
Seagoing Barges (A)	Greater disruption of soils due to need for larger barge facilities and pipeline across island.	More land required for dock facilities.	Fewer water impacts due to expected spillage of 42% less oil.	Hydrocarbon emissions 46% lower than from smaller barges.	Same as dock facilities	Less impact due to lower expected volume of spilled oil	Slightly greater than dock operation
FACILITIES OPERATIONS							
Filling (28 months); storage (unknown period); withdrawal (5 months)	No impact.	No impact	No impact.	Hydrocarbon emissions during barge loading at an annual rate of 2410 tons/yr, causing concentrations in excess of 160 μg/m³ as far as 5.7 mi downwind. Minor hydrocarbon and hydrogen sulfide leakage during pumping and minor sulfur dioxide emissions from flaring of vapors during fill.	Loading and unloading barges result in 55 dB at 500 feet (at least 12 dB lower than existing background).	No additional impact.	Negligible impact, non-local personnel estimated at less than 5 for storage periods, 15 workers (3 skilled, 12 unskilled) during transfer operations.

(P) Proposed system design

(A) Alternative to the proposed system design

revenues by $50,000. If construction interrupted salt production at both Weeks Island and Cote Blanche, only $11.7 million in salaries would be released, with $7 million to the local area. The resulting 3.5 million-ton decrease in salt production would proportionately reduce state revenues, through severance tax, by $210,000 and local revenues by $150,000.

A construction schedule for Weeks Island that does not require an interruption in salt mining would cause a shortage of laborers for the time that both mine relocation and storage conversion peak. One possible solution to this problem would entail a different coordination of activities between the two sites. If the Cote Blanche mine were closed during conversion at Weeks Island, the unoccupied work force could assist in mining operations at Weeks Island to expedite construction without drawing heavily from the outside labor market.

Dock Facilities and Pipelines

The proposed method of crude oil supply and distribution is designed for barge transport coordinated with a pipeline system. Six abutment docks would be constructed to accommodate 25,000-barrel barges,and the southern portion of an existing barge slip would be enlarged by 80 percent. An estimated 250,000 cubic yards, involving about 9 acres of marsh and spoil banks, would be excavated for the slip and transported to an approved Corps of Engineers site. Ancillary equipment (manifold, pumps, meters) would require ten acres adjacent to the slip. The excavation would temporarily displace local aquatic life, including benthic organisms such as blue crabs. Increased runoff from the grading of the adjacent ten acres would cause temporary turbidity, BOD, DO and nutrient problems.

Barge transport would require the construction of six 0.5-mile pipelines between the barge slip and the storage facility. Although excavation and backfilling would, in displacing several thousand cubic yards of soil, temporarily cause sediment to run off into the barge slips and Waterway, overall impact would be small.

Despite the probability that a pipeline rupture would cause oil spill is low, a maximum spill of 500 barrels would most likely affect three acres.

With both Weeks Island and Cote Blanche as storage facilities, the proximity of the two sites increases the possibility that a large diameter pipeline could replace the barge system as the means of supply and distribution for the sites. Two alternative pipeline routes to St. James are available, one running 80 miles along Beyou Teche and the other 60 miles along Atchafalaya. The first would more adversely affect virgin wetland forest. The pipeline would involve a lower operating expense and probability of oil spill than those of barge transport.

Marine Operations

Barge operations would involve a total distance of 225 miles. Oil would be offloaded from very large crude carriers to 45,000 DWT tankers in the Gulf of Mexico, transported up the Mississippi River to Venice, Louisiana, and transferred to 25,000-barrel barges for further transport up the Mississippi through Algiers Lock to the ICW and ultimately Weeks Island barge slip.

Daily barge traffic should increase 11 percent for the 28-month fill period and 36 percent for the shorter 9-month withdrawal period.

The maximum credible oil spill for the Gulf, possibly 60,000 barrels, could render 840 to 1,680 acres of marsh (1.5 percent of total marsh in the area) nonproductive for two years. Of the expected average spill of 1,827 barrels, 312 barrels may occur at the barge slip and 1,515 barrels anywhere in the ICW, Mississippi River, or the Gulf. The maximum credible spill from barges into the ICW, estimated at 20,000 barrels, could affect 10 miles of the channel. Transporting the oil from the dock at the storage site would result in significant hydrocarbon emissions, both during transit and at the transfer points in the Mississippi River and in the Gulf of Mexico. "Breathing" losses from tankers and barges would occur at a maximum annual atmospheric loading rate of 800 tons/year during fill and withdrawal. These emissions would be dispersed along the Mississippi River-Intracoastal Waterway route from the Gulf to the storage site. VLCC-tanker transfers in the Gulf and tanker-barge transfers in the Mississippi River would cause emissions at maximum annual rates of 4015 tons/year and 2140 tons/year respectively. Under worst case atmospheric conditions, transfers at the Mississippi River transfer point would cause hydrocarbon concentrations in excess of the three-hour Federal standard of 160 $\mu gm/m^3$ as far as 7.5 miles downwind. The State of Louisiana currently exempts from regulation emissions from crude oil transfers.

As an alternative to small barges, large, seagoing barges might be used to transport part of the oil directly between the tankers in the Gulf and the site. This system would require larger dock facilities and a pipeline across the island creating a greater impact on the ecology of the island. However, their use could result in a 42 percent reduction in spilled oil and a 46 percent reduction in hydrocarbon emissions.

Facility Operations

Transferring the oil from the storage cavern to the barges at the dock would result in significant hydrocarbon emissions as the barge tanks are filled with oil and the vapors contained therein are vented to the atmosphere. These venting losses would occur at a maximum annual atmospheric loading rate of 2,410 tons/year. Under worst case atmospheric conditions, this operation would cause hydrocarbon concentrations in excess of the 3-hour Federal standard of 160 $\mu gm/m^3$ as far as 5.7 miles downwind. Because of unavoidable system leaks, minor amounts of hydrocarbons and hydrogen sulfide would be emitted during pumping. Minor amounts of sulphur dioxide would be emitted during filling of the storage cavern as a result of flaring the vapors that would be vented during that operation.

Fifteen workers would be required for transfer operations during fill or withdrawal periods. A crew of five or less would be required during the storage phase of the program, primarily for security purposes.

7.2 ALTERNATIVE FACILITY COMPONENTS

The West Hackberry SPR facility has been designed for utilizing the most feasible options for distribution, brine disposal, and raw water supply system components. These options, however, may be subject to the following shortcomings:

The proposed tanker terminal on the Calcasieu Shipping Channel may prove to be too costly, or may not be approved and completed in time to be utilized for ESR fill requirements.

Subsurface brine injection may be discounted as a feasible disposal alternative after detailed subsurface surveys are completed.

Similarly, a raw water source other than/or in addition to surface waters from Black Lake may be required.

Possible alternatives and the environmental impacts for each of these components are summarized in Table 7.5 and are discussed in detail in the following subsections.

7.2.1 Alternative Distribution Facilities

The present plans for distribution facilities at West Hackberry call for initial fill operations from a temporary barge dock connected to the Intracoastal Waterway by a 4.2 mile canal. Alternatively, beginning fill operations would be delayed until the completion of the permanent facilities and pipeline connections. This would result in increased fill rates and correpondingly enlarged system's components if ESR rapid fill requirements are to be met. An enlarged physical plant would entail substantially greater costs and may be environmentally unacceptable due to increased water supply and brine disposal requirements, the problems of which are discussed in Sections 3.2.2 and 3.2.4. Several options exist, however, for satisfying the permanent distribution requirements.

Table 7.5 Summary of alternative facilities and major environmental impacts.

DISTRIBUTION	CONSTRUCTION	OPERATIONAL
1. Temporary barge dock (Proposed)	Dredging Alkali Ditch $\sim 35.0 \times 10^3$ yds; destroys benthos, temporarily (2 mo.) interrupts local population.	Increased traffic(4 barges/day; 10 mo. duration). Small risk of damaging oil spill (probability of 1.2×10^{-4} per trip for median spill of 1,100 bbls)
2. Permanent Hackberry Terminal (Proposed)	Dredging tanker berth $\sim 2.5 \times 10^6$ cu. yds.; channel area already a much disturbed habitat. On site grading and tank construction on 28 acres of shore property, precludes use for hunting or fishing. Pipeline crosses dry agricultural land, former use restored after construction.	Increased traffic (max. 2 tankers per dav, 400 MBPD; 5 mo. duration) Small risk of damaging oil spill (1.07×10^{-4} probability of median spill 8,300 bbls). Major spill could disastrously affect fishing and waterfowl feeding in Calcasieu Lake as well as shrimp and oyster production.
3. Adaptation of existing Lone Star Dock (Alternative)	Dredging tanker berth $\sim .66 \times 10^6$ cu. yds.; channel area already a much disturbed habitat. On site grading and tank construction on industrial property (300-400 acres) Longer pipeline route crosses 6 mi. of brackish marsh but use of existing Alkali Canal could minimize disruption of the habitat. Temporary interruption of ICW traffic.	Increased traffic (max. two tankers per day, 560 MBPD; 5 mo. duration) Increased transhipment time. Share facility with another SPR site. Small risk of damaging oil spill, same as Hackberry terminal. Major spill could disastrously affect fishing and waterfowl feeding in Moss Lake.
4. Existing pipelines (Alternative)	Pipeline connections follow much the same route as distribution line to Lone Star. May also involve rice farming areas which would affect production, maximum 80 acres or $32,800 years harvest.	Only a slight chance of a spill (3.0% probability of median spill of 1000 bbls). Except for waterway crossings, the effect of a leak would be localized. Spill into waterway would require emergency treatment. Direct industry connections avoiding possible terminal accidents.

5. New pipeline to Texoma terminal (Alternative)	Pipeline route must cross ~28 mi. marshland, Sabine and Neches R. Recovery of destroyed habitat should begin within 1 year. Complete recovery to natural state 3 yrs. after abandonment.	Would service all SPR sites in this storage region. Small chance of a spill (3.0% probability of median spill 1000 bbls) except for waterway crossing. The effect of a leak would be localized. Spill into waterway would require emergency treatment. Pipeline maintenance clearing continues to disturb habitat periodically.
<u>BRINE DISPOSAL</u>		
1. Subsurface injection (Proposed)	Pipeline Construction temporarily affects ~60 acres of grazing area. Full recovery within 1 yr. except ~1 acre per each wellhead maintained for life of project. Drilling noise (duration 12 mos.). Drilling mud to be reprocessed; pits reclaimed, little local impact. Slight probability of blowout	Small probability (1.0%) of brine spill due to pipeline or wellhead failure. May destroy local grasses. Overpressurization could fracture aquiclude resulting in possible fresh aquifer contamination. Well clogging may require flushing, resulting in oil fill delays.
2. Gulf disposal (Alternative)	Pipeline would affect 16 mi. marshland and must cross Sabine Nat. Wild. Refuge. If Starks canal were used, increased turbidity would have temporary deleterious effects on scenic and productive habitat. Pipeline extension into Gulf affects ~4 mi. ocean floor.	Small probability (> 1.0%) of brine spill. Increased salinities in Starks Canal would be temporary but could have profound effects in destruction of marsh biota. Detectable salinity increases (0.1 ppt) in Gulf waters will cover ~450 acres. Increases of 2.5 ppt extend over only 1 acre under normal current condition (duration 10 mo.) Benthos in diffuser area would be adversely affected but would repopulate within 2 months.
3. Black Lake disposal (Alternative)	Minimum disturbance (~3 acres) due to construction, pipelines, etc.	Profound increases in lake salinity (more than 1.5 ppt/day if lake had no connections) Dissipation would be slow, relying primarily on tidal influences for mixing. Long period changes of such magnitudes would be disasterous to lake biota (duration 10 mo.).

4. Calcasieu disposal (Alternative)	Pipeline route would parallel distribution line across dry agricultural land.	Shipping channel is already a disturbed and turbulent area but surrounding lake is extremely productive. Brine disposal would adversely affect the entire lake population because of the migration of organisms through the channel. Decrease of biological production would result in a decrease in seafood taken from the area.
RAW WATER		
1. Black Lake (Proposed)	Minimum disturbance (~3 acres) due to construction, pipelines, etc.	Replenishment from area canals and bayous and tidal inflows will offset any appreciable change in lake level. Ensuing velocities in connecting canals would be no greater than .06 ft/sec. Water quality would depend on quality of inflow. Low mobility, unattached organisms near the intake would be sacrificed.
2. Shallow aquifers (Alternative)	Minimum road and pipeline construction (0.75 mi. new road construction). Drilling duration ~ 3 mo.	Saline water taken. Saline/freshwater interface not adversely affected. Duration 5 mo. Extremely small probability of surface subsidence.

7.2.1.1 Alternative Distribution Terminal

An alternative location for the proposed tanker facility on the Calcasieu Shipping Channel near Hackberry is to construct a longer pipeline to the Lone Star terminal site, 16 miles farther north on the Calcasieu River, just south of Vincent Landing (see Fig. 7.2). The Lone Star property, of about 360 acres, is the site of a former cement plant which was abandoned in 1968. It has about 3400 ft. of channel frontage and an existing barge dock 1240 ft. long with a 14 ft. mooring depth. The property has existing buildings and warehouses, a railroad spur, 67KV primary electrical power, a 4 inch natural gas line, two deep fresh water wells, a private sanitary sewer, and other remnants of the industrial facility.

Terminal Site Considerations: In general, the same facilities as described in Section 1.3.1 for the permanent terminal near Hackberry would be constructed at the Lone Star site (refer also to Fig. 1.11). The docks at the terminal location would provide mooring for two 50,000 DWT (approx. 350,000 bbl) tankers or oil tank barges. The docks would be about 800 - 1000 ft. long, requiring a total shore line of about 2500 ft. Whereas, the dredging required at the lower Hackberry terminal would be an estimated 2.5 million cu. yds., only 0.66 million cu. yds. would be dredged at Lone Star. This reduction is due to the fact that the Lone Star docks would be closer and parallel to the channel, and the present depth at the existing barge dock is 14 ft. as opposed to 4 or 6 ft. at the other location.

Dredge spoil at the Lone Star site would be deposited in local designated spoil areas on the west bank of the ship channel's Moss Lake cutoff just south of the alternative terminal site(see Fig. 7.2). The spoil area is former intermediate marsh which has already been disturbed by deposition of spoil from the dredging of Moss Lake Cutoff and subsequent maintenance dredging. Thus much of the spoil area has already been raised to dry land elevations, leaving patches of isolated or subdivided marsh. Assuming, however, that all of the spoil is deposited in these marsh patches between existing spoil piles, roughly 100 acres of marsh would be converted to dry land. Since site specific investigations have not been conducted, reliable estimates of the biota to be destroyed by these operations is indeterminable.

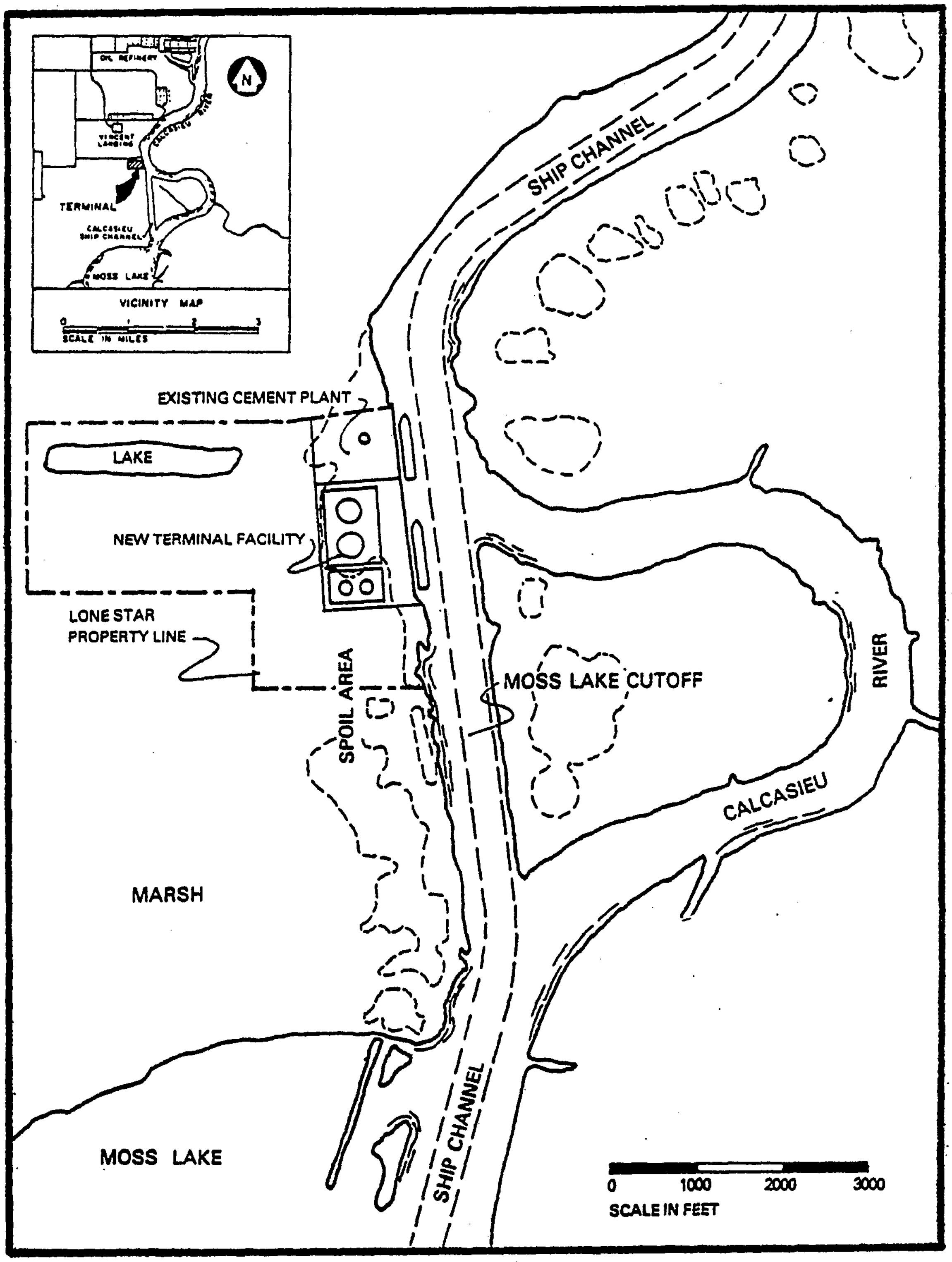


FIGURE 7.2 ALTERNATIVE TERMINAL SITE

Because the facility is on the Calcasieu River, turbidity resulting from dredging wouldextend considerable distances downstream to the lake. Although sedimentology data are not available for the site, it can be assumed that the river contains much the same sediment composition as the lake. For this reason, the extent and impacts of turbidity resulting from the proposed action would be similar to that of the proposed channel and dock facility on the lake.

Onshore improvements for conversion of the existing industrial site to a crude oil ship terminal would require the construction of two 400,000 bbl crude surge tanks, two 100,000 bbl ballast tanks, and two 15,000 bbl ballast treatment tanks, all enclosed in adequate retention dikes as required. The control building, power substation, and other support facilities may be adapted from part of the existing industrial facilities or they may be built new. The area occupied by the onshore terminal facilities for West Hackberry would be only about 30 acres of the approximately 360 acres of the Lone Star property.

Although the physical facilities at both terminal locations are essentially equal, the impacts of terminal construction at the Lone Star site would involve the conversion of an existing industrial site whereas the construction of an entirely new terminal at the Hackberry site would impact agricultural land and a relatively undisturbed shoreline. In addition, the smaller amount of dredge spoil at Lone Star would also be confined to an onshore disposal site which has less impact on increased turbidity than at the Hackberry site where spoil will be deposited against previously formed levees in a relatively open lake area (see Section 3.2.1 for discussion).

The potential for routine small oil spills during terminal transfer operations would be essentially the same at both locations. Generally small spills occurring during normal operations do not have long range damaging effects to the environment. Successive accidental spills of greater magnitude(from 30 to 100 barrels) can have pronounced effects, however, especially in relatively confined areas such as the Calcasieu Ship Channel where spilled oil would not have time for weathering before reaching shorelines. The probability of spills of this magnitude is calculated at 1.8×10^{-3} per tanker trip. Section 3.7.2 deals with marine accidents in more detail.

Due to increased shipment time, the potential for vessel accidents is slightly greater for the Lone Star location, which is nearly twice as far up the shipping channel as the proposed Hackberry terminal (assuming distribution by ocean going vessels). In addition, since the Lone Star mooring is parallel and adjacent to the ship channel rather than offset in a mooring slip as planned at the Hackberry site, the potential for accidents involving ship channel traffic and moored ships at Lone Star is somewhat increased. As discussed in Section 3.7.2, the probability of a moored tanker being rammed by another vessel resulting in an oil spill is only 1.3×10^{-7}.

Terminal Pipeline Connections: Whereas the pipeline route to the presently proposed terminal near Hackberry is approximately 4 miles long, crossing some 55 acres of dry agricultural terrain of 5 or more feet in elevation, the alternate route to the Lone Star site is approximately 12 miles long, involving considerable wetlands area(see Tab. 7.6).

The first half of the alternate route from the storage site runs parallel to the Alkali Ditch (see Fig. 7.3) and thereby crosses approximately 70 acres of brackish marsh-land between the storage site and dry land about one mile north of the Intracoastal Waterway (ICW). The existing brine pipeline from the Olin brining facility at West Hackberry is exposed above the marsh along the west bank of the Alkali Ditch. The alternate oil line would be buried on an additional right-of-way, either on the opposite side of the canal or by reaching over the existing brine line during construction. In either case, barge-lay construction techniques (see Section 1.3.4) would probably be required for this portion of the pipe-line. The existing Alkali Ditch may be utilized for this construction. The ditch would possibly require some widening to allow barge traffic to pass, but the use of the ditch would entail less disturbance to the existing surface environment. Assuming, however, a total of 70 acres brackish marsh and a normal marsh productivity of 1,518 gr. dry wt./m^2/yr., a lost productivity of only 312 tons for the year can be estimated.

Construction of the remaining 6 mi. of the pipeline would affect about 50 acres of dry land and 25 acres of inter-mediate marsh in the vicinity of Bayou Choupique, and

Table 7. 6 Pipelines Alternatives and Affected Areas

	Developed areas	Dry or agricultural	Intermediate March	Brackish Marsh	Protected Areas	Total Mileage	Total Acreage	Major Waterways Involved
DISTRIBUTION (Mi/Acres)								
1. Temporary barge dock	No pipeline required							
2. Permanent Hackberry terminal	Crosses Hwy 27	4/60	0	0	0	4	60	None
3. Adopt existing Lone Star Dock	Crosses Hwy 27, ICW	4/60	2/30	6/90	0	12	180	ICW Black Bayou
4. Existing pipelines	Crosses ICW	6/75	2/30	6/90	0	14	195	ICW Bayou Choupique
5. New pipeline to Texoma terminal	Gum Cove oil field	7/85	10/150	18/275	0	35	510	Black Bayou Sabine River Neches River
BRINE DISPOSAL								
1. Subsurface injection		4/60	0	0	0	4	60	Unnamed bayou
2. Gulf disposal	Crosses Sabine National Wildlife Refuge	4/60	0	6/90	10/150	20	300	Starks Canal Gulf of Mexico
3. Black Lake		0	0	.5/3	0	0.5	3	None
4. Calcasieu Lake	Parallels Distribution Pipeline					4	60	None
RAW WATER								
1. Black Lake		0	0	.5/3	0	0.5	3	None
2. Shallow Aquifers		1/6				1	6	None

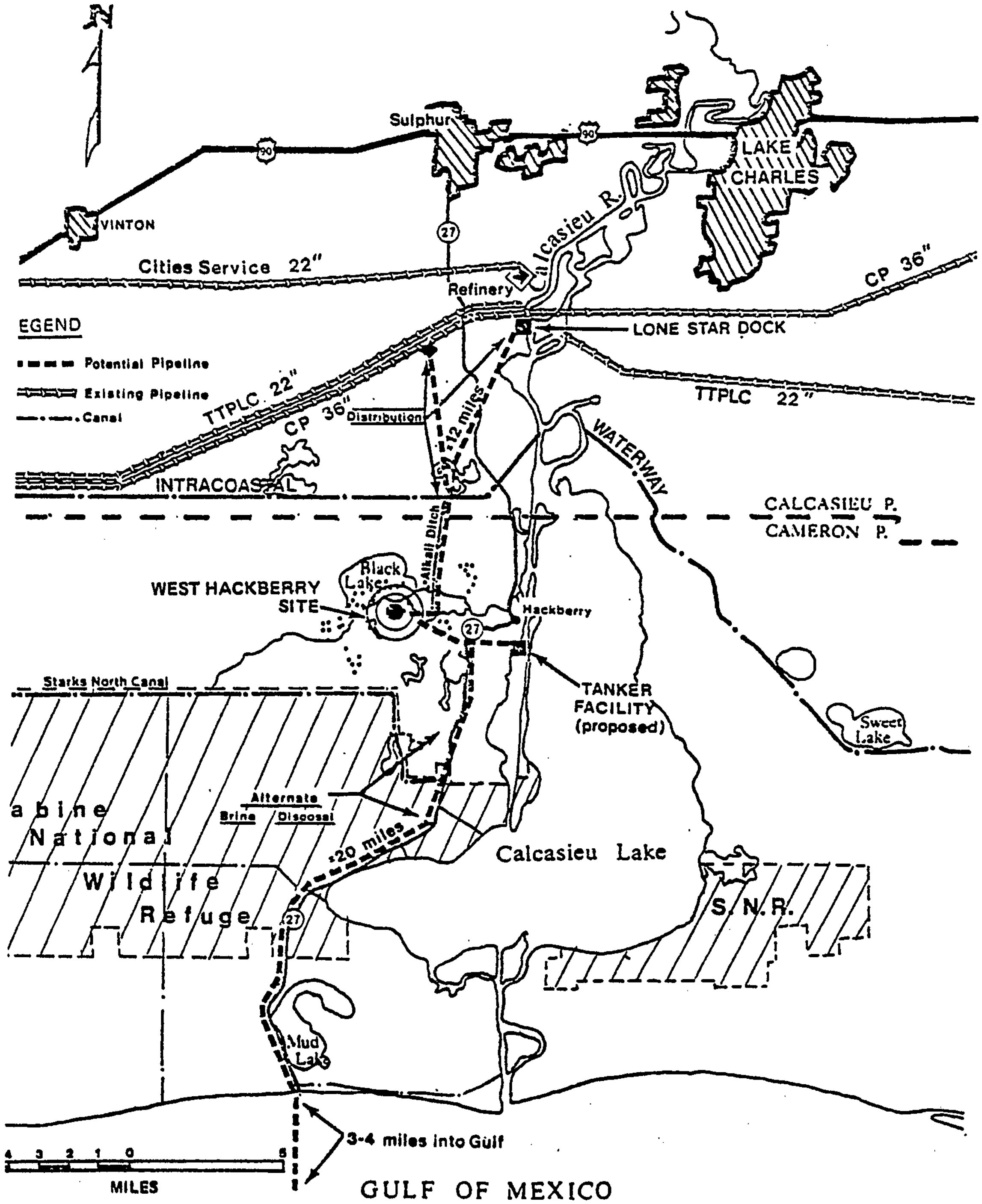


Fig. 7.3 Proposed and Alternate Pipeline Routes

will require both conventional and push-ditch construction techniques (see Section 1.3.4). The overall impact over this section of pipeline construction would be less severe than that imposed by the barge-lay methods. Push-ditches and dry land ditches directly affect only the width of the ditch plus the access road along side, resulting in temporary destruction within a 20 to 30 ft. swath.

Construction of the pipeline across the Intracoastal Waterway should cause little interruption to ICW traffic. The pipeline dredge barge may be a temporary obstacle but could usually be bypassed without delay. The pipeline itself would be assembled on shore and pulled across the ICW when completed. This operation may interrupt traffic for one or two hours. In addition, both pipeline routes cross Highway 27, but in a rural location where existing development is not likely to be affected.

7.2.1.2 Alternative Pipeline Distribution

Alternative sources for limited fill requirements at West Hackberry may be obtained through pipeline connections to existing oil refineries and transport facilities in the area. The Cities Services 20 inch pipeline, which carries domestic crude oil from Texas to their refinery at Lake Charles, is a possibility with a 16 mile new pipeline connection. Also, the Texas Pipeline Company's 22 inch line, which carries domestic crude oil from south Louisiana and offshore Louisiana to refineries at Port Arthur and Beaumont, is another possibility with a 10 to 12 mile connection (see Fig. 7.3). The surplus capacities in these existing pipelines have not been examined, but limited supplies might be negotiated.

The required pipeline connections to these facilities would cross approximately 70 acres of brackish marsh, probably using the Alkali Ditch route as described above, and some 50 to 80 acres of agricultural terrain. The primary crop in the area is rice. Disruption and temporary loss of rice production through pipeline construction will be 12 acres per mile of construction. Based on data furnished by the Soil Conservation Service (personal communication), this may be as much as 38 barrels of rice per acre, which is equivalent to 6,056 pounds of rice. At average 1974 market price, this loss of production would amount to $410 per acre, or a total of $32,800, assuming a maximum of 80 acres of rice land were disturbed. Even though rice farming could be continued within a year of construction, conventional pipeline laying techniques, which often bury top soil and deposit clay subsoils on the surface, would result in a substantial reduction in productivity for several years. Assuming as a worst case that the land was, on the average, only one-half as productive for the next 10 years, then an additional $164,000 of potential rice harvest would be lost as a result of the SPR project.

A long range distribution alternative for West Hackberry is to eventually link all the SPR storage sites in the Beaumont/Lake Charles storage region by pipeline and probably to connect the system to the Texoma terminal at Nederland Texas. Texoma is a major inland distribution 30 inch pipeline to northwest and midwest market regions from the Beaumont-Port Arthur area. Existing docks at the Texoma terminal serve up to 100,000 DWT tankers. It is planned by the Corp of Engineers to deepen the Port Neches terminal which would allow larger tankers at the facility. There are also plans for a private pipeline connection from the Texoma terminal to Seadock, if that superport is built.

The new pipeline connecting West Hackberry to the Texoma terminal would traverse approximately 55 miles of various terrain and marshlands, requiring right-of-way of roughly 180 acres in brackish marsh, 106 acres in intermediate marsh, 48 acres in fresh marsh, and about 24 acres of dry land to cross the Gum Cove oil field. These acreages assume a 100 ft. right-of-way in crossing wetlands where push-ditch construction techniques may be employed. In some areas where barge-lay construction techniques might be required, the affected area may be from 50 to 100 percent greater (see Section 1.3.4).

The greatest impact of new pipeline construction occurs with clearing additional right-of-way, with up to several hundred feet required in some marshlands. A pipeline which crosses the marshes in a generally east-west direction would be extremely disruptive to wildlife, rice farming and trapping. Numbers of wildlife temporarily displaced would be somewhat dependent upon the time of the year when construction takes place. During the winter months, when migratory waterfowl are wintering in Southern Louisiana, several thousand ducks and geese may potentially be disturbed. Alligators residing in the marshland would be disrupted, as well as nutria, muskrat, and other furbearers. Because the degree of disruption and the season when construction takes place cannot be predicted, estimates of impact cannot be made.

In an area along the Sabine-Neches waterway where the pipeline would cross to the Nederland, Texas Terminal, dredging of the waterway must take place. Like all dredging activities, this would cause disruption and loss to the benthic community, migratory fish, and shrimp at and downstream from the site. Because much of the Nederland region is heavily industrialized, construction activities within the region of the terminal would not create a severe impact to local inhabitants.

The greatest environmental impact from pipeline operation would occur if an accident resulted in spillage of a large amount of crude oil. This could have serious and potentially long term detrimental effects on terrestrial or aquatic biological communities. As discussed in Section 3.7.2, the probability that any pipeline spills would occur during operation of the proposed pipelines are only 3%. The alternate pipelines extend over greater distances, but the increase of spill probability is only slight. The environmental impacts caused by pipeline oil spills are discussed in Section 3.7.2.

7.2.2 Alternative Brine Disposal Facilities

The rapid fill rates dictated by the ESR goals result in correspondingly greater disposal rates for the displaced brine. Alternatives are to redesign the facility to meet a more lenient timetable for fill operations, or to reduce the total design storage capacity of the facility, thus decreasing the rates at which the brine is discharged. At lesser rates, a greater percentage of the brine might be marketed, reducing the total amount of waste. This alternative may seriously limit, however, the effectiveness of the SPR program.

Disposal to the Gulf

The primary physical alternative to deep-well brine injection is the construction of a pipeline for direct disposal into the Gulf of Mexico. The probable pipeline route from West Hackberry would run in course with State Highway 27, passing through the Sabine National Wildlife Refuge, a distance of about 20 miles to the Gulf (see Fig. 7.3). Use of the highway right-of-way, or the Starks Canal which parallels the western edge of the road, would spare the major disruption of some 200 acres of brackish marshland through the Refuge. If conventional pipeline construction were permitted on the levee upon which the road is built, the overall environmental impact to the protected habitat during construction would be limited primarily to the loss of soil in rain runnoff and the temporary increase of suspended matter in the local surface water. If the pipeline were laid in Starks Canal, using barge-lay techniques, this scenic canal, which is an integral part of the Refuge and is heavily populated by migratory and other waterfowl, would be disturbed.

If the alternate pipeline route through Sabine National Wildlife Refuge did not follow existing right-of-way or was not placed along the Starks Canal, a path of brackish marsh vegetation (Spartina spp. and other marsh grasses) up to 150' wide would be eliminated during probable barge-laying of the line. This vegetation would return within a one-year period except on the access road which would require filling. Turbidity would result from filling and pipe-laying within the marsh, possibly along a path as wide as 1/4 mile depending on currents, wind action and the type of sediment present. The increased turbidity would not affect the surrounding marsh grasses but may interrupt habitation of the area by fish, shellfish, benthic organisms in general, and wildlife. Fish which feed by sight primarily would move out of the area until the water cleared. Shellfish such as crabs and mollusks could be killed by the clogging or abrasion of the gills with sediment. Clams or oysters would be especially subject to sedimentation and normal growth and reproduction may be severely limited or halted or mortality may result. Oysters have some defenses against silt conditions.[1] Some mussels are much more limited by sediment than others and research would be necessary to discover the magnitude of effects on populations along the proposed pipeline route. One study has shown that over 90 percent mortality of freshwater mussels occurred when siltation permanently covered the original substrate.[2] If the mussels are suspended above the substrate, as in some commercial operations, mortality is much lower.

Blue crabs would be affected but probably would not be eliminated. Mussels and blue crabs would return to the area within a year although growth of mussels to large size may take several years. Oysters generally occur permanently only at salinities which are generally above 12 ppt.[1] Probably few or no oysters would be present very far into the marsh. Restricted water circulation, also present in the marshes areas, is related to absence or low abundance of oysters.[3]

Constructing the pipeline through the Sabine Refuge marsh also will affect wildlife populations, especially waterfowl and small mammals. During November through March thousands of overwintering ducks, geese and other waterfowl primarily would be impacted in the eastern portion of the Refuge along with birds which are present the entire year. Waterfowl would avoid the construction route for feeding and nesting but would return after construction. An undeterminable number of birds would be forced to utilize other areas of the Refuge or surrounding land. Numerous resident waterfowl and other birds would be affected by construction at times other than winter.

Mammals such as nutria, mink, otter, musrat and raccoon (see Table 2.12) would emigrate from areas near construction but probably would produce little stress on the surrounding ecosystem because of its high productivity. Trapping is permitted in the area and several trapline areas may be interrupted for one season. Small mammals should repopulate the construction area within a year or two.

If the pipeline is laid along the levee on which Highway 27 is built, little effect on marsh vegetation or biotic components will occur. Only minor turbidity from runoff could affect a small amount of shellfish or fish. Birds and other wildlife would temporarily leave the area because of noise.

If the pipeline were laid in or along the Starks Canal, noise would affect wildlife to the extent that animals would evacuate the area during construction. Turbidity resulting from barge-laying of pipeline in the canal could result in disturbance of birds, fish, and other aquatic life, but probably in an area about 1/4 as extensive as if the pipeline were placed across open marsh as described earlier.

There is a measurable hazard (one percent probability) that rupture of the pipeline could occur. Planned monitoring systems could detect small pressure changes, allowing a rapid shutdown of pumping. The saturated brine released would have severe effects on biota locally, but these would not persist. Recovery or replacement of affected nonmobile organisms would occur at different rates, depending on ease of establishment, life span, and other factors.

The alternate brine disposal line to the Gulf would extend into the Gulf approximately 4 miles to water 20 ft. deep. Installation of this segment of the line would eliminate approximately 48 acres of non-motile benthic organisms and would temporarily drive fish populations from the immediate vicinity of the line. Once the line is installed fish will immediately return to the area and benthic invertebrate populations should be back to normal within 6 months.

A simple diffuser design having twelve 9 inch ports oriented upwards at about 5 feet above the ocean floor and spaced 10 feet apart was assumed for the analysis. As calculated in assessment of Gulf disposal for other SPR sites, the 250 ppt brine* is rapidly diluted in 35 ppt sea water under current conditions, assumed to be .8 knots or 1.35 ft/sec. The overall increase in salinity is reduced to 3.4 ppt at a distance of 16 feet down current and 2.0 ppt at a distance of 50 feet. The far field traces of 1.0 ppt and 0.1 ppt excess isohalines however, extended 1,300 feet and 18,000 feet, respectively. The total ocean area affected by increased salinities of 0.1 ppt or greater is shown to be approximately 250 acres under normal current conditions.

Impacts of Brine Disposal in the Gulf

In general, the results of the two models presented indicate that except for points immediately downstream of the diffuser ports, the salinity excesses are relatively moderate, with no portion of the ocean floor in the disposal area experiencing excesses greater than 3.5 ppt. The mortality to low mobility organisms, such as phoronids, pelecypods, and polychaetes, close to the diffuser would be irreversible. Recolonization, however, should occur relatively quickly once the brine discharges have ceased. There is no reason to believe that mobile organisms susceptible to higher salinities will not avoid the discharge area. Some stimulation of primary and secondary production throughout the marine communities may occur at the edges of the area of appreciable mixing. Nutrients availability for primary producers and consumers may be increased by the mixing.

* In the report for which these calculations were made, the concentration of 250 parts by weight of salt in one thousand parts of water was used. At West Hackberry the corresponding number used is 265. The resulting changes in the salinity increases however are not significant.

Non-Benthic Organisms: Either due to current transport or free mobility, non-benthic organisms would encounter minimal impacts from brine discharges into the marine environment. Mackin, working on oil field brine discharge, reports that marine fishes, mobile organisms, and current carried forms apparently are not affected by high salinity discharges in large water bodies.[4] Their time in traversing the zone of high salinity is too brief for long lasting impacts.

All available data indicate that organisms which prefer low salinity levels wouldavoid the brine discharge area with no apparent difficulty. It is expected that such species as the Southern oyster drill (*Thais haemastoma*), the stone crab (*Menippe mercenaria*), the sea robin (*Prionotus scitulus*), the gray snapper (*Latjanus griseus*) and the sea bass (*Centropristes philadelphica*) would avoid areas of high brine discharge.

Benthos: Mackin reports that if brine concentrations are great enough, an effect on benthic organisms can be measured.[4] In large bodies of water where the capability of dilution is great, dilutions of 1000 parts of seawater to one part of brine can occur in distances of from 8 to 50 feet.[4] However, a continuous discharge over several years, creating localized plumes may serve to increase local salinities by 5 ppt. The effect on mobile organisms would be slight to negligible (similar to that reported for nekton) but the effect on sessile or slightly mobile organisms with narrow salinity tolerances could be moderate to severe.

Given a substantial salinity increase (5-10 ppt) three impact zones would develop. The first zone would be an area of near total destruction. Phoronids, pelecypods, and polychaetes would be destroyed, bacteria may be an exception. In the second, or transition zone, a depression of species and individuals may occur. Stunted development may also be detectable. The extent of the second zone would vary depending on dilution factors. Mackin believed this zone may extend from 100-300 ft. in a large body of water.[4]

The third impact zone would be an area of stimulation of the marine communities. Bacteria, yeasts, fungi and phytoplankton numbers would be increased. Minter and Mackin reported heavy phytoplankton and algal productivity near the edge of a transition zone. Increased productivity of organisms near the bottom of the food chain will elicit corresponding increases in primary consumers (zooplankton and filter feeders such as polychaetes and pelecypods) and secondary consumers (crabs).[5,6]

The impact of offshore brine disposal in an area of limited benthic productivity should not be significant. The localized destruction of the benthic fauna in the immediate vicinity of the diffuser should have negligible effects on total production of the coastal area.[7]

Disposal in Local Saline Bodies

The possibilities of brine disposal into either Calcasieu or Black Lake are not being considered as viable alternatives due to the probable adverse environmental effects of introducing large quantities of saturated brine. Because of Calcasieu Lake's highly productive estuarine characteristics, damaging increases in salinity would probably not be tolerated. Black Lake, with salinities ranging from 0 to 12 ppt, presently accepts small quantities of waste brine from area oil production and existing salt dome storage facilities. Large quantities of brine would cause drastic biological changes.

As discussed in Sections 2.4.3, 2.4.4 and 2.4.6, Calcasieu Lake and adjacent areas are quite productive, with many species of economic importance. The large amount of saturated (concentration about 265 ppt) brine to be disposed of during filling of stored oil, the relatively slow dilution of such contamination, and the low biological diversities reflecting an already severe salinity regime inveigh strongly against these alternatives. The brine would tend to be moved with the tides rather than being flushed out by a rapid river flow in a Gulfward direction. The salinity would only gradually dissipate and in every direction. The normal salinity fluctuations at the level in the estuary into which releases would be made are so great that relatively few species of organisms can permanently endure them.

Salinity tolerances of some of the organisms in Calcasieu Lake or Black Lake are discussed below. Oysters (*Crassostrea virginica*) can tolerate salinities of 10-30 ppt and have been collected in waters from 10.0 to 34.9 ppt.[8,9] Blue crabs (*Callinectes sapidus*) and several species of penaeid shrimp (white, pink and brown) have been collected in salinities as low as 1.0 ppt up to 34.9 ppt. Abundances of different life stages are related to much narrower salinity ranges however. Oysters are reported to have abnormal larval development, altered growth rates and to have "thin, flabby tasteless meat" at increased salinities.[9] Salinity ranges as great as those anticipated in the brine disposal areas of Black Lake or Calcasieu Lake probably would kill all oysters, crabs and shrimp in a short time. Fish would also be eliminated as well as zooplankton and even marsh grasses. Each brine disposal cycle during fill operations would again decimate the community. As presented in Chapter 2, salinity is the paramount environmental factor controlling distribution of organisms in Calcasieu Lake and associated water bodies such as Black Lake.

The main food chains in the food webs of the estuary are rich detritus-based systems rather than grazing chains. In such ecosystems, there is a comparatively great number of individual organisms represented at the first step in the food chains. A high proportion of the attached or little mobile, permanently resident, animal life in Calcasieu Lake and Black Lake functions at the first consumer step level. Most of the animals which use the estuary as a nursery function primarily at the second step level or partly at the first and partly at the second step level. Sometimes the third level is also important. Corresponding to the great amount of detritus at the base, there is a greater biomass and production of new biomass per unit time at the first trophic levels than in ecological systems located nearly anywhere else.[10]

Use of Calcasieu Lake to receive brine would severely affect the entire western part of the lake from north to south since the diffuser would lie adjacent to the Lake Charles Ship Channel. This is especially significant since organisms entering the estuary enroute to feeding and nursery areas pass from the Gulf of Mexico by way of the ship channel. Impact on the organisms on the eastern side of the lake would not be as severe. A total seafood harvest of more than 2,000,000 lbs.(Table 2.32) would be sharply curtailed. A decline in production attributable to increased salinity would occur northward into Moss Lake also, although direct economic consequences would not be so apparent. Waterfowl from the Sabine

National Wildlife Refuge use both Calcasieu Lake and Moss Lake as feeding areas. There is a large bird population. The Refuge is one of the most important overwintering areas for migratory waterfowl using the Mississippi Flyway. Records reveal a highest bird count in North America for 44 species during the period 1948-1972.[11] Moss Lake has areas of shallow water which particularly attract wading birds. Calcasieu Lake not only splits Sabine National Wildlife Refuge but has a bird island at its lower end near the ship channel.[12] In turn, the bird island is near a large oyster reef.[3,13]

Far and away the largest direct economic impact would be on shrimp, which account for 1,361,567 pounds of the annual seafood harvest. The other 638,733 pounds (values are averages for 1966-1970) derive from five fish species, oysters, and crabs (Table 2.15). Shrimp production has shown a resurgence since the near collapse of the Louisiana shrimping industry during the period of 1957-61.[14] The state has assumed management authority for production. Calcasieu Lake contains the major shrimp fishing grounds of west Louisiana, with over 1,000 vessels fishing daily during the first week of the inside spring shrimp season.[14] Black Lake is reported rich in shrimp and fish.[15] Although it has not been censused, its physical conditions are similar to those of Calcasieu Lake at the same level and, since it is closely connected, it may reasonably be considered a functional extention of Calcasieu Lake. Shrimp are very sensitive to salinity.[14] White shrimp larvae migrate, mostly passively, into shallow, fresher areas of the estuary. They feed, grow, and metamorphose in such areas but return to deeper, more saline water to spawn. The developing postlarval shrimp are omnivores that feed on such materials as algae, small mollusks, marine worms, and small crustaceans. When larger, they may attack small fish and other shrimp.[14] Young brown shrimp require higher salinities of about 10-30 ppt, with best average production at about 15 ppt. Many of the brown shrimp in Calcasieu Lake are larger juveniles which may have migrated from nursery grounds of Rockefeller Wildlife Refuge. This refuge is to the east. Calcasieu Lake is a final staging area before return migration to the Gulf, maturation, and spawning.[14]

Most (97.5 percent) of the commercial fish catch of the Gulf states is made up of estuarine dependent species. In most cases this means the estuary is a nursery area into which they come as eggs or larvae and leave as sub-adults or adults.[16] These species would be affected by a large salinity increase and adverse effects on their food supply. The estuaries of the Gulf have been estimated to produce an average of 230 pounds per acre in commercial catches of fish and shellfish (estimated for 1960).[16]

Zooplankton levels in Calcasieu Lake deriving from inward movement of Gulf water must be judged low based on sampling at Calcasieu Pass and nearby areas such as Sabine Pass at the mouth of the Mermentau River. These areas are deficient as compared to other Louisiana coastal areas that have been sampled. The general maxima recorded are on the order of 2,000 to 3,000 individuals per 100 cubic meters. This was exceeded in one instance by a protozoan which attained 5154 individuals per 100 cubic meters. Other main zooplankters are crustacean nauplii, decapod larvae, copepods, and fish eggs. In terms of biomass, copepods of the genus Acartia are most important. They constituted approximately one-half of the biomass in samples.[13]

There is evidence for higher local zooplankton production in Calcasieu and Black Lakes. A rotifer survey of the general area in 1966-67 revealed maximum quantities of main species of over 2,000 individual per liter.[17] More recently, Dr. Stickele, of the Louisiana State University Zoology Department, who has been directing a survey in the estuary, has recorded a relatively high number of copepods, fish, and benthic invertebrates (total well over 100 species; copepods approximately 30 species).[18]

Black Lake would, under the present system design rates, have to receive enough brine to raise the total salinity more than 1.5 ppt per day for 150 days if the lake had no connections. There would be a buildup to a high salinity level with consequent contamination of Calcasieu Lake, the Intracoastal Waterway, and Black Lake Bayou since Black Lake is interconnected with these bodies of water. Adjacent marshland and canals could also be affected, including surface water in the Sabine National Wildlife Refuge. Significant harm would be done to marsh vegetation. Waste salt water from oil production is already thought to be a factor in the decline in vegetation in some Wildlife Refuge areas in the immediate vicinity of the West Hackberry Salt Dome. Die-outs and die-backs are the extreme result seen in some locations.[19] Loss of such habitat will reduce the resources available to waterfowl, fur-bearing mammals, and other wildlife inhabitants of the area. Although some organisms in Black Lake might adjust to the increase in salinity over time as individuals, reproduction and population dynamics would still be gravely affected, curtailing future generations. More sensitive organisms would be killed outright.

Disposal into Calcasieu Lake would not require additional pipeline right-of-ways, since the proposed route for the oil transfer lines to the tanker terminal would be used. The diffuser would be located adjacent to the ship channel, which is already a disturbed and anomalous 40 foot draft swath through the estuary and sustains relatively little biological production. On the other hand, migratory animals must enter the estuary by way of the channel and furthermore, calculations for salinity increases as discussed in the Gulf disposal alternative do not apply here since the saline balances are so complex, being dependent upon tidal influences, river discharge, rainfall runoff, winds, etc.

7.2.3 Alternative Displacement Water Supplies

An alternative to the use of Black Lake Bayou as a source of displacement water is to drill ground water wells for that purpose. The tentative location for the required wells is over the -7000 ft. depth to salt contour directly south of the proposed storage site. The pipeline connections to the well area would follow the same route as that proposed for the brine disposal line; thus no new terrain would be disturbed by this additional pipeline construction. The wells would have the same spacing and layout as the brine disposal wells, i.e. a linear system with wells spaced about 1000 ft. apart. The number of wells required would depend upon the actual yield capacities obtainable as discussed in Section 2.2.2. A total of 11,800 gpm displacement water supply is required. Assuming 5 wells for example and the use of the brine disposal right-of-way for connection to the central pumping facility, at least 4000 ft. by 50 ft. (4.5 acre) surface area would be required for the well system. The wells at this location would be situated on dry ground.

Impacts would include a temporary loss of coastal prairie grass production (2500 $Kcal/m^2/year$)[20] for approximatley one year. Wildlife would leave the area for the duration of drilling and pipeline laying and birds would temporarily be restricted by human activity from using the area as feeding or nesting sites. Once the wells are drilled and operations commence there should be negligible impacts from pump noise and the vegetation should recover within one year.

As discussed in Sections 2.2.2, the Chicot acquifer near West Hackberry extends from the surface to about-1120 ft., providing fresh water of less than 1.0 part per thousand (ppt) dissolved salts in strata-600 ft. and above. Slightly saline reservoirs containing water of 1.0 to 3.0 ppt are encountered in the-600 to-850 ft. depth range. Up to 10 ppt salinity is found at depths from-950 to about-3300 ft. In the local area directly over the dome, however, the interface between slightly saline and fresh water is deflected upward such that brackish water occurs up to near 300 ft. below the surface as shown in the dome cross section B-B' (Fig. 2.5). Based on available data described in Section 2.2.2 a flow rate of 11,800 gpm could be achieved with four wells for slightly saline water (1.0 to 3.0 ppt) at depths of about-625 ft. or for moderately saline water (3.0 to 10.0 ppt) at depths of about-10,000 ft. If ground wells are used as a source of displacement water, plans are that these saline strata would be tapped at depths of from -700 to -1000 ft. rather than the more shallow fresh water layers since fresh water is not required for displacement.

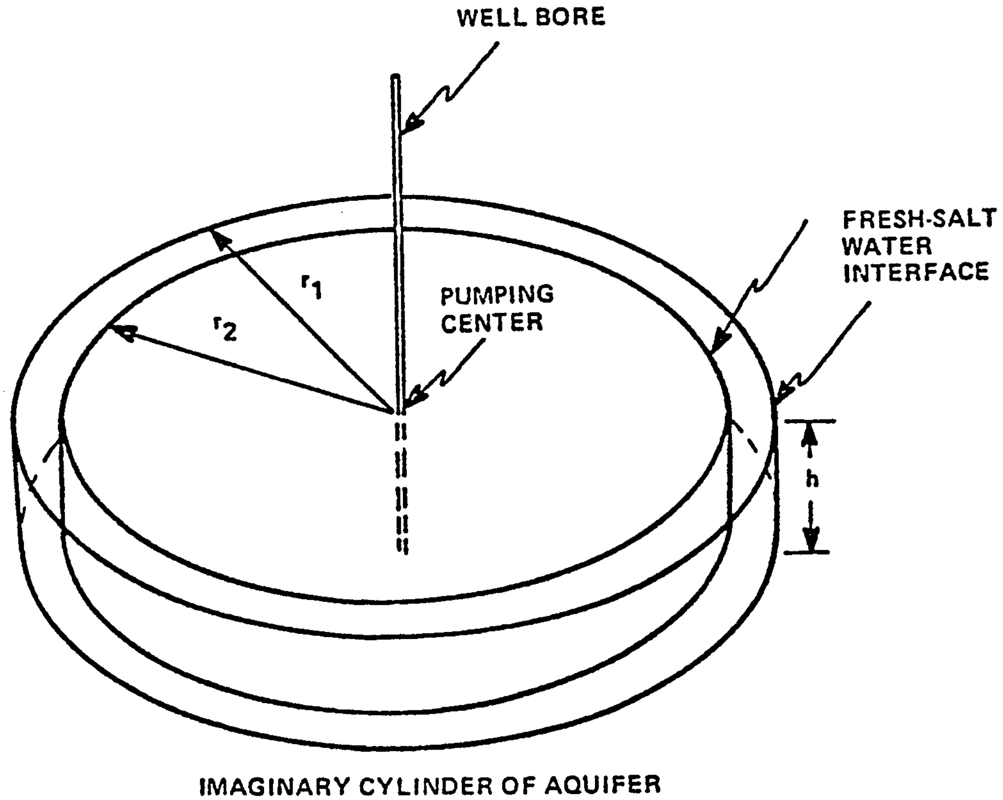
The use of ground water from the top 500 feet of the Chicot aquifer in the quantities projected would create a local cone of depression. This action would change the direction of flow in the local area. It is probable that the fresh-salt water interface would rise above present levels.

In addition, the location where the fresh-salt water interface rises to the surface (currently south of the West Hackberry site) might move northward. As discussed in Appendix D-7, if the intereface is 1 mile from the center of pumping and water moves with equal ease from all directions around the pumping center, the saltwater interface will move 135 feet during the first pumping cycle. In succeeding cycles the interface will move only slightly further each time. If the interface is originally 5 miles from the pumping center, the interface will move only 5 feet during the first cycle. This assumes that the pumped volume is 2.888×10^8 cu. ft. (10,000 gpm for 150 days), and that the aquifer is 200 feet thick with a total porosity of 33 percent. This approach simply subtracts the required (or pumped) volume of water from the volume of water present in a cylindrical aquifer of given radius, height and porosity and solves for the new radius required for the remaining volume of water, as shown in Figure 7.4. The difference of the two radii is the amount of movement of the salt water interface caused by pumping.

The existing rate of advance of the salt water in the West Hackberry area must be considered and added to effects caused by future pumping operations. Also, any salt water advance caused by a new ground water supply at West Hackberry should be considered as a permanent change in the local position of fresh and saline ground water.

Raising the fresh-salt water interface and/or moving the interface northward are each undesirable effects which could adversely impact other users of fresh ground water in the area. The two wells which provide water for the town of Hackberrv apoear especially susceptable to salt water contamination from such a shift in the interface. The water wells at Sulphur and Lake Charles are further removed and thus would be affected to a lesser degree.

The use of ground water from the "700-foot" sands below -900 feet at station 23 of Figure 2. 13 would not cause a similar impact because of relatively poor vertical hydraulic connections to fresh water. Removal of saline water here would tend to move the fresh-salt water interface southward toward the site, possibly causing marginal improvement in water quality to the north. In general, the withdrawal of water from the aquifer at depths greater than about -500 feet should not have any adverse effect on the yield or quality of the fresh water layers at lesser depths.



h	=	THICKNESS OF AQUIFIER
r_1	=	DISTANCE FROM PUMPING CENTER TO FRESH-SALT WATER INTERFACE
r_2	=	DISTANCE FROM PUMPING CENTER TO SALT WATER AFTER PUMPING GIVEN VOLUME
$r_1 - r_2$	=	AMOUNT OF MOVEMENT OF FRESH-SALT WATER INTERFACE TOWARD PUMPING CENTER

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Figure 7.4

7.3 NO-ACTION ALTERNATIVE

A description of the no-action alternative and its impacts, as it applies to the entire program, is provided in the Final Programmatic EIS (FES-76-2). Within the SPR, a decision not to develop the West Hackberry facilities would result in the development of one of the other candidate sites to take its place. In that case, the impacts described in Section 3.0 would not occur and the existing environment of West Hackberry (as described in Section 2.0) would be maintained. However, a decision not to develop West Hackberry would result in other impacts: those associated with the alternate facility. Since many of the candidate sites are also located in the Gulf Coast Region, it is likely that many of the impacts resulting from the development of the replacement site would be substantially the same as those for West Hackberry. However, the detailed impacts of any particular facility are very site-specific and would be discussed in the EIS for that site.

