THE FEASIBILITY OF STORING LARGE QUANTITIES OF CRUDE OIL IN SALT DOME SOLUTION CAVITIES

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THE FEASIBILITY OF STORING LARGE QUANTITIES OF CRUDE OIL IN SALT DOME SOLUTION CAVITIES

by

ANTHONY EDWARD CORCORAN, B.S. in Geological Engineering

THESIS

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A. E. C.

The University of Texas at Austin
Austin, Texas
April 1, 1972

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CHAPTER I

INTRODUCTION AND PURPOSE

What would be the effect on the United States if all the imports of petroleum from the Middle East and Africa were stopped? What would the United States do if the Organization of Oil Exporting Countries (OPEC) demanded $5.00 a barrel for their oil? Would we pay it? Would we have any choice?

The purpose of this study is to show the significance of the above situations and to offer a possible alternative to a slow down in the United States' economy if the first situation occurred and an alternative to paying an exorbitant price for oil under the second situation. The dependence of this country on energy in its many forms and the part that petroleum plays in the total energy picture will be shown as will an increasing reliance on imported oil.

The 'alternative' is to store a large quantity of crude oil in solution cavities in salt domes in such a manner that the stored oil can be used to replace imported oil should imports be seriously curtailed.

CHAPTER II

THE NEED

The United States is the largest consumer of energy in the world. In 1967 this country consumed 30 percent of the world's energy requirement while representing only 7 percent of the world's population. (25) Our very 'way of life' depends on energy. Personal comfort, the automobile and the airplace are dominant factors in our life style. With an ever increasing dependence on these factors and an ever increasing population there can only be a skyrocketing increase in energy consumption in this country. Figure 1 shows the projected per capita consumption of energy based on the 1965 rate of consumption.

In 1971 the National Petroleum Council projected an increase in energy consumption of 4.2 percent per annum through 1985. (23) One can visualize the serious effect on this country if one of our major energy sources such as oil were taken away or seriously reduced. In 1970 petroleum liquids (crude oil, condensate and natural gas liquids) accounted for 43 percent of this country's energy consumption. (23) Figure 2 shows the relative importance of each of the elements of our energy supply.

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FIGURE 1

PER CAPITA ENERGY USE [16]