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8. RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS

Land use plans for this area of Louisiana have been developed by the Imperial Calcasieu Regional Planning and Development Commission in conjunction with the Louisiana State Planning office. Present land use designations for Cameron Parish reflect the fact that it is located in a coastal marsh. The distribution of total area in the parish is as follows:[1]

Undevelopable wetlands	567,329 acres	53.31%
Public/semi-public lands*	229,235 acres	21.54%
Water bodies	171,144 acres	16.08%
Agricultural lands	85,710 acres	8.06%
Residential, commercial, and industrial areas	10,713 acres	1.01%
Total	1,064,131 acres	100.00%

Hackberry itself is an unincorporated community, and neither it nor Cameron Parish has established zoning regulations to govern areas affected by the proposed project. As discussed in Section 2.6.1, there are no historical sites in Cameron Parish on the National Register of Historic Places. In addition, it has been determined that no non-Federally owned sites of historical, architectural, or archaeological significance would be affected by the project.

The land use plans for Hackberry in 1990, developed by the Imperial Calcasieu Regional Planning and Development Commission, are based on existing land use and projected population figures.[2] They take into consideration the influences of industrialization patterns, flood prone areas, soil quality, and major highway arteries. These factors are particularly important in projecting the development of Hackberry because it is situated on a limited area of dry land bounded by wetlands on the north and south, Black Lake on the west, and Calcasieu Lake on the east. Total dry land area at Hackberry is approximately 10 square miles.

The population of West Hackberry in 1970 was about 1,340; and is projected to be 1,490 in 1980 and 1,640 in 1990. The formula used to determine future land requirements has been based on the proportion of present population to land usage, and assumes a relatively constant growth pattern. The resulting delineation of various additional urban land requirements in 1990 is shown on Table 8.1. The total additional acreage, 1990 urban acreage, and percent increase

*Includes the Sabine National Wildlife Refuge, the Lacassine Migratory Waterfowl Refuge and the Rockefeller Wildlife Refuge and Game Preserve.

Table 8.1 1990 PROJECTED ADDITIONAL URBAN ACREAGE OF HACKBERRY

Residential	17.1 acres
Commercial-Services	2.1
Industrial	49.7
Transportation-Communication-Utilities	18.7
Institutional	16.9
Total Additional Urban Acreage	104.5
Total Existing Urban Acreage	169.0
Total 1990 Urban Acreage	273.5
Percent Increase 1970-1990	61.8%

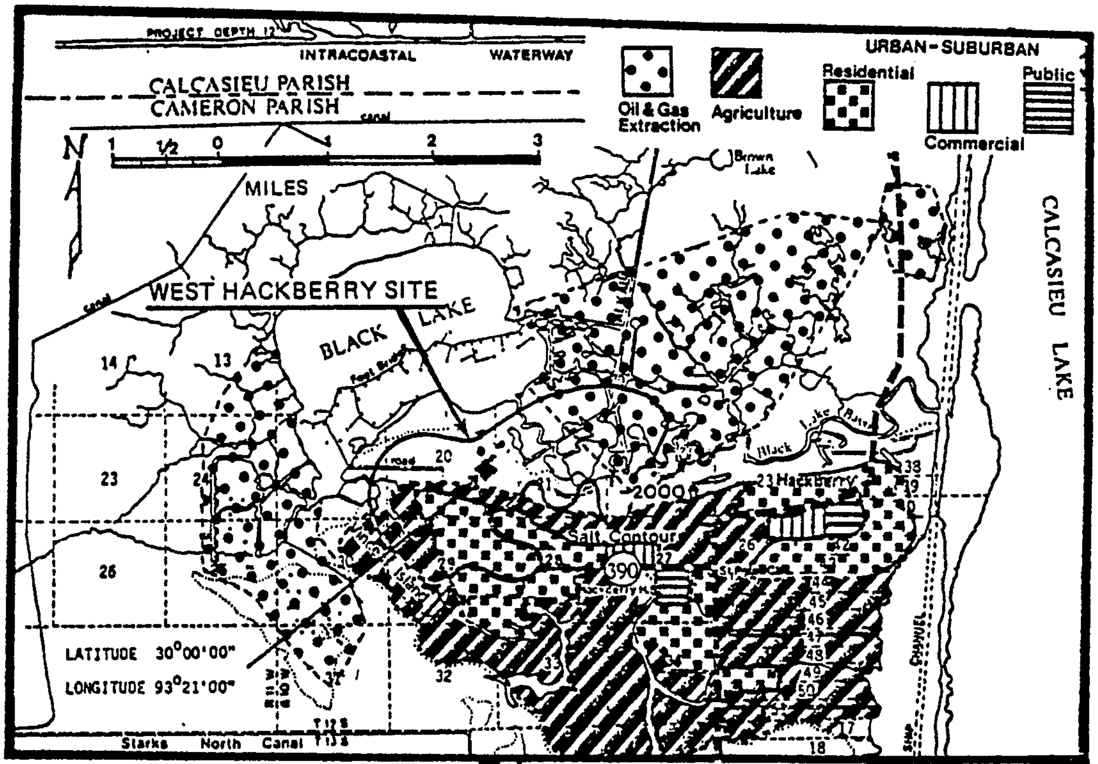
Source: Adapted from materials published by the Imperial Calcasieu Regional Planning and Development Commission.

should be considered as maximum figures since the percentage increase in population is only 22%. Also, it should be noted that the projected development of the community is dependent on the continued rapid expansion of industry in the area.

Due to the limited dry land area, a substantial part of future development is anticipated to occur in a strip along Highway 27 south of the present commercial area. The areas of land affected by this growth are shown in Figure 8.1.

Current use of the storage site and brine disposal field is for brine production operations and cattle pasture. The land near the site being considered for dock facilities is used for industrial purposes: there are other docks, warehouses, and fishpacking houses. Large tracts of land around the site are occupied by oil and gas production facilities. Consideration of these present activities in the area indicates that the construction and operation of the storage facilities would not be inconsistent with current land usage patterns.

Use of the West Hackberry site for oil storage would affect future land use plans for this area in minor ways. The maintenance of a pipeline right-of-way through an area of projected residential and commercial development would impose some restrictions on construction, but since the anticipated development is not extensive or rapid, these restrictions will probably not produce a hardship on the community. While the project would not create a sufficient number of permanent jobs to alter the rural character of Hackberry, it could assist the town in attaining the moderate population growth projected for it by providing a limited number of employment opportunities to local residents.



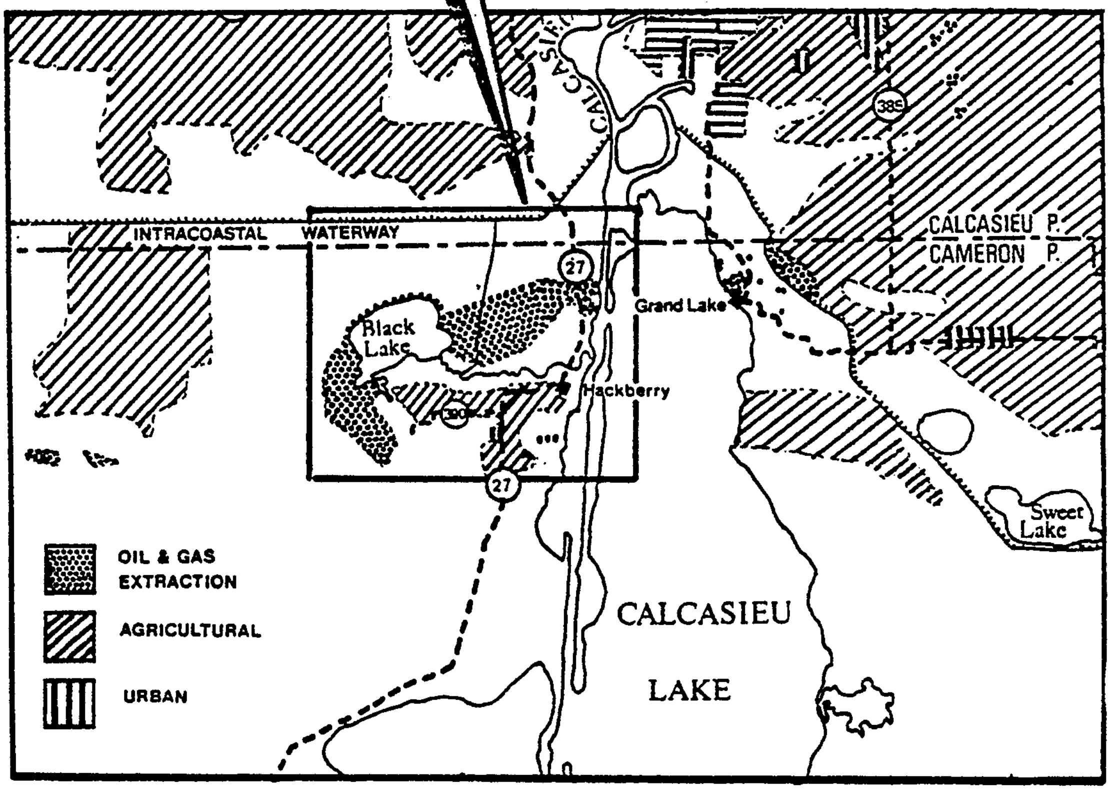


Figure 8.1 Land Use Plans

REFERENCES

[1] Existing Land Use Study, Imperial Calcasieu Regional Planning and Development Commission, June 1974.

[2] Future Land Use Plan for 1990, Imperial Calcasieu Regional Planning Commission, June 1975.

9. CONSULTATION, RELATED PERMITS, AND DISCUSSION OF COMMENTS

Various local and regional agencies contributed information and assistance for the preparation of this Environmental Impact Statement. A list of these agencies is given in Section 9.1. Further advice and coordination will be sought from agencies having regulatory jurisdiction over those segments of the environment which will or could potentially be affected by the proposed project. Procedures are currently underway to prepare applications for those permits and licenses which would be required to proceed with the implementation of the project. Those Federal and state agencies whose concerns interface with the proposed actions are listed in Section 9.2.

The Draft Environmental Impact Statement was released for public review and comment in September 1976. A list of those agencies and organizations from which comments were requested is given in Section 9.3. The Draft Statement was sent to the Louisiana State Clearinghouse so that all state agencies of Louisiana having an interest in the proposed project could review the document and respond to statements and conclusions relating to their concerns. Those comments which were received within the time allotted, are included in Section 9.4. Minor changes to the text of the statement have been made in response to these comments. The comments from various agencies are included in their entirety in Appendix K.

9.1 AGENCIES AND GROUPS CONSULTED

In preparation of the Draft Environmental Impact Report numerous agencies, governmental units, and other groups were consulted for information and technical expertise pertaining to the proposed project. These groups are listed below:

<u>Federal Agencies</u>

United States Army Corps of Engineers,
New Orleans, Louisiana
Environmental Protection Agency, Dallas, Texas
Federal Insurance Administration
United States Geological Survey
Housing and Urban Development Administration,
New Orleans, Louisiana
United States Bureau of Indian Affairs
Department of the Interior
Bureau of Land Management, New Orleans, Louisiana
National Marine Fisheries Commission
National Oceanic and Atmospheric Administration,
New Orleans, Louisiana
Occupational Safety and Health Administration (OSHA),
New Orleans, Louisiana

<u>State Agencies</u>

Louisiana Agricultural, Stabilization and Conservation
Service, Alexandria, Louisiana
Louisiana Air Control Commission, New Orleans, Louisiana
Louisiana Department of Conservation
Louisiana Economic Development Administration,
Baton Rouge, Louisiana
Louisiana State Department of Education,
Baton Rouge, Louisiana
Louisiana State Department of Employment Security,
Baton Rouge, Louisiana
Louisiana Governor's Council on Environmental Quality
Louisiana State Planning Office, Baton Rouge, Louisiana
Louisiana Soil Conservation Service
Louisiana Commission on Stream Control,
Baton Rouge, Louisiana
Louisiana Wildlife and Fisheries Commission,
Baton Rouge and New Orleans, Louisiana

Local Agencies

Secretary of Police Jury, Cameron Parish, Louisiana

Other

Butler Associates, Inc., Tulsa, Oklahoma
Fenix and Scisson, Inc., Tulsa, Oklahoma
Gulf Coast Towing Association, Golden Meadows, Louisiana
Gulf Oil Corporation, Houston, Texas
Imperial Calcasieu Regional Planning and Development Commission
Lake Charles Harbor and Terminal District
LOOP, Inc. (Louisiana Offshore Oil Port), New Orleans, Louisiana
Louisiana Power and Light
Louisiana State University, Center for Wetland Resources, Baton Rouge, Louisiana
Louisiana State University, Institute for Environmental Studies, Baton Rouge, Louisiana
McNeese State University, Lake Charles, Louisiana
Nicholls State University, Thibodaux, Louisiana
Olin Corporation
Texas A & M University, College Station, Texas
Texas Eco, Bryan, Texas

9.2 ENVIRONMENTALLY ORIENTED PERMITS AND LICENSES

Regulatory Bodies and Their Jurisdictional Concerns:

A number of Federal regulations which must be complied with during project development are listed in Table 9.1. Also included in the list are state regulations which are relevant to the program. FEA will consult with the state agencies in charge of implementing these regulations pursuant to the Intergovernmental Coordination Act of 1968.

Table 9.1 Regulatory Bodies

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
1. U.S. Army Corps of Engineers, New Orleans, District Engineer	"<u>Regulations on Navigable Waters</u>"	33 CRF 209	
	A. "Permits for Activities in Navigable Waters or Ocean Waters"	33 CFR 209.120	
	1. Prohibits the unauthorized obstruction or alteration of any navigable waters.	33 CFR 209.120b(2)	
	2. Discharge of dredged materials into navigable waters.	33 CFR 209.120,(b)(3),(b)(7),(g)(5)(ii)	
	3. Structures or activities affecting the navigability of navigable waters; includes structures under a navigable waterway.	33 CFR 209.120,(b)(3) (e)(i),(g)(5)(ii)	
	4. Discharge of refuse into navigable waters.	33 CFR 209.120(b)(4)	
	5. Temporary occupation with use of any sea-wall, bulkhead, etc.	33 CFR 209.120(b)(5)	
	6. Declares a national policy to encourage a productive and enjoyable harmony between man and his environment.	33 CFR 209.120 (c)(4)	
	7. Preservation of the quality of the aquatic environment as it affects the conservation, improvement and enjoyment of fish and resources.	33 CFR 209.120(c)(5)	
	8. License needed which will reflect upon properties listed in the National Register of Historic Places.	33 CFR 209.120(c)(7)	
	B. "Piers, Dredging, etc. in Waterways."	33 CFR 209.130	
	1. Structures or activities affecting the navigability of navigable waters; includes structures <u>under</u> a navigable waterway.	33 CFR 209.130(b)(14)	
	2. Work connecting canals to navigable waters.	33 CFR 209.130(b)(16)	
	3. Fixed structures on the outer continental shelf.	33 CFR 209.130(q)	

Table 9.1 Regulatory Bodies (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
	4. Piers or bulkheads at the coastline.	33 CFR 209.130(b)(13), (b)(12)	
	C. "Permits for Discharges or Deposits into Navigable Waters."	33 CFR 209.131	
2. U.S. Coast Guard, District Commander of 8th Coast Guard District (New Orleans)	Coast Guard Regulations on Oil Spills	33 CFR 154	Letters of intent must be submitted and approved 60 days prior to date the operation is intended to begin.
	A. Letter of intent to operate oil transfer facility.	33 CFR 154.110	
3. U.S. Environmental Protection Agency, Region VI	Regulations on Policies and Procedures for the National Pollutant Discharge Elimination System (NPDES)	40 CFR 125	
	1. These Regulations proscribe the policy and procedures to be followed by the Administrator of the U.S.E.P.A. pursuant to Sections 402 and 403 of the Federal Water Pollution Control Act.	33 USC 1251 nt	
	2. Requires permits . . .for any industrial discharges into navigable waters including the "contiguous zone" territorial sea. Such a permit would probably be necessary for discharge of effluents from the offshore and onshore terminal waste treatment facilities. In addition, should the NPDES permit system requirements not apply to a particular operation, certification is still required from the EPA administrator (or from appropriate designated State or Interstate agencies) whenever a Federal license or permit is being sought for activities which may result in discharge into the navigable waters.		The State of Louisiana does not yet have an approved program for issuing NPDES permits. However, the State has to certify that it has seen and approved the permit application before EPA will act on it.

Table 9.1 Regulatory Bodies (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
	<u>Regulations on Oil Pollution Prevention</u>	40 CFR 112	
	A Spill Prevention, Control, and Countermeasures Plan (SPCC) must be prepared for each oil handling facility, within six months of the commencement of facility operations.	40 CFR 112.3	
	<u>Regulations on Transportation for Dumping, and Dumping of Materials into Ocean Waters</u>	40 CFR 220	
	Permit for ocean dumping required for brine disposal.	40 CFR 220.1(b)(2)	
4. Louisiana Stream Control Commission (enforcement agency is the Louisiana Division of Water Pollution Control) (Baton Rouge)	(a) Certificate of Approval required for permission to discharge wastes into the public water. (b) State must approve applications for NPDES permits before submission to U.S. Environmental Protection Agency.	Louisiana Regulation Requiring Submission of Reports for the Discharge of Industrial Waste. . . 40 CFR 123 Subpart A, Section 123.3.	Certificate of Approval required 3 to 12 weeks before beginning discharges.
	(c) Permit for waste disposal.		
5. Louisiana Air Control Commission (enforcement agency is the Louisiana Division of Air Control and Occupational Health)	(a) Certificate of Approval for construction of sources of air pollution emissions. Applies to onshore turbines, barge loading and unloading facilities, surge tanks, pumps, and related facilities.	Louisiana Air Control Commission Regulations Section 6.1.	At present, no permit is required if only crude oil is handled, but this will be changed by early 1977.
	(b) Approval for open burning of land clearing debris is not specifically required at present so long as the guidelines stipulated in the air control regulations are met. However, it is advisable to notify the Division prior to such burning to determine that predicted ambient air quality and atmospheric conditions at the time of burning will be suitable and to alert the Division that burning is planned and will be properly conducted.	Louisiana Air Control Commission Regulations, Section 11.0.	

Table 9.1 Regulatory Bodies (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
6. Louisiana State Division of Health Bureau of Environmental Services	(a) Permit for installation of sewage treatment facilities and for disposal of solid and oily water wastes. (b) Plans and specifications must be approved before construction of a water supply system is commenced.	Chapter 10. Sanitary Codes, Sections 10.50 and 10.56.4, State of Louisiana	
7. Louisiana State Department of Conservation	(a) Well drilling for brine production. (b) Injection wells for salt water or waste disposal. (c) Permit required for storage of hydrocarbons.		
8. Louisiana State Department of Highways.	Right-of-way for pipelines and power lines passing under or over highways.		
9. Louisiana State Land Office	(a) Right-of-way for pipeline crossing state-owned lands and navigable waterways. (b) Surface lease for storage and transportation of oil and gas.		
10. State of Louisiana Department of Public Works	(a) Levee Leakage - for pipeline crossing, construction of ramps for access to the pipeline; construction of a dock. (b) Permit to lay pipelines under or across navigable waterways or across stream. (c) Letters of objection or no objection concerning construction of barge facilities and tanker facilities.		
11. Louisiana State Fire Marshal	(a) Approval of plans and specifications for all barge facilities, tanker facilities, and pipeline construction.		
12. Not Established	Compliance with Coastal Zone Management Plan, when adopted.*		

*Note: The State of Louisiana is in the process of developing a Coastal Zone Management Plan, but a final program has not yet been adopted. None of the adjacent coastal states have Federally approved management programs.

Table 9.1 Regulatory Bodies (continued)

AGENCY	REGULATORY JURISDICTIONAL CONCERNS	REFERENCE	REMARKS
13. Louisiana Wildlife and Fisheries Commission	Commission will submit letter of objection or no objection to Corps; consultation and coordination with Commission required.		
14. Texas Air Control Board	Permit required for constructing and operating surge tanks, dock facilities used to load vessels, and other air contaminant sources at the new tanker facility at Nederland, Texas.	Texas Clean Air Act (Article 4477-5) Section 3.27 Texas Regulation VI, Rule 601	
15. Texas General Land Office	Easements required to use state-owned lands for construction of pipeline and new tanker facility at Nederland, Texas.		Office will submit letter of objection or no objection to Corps.
16. Texas Parks and Wildlife Department	Dredging permit may be required for construction of pipeline and new tanker facility at Nederland, Texas.		Department will submit letter of objection or no objection to Corps.
17. Texas Water Quality Board	Permit required for discharge, including storm water runoff, into surface waters due to construction of pipeline and new tanker facility at Nederland, Texas.	Texas Water Quality Rule 635.6	
18. Cameron Parish Police Jury	(a) Permits required for construction of decks, pipelines, and buildings to existing dock and new tanker facilities. (b) Approval required for crossing roads, ditches, canals, and waterways during pipeline construction.		
19. Jefferson County Commissioners Court	Permit required for crossings of county roads and any other county property due to construction of pipeline to tanker facility.		
20. Orange County Commissioners Court	Permit required for crossings of county roads and any other county property due to construction of pipeline to tanker facility.		
21. Orange County Drainage District	Permit required for crossing drainage ditches due to construction of pipeline to tanker facility.		

9.3 PARTIES FROM WHICH COMMENTS WERE REQUESTED

As a part of the review process for the Draft Environmental Impact Statement, comments have been requested from the departments, agencies, and organizations listed below:

Federal Agencies

Advisory Council of Historic Preservation
Department of Agriculture
Appalachian Regional Commission
Department of the Army, U.S. Corps of Engineers
Department of Commerce
Department of Defense
Energy Research and Development Administration
Environmental Protection Agency
Council on Environmental Quality
Federal Power Commission
Department of Health, Education, and Welfare
Department of Housing and Urban Development
Department of Interior
Interstate Commerce Commission
Department of Labor
Nuclear Regulatory Commission
Department of State
Tennessee Valley Authority
Department of Transportation
Department of Treasury
Water Resources Council

State Agencies

Louisiana Clearinghouses
New York State, Office of Environmental Analysis
Texas Clearinghouse

Local Agencies

Cameron Parish Police Jury
Gulf States Marine Fisheries Commission
Louisiana Offshore Terminal Authority

Other Organizations

American Fisheries Society
American Littoral Society
American Petroleum Institute

Center for Law and Social Policy
Ecology Center of Louisiana, Inc.
Electric Power Research Institute
Environmental Defense Fund, Inc.
Environmental Policy Center
Friends of the Earth
Funds for Animals, Inc.
Institute of Gas Technology
Interstate Natural Gas Association
Izaak Walton League of America
LOOP, Inc.
National Association of Counties
National Audubon Society
National League of Cities
National Parks and Conservation Association
National Resource Defense Council, Inc.
National Science Foundation
National Wildlife Federation
Olin Corporation
Seadock, Inc.
Sierra Club
Sierra Club-Gulf Coastal Regional Conservation Committee
Sierra Club-Southern Plains Regional Conservation Committee
U. S. Conference of Mayors

9.4 PARTIES FROM WHICH COMMENTS WERE RECEIVED

9.4.1 Federal Agencies

9.4.1.1 Advisory Council on Historic Preservation

Comment a

"We would suggest . . . that the final environmental statement for the project contain evidence of the Louisiana State Historical Preservation Officer's concurrence in FEA's determination of no effect."

Response

The Louisiana State Historical Preservation Officer was contacted by letter dated November 29, 1976 regarding existing or potential sites of historical interest which might be affected by the project, and a response is anticipated.

Comment b

"Compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470[6]) The Council must have evidence that the most recent listing of the National Register of Historic Places has been consulted . . . If no National Register property is affected by the project, a Section must appear in the environmental statement."

Response

Section 2.6.1 (page 2-107) of the Draft Environmental Impact Statement discusses archaeological and historical sites. There are no National Register Historical sites that would be affected by the proposed project. The draft has been supplemented with a description of FEA's compliance with Section 106 of the National Historic Preservation Act of 1966.

Comment c

Compliance with Executive Order 11593, 'Protection and Enhancement of the Cultural Environment' of May 13, 1971. Under Section 2(a) of the Executive Order, Federal agencies are required to locate, inventory, and nominate eligible historic, architectural, and archaeological properties under their control or jurisdiction to the National Register of Historic Places. The results of this survey should be included in the environmental statement as evidence of compliance with Section 2(a) . . . The environmental statement should contain a determination as to whether or not the proposed undertaking will result in the transfer sale, demolition, or substantial alteration of eligible National Register properties under Federal jurisdiction."

Response

In compliance with Section 2(a) of Executive Order 11593, the project area has been surveyed for this purpose. The results of this survey show that the proposed undertaking will not result in the transfer, sale, demolition, or substantial alteration of eligible National Register properties. The Draft Statement has been supplemented with this information which appears in Section 2.6.1 and Section 8 of the Final Statement.

The Draft Statement has also been supplemented with the information that as the project progresses, additional surveys will be carried out to determine that no additional eligible properties have been uncovered.

Comment c

"In compliance with Section 1(3) of Executive Order 11593. . . The environmental statement should contain a determination as to whether or not the proposed undertaking will contribute to the preservation and enhancement of non-Federally owned districts, sites, buildings, structures, and objects of historical, architectural, or archaeological significance."

Response

In compliance with Section 1(3), FEA has determined that no non-Federally owned sites would be affected by the proposed project. This determination appears in the Final Environmental Statement, Sections 2.6.1 and Section 8.

9.4.1.2 Department of the Army, New Orleans District, Corps of Engineers

Comment a

The West Hackberry site has significant potential for adverse impacts upon the water quality of the adjacent area. The assumption that the naturally occurring sediments in the area of Black Lake are predominantly sand, may be in error. Available soil curves for the material removed during dredging activities in the Calcasieu River at this point indicate a high amount of silt. This could greatly increase the amount of heavy metals, nutrients, and pesticides released to the water column over that as assumed in the EIS. The establishment of soil characteristics (soil curves) and elutriate analysis should be made to quantify the impacts upon the water column. The effluent from any unconfined disposal or open water disposal of dredged material could have a significant impact upon Calcasieu Lake. The minimal release of mercury mentioned (15 g/l) is significantly above the criteria limit of 0.1 g/l as established by the 1975 EPA, Proposed Criteria for Water Quality-Marine Water Constituents (Aquatic Life).

Response

No sediment data is currently available for Black Lake, Black Lake Bayou, or Alkali Ditch. Sediment quality data for the Calcasieu Ship Channel in the vicinity of Hackberry have been recently obtained. These data indicate the sediment in the channel is primarily silt. Certain problems associated with sediment quality are indicated. An analysis of these data has been incoporated into the EIS.

Comment b

Some areas lack site-specific information which is required to adequately assess the probable impacts. Emphasis is placed too heavily on data taken from areas removed from the project area.

Response

Additional monitoring is anticipated in order to validate the conclusions that nearby lakes contain similar type environments, and therefore data from those lakes may be used to characterize locations where project activities are occurring.

Comment c

Page 1-6, paragraph 2. Sabine National Migratory Waterfowl Refuge is not the name of the refuge.

Response

Sabine National Migratory Waterfowl Refuge has been changed to Sabine National Wildlife Refuge.

Comment d

This statement excludes the push-ditch method of pipeline installation which is normally preferred for installation of pipelines in marsh areas of coastal Louisiana. Experience has shown that this method greatly reduces potential environmental damage, and it has been proven feasible for lines in excess of 40 inches in diameter.

Response

This method is described on Page 1-26 of the Draft Environmental Statement. We have noted that this is a preferred method for this type of line.

Comment e

Page 2-15. Aerial photograph is erroneously labeled. The area labeled "flooded marsh" has not been a marsh for many years; and, "road platform to oil wells" is not a road, but is a walkway.

Response

These changes have been made in Figure 2.7.

Commend f

Page 2-26, paragraph 1. Black Lake is part of a contributing productive marsh system and specific water quality and sediment data are required to fully assess and evaluate the impacts.

Response

This data is not presently available. Additional monitoring is anticipated in order to validate the conclusions that nearby lakes may be used to characterize locations where project activities are occurring.

Comment g

Page 2-63, Table 2.8. We recommend inclusion of Delphinids under "Typical Mammals" and "Inland and Estuarine Waters."

Response

Dolphins have been added to the Table (page 2-65).

Comment h

Page 2-72, paragraph 1. Primary productivity, as well as salinity is certainly a controlling factor in the number of species present.

Response

Although certainly primary productivity is a prerequisite for the existence and maintenance of life forms, the diversity of species is not a simple function of such productivity, but also is dependent on other factors which may be more important. Thus, in eutrophic situations and estuaries, high production is usually associated with low species diversity. The relations between zooplankton species diversity and environmental factors are not yet completely known for the area in question. Based on the factors investigated in field surveys, salinity was interpreted to have the most important influence on diversity and other factors which were also inferred to be important. Among the latter, the concept of ecological competition includes the idea of dependence on food. Primary productivity determinations were not included in the field studies and there is no objective basis for relating the number of species to this factor.

Comment i

Page 2-72, Paragraph 2, line 13. Does this statement imply that the genus is present and/or dominant in the project area?

Response

Lake Pontchartrain is very similar to Calcasieu Lake in both its latitude and salinity. Algae such as *Coscinodiscus* sp. is known to be easily distributed* and this indicates that it may be present and perhaps even abundant under these similar conditions. The sentence has been changed in the text to reflect this viewpoint.

*C. C. Davis, The Marine and Fresh-Water Plankton, Michigan State University Press, 1955.

Comment j

Page 2-72, paragraph 2, line 17. Some of these genera are not "epiphytic" algae.

Response

The designation of these algae has been changed in the text to benthic, sediment, epiphytic, and periphytic algae.

Comment k

Page 2-72, paragraph 4. Site specific information is necessary. Black Lake cannot be accurately compared to Calcasieu Lake.

Response

Site specific information is not available at the present time. Additional monitoring is anticipated in order to validate the conclusions that nearby lakes contain similar type environments and therefore data from those lakes may be used to characterize locations where project activities are occurring.

Comment l

Page 2-73, paragraph 1. Further explanation is needed concerning recent salinity increases in the project area, especially the impacts of the Intracoastal Waterway and Calcasieu River upon salinity alterations.

Response

The statement about salinity changes is misleading. Salinity encroachment has affected the use of surface water in the area around the West Hackberry salt dome since the Calcasieu Ship Channel was created in 1941. Subsequent enlargement and deepening of the Channel has worsened the intrusion. It was noted in 1956 that there were no longer any diversions of surface water from the Calcasieu River or its tributaries for irrigation below Lake Charles. Salinity increases have been recorded at locations more than 61 miles inland. The text has been changed to indicate that salinity intrusion in the project area is not a recent phenomenon.

Comment m

Page 2-76, last paragraph. In 1975 and 1976, the American alligator was harvested for its hide in parts of Cameron, Calcasieu, and Vermilion Parishes.

Response

This information has been added to the text (page 2-78).

Comment n

Page 2-80, paragraph 2. We suggest the word "Atlantic" be placed before "Croaker."

Response

The word "Atlantic" has been placed before "Croaker" in the text (page 2-82).

Comment o

Page 3-3, paragraphs 2 and 3. There will be significant turbidity and bottom erosion due to the turbulence. Reference 4 is not based on sound data from properly conducted studies.

Response

A text change has been made to address geologic impact and the reference to the significance of turbidity will be omitted in the absence of site specific data that would quantify the increases in turbidity with increased barge traffic (page 3-3).

Comment p

Page 3-10, paragraph 4. Figure 3.4 has been omitted. The location of dredged material disposal areas will be determined by the Corps permit application process.

Response

Figure 3.4 is on page 3-12, but the title is missing. The Figure indicates where the dredging would take place according to the present design, but this is subject to change due to the permit application process. The omission of the title has been corrected.

Comment q

Page 3-19, paragraph 3. A description of the disposal operation is necessary before the impacts can be adequately assessed.

Response

Subject to concurrence by the U.S. Army Corps of Engineers, New Orleans District, the following disposal procedure would be used:

The disposal operation of dredged materials from Alkali Ditch includes the use of a confined disposal area adjacent to the existing spoil bank on the western side of Alkali Ditch. This confined disposal area is capable of containing 35,000 cubic yards of dredging spoil. Based on the assumption that the spoil can be stacked to a mean height of two feet, this volume of spoil would impact and cause loss of approximately 11 acres of marsh vegetation and wetland habitat. This information is included on pages 3-19 and 3-20.

Comment r

Page 3-29, last paragraph. Water quality data for the Calcasieu River is available from the New Orleans District Office.

Response

Water quality data from the New Orleans District Office of the Corps of Engineers have been obtained and incorporated into the EIS (Appendix D).

Comment s

Page 3-66, paragraph 4. Construction of roads in wetlands usually constitutes a permanent loss of wetlands and should not be considered a "short-term" impact.

Response

This text has been changed to give a clearer statement of our evaluation, which is that the road itself would destroy a limited area of wetlands, but recovery from disturbance and damage to biota in areas to the sides of the road resulting from construction activities would be relatively rapid (page 3-72).

Comment t

Page 3-68, paragraph 3. Further discussion is needed to explain phytoplankton productivity increases resulting from turbidity. We believe there will be decreases in productivity.

Response

We concur and the error has been corrected in the text (page 3-74).

Comment u

Page 3-112, paragraph 2. Reduction of food supply and habitat disruption will definitely be of importance.

Response

We agree that reductions in food supply and habitat would definitely be important. Our intended meaning was that it was uncertain whether reduction of food supply and habitats would actually occur. The text has been clarified (page 3-118).

Comment v

Page 4-5, paragraph 2. Direct contact of the less mobile benthic organisms with oil is likely, and not unlikely as stated in the EIS.

Response

Whether or not such contact is likely depends greatly on the environmental conditions. However, the text has been changed to indicate that direct contact may occur.

Comment w

Page 4-9. Shared uses of disposal areas may not always be permissible.

Response

The disposal of dredge spoil along the Alkali Ditch involves the confined disposal behind an existing spoil bank. Where dredging is required in the Calcasieu River, the disposal of spoil material may require the shared use of designated disposal areas. Where this is the case, the use will be coordinated through the Corps of Engineers to assure that use of such areas is permissible.

Comment x

"Including consideration of admittedly excessive emissions and conservation and economic factors, it would seem that application of vapor recovery technology should be given equal consideration for all SPR sites."

Response

A discussion of emission control technology appropriate for the West Hackberry Marine terminal and an estimated control efficiency have been included in the text of Section 3.3.2.

Comment y

Page 6-1, paragraph 6. In wetlands, natural grasses are usually allowed to revegetate pipeline corridors; hence, installation would not represent a permanent loss of resources. The total of 350 acres of land appears to be excessive for pipeline right-of-way.

Response

There would not be a permanent loss of resources, as pointed out, but a loss would be sustained until revegation was complete. This change is now indicated in the text (page 6-2).

Comment z

Page 6-2, paragraph 2. The withdrawal of surface water may be very significant depending upon the volume of runoff and the time of the year the surface water is withdrawn.

Response

The primary source of water in the West Hackberry area is the Calcasieu River which has an average flow rate of 2574 ft^3/sec. This value is tabulated from data over a 27-year period. Thus, the Calcasieu River has an average flow rate of 607,220,000,000 gallons per year or a volume flow of 6,072,200,000,000 gallons for a 10-year period. The lifetime of the project is expected in excess of 10 years and 5 cycles are to be utilized in that time period. The total amount of water withdrawn (12,600,000,000 gallons) would represent .2 percent or less of this volume of water and thus appear negligible. However, during the dry seasons, when the river flow is low, the withdrawal rate could increase the amount of salt water intrusion in the surface water system in the vicinity of West Hackberry.

Comment aa

Page 9-3. State of Louisiana regulatory bodies were omitted from this Table.

Response

The correct State of Louisiana and Texas regulatory bodies have been placed in the text.

Comment bb

"Applications for permits should be made as soon as practicable and well in advance of any need to perform the proposed work."

Response

Applications for permits will be filed well in advance of the proposed work.

Comment cc

"Two factors of considerable concern are critical to continuing use of disposal areas; they are: encroachment of water courses that provide natural circulation of surface waters and creation of vector problems. Scheduling of work may create difficult and costly disposal problems."

Response

All disposal areas will be designed and/or utilized in accordance with all applicable Federal laws and regulations. Such a procedure should preclude any encroachment of water courses in the area that provide natural circulation of surface waters and should also prevent the creation of vector problems. The work schedules will be designed, consistent with other considerations, to minimize the difficulty and cost of the disposal process.

Comment dd

"[The statement does not consider] the impacts of surface preparation for painting during construction and operation phases. The adverse impacts on inhabitants, structures, equipment, and terrain can be significant."

Response

The painting of the on-site storage tanks during the construction phase will constitute the major effort in this area. Surface preparation activities will probably include abrasives blasting prior to the application of paint. It is assumed that the tanks will have been primed prior to shipment. Emissions associated with the use of abrasive materials vary as a function of the material used as well as the type of surface. Typical abrasive materials include sand, slag, garnet, and steel grit. The amount of particulate matter entrained into the atmosphere due to the use of the substances would be a maximum for sand blasting. Emission factors developed by the San Diego County APCD* indicate that for operations using sand as the abrasive material, approximately one percent of the applied material would be emitted as fugitive dust. The impact of these emissions at the site boundary during sand blasting operations are expected to be minor assuming worst-case meteorological conditions and a violation of the applicable standards for particulate matter is not anticipated.

On the basis of the above, it is concluded that the impact of surface preparation activities for painting during the construction and operational phases on ambient air quality is acceptable.

*Private Communication with Andy Segal, San Diego County APCD, December 1976.

Comment ee

"It is noted that (in connection with the taking of excavated material from a barge slip to a suitable disposal site in accordance with a permit) mention of two important documents have been omitted from each EIS. They are the Federal Water Pollution Control Act (FWPCA), Title 33 U.S.C. 1323 and 1344, and the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Title 33 U.S.C. 1413(e). Section 404 of FWPCA provides for control of dredged material disposals in navigable waters and MPRSA provides for control of dredged material disposal and transportation of dredged material for disposal in ocean waters. Federal projects involving disposal in navigable or ocean waters or transportation for disposal in navigable or ocean waters are evaluated for permit and other regulatory actions by the Corps of Engineers and the Environmental Protection Agency under guidelines and criteria promulgated pursuant to the requirements of the FWPCA and MPRSA. The regulatory guidelines and criteria for Corps of Engineers evaluations of proposed projects are contained in Title 33 C.F.R., Part 209 which has also not been mentioned. Other laws enacted before 1972 are also directly related to the procedures for processing permit applications. These include the River and Harbor Act of 1899, the Fish and Wildlife Coordination Act of 1958, the National Environmental Policy Act of 1969, and the Coastal Zone Management Act of 1972, all of which are referenced in Title 33 C.F.R., Part 209. A statement to the effect that, 'the proposed disposals and transportation for disposal of dredged materials will be performed in accordance with all applicable Federal laws and regulations, should be included in each EIS or Statement of Findings for each project."

Response

Permits required pursuant to the Federal Water Pollution Control Act and the Marine Protection, Research and Sanctuaries Act of 1972 are issued by the Department of the Army, Corps of Engineers. The permit procedures and the Acts upon which they are based are outlined in the Army Corps of Engineers Regulations on Navigable Waters, 33 CFR 209. Compliance with 33 CFR 209 was indicated in Table 9.1 on page 9-5, of the Draft Statement. These regulations also appear in Section 9.2 of the Final Environmental Impact Statement. The assurance that the proposed disposals will be carried out in accordance with all applicable Acts and Regulations was added to the Draft Statement, Section 3.2.1.

9.4.1.3 United States Environmental Protection Agency, Dallas, Texas

Comment a

"When the oil is removed from the storage cavities, some of the oil will remain on the walls of the cavities and therefore in the brine. When oil is reintroduced to the caverns, the brine will carry the entrained oil with it. The statement should provide assurances that the concentration of entrained oil in this brine will be such that no adverse impacts to the disposal aquifer will occur. The statement should discuss the possibility of the need for treatment of the brine for removal of the oil as well as the ultimate disposal of any recovered oil. A quantitative discussion of evaporative hydrocarbon emissions originating from the proposed brine storage reservoir should also be included in the statement."

Response

All of the caverns under consideration for petroleum storage are currently filled with brine. The walls of such caverns will thus be water-wetted when the brine is displaced by crude oil during the first storage cycle. Although experimental data is currently not available involving water, oil, and salt, past experience involving water, oil, and other material* such as sand or rock suggest that water as opposed to oil will preferentially wet the salt wall. Thus, even when the cavern is filled with oil, there is reason to believe that the walls will remain water-wetted. In this case, when the oil is displaced by water, no oil film will be present on the walls. If, however, the walls are oil-wetted, a thin film of oil might initially occur along the walls when the oil is being displaced by water. Near the bottom of the cavern, however, the walls would remain water-wetted because this portion of the cavern always contains brine. Thus, as the oil is displaced by fresh or brackish water, the salt walls at the bottom will commence being dissolved by incoming water. Thus, any oil film will tend to be "rolled up" as the salt wall to which the film is attached is essentially dissolved out from under it. For these reasons the presence of an oil film on the walls for any long period of time is unlikely when the cavern is filled with either water or brine.

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*V.L. Streeter, Handbook of Fluid Dynamics, New York, 1961.

Although the film may not be present, the horizontal interface between the oil (above) and the water (below) will always be present whether the cavern is filled with oil or water. This interface will allow some of the more soluble constituents of the oil to pass into solution in the water which will with time grow increasingly saline. The solubility of crude oil in brine is unknown, but in sea water such solubility ranges from 12.3 to 17.4 ppm for representative crude oils.* With increasing salinity, the solubility of the oil should decrease and thus the maximum level of oil dis solved in the brine should not exceed the range for sea water.

In addition to dissolved oil, some of the oil will form an emulsion in the water due to the instabilities at the oil-water interface. Such an emulsion can be divided into two parts. The first part consists of the larger globules which may initially be present, but which with time will tend to rise to the oil-water interface. At the interface, these globules may coalesce with the main body of oil or they may cluster together, possibly forming a separate layer along the interface. The second part of the emulsion consists of the smaller globules or micelles which are sufficiently small to remain permanently in emulsion. These micelles may be distributed throughout the brine in the emulsion layer, but logically would be present in greatest concentration near the interface already noted. The amount of oil in either type of emulsion is generally dependent upon the type and degree of agitation occurring at the oil-water interface during both the filling and withdrawal operations and cannot be predicted. To minimize producing such an emulsion, the filling and withdrawal operations should be accomplished with minimum agitation of the interface in general.

Because of the factors already described during the process of filling the cavern with oil, a certain amount of oil in solution will be transported with the displaced brine. The maximum amount in solution would appear to be ~18 ppm. For a ten million barrel cavern this would be approximately 180 barrels of oil. The amount in emulsion cannot be predicted, but this amount can be minimized by insuring that oil-water interface remains a safe distance above the withdrawal point. With respect to oil in emulsion, the Louisiana State Water Quality Standards requires that no

*I. Lysyl and E. C. Russell, Water Research, Volume 8, p. 863, 1974.

visible film of oil be produced on the water surface.* The concentration of oil necessary to produce a visible film is not precisely established, but available experimental data** suggests that such a film becomes visible when oil concentration lies between 5 and 10 ppm.

With respect to the disposal of the brine by subsurface injection, the presence of oil in solution in the quantities noted previously would pose no apparent problem, but the presence of oil in emulsion could possibly cause clogging of the sands of the receiving formation in or near the well bore. Such clogging would reduce permeability, and would thus produce larger pressure increases than originally anticipated. This is clearly undesirable. Thus, the level of emulsion of oil in water must be minimized for safe and efficient subsurface disposal.

Based on the available information, sound engineering practices would dictate monitoring the displaced brine for the level of oil in solution or emulsion prior to subsurface disposal. By use of proper operating procedures, however, these levels can be minimized and an oil-water separation system does not appear necessary at this time. Such a system will be incorporated into the design, however, if studies which are currently underway provide any indication that unacceptable levels of oil in emulsion will be encountered. A quantitative assessment of vapor releases from the surface of the brine pond would be very conjectural since the primary source of such releases would be from oil globules in the emulsion, and efforts will be made to prevent the emulsion from being pumped out of the cavern.

Comment b

The buried pipelines will be coated with cathodic protection. The Final EIS should address the effects of any potential leaching of cathodic material on the groundwater."

Response

Pipelines are usually coated with a relatively inert asphaultic material which provides oxidation protection and insulation properties. In addition cathodic protection

*Louisiana Water Quality Criteria, Louisiana Stream Control Commission, Baton Rouge, Louisiana, August 1976.

**B. Hornstein, "The Visibility of Oil-Water Discharges," Proceedings of Joint Conference on Prevention and Control of Oil Spills, Washington, D.C., March 13-15, 1973.

is achieved by having a small DC current on the pipeline or by having a sacrificial metal such as a magnesium alloy (e.g., 6% Al, 3% Zn, and 91% mg) as the anode and the pipeline as the cathode. The technique of utilizing a small DC current to inhibit electrochemical reactions introduces no foreign materials into the environment. The sacrificial anode scheme utilizes the oxidation of the magnesium anode to provide the current flow to inhibit oxidation of the pipeline and consequently forms ionic materials over the lifetime of the anode.

It is generally assumed that for a large pipeline of 30 inches in diameter or more, a 17 to 32 pound anode rod will be utilized with a coating of plaster, which is composed of gypsum, bentenite clay, and sodium sulfate to provide protection for a section of pipe several hundred feet long (e.g., 500 ft) for approximately 12 to 14 years. The plaster will also deteriorate as the anode is oxidized. One would expect to obtain sulfates, silicates, oxides, and carbonates of the aluminum, magnesium, zinc, and calcium materials from the anode and its coating.

The proposed pipeline from the West Hackberry dome to the Calcasieu River Dock will be buried primarily in prairie-type soils which are composed of pleistocene clays. Smaller segments of the pipeline may potentially be buried in marshy soils. These soils represent the upper layer of an impermeable clay aquitard from 100 to 400 feet thick. Because the water table is within one or two feet of the surface, the soil will be generally water-saturated. Thus, due to the presence of ground water some dissolution of the cathodic system will occur. The carbonates, which are formed from the ground water are relatively insoluble, and contribute to the hardness of water. The sulfates are relatively soluble in water. All of these materials are relatively common constituents of ground water. The insoluble materials will no doubt aggregate onto clay particles present in the soil and present no problem.

The surface water system in the area is isolated from the shallow Chicot aquifer by the impermeable clays. Because no surface water recharge of the aquifer occurs in the West Hackberry area, the potential contamination of the various aquifers by these relatively inert materials is considered very remote.

Comment c

The water withdrawal source for displacement operations is stated to be either Black Lake Bayou (pages 1-10, 1-19, 3-70, 4-9), Black Lake (page 3-26, 7-52) or Black Lake/Black Lake Bayou (page 4-1). The EIS should be consistent in its description. Apparently, the actual source will be the Bayou, at a point 1,500 feet downstream from Black Lake. The Final EIS, should provide representative water quality data for the Black Lake Bayou.

Response

The water withdrawal source will be Black Lake Bayou at a point approximately 1,500 feet from the junction of the Bayou with Black Lake. The EIS will be modified to insure consistency. Water quality data for Black Lake Bayou is currently not available.

Comment d

Salt water intrusion is described as a major problem in the area. Although the EIS claims that withdrawal of displacement water and dredging will have a minimal impact on the salinity of the affected water bodies, we suggest that a periodic monitoring system be considered to determine if changes in the salinity of the lakes and bayous as well as northern migration of isohalines is occurring.

Response

FEA, based on its evaluation of the withdrawal rate and the subsequent effects which could occur, has concluded that the changes would be so small that they should be indetectable. In the event that re-evaluation should prove that this conclusion is in error, FEA will consider development of a monitoring program to detect changes during pumping operations.

Comment e

The effects of the disposal of dredged material from Alkali Ditch cannot be assessed at this time because the exact arrangement has not been defined. This decision should be made in the Final EIS to provide for a description of the impacts. Also, the Final EIS should state whether the disposal area will be confined or unconfined.

Response

Dredge spoils along the Alkali Ditch will be confined behind the existing spoil bank. This will enable the area affected to be minimized, and will prevent silt from re-entering the waterway.

Comment f

The actual effects of the disposal of the brine in the salt water aquifers cannot be determined because chemical and biological tests have not been conducted on the brine and aquifer waters. The Final EIS should state when such tests will be performed, especially since deep well injection is the proposed method of brine disposal.

Response

Prior to the development of the site, tests will be conducted to determine compatibility of brine and aquifer waters. This determination will be made prior to the commitment to deep well injection for the site.

Comment g

The final EIS should describe methods for the treatment and disposal of sanitary wastes during and after construction of the facility.

Response

The facility will contain a system for treatment of sanitary waste. While the final design is not complete, this facility will be designed to conform to applicable state and Federal regulations.

During construction, it is anticipated that existing facilities on the site will be utilized for sanitary waste, and these facilities will be supplemented by self-contained portable toilet facilities which are serviced by commercial sanitary waste companies.

Comment h

The EIS mentions a Coast Guard recommendation to minimize the effects of pipeline failure by using trenches for collection at the points of entry to the water bodies (page 4-3). The EIS should state whether this recommendation is feasible and if it will be followed.

Response

The U.S. Coast Guard's recommended technique of digging trenches at the point of entry into nearby water bodies (Black Lake and Calcasieu Lake) is feasible, and it is anticipated that it will be employed in case of oil spill.

Comment i

The Lone Star site would produce considerably fewer construction and dredging impacts than the proposed new terminal, with the exception of more pipeline construction through marsh land. We suggest that this alternative be explored further in the Final EIS.

Response

We have reviewed the discussion of the Lone Star site in the Draft Environmental statement and concluded that the discussion is sufficient to compare this alternative with the proposed terminal. It is currently believed that the proposed terminal is more desirable than the use of the Long Star site. This results from the fact that use of the Lone Star site would require additional dredging of the channel along the dock, the installation of new pilings (since the dredging would take place to a depth below the existing pilings), and the rebuilding of the dock would involve an expenditure which is approximately that of the new terminal. When both environmental effects on the required pipeline and cost of facility modification are considered, it is believed that the proposed terminal is more desirable than the Lone Star site.

Comment j

The Louisiana State Implementation Plan (SIP) required revision for photochemical oxidants for the Louisiana portion of the Southern Louisiana-Southeast Texas Air Quality Control Region (AQCR) 106 in the Federal Register, Volume 41, No. 138, July 16, 1976. Oxidant air quality data recorded during 1975 showed the AQCR recorded second high oxidant levels for the Baton Rouge area at 0.170 ppm, New Orleans at 0.094 ppm and Lake Charles at 0.174 ppm. We feel that the above information should be included in the final impact statement along with discussion of how this facility will affect the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS).

Response

The noted elevated oxidant levels during 1975 in the Southern Louisiana-Southeast Texas Air Quality Control Region (ACQR) have been incorporated into Section 2.3.2 as is discussed below.

Also as indicated below, the text in Section 3.3.2 has been augmented to include a discussion of the required revision to the Louisiana State Implementation Plan for photochemical oxidants for the Louisiana portion of the above AQCR. Also, 4.1 has been expanded to include a discussion of available means for reducing hydrocarbon emissions.

Comment k

The draft statement indicates that vapor recovery systems may be used for vessel loading/unloading (page 3-51), with surge and floating roof storage tanks (pages 4-16 and 4-17) leading to negligible hydrocarbon emissions. We would recommend consideration be given to the use of vapor recovery systems because of the area's oxidant problems. The final impact statement should discuss the technical and emission characteristics of such systems.

Response

These changes have been made in the text (page 3-62) and also refer to comment x, U.S. Army Corps of Engineers.

9.4.1.4 Federal Power Commission

Comment a

". . .there does not appear to be any conflict between the development of the SPR and the continued production, transportation, and sale of natural gas from domestic sources. It therefore does not appear that the proposed project presents any conflict with FPC jurisdictional interests."

No Response

9.4.1.5 Department of Health, Education, and Welfare

Comment

"We feel the concerns of this Department have been adequately addressed."

No Response

9.4.1.6 Nuclear Regulatory Commission

Comment a

"We have determined that the proposed actions, per se, have neither radiological, health, and safety aspects nor will they adversely affect any activities subject to regulation by the Nuclear Regulatory Commission."

No Response

9.4.1.7 Tennessee Valley Authority, Chattanooga, Tennessee

Comment a

"We have determined that we have no significant comments on any of the five sites or statements involved in the Strategic Petroleum Reserve."

No Response

9.4.1.8 Department of Transportation, Federal Highway Administration, Baton Rouge, Louisiana

Comment a

For states where the proposed sites are located, a circulation of the Draft Environmental Statement directly to the state agency would be appropriate.

Response

FEA policy regarding distribution of environmental statements indicates that distribution is to be made through the State Clearinghouse. It is believed that the Clearinghouse can better identify those state agencies which should comment on the draft environmental statement.

Comment b

Where proposed pipelines would cross or utilize highway rights-of-way, coordination with the Louisiana Department of Highways is recommended.

Response

FEA, as it develops construction plans, will consult with state agencies and will coordinate its activities with the Louisiana Department of Highways as is appropriate.

Comment c

Table 9.2, page 9-5, lists Texas regulatory bodies instead of appropriate Louisiana regulatory bodies.

Response

The change has been made in the Table.

9.4.1.9 Department of the Treasury, Washington, D. C.

Comment a

"We find the statements to be objectively directed to their stated purpose, and it appears that the salt dome and mine storage facilities . . . are superior to above ground storage from both the economic and environmental viewpoints."

No response

Comment b

" . . . such facilities and the petroleum stored therein should be owned by the Government and . . . the costs should be borne directly by the beneficiaries--the U. S. energy consumers."

Response

It is intended that the proposed storage facility and petroleum stored therein would be financed by the Federal Government, with funds for the project provided out of general tax revenues. However, as stated in the programmatic EIS for the Strategic Petroleum Reserve, FEA expects to propose utilizing its "entitlements" program so as to cause the petroleum industry and ultimately energy consumers, to share the cost of the oil to be stored.

Response

It is intended that the proposed storage facility and petroleum stored therein would be owned by the Government. Funds for the project are allocated by Congress in behalf of the U.S. energy consumers.

Comment c

The statement implies that among the benefits and costs of the project are the employment effects. Conventional cost-benefit analysis deals with a national perspective and assumes a full employment economy. Social costs of lay-offs, such as unemployment compensation can be expected to be miniscule and probably need not be considered in the analysis.

Response

It is recognized that the work force required at each individual site is insignificant compared to national employment levels. However, the sites are located in rural areas where a small scale economy could potentially be disrupted. A local perspective of employment effects was chosen in order to ascertain whether there would be any impact on the surrounding towns and parishes, and if so, to assess the magnitude of such impacts.

9.4.2 State Agencies

9.4.2.1 Louisiana Geological Survey, Baton Rouge, Louisiana

Comment a

"It is our opinion that the geological presentations are well done and adequate for the purposes intended."

No Response

9.4.2.2 Louisiana State Soil and Water Conservation Committee, Baton Rouge, Louisiana

No Comments 9-35

9.4.3 Individuals and Organizations

9.4.3.1 LOOP, Inc. (Louisiana Offshore Oil Port), New Orleans, Louisiana

Comment a

"There is no indication that specific, competent geomechanic analyses will be made to assure stability of multicavity configurations after five fill/withdrawal cycles. Such analyses should be required for each of the candidate salt domes (DES 76-4, -5, -6) actually selected.

"The analyses would establish allowable roof distance below the caprock, center to center spacing versus diameter (s/d ratio), vertical separation, and plastic zone proximity to the dome flank. These criteria should be related to calculated creep, stress, and subsidence for the actual or safe strength levels of the specific salt and surrounding rock. The arbitrary criteria enumerated in the programmatic draft EIS's are no substitute for geomechanic analyses."

Response

Additional studies of salt dome and storage cavern properties will be conducted as appropriate. A special analysis of cavern stability parameters at West Hackberry conducted for the FEA SPR office is included as Appendix I. These parameters include roof and wall thickness and cavern dimensions.

Comment b

The impact of the alternative brine disposal by pipeline to the Gulf of Mexico can be quantified while disposal by subsurface injection cannot, in particular, the effect on the freshwater aquifer. Why should not pipeline disposal be preferable here?

Response

Current project designs call for the disposal of brine by subsurface injection. These wells are to be drilled to between 5,000 and 7,000 feet (page 1-19). The Chicot aquifer, the only freshwater aquifer near the site is located at 1,120 feet. This means there is between 3,880 and 5,880 feet between where the project is disposing of the brine and the freshwater aquifer. This difference of levels would indicate that there would be no effect on the Chicot freshwater aquifer. Also, if pipeline disposal was employed, it would adversely affect 16 additional miles which would include both marshlands and the Sabine Wildlife Refuge besides creating additional cost during construction.

APPENDIX A

ATMOSPHERIC DISPERSION MODEL

Emission concentrations for a 10 minute sampling time are based on a Gaussian dispersion model:[1]

$$\chi\ (x,0,0;H) = \frac{Q}{\pi \sigma_Y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

where:

χ Concentration in ug/m^3 at x meters downwind

Q Emissions rate in ug/sec of pollutants

σ_Y Sutton factors σ_Y (x); for a given Pasquill stability class

σ_z Sutton factors σ_z (x); for a given Pasquill stability class

u Average wind velocity, meter/sec

H Effective Stack height in meters

The values for σ_Y and σ_z are taken from graphs from Workbook of Atmospheric Dispersion Estimates.[1] H is taken to be zero for ground release. Stability condition F is assumed.

The equation given above is for stationary wind conditions over a 10 minute sampling period. The concentration can be corrected for wind meander up to 24 hour sample times by multiplying the 10 minute sample concentration by $\left(\frac{10\ \text{min.}}{t\ \text{min.}}\right)^{.17}$. Table A-1 gives concentration correction ratios for 1, 3, and 24 hour averages assuming (worst case) no change in wind conditions. A wind speed of 2m/sec is assumed.

Table A-1: Variation of Calculated Concentration with Sample Time.

Sample Time t	X(t)/X(10 min)
10 min	1.00
1 hour	.74
3 hour	.61
8 hour	.52
24 hour	.44

The tabular correction data cannot be extended to one year to obtain annual average concentration. Instead, the "worst case" wind direction(s) are chosen from the annual wind rose of Section 2.3. A typical wind speed is chosen to represent each speed group.

* X = chi

The neutral stability Class D, is assumed. The annual average concentration is:[1]

$$\overline{X} = \sum_i \frac{\{2.03\} Q}{\sigma_z U_i x} f_i$$

where:

$\overline{X}$ = annual average concentration (gm/m^3)

Q = Source (gm/sec)

σ_z = vertical dispersion coefficient (m)

U_i = wind speed for i^{th} group (m/sec)

x = downwind distance (m)

f_i = fraction of the time the wind is blowing in the chosen direction in the i^{th} wind speed group.

The wind speed for a group is taken to be the midvalue. The parameter, σ_z, is taken from graphs.[1] Typical values are:

x(m)	500	1000	2000	5000
σ_z(m)	18	31	50	89

The values of f_i and u_i from the wind rose are:

u_i (m/sec)	f_i
.772	.010
2.57	.042
4.37	.046
6.94	.032
9.77	.003

The values of these parameters are combined as indicated above for a source strength of 1 gm/sec from a point, ground level source. The annual average concentrations (converted to $\mu gm/m^3$) for the unit source are listed in Table A-2 at several distances.

Table A-2: Annual Average Concentration for a 1 gm/sec Source

x (km)	$\overline{X}$ (u gm/m^3)
0.5	10.1
1.	2.93
2.	0.910
5.	0.204

Reference

1. U.S. Environmental Protection Agency, "Workbook of Atmospheric Dispersion Estimates", Office of Air Program, Publication No. AP-26, Revised 1970.

APPENDIX B
AIR POLLUTION MONITORING DATA

The following data was provided by the Louisiana Air Control Commission. This data represents the most thorough and consistent monitoring results the Commission has compiled to date. The suspended particulate data monitoring capabilities are the most refined in the State, and a few key locations are operable for oxidant and sulfur dioxide monitoring. This data is included in the last two tables representing Lake Charles. This is representative only of the maximum concentrations measured during the stations on-time, as well as the number of violations of the standards recorded.

<u>Monthly Suspended Particulate Sampling Data (1975)</u>

Table B-1	Lake Charles	Suspended Particulate Sampling Data
Table B-2	Lake Charles	Suspended Particulate Sampling Data
Table B-3	West Lake	Suspended Particulate Sampling Data

<u>Continuous Oxidant (O_3) Monthly Sampling Report (1975)</u>

Table B-4	Lake Charles	Monthly Oxidant (O_3) Concentrations

<u>Continuous Sulfur Dioxide (SO_2) Monthly Sampling Report (1975)</u>

Table B-5	Lake Charles	Monthly Sulfur Dioxide (SO_2) Concentrations

Table B-1 Monthly Suspended Particulate Sampling Data

CITY: Lake Charles SITE: Corner Ryan and McNeese

YEAR: 1975 SAROAD CODE: 191600002

1° Standard 24-hr. max. = 260 μg/m^3 SAMPLING TYPE:

2° Standard 24-hr. max = 150 μg/m^3, Annual Geometric mean = 60 μg/m^3

NUMBER OF SAMPLES: 56

ANNUAL GEOMETRIC MEAN: 43

MONTH	DAY	24 HR. MEASURE μg/m^3
Jan	6	33
	12	22
	30	24
Feb.	5	31
	23	31
Mar.	1	38
	7	79
	13	54
	19	60
	25	121
	31	40
Apr.	6	50
	12	38
	18	68
	24	45
	30	28
May	6	45
	12	42
	18	67
	24	41
	30	18
June	5	49
	11	37
	17	33
	23	77
	29	40
July	5	47
	11	51
	17	44
	23	32
	29	44
Aug.	4	35
	10	27
	16	33
	22	37
	28	43
Sep.	3	85
	9	40
	15	70
	21	49
	27	68
Oct.	3	88
	9	48
	15	29
	21	52
	27	38
Nov.	2	41
	8	30
	14	83
	20	27
	26	42
Dec.	2	53
	8	37
	14	41
	20	51
	26	37

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-2 Monthly Suspended Particulate Sampling Data

CITY: Lake Charles SITE: 721 Prien Lake Road

YEAR: 1975 SAROAD CODE: 191600001

1° Standard 24-hr. max. = 260 μg/m^3 SAMPLING TYPE: Population Oriented

2° Standard 24-hr. max = 150 μg/m^3, Annual Geometric mean = 60 μg/m^3

NUMBER OF SAMPLES: 57

ANNUAL GEOMETRIC MEAN: 68

MONTH	DAY	24 HR. MEASURE μg/m^3	MONTH	DAY	24 HR. MEASURE μg/m^3
Jan.	6	99	July	5	46
	12	40		11	68
	24	98		17	64
	30	74		23	45
Feb.	5	57		29	54
	17	70	Aug.	4	48
	23	39		10	37
Mar.	1	101		16	51
	7	86		22	55
	13	52		28	99
	19	79	Sept.	3	85
	25	165		9	60
	31	81		15	83
Apr.	6	68		21	60
	12	100		27	79
	18	154	Oct.	3	64
	24	215		9	51
	30	73		15	29
May	6	113		21	96
	12	74		27	59
	18	93	Nov.	2	59
	24	126		8	50
	30	76		14	79
June	11	81		20	39
	17	129		26	39
	23	53	Dec.	2	96
	29	40		8	41
				14	47
				20	52
				26	54

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-3 Monthly Suspended Particulate Sampling Data

CITY: West Lake | SITE: 701 Johnson Street

YEAR: 1975 | SAROAD CODE: 193180002

1° Standard 24-hr. max. = 260 μg/m^3 | SAMPLING TYPE: Population Oriented

2° Standard 24-hr. max = 150 μg/m^3, Annual Geometric mean = 60 μg/m^3

NUMBER OF SAMPLES: 55

ANNUAL GEOMETRIC MEAN: 57

MONTH	DAY	24 HR. MEASURE μg/m^3	MONTH	DAY	24 HR. MEASURE μg/m^3
Jan.	6	56	July	5	115
	12	27		11	93
	24	51		17	96
	30	48		23	57
				29	64
Feb.	5	17	Aug.	4	57
	17	42		10	56
	23	35		16	88
				22	47
Mar.	1	103	Sep.	15	66
	7	89		21	39
	13	44		27	76
	19	55	Oct.	3	63
	25	146		9	50
	31	51		15	29
Apr.	6	63		21	99
	12	50		27	52
	18	102	Nov.	2	47
	24	75		8	36
	30	41		14	76
May	6	97		20	25
	12	55		26	34
	18	96	Dec.	2	53
	24	43		8	31
	30	45		14	43
June	5	122		20	63
	11	71		26	38
	17	125			
	23	52			
	29	54			

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-4 Continuous Oxidant (O_3) Sampling Monthly Report

CITY: Lake Charles SAROAD CODE 191600001

YEAR: 1975

1^{o} and 2^{o} Standard: 1-hr. max. = 0.08 ppm

MONTH	HIGHEST	2ND HIGHEST	# VIOLATION	%TIME OBSERVED
January	0.0790 1/25/75	0.0290 1/19/75	0	74
February	0.0530 2/19/75	0.0470 2/27/75	0	97
March	0.0390 3/19/75	0.0370 3/16/75	0	97
April	0.0390 4/6/75	0.0290 4/8/75	0	34
May	0.0790 5/18/75	0.0680 5/12/75	0	98
June	0.0500 6/2/75	0.0450 6/6/75	0	88
July	0.1160 7/10/75	0.0990 7/8/75	14	87
August	0.1220 8/20/75	0.0990 8/31/75	8	97
September	0.0890 9/1/75	0.0850 9/12/75	3	96
October	0.1780 10/10/75	0.0730 10/12/75	7	53
November	0.1250 11/4/75	0.0750 11/5/75	4	98
December	0.0520 12/20/75	0.0450 12/3/75	0	98

Source: Louisiana Air Control Commission, New Orleans, Louisiana

Table B-5 Continuous Sulfur Dioxide (SO_2) Sampling Monthly Report

CITY: Lake Charles SAROAD CODE: 919600001

YEAR: 1975

1° Standard: 24-hr. max. = 0.14 ppm, Annual Geometric Mean = 0.03 ppm

2° Standard: 24-hr. max. = 0.10 ppm, Annual Geometric Mean = 0.02 ppm

MONTH	HIGHEST	2ND HIGHEST	# VIOLATION	%TIME OBSERVED
June	0.0300 6/28/75	0.0180 6/1/75	0	82
July	0.0250 7/8/75	0.0230 7/9/75	0	85
August	0.0450 8/20/75	0.0180 8/11/75	0	91
September	0.0200 9/28/75	0.0180 9/2/75	0	52
October	0.0440 10/10/75	0.0210 10/19/75	0	97
November	0.0150 11/24/75	0.0130 11/25/75	0	82
December	0.0440 12/20/75	0.0180 12/10/75	0	98

Source: Louisiana Air Control Commission, New Orleans, Louisiana

APPENDIX C

NOISE ANALYSIS

Definitions and Terminology

A-Weight - A frequency weighting network which is used in sound analysis to simulate the response of the human ear. (A-weighted sound levels are expressed in units of dBA).

Environmental Noise - By section 3 (11) of the Noise Control Act of 1972, the term "environmental noise" means the intensity, duration, and character of sounds from all sources.

Equivalent Sound Level - The level of a constant sound which, in a given situation and time period, has the same sound energy as does a time varying sound. Technically, equivalent sound level is the level of the time weighted, mean square, A-weighted sound pressure. The time interval over which the measurement is taken should always be specified.

Sound Level - The quantity in decibels measured by a sound level meter satisfying the requirements of American National Standards Specification for Sound Level Meters S1.4-1971. Sound level is the frequency-weighted sound pressure level obtained with the standardized dynamic characteristic "fast" or "slow" and weighting A, B, or C; unless indicated otherwise, the A-weighting is understood. The unit of any sound level is the decibel, having the unit symbol dB.

Sound Pressure Level - In decibels, 20 times the logarithm to the base ten of the ratio of a sound pressure to the reference sound pressure of 20 micropascals (20 micronewtons per square meter). In the absence of any modifier, the level is understood to be that of a mean-square pressure.

Symbols

L_{eq} Equivalent A-weighted sound level over a given time interval.

L_d Daytime equivalent A-weighted sound level between the hours of 0700 and 2200.

L_n Nighttime equivalent A-weighted sound level between the hours of 2200 and 0700.

L_{dn} Day-night average sound level - the 24 hour A-weighted equivalent sound level, with a 10 decibel penalty applied to nighttime levels.

i.e.,

$$L_{dn} = 10 \log \left[\frac{15}{24} \times 10^{\frac{L_d}{10}} + \frac{9}{24} \times 10^{\frac{L_n+10}{10}}\right].$$

Analysis of Construction Operations Noise

The calculation of L_{eq} and L_{dn} requires the estimations of the noise level for each type of machine, the number of machines for each machine type, and the usage factor at each construction site. From these factors a noise impact area about each construction site is calculated. The impact area is then examined for type of land use, i.e., residential, limited outdoor use, schools, playgrounds, etc. Where people are exposed to levels of L_{dn} >55dB or $L_{eq}(24)$>55dB, a noise impact is indicated.

FEDERAL GUIDELINES

The Federal Environmental Protection Agency has established guidelines for limits of L_{dn} requisite for the protection of public health and walfare.*

Summary of Noise Levels Identified As Requisite to Protect Public Health And Welfare with an Adequate Margin of Safety

Effect	Level	Area
Hearing Loss.	$L_{eq}(24) \leq 70dB$	All areas.
Outdoor Activity interference and annoyance.	$L_{dn} \leq 55dB$	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.
	$L_{eq}(24) \leq 55dB$	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor Activity interference and annoyance.	$L_{dn} \leq 45dB$	Indoor residential areas.
	$L_{eq}(24) \leq 45dB$	Other indoor areas with human activities such as school, hospitals, 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.

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

Noise Measures

The descriptors L_{eq} and L_{dn} quantify those aspects of sound which have been found to correlate well cumulative community exposure to noise and community annoyance. Accordingly, the Environmental Protection Agency has selected Equivalent Sound Level (L_{eq}) for the purpose of identifying levels of environmental noise.

Equivalent Sound Level is formulated in terms of the equivalent steady noise level which in a stated period of time would contain the same noise energy as the time-varying noise during the same time period.

The mathematical definition of Leq for an interval defined as occupying the period between two points in time t_1 and t_2 is:

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p_o^2} \, dt \right]$$

where p(t) is the time varying sound pressure and p_o is a reference pressure taken as 20 micropascals.

APPENDIX D

WATER QUALITY ANALYSIS AND CONCLUSIONS

APPENDIX D.1

PRECIPITATION DATA IN THE VICINITY

OF THE WEST HACKBERRY DOME

This appendix contains three figures and one table concerning precipitation in the vicinity of the West Hackberry Dome. Figure D.1-1 presents the distribution of average winter-spring precipitation surplus in southern Louisiana based on monthly water balances for the 24-year period from 1945 to 1968. The corresponding summer-autumn precipitation surplus is given in Figure D.1-2. The average seasonal precipitation deficits for the same area is provided in Figure D.1-3. The recorded average monthly precipitation at Lake Charles, Louisiana is presented in Table D.1-1.

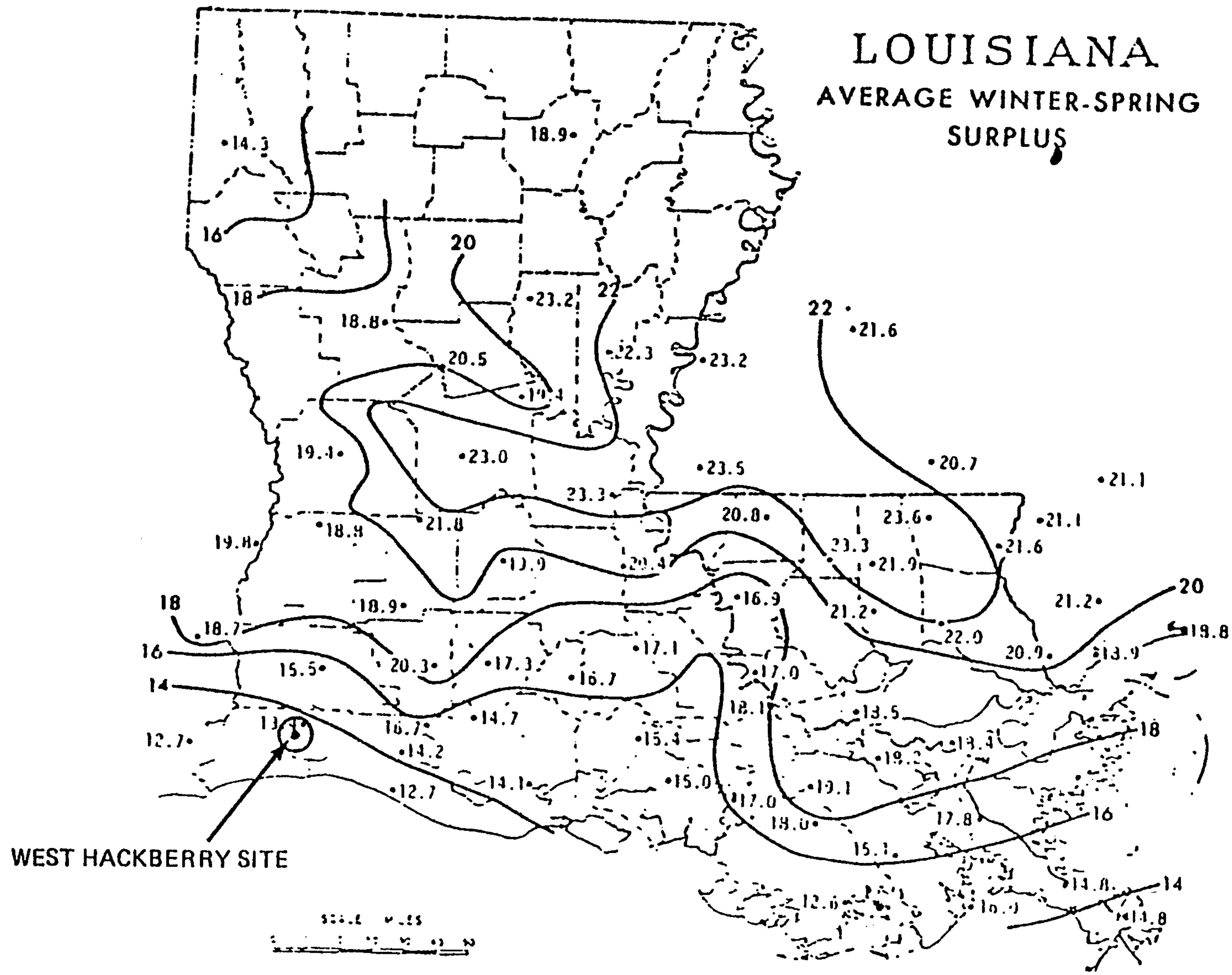

Figure D.1-1 Distribution of average winter-spring precipitation surplus in southern Louisiana. Station averages were determined from monthly water balances for the 24-year period between 1945 & 1968. Surplus values are given in inches.

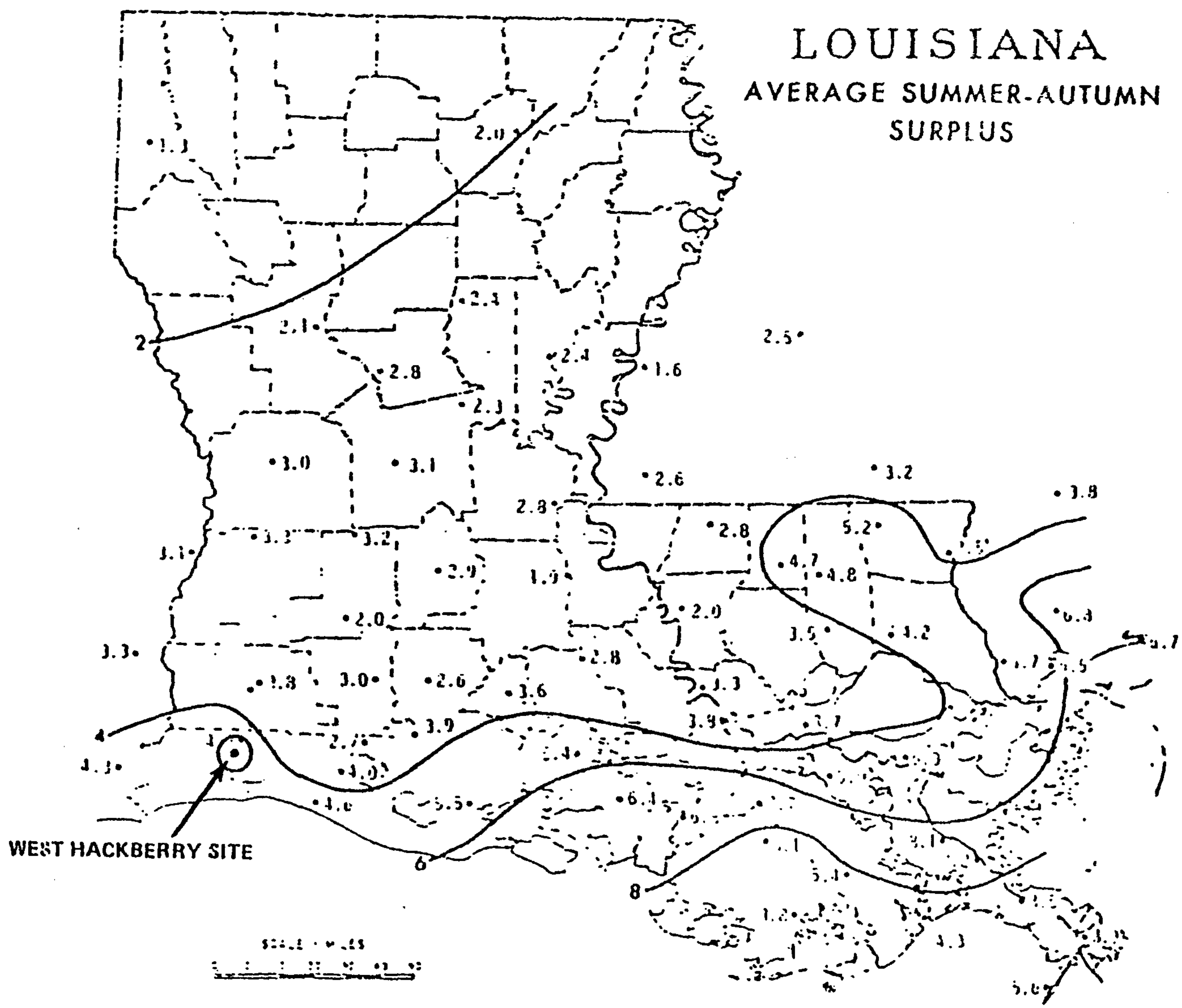

Figure D.1-2 Distribution of average summer-autumn precipitation surplus in south and central Louisiana. Station averages were determined from monthly water balances for the 24-years period between 1945 and 1968. Surplus values are given in inches.

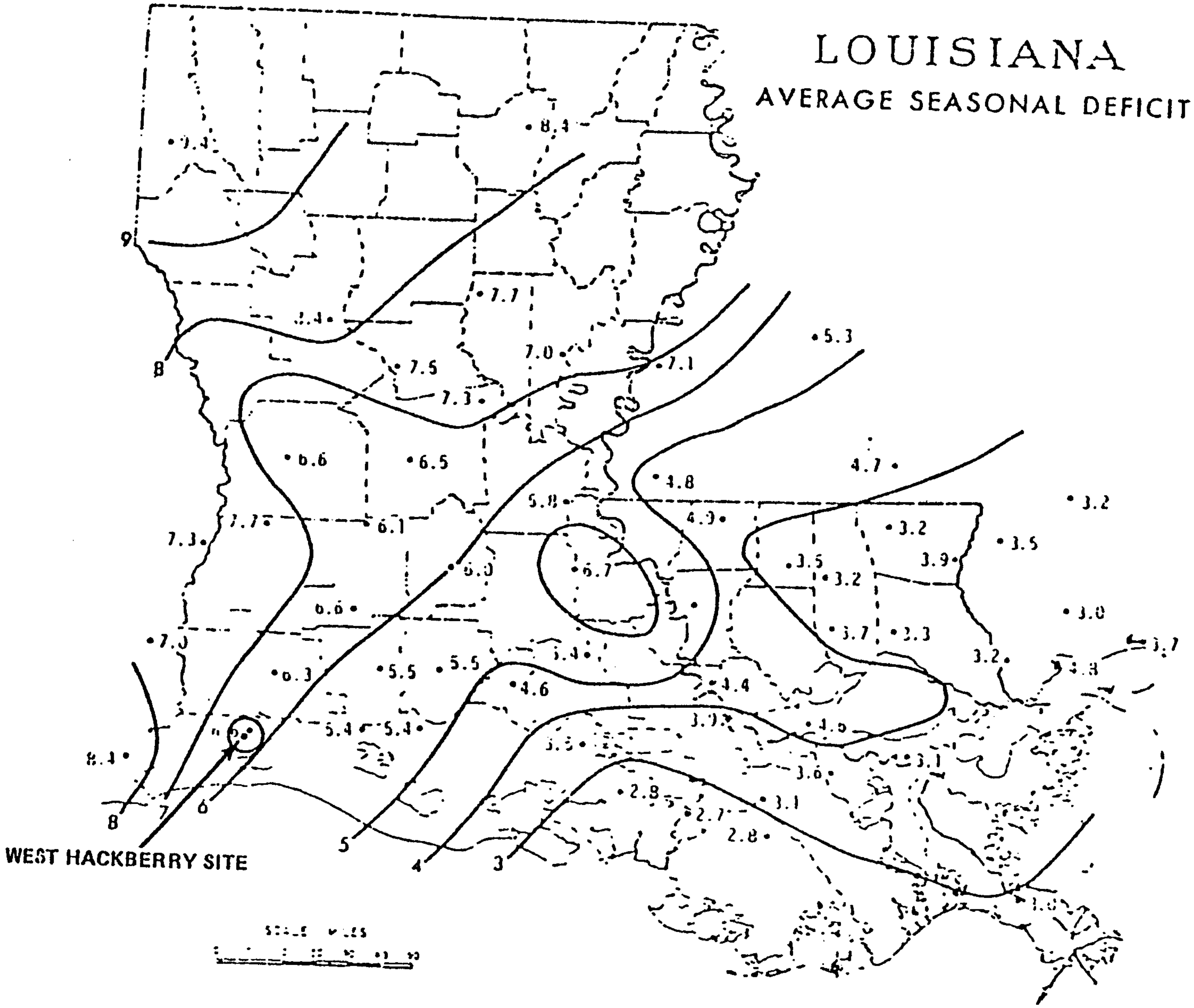

Figure D.1-3 Average seasonal precipitation deficits in south and central Louisiana. Station averages were determined from monthly water balances for the 24-year period between 1945 and 1968. Deficit values are given in inches.

Table D.1-1 Recorded Average Monthly Precipitation at Lake Charles, Louisiana Meteorological Station. Latitude N30°07'; Longitude W93°12'.

(in inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1934	6.62	7.04	9.21	3.62	3.19	0.45	8.31	3.29	6.44	2.47	7.84	2.67	61.35
1935	2.37	3.44	6.84	3.29	4.48	8.87	6.72	5.69	2.87	1.44	4.60	7.85	58.46
1936	3.09	3.93	1.27	1.77	4.65	0.02	6.24	6.46	4.73	1.96	3.99	4.68	42.79
1937	8.06	1.43	3.76	1.16	1.57	4.11	2.73	6.38	4.03	5.60	1.66	2.22	42.71
1938	6.47	1.78	2.89	5.95	2.78	3.99	5.32	4.37	3.98	2.11	3.08	2.49	45.21
1939	3.75	2.82	1.61	1.56	1.75	2.03	6.68	2.25	3.34	1.41	1.93	2.53	31.66
1940	1.71	4.57	1.89	15.30	0.85	8.22	4.97	14.56	2.44	1.54	8.54	8.24	72.83
1941	3.34	2.69	3.99	1.92	12.24	5.57	9.56	3.52	8.09	5.97	1.92	11.68	70.49
1942	1.14	3.70	5.30	5.30	4.51	10.93	8.66	6.98	4.02	3.00	0.76	6.67	50.97
1943	4.79	7.72	8.74	1.73	2.71	5.19	9.99	1.95	11.83	1.03	6.38	6.95	69.01
1944	8.37	2.30	4.61	5.89	6.99	0.68	1.92	6.58	5.17	4.75	9.97	4.83	62.06
1945	2.61	3.98	4.10	3.21	4.93	5.01	12.72	5.85	3.67	5.11	2.80	7.54	61.51
1946	9.44	3.64	4.99	2.62	14.28	5.12	7.20	2.68	6.63	4.98	5.97	2.26	69.81
1947	6.07	3.27	6.65	4.32	6.17	17.90	2.82	4.53	1.19	0.63	5.06	6.45	65.06
1948	6.07	4.97	2.86	3.04	2.48	1.68	1.18	4.52	3.71	0.93	5.99	2.52	39.95
1949	3.62	8.03	9.67	4.98	1.94	8.38	9.21	2.09	3.64	11.15	0.88	5.77	69.36
1950	3.17	5.22	4.84	3.59	7.53	12.87	5.98	2.73	5.45	2.35	1.45	4.19	59.37
1951	7.28	2.18	7.75	1.18	0.87	1.61	1.94	1.00	4.63	0.65	2.21	6.08	37.38
1952	2.32	7.96	3.56	9.75	6.48	3.28	17.83	1.36	1.77	T	4.90	8.79	68.01
1953	1.95	5.03	1.03	6.33	11.13	1.18	11.73	3.25	0.65	2.66	4.82	5.74	55.50
1954	2.26	0.44	2.37	1.65	4.05	1.78	3.65	2.43	0.70	3.62	4.25	2.88	30.08
1955	5.74	7.35	0.12	6.43	3.42	4.85	6.57	8.81	1.57	2.49	4.09	3.89	55.33
1956	2.94	4.56	4.68	1.27	5.25	1.94	0.48	3.77	0.07	1.69	2.29	10.43	39.37
1957	0.96	2.13	7.08	13.71	1.59	11.46	2.92	2.35	6.35	5.21	10.35	4.05	68.16
1958	3.51	3.87	4.01	4.94	4.57	3.58	9.02	9.41	10.04	1.45	1.57	3.22	59.19
1959	4.89	10.67	1.97	4.16	5.85	3.49	17.94	4.72	1.21	4.62	2.98	5.55	68.05
1960	3.79	4.35	0.84	5.92	0.42	1.44	5.05	6.25	2.58	5.17	4.32	7.83	27.96
1961	4.39	7.75	2.58	3.47	4.11	5.31	8.43	4.04	3.48	1.92	14.09	4.03	63.60
1962	4.01	0.80	1.39	3.11	1.73	5.33	0.48	17.36	1.01	2.70	4.40	4.01	46.33
1963	5.07	4.13	0.55	0.64	0.57	4.60	5.28	1.87	8.78	T	4.70	3.36	39.55
1964	5.49	3.05	4.02	1.84	2.12	5.87	4.86	5.58	6.14	0.30	2.06	5.84	47.17
1965	2.49	3.86	3.34	0.96	4.05	1.49	1.85	6.79	3.43	0.32	1.22	5.00	34.80
1966	6.48	6.17	0.75	8.59	6.30	5.10	4.90	6.63	3.54	2.96	4.45	3.78	59.65
1967	1.70	2.26	1.05	5.63	8.59	1.64	5.47	6.21	4.21	4.57	0.11	13.27	54.71
1968	3.89	2.68	2.76	2.39	3.16	8.90	7.82	3.59	3.11	2.38	5.83	4.73	51.24
1969	1.13	6.75	4.27	9.53	6.65	0.84	10.06	1.97	3.23	4.42	0.70	5.57	55.12
1970	2.16	2.68	5.25	1.81	7.11	4.28	0.97	3.56	4.13	17.28	1.78	4.10	55.20
1971	0.78	3.45	0.27	0.93	5.78	2.23	4.45	6.31	5.38	2.64	1.64	9.90	43.76
1972	7.73	2.24	2.23	1.58	4.53	0.93	7.75	6.64	5.82	6.44	4.30	5.47	55.66
1973	4.14	2.94	7.40	10.95	7.48	3.86	2.96	3.29	19.96	4.12	3.01	4.80	75.03
RECORD MEAN	3.95	4.29	3.68	4.58	4.92	4.82	6.38	5.01	4.59	3.44	3.99	5.71	55.36

Source: U. S. Department of Commerce, NOAA, Asheville, North Carolina, 1974.

APPENDIX D.2

VOLUMETRIC FLOW DATA FOR THE CALCASIEU RIVER

This appendix contains six tables containing data for the volumetric flow of the Calcasieu River. Table D.2-1 presents data for the average discharge rate for the river during 1974. The monthly mean and maximum flow rates of the river at Kinder from October 1973 through September 1974 are included in Table D.2-2. At that same location on the river for the same time period the daily discharge rates are provided in Table D.2-3. The monthly discharge rates at Kinder from October 1953 to September 1967 are given in Table D.2-4. Monthly streamflow data for the Calcasieu River basin for the period 1947 to 1951 are provided in Table D.2-5, while similar weekly data are given in Table D.2-6. The locations of all sites noted in the tables are provided in Figure D.2.

Table D.2-1 Average Discharge Rates, Calcasieu River

Location	Flow Rate (cfs)
Glenmora, Louisiana (Rapides Parish)	710
Oberlin, Louisiana (Allen Parish)	1,381
Kinder, Louisiana (Allen Parish)	2,554

Table D.2-2 Calcasieu River Flow at Kinder, Louisiana

Year	Month	Flow Rate (cfs) Mean	Maximum
1973	Oct	3,167	10,500
	Nov	2,535	8,220
	Dec	4,437	10,000
1974	Jan	12,670	23,200
	Feb	5,766	18,800
	Mar	2,127	7,600
	Apr	4,336	15,000
	May	1,926	5,560
	Jun	1,515	6,470
	Jul	809	2,580
	Aug	637	988
	Sep	1,048	3,210

Table D.2-3 Discharge Rates for the Calcasieu River at Kinder October 1973 to September 1974.

CALCASIEU RIVER BASIN

08015500 Calcasieu River near Kinder, La.

LOCATION.--Lat 30°30'10", long 92°54'55", in NW¼SE¼ sec.30, T.6 S., R.5 W., Allen Parish, on left bank on downstream side of bridge on U. S. Highway 190, 0.5 mi (0.8 km) downstream from Whisky Chitto Creek, and 4.0 mi (6.4 km) west of Kinder.

DRAINAGE AREA.--1,700 mi² (4,403 km²).

PERIOD OF RECORD.--August 1922 to January 1925, October 1938 to September 1957, October 1961 to current year. October 1957 to September 1961 (annual maximums) from U. S. Weather Bureau records.

GAGE.--Water-stage recorder. Datum of gage is 11.95 ft (3.642 m) above mean sea level (Louisiana Geodetic Survey bench mark). August 1922 to January 1925, water-stage recorder 400 ft (122 m) downstream at datum 1.77 ft (0.539 m) higher. October 1938 to July 9, 1939, nonrecording gage at present site and datum.

AVERAGE DISCHARGE.--34 years (1922-24, 1938-57, 1961-74), 2,554 ft³/s (72.32 m³/s), 1,850,000 acre-ft/yr (2.28 km³/yr).

EXTREMES.--Current year: Maximum discharge, 24,100 ft³/s (682 m³/s) Jan. 22 (gage height, 18.79 ft or 5.727 m); minimum, 467 ft³/s (13.2 m³/s) Aug. 25 (gage height, 2.57 ft or 0.783 m).
Period of record: Maximum discharge, 182,000 ft³/s (5,154 m³/s) May 19, 1953 (gage height, 32.00 ft or 9.754 m); minimum, 136 ft³/s (3.85 m³/s) Aug. 15, 1956; minimum gage height, 1.99 ft (0.606 m) Aug. 17, 1951, Oct. 20, 1973.

REMARKS.--Records good. Paper mill at Elizabeth pumps about 11 ft³/s (0.31 m³/s) from wells which is later discharge into Mill Creek 36 mi (58 km) above station. This discharge is continuous and fairly constant. Water is diverted during period April to September at points just above station and 5.0 mi (8.0 km) above station for the irrigation of about 7,500 acres (30.4 km²) of rice, part of which is below station. The maximum rate of withdrawal is about 100 ft³/s (2.83 m³/s) and this diversion results in marked regulation of the low-water flow. See following page for table of daily gage height. Records of chemical analyses and water temperatures for the water year 1974 are published in Part 2 of this report.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1,240	1,080	7,570	5,100	18,800	2,460	7,800	849	6,470	528	567	618
2	1,240	1,100	5,040	4,820	15,800	2,220	6,000	856	5,470	525	602	570
3	1,130	1,180	3,510	5,230	12,800	1,990	7,600	856	4,160	515	664	595
4	1,050	1,090	3,320	6,520	9,690	1,790	4,900	849	2,980	509	796	648
5	1,040	1,230	3,830	7,160	7,990	1,630	3,500	919	2,080	509	988	599
6	1,030	1,890	4,040	7,160	6,930	1,480	2,500	997	1,350	570	796	615
7	981	2,150	3,950	7,130	6,360	1,450	1,900	821	1,090	803	674	592
8	932	3,860	3,590	6,690	6,410	1,390	1,500	856	958	1,740	612	938
9	683	4,710	2,910	6,010	5,930	1,330	1,080	935	882	2,580	583	2,600
10	845	3,680	2,250	5,540	5,700	1,270	982	768	892	2,240	554	3,210
11	817	2,600	1,990	7,340	3,870	1,250	908	2,580	1,530	1,289	528	2,990
12	1,020	1,870	1,900	11,700	2,980	1,290	967	5,560	1,490	875	538	2,540
13	1,920	1,560	1,960	14,500	2,610	1,700	3,350	4,720	1,290	744	595	1,990
14	7,030	1,420	2,030	14,300	2,410	2,060	7,310	3,420	2,050	754	864	1,440
15	9,100	1,370	2,000	12,600	2,480	2,130	11,700	2,750	2,030	866	757	1,220
16	10,500	1,310	1,730	10,300	2,940	1,780	15,000	1,840	1,190	773	757	1,150
17	10,100	1,200	1,430	8,120	3,440	1,530	14,300	1,430	905	743	497	1,110
18	8,860	1,080	1,310	6,190	3,780	1,450	11,300	1,290	836	929	602	1,030
19	7,000	1,030	1,460	6,700	4,170	1,420	6,970	1,210	829	796	573	905
20	5,430	1,020	3,400	13,100	4,490	1,300	3,980	1,060	773	734	589	770
21	3,910	1,290	5,040	19,700	4,620	1,290	2,740	964	714	661	551	678
22	3,490	1,620	5,190	23,200	4,590	1,240	2,110	1,040	684	622	538	615
23	3,240	1,760	4,980	23,000	4,540	1,190	1,670	1,110	671	605	525	567
24	3,050	1,590	5,060	21,000	4,530	1,200	1,410	2,580	661	573	446	531
25	2,790	1,950	7,240	19,000	4,370	1,210	1,300	4,750	645	551	474	509
26	2,450	3,840	9,010	20,400	3,520	1,220	1,270	4,990	592	541	480	490
27	2,010	5,150	9,900	20,900	3,030	2,100	1,140	3,230	579	528	496	483
28	1,580	6,660	10,000	20,800	2,680	3,580	1,040	1,920	563	515	531	440
29	1,280	7,540	9,300	19,600	------	5,600	975	1,420	557	509	757	487
30	1,130	8,220	7,120	19,400	------	6,800	912	1,210	535	495	820	483
31	1,100	------	5,490	19,700	------	7,600	------	2,150	------	541	744	------
TOTAL	98,178	76,050	137,550	392,900	161,460	65,950	130,094	59,720	45,456	25,076	19,750	31,453
MEAN	3,167	2,535	4,437	12,670	5,766	2,127	4,336	1,926	1,515	809	637	1,048
MAX	10,500	8,220	10,000	23,200	18,800	7,600	15,000	5,560	6,470	2,580	988	3,210
MIN	817	1,020	1,310	4,820	2,410	1,190	908	768	535	496	474	490
AC-FT	194,700	150,800	272,800	779,300	320,300	130,800	258,000	118,500	90,160	49,740	39,170	62,390

CAL YR 1973 TOTAL 1,709,807 MEAN 4,684 MAX 49,200 MIN 519 AC-FT 3,391,000
WTR YR 1974 TOTAL 1,243,637 MEAN 3,407 MAX 23,200 MIN 474 AC-FT 2,467,000

Table D.2-3(continued) Discharge Rates for the Calcasieu River at Kinder

CALCASIEU RIVER BASIN

08015500 Calcasieu River near Kinder, La.--Continued

GAGE HEIGHT, IN FEET, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4.90	4.77	14.43	12.31	17.82	8.21	--	4.11	13.66	2.76	2.88	3.04
2	4.89	4.82	12.92	11.98	17.12	7.68	--	4.13	13.07	2.75	2.99	2.89
3	4.58	5.03	10.66	12.45	16.38	7.11	--	4.13	11.60	2.72	3.18	2.97
4	4.35	4.81	9.70	13.70	15.43	6.61	--	4.11	9.57	2.70	3.58	3.13
5	4.33	5.19	10.61	14.18	14.65	6.20	--	4.31	7.06	2.70	4.16	2.98
6	4.29	6.84	10.92	14.18	14.02	5.82	--	4.22	5.19	2.89	3.58	3.03
7	4.16	7.50	10.78	14.16	13.57	5.74	--	4.03	4.45	3.60	3.21	2.96
8	4.02	9.93	10.24	13.84	13.61	5.59	--	4.13	4.07	6.21	3.02	4.01
9	3.88	11.86	9.10	13.25	13.18	5.45	4.77	4.07	3.84	8.25	2.93	8.23
10	3.77	10.85	7.76	12.79	12.42	5.31	4.48	3.88	3.87	7.46	2.84	9.52
11	3.69	8.50	7.10	13.82	11.09	5.26	4.27	8.27	5.65	4.99	2.76	9.07
12	4.26	6.79	6.88	15.97	9.49	5.36	4.34	12.26	5.57	3.92	2.79	9.15
13	5.48	6.02	7.07	16.74	8.51	6.37	9.15	12.28	5.02	3.62	2.97	6.85
14	13.40	5.67	7.21	16.75	8.11	7.27	13.66	10.38	5.96	3.45	3.74	5.42
15	15.18	5.55	7.13	16.30	8.25	7.46	15.84	8.79	6.93	3.79	3.46	4.86
16	15.71	5.41	6.65	15.63	9.15	6.57	16.92	6.72	4.75	3.51	3.46	4.64
17	15.57	5.10	5.71	14.72	9.99	5.95	16.75	5.69	3.91	3.48	3.28	4.51
18	15.08	4.77	5.40	13.69	10.56	5.75	15.92	5.34	3.70	3.69	2.99	4.28
19	14.31	4.62	5.78	13.67	11.10	5.07	14.64	5.13	3.68	3.58	2.90	3.91
20	13.09	4.59	9.41	16.15	11.55	5.38	11.80	4.71	3.51	3.39	2.95	3.50
21	11.28	5.35	11.95	18.01	11.72	5.36	9.07	4.43	3.33	3.17	2.83	3.22
22	10.06	6.19	12.41	18.65	11.69	5.22	7.60	4.67	3.24	3.05	2.79	3.03
23	9.65	6.52	12.18	--	11.62	5.08	6.30	4.86	3.20	3.00	2.75	2.88
24	9.34	6.09	12.27	--	11.61	5.11	5.66	8.34	3.17	2.90	2.64	2.77
25	8.87	7.01	13.85	--	11.39	5.13	5.38	11.54	3.12	2.83	2.59	2.70
26	8.20	10.19	15.15	19.16	10.43	5.18	5.31	12.19	2.96	2.80	2.61	2.64
27	7.14	11.95	15.50	18.25	9.30	7.37	4.93	10.51	2.92	2.76	2.66	2.62
28	6.07	13.50	15.54	18.23	8.65	9.93	4.65	6.91	2.87	2.72	2.77	2.61
29	5.32	14.41	15.28	18.00	------	--	4.47	5.68	2.85	2.70	3.46	2.63
30	4.90	14.77	14.43	17.95	------	--	4.29	5.12	2.78	2.66	3.65	2.62
31	4.82	------	13.09	18.02	------	--	------	6.92	------	2.80	3.42	------
MAX	15.71	14.77	15.54	--	17.82	--	16.92	12.28	13.66	8.25	4.16	9.52
MIN	3.69	4.59	5.40	11.98	8.11	5.08	4.27	3.88	2.78	2.66	2.59	2.61

From U.S. Geological Survey. 1974. Water Resources Data for Louisiana.

Table D.2-4 Discharge data for Calcasieu River (U.S.G.S. Station 8-0155 at Kinder, La.) For the Years 1953 through 1967

Water Year	Monthly and yearly mean discharge in cubic feet per second (cfs)												The Year
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	
1953	263	332	1,184	1,611	4,707	5,155	1,539	36,390	980	1,195	787	458	4,565
1954	394	439	1,379	2,014	819	720	1,374	9,123	392	272	299	241	1,470
1955	348	298	308	1,387	9,521	1,237	4,680	4,067	534	1,850	6,684	932	2,609
1956	554	394	1,119	1,505	7,498	3,398	1,668	510	445	265	214	276	1,463
1957	235	409	5,649	1,225	1,619	5,664	3,993	2,095	1,332	1,728	470	642	2,098
1958													
1959													
1960													
1961													
1962	547	3,351	9,583	4,786	2,302	1,358	2,108	1,522	2,276	606	559	1,031	2,507
1963	381	532	2,107	4,019	2,620	1,963	578	378	464	855	433	353	1,220
1964	248	480	1,324	2,769	1,447	6,294	4,299	2,077	504	432	399	435	1,731
1965	378	396	4,364	1,509	3,357	4,893	1,502	610	506	327	297	403	1,540
1966	268	354	2,295	4,146	11,290	1,804	3,226	2,248	454	405	545	696	2,249
1967	1,186	3,121	1,684	1,818	2,731	1,329	5,985	2,899	1,101	644	410	313	1,921
Mean	437	919	2,818	2,436	4,356	3,074	2,813	5,629	817	779	1,008	525	2,124

Drainage area: 1,700 sq. miles
Records maintained from 1938 to 1957 to 1961 to 1967; Average discharge: 2,574 cfs for 27 yrs.
Maximum discharge: 182,000 cfs, May 19, 1953; Minimum discharge: 136 cfs, August 15, 1956

From Louisiana Wildlife and Fisheries Commission. 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area Description, and Phase IV, Biology

Table D.2-5 Monthly Streamflow, in acre-feet, Calcasieu River Basin, 1947-51

Month	Beckwith Creek	Hickory Branch	Bundick Creek	Whiskey Chitto Creek	Calcasieu River at Oberlin	Ungaged area *A*	Ungaged area *B*	Ungaged area *C*	Total
1947									
October	100	30	4,300	10,000	3,100	9,500	300	4,000	31,300
November	2,300	1,300	18,400	37,100	26,200	37,000	37,800	40,600	201,000
December	12,800	7,700	36,100	71,900	136,000	71,900	46,700	39,500	423,000
1948									
January	14,200	13,000	27,700	53,900	92,400	54,300	79,000	46,500	381,000
February	26,500	19,700	45,500	94,700	198,000	93,400	123,000	100,000	701,000
March	8,600	6,800	20,400	56,400	111,000	51,100	39,400	28,400	322,000
April	2,600	800	8,500	21,500	40,500	19,900	11,800	13,100	119,000
May	500	50	7,400	20,000	11,900	18,200	1,700	3,600	63,400
June	200	30	4,600	11,100	4,300	10,400	800	600	32,000
July	900	100	4,700	11,100	4,200	10,500	5,400	7,700	44,600
August	100	10	4,000	8,800	3,000	8,500	1,400	8,200	34,000
September	80	20	4,800	10,200	3,200	10,000	600	9,300	38,200
October	200	10	4,300	7,900	2,800	8,100	300	2,400	26,000
November	12,200	6,600	45,500	90,300	106,000	90,400	30,200	6,600	388,000
December	8,500	6,600	20,200	60,100	120,000	53,400	32,900	34,400	336,000
1949									
January	23,500	19,100	41,300	95,500	157,000	91,100	93,200	42,400	563,000
February	38,300	26,200	45,600	90,900	189,000	90,800	170,000	126,000	777,000
March	51,900	36,800	66,200	130,000	228,000	130,000	241,000	77,000	961,000
April	61,500	34,000	83,300	216,000	348,000	199,000	186,000	91,800	1,220,000
May	9,100	2,900	25,900	37,300	77,700	42,000	25,200	22,900	243,000
June	5,500	1,200	10,100	22,400	9,300	21,600	22,600	12,300	105,000
July	5,900	3,700	10,600	32,300	31,100	28,600	25,200	53,200	190,600
August	500	200	7,400	20,000	24,600	18,200	2,300	17,200	90,400
September	200	400	6,500	13,500	5,600	13,300	1,400	11,400	52,300
October	12,100	11,000	20,200	37,700	30,700	38,500	99,800	99,500	350,000
November	600	500	6,600	17,000	11,100	15,700	4,400	4,600	60,500
December	21,700	14,800	36,000	65,400	98,400	67,500	97,800	39,300	441,000
1950									
January	17,800	8,500	35,700	81,400	158,000	78,000	56,600	59,300	495,000
February	48,400	28,800	98,700	165,000	329,000	176,000	133,000	86,400	1,065,000
March	28,500	23,000	41,300	94,400	180,000	90,300	122,000	86,600	666,000
April	8,000	7,100	15,500	51,500	33,100	44,600	23,200	2,300	185,000
May	27,400	9,400	53,100	137,000	192,000	127,000	85,100	45,000	676,000
June	50,200	26,900	77,700	151,000	257,000	152,000	274,000	98,800	1,088,000
July	3,800	2,000	15,200	33,900	23,900	32,700	19,400	13,700	145,000
August	1,000	90	6,400	19,400	11,700	17,100	2,800	13,400	71,900
September	1,000	200	6,500	17,900	11,600	16,200	3,000	12,700	69,100
October	400	20	5,700	13,900	6,400	13,100	1,800	4,700	46,000
November	600	50	6,100	14,500	14,600	13,800	2,300	7,300	59,200
December	700	70	7,000	18,200	14,600	16,800	4,000	12,700	74,000
1951									
January	8,100	6,100	24,300	60,400	166,000	56,400	10,200	29,700	361,000
February	8,200	5,100	16,900	48,000	91,200	43,200	48,600	53,800	315,000
March	7,900	3,500	15,700	37,400	42,400	35,300	41,000	27,400	211,000
April	4,900	400	12,600	33,200	113,000	30,500	14,900	26,600	236,000
May	400	50	5,800	15,900	46,800	14,400	1,200	2,800	87,400
June	200	10	4,600	11,300	8,000	10,600	400	7,500	42,600
July	1,100	2,400	5,000	12,500	8,000	11,700	11,800	10,500	63,000
August	400	200	4,100	8,700	4,700	8,500	2,200	7,200	36,000
September	6,200	9,200	14,900	17,400	4,600	21,500	29,800	15,500	119,000
October	1,000	200	4,800	10,700	6,400	10,300	2,500	3,400	39,300

From Jones, P.H., Hendricks, E.L., Irelan, B., and others. 1956. Water Resources of Southwestern Louisiana. U.S. Geological Survey Water-Supply Paper No. 1364.

Table D.2-6 Weekly streamflow, in acre-feet
Calcasieu River Basin, 1948-51

Week ending	Beckwith Creek	Hickory Branch	Bundick Creek	Whiskey Chitto Creek	Calcasieu River at Oberlin	Ungaged area A	Ungaged area B	Ungaged area C	Total
1948									
Apr. 8	200	50	1,700	5,200	5,100	4,600	700	20	17,600
15	1,100	400	2,100	4,800	3,500	4,600	5,500	200	22,200
22	600	100	2,500	5,900	14,700	5,600	2,700	400	32,500
29	600	200	1,600	4,200	15,900	3,900	2,500	10,800	39,700
May 6	200	30	1,400	3,900	3,300	3,500	700	2,400	15,400
13	100	20	2,800	7,300	4,300	6,700	500	1,900	23,600
20	80	10	1,500	4,100	2,600	3,700	300	400	12,700
27	60	0	1,200	3,000	1,500	2,800	200	100	8,900
June 3	100	10	1,400	3,600	1,300	3,300	400	500	10,600
10	50	0	1,100	2,800	1,200	2,600	200	200	8,200
17	50	10	1,100	2,600	1,000	2,400	200	200	7,600
24	30	0	1,000	2,400	900	2,200	100	100	6,700
July 1	60	20	1,000	2,200	800	2,100	300	70	6,600
8	90	50	1,000	2,500	900	2,400	700	1,500	9,100
15	400	50	1,300	3,300	1,300	3,100	2,700	3,900	16,000
22	300	20	1,000	2,400	900	2,200	1,600	1,300	9,700
29	40	10	900	2,000	800	2,000	300	500	6,600
Aug. 5	20	0	900	2,300	800	2,100	200	1,400	7,700
12	50	10	900	2,000	700	1,900	600	3,700	9,900
19	20	0	800	1,700	700	1,700	200	1,200	6,300
26	10	0	800	1,800	600	1,700	100	700	5,700
Sept. 2	20	0	1,100	2,200	800	2,200	300	2,300	8,900
9	20	0	1,300	2,000	700	2,200	200	1,400	7,800
16	20	20	1,400	3,200	800	3,100	200	3,500	12,200
23	20	0	1,000	2,400	800	2,200	100	3,200	9,700
30	10	0	900	2,000	700	1,900	40	400	6,000
Oct. 7	10	0	900	1,800	700	1,800	30	100	5,300
14	100	10	1,200	1,900	600	2,110	200	400	6,500
21	40	0	900	1,800	600	1,800	70	1,300	6,500
28	20	0	900	1,700	600	1,700	30	500	5,400
Season total	4,420	1,020	37,600	89,000	69,100	84,100	21,870	44,590	352,000
1949									
Apr. 8	11,900	2,500	20,000	47,700	110,000	45,100	32,600	23,100	293,000
15	15,400	11,000	16,800	40,700	65,800	36,300	48,400	15,100	252,000
22	4,300	4,000	6,700	15,400	18,200	14,700	15,200	10,800	89,300
29	24,500	13,700	31,700	93,100	110,000	63,100	69,800	32,700	459,000
May 6	8,200	3,200	18,400	23,200	57,700	27,700	23,100	23,700	185,000
13	600	100	4,000	7,500	25,300	7,700	1,500	1,800	48,500
20	300	40	2,400	5,200	4,300	5,100	600	200	18,100
27	300	90	1,900	4,300	2,200	4,100	900	100	13,900
June 3	1,700	400	2,900	5,100	1,800	5,300	4,900	4,700	26,800
10	200	70	1,600	3,800	1,500	3,600	700	700	12,200
17	3,600	500	4,200	6,800	2,400	7,300	14,600	4,500	43,900
24	900	500	1,900	5,500	2,500	4,900	4,800	2,000	23,000
July 1	100	60	1,700	4,900	2,500	4,400	600	3,100	17,400
8	200	40	1,700	4,000	2,100	3,800	800	1,600	14,200
15	800	400	1,800	4,900	4,100	4,500	3,200	4,000	23,700
22	3,300	1,100	2,400	9,300	11,200	7,800	11,600	17,900	64,600
29	1,500	2,100	3,800	11,800	11,000	10,400	9,200	26,100	75,900
Aug. 5	100	70	2,800	5,600	8,800	5,600	600	6,100	29,700
12	300	20	1,900	4,500	4,100	4,300	1,000	3,300	19,400
19	60	10	1,400	5,600	8,900	4,600	200	5,600	26,400
26	50	50	1,200	3,700	3,900	3,300	400	4,400	17,000
Sept. 2	80	100	1,400	3,100	1,700	3,000	600	1,600	11,600
9	40	100	1,600	3,400	1,500	3,300	300	1,500	11,700
16	60	200	1,700	3,300	1,300	3,400	500	4,900	15,400
23	30	70	1,400	3,300	1,200	3,200	200	3,300	12,700
30	20	10	1,100	2,600	1,100	2,500	50	1,200	8,600
Oct. 7	2,400	6,500	7,800	12,600	7,300	13,600	42,800	18,800	112,000
14	5,850	2,400	3,700	10,400	9,600	9,400	35,400	56,200	132,000
21	900	500	2,400	5,000	7,100	4,900	6,000	22,500	49,300
28	1,600	1,500	5,200	7,300	3,400	8,300	13,400	1,500	42,200
Season total	90,240	51,330	157,500	263,600	492,500	347,200	343,950	302,000	2,150,000

Table D.2-6 (continued) Weekly streamflow, in acre-feet
Calcasieu River Basin, 1948-51

Week ending	Beckwith Creek	Hickory Branch	Bundick Creek	Whiskey Chitto Creek	Calcasieu River at Oberlin	Ungaged area A	Ungaged area B	Ungaged area C	Total
1950									
Apr. 8	300	100	2,900	11,000	9,300	9,200	900	200	33,900
15	1,200	600	2,100	6,800	5,500	5,900	2,900	100	25,100
22	2,000	1,700	3,100	10,400	6,300	9,000	5,500	300	38,300
29	1,200	600	2,800	7,400	5,000	6,800	2,700	400	26,900
May 6	21,900	9,300	38,700	104,000	86,000	95,200	59,700	19,300	434,000
13	1,400	400	3,800	13,500	57,900	11,600	4,500	12,300	105,000
20	2,600	900	7,600	21,200	26,700	19,200	9,800	11,000	99,000
27	1,000	200	4,300	8,000	21,700	8,200	3,200	1,000	47,600
June 3	11,800	12,800	14,600	21,600	17,700	24,100	82,000	13,200	198,000
10	29,600	13,400	47,900	99,000	185,000	97,800	153,000	53,200	679,000
17	5,000	1,100	6,300	14,400	37,900	13,800	21,700	14,600	114,800
24	6,200	2,100	9,000	13,800	13,900	15,200	29,700	12,800	103,000
July 1	1,500	200	3,900	8,300	7,800	8,100	5,800	9,100	44,700
8	400	100	3,700	7,600	5,100	7,500	1,900	3,100	29,400
15	1,000	800	2,800	6,600	5,200	6,200	5,900	1,100	29,600
22	2,100	1,000	5,400	10,000	6,700	16,300	10,400	2,800	54,700
29	200	60	1,800	6,000	4,400	5,200	800	2,700	21,200
Aug. 5	200	20	1,700	6,100	4,400	5,100	600	5,800	23,900
12	100	10	1,600	4,600	2,700	4,100	400	3,100	16,600
19	90	0	1,400	3,600	2,200	3,300	300	2,200	13,100
26	90	30	1,400	4,800	2,600	4,100	300	3,000	16,300
Sept. 2	1,000	50	1,400	3,800	2,000	3,400	2,500	2,800	17,000
9	300	10	1,600	5,300	3,500	4,600	700	6,800	22,800
16	90	0	1,200	3,300	3,800	3,000	200	1,800	13,400
23	80	60	1,300	3,600	1,800	3,200	400	2,100	12,500
30	100	100	2,000	4,500	1,900	4,300	700	1,000	14,600
Oct. 7	100	10	1,700	3,500	1,800	3,400	500	900	11,900
14	60	0	1,100	2,900	1,200	2,700	200	700	8,900
21	70	0	1,200	3,000	1,100	2,700	300	1,300	9,700
28	90	0	1,300	3,400	1,700	3,100	600	1,400	11,600
Season total	91,770	45,650	179,600	422,000	533,800	406,300	408,100	190,100	2,276,000
1951									
Apr. 8	2,500	200	3,800	10,300	65,700	9,400	7,400	16,800	116,000
15	800	60	3,000	7,800	18,700	7,200	2,300	400	40,300
22	200	20	1,700	5,000	14,200	4,500	700	200	26,500
29	200	40	1,600	5,100	7,500	4,400	600	3,100	22,500
May 6	200	40	1,600	4,800	3,600	4,200	500	300	15,200
13	100	10	1,400	4,000	32,900	3,600	300	800	43,100
20	80	10	1,200	3,400	7,500	3,100	200	1,400	16,900
27	50	0	1,100	2,900	2,400	2,600	200	200	9,400
June 3	40	0	1,100	2,600	2,300	2,400	100	300	8,800
10	40	0	1,100	2,700	2,000	2,500	100	700	9,100
17	30	0	1,200	2,800	1,600	2,700	80	800	9,200
24	40	0	1,100	2,700	1,800	2,500	80	5,200	13,400
July 1	50	0	1,100	2,400	1,500	2,300	100	1,200	8,600
8	40	0	1,400	4,400	2,400	3,900	100	4,500	16,700
15	30	0	1,000	2,300	2,600	2,200	90	1,400	9,600
22	30	0	1,000	2,000	1,300	2,000	90	800	7,200
29	200	1,600	1,000	2,400	1,200	2,300	6,300	2,400	17,400
Aug. 5	900	900	1,200	2,900	1,800	2,800	6,200	2,900	19,600
12	70	20	900	2,000	1,100	2,000	300	1,400	7,800
19	60	0	1,000	1,800	900	1,900	200	1,200	7,100
26	70	60	800	1,700	800	1,700	600	2,000	7,700
Sept. 2	30	0	800	1,600	700	1,600	200	1,000	5,900
9	100	20	900	1,800	700	1,800	300	1,200	7,800
16	1,500	1,700	5,200	4,400	800	6,400	6,200	4,100	30,300
23	600	2,000	1,900	3,600	1,300	3,700	5,100	2,400	20,600
30	3,900	5,500	6,600	7,200	1,600	9,200	18,200	6,400	58,600
Oct. 7	800	200	1,600	3,100	1,800	3,100	1,900	1,700	14,200
14	90	30	1,000	2,400	1,200	2,200	200	500	7,600
21	60	10	900	2,100	1,100	2,000	100	400	6,700
28	50	10	900	2,200	1,700	2,100	100	500	7,600
Season total	12,860	12,430	49,100	104,400	184,700	102,300	58,340	67,200	591,000

From Jones, P. H., Hendricks, E. L., Irelan, B., and Others. 1956. Water Resources of Southwestern Louisiana, U. S. Geological Survey Water-Supply Paper 1364.