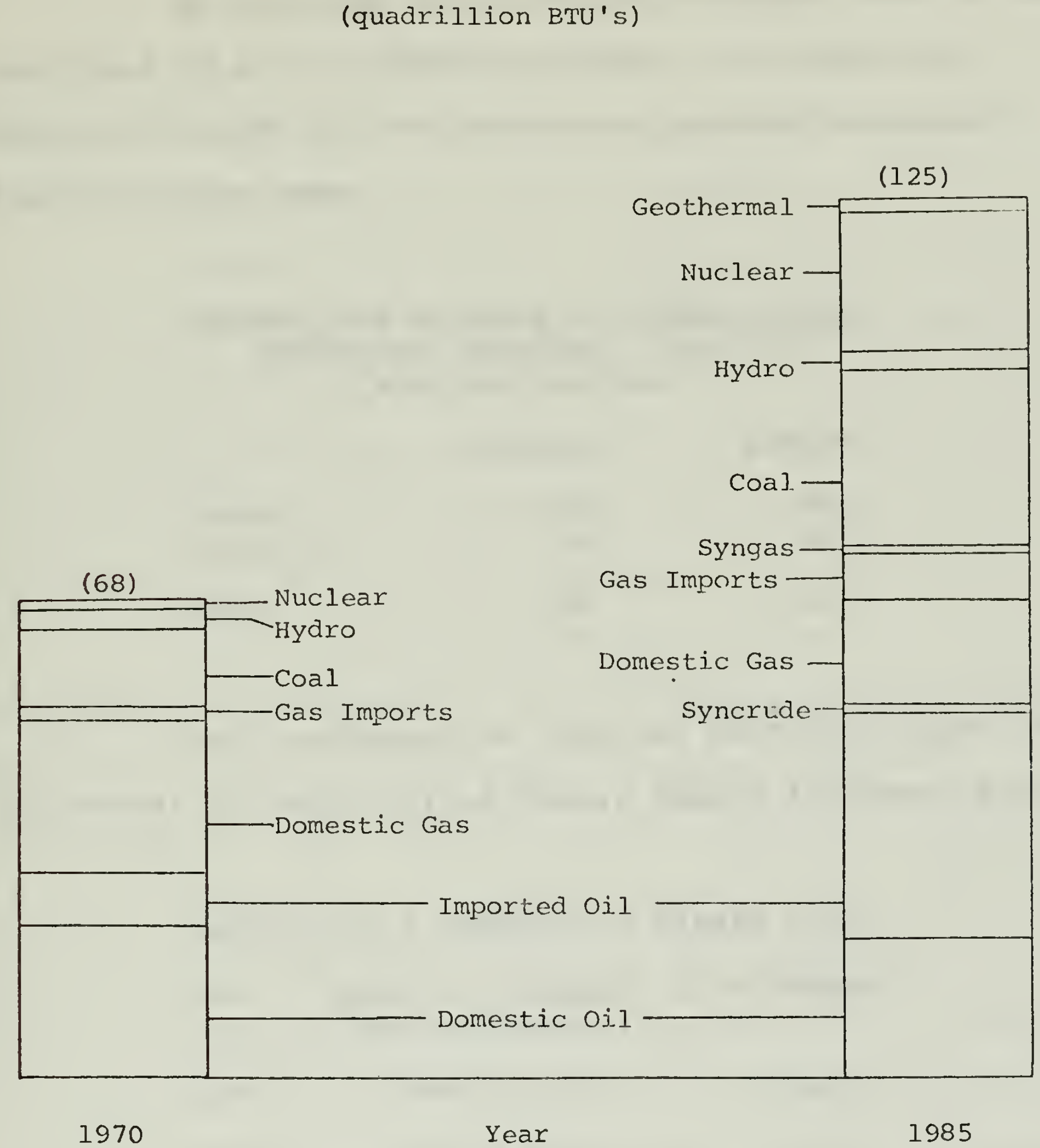

FIGURE 2

TOTAL ENERGY DEMAND FOR THE U. S.[11]

In 1948 the United States switched from an oil exporting to an oil importing status. In that year imports of crude oil and petroleum products surpassed exports of the same.

IMPORTS AND EXPORTS OF CRUDE OIL AND PETROLEUM PRODUCTS- 1948 (17)
(million barrels)

	Imports	Exports
Crude	130	40
Products	39	95
Total	189	135

Our dependence on imported petroleum expressed in percent of total United States demand is shown below.

IMPORTS AS A PERCENT OF DEMAND (17)

Year	Imports / Demand (million bbls.)	% of Demand
1938	(140)/ 1,137	(12.3)
1948	54 / 2,114	2.5
1958	521 / 3,315	15.7
1968	953 / 4,788	19.8
1970	1,248 / 5,371	22.7

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The National Petroleum Council projects that by 1985 this import dependence will rise to 57 percent and represent 25 percent of the U.S. energy consumption. Figure 3 illustrates this growing dependency.

Imports of crude and products come from five distinct geographical regions. These are Latin America, Canada, Africa, the Middle East, and the Far East. There are several situations (political, military, or natural disaster) that might develop that could obstruct the flow of foreign oil to the United States.

It is possible that the Panama Canal could be destroyed or obstructed for a long period of time. The West Coast of the United States depends heavily on Venezuelan oil which is shipped via the Canal. Under existing conditions, loss of the Panama Canal would require an increase in imports via the Pacific route from the Middle or Far East or shipment of Venezuelan oil around the treacherous Cape Horn. Pipelines offer no alternate transportation route as there is only one crude transmission line to California from the oil rich Midwest and Gulf Coast. The seriousness of this possible calamity will be diminished in the future as petroleum resources are developed in Colombia, Ecuador, and Peru. Alaskan North Slope