APPENDIX D.3

DISCHARGE DATA FOR INDUSTRIAL AND MUNICIPAL WASTES EMPTYING INTO THE CALCASIEU RIVER ESTUARINE REGION

This appendix consists of two tables which contain discharge data for industrial and municipal wastes emptying into the Calcasieu river estuarine region during 1969. Table D.3-1 provides data for industrial wastes, while Table D.3-2 presents data for municipal wastes.

Table D.3-1 Quantity and Quality of Industrial Waste Emptying Into the Estuarine Part of the Calcasieu River - 1961

Source of Waste, Principal Products	Receiving Waters	Avg. Daily Dis-charge (mgd)	Sewerage[2] Disposal Facilities	Indus-trial Waste Facilities[3]	Estimated Pounds BOD Dis-charged Daily
Louisiana Menhaden-fish oil	Calcasieu River	Unk.	Unk.	C.B.	Unk.
Gulf Menhaden-fish oil	Calcasieu River	Unk.	Unk.	Unk.	Unk.
Ocean Protein, Lake Charles-fish oil	Calcasieu River	Unk.	Unk.	Unk.	Unk.
Olin Mathison-Chemicals	Calcasieu River	115.200	Unk.	I.R.	Unk.
Petroleum Chemicals, Inc.-petrochemicals	Bayou D'Inde to Calcasieu River	0.720	Unk.	C.S.R.	Unk.
Continental Oil Co.-complete refinery	Calcasieu River	12.960	Unk.	S.B.	Unk.
Tenneco Refinery - Naval stores products	Calcasieu River	Unk.	Unk.	I.B.S.	Unk.
Stauffer Chemicals - Vinyl clorides	Calcasieu River	0.720	Unk.	N.R.	Unk.
Columbia Southern - Chemicals	Calcasieu River	270.000	I.T.	R.T.	Unk.
Herculese Corporation - Petrochemicals	Calcasieu River	0.720	L.	F.R.S.	1,700
Firestone-synthetic rubber	Calcasieu River	0.820	I.T.	S.B.S.	750
Louisiana Polymer Corp.-Polyethylene	Calcasieu River	0.170	Unk.	S.G.	Unk.
Cities Service Refinery-Petrochemical and Petroleum refinery	Calcasieu River	288.000	O.P.	H.P.S.	1,750
Davidson Chemical-Inorganic chemicals	Calcasieu River	0.576	Unk.	Unk.	Unk.
Union Texas Petroleum-sulphur mine (Frasch process)	Bayou D'Inde to Calcasieu River	Unk.	Unk.	R.S.A.	Unk.

[1]Information on sources, amounts, and degree of treatment of waste obtained from the Pollution Control Division, Louisiana Wild Life and Fisheries Commission, 1969

[2]Symbols for degree of treatment: Unk.--Unknown; P.S.P.--Primary Settling Pond; I.T.--Imhoff Tank; L.--Lagoon; O.P.--Oxidation Pond.

[3]Symbols for degree of treatment: B.D.--Betz Dionodic water treatment; I.W.--Injection Wells, separaters, and skimmers; S.--Save, all solid removal; O.P.--Oxidation Pond; O.W.S.--Oil and water Separator; S.R.P.--Secondary Retention Ponds; C.B.--Cooling Basin; H.T.--Holding Tanks;

Table D.3-1 (Continued). Quantity and Quality of Industrial Waste

W.R.P.--Water Retention Ponds; I.R.--Impoundment Reservoir, solids removal; C.S.R.--through Cities Service Refinery; S.B.--Settling Basin and strippers; I.B.S.--Impoundment Basin and Skimmer; N.R.--Neutralization and Removal of dissolved solids; R.T.--Routine Testing of discharge water; R.F.S.--Facilities for Reduction in Solids; S.B.S.--Settling Basin and Skimmers; S.G.--Sump Gathering and burning of hydrocarbons; H.P.S.--Holding Ponds and Skimmers; R.S.A.--Reservoir, Spray Aeration--removal of H_2S.

From Louisiana Wildlife and Fisheries Commission. 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area Description, and Phase IV, Biology.

Table D.3-2

Quantity and Quality of Domestic Waste Emptying into Estuarine Areas - 1969[1]

Source of Waste	Receiving Waters	Average Daily Discharge (mgd)	Degree[2] of Treatment	Est. Average[3] ppm B.O.D. in Discharge	Estimated[4] Population Served
Cameron	Calcasieu River	0.20	P.T.	140	2,000
Hackberry	Calcasieu River	0.05	P.T.	140	500
Lake Charles - Greenwich Terrace	Calcasieu River	0.35	B.F.	30	3,500
Lake Charles - A & B Plant	Calcasieu River	7.70	A.S	30	71,300
Lake Charles - Firestone	Calcasieu River	0.05	B.F.	30	500
Westlake	Calcasieu River	0.44	B.F.	30	3,301
Maplewood	Calcasieu River	0.30	A.S.	30	275
Hollywood	Calcasieu River	0.05	B.F.	30	545
Lake Charles - Cities Service	Calcasieu River	0.60	O.P.	25	500
Sulphur	Bayou D'Inde to Calcasieu River	1.20	B.F.	30	12,800

[1]Information on sources, amounts, and degree of treatment of waste was obtained from the Louisiana Department of Health, 1969.

[2]Symbols for degree of treatment: B.F. - Biological Filtration; O.P. - Oxidation Pond; A.S. - Activated Sludge; P.T. - Primary Treatment.

[3]Based on an estimate that the average B.O.D. of untreated domestic sewerage is 200 ppm; primary treated is 140 ppm; and secondary treatment is 20 ppm unless known to be higher.

[4]Represents the actual number of domestic sewerage installations.

From Louisiana Wildlife and Fisheries Commission, 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area Description, and Phase IV, Biology.

APPENDIX D.4

WATER QUALITY DATA FOR BODIES OF WATER NEAR WEST HACKBERRY DOME

This appendix contains 11 tables and 3 figures relating to water quality in the vicinity of the West Hackberry site.

Table D.4-1 presents salinity data taken in the Sabine National Wildlife Refuge. The location of the five stations at which data were taken are indicated in Figure D.4-1.

Surface water temperature and salinity data from Calcasieu Pass are provided in Table D.4-2. Similar data for the lower Calcasieu River are presented in Table D.4-3. Water quality data at three stations on Calcasieu Lake are included in Table D.4-4. The locations of the stations involved in the three preceeding tables are indicated in Figure D.4-2.

Water quality data based on samples collected at Mile 40 on the river are presented in Table D.4-5. Similar data from samples collected at St. John's Island in Calcasieu Pass are included in Table D.4-6.

Measurements of certain water quality parameters obtained in the Gulf Intracoastal Waterway during 1975 are provided in Table D.4-7. The results of chemical analysis of the corresponding samples are presented in Table D.4-8, while the results of the pesticide analysis of the samples are included in Table D.4-9.

The locations of the sampling stations associated with Tables D.4-5 through D.4-9 are indicated in Figure D.2-1.

Additional water quality data are shown in Tables D.4-10 and D.4-11 for the Calcasieu Ship Channel. The sample stations, as shown in Figure D.4.3 are very close to the proposed distribution terminal which will be used for the West Hackberry facility.

Table D.4-1 Salinity (Parts per Thousand) at Selected Station

	#1	#2	#3	#4	#5
September, 1973	-	-	-	2.55	-
October, 1973	-	-	-	6.10	-
November, 1973	-	-	-	5.95	-
December, 1973	-	-	-	11.55	-
January, 1974	-	-	-	0.40	-
February, 1974	-	-	-	4.25	-
March, 1974	-	-	-	5.85	-
April, 1974	-	-	-	4.80	-
May, 1974	-	-	-	8.05	-
June, 1974	-	-	-	5.85	-
July, 1974	-	-	-	12.50	-
August, 1974	-	-	-	12.75	-
September, 1974	-	-	-	11.35	-
October, 1974	-	-	-	14.85	-
December, 1974	-	-	4.00	-	2.75
January, 1975	1.85	-	2.45	-	1.30
February, 1975	0.95	7.25	4.90	6.65	0.85
March, 1975	2.85	8.05	4.95	11.25	0.45
April, 1975	4.20	6.95	7.90	3.00	0.35
May, 1975	5.80	2.95	5.70	0.60	0.55
June, 1975	-	3.00	5.30	2.90	0.50
July, 1975	2.30	5.30	2.75	6.00	1.15
August, 1975	1.00	3.05	2.15	8.10	-
September, 1975	-	3.25	2.80	9.00	1.35
October, 1975	2.85	-	4.90	8.60	6.45
December, 1975	-	-	11.50	-	4.75
January, 1976	-	-	7.10	-	2.35
February, 1976	11.95	13.40	5.55	3.85	3.40

#1 - Station N - E-W Canal
#2 - Station NH - Roadside Canal
#3 - Station B - Near Brown's Lake
#4 - Station S - Hog Island Canal at Lake Calcasieu
#5 - - Black Bayou

Source: Unpublished data from the Sabine National Wildlife Refuge.

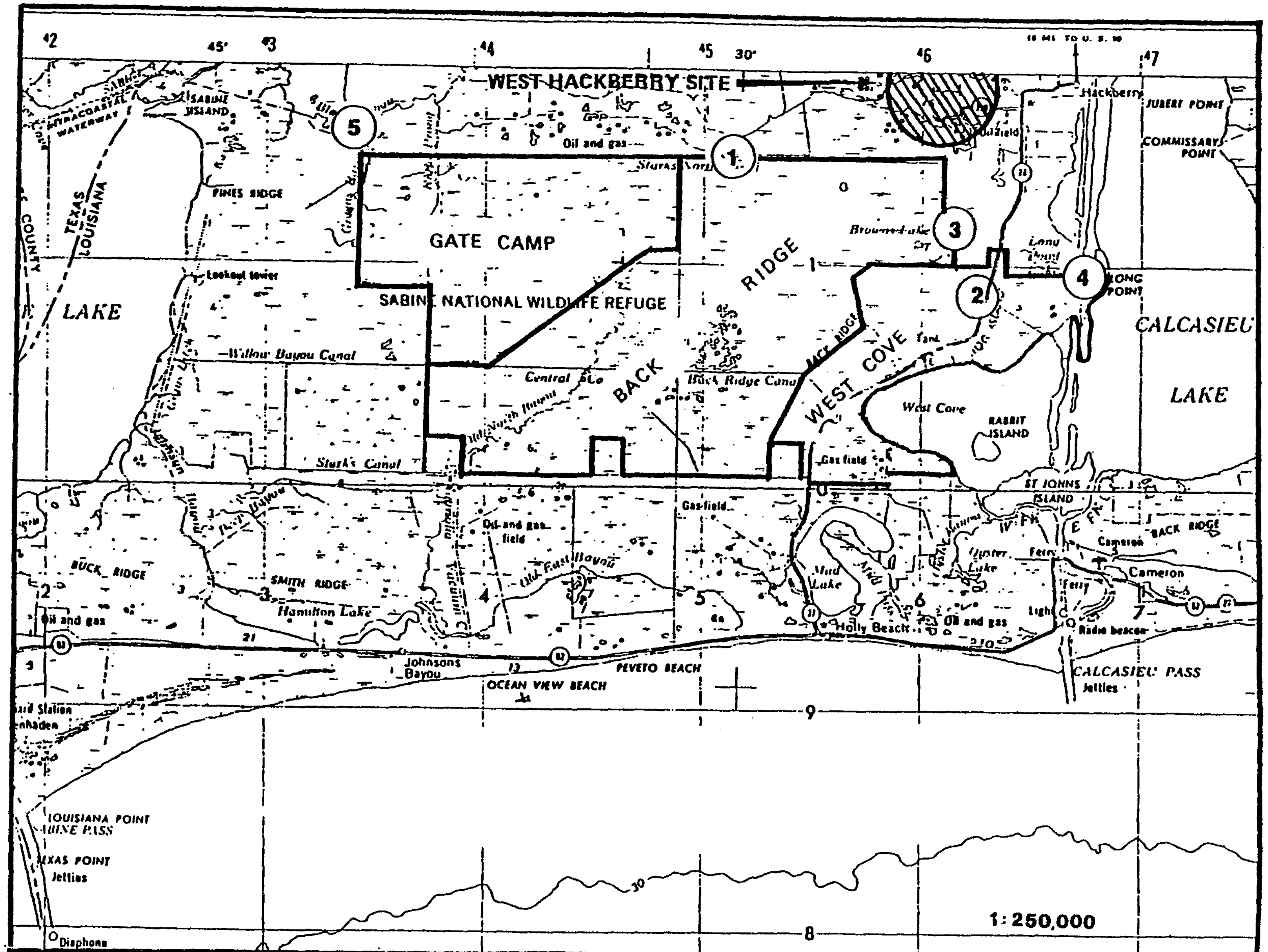

Figure D.4-1 Salinity Stations - Sabine National Wildlife Refuge
Unpublished Data from Refuge Records

Table D.4-2 Surface Water Temperature and Salinity Data at Station 19 - Calcasieu Pass

Yr	Mo	Day	Water Temp (°C)	Sal (ppt)
68	1	5	10.7	23.9
68	1	11	6.9	
68	1	27	9.3	11.4
68	1	30		
68	2	1	16.1	14.5
68	2	8	11.4	10.2
68	2	16	8.2	15.4
68	2	26		
68	2	29	9.5	19.0
68	3	7	13.8	19.9
68	3	15	13.2	22.7
68	3	21	13.6	22.7
68	3	29	20.5	18.9
68	4	5	18.7	23.7
68	4	11	22.1	10.6
68	4	19	24.3	15.3
68	4	29	25.9	19.3
68	5	5		
68	5	9		
68	5	10	26.1	15.0
68	5	17		
68	5	25	25.5	14.0
68	6	15	29.2	16.7
68	6	21		
68	6	28	33.6	
68	7	12	33.9	
68	7	19	34.1	19.7
68	7	26	35.0	18.4
68	8	1	34.6	6.1
68	8	8	32.9	20.3
68	8	16	34.1	25.4
68	8	23	26.7	18.3
68	8	29	26.7	19.3
68	9	6	25.7	8.5
68	9	13	25.7	9.1
68	9	20	26.8	18.0
68	9	27	23.9	17.8
68	10	2		
68	10	9	26.7	16.9
68	10	16	25.6	21.6
68	10	23	22.9	21.1
68	10	30	21.1	30.1
68	11	5	16.6	20.8
68	11	13	13.3	33.1
68	11	20	14.4	28.6
68	11	27	14.6	17.9
68	12	4	12.0	22.1
68	12	11	14.4	24.4
68	12	18	12.2	23.1
68	12	26	13.3	28.5
69	1	2	8.0	13.9
69	1	9	12.2	
69	1	29	16.7	
69	2	5	14.4	
69	2	12	15.6	
69	2	19	15.6	
69	2	26	15.6	
69	3	5		
69	3	12	15.6	
69	3	19	14.4	

From O'Neal and Scerva, J. 1971. The Effects of Dredging on Water Quality. World Dredging and Marine Construction 7(14): 24-31.

TABLE D.4-3

Monthly average surface water temperature and salinity at station 21 in Study Area VI, Lower Calcasieu River [14]

	Water temperature (°C)		*Salinity (ppt)*
	1968	*1969*	*1968*
Jan.	10.8	11.4	12.2
Feb.	11.5	13.9	19.2
March	14.0	13.9	22.0
April	21.5	21.2	13.5
May	25.6	25.3	14.5
June	28.9	28.2	27.3
July	29.6	30.0	24.3
Aug.	30.4	30.0	26.8
Sept.	25.8	27.5	
Oct.	24.1	23.3	
Nov.	17.1	18.8	
Dec.	12.8		
Ann. Average	21.0		

From Louisiana Wildlife and Fisheries Commission, 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase II, Hydrology and Phase III, Sedimentology.

Table D.4-4 Water Quality Data in Calcasieu Lake[14]

Station	Yr	Mo	Day	Water Temp (°C)	Sal (ppt)	O_2 (ppm)	NO_3	NO_2	PO_4	Total P	Turbid (ft.)	Wind Dir	Wind Vel (knots)	Sea State (ft.)	% Cloud Cover	Tide Water Level (ft.)	Tide Stage
							..........μg-at/liter..........										
Station 12	67	12	4	15.4	19.9		73.50	2.55	0.55	1.18				0.6-1.0	10	0.6	High Rising
	68	1	15	7.3	0.0	8.5	4.17	2.02	0.23	0.35	0.4	NE	0-1	Calm	0	1.4	Low Falling
	68	2	30	15.1	4.2	10.0	17.51	0.53	0.43	0.92	0.0	NE	7-10	0.1-0.5		0.9	High Falling
	68	3	4	11.0	10.0		7.81	0.96	0.91	5.17	0.0			1.1-1.5		1.0	Mid Falling
	68	4	8	21.7	8.0	7.8	18.90	1.11	0.74	4.67		SSE	17-21	1.1-1.5		1.1	High Rising
	68	5	6	23.8	7.5	7.0	13.47	1.82	0.27	5.36		SE	22-27	0.6-1.0	0	1.1	High Standing
	68	6	11	33.1	6.0	5.0	6.72	1.66	0.51	2.83	2.4	SSE	7-10	0.1-0.5	75	1.3	Low Falling
	68	7	8	33.0	7.8	5.5	31.11	2.34	0.29	2.40	1.0	WSW	4-6	0.1-0.5		1.0	High Falling
	68	8	5	34.5	7.9	6.0	69.39	2.09	0.45	2.49	1.0	NNE	11-16	0.6-1.0	40	0.8	High Falling
	68	9	11	26.8	3.7	8.2	5.52	0.78	1.76	2.06	0.5	NE	7-10	0.6-1.0	40	1.2	High Standing
	68	10	8	22.9	14.3	4.5	8.23	2.10	5.31	6.80	0.7	E	4-6	0.6-1.0	40	0.9	Mid Rising
	68	11	6	20.4	20.4	9.0	7.73	1.99	0.74	2.74	0.8	E	7-10	0.1-0.5		1.2	High Falling
	68	12	5	13.1	3.4	9.0	36.32	2.17	1.00	3.54	0.4		0-1	Calm	0	1.5	Low Rising
	68	1	7	12.1	8.5	8.5	25.18	0.62	0.78	1.99	0.5	SSE	4-6	Calm	25	1.0	Low Falling
	68	2	4	14.6	7.2	10.5	12.00	1.05	2.16	5.17	0.8	SE	7-10	0.6-1.0	25		
	69	3	4	12.6	2.4	10.5	8.16	0.25	0.32	2.77	0.8	ENE	7-10	0.6-1.0	25		High Falling
	69	4	8	21.6	0.4	6.5	8.89	0.62	1.98	4.69	0.8	SE	7-10	0.6-1.0	25		High Falling
	69	5															
	69	6															
Station 13	67	12	4	13.1	19.0		23.10	0.26	0.55	1.45				0.6-1.0	10	0.6	High Rising
	68	1	15	6.4	0.0	8.7	6.68	0.76	0.56	0.95	0.4	NE	0-1	Calm	0	1.4	Low Falling
	68	2	30	16.6	10.2	10.7	7.76	0.54	0.65	0.69	0.0	NE	7-10	Calm		0.9	High Falling
	68	3	4	11.0	0.0		4.71	0.64	0.49	2.48	0.0			1.1-1.5		1.0	Mid Falling
	68	4	8	21.7	15.0	8.3	1.00	0.49	0.98	3.36		SSE	17-21	1.1-1.5		1.1	High Falling
	68	5	6	23.5	6.8	7.3	0.00	5.40	0.51	2.98		SE	22-27	0.6-1.0	0	1.1	High Standing
	68	6	11	33.4	8.3	7.2	2.82	0.31	0.17	2.23	2.3	SSE	7-10	0.1-0.5	50	1.1	High Standing
	68	7	8	33.3	4.1	6.2	62.07	1.35	0.60	2.62	1.1	W	4-6	Calm	10	1.2	High Falling
	68	8	5	35.0	12.1	6.5		0.88	0.43	7.08	1.0	NNE	11-16	0.6-1.0	40	0.8	High Falling
	68	9	3	26.5	17.0	9.0	0.98	0.70	0.90	1.76	0.7	SSE	4-6	0.6-1.0	25	1.1	High Standing
	68	10	8	22.9	12.8	6.2	7.54	2.85	1.00	3.09	0.9	E	4-6	0.6-1.0	40	0.9	Mid Rising
	68	11	6	19.7	15.7	10.0	3.69	2.00	0.87	3.40	0.7	E	7-10	0.1-0.5		1.2	High Falling
	68	12	5	11.8	16.5	9.3	20.12	0.96	0.47	3.09	0.8		0-1	Calm	10	1.5	Low Rising
	69	1	7	10.1	8.2	9.0	15.05	1.19	0.66	3.12	0.7	SSE	4-6	Calm	25	1.0	Low Falling
	69	2	4	12.8	11.7	10.2	1.64	0.11	1.31	3.50	0.6	NE	7-10	0.6-1.0	25		
	69	3	4	10.1	3.5	10.7	13.17	0.51	0.49	3.10	0.8	ENE	7-10	0.6-1.0	60		High Falling
	69	4	8	21.8	2.7	7.0	8.46	0.47	0.42	2.35	1.0	SE	7-10	0.6-1.0			High Falling
Station 14	67	12	4	13.4	23.9		12.60	0.65	0.50	1.05				0.6-1.0	10	0.6	High Rising
	68	1	15	6.9	10.0	9.0	10.71	1.97	0.40	0.56	0.4	NE	0-1	Calm	0	1.4	Low Falling
	68	2	30	15.0	1.2	11.0	8.91	0.40	0.43	1.03	0.0	NE	7-10	0.1-0.5		0.9	High Falling
	68	3	4	12.0	24.0		2.76	0.54	0.58	2.86	0.0			1.1-1.5		1.0	Mid Falling
	68	4	8	20.7	14.7	8.5	9.75	1.11	0.42	4.67		SSE	17-21	1.1-1.5		1.1	High Rising
	68	5	6	23.5	9.9	8.5	0.00	5.40	0.27	2.60		SE	22-27	0.6-1.0	0	1.1	High Standing
	68	6	11	34.0	19.4	7.0	1.84	0.49	0.44	2.56	1.5	SSE	7-10	0.1-0.5	50	1.2	High Standing
	68	7	8	33.7	10.8	7.9	6.03	0.85	0.47	1.92	1.3		0-1	Calm	10	1.2	High Rising
	68	8	5	35.0	25.6	6.0	2.91	0.28	0.61	2.53	0.2	NE	1-3	0.6-1.0	40	0.8	High Falling
	68	9	3	27.0	21.2	8.0	4.73	0.40	0.53	1.36	0.0	SSE	4-6	0.6-1.0	25	1.1	High Standing
	68	10	8	23.8	14.2	6.2	7.31	2.71	0.95	2.44	0.8	E	4-6	0.6-1.0	40	0.9	Mid Rising
	68	11	6	20.1	17.7	8.5	4.36	1.63	0.74	2.74	1.1	E	7-10	0.1-0.5		1.2	High Falling
	68	12	5	12.6	20.3	7.0	22.03	1.51	0.33	1.69	4.2	S	1-3	Calm	10	1.5	Low Rising
	69	1	7	10.1	9.0	9.0	13.61	0.62	0.37	0.02	2.0	SSE	4-6	Calm	25	1.0	Low Falling
	69	2	4	12.7	11.2	10.7	6.59	0.21	0.90	3.50	1.0	SE	7-10	0.6-1.0	25		
	69	3	4	10.1	7.4	11.5	12.59	0.74	0.29	0.34	1.0	ENE	7-10	0.6-1.0	60		High Falling
	69	4	8	21.8	7.2	7.7	8.65	0.43	0.81	3.47	1.2	SE	7-10	0.6-1.0			High Falling

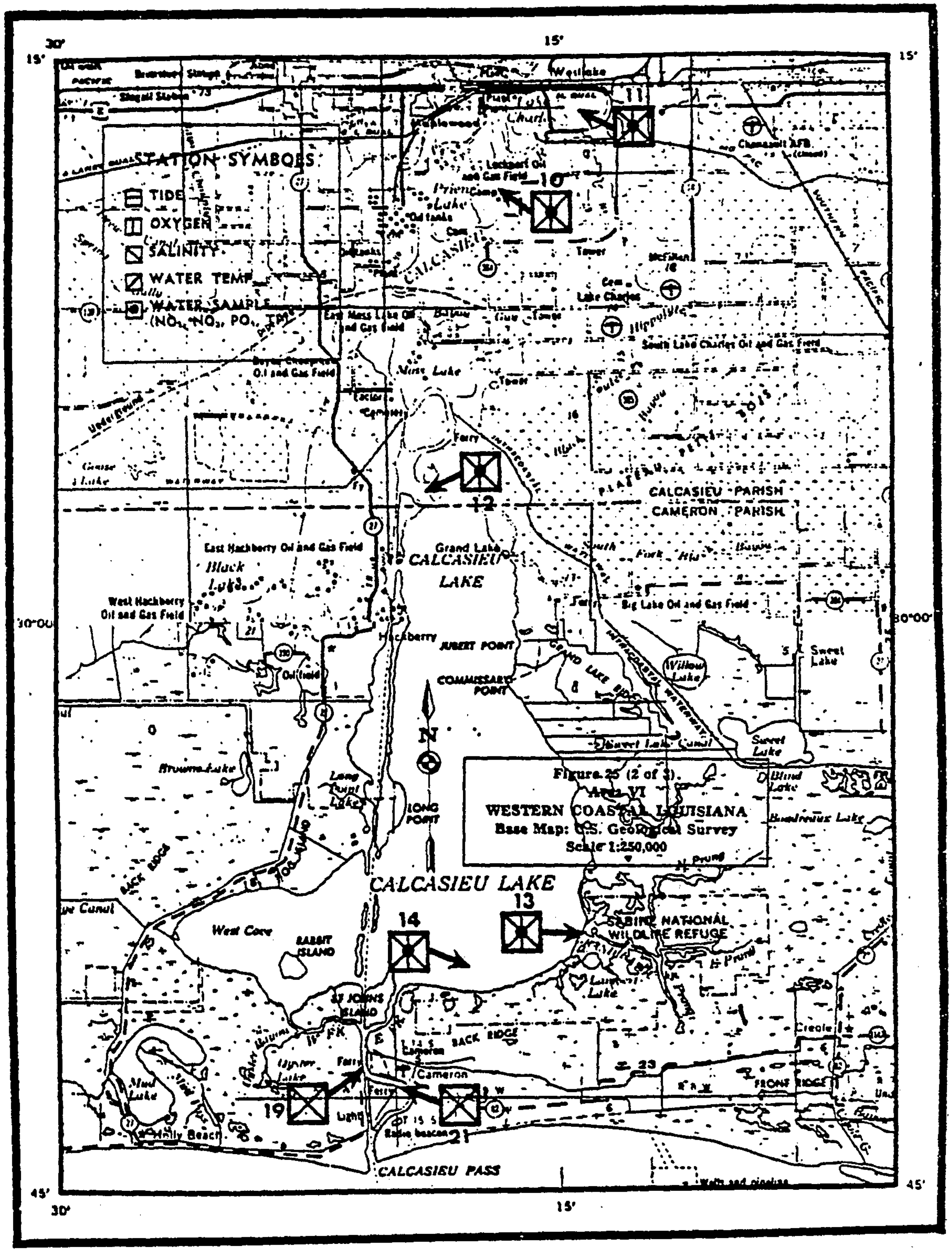

Figure D.4-2 Location of Water Quality Stations

Table D.4-5 Analyses of Samples Collected at Mile 40 on the Calcasieu River

October 1973 to September 1974

Date	Dis-solved Iron (FE) (UG/L)	Bicar-bonate (HCO3) (MG/L)	Alka-linity as CACO3 (MG/L)	Dis-solved Sulfate (SO4) (MG/L)	Dis-solved Nitrate (N) (MG/L)	Total Phos-phorus (P) (MG/L)	Total Nitrate (N) (MG/L)	Sus-pended Solids (MG/L)	Hard-ness (CA,MG) (MG/L)	Hard-ness (MG/L)	Non-car-bonate Hard-ness (MG/L)	Specific Conduct ance (Micro-mhos)	Salin-ity (ppt)	PH (Units)	Color (Plat-inum-Cobalt Units
June															
12	110	14	11	58	.10	.10	--	22	44	33	33	477	0.31	6.9	50
25	70	37	30	180	.08	.13	--	24	560		530	5490	3.51	7.4	50
July															
09	140	32	26	29	--	.07	.07	26	180		150	1560	1.00	6.9	30
Aug															
06	10	59	48	180	--	.12	.15	7	190		140	1300	0.83	6.9	30
20	90	19	16	74	--	.17	.09	5	110		94	4660	2.98	6.6	20
Sep															
04	60	56	46	310	--	.15	.10	16	1200		1200	8720	5.58	7.6	10
17	130	29	24	140	--	.14	.14	3	370		350	2730	1.75	7.2	70

Date	Turbid-ity (MG/L)	Dis-solved Oxygen (MG/L)	Bio-chem-ical Oxygen Demand (MG/L)	Imme-diate Coli-form (Col.per 100 ML)	Fecal Coli-form (Col. per 100 ML)	Total Organic Carbon (C) (MG/L)	Cya-nide (CN) (MG/L)	Phenols (UG/L)	Oil and Grease (MG/L)	Aldrin (UG/L)	Chlor-dane (UG/L)	DDD (UG/L)	DDE (UG/L)	DDT (UG/L)
June														
12	21	6.3	.2	1200	20	6.0	.01	0	2	.00	.0	.00	.00	.00
25	47	5.1	1.0	450	40	4.9	.00	3	1	.00	.0	.00	.00	.00
July														
09	30	4.4	>4.4	520	440	6.9	.00	4	1	.00	.0	.00	.00	.00
Aug														
06	50	4.5	.7	220	12	5.1	.00	0	1	.00	.0	.00	.00	.00
20	5	2.7	1.2	110	70	11.0	.00	8	2	--	--	--	--	--
Sep														
04	20	4.9	2.6	80	6	7.0	.00	2	--	.00	.0	.00	.00	.00
17	25	3.6	1.8	1900	92	10.0	.00	0	0	.00	.00	.00	.00	.00

Table D.4-5 (continued). Analyses of Samples Collected at Mile 40 on the Calcasieu River

Date	Di-eldrin (UG/L)	Endrin (UG/L)	Hepta-chlor (UG/L)	Hepta-chlor-Epoxide (UG/L)	Lindane (UG/L)	PCB (UG/L)	Tox-aphene UG/L)	Total Arsenic (AS) (UG/L)	Dis-solved Arsenic (AS) (UG/L)
June									
12	.00	.00	.00	.00	.00	.0	0	9	1
25	.00	.00	.00	.00	.00	.0	0	0	0
July									
09	.00	.00	.00	.00	.00	.0	0	0	1
Aug									
06	.00	<.01	.00	.00	.00	.0	0	1	1
20	--	--	--	--	--	--	--	2	1
Sep									
04	<.01	.00	.00	.00	.00	.0	0	2	2
17	.00	.00	.00	.00	.00	.0	0	1	1

Date	Total Cad-mium (CD) UG/L)	Dis-solved Cad-mium (CD) (UG/L)	Hexa-valent Chro-mium (CR6) (UG/L)	Total Lead (PB) (UG/L)	Dis-solved Lead (PB) UG/L)	Total Mercury (HG) (UG/L)	Dis-solved Mercury (HG) (UG/L)	Total Zinc (ZN) (UG/L)	Dis-solved Zinc (Zn) (UG/L)
June									
12	1	--	--	10	5	--	.0	20	10
25	8	3	0	7	7	--	.2	30	0
July									
09	22	12	0	8	0	--	.3	60	30
Aug									
06	0	1	0	0	0	.0	.0	40	20
20	1	0	0	4	0	.1	.1	20	0
Sep									
04	1	1	0	10	13	.0	.0	30	0
17	0	5	0	15	4	.3	.3	20	10

From U. S. Geological Survey, 1974. Water Resources Data for Louisiana

Table D.4-6 Analyses of Samples Collected at Calcasieu Pass at St. John's Island

October 1973 to September 1974

Date	Dis-solved Iron (FE) (UG/L)	Bicar-bonate CHCO31 (MG/L)	Alka-linity as CACO3 (MG/L)	Dis-solved Sulfate (504) (MG/L)	Dis-solved Nitrate (N) (MG/L)	Total Phos-phorus (P) (MG/L)	Total Nitrate (N) (MG/L)	Sus-pended Solids (MG/L)	Hard-ness (CA,MG) (MG/L)	Non-car-bonate Hard-ness (MG/L)	Specific Conduct-ance (MICRO-MHOS)	Salin-ity (ppt)	PH Units
June													
12	20	81	66	170	.08	.11	--	26	1300	1200	13000	8.32	8.2
25	30	74	61	290	.04	.18	--	151	1900	1800	17700	11.33	7.7
July													
09	--	107	88	160	--	.23	.02	--	3900	3800	27300	17.47	7.7
Aug													
06	40	84	69	100	--	.10	.09	29	3800	3700	31400	8.58	7.8
20	90	97	80	130	--	.09	.00	3	4400	4300	30600	19.58	7.6
Sep													
04	120	59	48	190	--	.19	.07	220	3500	3500	25200	16.13	7.6
17	70	85	75	240	--	.09	.10	62	3400	3300	25200	16.13	8.5

Date	Color (Plat-inum-cobalt Units)	Tur-bid-ity (MG/L)	Dis-solved Oxygen (MG/L)	Bio-Chemical Oxygen Demand (MG/L)	Imme-diate Coliform (Col.per 100 ML)	Fecal (Col.per 100ML)	Total Organic Carbon (C) (MG/L)	Cyanide (CN) (MG/L)	Phenols (UG/L)	Oil and Grease (MG/L)	Aldrin (UG/L)	Chlor-dane (UG/L)	DDD (UG/L)
June													
12	40	42	7.4	1.0	--	--	8.9	.00	0	2	.00	.00	.00
25	20	75	7.7	2.2	250	100	--	.00	0	1	.00	.00	.00
July													
09	20	20	7.4	6.0	18	0	5.8	--	1	--	--	--	--
Aug													
06	30	7	7.1	2.3	--	2	4.6	.00	0	5	.00	.00	.00
20	10	40	5.2	2.8	7	1	11.0	.00	2	2	.00	.00	.00
Sep													
04	20	75	7.5	4.0	0	0	--	.00	2	1	.00	.00	.00
17	30	40	6.8	>6.8	330	2	8.2	.00	0	0	.00	.00	.00

Table D.4-6 (continued) Analyses of Samples Collected at Calcasieu Pass at St. John's Island

Date	DDE (UG/L)	DDT (UG/L)	Dieldrin (UG/L)	Endrin (UG/L)	Heptachlor (UG/L)	Heptachlor Epoxide (UG/L)	Lindane (UG/L)	PCB (UG/L)	Toxaphene (UG/L)	Total Arsenic (AS) (UG/L)	Dissolved Arsenic (AS) (UG/L)	Total Cadmium (CD) (UG/L)
June												
12	.00	.00	.00	.00	.00	.00	.00	.0	0	0	3	3
25	.00	.00	.00	.00	.00	.00	.00	.0	0	11	0	9
July												
09	--	--	--	--	--	--	--	--	--	--	--	--
Aug												
06	.00	.00	.00	.00	.00	.00	.00	.0	0	1	1	0
20	.00	.00	.00	.00	.00	.00	.00	.0	0	2	0	0
Sep												
04	.00	.00	.00	.00	.00	.00	.00	.0	0	4	1	1
17	.00	.00	.00	.00	.00	.00	.00	.0	0	2	1	2

Date	Dissolved Cadmium (CD) (UG/L)	Hexavalent Chromium (CRS) (UG/L)	Total Lead (PB) (UG/L)	Dissolved Lead (PB) (UG/L)	Total Mercury (HG) (UG/L)	Dissolved Mercury (HG) (UG/L)	Total Zinc (ZN) (UG/L)	Dissolved Zinc (ZN) (UG/L)
June								
12	--	--	10	5	--	.2	140	10
25	3	0	18	3	--	.2	10	10
July								
09	--	--	--	--	--	--	--	--
Aug								
06	1	0	2	1	.1	.0	10	10
20	--	0	6	4	.1	.5	40	7
Sep								
04	5	0	3	0	.0	.0	50	30
17	3	0	11	12	.0	.0	40	20

From U. S. Geological Survey, 1974. Water Resources Data for Louisiana.

Table D.4-7 *In Situ* parameters measured in the Gulf Intracoastal Waterway during the period 23-28 March 1975+

Sample Station	Date	Depth (m)	Temp (°C)	DO (mg/l)	pH	Cond. (umho/cm)	Salinity (ppt)	ORP** (mv)	Sed. pH	Direction of Flow
12	3/25	4.2	21.0	8.52	7.50	195	0.12	+420	7.60	I
13	3/25	5.6	19.5	8.05	6.75	270	0.17	+820	7.30	E

** Oxidation-reduction potential

I = Indeterminate

+ See Figure 2-10 for Station location.

From U.S. Army Corps of Engineers, New Orleans, 1975. Draft Environmental Statement - Gulf Intracoastal Waterway Petit Anse, Tigre and Carlin Bayous; and Bayou Grosse Tete, Louisiana.

Table D.4-8 Analysis of water samples taken from the Gulf Intracoastal Waterway during the period 23-28 March 1975.+

Sample Station	Total COD (mg/l)	Dissolved COD (mg/l)	Total TKN (mg/l)	Dissolved TKN (mg/l)	NO_3 (mgN/l)	NO_3 (mgN/l)	Solluble Ortho P (mgP/l)	Tot. P (mgP/l)	Total P (mg/l)	Dissolved Organic Carbon (mg/l)	Grease & Oil (mg/l)	Tot. Susp. Solids (mg/l)	Volatile Susp. Solids (mg/l)
12	37.3	32.9	1.46	0.80	0.18	0.16	<0.01	0.29	36.0	36.0	19.2	211	206
13	33.0	33.0	1.84	0.89	<0.10	0.12	<0.01	0.24	29.0	29.0	<5.0	43	30

Sample Station	Tot. Zn (μg/l)	Sol. Zn (μg/l)	Tot. Cd (μg/l)	Sol. Cd (μg/l)	Tot. Cu (μg/l)	Sol. Cu (μg/l)	Tot. Cr (μg/l)	Sol. Cr (μg/l)	Tot. Ni (μg/l)	Sol. Ni (μg/l)	Tot. Pb (μg/l)	Sol. Pb (μg/l)	Tot. As (μg/l)	Sol. As (μg/l)	Tot. Hg (μg/l)	Sol. Hg (μg/l)
12	39	13	0.6	0.3	8	8	30	<0.5	54	26	8.7	3.7	63	63	13.4	13.4
13	235	13	0.6	<0.2	10	9	6	<0.5	91	18	2.0	1.0	60	60	9.9	9.9

+ See Figure 2-10 for Station Location

From U.S. Army Corps of Engineers, New Orleans, 1975. Draft Environmental Statement - Gulf Intracoastal Waterway Petit Anse, Tigre and Carlin Bayous; and Bayou Grosse Tete, Louisiana.

Table D. 4 - 9 Pesticide Analysis of Water Samples Taken from the Gulf Intracoastal Waterway during the Period 23-29 March 1975[+] (All concentrations expressed as µg/1)

	Station 12 East of Calcasieu R.	Station 13 Near Black Lake
Toxaphene	<50	<50
Lindane	55	51
Heptachlor	<1.0	<1.0
Heptachlor Epoxide	29	<1.0
Aldrin	<1.0	<1.0
Chlordane	830	10
Dieldrin	190	<2.0
Ethion	ND	ND
Methoxychlor	<1.0	<1.0
Endrin	<3.0	<3.0
O,P'-DDT	<3.0	3.2
P,P'-DDT	31	<3.0
O,P'-DDE	<1.0	<1.0
P,P'-DDE	<2.0	<2.0
O,P'-DDD	9.5	<2.0
P,P'-DDD	<3.0	<3.0

+See Figure 2-10 for Station Location

Stations 12 and 13 from Slotta, L.S. and Williams, 1974. Estuarine Impacts Related to Dredge Spoiling. In: Proceedings of the Sixth Dredging Seminar, Texas A & M University Center for Dredging Studies. Report No. eds 176: 20-37.

and

O'Neal, G. and Scerva, J. 1975. The Effects of Dredging on Water Quality, World Dredging and Marine Construction 7(14): 24-31.

Table D.4-10 Water Quality Data for Calcasieu Ship Channel Stations #7 and #8

	Station #7		Station #8	
Sample No.:	1	2	1	2
Date:	4/4/75	4/6/75	4/4/75	4/6/75
SOURCE	SURFACE WATER QUALITY			
Units	(ug/l)	(ug/l)	(ug/l)	(ug/l)
As	0	1	1	1
Cd	0	0	0	2
Cr	0	10	0	10
Cu	3	3	3	6
Pb	2	1	1	0
Hg	0.0	0.2	0.1	0.2
Ni	0	2	0	2
Zn	30	10	30	30
Phenols	6	6	15	8
Units	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Cn	0.00	0.00	0.00	0.00
COD	290	320	400	450
TKN	0.56	0.57	0.49	0.61
TVS	4	12	12	8
Oil and Grease	2	2	2	1

Table D.4-11 Water Quality Data for Calcasieu Ship Channel Stations #10 and #11

RESULTS OF FIELD SAMPLING SURVEY PESTICIDES IN WATER

	Parameter	Concentration µg/l
Station 10	2,4D	0.01
	Diazinon	0.02
Station 11	2,4D	0.01

RESULTS OF WATER QUALITY FIELD SAMPLING

	Temp. °C	pH	DO mg/l	COD mg/l	SS mg/l	VSS mg/l	TKN mg/l	TP mg/l	Oil and Grease mg/l;
Station 10	23.4	6.6	13.9	169	18	2	1.1	0.072	26.8
Station 11	24.6	6.8	7.0	684	22	3	2.2	0.052	<0.5

RESULTS OF WATER QUALITY FIELD SAMPLING HEAVY METALS*

	Hq g/l	Pb*** mg/l	Zn mg/l	As mg/l	Cd*** mg/l	Cu mg/l	Cr (Total) mg/l	Ni mg/l
Station 10	90	<0.10	0.055	<0.025	<0.05	<0.05	0.07	<0.10
Station 11	56	<0.10	0.063	<0.025	<0.05	<0.05	<0.05	<0.10

*Detection limits for Weston's equipment: Hg, 0.2 g/l; Pb and Ni, 0.1 mg/l; Zn and As, 0.025 mg/l; Cd, Cr, and Cu, 0.05 mg/l.

**Corps of Engineers Data, June 17, 1975.

***The listed sensitivities of 0.1 mg/l for lead (Pb) and 0.05 mg/l for cadmium (Cd) are above the proposed standards of 0.05 mg/l for lead and 0.01 mg/l for cadmium set by EPA due to lower detection limits of the instrumentation used (Perkins-Elmer Model 303 Atomic Absorption Unit).

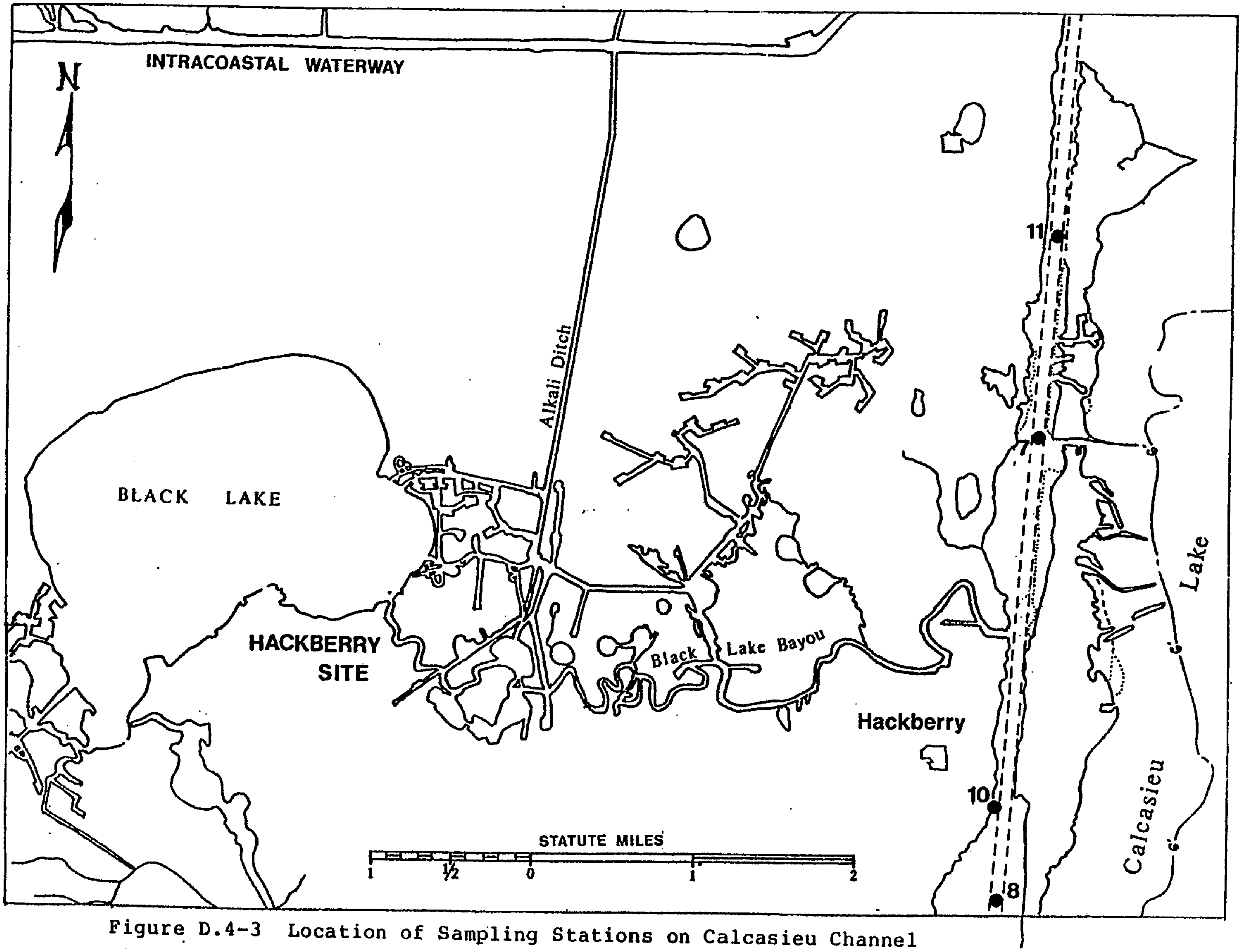

Figure D.4-3 Location of Sampling Stations on Calcasieu Channel

APPENDIX D.5

WATER QUALITY STANDARDS

Five tables comprise this appendix. Table D.5-1 presents State of Louisiana water quality criteria for the Calcasieu River and the Gulf Intracoastal Waterway. Table D.5-2 provides the maximum EPA-recommended levels for pesticides. Recommended limits for concentrations of selected sediment parameters are presented in Table D.5-3. The proposed EPA numerical criteria for water quality appropriate for freshwater aquatic life are included in Table D.5-4 and for marine life are included in Table D.5-5.

Table D.5-1 State of Louisiana Water Quality Criteria. Selected Segments of the Gulf Intracoastal Waterway and Adjacent Areas.[15] (Louisiana Stream Control Commission, 1973).

		CRITERIA						
Basin	Description	Cl^- (mg/l)	$SO_4^=$ *mg/l)	DO (mg/l)	pH	Total Coliform (#/100ml)	Temp (°C)	TDS (mg/l)
Calcasieu	Calcasieu River - Headwaters to Calcasieu River Salt Water Barrier (Above Lake Charles)	62	35	5.0	6.0 to 8.5	1	32	225
	Calcasieu River - Salt Water Barrier to Moss Lake (Tidal)	-	-	4.0	6.0 to 8.5	1	32	300
	Calcasieu River - Moss Lake to the Gulf of Mexico (Tidal)	-	-	4.0	6.0 to 8.5	4	35	-
	Intracoastal Water-way (East-West) - Sabine River to Calcasieu Lock (Tidal)	-	-	4.0	6.0 to 8.5	2	35	-

Table D.5-2 Maximum EPA Recommended Levels for Pesticides (All concentrations expressed as μg/l)

Toxaphene	10
Lindane	20
Heptachlor	10
Heptachlor Epoxide	-
Aldrin	10
Chlordane	40
Dieldrin	5.0
Ethion	-
Methoxychlor	5.0
Endrin	2.0
O,P'-DDT	2.0
P,P'-DDT	2.0
O,P'-DDE	-
P,P'-DDE	-
P,P'-DDD	6.0
P,P'-DDD	6.0

Maximum EPA Recommendations from

U.S. Environmental Protection Agency, 1973. Ocean Dumping: Final Regulations and Criteria. Federal Register 38(198): 286-28621

U.S. Environmental Protection Agency, 1973. Proposal Criteria for Water Quality, Vol. I., Washington, D.C.

U.S. Environmental Protection Agency, 1973. Proposed Water Quality Information, Vol. II, Washington, D.C.

Table D.5-3 Recommended Concentration Limits of Selected Sediment Parameters

Parameter	Units (dry weight basis)	Non-polluted mean	Non-polluted range	Polluted mean	Polluted range
COD[a]	mg/kg	21,000	2,000-48,000	177,000	39,000-395,000
TKN[a]	mg/kg	550	10-1,310	2,640	580-6,800
grease - oil[a]	mg/kg	560	110-1,310	7,150	1,380-32,100
sulfide[a]	mg/kg	140	30-150	1,700	100-3,700
COD[b]	mg/kg			50,000	
TKN[b]	mg/kg			1,000	
grease - oil[b]				1,500	
mercury[b]	mg/kg			1	
lead[b]	mg/kg			50	
zinc[b]	mg/kg			50	

a) O'Neal, G. & J. Scerva. "The Effects of Dredging on Water Quality", World Dredging & Marine Construction, 7 (14) pp. 24-31. 1971.

b) Slotta, L.S. & K.J. Williamson. "Estuarine Impacts Related to Dredge Spoiling", proceedings of the 6th Dredging Seminar, Texas A & M University.

Table D.5-4 Proposed EPA numerical criteria for water quality (freshwater aquatic life).

Parameter	μg/l
Cadmium	30 (hardness > 100 mg/l) 4 (" < 100 mg/l)
Chromium	50
Copper	1/10 LC50
Lead	30
Mercury	0.2
Nickel	1/50 LC50
Zinc	5/1000 LC50
pH	6-9
Ammonia	1/20 LC50 (20 μg/l)
Sulfides	2
Suspended & settleable solids	80 mg/l
Turbidity and light penetration	10% change in compensation pt.
Color	10% change in compensation pt.
Oils	1. None visible on surface 2. 1000 mg/kg Hexane extractable substances in sediments 3. 1/20 LC50
Phenols	1/20 LC50 (0.1 mg/l)
Cyanides	1/20 LC50 (.005 mg/l)
PCB	0.002
Aldrin	0.01
DDT	0.002
Dieldrin	0.005
Chlordane	0.04
Endrin	0.002
Heptachlor	0.01
Lindane	0.02
Toxaphene	0.01
Diazinon	0.009
Malathion	0.008
Parathion	0.001
DO	4.0 mg/l (>31°C)

Table D.5-5 Proposed EPA Numerical Criteria for Water Quality, Marine Water Constituents (aquatic life)

Parameter	µg/l
Arsenic	50
Cadmium	10
Chromium	100
Copper	50
Lead	50
Mercury	1.0
Nickel	100
Zinc	100
Cyanides	10
Oil and Grease	a. Not detectable as a visible film, sheen, discoloration of the surface, or by odor. b. Does not cause tainting of fish or invertebrates or damage to biota. c. Does not form an oil deposit on the shores or bottom of the receiving body of water.
Aldrin	5.5
DDT	0.6
Dieldrin	5.5
Endrin	0.6
Heptachlor	8
Lindane	5
Toxaphene	0.010
pH	6.5 - 8.5
Ammonia	400
Hydrogen Sulfide	10
Dissolved Oxygen	6.0 mg/l
Phosphorus	0.1

Source: "Proposed Criteria for Water Quality," Vol. 1, U.S. Environmental Protection Agency, 1973.