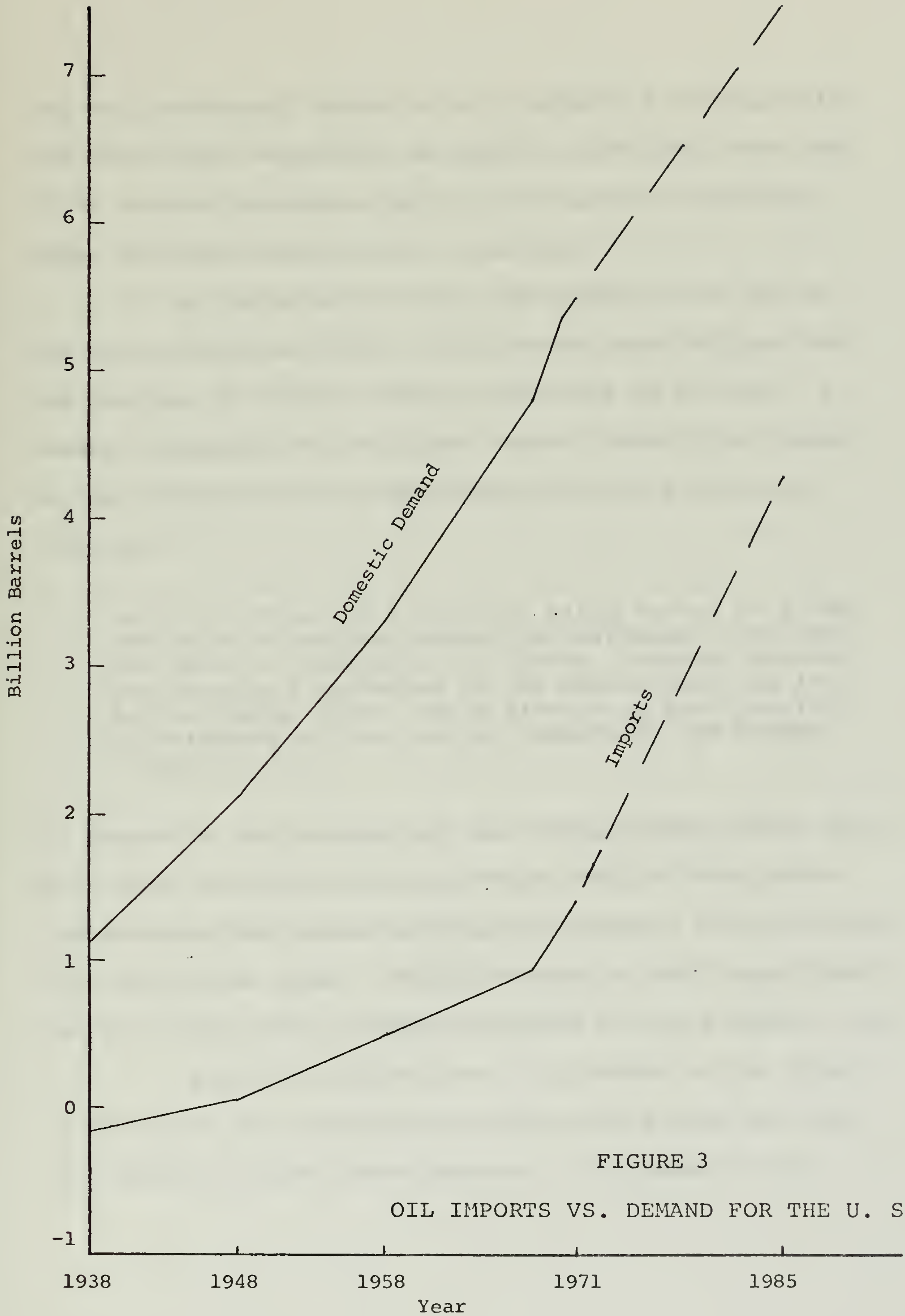

FIGURE 3

OIL IMPORTS VS. DEMAND FOR THE U. S.

oil will certainly lessen if not completely do away with the West Coast dependence on imported petroleum when and if it becomes available but it too might be vulnerable under the next hypothetical situation.

An isolated or world wide naval war is not at all far fetched in light of the Soviet naval buildup and the decline of the U.S. Navy's dominance of the sea. A recent commander of the United States' Sixth Fleet summed up the situation in the Mediterranean in the following statement.

> Our still formidable fleet is being forced to accommodate to a new environment far different from the one which it dominated for almost a quarter century. The designing influence is the Soviet Navy and its Mediterranean fleet, which gives ever more convincing evidence of its growing capability and professionalism. (13)

In regard to the Persian Gulf and Indian Ocean areas, the U.S. Naval Institute reports, "Over the last four years, the Russians have moved substantial elements of their fleet into the Indian Ocean. Their presence is now larger than the U.S. fleet with 15 ships compared to our 3 ships." (19)

Based on 1970 figures, a blockade of the Strait of Gibraltor by an unfriendly nation would mean the loss of 6 percent of our crude imports. A blockade of the

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Persian Gulf would result in the loss of 12 percent of our crude imports.(24) A world wide naval conflict stopping all international tanker traffic would halt 77 percent of our imported crude and petroleum products. (24) A 77 percent loss in petroleum imports would amount to over one billion barrels of oil in a year's time. There are a number of other possibilities such as local or regional hostilities and political denials that could have similar effects on our oil imports.

Any loss of imports that caused this country to dip into its stocks of crude and products would place not only our military security in jeopardy but also our economic security. In addition, the country is in a disadvantageous position in that we become more dependent on fewer sources of oil. As our dependence grows our bargaining position with respect to the price we pay becomes more tenuous. One immediate solution to this problem is to have in storage such a large quantity of oil that even a large import loss for a relatively long period of time can be countered while a replacement source is developed.

CHAPTER III

STORAGE

Storage of any commodity in large quantities is an expensive proposition. The cost is increased if the material to be stored requires specialized storage facilities. Petroleum in various forms is stored in facilities varying from steel tanks to abandoned quarries and solution cavities in bedded salt and salt domes. The most widely used storage facility is the above ground steel tank. The petroleum industry has in storage at any one time from 500 to 600 million barrels of crude oil and refined products.

If stored above ground, petroleum requires expensive steel tanks for safety and special fire protection provisions such as berms, dispersal, and fire fighting equipment. Above ground steel storage tanks cost up to 100 dollars per barrel of capacity. (18) Large concrete tanks such as those to be used in the North Sea cost 50 dollars per barrel of capacity. (12) Costs for construction of salt dome solution cavities have been reported to range from a low of $0.15 to a high of $2.50 per barrel of

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capacity. (11) The most economical storage method based on these data is a solution cavity in a salt body. Hawkins and Jirik in their 1966 report listed liquified petroleum gas (LPG) storage projects in 24 domes having a total capacity of over 57 million barrels. (11) By 1971 the capacity had reached 125 million barrels. (1) Salt dome storage was expanded in 1970 to include natural gas with the completion of the Transcontinental Gas Pipeline Corporation's 2 million barrel project in the Eminence dome in Mississippi. (1) Mobil Oil A.G. will complete two 940,000 barrel crude oil storage cavities at Lesum, Germany, in 1972. (3) The question remains, is it feasible to store as large a quantity as one billion barrels in salt dome cavities in such a manner that it will be readily available for use?

CHAPTER IV

SALT DOME SELECTION

Salt domes are found in Arizona, Alabama, Mississippi, Texas and Louisiana. Arizona has only one identified salt dome, Alabama has two, Mississippi has 60, Texas has 82, and Louisiana has 183. Of these 328 domes, 71 are located offshore in the Gulf of Mexico. Four are off the Texas coast and the remaining 67 off the Louisiana coast. (11, 9)

In selecting a dome for use as a storage structure several factors must be considered the first of which is the depth to the top of the salt. Cavities can be maintained full of liquid at all times by floating the oil on salt water and in the case of storage of LPG or natural gas the stored material is under pressure approaching that of the overburden. This type of facility is a working storage and can be filled and emptied several times during a year. The case under study is a long term storage facility with the possibility that it will be filled and emptied only once. In the interest of simplicity and economy it is assumed that the cavity will not be

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pressurized or filled with liquid at all times. Empty cavities with overburden pressures greater than 3000 psi. and temperatures of 400 degrees Farenheit will start to close. (2) The amount of closure increases with depth because of increasing pressure and temperature since the viscoplastic property of salt is heavily dependent on both pressure and temperature. Temperature is of greater significance. At depths up to 5,000 feet the temperature will most likely not exceed 180-190^{o} F., and with such temperatures, stable cavities can be constructed. A maximum depth to top of salt was chosen as 3,000 feet. Domes with tops more than 3,000 feet deep will probably not have sufficient useable volumes for construction of cavities using the techniques chosen. Hawkins and Jirik in their 1966 report (11) also used 3,000 feet as the limiting depth to top of salt in their selection of salt domes as possible storage sites. Out of the 328 known domes, 159 meet this requirement.