APPENDIX D.6

BOTTOM SEDIMENT DATA

This appendix consists of eight tables which contain data pertaining to bottom sediments taken from the Gulf Intracoastal Waterway. Table D.6-1 contains the results of the chemical analysis of such samples for Station #12 on the Intracoastal Waterway. The results of pesticide analysis of bottom sediment at the same station are provided in Table D.6-2. Chemical analysis of a standard elutriate* derived from the sediment and the water samples taken at the same station are presented in Table D.6-3. Results of a pesticide analysis for the standard elutriate are given in Table D.6-4. The location of Station #12 is indicated in Figure D.2-1.

Tables D.6-5 and D.6-6 contain sediment data from the Caslcasieu Ship Channel for Stations 7, 8, 10, and 11 as shown in Figure D.4-3. The results of standard elutriate tests are shown in Tables D.6-7 and D.6-8 for the same stations.

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*Standard elutriate is the supernatant resulting from the vigorous 30-minute shaking of one part of bottom sediment with four parts water (on a volumetric basis) collected from the same sample site, followed by a one-hour settling time and appropriate 0.45 μm filtration.

Table D.6 - 1. Analysis of sediment samples taken from the Gulf Intracoastal Waterway During the period 23-29 March 1975.

Sample Station	Percent Water (%)	% Coarser Than Sand	% Sand	% Finer Than Sand	COD (mg/kg)	TKN (mg/kg)	Grease & Oil (mg/kg)	H_2S (mg/kg)
12	14	0	90	10	8,600	1,200	3,100	1.65

Sample Station	Total Zn (mg/kg)	Total Cd (mg/kg)	Total Cu (mg/kg)	Total Cr (mg/kg)	Total Ni (mg/kg)	Total Pb (mg/kg)	Total As (mg/kg)	Total Hg (mg/kg)
12	22	<2	10	7	12	10	15.4	3.1

Table D.6-2 Pesticide analysis of sediment samples taken from the Gulf Intracoastal Waterway during the period 23-29 March 1975. (All concentrations expressed as ug/l).

Sample Station	Toxa-phene	Lin-dane	Hepta-chlor	Hepta-chlor Epoxide	Aldrin	Chlor-dane	Diel-drin	Ethion	Methoxy-chlor	Endrin	O,P' -DDT	P,P' -DDT
12	<5.0	1.1	<0.10	0.50	<0.10	44	3.5	ND*	0.86	<0.30	<0.30	<0.30

Sample Station	O,P' -DDE	O,P' -DDE	O,P' -DDT	O,P' -DDD
12	<0.20	<0.30	<0.10	<0.20

*Not Detectable

Table D.6-3 Analysis of standard elutriate of sediment samples taken from the Gulf Intracoastal Waterway during the period 23-28 March 1975.

Sample Station	COD (mg/l)	TKN (mgN/l)	Soluble Ortho P (mgP/l)	Dissolved Organic Carbon (mg/l)
12	509	6.42	0.02	17.1

Sample Station	Sol. Zn (μg/l)	Sol. Cd (μg/l)	Sol. Cu (μg/l)	Sol. Cr (μg/l)	Sol. Ni (μg/l)	Sol. Pb (μg/l)	Sol. As (μg/l)	Sol. Hg (μg/l)
12	7.7	1.2	15	<0.5	71	1.0	70	15.0

Table D.6-4 Pesticide analysis of standard elutriate of sediment samples taken from the Gulf Intracoastal Waterway during the period 23-29 March 1975. (All concentrations expressed at ug/l).

Sample Station	Toxa-phene	Lin-dane	Hepta-chlor	Hepta-chlor Epoxide	Aldrin	Chlor-dane	Diel-drin	Ethion	Methoxy-chlor	Endrin	O,P' -DDT	O,P' -DDT
12	<50	<1.0	<1.0	<1.0	<1.0	12	3.5	ND*	<1.0	3.0	<3.0	<3.0

Sample Station	O,P' -DDE	O,P' -DDE	O,P' -DDD	O,P' -DDD
12	<2.0	<3.0	<4.0	<2.0

*Not Detectable.

Table D.6-5 Sediment Data for Calcasieu Ship Channel for Stations #7 and #8

Location: Calcasieu River at Hackberry	Station #7		Station #8	
Sample No.:	1	2	1	2
Date:	4/4/75	4/6/75	4/4/75	4/6/75
Units	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
As	>8	>8	>7	>9
Cd	>4	1	2	<1
Cr	18	15	12	13
Cu	23	16	21	15
Pb	30	30	30	20
Hg	0.10	0.14	0.09	0.10
Ni	15	10	15	10
Zn	56	53	54	53
Phenols	-	-	-	-
Units	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Cn	0	0	0	0
COD	>59,000	>60,000	45,000	>57,000
TKN	>2,300	>2,300	>1,900	>2,300
TVS	>81,900	>86,300	73,600	>81,500
Oil and Grease	<1	1	<1	1

Table D.6-6 Sediment Data for Calcasieu Ship Channel Stations #10 and #11

RESULTS OF FIELD SAMPLING SEDIMENTS

	COD mg/kg	TS % Solids	TVS % Solids-Dry Weight	TKN mg/kg	Oil mg/kg
Station 10	16,919	32.0	3.5	366	100
Station 11	16,945	34.0	3.7	522	175

RESULTS OF FIELD SAMPLING HEAVY METALS IN SEDIMENTS

	Hg mg/kg	Pb mg/kg	Zn mg/kg	As mg/kg	Cd mg/kg	Cu mg/kg	Cr (Total) mg/kg	Ni mg/kg
Station 10	1.11	10.0	48.0	1.02	2.0	5.0	11.0	12.0
Station 11	0.070	10.0	38.0	0.97	1.0	5.0	9.0	8.0

RESULTS OF FIELD SAMPLING SURVEY PESTICIDES IN SEDIMENTS

	Parameter	Concentration μg/kg
Station 10	DDD	1.3
	Dieldrin	0.9
	PCB	3
Station 11	DDD	1.7
	Dieldrin	0.8
	PCB	4

Table D.6-7 Standard Elutriate Data for Calcasieu Ship Channel Stations #7 and #8

	Station #7		Station #8	
Sample No.:	1	2	1	2
Date:	4/4/75	4/6/75	4/4/75	4/6/75
Units	(ug/l)	(ug/l)	(ug/l)	(ug/l)
As	3	6	6	2
Cd	0	0	0	0
Cr	10	10	10	10
Cu	1	3	2	2
Pb	0	0	0	0
Hg	0.0	0.0	0.0	0.1
Ni	2	1	0	2
Zn	20	30	30	30
Phenols	4	9	15	8
Units	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Cn	0.00	0.00	0.00	0.00
COD	500	520	250	410
TKN	3.6	4.6	3.2	2.4
TVS	-	-	-	-
Oil and Grease	-	-	-	-

Table D.6-8 Standard Elutriate Data for Calcasieu Ship Channel Stations #10 and #11

RESULTS OF FIELD SAMPLING ELUTRIATE TESTS
INLAND STATIONS

	Hg $\mu g/l$	Pb mg/l	Zn mg/l	As mg/l	Cd mg/l	Cu mg/l	Cr (Total) mg/l	Ni mg/l
Station 10	>0.20	0.20	0.060	<0.025	<0.05	<0.05	<0.10	<0.05
Station 11	0.45	0.25	0.115	<0.025	<0.05	<0.05	0.19	0.08

APPENDIX D.7

WEST HACKBERRY WATER SUPPLY AND BRINE DISPOSAL DISCUSSIONS

The following appendix contains discussions principally concerned with water supply and brine disposal questions in the West Hackberry Salt Dome area. The sources of these discussions were

Charles G. Smith
Senior Research Associate
Institute for Environmental Studies
Louisiana State University
Baton Rouge, Louisiana

and

Bill R. Hise, Ph.D.
Professor
School of Petroleum Engineering
Louisiana State University
Baton Rouge, Louisiana

D.7-1 Brine Disposal Reservoirs at West Hackberry Salt Dome (by Charles Smith)

The area south of West Hackberry dome is the proposed location for brine disposal wells. This area is nearly devoid of exploratory wells. I evaluated logs of the following wells, 3 of which are in West Hackberry field (see Figure 1).

1.	Texaco, Burton #1	Sec. 4 - 13S - 10W	TD 15700
2.	Texaco, Burton #2	Sec. 5 - 13S - 10W	13071
3.	Texaco, Burton #3	Sec. 4 - 13S - 10W	13520
4.	Texaco, Miami BR#1	Sec. 25 - 13S - 11W	12500
5.	Texaco, Miami - Starks #1	Sec. 32 - 13S - 11W	10300
6.	Hunt, State Lease 2397,#1	13S - 9W	11001

No other wells exist in T13S, R10 and 11W.

Because the wells are few and widely spaced correlations of major sand units was not successful. Probably these reservoirs are continuous for several miles east and west (analogous to sands at Chacahoula dome). In the north-south direction these sands are probably less extensive due to salt stru· ·res and associated major east-west trending faults.

Massive sands (50 feet or thicker) were inventoried for wells numbered 1 and 4 in the above list. There wells are presumed to be representative of the geologic section in which brine disposal wells will be completed.

In each well 6 sands 100 feet thick or thicker were present. In well 1 24% of the section between 3000 feet and 8200 feet (bottom of sand section) or a total of 1270 feet was massive sand beds (50 feet or thicker). In well 4 18% or 1100 feet of the interval between 3000 feet and 9000 feet (bottom of sand section) was massive sands.

The sands slope southward approximately 1000'/mile at a depth of 9000' for approximately 6 miles south of the dome. There the slope begins to reverse due to complex positive structures in the vicinity of East Mud Lake field.

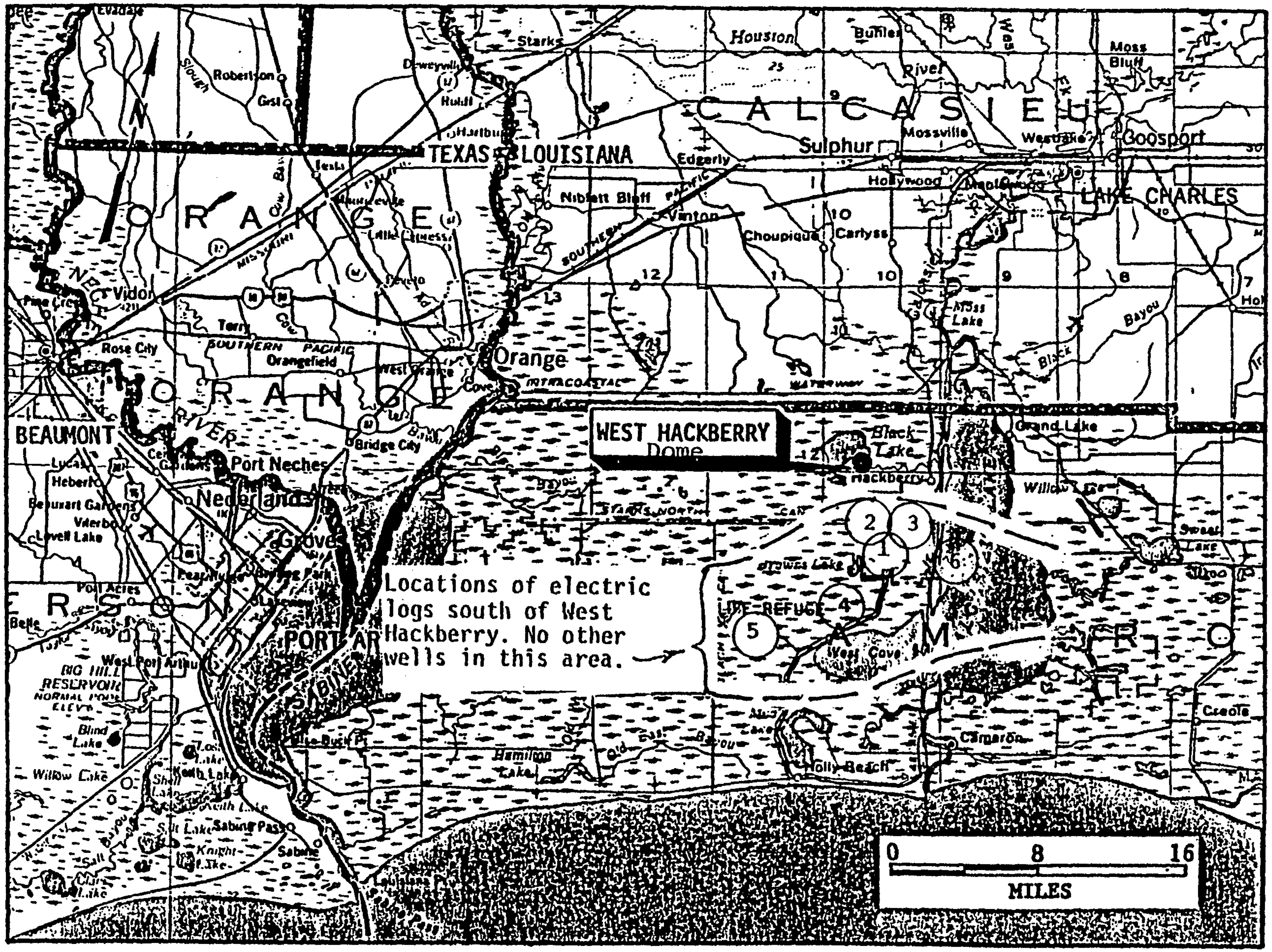


Figure 1 Location Map - West Hackberry Dome.

D.7-2 Geohydrology of West Hackberry (by Charles G. Smith)

West Hackberry - Recharge Source of Chicot Aquifer

The major recharge for the Chicot aquifer occurs at the outcrop, more than 30 miles north of West Hackberry dome (Jones et. al., 1954) (see pl e 4). The Chicot aquifer is not recharged from the surface in the West Hackberry area. Where pumping tests were performed the Chicot responded as a confined aquifer, i. e. separate from surface recharged sources. Plate 2 of Harder, et.al., (1967) shows 100's of feet of impermeable clay overlying the Chicot near West Hackberry.

A recharge area shown at West Hackberry in Plate 13* of Jones et.al. (1954) is not an area of surface recharge. The authors explain:

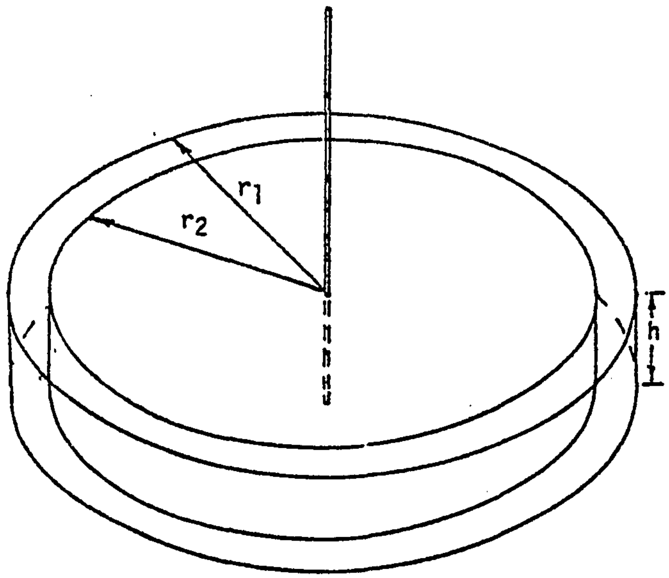
> "Faulting joins aquifers that are heavily drawn upon to aquifers that are tapped by few wells and thus enables flow from one to the other. An example of this is indicated on the map of the greater Lake Charles area (pl. 13) in the vicinity of the Hackberry dome at the northern end of Calcasieu Lake. The thickness of the clay that overlies the principal aquifer in this area (pl.2) is so great that recharge from Calcasieu Lake does not appear likely, but salt-water encroachment from upthrown aquifers probably is not taking place (pl.8)."

Pumping and Salt Water Encroachment in Chicot Aquifer

If a ground-water supply is developed from a fresh-water sand in the Chicot aquifer the salt-water/fresh-water interface will move toward the pumping center. If the interface is 1 mile from the center of pumping and water moves with equal ease from all directions around the pumping center the salt-water interface will move 135 feet during the first pumping cycle.

* See page D-49.

In succeeding cycles the interface will move only slightly further each time. If the interface is originally 5 miles from the pumping center the interface will move only 5 feet during the first cycle. This assumes the pumped volume is 2.888×10^8 cu. ft. (10,000 gpm for 150 days), the aquifer is 200 feet thick and 33% porous. This approach simply subtracts the required (or pumped) volume of water from the volume of water present in a cyclinder of aquifer of given radius, height and porosity and solves for the new radius required for the remaining volume of water (Fig. 1). The difference of the two radii is the amount of movement of the salt-water interface caused by pumping.



h = thickness of aquifer
r_1= distance from pumping center to salt water interface
r_2= distance from pumping center to salt water after pumping given volume
r_1-r_2= amount of movement of salt water interface toward pumping center

Imaginary Cylinder of Aquifer

The existing rate of advance of the salt-water in the West Hackberry area must be considered and added effects caused by future pumping operations. Also, any salt water advance caused by a new ground-water supply at West Hackberry should be considered as a permanent change in the local position of fresh and saline ground water.

It is likely that developing a water supply from the brackish or saline zones of the Chicot aquifer (e.g., the salaquifer between 350 and 525 feet in well 12, plate 8, section A-A', Bull. 30)*would actually improve conditions in the aquifer. Pumping saline water could slow or even reverse salt-water encroachment locally although the amount of change might be negligible (note the amount of salt-water movement resulting from fresh water offtake calculated above.)

Harder, A. H., Chabot Kilburn, H. M. Whitman, and S. M. Rogers, 1967
Effects of ground-water withdrawals on water levels and salt-water encroachment in southwestern Louisiana: Louisiana Department of Conservati and Department of Public Works, U.S. Geological Survey Water Resources Bulletin No. 10, 56 p.

Jones, P. H., A. N. Turcan, Jr., and H. E. Skibitzke, 1954
Geology and ground-water resources of southwestern Louisiana: Louisiana Department of Conservation, Geological Survey Bulletin 30, 285 p.

* See pages D-51 to D-53.

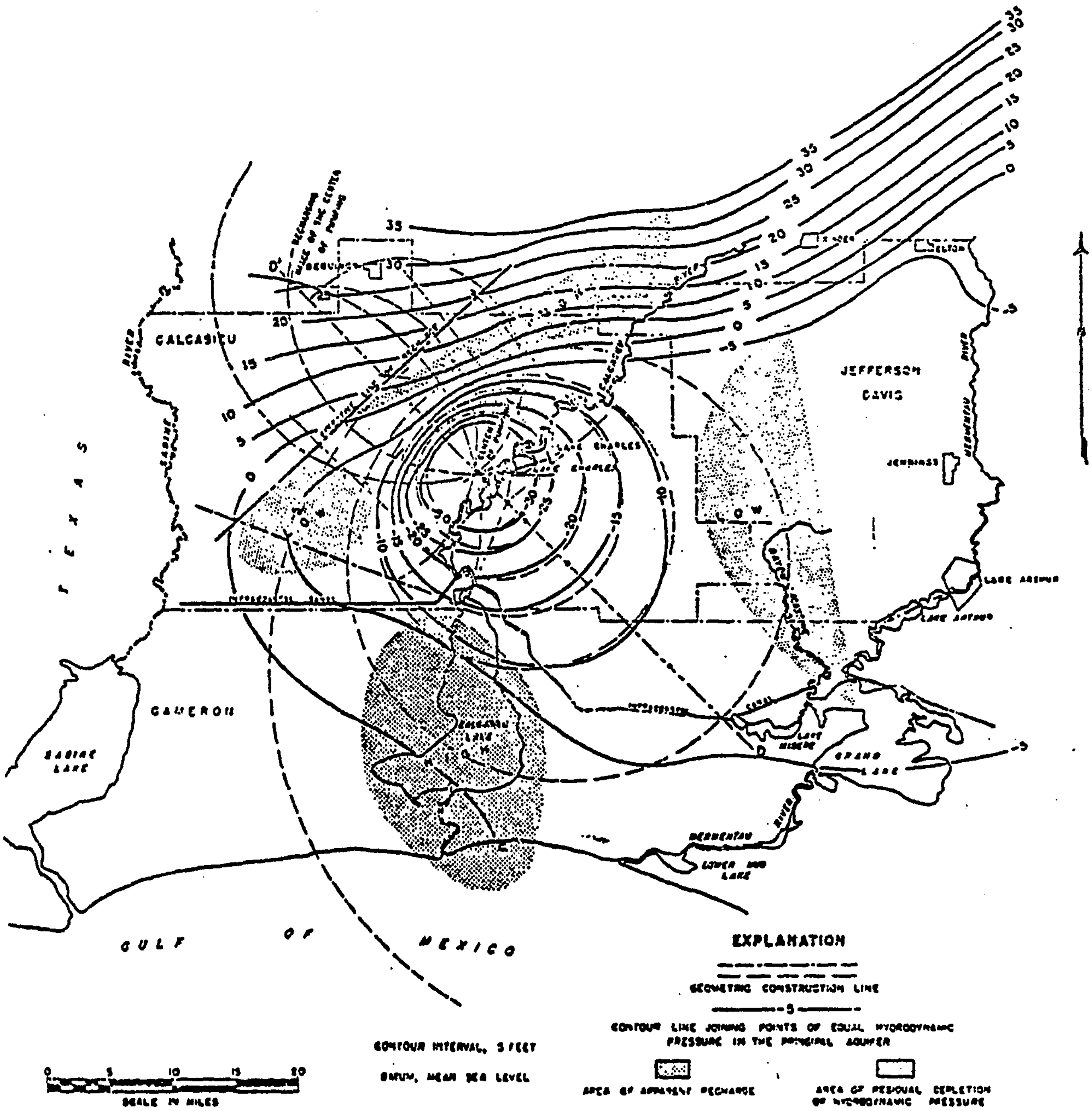
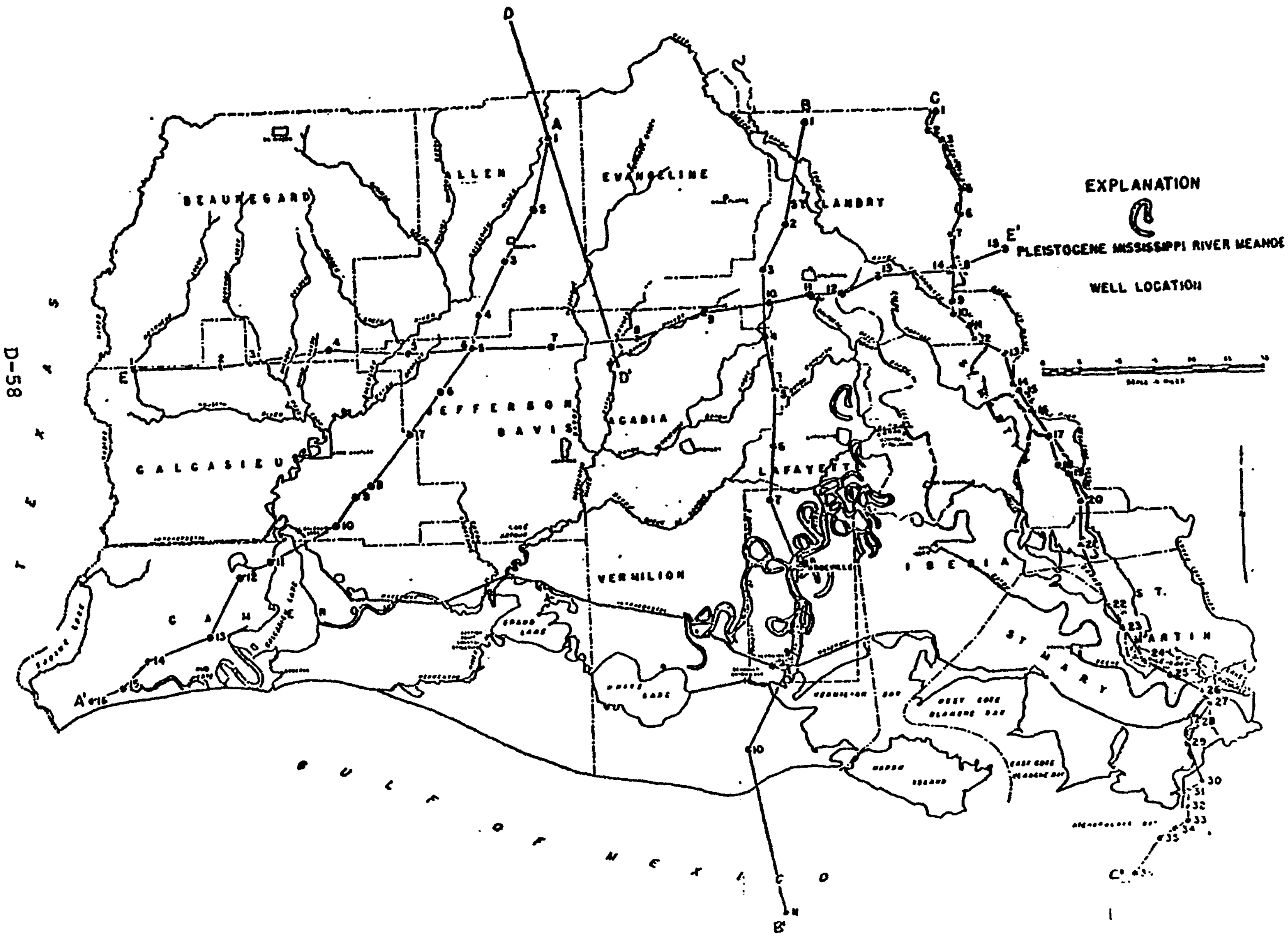


Plate 13, La. Dept. Cons. Geol. Bull. No.

ANALYSIS OF PIEZOMETRIC CONDITIONS IN THE CHICOT RESERVOIR IN THE GREATER LAKE CHARLES IN MARCH 1951


EXPLANATION
PLEISTOCENE MISSISSIPPI RIVER MEANDE
WELL LOCATION
BEAUREGARD
ALLEN
EVANGELINE
ST. LANDRY
CALCASIEU
JEFFERSON DAVIS
ACADIA
LAFAYETTE
VERMILION
IBERIA
ST. MARTIN
ST. MARY
TEXAS
GULF OF MEXICO
A
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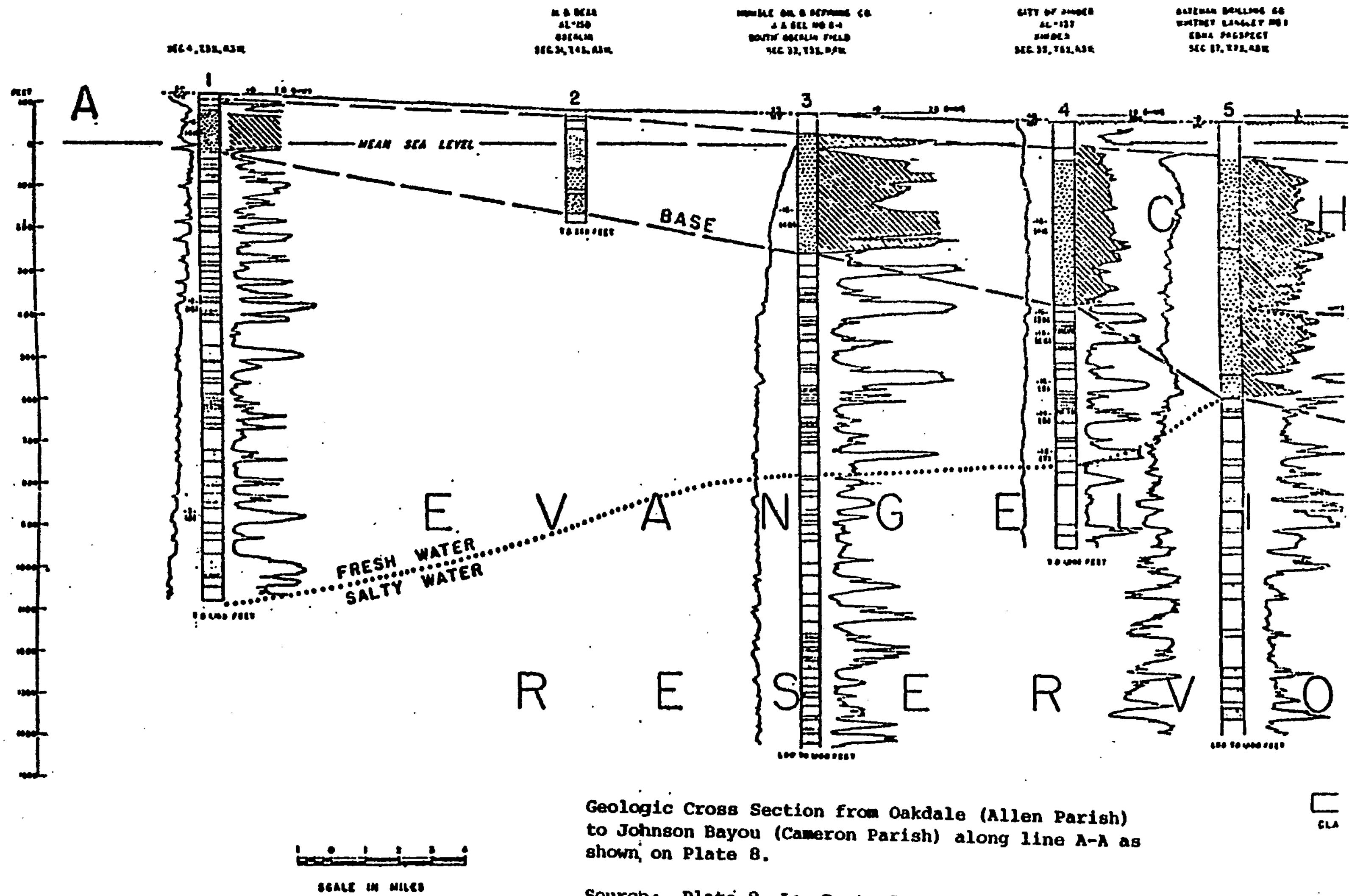
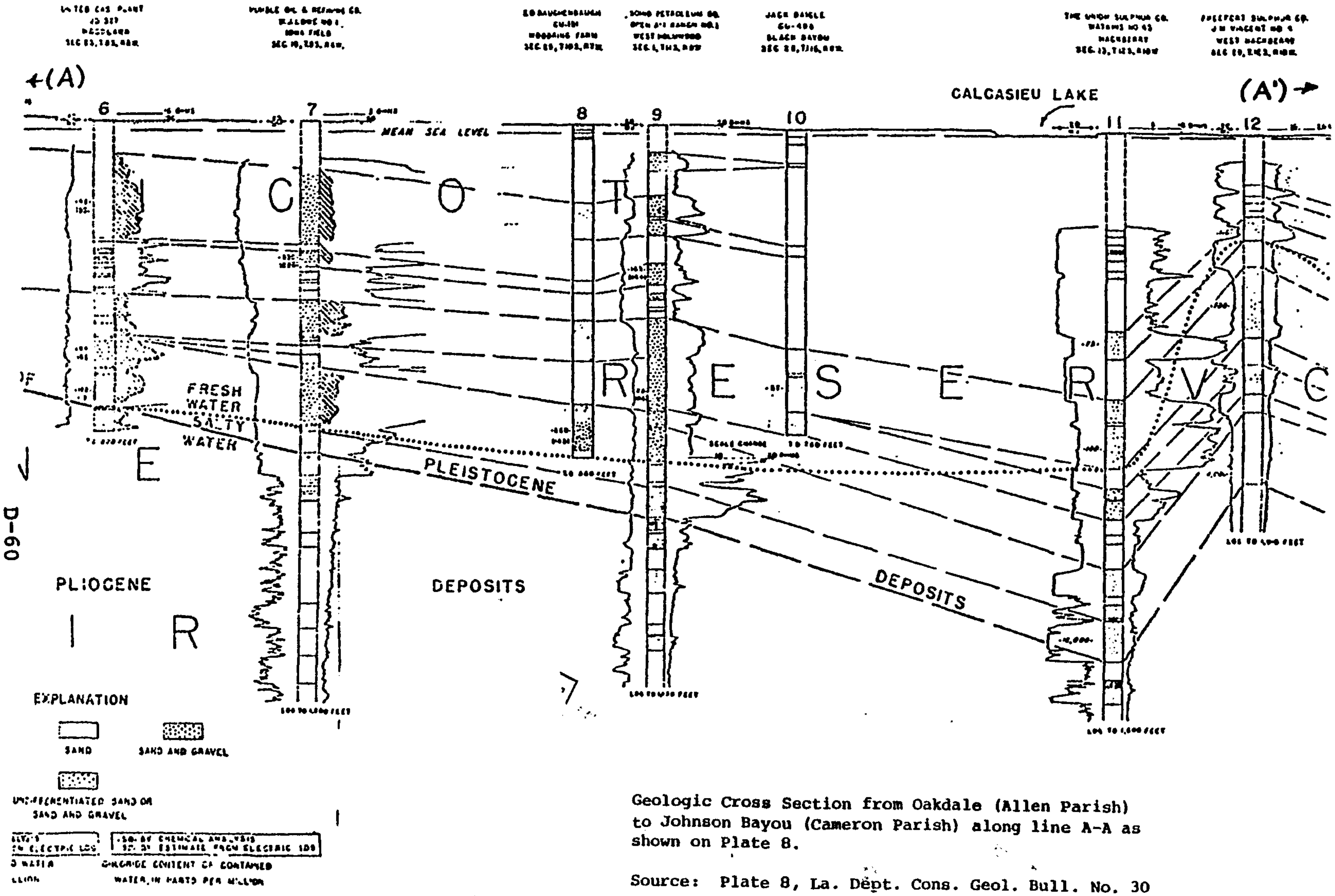


Geologic Cross Section from Oakdale (Allen Parish) to Johnson Bayou (Cameron Parish) along line A-A as shown on Plate 8.

Source: Plate 8, La. Dept. Cons. Geol. Bull. No. 30

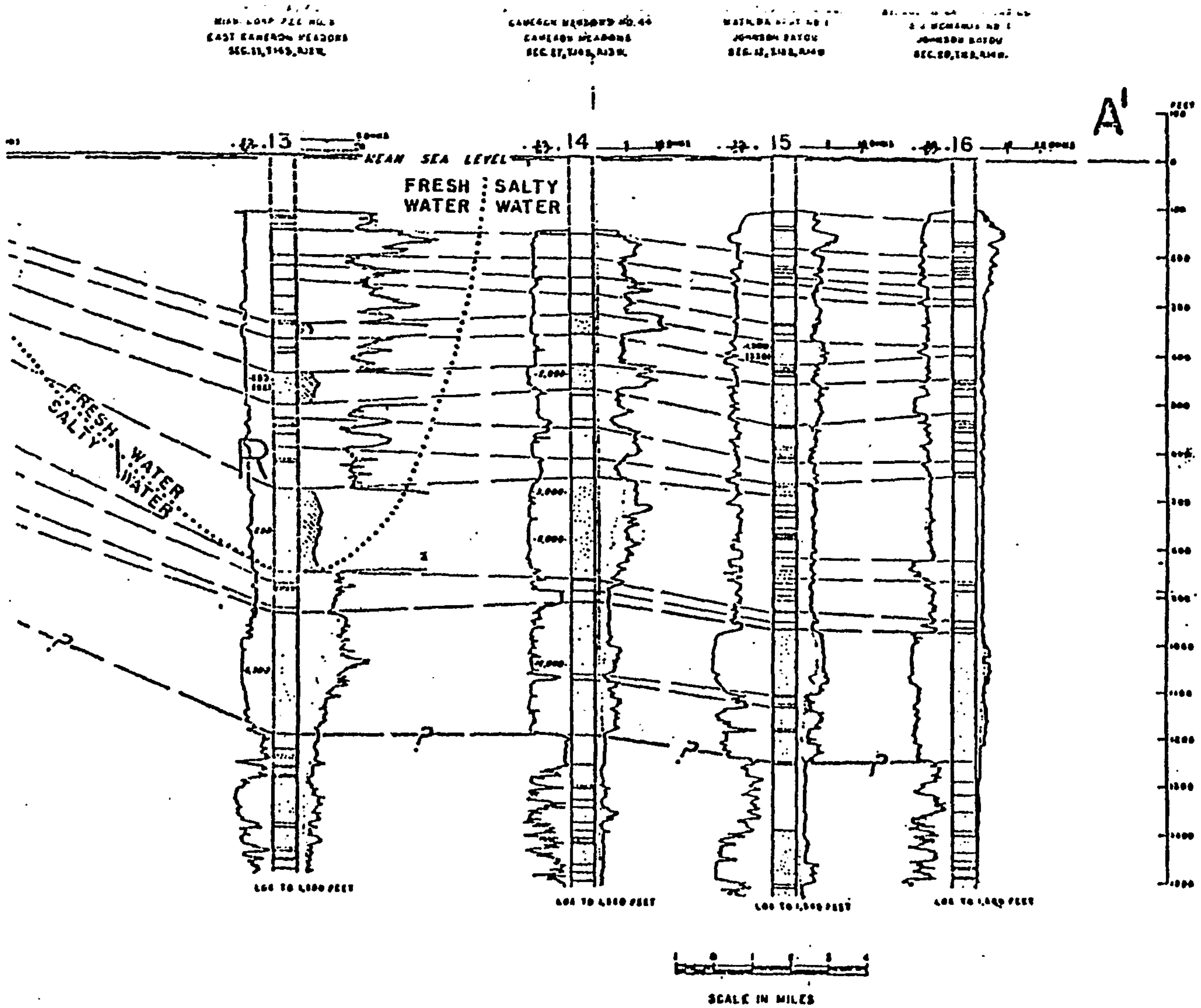
Part 1 of 3

D-60



Geologic Cross Section from Oakdale (Allen Parish) to Johnson Bayou (Cameron Parish) along line A-A as shown on Plate 8.

Source: Plate 8, La. Dept. Cons. Geol. Bull. No. 30



Geologic Cross Section from Oakdale (Allen Parish) to Johnson Bayou (Cameron Parish) along line A-A as shown on Plate 8.

Source: Plate 8, La. Dept. Cons. Geol. Bull. No. 30

D.7-3 Potential Problems Involved in Brine Injection at West Hackberry (by Charles G. Smith)

A question has been raised regarding the possibility of chemical or biological reactions occurring during brine injection at West Hackberry which would clog the well or reservoir sediments and reduce brine disposal efficiency. A complete answer cannot be given in the absence of a chemical comparison of the injected brine and the native groundwater. Presently neither of these components have been analyzed.

Nevertheless, a partial list of possible problems and potential solutions is appropriate.

Reservoir permeability reduction by clay swelling. Donaldson (1972) and Hower and others (1972) outline the problem of clay hydration and permeability reduction during subsurface injection operations. The concentration of brine anticipated for injection at W. Hackberry may be sufficiently high to prevent clay hydration. The use of zirconium chloride to pretreat the aquifer has successfully reduced the adverse effects of clay swelling (Donaldson, 1972).

Bacteria in injection stream. Clogging of injection well screens by organic matter, including algae, is a potential problem. Control procedures are outlined for various organisms by Ehrlich (1972) and Ostroff (1965). Chlorine, hypochlorite and formaldehyde are mentioned as commonly used disinfectants in water and waste injection systems.

Scale. Mineral precipitation in pipelines, well screens, and on the reservoir face may occur during brine injection operations (Donaldson, 1972; Barnes, 1972). Phosphates may be added to the system to control these scale deposits.

Insoluable Residue. Ostroff (1965) describes filtration systems necessary to remove insoluable minerals and sediment from solutions prior to injection. Sedimentation and filtration may be required at West Hackberry, due to sediment in the source water (from Black Lake) or because of insoluable minerals in the produced brine.

References for D.7-3

- Barnes, Ivan, Water-Mineral Reactions Related to Potential Fluid-Injection Problems, in T. D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 294-297.

- Donaldson, Erle C., 1972, Injection Wells and Operations Today, in T. D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 24-46.

Ehrlich, Garry G., Role of Biota in Underground Waste Injection and Storage, in T. D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 298-307.

Hower, W. F., R. M. Lasater, and R. G. Mihram, Compatibility of Injection Fluids with Reservoir Components, in T. D. Cook, ed., Underground Waste Management and Environmental Implications: Am. Assoc. Petroleum Geologists Mem. 18, p. 287-293.

- Ostroff, A. G., 1965, Introduction to Oilfield Water Technology; Englewood Cliffs, N. J., Prentice-Hall, Inc. 412 p.

D.7-4 Reservoir Mechanics Analysis in Brine Disposal (by Bill R. Hise)

The analysis of the subsurface pressure involved in the injection of brine through wells into subsurface aquifers is needed to predict when that pressure may approach the fracture pressure. If brine injection is continued when the subsurface pressure approaches or exceeds the fracture pressure the brine may escape the disposal aquifer and contaminate nearby fresh water aquifers.

The analysis of the pressures involved in brine disposal involves two considerations. The first is the total brine storage capacity of the disposal aquifer neglecting any pressure build up around the disposal wells during injection. The calculation of the maximum amount of brine which can be stored in disposal aquifer(s) before reaching fracture pressure can be made using the following equation:

$$Q = \frac{l \times w \times h \times \phi \times C_e \times \Delta p}{5.61} \qquad (1)$$

where:

Q = Brine Disposal Capacity ~ Bbls

l = Length of disposal aquifer(s) - feet

w = Width of disposal aquifer(s) - feet

h = Thickness of disposal aquifer(s) - feet

ϕ = Porosity

C_e = System compressibility ~ vol/vol/psi

Δp = Allowable aquifer pressure increase ~ psi

5.61 = Conversion constant - ft^3 to Bbls.

Equation (1) yields the theoretical maximum brine storage capacity for a linear model of any dimensions. In order to investigate the problems associated with injecting brine through wells into a reservoir, it is more convenient to sub-divide the total linear volume of the disposal aquifer into individual cylindrical reservoirs and prorate the amount of brine to be injected into each one. The radius of the individual cylindrical reservoirs can be derived from the length and width of the linear system. The reservoir thickness for the cylindrical reservoirs can be adjusted to force the total volume of the cylindrical reservoirs to equal the total volume of the linear disposal system.

The problem posed by injecting the disposal brine through wells is the pressure build up at the injection well due to radial flow from the well into the reservoir. This build up is in addition to the increase in average reservoir pressure which can be calculated from the cylindrical equivalent of equation (1). In practice, injection must cease when the well bore pressure reaches the fracture pressure even though the average pressure in the reservoir may still be below fracture pressure.

There are two phases in the analysis of the pressure build-up at the well bore during injection. First, when injection is started at a constant rate a transient pressure distribution is set up in the reservoir and the well bore pressure begins increasing. The character and magnitude of this increase can be calculated from the following equation:

$$p_w = p_i + \frac{qu}{7.08\ kh} \ln\left[\frac{14.22\ kt}{uC_e\ \phi\ r_w^2}\right] \qquad (2)$$

where:

p_w = Well bore pressure, psig

p_i = Reservoir pressure, psig

q = Flow rate, Bbls/Day

u = Brine viscosity, cps

k = Permeability, darcys

h = Thickness, feet

t = Time, days

C_e = System compressibility ∿ vol/vol/psi

ϕ = Porosity

r_w = Well bore radius, feet

The relationship shown as Equation (2) sets forth the behavior of the well bore pressure until the pressure affects are felt at the boundary of the reservoir. The time at which this occurs can be calculated from the so called "readjustment time". The equation for the readjustment time is:

$$t_R = .04 \frac{uC_e r_e^2}{k} \qquad (3)$$

where:

t_R = Readjustment time, days

u = Viscosity, cps

C_e = System compressibility, vol/vol/psi

r_e = Reservoir radius, feet

k = Permeability, darcys

Equation (3) specifies the injection time during which Equation (2) is applicable. After this time, there is a period of pressure adjustment and then the reservoir pressure enters a phase known as "semi-steady state". In this latter phase the reservoir pressure is increasing at every point in the reservoir, but at the same rate of increase. The time for the transition from transient to semi-steady state requires an additional unit of time equal to the readjustment time. Therefore, it takes an injection time equal to $2t_R$ from the start of injection for the injection pressure at the well bore to be described by the semi-steady equation:

$$P_w = P_i + \frac{5.615\ qt}{\pi r_e^2\ h\ \phi\ C_e} + \frac{q\ u}{7.08\ kh}\left[\ln\frac{r_e}{r_w} - \frac{3}{4}\right] \qquad (4)$$

In this equation the first term (P_i) is the initial reservoir pressure, the second is a volumetric term that accounts for the increase in average pressure in the disposal aquifer, and the third term gives the frictional pressure difference between the well bore and the external boundary of the reservoir for any flow rate and flow geometry. If the injection time needed to dispose of a given amount of brine exceeds $2t_R$, then the analysis of the injection pressures can be made by the use of equation (4).

Equations (1) through (4) pertain to subsurface pressures. If it is desired to predict the surface pressure from the well bore pressure, terms must be included to account for the static pressure loss of the brine and friction loss of the flowing brine in the well between the surface and the reservoir. These two relationships are well known in the field of hydraulics. Therefore, the final relationship necessary to predict surface injection pressure during brine disposal at "semi-steady state" conditions is:

$$P_{ws} = P_i + \frac{5.615\ qt}{\pi r_e^2\ h\phi C_e} + \frac{q\ u}{7.08\ kh}\left[\ln\frac{r_e}{r_w} - \frac{3}{4}\right] \qquad (5)$$

$$- \Delta_p\ \text{(head loss)} + \Delta_p\ \text{(pipe friction)}$$

Equation (5) can be conveniently solved either by hand or on a computer and a schedule of surface and well bore pressure versus time can be obtained. This is the equation on which the results presented as Table 2 in the section on brine disposal was based.

D.7-5 West Hackberry Reservoir Mechanics (by Bill R. Hise)

Geological correlations from electric logs of wells in the vicinity of the West Hackberry Dome indicate that individual disposal aquifers can be traced over distances of at least 4 miles. If an additional 50% is added to this to allow for a reasonable extrapolation beyond the proved value, a single aquifer might be expected to be continuous for some 6 miles. Geological investigation revealed at least 6 potential disposal sands in the section of at least 100 feet in thickness or greater. Other data and project requirements at West Hackberry are:

1. Disposal wells: 12
2. Injection Rate: 1000 gpm (34,286 BPD) per well
3. Total Brine Injection per Cycle: 64,000,000 Bbls
4. Injection Time: 150 days
5. No. of Cycles: 5
6. Total Thickness of Disposal Aquifers: 600 feet
7. Porosity: 33%
8. Average Depth: 6000 feet
9. Initial Reservoir Pressure: 3000 psig
10. Average Permeability: 1000 mds (1 darcy)
11. System Compressibility: 10^{-5} vol/vol/psi
12. Fracture pressure: 4500 psig (.75 psi/ft)
13. Brine Viscosity: 0.55 cps
14. Reservoir Temperature: 130°F
15. Brine Density: 10 ppg

Table 1 shows the results of a calculation of the total brine disposal capacity available assuming injection to an average reservoir pressure equal to the fracture pressure. As shown, the total capacity is estimated at approximately 1 billion barrels (1.06×10^9 Bbls). Items 8 and 9 on Table 1 pertain to a single injection cycle. The 64 million barrels of brine to be disposed of in a single cycle would raise the average reservoir pressure in the brine disposal aquifers by 90 psi. A total of 5 cycles of injection would increase the average reservoir pressure by 5 x 90 psi or 450 psi.

In order to investigate the problems associated with injecting brine through wells into the total disposal volume, it is more convenient to subdivide the gross sand volume shown in Table 1 into individual cylindrical reservoirs, and prorate the amount of brine to be injected into each one. The model equivalent cylindrical reservoir for West Hackberry had the following parameters:

1. Reservoir Diameter: 3 miles
2. Reservoir Thickness: 152 feet

All other parameters were as previously listed. The assumption was made that each well would be injecting into a reservoir of the model size. For 12 injection wells, the total reservoir volume for injection would equal the total reservoir volume shown on Table 1. The average reservoir thickness was the slack variable used to force the linear and cylindrical systems to be of equal volume.

A calculation of the readjustment time for the cylindrical equivalent reservoir indicates that the transient phase of the pressure distribution lasts for less than a day after injection starts. This means that after two days the radial pressure distribution across the reservoir during injection will be controlled by the "semi-steady state" equations. (Refer to the appendix on reservoir mechanics for further discussion on transient and "semi-steady state" flow condition (App. D. 7-4, p. D-48). As an injection cycle will last approximately 150 days, it appears that analysis of the pressure build-up across the reservoir during injection will be primarily spedified by "semi-steady state" mechanics.

Table 2 is a computer printout of surface and bottom hole injection pressures as a function of time "for semi-steady state" flow for the injection rates and reservoir conditions expected at West Hackberry. As shown, after 5 months or 150 days of injection (1 cycle), the reservoir pressure at the well bore has increased to 3259 psig or some 259 psi above the initial pressure. Based on the analysis shown on Table 1, some 90 psi of this increase is due to an increase in average pressure while the other 169 psi is attributable to a pressure increase at the well due to radial flow friction loss of the injected brine in the cylindrical reservoir.

An analysis of the reservoir pressure at the well bore at the end of injection for the fifth injection cycle can be made by combining the data from Table 1 and 2. Table 1 shows the total reservoir pressure increase after 5 injection cycles to be 5 x 90 or 450 psi. The information in Table 2, based on the analysis in the preceeding paragraph, indicates the increased reservoir pressure due to injection only as 169 psi. The total of the two, or 619 psig, is the approximate increase in reservoir pressure at the injection well at the end of pumping on the fifth cycle. This should be the worst condition from the standpoint of reservoir pressure increase and potential fracture problems. As the 619 psi appears to be substantially under the estimated increase that would cause fracturing (± 1500 psi), it would appear that the disposal reservoirs at West Hackberry have sufficient capacity to accept the brine disposal requirements for the project.

The Possibility of Triggering an Earthquake (by Bill Hise)

There is documented evidence of earthquakes being triggered as a result of subsurface injection of fluid accompanied by an increase in injection reservoir pressure. The two known cases of this phenomena have occurred in Colorado in an area of high natural rock stress. One is near Denver in association with a disposal well that injected liquid waste from the Rocky Mountain Arsenal, and the other is near Rangly, Colorado in association with a water flood in the Rangly oil field. The mechanism causing the earthquake is not well understood. However, all those who have studied the problem agree that the existence of high natural earth stress (e.g., Colorado, Wyoming, California) is a prerequisite.

In the Texas-Louisiana Gulf Coast the natural earth stress is low--here we deal with a tectonically relaxed area which is characterized almost exclusively by normal faulting. (No reverse or overthrust faults). Numerous water flood and liquid waste injection sites have been in operation along the Louisiana-Texas Gulf Coast for many years without reported occurrences of earthquakes. Therefore, it would appear that earthquake occurrence along the Louisiana-Texas Coast as a result of the injection of brine from the Strategic Petroleum Reserve project would not be a problem that can be foreseen at this time.

TABLE 1
Brine Storage Capacity at West Hackberry
(Assuming No Interconnection of Sands)

1. Length of Disposal Area = 12 miles

2. Width of Disposal Area = 6 miles

3. Area of Disposal Area = 72 $miles^2$

4. Thickness of Disposal Sands - 600 feet

5. Gross Volume of Disposal Sands - 1.2×10^{12} ft^3
   ($72\ mi^2 \times 5280 \times 5280 \times 600$)

6. Net Volume of Disposal Sands - 70.6×10^9 bbls
   ($1.2 \times 10^{12} \times .33$ porosity $\div$ 5.61 ft^3/bbl)

7. Brine Disposal Capacity - 1.06×10^9 bbls
   a. Compressibility - 10^{-5} vol/vol/psi
   b. Reservoir Pressure - .5 psi/ft
   c. Fracture Pressure - .75 psi/ft
   d. Depth - 6000 feet
   e. Average Pressure Increase - 1500 psi

8. Disposal Volume of Brine on Initial Cycle - 64×10^6 bbls

9. Average Pressure Increase for Initial Cycle - 90 psi

TABLE 2
West Hackberry

RESERVOIR PRESSURE BUILDUP HISTORY

RESERVOIR CONDITIONS ARE AS FOLLOWS:
- INITIAL RESERVOIR PRESSURE OF 3000. PSIG.
- RESERVOIR TEMPERATURE OF 130. DEGREES F.
- AVERAGE POROSITY OF 0.330.
- AVERAGE PERMEABILITY OF 1.00 DARCIES.
- AVERAGE WIDTH OF 152. FEET.
- DEPTH OF 4000. FEET.
- RADIUS OF 15840. FEET.

WELL CONDITIONS ARE AS FOLLOWS:
- DIAMETER OF 10.000 INCHES.
- MAXIMUM SURFACE FLOWING PRESSURE OF 3000. PSIG.
- SURFACE FLOW RATE OF 34286. BPD.

FLUID PROPERTIES ARE AS FOLLOWS:
- VISCOSITY OF 0.550 CENTIPOISES.
- COMPRESSIBILITY OF 0.000010.
- DENSITY OF 10.00 PPG.

MONTH	SURFACE PRESSURE	BOTTOM HOLE PRESSURE
1.	81.	3184.
3.	125.	3229.
4.	140.	3244.
5.	155.	3259.
6.	170.	3274.
7.	185.	3288.
8.	199.	3303.
9.	214.	3318.
10.	229.	3333.
11.	244.	3348.
12.	259.	3363.
13.	274.	3377.
14.	288.	3392.
15.	303.	3407.
16.	318.	3422.
17.	333.	3437.
18.	348.	3451.
19.	362.	3466.
20.	377.	3481.
21.	392.	3496.
22.	407.	3511.
23.	422.	3525.
24.	436.	3540.
25.	451.	3555.
26.	466.	3570.
27.	481.	3585.

APPENDIX D.8

SUBSURFACE WATER DATA

Five figures and two tables pertaining to subsurface water quality comprise this appendix. Figures D.8-1 through D.8-3 consist of contour maps for the approximate altitude of the 1, 3, and 10 ppm dissolved solids surfaces. The potential water yield and aggregate sand thickness of the slightly saline water zone is presented in Figure D.8-4 while similar information for the moderately saline water zone is presented in Figure D.8-5 The results of chemical analysis of subsurface water taken from water wells in Cameron Parish are included in Table D.8-1. The 1974 salt water disposal report for that same parish is presented in Table D.8-2.