Of second concern is the availability of water to dissolve the salt and a place to dispose of the resulting brine. Sources of water can be rivers, lakes, wells, or saline bodies of water such as the Gulf of Mexico. Fresh water wells have been the primary source for

solution water used in cavities constructed to date. Rivers are considered as a viable source in this report although it should be noted that since construction periods of one, two, or three years and quantities of water in the range of 10 to 600 million barrels are contemplated for any one site, only rivers having a large reliable flow have been considered. Saturated brine contains 260,000 parts per million dissolved salts and normal sea water contains 35,000 parts per million dissolved salts. Using salt water from the Gulf of Mexico or a salt water embayment along the Gulf Coast is feasible and has the advantage of low cost and unlimited supply. Of the 71 offshore domes, 23 meet the 3,000 foot depth to top of salt requirement. In addition, 34 of the onshore domes are within 10 miles of the Gulf or an embayment and hence in realistic reach of salt water.

Ideally the dissolved salt could be reclaimed and sold. This was done in 1953 by the Cities Service Company in a storage project in Reno County, Kansas. The company in constructing four 25,000 barrel LPG storage cavities in bedded salt disposed of the brine by piping it to a nearby salt plant. (22) Such a method is feasible for small scale projects as construction rates are controlled by salt extraction plant capacities.

The next, and most widely used, method of brine disposal is injection of the brine into a salt water aquifer. The Transcontinental Gas Pipe Line Corporation constructed two 1,000,000 barrel cavities for natural gas storage in the Eminence Dome in Mississippi using this method. (1) Disadvantages of this method are the costs of drilling the injection well (5,300 feet in this case) and the injection of the brine. Also cavity construction rates are dependent on the injectivity of the salt water aquifer and the quality of the brine injected may be restricted by governmental regulations or chemical limitations to prevent plugging the aquifer.

The third method is to dump the brine into a saline body of water or for the purposes of this study, the Gulf of Mexico. The advantages of this disposal method are an unlimited disposal rate and few or no restrictions on the quality of the water dumped.

Disposal of brine in rivers was considered as feasible if well controlled and limited to large rivers, however, in view of the current concern over protection of the environment, it is doubtful that any dumping of brine in the quantities that would result from the proposed construction would be allowed by state or the

federal governments. This disposal method has therefore been ignored.

For the purpose of this study, cavity shape was assumed to be cylindrical and the total quantity of crude oil to be stored to be one billion barrels. One billion barrels of crude will replace approximately 77 percent of the United States' imported petroleum for one year based on 1970 rates. (24) Figure 4 shows volume and number of cavities required for various sizes of cavities to store the above quantity.

The optimum condition as far as costs are concerned would be one large cavity. Such a cavity would be unstable but more importantly it would be vulnerable to accidental or intentional destruction and it would be impractical to remove and transport large quantities of crude at rates sufficient to compensate for import losses up to three million barrels a day. Again considering cost, the least number of cavities capable of delivering the quantities of crude required would be best. For example thirty cavities would yield a total of three million barrels per day supplying 100,000 barrels per day each. Such rates are feasible if the cavities are properly located in relation to a means of transport.