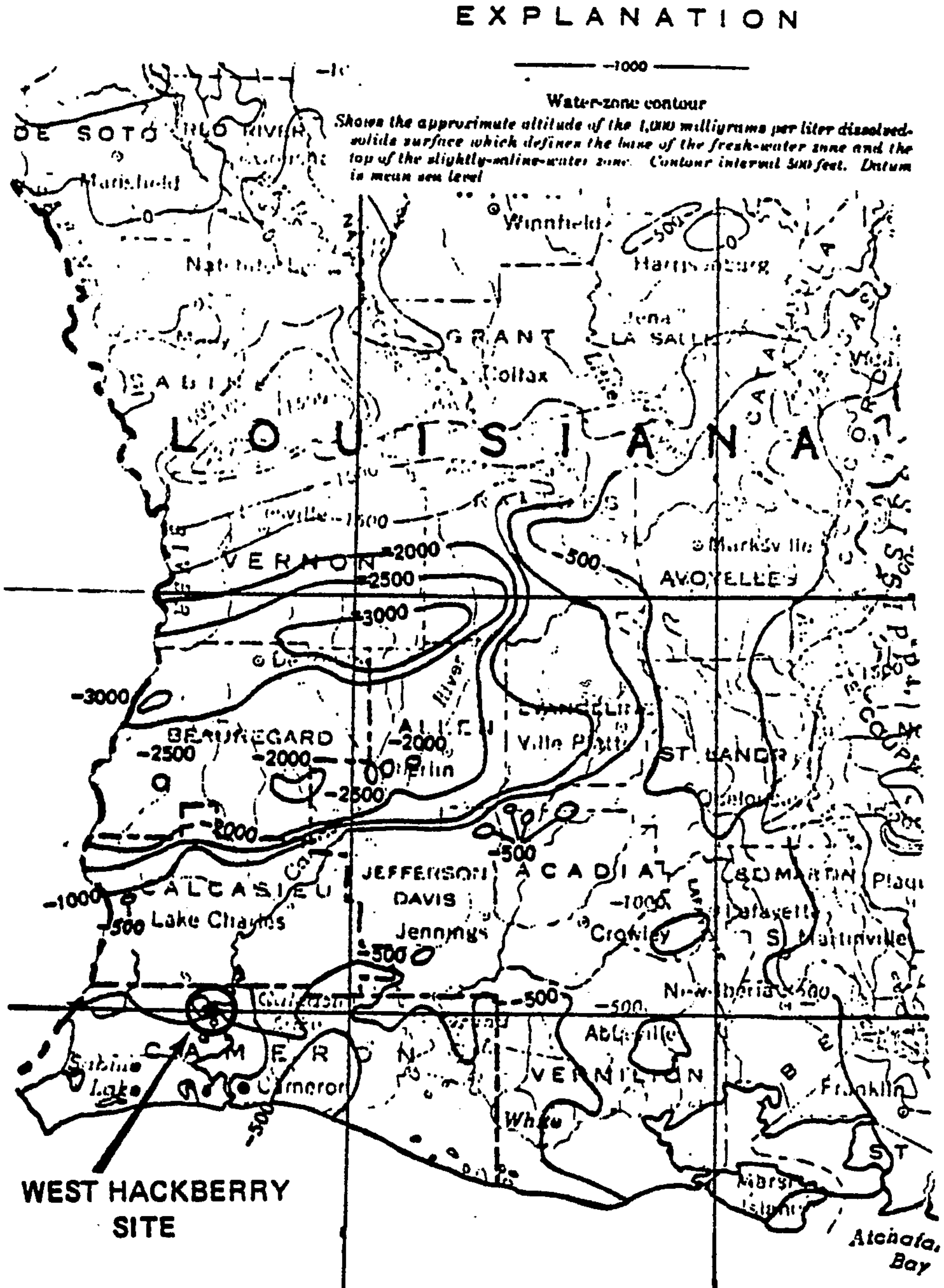


Figure D.8-1
Approximate Altitude of the 1000 mg/l Dissolved-Solids Surface

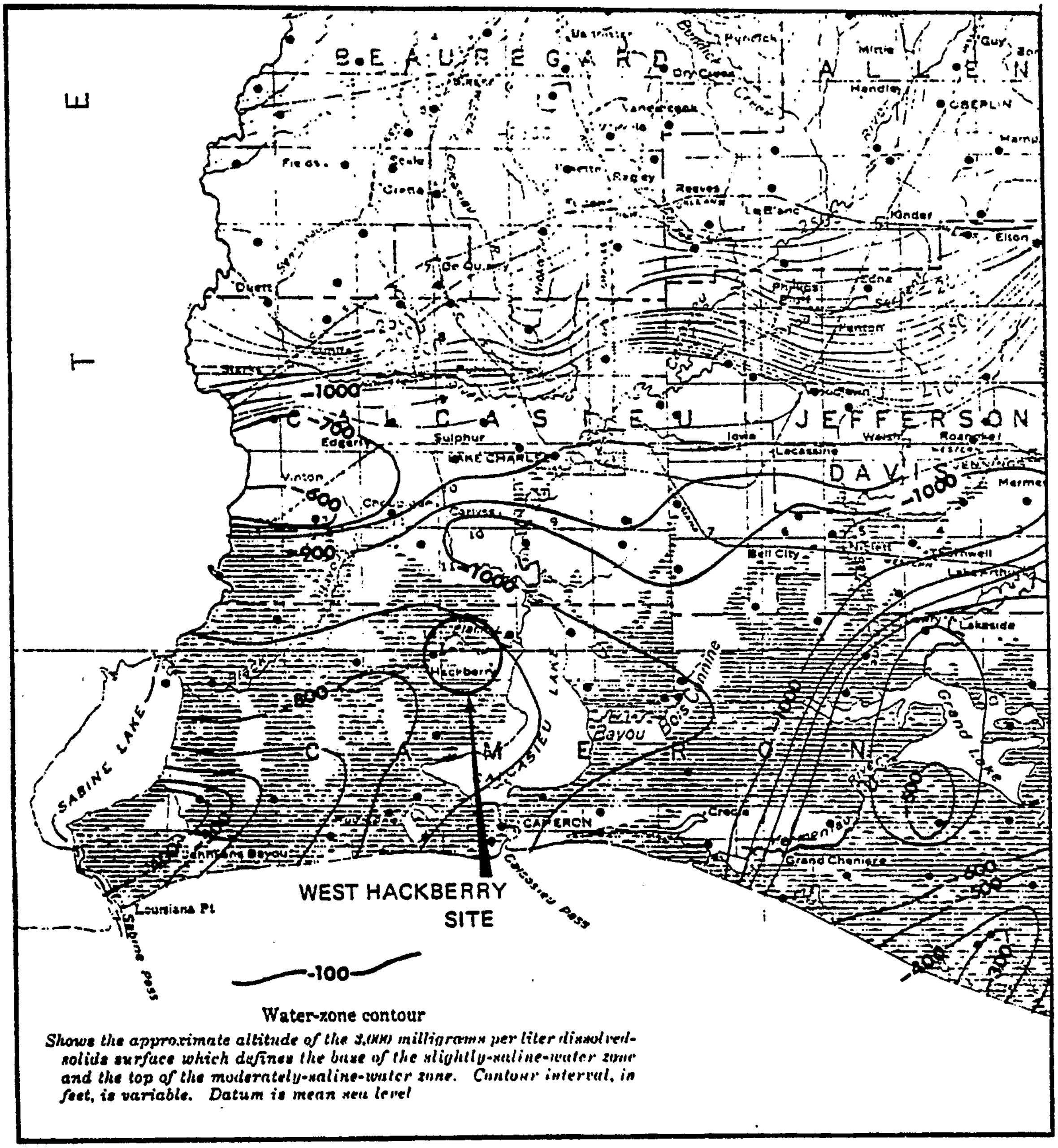


Figure D.8-2
Map Showing Approximate Altitude of the 3,000 Milligrams
Per Liter Dissolved-Solids Surface

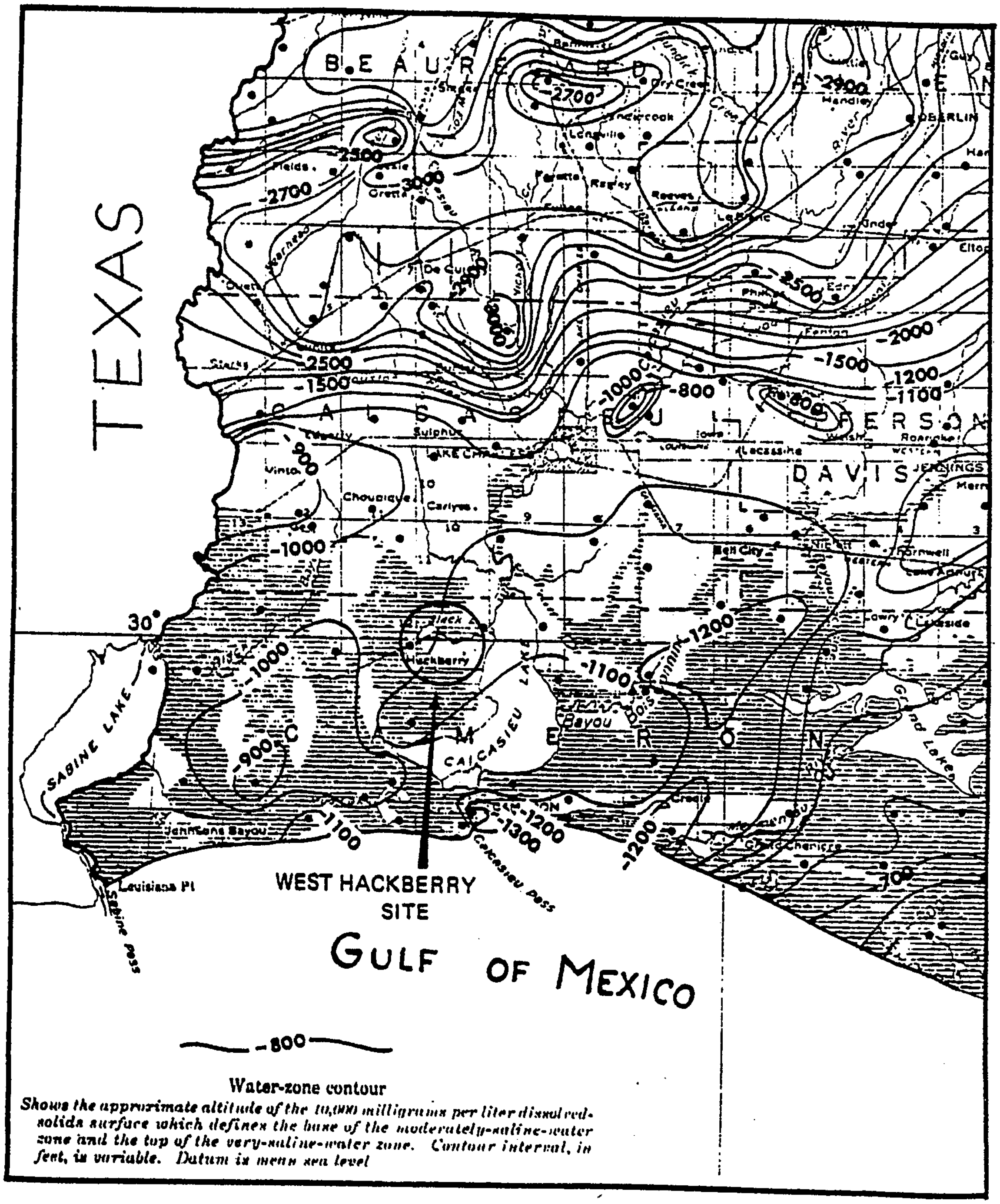


Figure D.8-3
Approximate Altitude of the 10,000 mg/l Dissolved-Solids Surface

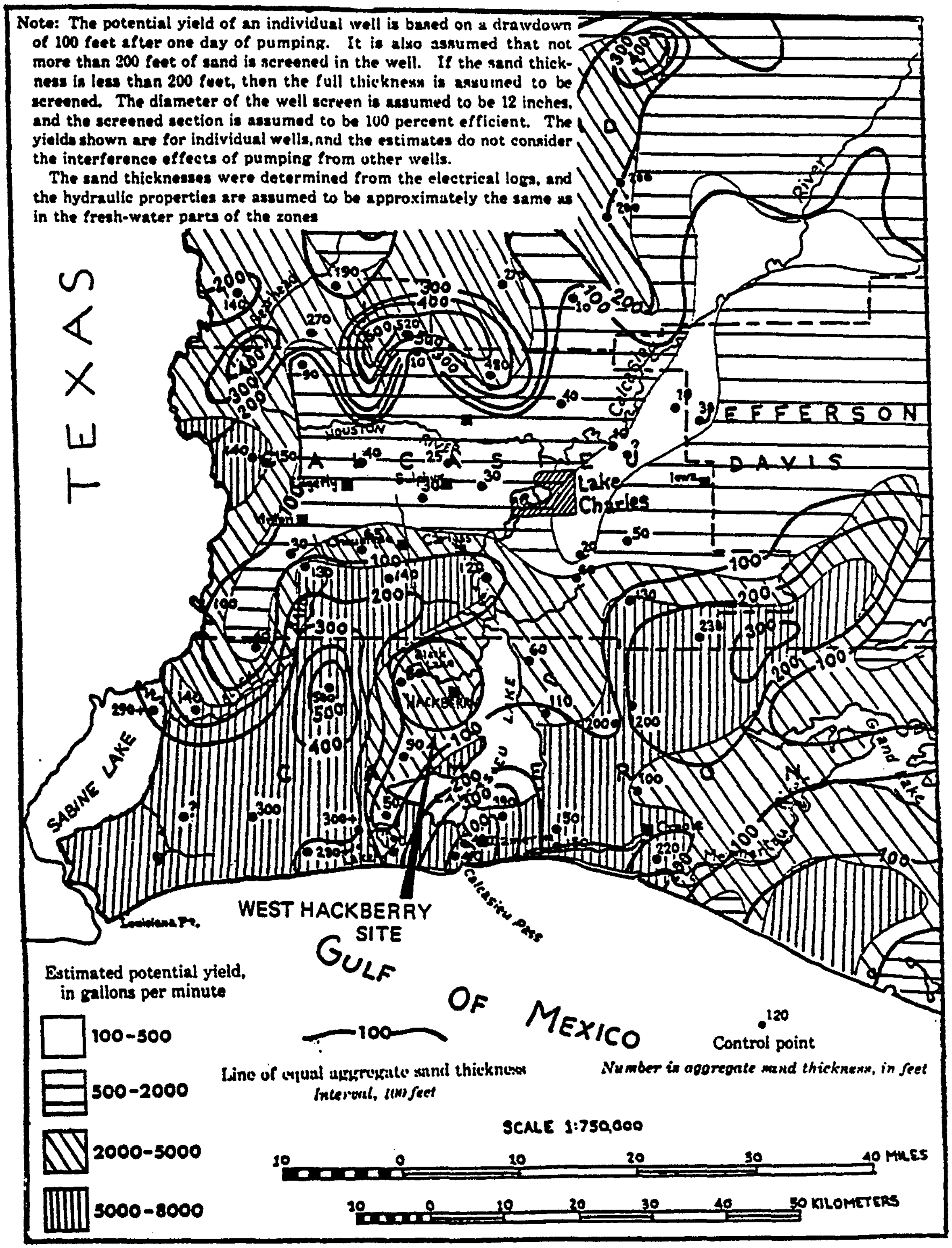


Figure D.8-4
Map Showing Estimated Potential Yield and Aggregate Sand Thickness of the Slightly-Saline-Water Zone (1,000-3,000 milligrams per liter dissolved solids)

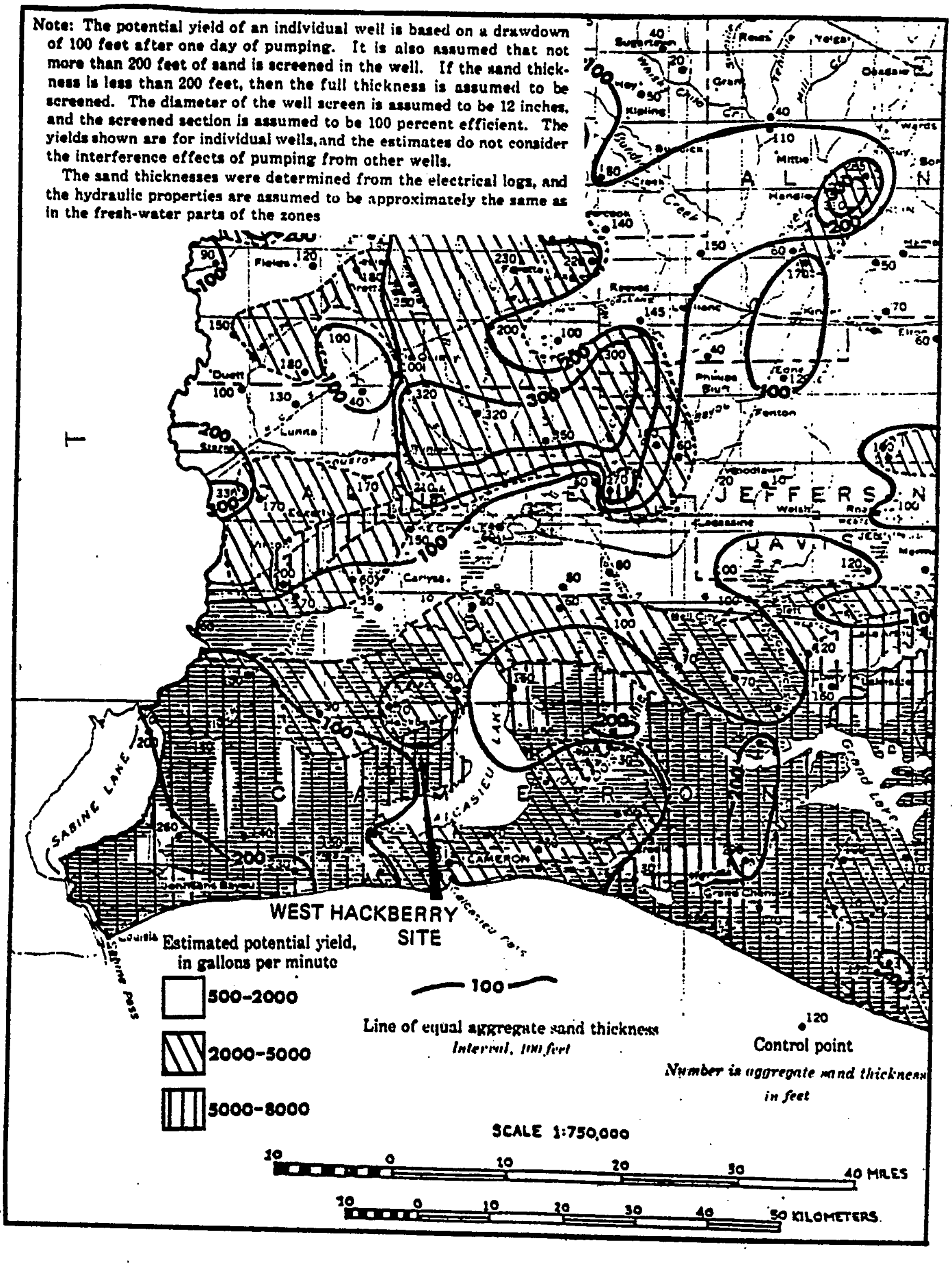


Figure D.8-5
Map Showing Estimated Potential Yield and Aggregate Sand Thickness of the Moderately-Saline-Water Zone (3,000 to 10,000 milligrams per liter dissolved solids)

Parish	Location	Depth or producing interval (feet)	Date of Collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)
Cameron	T.13S.,R.12W	-	6-15-34	-	-	62	19	1,106	-	299	-	-
Do.	T.15S.,R.14W., sec. 14	530	4-17-32	-	-	214	86	2,215	-	345	-	-
Cameron	T.15S.,R.4W., sec. 41	460	2-2-55	30	.04	48	19	408	4.5	416	0	2.1
Do.	T.15S.,R.11W., sec. 41	836	9-20-51	33	1.5	32	14	769	2.8	340	0	3.3
Cameron	T.11S.,R.6W.	8,859-8,885	11-21-60	-	5	595	136	16,308	-	877	0	19
Do.	T.13S.,R.12W.	2,840-2,878	8-21-36	-	-	900	433	37,965	-	372	-	-
Cameron	T.12S.,R.3W., sec. 24	837-847	5-20-63	22	1.3	206	105	4,370	4.1	355	0	0.0
Do.	T.15S.,R.13W., sec. 8	1,112-1,117	5-30-65	28	3.4	660	212	7,240	39	287	0	40
Do.	T.15S.,R.15W., sec. 22	1,208	4-17-32	-	-	350	145	4,282	-	317	-	-
Calcasieu	T.10S.,R.11W., sec. 36	800-805	12-4-64	32	.18	29	22	391	4.0	316	0	0.0

Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids	Barium (Ba)	Strontium (Sr)	Iodine (I)	Bromine (Br)	Manganese (Mn)	Phosphate (PO_4)	Calcium Manganese	Hardness as $CaCO_3$ Non-Carbonate	Specific Gravity	Specific conductance (Micromhos at 25°C)	pH	Temperature (°C)
1,700	-	-	-	3,186	-	-	-	-	-	-	234	-	-	-	7.4	-
3,840	-	-	-	6,198	-	-	-	-	-	-	-	-	-	-	7.4	-
547	.1	.2	.05	1,260	-	-	-	-	.01	.19	198	0	-	2,270	7.5	22
1,080	.6	.5	.38	2,100	-	-	-	-	0.0	0.0	138	0	-	3,860	7.6	26
26,100	-	-	-	44,035	-	-	-	-	-	-	-	-	1.0305	-	7.6	-
61,251	-	-	-	100,920	-	-	-	-	-	-	-	-	-	-	7.4	-
7,130	0.2	-	0.54	12,000	-	-	-	-	0.30	0.07	947	656	-	20,400	7.6	24+
12,800	0.4	-	-	21,160	-	-	-	-	0.9	-	2,520	2,280	-	32,500	7.3	-
7,400	-	-	-	12,554	-	-	-	-	-	-	-	-	-	-	-	-
533	.3	.1	.19	1,180	-	-	-	-	.04	.08	164	0	-	2,110	7.6	21

Table D-8.1

Chemical and Physical Parameters of Several Wells in Cameron and Calcasieu Parishes

Table D.8-2

SALT WATER DISPOSAL REPORT

CAMERON PARISH 1974

Field	Number of Wells	Average Depth	Pressure Range	Injection for Year	Cumulative Injection M (bbls)
CAMERON					
Big Lake	1	2,046	250-100	210,900	721.9
Cameron	1	3,320	700-400	3,738,236	8,302.2
Chalkley	3	2,550	575-50	1,788,789	13,849.7
Cheniere Perdue	1	1,515	600-0	945,600	3,590.0
Crab Lake	0	0	0	0	691.3
Deep Lake	1	2,370	55-Vac	1,223,433	15,168.1
E. Cheniere Perdue	1	2,496	0-0	54,750	86.7
Grand Cheniere	2	1,725	500-0	530,000	4,000.4
Grand Lake	4	2,200	450-Vac	2,946,979	24,214.8
High Island	1	10,314	90-0	15,680	353.6
Johnsons Bayou	2	1,450	125-25	12,775	670.6
Eings Bayou	1	1,455	50-0	14,840	2,289.1
Lacassine Refune	2	1,523	536-0	581,182	4,641.5
Lakeside	1	2,665	-Vac	50,653	1,596.1
Little Pecan Lake	3	2,750	450-0	1,399,833	7,661.4
Mallard Bay	1	1,900	300-250	364,028	5,003.1
Mud Lake	0	0	0	0	4,030.0
North Sweet Lake	2	3,250	350-0	147,455	707.4
Pecan Lake	1	3,900	-Vac	1,731,441	10,054.4
Sabine Lake	0	0	0	0	668.4
Second Bayou	0	0	0	0	2,906.8
S. Black Bayou	0	0	0	0	2,091.1
S. Grand Cheniere	1	3,022	8-0	7,076	7.1
S. Lake Misere	0	0	0	0	288.6
S. Pecan Lake	1	2,405	600-0	831,923	5,982.2
S. Thornwell	1	2,780	300-0	454,206	3,191.7
SW Lake Arthur	2	2,550	150-0	41,440	976.5
Sweet Lake	4	2,950	450-200	12,323,831	65,201.5
Twin Island	0	0	0	0	669.6
West Hackberry	0	0	0	0	732.0
PARISH TOTAL	37			29,415,055	190,447.6

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APPENDIX E

CALCULATIONS OF SEDIMENT TRANSPORT

The annual volumetric transport rate for sediment, Q_s, can be expressed as

$$Q_s = C_{ro} A_d P$$

where

C_{ro} = run-off coefficient

A_d = disturbed area (ft^2)

P = annual precipitation (ft/year)

Values of the run-off coefficient are not know precisely. A conservative estimate would be

$$C_{ro} \sim .02$$

Now, as noted in subsection 3.2.2, the disturbed area is

$$A_d = 34 \text{ acres}$$
$$= 1.48 \times 10^6 \text{ ft}^2$$

Also, as noted in subsection 2.2,

$$P = 55 \text{ inches}$$
$$= 4.58 \text{ ft}$$

Thus, for an assumed 6-month exposure

$$Q_s \sim .02 \times 1.48 \times 10^6 \times 4.58 \times 0.5 \text{ years}$$
$$= 6.78 \times 10^4 \text{ ft}^3/\text{year}$$
$$= 2.51 \times 10^3 \text{ yd}^3/\text{year}$$

The increase in turbidity on the surface water system will depend on the total volume of water present in the surface water system (V_{sw}) in the vicinity of the West Hackberry site. This volume is difficult to calculate precisely. Based on Table 2.2

$$V_{sw} \sim 17.2 \times 10^9 \text{ ft}^3$$
$$\sim 6.37 \times 10^8 \text{ yd}^3$$

Now the mass of the sediment (M_s) transported annually would be

$$M_s = Q_s \rho$$

where ρ = density of the sediment

$$M_s = Q_s \rho$$
$$= 2.51 \times 10^3 \text{ yd}^3/\text{year} \times (100 \text{ lb}/\text{ft}^3 \times 27 \text{ ft}^3/\text{yd}^3)$$
$$= 6.78 \times 10^6 \text{ lb}/\text{year}$$
$$M_s = 6.78 \times 10^6 \times 454 \text{ gm/lb}$$
$$3.08 \times 10^9 \text{ gm/year}$$

The most conservative assumptions would be that none of the transported sediment settle out except for the sand and larger aggregate. Sand and larger aggregate typically exceeds 50 percent in this area. Thus, the annual increase in suspended sediment in the water would be a maximum of:

$$\frac{M_s}{V_{sw}} = \frac{3.08 \times 10^9 \text{ gm/year} \times 0.5}{6.37 \times 10^8 \text{ yd}^3}$$
$$= 2.42 \text{ gm/yd}^3$$
$$= \frac{2.42 \text{ gm/yd}^3}{7.65 \times 10^5 \text{ cm}^3/\text{yd}^3} =$$

$$= 3.16 \times 10^{-6} \text{ gm/cm}^3$$

$$= 3.16 \times 10^{-3} \text{ gm/l}$$

$$= 3.16 \text{ mg/l}$$

Now, the average level of suspended solids for the area is ∿ 20 mg/l. Thus, the increase in the suspended solid would be

$$SS = 3.16/20$$

$$= 15.8 \text{ percent}$$

$$= 3.16 \times 10^{-6} \text{ gm/cm}^3$$

$$= 3.16 \times 10^{-3} \text{ gm/l}$$

$$= 3.16 \text{ mg/l}$$

Now, the average level of suspended solids for the area is $\sim$ 20 mg/l. Thus, the increase in the suspended solid would be

$$SS = 3.16/20$$

$$= 15.8 \text{ percent}$$

APPENDIX F

CALCULATIONS RELATING TO EFFECTS OF WITHDRAWING DISPLACEMENT WATER FROM BLACK LAKE

1. Change of Surface Level of Black Lake

A simple conservation-of-mass model has been used. The governing equation is

$$A \frac{dh}{dt} = Q_i - Q_o \qquad (1)$$

where

A = surface area of Black Lake

h = surface height of lake

t = time

Q_i = volumetric flow rate into lake from replenishment source

Q_o = volumetric flow rate from lake

Now the withdrawal rate is:

$$Q_o = 10{,}650 \text{ gpm}$$
$$= 1423 \text{ ft}^3/\text{min}$$
$$= 2{,}049{,}120 \text{ ft}^3/\text{day}$$

The surface area of the lake is:

$$A = 3.425 \text{ sq. miles}$$
$$= 95.5 \times 10^6 \text{ ft}^2$$

The replenishment rate is

$$Q_i = H\ W\ U_i \qquad (2)$$

where

H = depth of replenishment channel

W = width of replenishment channel

U_i = induced velocity in replenishment channel

Based on Manning's relation[1]

$$U_i = \frac{1.49}{n} R^{2/3} S^{1/2} \qquad (3)$$

where n = coefficient of roughness

R = hydraulic radius

S = surface slope

Now the coefficient of roughness for earth bottoms is[2]

$$n = .025\ /(ft^{1/3}\ sec)$$

The hydraulic radius is defined as the cross-sectional area of the channel divided by the wetted perimeter. Thus

$$R = H\ W/_{(2H+W)} \qquad (4)$$

The surface slope can be approximated by the relation

$$S = (h_o - h)/L \qquad (5)$$

where

h_o = initial height of Black Lake (=4 feet)

L = length of replenishment channel

Substitution of the relations for Q_i, U_i, R, and S into the original differential equation yields

$$A \frac{dh}{dt} = H\ W \left(\frac{1.49}{.025}\right)\left(\frac{H\ W}{2H+W}\right)^{2/3} \left(\frac{h_o-h}{L}\right)^{1/2} - Q_o \qquad (6)$$

or

$$\frac{dh}{dt} = 59.6 \frac{H\ W}{A\sqrt{L}} \left(\frac{H\ W}{2H+W}\right)^{2/3} \left(h_o-h\right)^{1/2} - Q_o/A \qquad (7)$$

Let

$$a = Q_o/A \qquad (8)$$

$$b = 59.6 \frac{H\ W}{A\sqrt{L}} \left(\frac{H\ W}{2H+W}\right)^{2/3} \qquad (9)$$

$$f = \left(h_o-h\right)^{1/2} \qquad (10)$$

Then

$$f^2 = h_o-h \qquad (11)$$

and

$$2f \frac{df}{dt} = -\frac{dh}{dt} \qquad (12)$$

By substitution

$$-2f \frac{df}{dt} = bf - a \qquad (13)$$

The corresponding initial condition is

$$f = 0 \quad (t = 0) \qquad (14)$$

Equation 13 can be integrated directly to yield

$$\frac{2}{b^2}\left[a \ln\left(\frac{1}{1-bf/a}\right) - bf\right] = t \qquad (15)$$

Now

$$a = 2,049,120/(95.5 \times 10^6)$$

$$= 2.15 \times 10^{-2} \text{ ft/day} \quad (16)$$

If Black Lake Bayou serves as the replenishment channel;[3]

$H = 4$ feet

$W = 100$ feet

and

$L = 6.4$ miles

$= 33,792$ feet

Then

$$b = \frac{59.6 \times 4 \times 100}{95.5 \times 10^6 \sqrt{33,792}} \left(\frac{4 \times 100}{2 \times 4 + 100}\right)^{2/3}$$

$$= 3.25 \times 10^{-6} \text{ ft}^{\frac{1}{2}}/\text{sec}$$

$$= .281 \text{ ft}^{\frac{1}{2}}/\text{day} \quad (17)$$

If Alkali Ditch serves as the replenishment channel[3]

$H = 6$ feet

$W = 100$ feet

and

$L = 3.6$ miles

$= 19,008$ feet

Then

$$b = \frac{59.6 \times 6 \times 100}{95.5 \times 10^6 \sqrt{19,008}} \left(\frac{6 \times 100}{2 \times 6 + 100}\right)^{2/3}$$

$$= 8.32 \times 10^{-6} \text{ ft}^{\frac{1}{2}}/\text{sec}$$

$$= .718 \text{ ft}^{\frac{1}{2}}/\text{day} \quad (18)$$

The variation of f with t can be computed by means of Eq (15), with the value of "a" given by Eq (16) and the value of "b" given by Eq (17) or (18), depending on which replenishment channel is used. With f known, the height, h, can be computed by means of Eq (11). The resulting variation of height with time is presented in Figure 3.6 and 3.8.

2. Induced Velocity in Replenishment Channel

As noted previously,

$$U_i = \frac{1.49}{n} R^{2/3} S^{1/2} \tag{3}$$

Based on the preceding development Eq (3) can be written

$$U_i = \frac{59.6}{\sqrt{L}} \left(\frac{H W}{2H+W}\right)^{2/3} f \tag{19}$$

$$= \frac{bA}{HW} f \tag{20}$$

For Black Lake Bayou,

$$\frac{bA}{HW} = \frac{.281 \times 95.5 \times 10^6}{4 \times 100}$$

$$= 6.71 \times 10^4 \text{ ft}^{1/2}/\text{day}$$

$$= .776 \text{ ft}^{1/2}/\text{sec} \tag{21}$$

For Alkali Ditch,

$$\frac{bA}{HW} = \frac{.718 \times 95.5 \times 10^6}{6 \times 100}$$

$$= 1.14 \times 10^5 \text{ ft}^{1/2}/\text{day}$$

$$= 1.32 \text{ ft}^{1/2}/\text{sec}$$

The variation of f with time, as already noted is given by Eq (15). The variations of U_i with time can then be computed by means of Eq (19), with the appropriate value of (bA/HW). The resulting variation of U_i with t is presented in Figures 3.7 and 3.9.

3. Salinity Variation in Black Lake

For calculating the variation of salinity in Black Lake as a function of time a simple model has been used involving the following assumptions:

1) Constant volumetric flow rate between the replenishment source and the lake $\left(\frac{dQ_i}{dt} = 0\right)$

2) Constant salinity in the replenishment source $\left(\frac{dC_i}{dt} = 0\right)$

3) Constant volume is maintained in the lake $\left(\frac{dV}{dt} = 0\right)$

4) Instantaneous mixing of inflowing water with lake water

With these assumptions the governing differential equation for the model is

$$V \frac{dC}{dt} + QC - QC_i = 0$$

with the initial conditions

$$C = C_o \quad (t = 0)$$

where

V = volume of the lake (ft^3)

C = salinity (ppt)

Q_i = volumetric flow rate into the lake (ft^3/day)

C_i = salinity of the replenishment source

t = time (days)

The solution to the equation is

$$C = C_i - (C_i - C_o) \exp(-Q_i t/V)$$

or in dimensionless form,

$$\frac{C - C_o}{C_i - C_o} = 1.0 - \exp \; (-Q_i t/V)$$

Now the volume of the lake

$$\begin{aligned} V &= A \times h_o \\ &= 95.5 \times 10^6 \times 4 \\ &= 382 \times 10^6 \ ft^3 \\ Q_i &= 1423 \ ft^3/min \\ &= 2.05 \times 10^6 \ ft^3/day \end{aligned}$$

then

$$\frac{C - C_o}{C_i - C_o} = 1.0 - \exp \left[(-2.05 \times 10^6 \ t)/(382 \times 10^5)\right]$$

$$= 1.0 - \exp(-5.37 \times 10^{-3} \ t)$$

The variation of $(C-C_o)/(C_i-C_o)$ with t is presented in Figure 3.10.

4. Tidal Flow in Black Lake Bayou and Alkali Ditch

The tidal range in Black Lake is approximately equal to that in Calcasieu Ship Channel[4] Thus

$$\Delta h_{Tidal} = 0.5 \text{ ft}$$

As previously noted the area of the lake is

$$A = 95.5 \times 10^6 \text{ ft}^2$$

Thus the total change in the volume of the lake is

$$\Delta V_{Tidal} = .5 \times 95.5 \times 10^6$$
$$= 47.7 \times 10^6 \text{ ft}^3$$

The time between low and high tides in this region is on the order of 8 hours[5] Thus the mean volumetric flow rate due to the tides would be

$$\dot{V}_{Tidal} = 47.7 \times 10^6/(8 \times 3600)$$
$$= 1666 \text{ ft}^3/\text{sec}$$

The assumption is made that 50% of this tidal flow passes through Black Lake Bayou and 50% through Alkali Ditch. The crosssectional area of Black Lake Bayou is

$$A = 4 \times 100$$
$$= 400 \text{ ft}^2$$

The tidal induced velocity would be

$$U_{Tidal} = .5 \times \dot{V}_{Tidal}/A$$
$$= .5 \times 1666/400$$
$$= 2.08 \text{ ft/sec}$$

The crosssectional area of Alkali Ditch is

$$A = 6 \times 100$$
$$= 600 \text{ ft}^2$$

The tidal induced velocity would be

$$U_{Tidal} = .5 \times 1666/600$$
$$= 1.38 \text{ ft/sec}$$

These velocities due to tidal effects appear large when compared with the induced velocities resulting from the withdrawal of water in Black Lake Bayou, as shown in Figures 3.6 and 3.8.

REFERENCES

APPENDIX F

1 Streeter, V. L., (Editor), Handbook of Fluid Dynamics, McGraw-Hill Book Company, New York, 1961.

2 Streeter, V. L., Fluid Mechanics, McGraw-Hill Book Company, New York, fourth edition, 1966.

3 "Calcasieu River and Lake Louisiana" Nautical Chart 11347, U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Edition 9, July 1975.

4 Larry Rocca, Personal Communication, Louisiana State Wildlife and Fisheries Commission, Lake Charles, Louisiana, December 10, 1976.

5 Tide Tables 1976, High and Low Water Predictions East Coast of North and South America Including Greenland, NOAA, U.S. Department of Commerce, 1975.

Appendix G

TERMINAL VULNERABILITY AND OIL SPILL RESPONSE

Spill Vulnerability

Data compiled by the U.S. Environmental Protection Agency[1], based upon a survey of oil gathering and distribution facilities involving 4,423 oil spills, corroborates the Department of Transportation spill data used in Section 3, with respect to the ratio of pipeline leaks versus terminal equipment that contributed to the spills, but much of the pipe was very old (over 25 years) and corrosion accounted for over 54 percent of the reported leaks.

The corrosion protection systems to be employed in the Strategic Petroleum Reserve Project will reduce significantly the incidence of corrosion related oil spills, but pipeline leaks clearly pose the greatest hazard. The following tables show the distribution of spills by subsystem, (Table G-1) and the relative severity of spills associated with each subsystem, (Table G-2).

Another study sponsored by the U.S. EPA[2] to develop data for a source in oil spill prevention and control, collected the judgments and experience of oil facility operators with respect to the principal causes of leaks and spills within each subsystem. These judgments, presented on Table G-3, are related in terms of the probability and severity of leaks or spills that are associated with components of those subsystems for which spill data is shown on Tables G-1 and G-2.

The probability symbols, H, M and L represent High, Medium and Low probability of that components failing. The severity of a spill has been evaluated on the basis of cleanup requirements according to the following:

1 - Major cleanup required to restore environment

2 - Intermediate cleanup required to restore environment

3 - Minor cleanup required to restore environment

ELEMENT	NUMBER OF EVENTS	% SYSTEM EVENTS	% SUBSYSTEM EVENTS
Pipeline Subsystem	3226	73.03	100.00
Pipe	3117	70.44	96.44
Scraper Trap Equipment	28	0.63	0.87
Pipe Support Structure	0	—	—
Stream Crossing	7	0.16	0.22
Road Crossing	50	1.13	1.55
Equipment Not Identified	30	0.68	0.93
Storage Subsystem	138	3.12	100.00
Tanks	78	1.76	56.52
Tank Firewall	0	—	—
Tank Associated Equipment	57	1.29	41.30
Power Equipment	0	—	—
Equipment Not Identified	3	0.07	2.17
Pump Station Subsystem	165	3.66	100.00
Pumps	88	1.99	4.32
Centrifugal Pumps	1	0.02	0.62
Reciprocating Pumps	3	0.07	1.85
Manifold Equipment	6	0.14	3.70
Rotary Pumps	0	—	—
Steam Engine	0	—	—
Gas Turbine	0	—	—
Steam Turbine	0	—	—
Internal Combustion Engine	0	—	—
Electrical Motor	0	—	—
Pressure Controls	1	0.02	0.62
Metering Equipment	4	0.09	2.47
Valve	23	0.52	14.20
Valve Operating & Control Equipment	4	0.09	2.47
Electric Power & Control Equipment	2	0.05	1.23
Communications Equipment	0	—	—
Drainage System Equipment	3	0.07	1.85
Power Equipment	0	—	—
Equipment Not Identified	27	0.61	6.67
Safety Subsystem	3	0.05	100.00
Pressure Sensing Equipment	0	—	—
Pressure Switching Equipment	0	—	—
Flow & Gauge Equipment	1	0.02	50.00
Temperature Recorders	0	—	—
Power Equipment	0	—	—
Equipment Not Identified	1	0.02	50.00
Gathering Subsystem	870	19.66	100.00
Gravity	73	1.65	8.39
Suction	41	0.93	4.71
Pressure	8	0.18	0.92
Equipment Not Identified	748	16.90	85.98
Subsystem/Equipment Not Identified	21	0.47	N/A
Total G/D System Failures	4423	100.00	N/A

Table G-1 Gathering/Distribution System Spill Events By Subsystem and Equipment.

Table G-2 Spill Events for Onshore Gathering/Distribution Systems by Subsystem and Spill Category

Subsystem	Number of Spill Events				
	Minor	Moderate	Major	Not Identified	Totals
Pipeline	36	2429	634	83	3182
Storage	1	96	38	1	136
Pump Station	1	111	38	10	160
Safety	0	1	1	0	2
Gathering	8	775	83	2	868
Not Identified	2	15	2	0	19
Totals	48	3427	796	96	4367

	Tank Farms	Terminals	Onshore Production
<u>EQUIPMENT</u>			
<u>Tanks</u>			
Gauges	H/3	M/3	M/3
Sampling facilities	H/3	H/3	
Shell and bottoms	L/1	L/1	L/1
Underground seepage	L/1	L/1	
Containment dikes	M/2	M/2	L/2
Dike drains	H/2		M/2
<u>Pipe, Valves & Fittings</u>			
Seal failure			L/1
Valve stem packing	M/3	M/3	M/2
Gaskets	M/2	H/3	M/2
Pipe rupture	L/1	L/1	L/1
<u>Pump & Mechanical Equipment</u>			
Seals	M/2	M/3	H/1
Lubricating systems			
<u>Loading Stations</u>			
Fill safeguards		L/1	H/2
Curbs and drains		H/2	M/2
<u>OPERATIONS</u>			
<u>Tanks</u>			
Filling/Overfilling	H/1	H/1	L/2
Sampling	H/2	M/3	L/3
Cleaning	H/1	L/2	L/2
Dike draining	H/2		
<u>Pipe, Valves & Fittings</u>			
Maintenance		H/2	H/2
Collision		H/1	
<u>Pumps</u>			
Maintenace	H/3	H/3	H/2
<u>Loading Racks</u>			
Overfills		H/2	
Loading drips		H/3	

Table G-3 Areas of Potential Spills Probability/Severity.

Oil Spill Cleanup Capacity in Vicinity of West Hackberry Dome

Due to the extensive oil production and pipeline transmission activity in the Beaumont/Pt. Arthur to Lake Charles area, there are many other oil handling facilities and third party cleanup services, with modern equipment, chemicals and absorbent materials. A Crossley survey of Oil Spill control facilities, conducted for the American Petroleum Institute in 1970[3], reports the availability of cooperating oil handling facilities and cleanup contractors by ZIP code, within each state.

This survey shows that there are 69 oil handling facilities, each one with some cleanup capacity, and 7 third party cleanup services in the same ZIP Area as the West Hackberry Dome Site. In the western contiguous Texas Area, there are 114 oil handling facilities and 18 third party cleanup services and in the eastern contiguous ZIP Area, there are 147 oil handling facilities and another 34 third party cleanup services.

Assuming that the Federal Energy Administration relies principally on third party cleanup contractors for assistance, there are approximately 60 such sources of personnel and equipment within a 100 mile radius of the petroleum storage site.

Reference
APPENDIX G

[1]"Petroleum Systems Reliability Analysis" (2 Volumes) EPA Report No. EPA-R-2-73-280a, August 1973.

[2]"Oil Spill Presentation Control and Countermeasure Plan Review" by Rue University and The School of Public Health, The University of Texas, Sponsored by U.S. EPA, February 1975.

[3]"Oil Spill Control Survey for Onshore and Offshore Facilities" American Petroleum Institute, March 1970.

APPENDIX H

SUMMARY OF INFORMATION ON EXISTING CAVITIES, CAVITY CONVERSION PROCEDURES AND DRILLING PROCEDURES

1. Existing Cavities

Olin Corporation's brine production field at West Hackberry currently consists of 5 solution cavities totaling approximately 64 million barrels of gross storage space (see Figure H.1 through H.11). They are used to produce brine feedstock for Olin's chemical facilities. A summary of the current cavern conditions follows:

Cavern No. 6 has a deep dishpan shape with the bottom at a depth of 3,404 feet. It has an average diameter of approximately 804 feet, and a height of 164 feet. Upward development of this cavity is permissible but is not currently planned. Production casing is 12-3/4 inches cemented to a depth of 2,632 feet.

Cavern No. 7 has the general shape of a cylinder with a total depth of 3,493 feet. It has a cavern height of 958 feet, and a maximum diameter of 300 feet. Upward growth could not be tolerated, and several feet of blanket oil would be required to protect the ceiling's integrity. Production casing is 12-3/4 inches cemented to 2,400 feet.

Cavern No. 8 has the general shape of a cylinder with a cavern bottom depth of 3,453 feet. It is approximately 1,023 feet high and has an average diameter of 355 feet. Production casing is 12-3/4 inches cemented to a depth of 2,402 feet. Here again blanket oil would be required to prevent additional upward growth.

Cavern No. 9 has a deep dishpan shape in the lower portion of the cavern and the section is now being developed in the shape of an inverted cone. The maximum diameter of the cavern is 560 feet. The total cavern depth is 3,443 feet with its height estimated to be 220 feet. New upward development has been continuing since 1973 and no further enlargement of the lower portion has occurred. Production casing is 12-3/4 inches cemented at 2,401 feet.

Cavern No. 11 has the general shape of a cylinder with a total bottom depth of 3,744 feet. Its average diameter is 264 feet and it is 852 feet high. No additional upward growth is permitted as this would encroach on the 13-3/8 inch casing cemented to a depth of 2,808 feet.

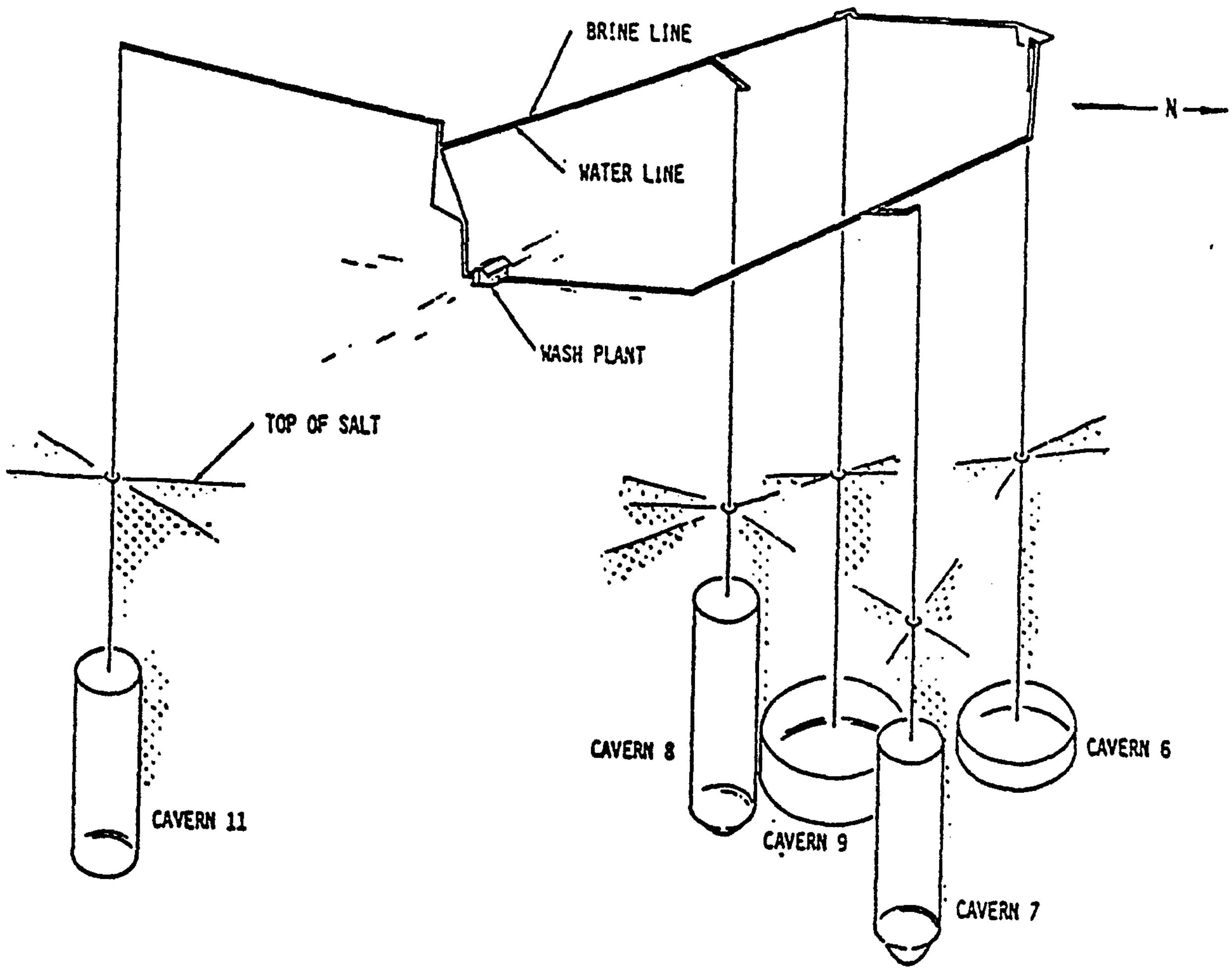

Figure H.1 Diagram of Existing Cavities (after Fenix & Scisson)

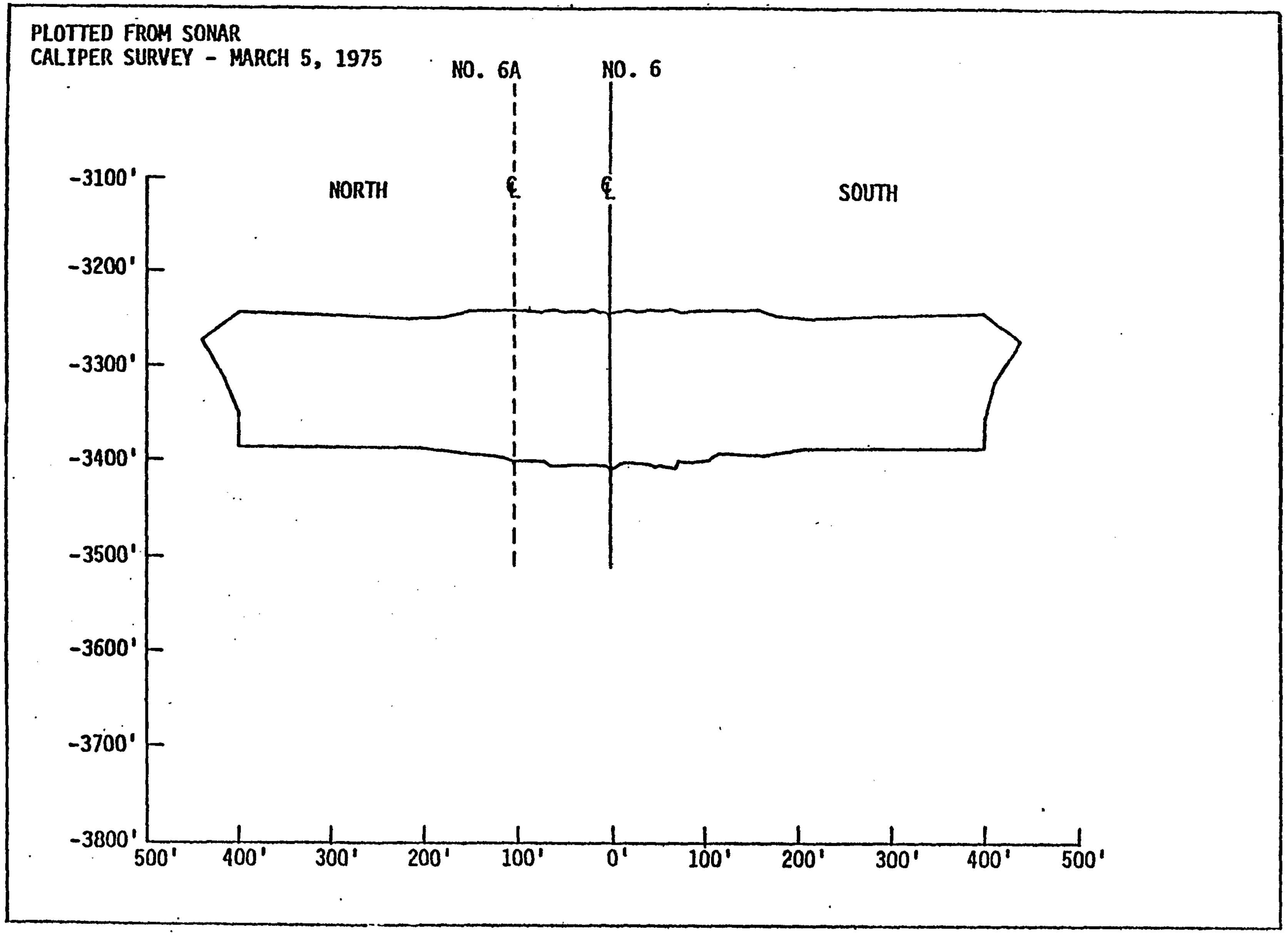

Figure H-2 Profile - Cavern No. 6 - West Hackberry Dome

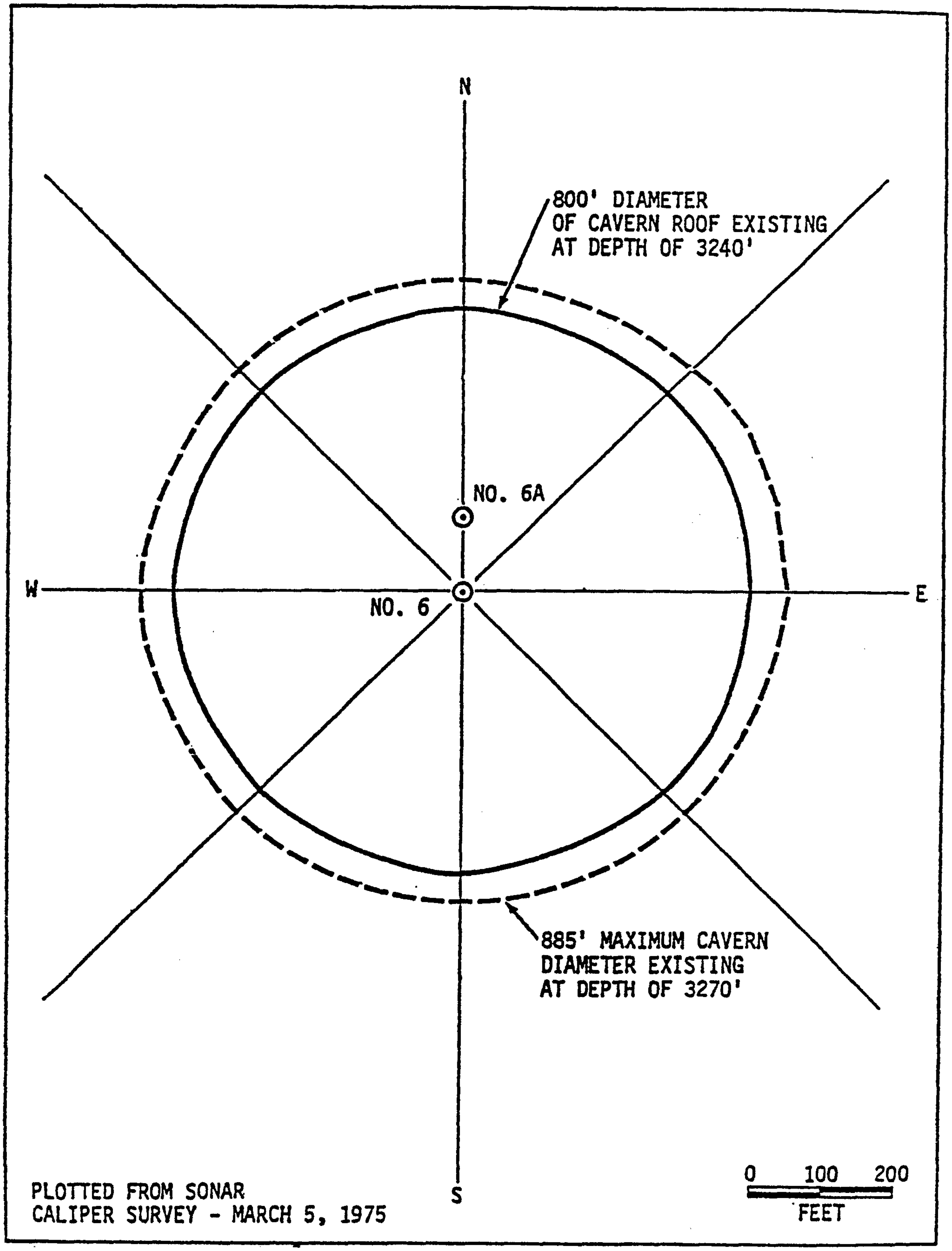

Figure H-3 Cavern No. 6 - West Hackberry Dome

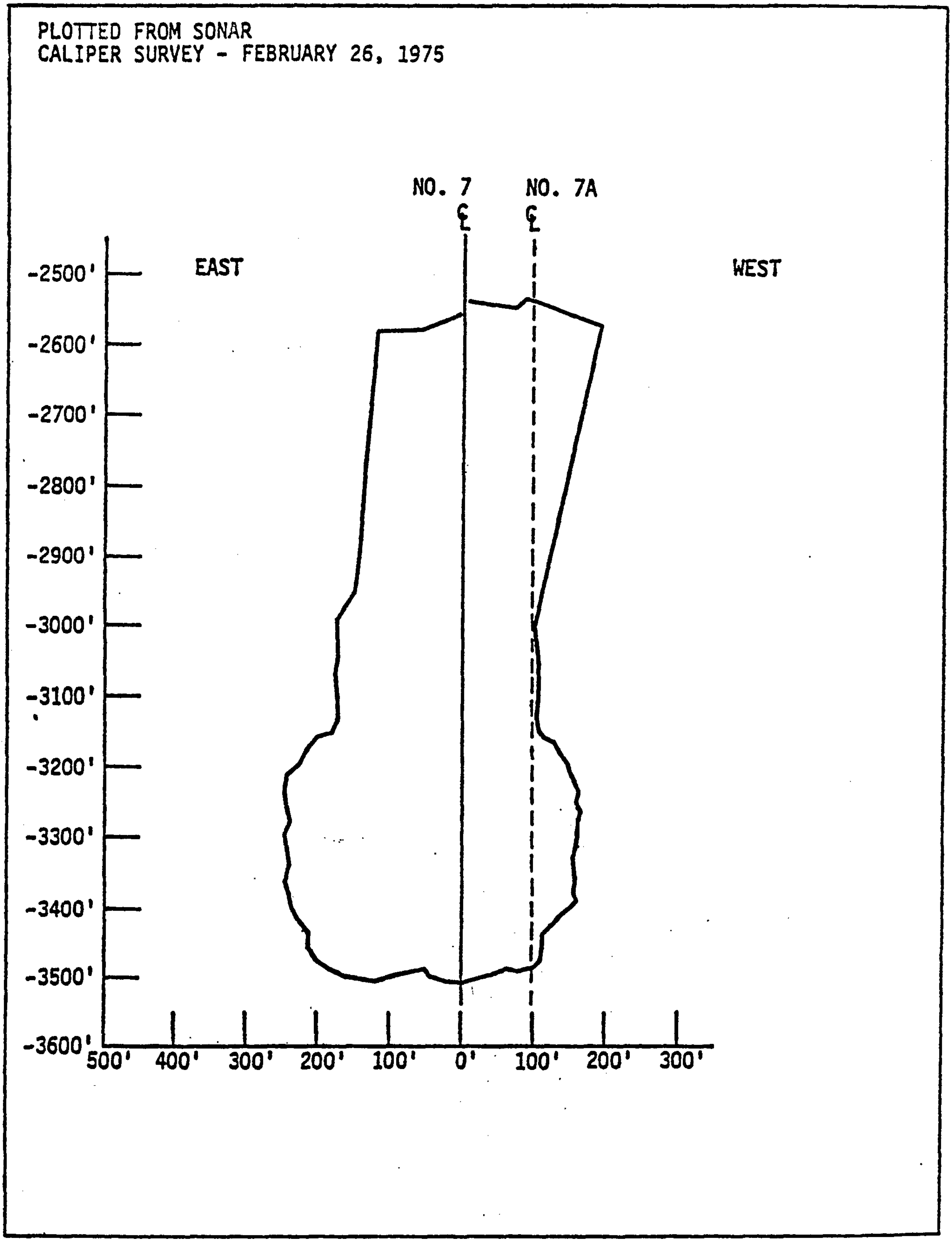

Figure H-4 Profile - Cavern No. 7 - West Hackberry Dome

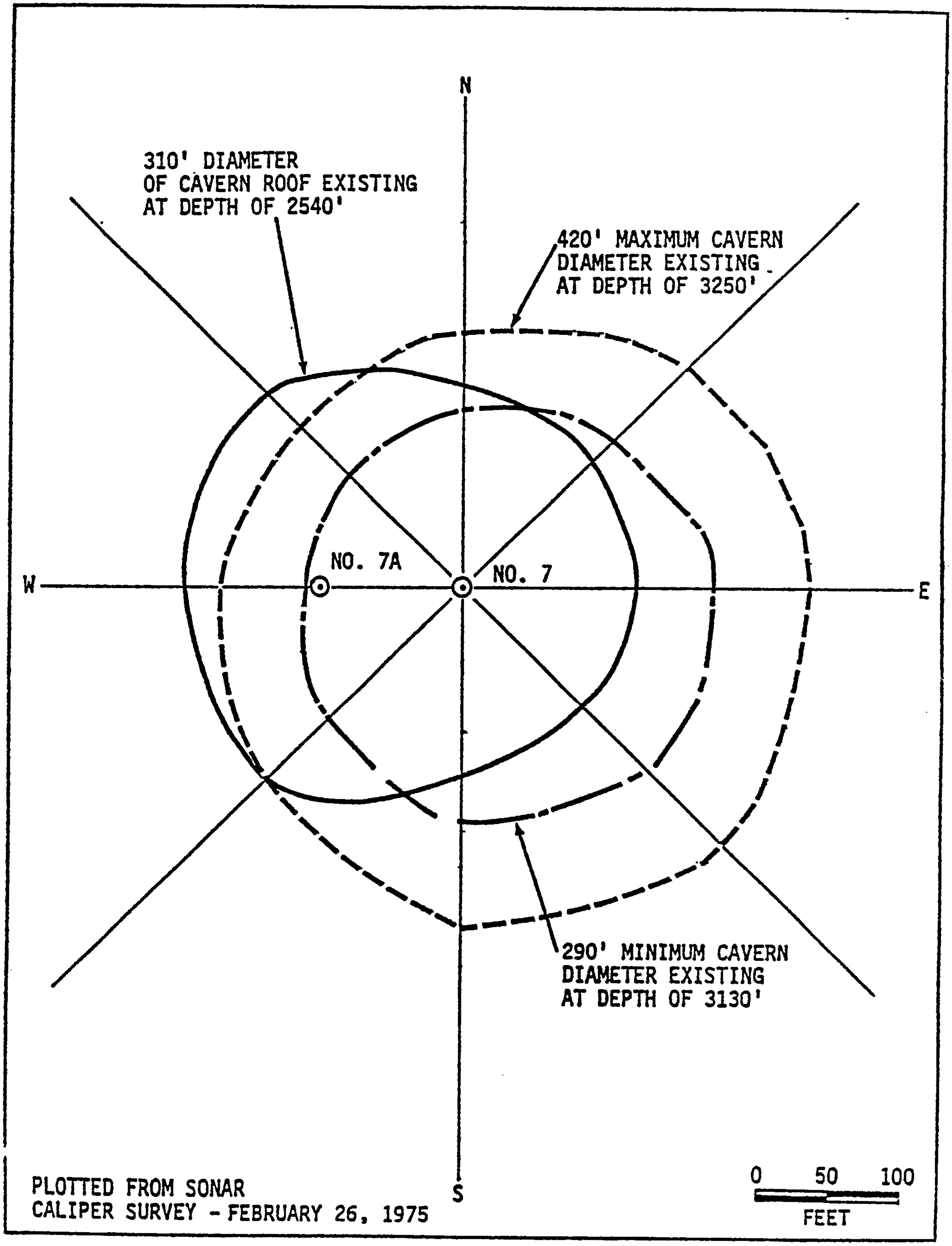

Figure H-5 Cavern No. 7 - West Hackberry Dome

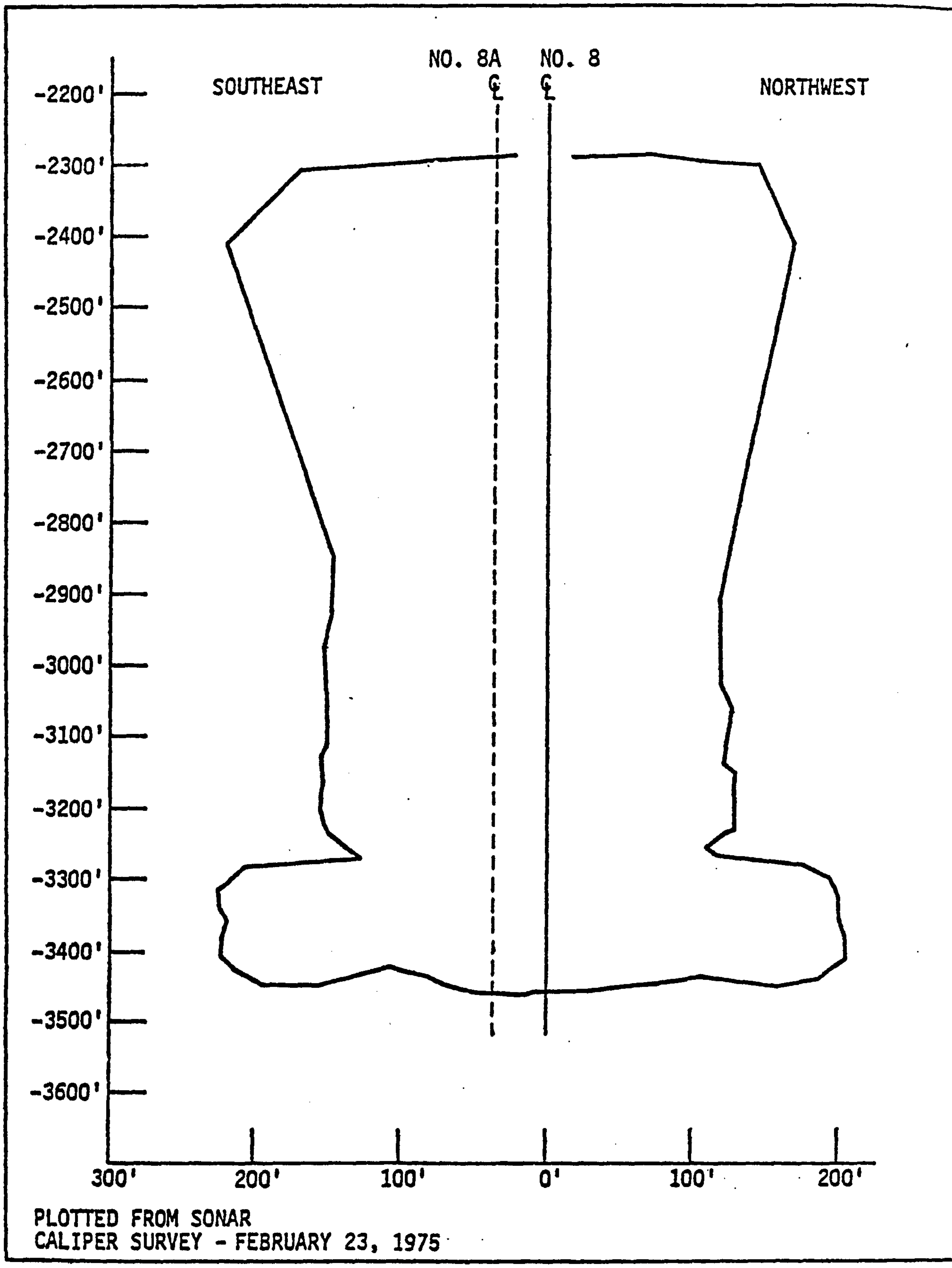

Figure H-6 Profile - Cavern No. 8 - West Hackberry Dome

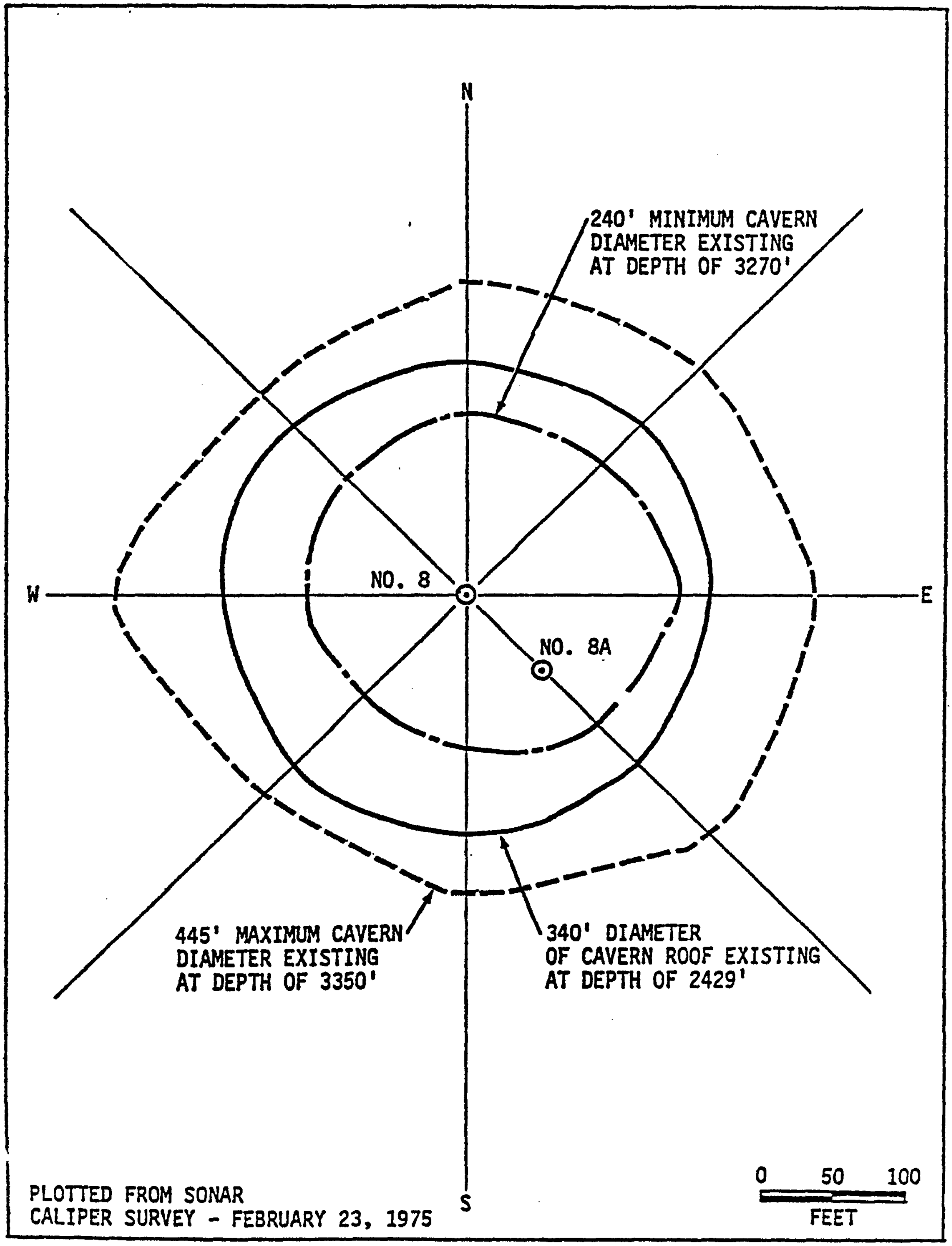

Figure H-7 Cavern No. 8 - West Hackberry Dome

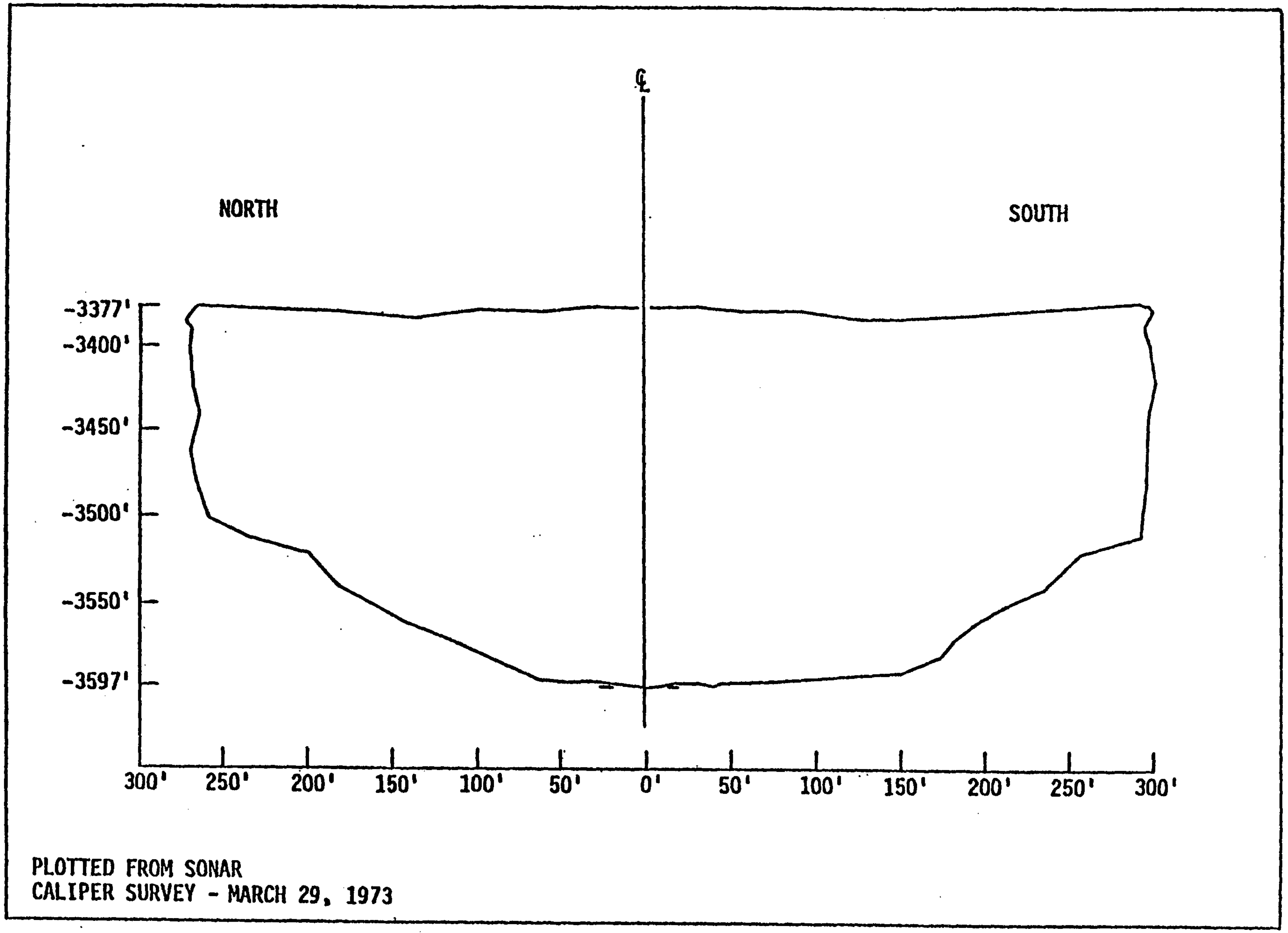

Figure H-8 Profile - Cavern No. 9 - West Hackberry Dome

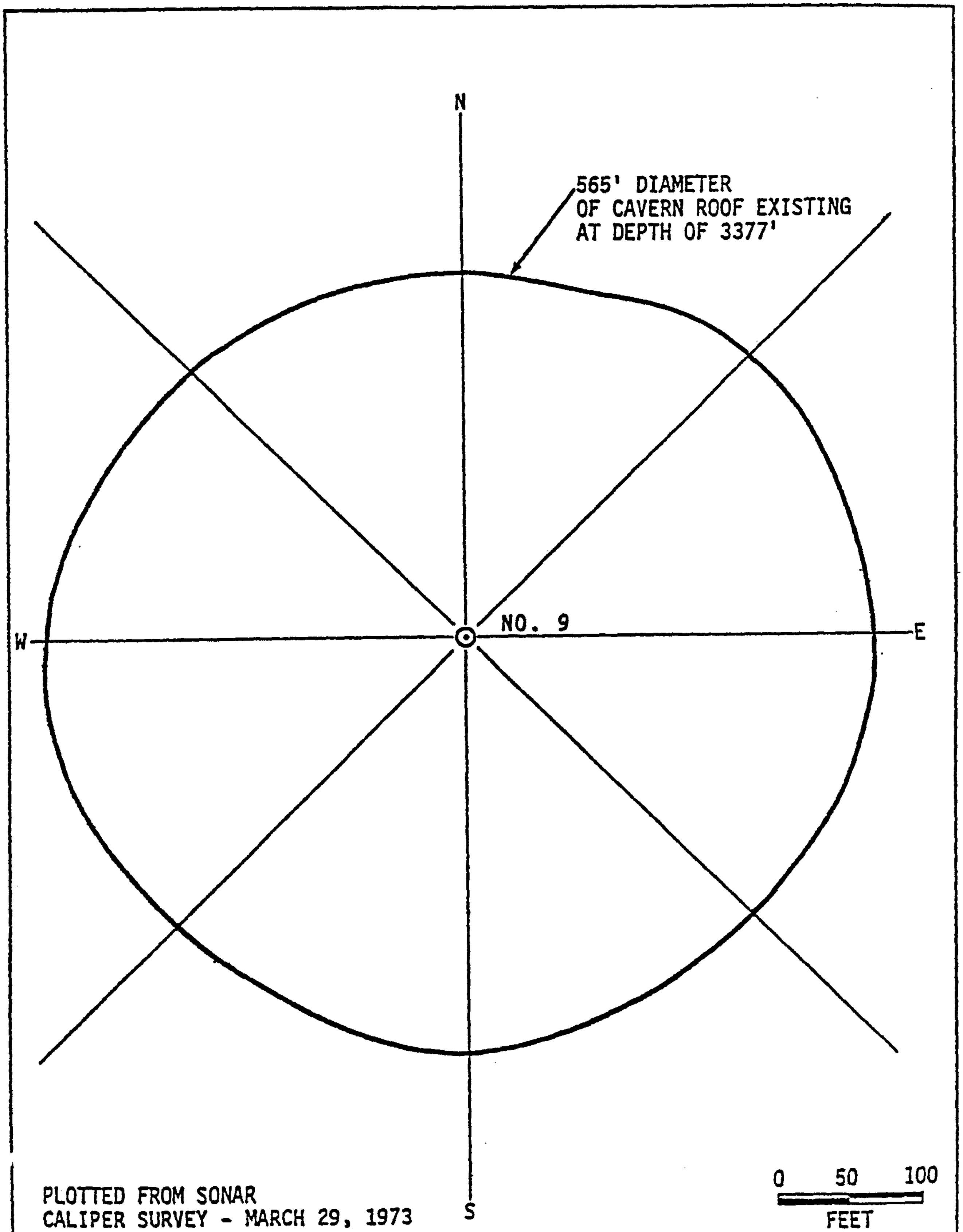

Figure H-9 Cavern No. 9 - West Hackberry Dome

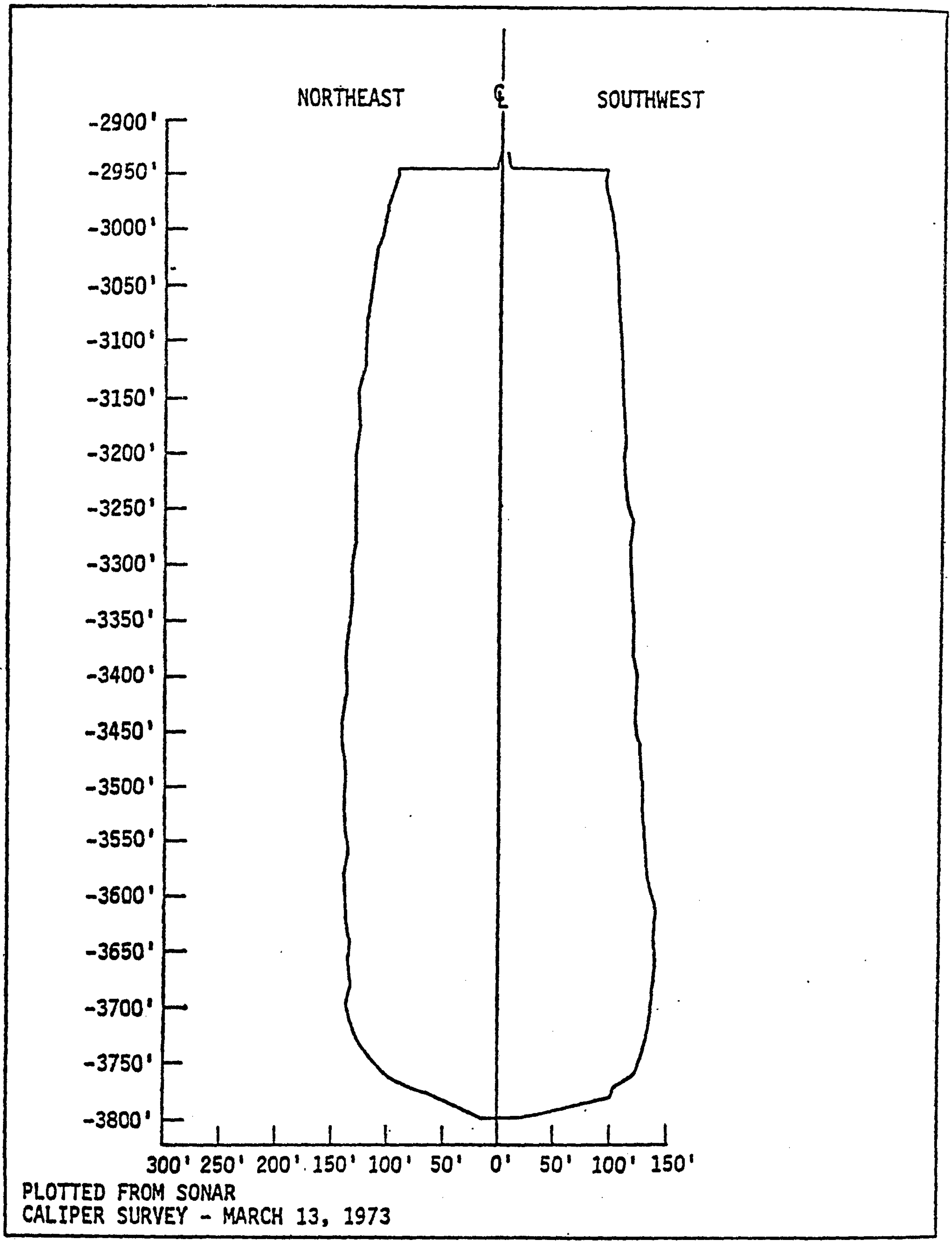

Figure H-10 Profile - Cavern No. 11 - West Hackberry Dome

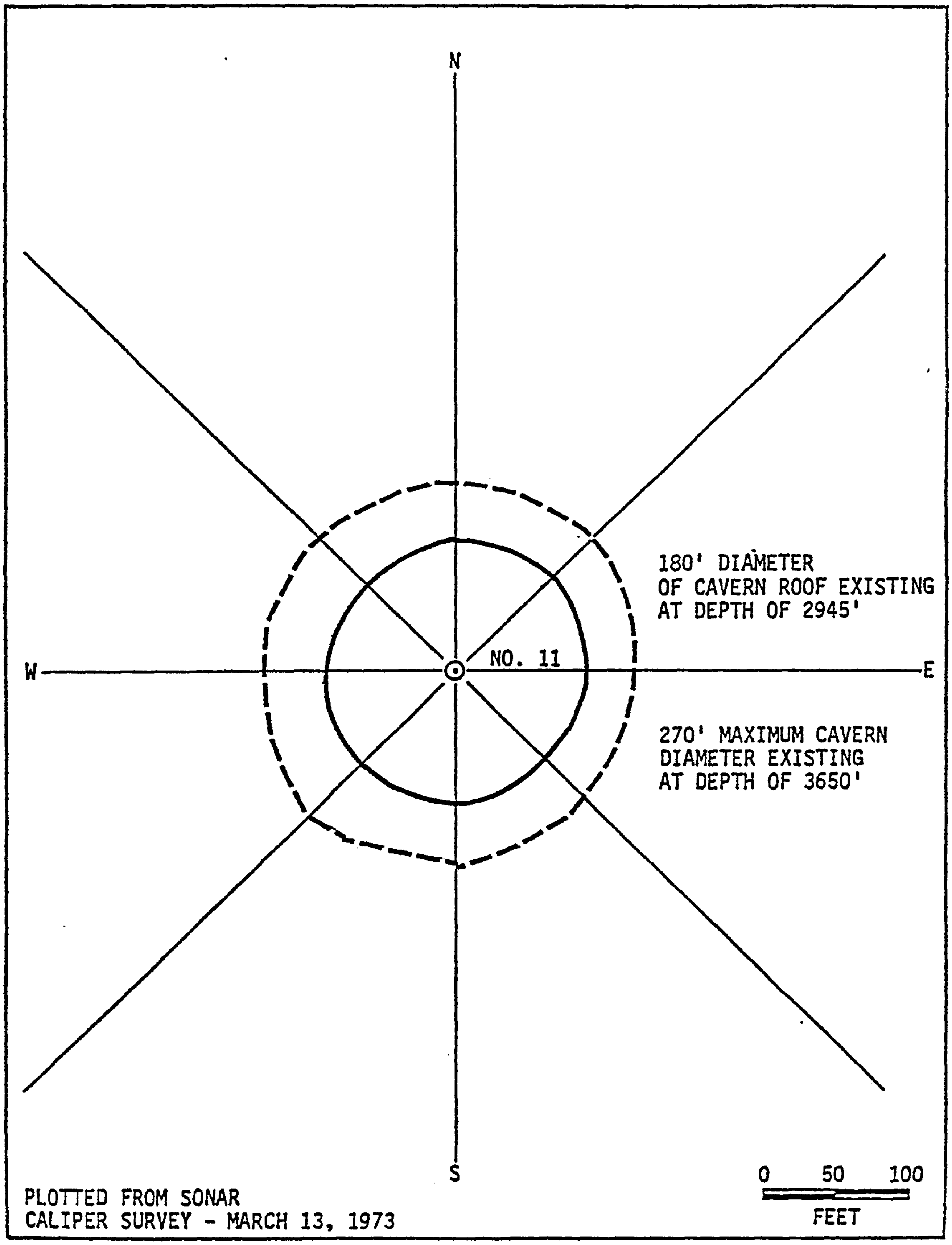

Figure H-11 Cavern No. 11 - West Hackberry Dome

The Olin caverns at West Hackberry are believed to be suitable for conversion to crude oil storage based on preliminary investigations. Three of the five caverns will require an auxiliary well to be drilled in order to meet the planned fill and withdrawal rates over a 150 day period. The existing well will be adapted to oil injection or recovery and the new well will be used for brine extraction and displacement water.

2. Cavity Conversion Procedures

The Olin caverns at West Hackberry are suitable for conversion to crude oil storage based on presently available information obtained from existing brine operations. All cavern roofs are below the cemented strings of casing. Sufficient salt sections exist in all wells between the cavern roofs and the top of the salt to minimize the possibility of oil loss through the caprock and into the upper strata. To certify the caverns for ultimate acceptability, pressure tests on both the casings and individual caverns will have to be conducted as part of the conversion procedures.

Caverns Nos. 6, 7, 8, and 9 are presently equipped with a 16 inch surface casing and 12-3/4 inch production casings. Cavern No. 11 is equipped with 20 inch surface casing and 13-3/8 inch production casings.

3. Well and Wellhead Conversions

Caverns No. 9 and 11 are scheduled for early fill from the temporary crude delivery facilities. To prepare these caverns for storage, the following steps are planned:

<u>Wells Nos. 9 and 11</u>:

(1) Remove blanket oil from cavern.
(2) Remove existing concentric brine casings.
(3) Run sonar caliper survey and cement bond and corrosion logs on the production casing.
(4) Pressure test casing.
(5) Pressure test cavern using saturated brine.
(6) Run and hang 9-5/8" displacement casing at the bottom of the storage interval and install new wellhead
(7) Connect well to oil, brine and raw water distribution systems.

Caverns No. 6, 7 and 8 are scheduled for later fill from the permanent crude delivery facilities. To accommodate the required flow rates for fill and withdrawal in 150 days, a twin entry well into each of these caverns will be constructed. The original wells will be adapted for crude oil injection and recovery. The new wells will be used for brine recovery and raw water injection.

<u>Wells Nos. 6, 7, and 8</u>:

(1) Remove blanket oil from cavern.
(2) Remove two concentric brine casings.
(3) Run sonar caliper survey and cement bond and corrosion logs on the 12-3/4" production casing.
(4) Pressure test casing.
(5) Pressure test cavern with saturated brine.
(6) Install new wellhead.
(7) Connect to oil distribution systems.

<u>Wells Nos. 6A, 7A, and 8A</u>:

(1) Drill 20"x13-3/8" cased hole into cavern, approximately 100' from the existing well. Before drilling into cavern, pressure test casing and cement job around casing shoe.
(2) Run and hang 10-3/4" displacement casing and install wellhead.
(3) Connect to brine and raw water distribution systems.

4. Drilling Procedures

The West Hackberry salt dome is reached at an average depth of 1,960 feet. Anhydrite caprock with a maximum thickness of 525 feet covers most of the dome's crest. The ceilings of the storage cavities range from 2,430 to 3,377 feet below the surface. The new wells will require 13-3/8 inch casing cemented to this depth and 10-3/4" displacement tubing suspended to the top of the sump interval (at about 3,500 feet).

Conventional oil rigs will be used. The majority of oil rigs are of the diesel powered rotary type. Some are directly coupled and some are diesel-electric. Casing sizes to be used for the project will be somewhat larger than required for "oil field" wells of comparable depth. Consequently, drill rigs may have "oil field" depth ratings up to

10,000 feet. The required finished casing size for the auxiliary wells is 13-3/8 inches, but because of the larger casings needed to cement the borehole at various intervals from the cavity to the surface, the various bore capabilities of the rig is critical.

A certain amount of difficulty in drilling through the caprock is expected. This happens most often when cavernous zones resulting from natural leaching of the anhydrite and gypsum formations cause a loss of the drilling fluid necessary for lubricating the bit and transporting spoil to the surface. In most cases, circulation can be re-established, but if caprock conditions at one of the re-entry wells fails in circulation, the well can be completed at greater expense without full circulation. It is estimated that in 20% of boreholing through caprock some difficulty with lost circulation may be experienced.

Drilling fluid, commonly called "mud," can be of a variety of constitutions, depending on drilling conditions. "Highly inhibited muds" may be required in difficult shales, but non-exotic clays will be used when possible. Needless to say, the cheapest and least toxic mud that will do the job would be used, but the actual formulation will be determined by experience on the site. It may be possible, in some instances, to get by with non-toxic "native muds" until the "top hole" is cased off, and then to convert to saturated brine. The salt must be drilled with salt saturated mud or brine to prevent hole enlargement by leaching.

Disposal of used muds is also an important consideration. Normal procedure is to transfer the mud with the rig, continually recycling a volume equal to twice the borehole size. There will be pits of saline mud which will have to be cleaned up and buried. In the Gulf Coast region, the humidity is too high to economically dry the waste. Therefore, mud will probably have to be hauled away when drilling operations are completed.

APPENDIX I

CAVERN DESIGN ANALYSIS

This appendix evaluates cavern design parameters at West Hackberry salt dome. The parameters include the cavern dimensions and configuration, proximity to other caverns, the salt dome boundary, the caprock, and the thickness of the plastic and brittle salt which encircles the caverns.[1,2]

Study of the available information for the five caverns has not revealed any reason to preclude recovery of all stored oil. All cavern roofs are below the cemented strings of casing and sufficient salt sections exist between the cavern roofs and the top of the salt to protect against oil loss into the caprock or the overlying strate. Cavern number 6, the closest to the salt dome boundary is approximately 900 feet from the northern boundary at a depth of 3,200 feet.

A detailed data summary of cavern descriptions based on sonar surveys of each cavern is shown in Table I.1. (Actual profiles appear in Appendix H). Sonar surveys, in addition to identifying cavern configuration, also provide a means for calculating the cavern volume, usually to within an accuracy of $\pm$ 5 percent.

Cones of influence* for each cavern were constructed based on empirical data from records of two cavern and mine collapses in the Gulf Coast. The cone boundary angles were 15° and 40° from the vertical. These data appear in Table I.2 (see Figure I.1 for graphic representation.

The growth of the caverns after various cycles cannot be precisely calculated. It is known that the caverns have the potential of increasing in volume by approximately 14 percent, but there are at least two major complicating factors: (1) some caverns have complicated shapes; (they differ significantly from cylinders, hence there is more

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*A cone of influence is actually a truncated cone (frustrum), apex down, projected from the caprock to the ground surface. The angle of the frustrum is dependent on the shear angle of the overburden. It is the largest volume of material above a cavern that could be influenced during a collapse.

Table I.1 Cavern Data* - for West Hackberry

Cavern No.	Depth Original	Depth Present	Top of Caprock	Top of Salt	Top of Cavern	Maximum Diameter	Cavern Height
6	4,060	3,404	1,598	1,949	3,240	885	164
7	3,538	3,498	1,551	1,965	2,540	420	958
8	4,010	3,453	1,515	1,991	2,429	490	1,024
9	4,053	3,597	1,550	2,153	3,377	565	220
11	4,060	3,797	1,529	2,056	2,945	270	852

* Measured in feet

Table I.2 West Hackberry Cone of Influence Data

Potentially Impacted Land	Cavern Number	Maximum Cavity Diameter (feet)	Depth to Caprock (feet)	Cone of Influence Angle (degrees)	Maximum-Minimum Cone Diameter (feet)	Acres in the Cone of Influence
3	6	885	1,598	40	3,567	229
				15	1,741	55
3	7	420	1,551	40	3,023	165
				15	1,251	28
3	8	490	1,515	40	3,032	166
				15	1,301	31
3	9	565	1,550	40	3,166	181
				15	1,396	35
1	11	270	1,529	40	2,836	145
				15	1,089	21

1 - Dry land
2 - Swamp/Marsh
3 - Flowing water
4 - Contained Reservoirs and Brine Ponds

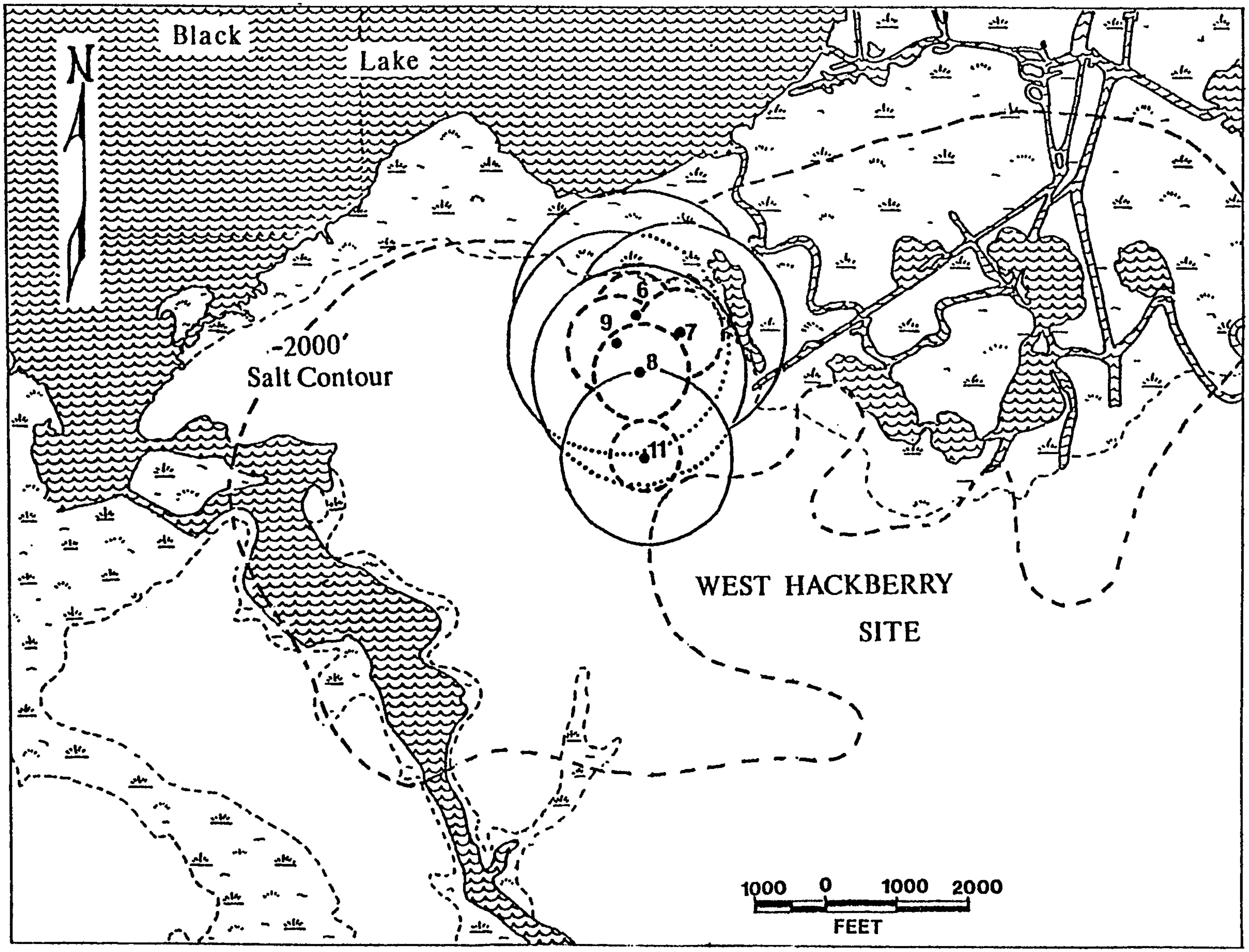

Figure I.1 Surface Projection of Maximum-Minimum Cones of Influence for each cavern at West Hackberry surface area at which dissolution could occur, and consequently the diameter increase estimates based on a 14 percent volume increase of a cylinder would be too large); (2) the length of time that the volume of fresh displacement water would have to become saturated is not known.* Nevertheless, to estimate the maximum possible cavern growth, diameters after each cycle were calculated for each cavern (Table I.3).** The assumptions were made that caverns were cylinders and that the displacement water became saturated in the caverns.

The maximum and minimum thicknesses of the combined brittle and plastic zone (Figure I.2) for the roof and walls were calculated using formulas (1) and (2), and the maximum range of values for the octahedral yield point τ_o reported in the literature[1] (τ_o = 700 psi to τ_o = 4,000 psi).

$$\delta_w = \frac{a}{2}\left[e^{\left(\frac{\Delta p}{6\sqrt{\tau_o}} - \frac{1}{2}\right)} - 1\right] \qquad (1)$$

where δ_w = thickness of plastic zone of the cavern wall

$\frac{a}{2}$ = radius of the cavern

Δp = pressure difference (between lithostatic pressure and minimum oil storage pressure)

τ_o = octahedral yield point**

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*Cavern growth can be prevented by using saturated brine as displacement water.

**It was assumed that the roof and floor were not leached because the roof is protected by an oil blanket and the floor is protected by insoluable residues that settle to the bottom during cavern formation. Natural gas pockets and unknown solution cavities cannot be predicted and therefore, are difficult to avoid where they exist. These conditions were not accounted for in these calculations.

**The octahedral yield point, is the magnitude of the shearing stress associated with the octahedral plane when yielding occurs. The octahedral plane is inclined so as to form an equal angle between the principal stress axes at a point in a stressed body. The octahedral yield point can only be determined by laboratory analysis of the compressive strength of salt taken from each specific site.

Table I.3 West Hackberry Cavern. - Diameter After Each Cycle

Cavern Number	Cavern Diameter (feet)	Cavern Height (feet)	Diameter after each Cycle* (feet)				
			1	2	3	4	5
6	800	164	854	912	973	1,038	1,100
7	420	958	448	480	513	548	586
8	425	1,024	453	484	516	551	588
9	565	220	604	645	690	737	788
11	270	852	288	308	329	352	377

*In theory the dissolution at any wall is equal to half the difference between the diameter of the cavern after each cycle and the original cavern diameter.

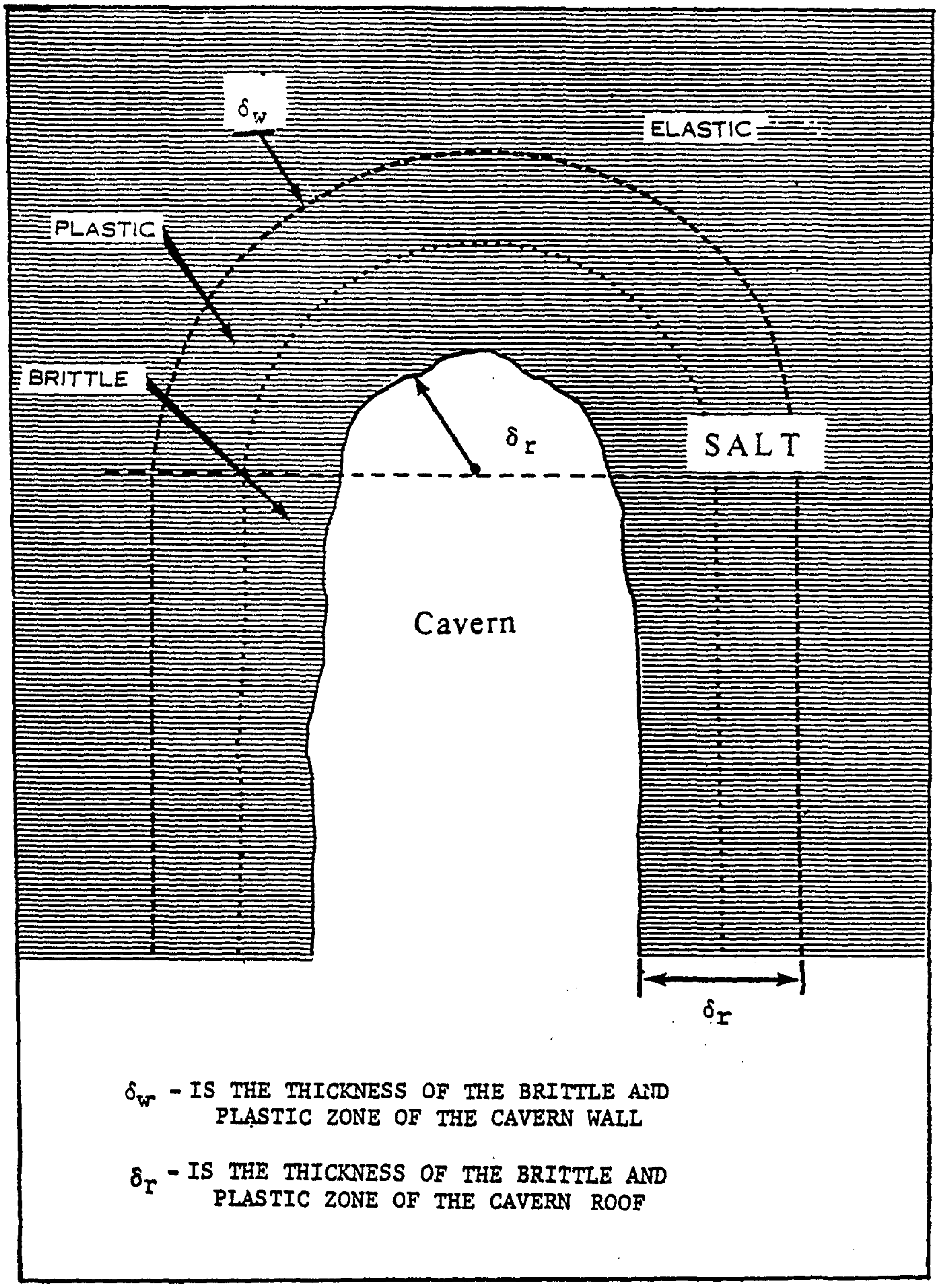

Figure I.2 Vertical Cross-Section of a Cylindrical Cavern With a Hemispherical Roof Illustrating the Thicknesses of the Brittle and Plastic Zones of the Walls and Roof

$$\delta_r = \frac{a}{2}\left[e^{\left(\frac{\Delta p}{\sqrt[3]{2}\,\tau_o} - \frac{1}{3}\right)} - 1\right] \qquad (2)$$

where δ_r = combined thickness of brittle zone and plastic zone at the roof of the cavern

a = diameter of the cavern

Δp = difference between the lithostatic pressure and the minimum oil storage pressure

τ_o = octahedral yield point

The pressure difference Δp can be calculated according to the relation

$$\Delta p = (\rho_r - \rho_o)(d_s + t)\, g \qquad (3)$$

ρ_r = average density of all solid material above the cavern

ρ_o = density of oil

d_s = depth to salt

t = thickness of salt roof

g = acceleration due to gravity

These formulas are based on plasticity theory and have been used successfully to size the critical dimensions of a system of storage cavities in salt.[1,3] The roof of salt over the cavity was designed so as not to be less than δ_w, and the horizontal distance between caverns was not to be less than $2\delta_r$. Figure I.2 illustrates a cylindrical cavern in vertical cross-section with the thickness of the brittle and plastic rock salt. In many cases, the computed thickness is observed to be a negative number (Table I.4 and I.5). This occurs when the upper range of the yield point is used for a particular cavern. Such a result indicates that for a high compressive strength there is no brittle or plastic zone; all of the salt surrounding the cavern is elastic. This, however, is unlikely and emphasizes the limitation of using ranges of data based on salt tests from other domes. The octahedral yield point of salt varies from dome to dome, and the actual value of this parameter is unknown at the caverns under consideration.

To obtain a closer approximation of the true value of τ_o for the roof and walls of each cavern, equations (1) and (2) were solved were solved for τ_o when the thickness of the combined brittle and plastic zone was assumed to be zero. The true value of τ_o then would be slightly greater than the result of this calculation.

Because of the form of equations (1) and (2), it is somewhat difficult to visualize the manner in which the computed thickness of the brittle and plastic zones varies with depth and with octahedral yield point. For the case of the cavern roof, based on equation (2), Figure I.3 provides a series of plots of the dimensionless ratio $2\delta_r/a$ (representing the computed thickness divided by the cavern radius) as a function of the roof depth, for values of τ_o varying from 100 psi to 4,000 psi. As indicated in Figure I.3, negative values of the roof thickness radius ratio are predicted for all the values of τ_o at shallow depth. With increasing depth, the ratio increases relatively slowly, but at some point becomes positive. The larger the value of τ_o, the greater the depth at which this crossover point occurs. For example, for a τ_o of 100 psi at the roof, the crossover point occurs at a depth of approximately 310 feet, while for a τ_o of 3,000 psi, the corresponding depth is roughly 8,900 feet. With increasing depth beyond the crossover point, the computed thickness continues to increase in an exponential fashion. Notice should be taken that the shapes of the curves presented in Figure I.3 (including the location of the crossover points) are independent of the cavern radius. The computed thickness itself is, however, directly proportional to the radius.

Similar plots of cavern wall thickness as a function of depth and octahedral yield point are provided in Figure I.4, based on equation (1). The general characteristics of the curves, as expected, closely resemble those given in Figure I.3. The computed thickness of the brittle and plastic zones for a cavern wall is, however, greater than the corresponding thickness for a cavern roof for the same depth and same value of τ_o.

The thickness of the zone of plasticity has been calculated for the roofs of all five caverns at West Hackberry (Table I.4). These thicknesses were calculated using formula (2). The thickness of the zone of plasticity has also been calculated for the walls of caverns 6 and 9, and 8 and 9 (Table I.5). The calculations for the cavern walls were made using formula (1).

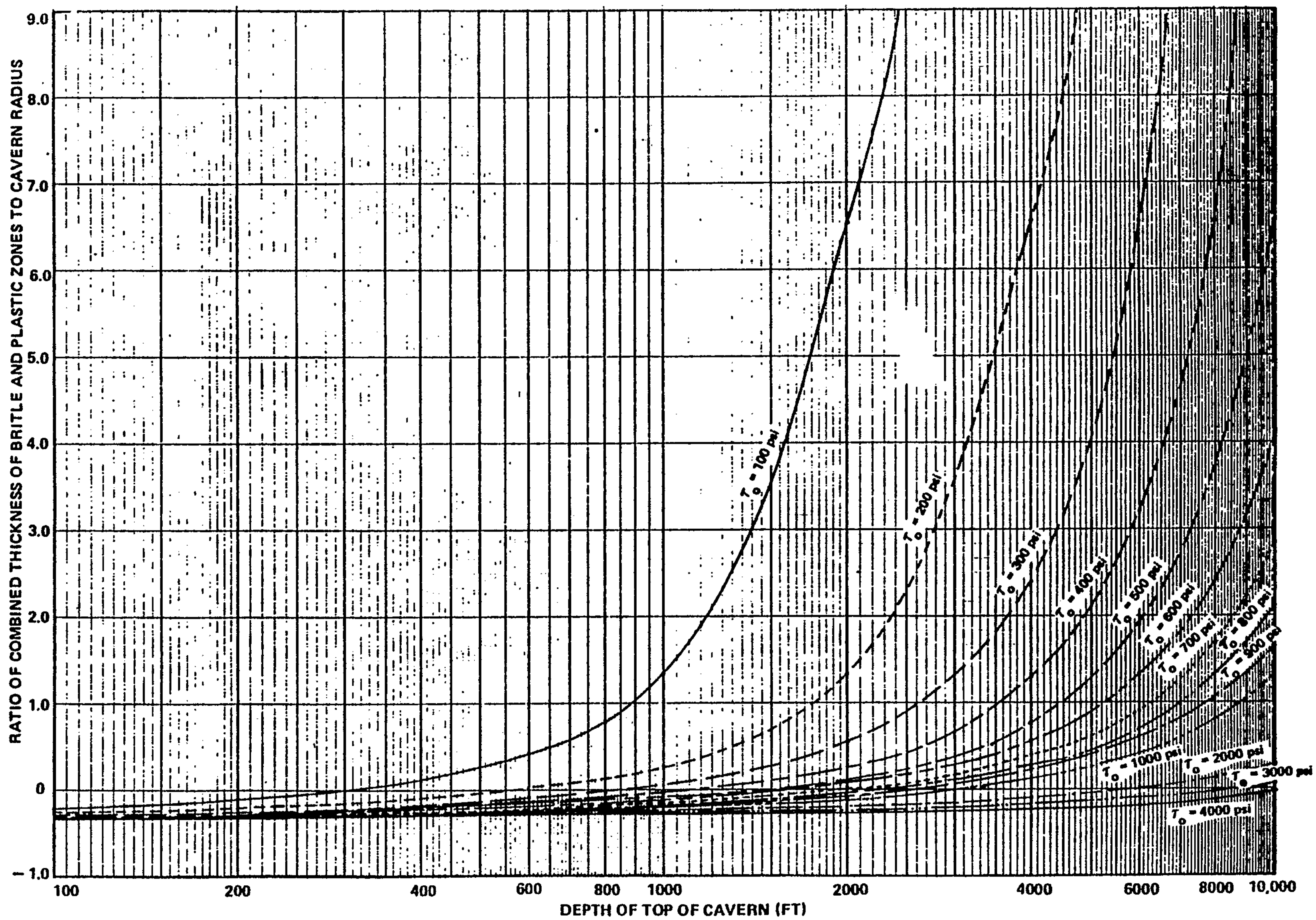

Figure I.3 VARIATION OF COMPUTED THICKNESS OF BRITTLE AND PLASTIC ZONES FOR CAVERN ROOF

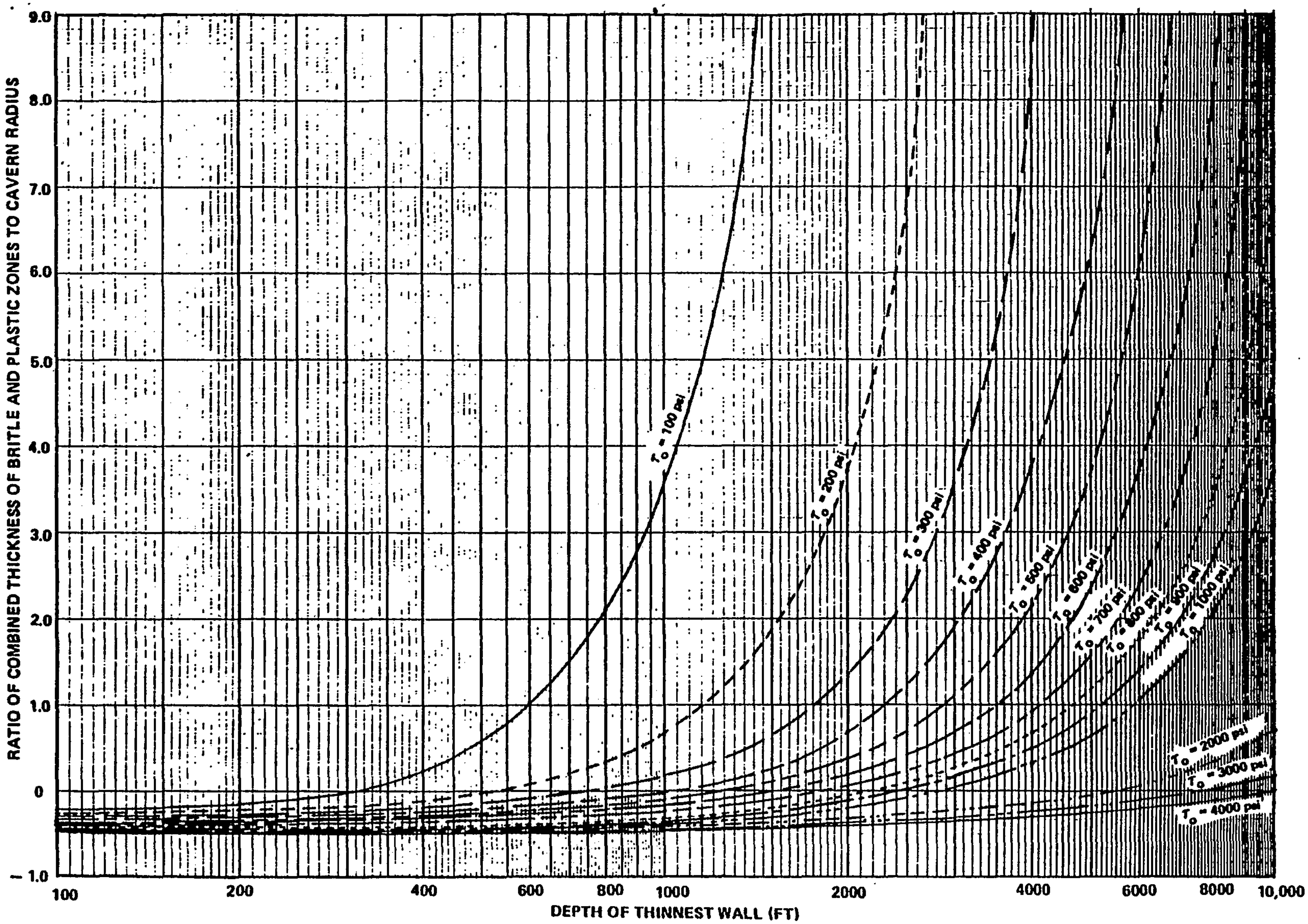

Figure I.4 VARIATION OF COMPUTED THICKNESS OF BRITTLE AND PLASTIC ZONES FOR CAVERN WALL

Table I.4 West Hackberry, Combined Thickness of Plastic and Brittle Zone in the Cavern Roof

(Expressed in Feet)

Cavern Number	Maximum Cavern Radius	Depth of Cavern Roof	Depth to Salt	Thickness of Roof Salt	Plastic Zone Thickness for Values of:		Values of τ_o With Zero Thickness of Plastic Zone
					τ_o = 700 psi	τ_o = 4000 psi	
6	443	3,240	1,949	1,291	104.7	-93.8	1,145 psi
7	210	2,540	1,965	575	20.8	-47.8	898 psi
8	445	2,429	1,991	438	35.0	-102.5	858 psi
9	283	3,377	2,153	1,224	75.0	-59.0	1,193 psi
11	135	2,945	2,056	889	23.8	-629.5	1,041 psi

Table I.5 West Hackberry - Combined Thickness of Plastic and Brittle Zone in the Cavern Wall

(Expressed in feet)

Cavern Number	Maximum Cavern Radius	Depth of Thinnest Wall	Actual Thickness Between Caverns	Plastic Zone Thickness for Values of: τ_0 = 700 psi		Plastic Zone Thickness for Values of: τ_0 = 4000 psi		Values of τ_0 With Zero Thickness of Plastic Zone
6	443	3,400	30 - 50	281.2	460.8	-123.4	null	1,388 psi
9	283	3,400		179.6		- 78.8		
8	245	3,400	140	155.5	335.1	- 68.2	null	1,388 psi
9	283	3,400		179.6		- 78.8		1,388 psi

Two octahedral yield points for salt were used: τ_o = 700 psi and τ_o = 4,000 psi. The roof thicknesses indicate that at τ_o 700 psi, 20 to 104 feet of salt are required to contain the plastic and brittle zones in the roof of these caverns. The negative values indicate that at, τ_o = 4,000 psi and at a given cavern depth and diameter, this value of the octahedral yield point of the salt exceeded the true value and therefore, there is no combined brittle and plastic zone.

Using τ_o = 700 psi, the thickness of the zone of plasticity of the wall of cavern 6 is 281 feet and for the wall of cavern 9 is 179 feet. Combined, the two zones exceed the 30 to 50 feet between the caverns. This means that there is no elastic salt between the caverns now and probably no plastic salt. The two caverns will have coalesced by dissolution of salt during the first cycle, or sooner if slabbing occurs. Similarly, caverns 8 and 9 combined have a thickness of plasticity that exceed the wall thickness between them. This again means that no elastic salt and little or no plastic salt exists between them. The possibility of coalescence by slabbing is therefore increased.

To reiterate, the calculations of diameter increase per cycle are based on the assumption that the displacement water will become saturated before being removed, and that the caverns are cylinders with dissolution of salt occurring at the walls only.

REFERENCES

APPENDIX I

[1]S. Serata and E. F. Gloyna, "Principles of Structural Stability of Underground Salt Cavities," Journal Geophysical Resources, 65, pp. 2979-2987, 1960.

[2]G. E. Korbin, "Simple Procedure for the Analysis of Deep Tunnels in Problematic Ground, 17th U.S. Symposium on Rock Mechanics," Snowbird, Utah, Utah Engineering Station, p. 1, A3-1, 7, 1976.

[3]H. Albrecht and M. Langer, "The Theological Behavior of Rock Salt and Related Stability Problems of Storage Caverns, Advances in Rock Mechanics, Proceedings of the Third Congress of the International Society for Rock Mechanics, Volume II, Part B, National Academy of Science, pp. 967-974, 1974.

APPENDIX J

DISCUSSION OF SUBSIDENCE

The collapse of a storage cavern in salt is not analgous to debris falling into an empty hole and causing a "sinkhole" at the surface. These caverns are always full of a nearly incompressible fluid, brine, or oil which if a collapse occurs is displaced volume for volume by falling caprock and overlying sediments.

There appear to be three possible types of surface subsidence associated with caverns in salt or the collapse of such caverns: subsidence due to creep closure of a cavern; subsidence due to surface emergence of oil, and subsidence due to absorption of oil into existing pore space. Only if the stored fluid reaches the surface or moves into voids or pores can there be surface subsidence during collapse.

Creep closure is the tendency of the salt surrounding a cavern to flow in toward the cavern causing a reduction in volume of the cavern. The caprock and sediments overlying a cavern with active closure will also tend to subside, but the rate of subsidence and ground surface manifestation will depend on the cavern depth and the elasticity of the salt and overlying sediments. The subsidence that might occur would probably be very broad (geographically) and shallow (nearly imperceptible without using surveying techniques).

Subsidence with surface emergence of oil can be envisioned by the following analogy. (This analogy is used to illustrate a point and it is not suggested in this report to be a real possibility). If the entire column of sediment, above the cavern has a diameter equal to the diameter of a cylindrical cavern and a height equal to the depth of the cavern roof, and it is lowered into the cavern by a distance equal to height of the cavern in a manner analogous to a piston in a cylinder, and if the fluid in the cavern was completely displaced by percolating through the sediments of the "piston" rather than compressed, there would be a surface depression equal in volume to the original cavern filled but not overflowing with the displaced fluid. This is a simplified case which assumes that, the imperfect packing of falling particles, adsorption, absorption, dissolution, and trapping of the displaced fluid do not occur. In reality, these five mechanisms reduce the amount of oil that will continue to rise through a cone of influence* and emerge on the surface. With these mechanisms, oil will probably reach the surface as small seeps, and as the sediment settles into the place formerly occupied by the oil, a small surface depression will form. Multiple depressions will appear as a wide area of shallow subsidence filled with oil.

The third type of subsidence occurs without surface emergence of oil. Using the piston and cylinder model again with the assumption that the oil percolates up through water saturated sediments that have zero empty pore space, there is a volume for volume displacement of oil and by the laws of conservation of mass, the combined volume of the oil and saturated sediments remains constant. Now envision an overlying layer of unsaturated sediment with unit volume and empty pore space. If the oil moves up from the saturated layer into the empty pores of the unsaturated layer, there would be a volume decrease in the saturated layer, but the volume of the unsaturated layer would remain constant as long as the oil only fills empty space. The result of "deflating" the saturated layer would be subsidence of the upper layer which now contains oil in the previously empty pore space. Oil would not emerge on the surface unless all of the pore space near a potential seep was filled with oil.

The rate at which collapse and subsidence proceeds has not been quantified, but estimates range from 36 hours to 36 days. Since the viscosity of oil is much greater than brine, the collapse will proceed slower when the cavity contains oil, a surface depression is less likely to form, and a depression caused by collapse of an oil-filled cavern probably will be smaller than a surface dispersion of a brine-filled cavern collapse. There are two reasons for this: (1) a smaller volume of oil will be injected into caprock voids and almost none into aquifers leaving less room for subsidence, and (2) less oil will reach the surface because oil will be trapped more easily than brine.

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*A cone of influence is actually a truncated cone (frustrum), apex down, projected from the caprock to the ground surface. The angle of the frustrum is dependent on the shear angle of the overburden. It is the largest volume of material above a cavern that could be influenced during a collapse.

APPENDIX K - LETTERS FROM RESPONDENTS

Advisory Council on
Historic Preservation
1522 K Street N.W.
Washington, D.C. 20005

October 1, 1976

Mr. Robert L. Davies
Deputy Assistant Administrator
Strategic Petroleum Reserve
Federal Energy Administration
Washington, D. C. 20461

Dear Mr. Davies:

This is in response to your request of September 10, 1976 for comments on the draft environmental statement for the proposed storage of crude oil at the West Hackberry Salt Dome located in Cameron Parish, Louisiana. Pursuant to its responsibilities under Section 102(2)(C) of the National Environmental Policy Act of 1969, the Advisory Council on Historic Preservation has determined that while you have discussed the historical, architectural, and archeological aspects related to the undertaking, the Advisory Council needs additional information to adequately evaluate the effects on these cultural resources. Please furnish additional data indicating:

I. Compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470[f]). The Council must have evidence that the most recent listing of the National Register of Historic Places has been consulted (see Federal Register, February 10, 1976 and monthly supplements each first Tuesday thereafter) and that either of the following conditions is satisfied:

   A. If no National Register property is affected by the project, a section detailing this determination must appear in the environmental statement.

   B. If a National Register property, or property "eligible for inclusion" in the National Register (Section 106, as amended September 28, 1976, PL 94-422) is affected by the project, the environmental statement must contain an account of steps taken in compliance with Section 106 and a comprehensive discussion of the contemplated effects on the National Register property. (36 C.F.R. Part 800 details compliance procedures.)

II. Compliance with Executive Order 11593, "Protection and Enhancement of the Cultural Environment" of May 13, 1971.

A. Under Section 2(a) of the Executive Order, Federal agencies are required to locate, inventory and nominate eligible historic, architectural and archeological properties under their control or jurisdiction to the National Register of Historic Places. The results of this survey should be included in the environmental statement as evidence of compliance with Section 2(a).

B. Until the inventory required by Section 2(a) is complete, Federal agencies are required by Section 2(b) of the Order to submit proposals for the transfer, sale, demolition, or substantial alteration of federally owned properties eligible for inclusion in the National Register to the Council for review and comment. Federal agencies must continue to comply with Section 2(b) review requirements even after the initial inventory is complete, when they obtain jurisdiction or control over additional properties which are eligible for inclusion in the National Register or when properties under their jurisdiction or control are found to be eligible for inclusion in the National Register subsequent to the initial inventory.

The environmental statement should contain a determination as to whether or not the proposed undertaking will result in the transfer, sale, demolition or substantial alteration of eligible National Register properties under Federal jurisdiction. If such is the case, the nature of the effect should be clearly indicated as well as an account of the steps taken in compliance with Section 2(b). (36 C.F.R. Part 800 details compliance procedures.)

C. Under Section 1(3), Federal agencies are required to establish procedures regarding the preservation and enhancement of non-federally owned historic, architectural and archeological properties in the execution of their plans and programs.

The environmental statement should contain a determination as to whether or not the proposed undertaking will contribute to the preservation and enhancement of non-federally owned districts, sites, buildings, structures and objects of historical, architectural or archeological significance.

III. Contact with the State Historic Preservation Officer.

The procedures for compliance with Section 106 of the National Historic Preservation Act of 1966 and the Executive Order 11593 require the Federal agency to consult with the appropriate State Historic Preservation Officer. The State Historic Preservation Officer for Louisiana is Ms. Ruth LeCompte, State Historic Preservation Officer, Department of Art, Historical and Cultural Preservation, Old State Capitol, North Boulevard, Baton Rouge, Louisiana 70801.

Should you have any questions or require any additional assistance, please contact Michael H. Bureman of the Advisory Council staff at P. O. Box 25085, Denver, Colorado 80225, telephone number (303) 234-4946.

Sincerely yours,

Michael H. Bureman

Louis S. Wall
Assistant Director, Office
of Review and Compliance

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60267
NEW ORLEANS, LOUISIANA 70160

IN REPLY REFER TO
LMNPD-RE

10 November 1976

Mr. Steven E. Ferguson
Executive Communications
Room 3309
Federal Energy Administration
Washington, DC 20461

Dear Mr. Ferguson:

Your draft environmental impact statements (EIS) for the first five candidate sites selected for possible use as petroleum storage facilities for the initial phase of the Strategic Petroleum Reserve (SPR) were referred to this office from our Washington Office for comment.

We have reviewed the EIS's for the following candidate sites: West Hackberry salt dome, Bayou Choctaw salt dome, Cote Blanche Island mine, Weeks Island mine, and Bryan Mound salt dome. They have been reviewed in accordance with our areas of responsibility and expertise as outlined in the Council on Environmental Quality guidelines, Title 40 C.F.R., part 1500, published in the Federal Register dated 1 August 1973, and US Army Corps of Engineers administrative procedures for permit activities in navigable waters or ocean waters, Title 33, C.F.R., Part 209, published in the Federal Register dated 25 July 1975.

We offer the following comments regarding the five draft impact statements for your consideration:

a. Comments on West Hackberry site.

(1) General comments.

(a) The West Hackberry site has significant potential for adverse impacts upon the water quality of the adjacent area. The assumption that the naturally occurring sediments in the area of Black Lake are predominantly sand, may be in error. Available soil curves for the material removed during dredging activities in the Calcasieu River at this point indicate a high amount of silt. This could greatly increase the amount of heavy metals, nutrients, and pesticides released to the water column over that as assumed in the EIS. The establishment of soil characteristics (soil curves) and elutriate analyses should be made to quantify the impacts upon the water column. The effluent from any unconfined disposal or open water disposal of dredged material could have a significant impact upon Calcasieu Lake. The minimal release of mercury mentioned (15 ug/l) is significantly above the criteria limit of 0.1 ug/l as established by the 1975 EPA, Proposed Criteria for Water Quality-Marine Water Constituents (Aquatic Life). This site is the least acceptable alternative as far as the impacts upon the water quality in the project area are concerned.

(b) Some areas lack site-specific information which is required to adequately assess the probable impacts. Emphasis is placed too heavily on data taken from areas removed from the project area.

(2) Specific comments.

(a) Page 1-6, paragraph 2. Sabine National Migratory Waterfowl Refuge should be Sabine National Wildlife Refuge.

(b) Page 1-26, paragraph 2. This statement excludes the push-ditch method of pipeline installation which is normally preferred for installation of pipelines in marsh areas of coastal Louisiana. Experience has shown that this method greatly reduces potential environmental damage and it has been proven feasible for lines in excess of 40 inches in diameter.

(c) Page 2-15. Aerial photograph is erroneously labeled. The area labeled "flooded marsh" has not been a marsh for many years; and, "road platform to oil wells" is not a road but is a walkway.

(d) Page 2-26, paragraph 1. Black Lake is part of a contributing productive marsh system and specific water quality and sediment data are required to fully assess and evaluate the impacts.

(e) Page 2-63, table 2.8. We recommend inclusion of Delphinids under "Typical Mammals" and "Inland and Estuarine Waters."

(f) Page 2-72, paragraph 1. Primary productivity, as well as salinity is certainly a controlling factor in the number of species present.

(g) Page 2-72, paragraph 2, line 13. Does this statement imply that the genus is present and/or dominant in the project area?

(h) Page 2-72, paragraph 2, line 17. Some of these genera are not "epiphytic" algae.

(i) Page 2-72, paragraph 4. Site-specific information is necessary. Black Lake cannot be accurately compared to Calcasieu Lake.

(j) Page 2-73, paragraph 1. Further explanation is needed concerning recent salinity increases in the project area, especially the impacts of the Intracoastal Waterway and Calcasieu River upon salinity alterations.

(k) Page 2-76, last paragraph. In 1975 and 1976, the American alligator was harvested for its hide in parts of Cameron, Calcasieu, and Vermilion Parishes.

(l) Page 2-80, paragraph 2. We suggest the word "Atlantic" be placed before "Croaker."

(m) Page 3-3, paragraphs 2 and 3. There will be significant turbidity and bottom erosion due to the turbulence. Reference 4 is not based on sound data from properly conducted studies.

(n) Page 3-10, paragraph 4. Figure 3.4 has been omitted. The location of dredged material disposal areas will be determined by the Corps permit application process. Note General Comment e(2) below, also.

(o) Page 3-19, paragraph 3. A description of the disposal operation is necessary before the impacts can be adequately assessed.

(p) Page 3-29, last paragraph. Water quality data for the Calcasieu River is available from the New Orleans District Office.

(q) Page 3-66, paragraph 4. Construction of roads in wetlands usually constitutes a permanent loss of wetlands and should not be considered a "short-term" impact.

(r) Page 3-68, paragraph 3. Further discussion is needed to explain phytoplankton productivity increases resulting from turbidity. We believe there will be decreases in productivity.

(s) Page 3-112, paragraph 2. Reduction of food supply and habitat description will definitely be of importance.

(t) Page 4-5, paragraph 2. Direct contact of the less mobile benthic organisms with oil is likely, and not unlikely as stated in the EIS.

(u) Page 4-9. Shared uses of disposal areas may not always be permissible. Note General Comment e(2) below, also.

(v) Page 6-1, paragraph 6. In wetlands, natural grasses are usually allowed to revegetate pipeline corridors; hence, installation would not represent a permanent loss of resources. The total of 350 acres of land appears to be excessive for pipeline right-of-way.

(w) Page 6-2, paragraph 2. The withdrawal of surface water may be very significant depending upon the volume of runoff and the time of the year the surface water is withdrawn.

(x) Page 9-3. State of Louisiana regulatory bodies were omitted from this table.

b. Comments on Bayou Choctaw site.

(1) General comment

As stated for the West Hackberry site, the comment on the push-ditch method of pipeline installation applies to this site also.

(2) Specific comments.

(a) Page 2-4, figure 2-2. The area labeled "marsh" should be changed to "swamp" to conform to the description on page 2-3, paragraph 3, which is correct.

(b) Page 2-15, paragraph 1, sentence 2. We disagree with this statement. The first sentence on page 1-23 indicates that about 1,150 acres of wooded swamp would be utilized for the brine disposal system. The wildlife resources of 1,150 acres of wooded swamp are not considered insignificant.

(c) Page 2-73, paragraph 1. The loblolly pine is generally absent from the Mississippi River flood plain and should be deleted from this paragraph.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIRST INTERNATIONAL BUILDING
1201 ELM STREET
DALLAS, TEXAS 75270

November 1, 1976

Mr. Robert L. Davies
Deputy Assistant Administrator
Executive Communications - Room 3309
Federal Energy Administration
Washington, D. C. 20461

Dear Mr. Davies:

We have reviewed the Draft Environmental Impact Statement for the Strategic Petroleum Reserve at West Hackberry Salt Dome, Cameron Parish, Louisiana. The purpose of the Reserve is to mitigate the social and economic impacts of future interruptions of petroleum imports to the United States of America. The Reserve will store 150 million barrels of oil by December of 1978 in the Early Storage Reserve (ESR), and 500 million barrels by 1982 under the entire program.

The proposed action with the West Hackberry Salt Dome is a part of the ESR and proposes to store 60 million barrels of crude oil in the salt dome presently used by Olin Corporation for brine production and by Cities Services for hydrocarbon product storage.

We offer the following comments for your consideration in developing the Final Environmental Impact Statement (EIS):

1. When the oil is removed from the salt domes for the first time, some oil will remain on the walls of the cavities and in the brine. The brine displaced when oil is reintroduced to the caverns will likely carry some of this oil with it. The final statement should provide assurances that the concentration of entrained oil in the brine would not adversely impact the water quality of salt water aquifers. The statement should discuss the possible need for treatment of the brine for removal of oil. Also, a quantitative discussion of evaporative hydrocarbon emissions originating from the brine storage pit should be included in the statement.

2. The buried pipelines will be coated with a protective coating. The Final EIS should discuss possible leaching of the protective material into the soil and groundwater.

3. The water withdrawal source for displacement operations is stated to be either Black Lake Bayou (pages 1-10, 1-19, 3-70, 4-9), Black Lake (pages 3-26, 7-52) or Black Lake/Black Lake Bayou (page 4-1). The EIS

should be consistent in its description. Apparently, the actual source will be the Bayou, at a point 1500 feet downstream from Black Lake. The Final EIS, should provide representative water quality data for the Black Lake Bayou.

4. Salt water intrusion is described as a major problem in the area. Although the EIS claims that withdrawal of displacement water and dredging will have a minimal impact on the salinity of the affected water bodies, we suggest that a periodic monitoring system be considered to determine if changes in the salinity of the lakes and bayous as well as northern migration of isohalines is occurring.

5. The effects of the disposal of dredged material from Alkali Ditch cannot be assessed at this time because the exact arrangement has not been defined. This decision should be made in the final EIS to provide for a description of the impacts. Also, the final EIS should state whether the disposal area will be confined or unconfined.

6. The actual effects of the disposal of the brine in the salt water aquifers cannot be determined because chemical and biological tests have not been conducted on the brine and aquifer waters. The Final EIS should state when such tests will be performed, especially since deep well injection is the proposed method of brine disposal.

7. The Final EIS should describe methods for the treatment and disposal of sanitary wastes during and after construction of the facility.

8. The EIS mentions a Coast Guard recommendation to minimize the effects of pipeline failure by using trenches for collection at the points of entry to the water bodies (page 4-3). The EIS should state whether this recommendation is feasible and if it will be followed.

9. The Lone Star site would produce considerably fewer construction and dredging impacts than the proposed new terminal, with the exception of more pipeline construction through marsh land. We suggest that this alternative be explored further in the Final EIS.

10. The Louisiana State Implementation Plan (SIP) required revision for photochemical oxidants for the Louisiana portion of the Southern Louisiana-Southeast Texas Air Quality Control Region (AQCR) 106 in the Federal Register, Volume 41, No. 138, July 16, 1976. Oxidant air quality data recorded during 1975 showed the AQCR recorded second high oxidant levels for the Baton Rouge area at 0.170 ppm, New Orleans at 0.094 ppm and Lake Charles at 0.174 ppm. We feel that the above information should be included in the final impact statement along with discussion of how this facility will affect the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS).

11. The draft statement indicates that vapor recovery systems may be used for vessel loading/unloading (page 3-51), with surge and floating roof storage tanks (pages 4-16 and 4-17) leading to negligible hydrocarbon emissions. We would recommend consideration be given to the use of vapor recovery systems because of the area's oxidant problems. The final impact statement should discuss the technical and emission characteristics of such systems.

These comments classify your Draft Environmental Impact Statement as LO-2. Generally, we have no objections to the project as proposed in the Draft Environmental Impact Statement. However, we are requesting more information regarding possible impacts to the water and air quality of the area. The classification and the date of our comments will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions, under Section 309 of the Clean Air Act.

Definitions of the categories are provided on the attachment. Our procedure is to categorize our comments on both the environmental consequences of the proposed action and on the adequacy of the impact statement at the draft stage, whenever possible.

We appreciate the opportunity to review the Draft Environmental Impact Statement, and we would be happy to discuss our comments with you. Please send us two copies of the Final Environmental Impact Statement at the same time it is sent to the Council on Environmental Quality.

Sincerely yours,

John C. White

John C. White
Regional Administrator

Enclosure

ENVIRONMENTAL IMPACT OF THE ACTION

LO - Lack of Objections

EPA has no objections to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER - Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to re-assess these aspects.

EU - Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

ADEQUACY OF THE IMPACT STATEMENT

Category 1 - Adequate

The draft impact statement adequately sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 - Insufficient Information

EPA believes the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However; from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3 - Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement. If a draft statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make such a determination.

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

IN REPLY REFER TO

OCT 14 1976

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

245001

Gentlemen:

We appreciate the opportunity to comment on the five site-specific Draft Environmental Impact Statements for the proposed Strategic Petroleum Reserve (SPR) mandated by Congress under the Energy Policy and Conservation Act of 1975 (P.L. 94-163). We note that this act requires that by 1983 the SPR contain a reserve of approximately 500 million barrels of crude oil to provide protection from potential disruptions to the national supply of petroleum products.

The Federal Power Commission, Bureau of Natural Gas staff has reviewed the SPR impact statements and offers the following comments:

> At the five site locations analyzed, there does not appear to be any conflict between the development of the SPR and the continued production, transportation, and sale of natural gas from domestic sources. It therefore does not appear that the proposed project presents any conflict with FPC jurisdictional interests.
>
> The staff believes that the development of an SPR would protect the supply of energy sources other than oil itself during an emergency. A drastic reduction in oil availability could, for example, be accompanied by increased demand for natural gas for use in electric generation. Such use is regarded as inferior and as having a low priority in view of the needs of industrial, commercial, and residential customers who are feeling the impact of a worsening natural gas shortage. The SPR would lessen the impact of a simultaneous shortage in oil and gas which together provide about three-quarters of the energy consumed in this country.

The Federal Power Commission is actively directing its attention and efforts toward regulatory actions to improve the current imbalance between natural gas supply and demand. After reviewing the SPR site-specific draft environmental impact statements, we believe that the proposed project would be in the national interest.

S. William Yost, Chief
Bureau of Natural Gas

00009

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

OFFICE OF THE SECRETARY

WASHINGTON, D.C. 20201

NOV 10 1976

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Gentlemen:

This Department has reviewed the draft environmental impact statements concerning 1) West Hackberry salt dome, 2) Bayou Choctaw salt dome, 3) Byran Mound salt dome, 4) Cote Blanche salt mine, and 5) Weeks Island salt mine. We feel that the concerns of this Department have been adequately addressed.

Thank you for the opportunity to review the document.

Sincerely,

Charles Custard
Director
Office of Environmental Affairs

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NOV 4 1976

Executive Communications
Room 3309
Federal Energy Administration
Washington, D. C. 20461

00001

Dear Sirs:

This is in response to your letter of September 10, 1976, inviting our comments on the draft environmental statements concerning the following projects:

West Hackberry Salt Dome, DES 76-4
Bayou Choctaw Salt Dome, DES 76-5
Bryan Mound Salt Dome, DES 76-6
Cote Blanche Mine, DES 76-7
Weeks Island Mine, DES 76-8

We have reviewed the statements and have determined that the proposed actions, per se, have neither radiological health and safety aspects nor will they adversely affect any activities subject to regulation by the Nuclear Regulatory Commission. Accordingly, we have no comments to offer.

Thank you for providing us with the opportunity to review these draft environmental impact statements.

Sincerely,

Voss A. Moore, Assistant Director
for Environmental Projects
Division of Site Safety and
Environmental Analysis

TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401

October 28, 1976

Mr. Robert L. Davies
Deputy Assistant Administrator
Federal Energy Administration
Room 3309, Executive Communications
Washington, D.C. 20461

Dear Mr. Davies:

We have determined that we have no significant substantive comments on any of the five sites or statements involved in the Strategic Petroleum Reserve.

Sincerely,

Peter A. Krenkel, Ph.D., P.E.
Director of Environmental Planning

U.S. DEPARTMENT OF TRANSPORTATION

REGIONAL REPRESENTATIVE OF THE SECRETARY
9-C-18 FEDERAL CENTER
1100 COMMERCE STREET
DALLAS, TEXAS 75202

Adm.
Dep.
Dep. Comp.
Exec.
Congr.
SWFRC
Consumer Aff.
EEO
PIO
Legal
RARP
Fred/Proc
Wh/Ret
Enf/Appeals
Mgmt.
Opns.
Consv.
Res. Dev.
Energy Study
Compliance
RARP
Fred/Proc
Wh/Ret
Area Mgrs.
Dist. A

October 27, 1976

Mr. Delbert Fowler
Regional Administrator
Federal Energy Administration
P. O. Box 35228
Dallas, Texas 75235

Dear Del:

Enclosed are comments concerning Environmental Impact Statements covering Weeks Island and Cote Blanche Mines and West Hackberry and Bayou Choctaw Salt Domes. One additional copy has been provided for your Washington office.

Thank you for the opportunity to review the Statements.

Sincerely,

Ed Foreman

ljb
Enclosures

Form FHWA 121 (Rev. 5-73)

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: October 15, 1976

In reply refer to: 06-22.2

SUBJECT: Other Agency Statements
Federal Energy Administration
Strategic Petroleum Reserve
Weeks Island and Cote Blanche Mines
West Hackberry and Bayou Choctaw Salt Domes

FROM: Division Administrator
Baton Rouge, Louisiana

TO: Mr.J. W. White, Regional Administrator
06-00.8 Fort Worth, Texas

Your September 27, 1976, memorandum requested our review and comments on the subject statements.

The following comments are offered for your consideration in responding to the Federal Energy Administration:

Circulation of the draft environmental impact statements to state agencies was handled through the state clearing houses. It would appear that for states where the proposed sites are located, direct circulation to affected state agencies would be appropriate.

For both the Bayou Choctaw and the West Hackberry Salt Dome facilities associated proposed pipeline alternatives will cross or utilize highway right-of-way. Coordination with the Louisiana Department of Highways is recommended, if not already done.

Table 9.2, page 9-5, in the West Hackberry statement, list Texas regulatory bodies instead of appropriate Louisiana regulatory bodies.

Consultation with the Louisiana Department of Highways is recommended if overweight construction traffic is anticipated during construction of the facility.

The proposed Strategic Petroleum Reserve sites should not have any adverse effect on the highway transportation facilities in the affected areas.

for: M. C. Reinhardt

THE DEPARTMENT OF THE TREASURY
WASHINGTON, D.C. 20220

ASSISTANT SECRETARY

NOV 1 1976

Dear Mr. Davies:

This is in response to your letter of September 16 requesting that this Department review and comment on the draft environmental impact statements for the first five candidate sites selected for possible use as petroleum storage facilities for the Early Storage Reserve. We find the statements to be objectively directed to their stated purpose and it appears that the salt dome and mine storage facilities addressed in the statements are superior to above ground storage from both the economic and environmental viewpoints.

The Department supports the concept of a strategic petroleum stockpile and considers it to be an essential national need. However, we wish to reiterate that such facilities and the petroleum stored therein should be owned by the Government and that the costs should be borne directly by the beneficiaries -- the U.S. energy consumers.

One other comment applicable to the five statements concerns the implication that among the benefits or costs of each project is the employment effects, positive in the case of employing construction workers to build storage facilities and negative in the case of "laying-off" salt mine workers. Conventional cost-benefit analysis deals with a national rather than a regional perspective and assumes a full employment economy. Under such assumptions employment effects are considered neither costs nor benefits since one more job in any region implies one less job elsewhere.

Similarly the "cost" of laying-off salt mine workers is not a cost at all if alternative employment opportunities exist. Some social costs of lay-offs, such as unemployment compensation paid during the time workers are between jobs, might be expected, but these costs relative to the "normal" job turnover costs for the region involved can be expected to be miniscule and probably need not be considered in the analyses.

Thank you for the opportunity to review the statements and I trust that our comments will be of assistance in the preparation of the final environmental impact statements.

Sincerely,

Warren F. Brecht
Assistant Secretary (Administration)

Mr. Robert L. Davies
Deputy Assistant Administrator for
Strategic Petroleum Reserves
Federal Energy Administration
1726 M Street, N.W.
Washington, D.C. 20461

Louisiana Air Control Commission

State Office Building
Phone (504) 527-5115

P.O. Box 60630
New Orleans 70160

October 11, 1976

Mr. Robert L. Davies
Deputy Assistant Administrator
Executive Communications, Rm. 3309
Federal Energy Administration
Washington, D.C.

RE: Strategic Petroleum Reserve. Draft Environmental Impact Statements for: Weeks Island Mine, Cote Blanche Mine, West Hackberry Salt Dome, and Bayou Chactaw Salt Dome.

Dear Mr. Davies:

This agency has reviewed the above referenced impact statements. The review indicated the section of the reports dealing with the air quality impact was not supplied. Until such data is made available to this office we are unable to comment on the proposals impact on air quality.

Very truly yours,

Orey Tanner Jr

Orey Tanner, Jr., P.E.
Air Quality Section
Louisiana State Division of Health

OT/yw

cc: Mr. DeWitt H. Braud, Jr.
Environmental Coordinator
State of Louisiana
Commission on Intergovernmental Relations
P. O. Box 44455
Baton Rouge, Louisiana 70804

STA.E OF LOUISIANA

COMMISSION ON INTERGOVERNMENTAL RELATIONS

EDWIN EDWARDS
GOVERNOR
SENATOR MICHAEL H O KEEFE
CHAIRMAN
LEON TARVER
EXECUTIVE DIRECTOR

P. O. BOX 44455
BATON ROUGE, LOUISIANA 70804
389-5684

October 13, 1976

Mr. Orey Tanner, Jr., P.E.
La. Air Control Commission
Air Quality Section
P. O. Box 60630
New Orleans, Louisiana 70160

RE: Strategic Petroleum Reserve, Draft Environmental Impact Statements for: Weeks Island Mine, Cote Blanche Mine, West Hackberry Salt Dome, and Bayou Choctaw Salt Dome.

Dear Mr. Tanner:

As indicated in our letter of transmittal of September 27, 1976, you were forwarded only excerpts from selected portions of each of the documents referenced above. As the number of available statements was limited, we hoped to provide you with enough information to make a determination of need for additional data, which we could provide.

Enclosed, please find excerpts from each document specifically pertaining to air quality impact.

If we can be of further assistance, please let us know.

Sincerely,

DeWitt H. Braud, Jr.
Environmental Coordinator

DHB:dn

Enclosures

cc: Mr. Robert L. Davies
Federal Energy Administration

ATE OF LOUISIANA
DEPARTMENT OF CONSERVATION
LOUISIANA GEOLOGICAL SURVEY

GEOLOGY BUILDING
BOX G
UNIVERSITY STATION
BATON ROUGE, LA. 70803

October 21, 1976

Mr. Robert L. Davies, Deputy Assistant Administrator
Executive Communications
Federal Energy Administration
Room 3309
Washington, D. C. 20461

Re: Stratigic Petroleum Reserve
Draft Environmental Impact Statement:
Weeks Island, Cote Blanche, West
Hackberry and Bayou Choctaw

Dear Mr. Davies:

Our staff has reviewed those sections of the (five) impact statements relative to the geological consideration involved in the Stratigic Petroleum Reserves plan.

It is our opinion that the geological presentations are well done and adequate for the purposes intended.

Thank you for the opportunity to comment.

Very truly yours,

LOUISIANA GEOLOGICAL SURVEY

Leo W. Hough, State Geologist

by: Harry L. Roland, Jr.
Assistant State Geologist

HLR:FMM

LOUISIANA
STATE SOIL AND WATER CONSERVATION
COMMITTEE

LOUISIANA STATE UNIVERSITY
P. O. DRAWER CS
Telephone 389-5017
BATON ROUGE, LOUISIANA 70893

October 1, 1976

Mr. Robert L. Davies
Deputy Assistant Administrator
Executive Communications, Room 3309
Federal Energy Administration
Washington, D. C. 20461

RE: Strategic Petroleum Reserve,
Draft Environmental Impact
Statements for:
Weeks Island Mine - DES 76-8
Cote Blance Mine - DES 76-7
Bayou Choctaw Salt Dome - DES 76-5
West Hackberry Salt Dome DES 76-4

Dear Mr. Davies:

A copy of the above documents have been received.

We have no additional comments to make at this time on information furnished us.

If you require further information concerning these documents, please let us know.

Sincerely,

Charley S. Staples
Executive Director

CSS:ry
cc: DeWitt H. Braud, Jr.
Fred Huenefeld, Jr.

LOOP INC

350 BANK OF NEW ORLEANS BLDG.
1010 COMMON STREET
NEW ORLEANS, LA 70112
(504) 529-7241

November 3, 1976

File: 5.03

00002

Executive Communications
Room 3309
Federal Energy Administration
Washington, DC 20461

Dear Sir:

The site-specific draft EISs for five candidate ESR sites have been reviewed per your request of September 10, 1976.

We agree that underground storage of crude oil, utilizing existing technology, offers maximum protection against fire, storm and sabotage and is low cost with small environmental impact relative to other storage concepts.

There is no indication that specific, competent geomechanics analyses will be made to assure stability of multicavity configurations after five fill/withdrawal cycles. Such analysis should be required for each of the candidate salt domes (DES 76-4,5,6) actually selected.

The analysis would establish allowable roof distance below the caprock, center to center spacing vs. diameter (s/d ratio), vertical separation and plastic zone proximity to the dome flank. These criteria should be related to calculated creep, stress and subsidence for the actual or safe strength levels of the specific salt and surrounding rock. The arbitrary criteria enumerated in the programmatic draft EIS are no substitute for geomechanics analyses.

For the West Hackberry salt dome (DES 76-4), the impact of the alternate brine disposal by pipeline to the Gulf of Mexico can be quantified while disposal by subsurface injection cannot, in particular, the effect on the freshwater acquifier. Why shouldn't pipeline disposal be preferable here as was the case for the Bryan Mound salt dome (DES 76-6)?

Yours very truly,

W. B. Read

W. B. Read
President

SOUTH CENTRAL PLANNING & DEVELOPMENT COMMISSIOI

MEMBER PARISHES: ASSUMPTION • LAFOURCHE • ST. CHARLES • ST. JAMES • ST. JOHN THE BAPTIST • TERREBON

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RIDLEY P. GUILLOT
Vice Chairman

OSCAR CORDE
Secretary-Treasurer

CHARLES J. MELANCON
Executive Director

November 3, 1976

00003

Executive Communications
Room 3309
Federal Energy Administration
Washington D.C. 20461

Dear Sirs:

We are in receipt of your request for comments on the draft site Specific and Environmental Impact statement for five (5) Salt Dome storage sites in Louisiana and Texas being considerate for use in the Strategic Petroleum Program. None of these sites noted are located within the jurisdiction of this district, and therefore, I have no adverse comments that I feel I can make being as we are not familier with these sites. I feel certain that the districts who have sites involved will make comments to the FEA.

Thank you for the opportunity to comment on this important matter, and I hope in the future, when something applies to my district arises I can be of assistance to you.

Sincerely,

Charles J. Melancon,
Executive Director

CJM/dmm

P.O. BOX 846
THIBODAUX,
LOUISIANA
70301

OFFICE
204 ST. LOUIS STREET

TELEPHONE
(504) 446-0514

Appendix L

GLOSSARY OF TERMS

The following glossary of terms is provided for the reviewer when reading this report.

acre-foot	-a measure of water drainage or run-off volume equal to the quantity of water that would cover one acre of land to a depth of one foot (43,560 cu.ft.).
adsorption	-an adhesion of an extremely thin layer of molecules to the surfaces of solid bodies or liquids with which it is in contact.
aldehydes	-various highly reactive compounds typified by acetaldehyde and characterized by the group CHO.
alluvium deposits	-rock fragments that are transported by modern rivers and deposited in river beds, flood plains, lakes and estuaries and natural levees.
amphipod	-small, free-swimming crustaceans (includes beach fleas).
anaerobic	-refers to life or processes occurring in the absense of free oxygen; refers to conditions characterized by the absence of free oxygen.
anhydrite	-an evaporite mineral, $CaSO_4$, associated with gypsum and found in sedimentary rocks.

aquiclude	-a geologic formation so impervious that for all practical purposes it completely obstructs the flow of ground water (although it may be saturated itself), and completely confines other strata with which it alternates in deposition.
aquifer	-a water-bearing strata.
aquitard	-a geologic formation of a rather impervious and semi-confining nature which transmits water at a very slow rate compared to an aquifer.
artesian water	-ground water that is under sufficient pressure to rise above the level at which it is encountered by a well, but which does not necessarily rise to or above the surface of the ground.
artesian well	-a well which reaches artesian water.
bayou	-a stream or small river that is a tributary to another river - term local to southern states.
bbl	-barrel or barrels - one barrel of petroleum equals 42 U.S. gallons.
benthos	-organisms fixed to or growing on the bottom of water bodies.
biocide	-substance destructive to many different organisms.
blanket oil	-used during formation of solution cavity to prevent undesired leaching of cavity ceiling.

bottom scour	-bottom scour is the erosion of sediment by moving water from the bottom of the stream channel.
BPD	-barrels per day - an oil production or distribution rate.
MB/D	-thousand barrels per day.
MMB/D	-million barrels per day.
brackish	-slightly saline water between fresh water (<0.3 ppt) and sea water concentrations (~35 ppt).
breccia	-a rock consisting of sharp cornered bits cemented together by sand clay or lime. Collapse breccias are derived from material broken up during the collapse of a solution cavity roof, while fissure breccias are accumulations of fragments in a solution fissure.
brine	-concentrated or nearly concentrated salt water achieved by dissolving water with the salt inside a salt dome, thus creating a cavity. Brine produced in this way is commonly used as feedstock (raw material) by chemical industries or for refining into common salt.
^{o}C	-degrees Celsius (formerly called Centigrade) - conversion of Celsius to Fahrenheit is $9/5\,^{o}C + 32^{o} = {}^{o}F$.
calcareous	-composed of or characteristic of calcium or limestone, having a chalky nature.

calcite	-calcium carbonate, $CaCO_3$, a mineral found in the form of limestone, chalk and marble.
caprock	-a mantle of associated minerals across the top of most shallow, piercement salt domes. No well defined layers are evident due to complexity and irregularity; however, three fairly well-defined zones are distinguishable in developed caprock: (1) anhydrite zone (2) transition zone - contains sulfur, gypsum, and less important minerals (3) calcite zone - top zone in developed caprock.
cast and stack dredging	-type of dredging that deposits dredge spoil on the bank of the canal/river by means of pipeline or conveyor belt.
Centipose	-unit for measuring viscosity, which is the tendency of a fluid to resist change of form.
cfs	-cubic feet per second -a rate of water volume flow.
cheniers	-long sinuous ridges of sand deposited on top of the swamp deposits of a delta. They represent stationary phases of a regressing shoreline. The type area for their development is the Mississippi Delta.
chlordane	-a chlorinated, highly poisonous, volatile oil $C_{10}H_6Cl_8$, used as an insecticide.

cladocera	-small, aquatic crustaceans (includes water fleas).
CO	-carbon monoxide - a colorless, odorless, highly poisonous gas, produced by the incomplete combustion of any carbonaceous material i.e., gasoline.
COD	-chemical oxygen demand.
colloid	-a substance that, when apparently dissolved in water, diffuses not at all or very slowly through a membrane, and usually has little effect on freezing point, boiling point, or osmotic pressure of the solution.
consolidated rock	-incoherent and relatively hard, naturally formed mass of mineral matter.
Cretaceous	-a period of time from 136 million years to 65 million years ago.
crude oil	-unrefined oil as it comes from the ground.
darcy	-a measure of the permeability of rock. One darcy (D) equals a permeability such that one millilitre (ml) of fluid, having a viscosity of one centipoise, flows in one second under a pressure differential of one atmosphere through a porous material having a cross-sectional area of one square centimeter (cm^2) and a length of one centimeter. The working unit is the millidarcy (mD) one thousandth of a darcy. Darcy's Law relates to the flow of fluids, especially gas oil, and water in underground rocks.

DDT	-dichloro-diphenyl-trichloroethane - a powerful insecticide effective on contact.
decibels: dB	-logarithmic unit method of expressing the relative intensity of sound pressure. The human ear is sensitive to changes in atmospheric pressure (sound vibrations) ranging from just barely audible at 0.0002 μbar to the threshold of pain at 2000 μbars. This range in sensitivity is so tremendous that a more workable expression of these ranges is to compress them on a logarithmic scale. In order to do this, the reference sound pressure is usually taken as the sound pressure detectable, that of 0.0002μbars. The intensity of sound is then measured in decibels by the following function:

$$\text{Intensity (in dB)} = 20 \log_{10} \left(\frac{\text{Pressure}}{0.0002\ \mu\text{bar}}\right)$$

Using this method, the range of human sensitivity is from 0 dB (pressure at 0.0002μbar) to approximately 140 dB (pressure at 2000 μbar).

Psychacoustic studies indicate that a 10 dB increase in sound intensity is perceived as a doubling of loudness.

dBA	-A-weighted level - a unit is similar to dB Sound Pressure Level (SPL) in that it represents sound intensity level. However, the A-weighted level includes attenuation at each frequency which is similar to the ear's attenuation of frequencies.

decibels: dBA (continued)	-A-weighted level - a unit is similar to dB Sound Pressure Level (SPL) in that it represents sound intensity level. However, the A-weighted level includes attenuation at each frequency which is similar to the ear's attenuation of frequencies. Since the human ear is much less sensitive to low frequencies, it implies that a sound at 250 Hz of 65 dB (SPL) is perceived relative to a sound at 1000 Hz of 65 dB (SPL) as much less intense. The A-weighted scale has been developed to adjust by frequency the overall sound pressure level of noise to an approximation of how the ear would hear this noise.
detritus	-material produced by the disintegration and weathering of rock that has been moved from its site of origin. Also, fragments of detached or broken down material such as leaves and other plant parts.
diapir	-an intrusion of salt from the salt bed into overlying sediments, often in the form of a ridge or stalk-like piercement structure.
diazonium	-the grouping (organic chemistry), = N ≡ N, (triple bond of nitrogen).
dieldrin	-chlorinated organic chemical, $C_{12}H_8Cl_6O$, a white crystalline contact insecticide, obtained by oxidation of aldrin; used in mothproofing.
disseminated anhydrite	-particles of anhydrite ($CaSO_4$) dispersed through enclosing rock.
diurnal	-recurring on a daily cycle or in the daytime as opposed to nocturnal.
DO	-dissolved oxygen
dwt or DWT	-deadweight capacity - naval architecture term for total carrying capacity of a ship expressed in long tons (2,240 lbs); displacement of a fully loaded vessel less the weight of the ship itself.

electric logs	-the log of a well or borehole obtained by lowering electrodes in the hole and measuring various electrical properties of the geologic formations traversed.
emulsification	-the process of dispersing one liquid in a second immiscible liquid (liquids that will not mix with one another).
endrin	-a poisonous white crystal, $C_{12}H_8OCl_6$, insoluble in water, used as a pesticide. A stereo-isomer of dieldrin.
entrainment	-capture of an object or organism by a flowing liquid or gas.
euryhaline	-organisms that can tolerate a wide range of salinities.
eurythermal	-organisms that can tolerate a wide range of temperature.
eutrophic	-rich in nutrients and organic materials, therefore, highly productive.
evaporite	-a sediment resulting from the evaporation of saline water. Most evaporites are derived from bodies of sea water. Evaporite minerals are formed in the reverse order of their solubilities, i.e., the least soluble form first.
fault	-a fracture in rock along which there has been an observed amount of displacement. Faults are rarely singular planar units; they normally occur as parallel sets of planes along which movement has taken place to greater or lesser extent. Such sets are called fault or fracture-zones.
flexure	-bending of sedimentary layers.

floating roof tank	-a vertical cylindrical tank with a roof designed to float on top of the stored liquid product (commonly oil) as the level in the tank rises and falls.
fluvial	-formed or produced by the action of flowing water.
Frasch mining	-much mined sulfur (elemental sulfur) is produced from caprock of salt domes by the Frasch process utilizing super-heated steam to melt the sulfur in caprock. Drilling well design consists of a concentric arrangement of pipes of various diameters. Steam is injected into the sulfur bearing zone through one of the inner tubing strings. Compressed air is injected through the innermost tubing string which forces water and molten sulfur to rise in the large outer diameter pipes. The molten sulfur then flows through heated pipes to settling tanks. Frasch process sulfur is very pure, producing as much as 9.5 percent sulfur.
g dry wt/m^2/yr	-grams dry weight per square meter per year - a measure of the rate or organic production per area of yield.
geosyncline	-a large, generally linear, geologic trough which subsided deeply through-out a long period of time, in which a thick succession of stratified sediments accumulated (for example, the Gulf of Mexico depression).
geosynclinal axis	-a line which is parallel to the longest horizontal dimension of, and roughly bisects, a geosyncline.

GPD	-gallons per day - flow rate for liquids.
GPM	-gallons per minute - flow rate for liquids.
gypsum	-an evaporite mineral, $CaSO_4 2H_2O$. found in clays and limestones, sometimes associated with sulfur.
H_2S	-hydrogen sulfide; an inflammable, poisonous gas with the characteristic smell of rotten eggs.
halite	-an evaporite mineral, NaCl, common salt.
herpetofaunal	-reptiles and amphibians regarded collectively as a faunistic grouping.
Holocene	-the period of time from one million years ago to present.
horizons	-the various layers of soil each of which is a few inches to a foot or more thick.
HP or hp	-horsepower; equal to a rate of 33,000 foot-pounds per minute: the power required to raise 33,000 pounds a distance of one foot in a time of one minute.
humic acid	-a gelatinous material formed as a precipitate when organic matter is treated with a strong base, and the resulting solution is acidified.
hydraulic dredging	-this method includes a suction pipeline with either plain suction or cutting heads for digging hard material. The sediments dredged are conveyed by pipeline either to a barge or to a deposition area on shore.

impingement	-entrapping of objects or organisms against a screen or filter by the force of a liquid or gas moving through or against the screen.
injection well	-a well that brine will be forced into.
inversion	-a reversal in the normal atmospheric temperature gradient such that temperature increases with altitude (within 300 to 600 ft) and results in an atmospheric inversion. The warmer air on top acts as a ceiling to any material normally diffusing vertically.
isopach	-a line on a map joining points of equal thickness of a rock or sediment type.
isopleth	-(1) a graph plotting the occurrence or frequency of a phenomenon in meteorology, etc., as a function of two variables, time and space. (2) the line connecting points on a graph that have equal or corresponding values with regard to certain variables - synonym - isoline.
isostatic	-subject to equal pressure from every side.
Kcal	-kilocalorie.
$Kcal/m^2/yr$	-kilocalorie per square meter per year - a measure of the rate of organic energy production per area of yield.
kg	-kilogram.
leach	-to remove soluble constituents from a substance by the action of a percolating liquid, in this case, water taking salt from a salt dome into solution.

littoral	-a shallow zone that extends from shore to the lakeward limit of rooted aquatic plants; the shoreward region of a water body; in marine environments, the tidal zone.
log normal distribution	-a distribution in which the logarithm of a parameter is normally distributed.
long ton	-2,240 pounds, as opposed to 2,000 pounds in a short ton.
lotic	-pertaining to flowing waters such as streams and rivers.
LPG products	-Liquid Petroleum Gas: commercial petroleum derivatives such as propane, ethane, ethylene, etc.
macrophyte	-any plant that can be seen with the naked, unaided eye; e.g., aquatic mosses, ferns, liverworts, rooted plants.
Mercalli scale	-a 12-point scale for classifying the magnitude of an earthquake.
meteoric water	-water which occurs in or is derived from the atmosphere.
mg	-milligrams - 1/1000 of a gram.
mg/l	-milligrams per liter.
Miocene	-the time span from 12 to 26 million years ago characterized by the development of large mountain ranges (the fourth epoch of the Tertiary Period).

Moh scale -an empirical hardness scale related to standard minerals:

	MINERAL	COMMON EQUIVALENTS
10.	Diamond	
9.	Corundum	
8.	Topaz	Hard File
7.	Quartz	Penknife
6.	Orthoclase	Window glass
5.	Apatite	Teeth
4.	Fluorite	
3.	Calcite	
2.	Gypsum	Fingernail
1.	Talc	

The steps between various minerals are by no means equal, e.g., diamond is about ten times as hard as corundum, whereas corundum is only about 10% harder than topaz.

monocline -(1) strata that dip for an indefinite or unknown length in one direction and which do not apparently form sides of hills or valleys.
(2) A step-like bend in otherwise horizontal or gently dipping beds.

MSL -Mean Sea Level.

N/A -not available or unknown.

NaCL -sodium chloride (salt).

Nekton -macroscopic swimming organisms able to navigate at will (fish, amphibians, large aquatic insects, etc.).

NO_x -Nitrogen Oxides - NO, NO_2, etc.

occluded	-prevents the passage of.
OCS	-Outer Continental Shelf.
OD	-Outer Diameter - in reference to pipe or tubing size.
Org/m^3	-organisms per cubic meter.
overburden	-material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials, minerals, coal, or salt.
pelagic sediments	-sediments derived from open ocean settling from the shells of unicellular organisms known as foraminifera. The shells are composed either of calcium or silicon. In addition red clays of land mass origin are also deposited.
permeability	-a rock is said to be permeable if water or other liquids in contact with its upper surface tend to pass through the rock more or less freely to the lower surface. Permeability may be achieved by the rock being either porous or pervious. The essential feature of a bed of permeable rock is that the liquid it contains may be extracted by pumping. Permeability is measured in darcies.
permeability of an aquifer	-the capacity of an aquifer to transmit water under pressure.
pervious	-a rock is said to be pervious if it is permeable by virtue of mechanical discontinuities such as joints, bedding planes, fissures, etc. (e.g., some limestones and some igneous rocks).

pH	-a measure of acidity of a liquid determined by the concentration of hydronium (H_3O^+) ions per mole of liquid. The pH value equals the negative logarithm of the hydronium concentration. A hydrogen ion concentration of 10^{-7} equals a pH of 7. The scale has a range from 1 to 14 with values below 7 indicating increasing acidity, and values above 7 indicating increasing alkalinity.
photosynthesis	-the metabolic process by which simple sugars are manufactured from carbon dioxide and water by plant cells using light as an energy source.
piercement dome	-a salt dome in which the salt core has broken through the overlying strata until it reaches or approaches the surface.
piezometric surface	-an imaginary surface that everywhere coincides with the static level of the water in the aquifer.
pimple-mounds	-small rounded circular elevations 15 to 30 feet in diameter and 2 to 6 feet in height.
Pleistocene	-a time span from 1 to 2 million years ago characterized by 4 ice ages in North America (the earlier of the 2 epochs comprised in the Quaternary Period).
Pliocene	-latest epoch of the Tertiary or the corresponding system of rocks.

porosity -A rock is said to be porous if it possesses cavities between the mineral grains making up the rock which can contain liquid. The term porosity ratio. or simply porosity, is given to the percentage of void space that a rock contains. Porosities of sedimentary rocks range from less than 1% to more than 50%; sandstones from 5% to 15%; loose sand and gravel may reach 45%; and clays, which are exceedingly porous rocks, sometimes reach 50% porosity. (Porous rock is not necessarily permeable.)

ppm -parts per million.

ppt -parts per thousand.

product -refined petroleum products.

psi -pounds per square inch - pressure measurement.

psig -guage pressure in pounds per square inch and including pressure of atmosphere, as opposed to absolute pressure (psia) pressure measure with respect to zero pressure.

raw water -As used in this report, raw water is that water used for cavity leaching or oil displacement.

re-entrant -re-entering or directed inward as a re-entrant angle in a coastline or any indentation in a land form, usually more or less angular in character.

revetment -a facing made on a soil or rock embankment to prevent scour by weather or water.

rose (wind rose)	-a graphic illustration of wind speed and direction related to percent frequency of occurrence.
rotifer	-a phylum of minute, multicellular aquatic organisms which possess a wheel-like bank of cilia at the anterior (oral) end.
saline	-water containing a significant quantity (>.3 ppt) of dissolved natural salts of sodium, magnesium, etc.
senescent	-the study of the biological changes related to aging.
sonar	-a system that uses underwater sound, at sonic or ultrasonic frequencies, to detect and locate objects in water.
sonar caliper survey	-a technique for measuring internal configurations of a cavity.
standard elutriate	-the supernatant resulting from the vigorous 30 minute shaking of one part of bottom sediment with 4 parts water (on a volumetric basis) collected from the same sample site, followed by a 1-hour settling time and appropriate 0.45 microns (μ) filtration,
stomata (plural of stoma)	-a small opening or pore in a surface.
strike	-The course or bearing of the outcrop of an inclined bed or structure on a level surface; the direction or bearing of a horizontal line in the plane of an inclined stratum, joint, fault cleavage plane or other structural plane. It is perpendicular to the direction of the dip.

substrata	-a layer or stratum of earth or rock lying immediately under another.
surge tank	-a storage tank which serves to keep the pumping rate/pressure through a pipeline constant by storing excess or providing a surplus when the rate of pumping 'surges' up or down, respectively.
suspended particulate matter (particulates)	-Any finely divided solid and/or liquid matter which does not settle from the ambient air.
suspended solids	-a direct measurement quantifying the actual amount of particulate material in the water.
sweet crude	-crude oil with a low sulfur content.
tectonic	-of, pertaining to, or designating the rock structure and external forms resulting from the deformation of the earth's crust. As applied to earthquakes, it is used to describe shocks due to volcanic action or to collapse of caverns or land slide.
Tertiary	-the period of time extending from 65 million to 2 to 3 million years ago.
thalweg	-a line joining the deepest points in a channel.
throw	-the amount of vertical displacement as a result of faulting.
TKN	-total Kjeldahl nitrogen (sum of free ammonia and organic nitrogen compounds).
toxaphene	-organic compound, $C_{10}H_{10}Cl_8$, a toxic, waxy, amber solid, with mild chlorine-camphor smell, soluble in organic solvents, melts at 65-90°C. Used as insecticide (also known as technical chlorinated camphene).

transmissibility, coefficient of	-the rate of flow of water in gallons per day through a vertical strip of the aquifer 1 foot wide extending through the vertical thickness of the aquifer at a hydraulic gradient of 1 foot per foot and at the prevailing temperature of the water. The transmissibility from a pumping test is reported for the part of the aquifer tapped by the well.
turbidity	-a measure of the amount of light that will pass through a liquid. It describes the degree of opaqueness produced by suspended particulate material.
turbidity plume	-a localized area of suspended sediments often associated with dredging operations that reduces the amount of light penetration through the water in that localized area.
Vol.	-volume.
vuggy porosity	-porosity due to vugs in calcareous rock.
vugs	-cavities often with mineral linings different in composition from the surrounding rock.

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