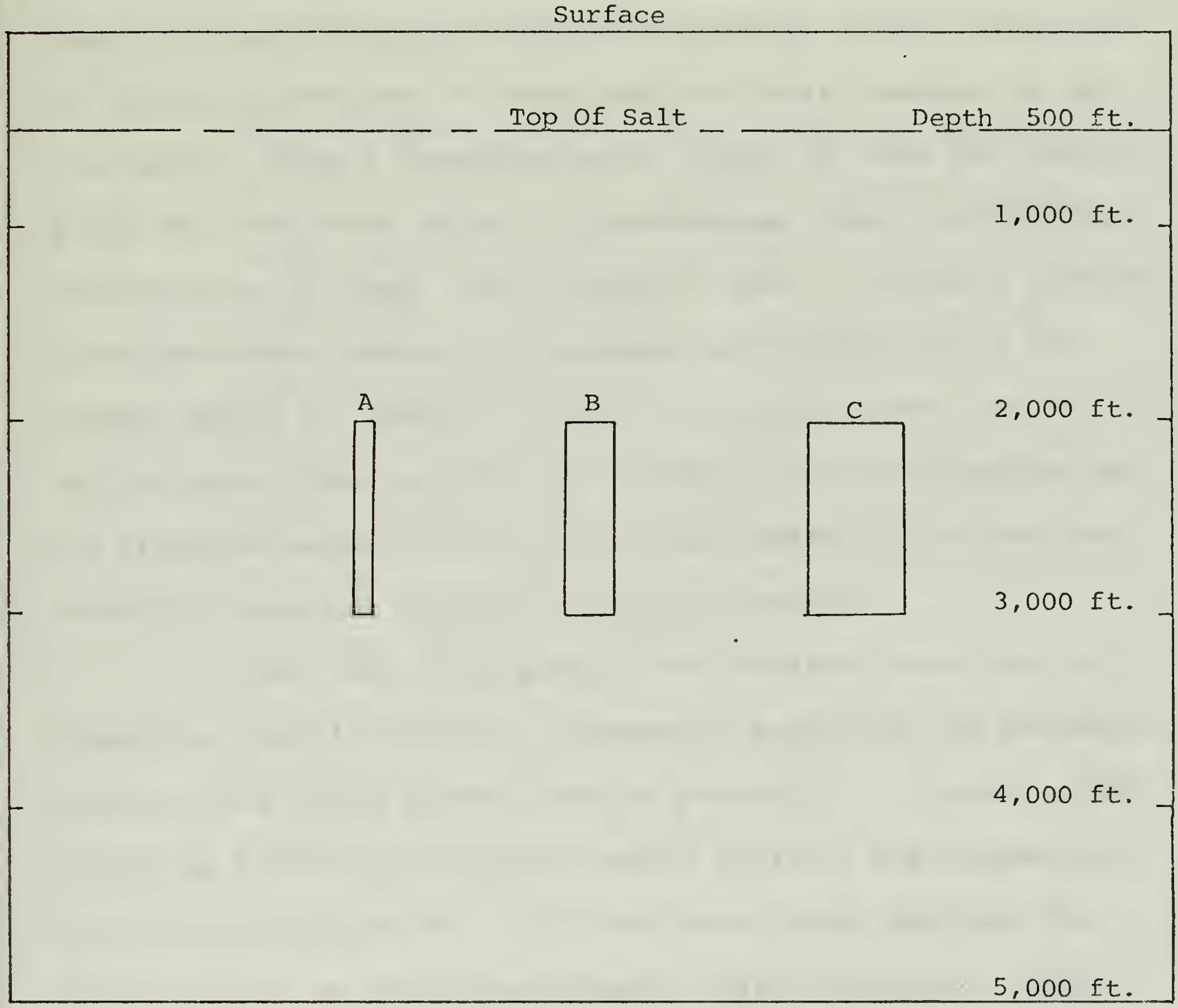
FIGURE 4

CYLINDRICAL CAVITY VOLUMES

Radius-feet	Length-feet	Volume-M bbls.	number of cavities required
25	500	175	5720
25	1,000	350	2,860
50	500	700	1,430
50	1,000	1,400	715
75	500	1,575	635
75	1,000	3,150	318
100	500	2,800	358
100	1,000	5,600	179
125	500	4,380	228
125	1,000	8,760	114
150	500	6,300	159
150	1,000	12,600	80
175	500	8,600	116
175	1,000	17,200	58
200	500	11,200	89
200	1,000	22,400	45
225	500	14,200	71
225	1,000	28,400	35
250	500	17,500	57
250	1,000	35,000	29

Any reserve of crude oil must have available to it a means to transport the oil to the refining centers needing it and in sufficient quantities to offset import losses. The refining centers most likely to suffer from the supposed import loss are those on the East and West Coasts. Unfortunately there are no salt domes near these centers. Transportation availability was given heavy weight in selecting domes for storage sites. Three transportation media; pipelines, tankers, and barges were considered as capable of moving significant quantities of crude oil. Trucks and railroads were not considered as prime transportation media based on the small quantity of crude oil they now transport in the United States.

It would be feasible to construct cavities and store crude oil in any of the salt domes with tops of 3,000 feet or less in depth. Figure 5 shows the relative size of a dome and various cavity sizes. Because of the size of the salt domes it will not be necessary to use all of them. The problem is to select the most advantageous domes. It is impossible in most cases to say that a certain characteristic is definitely a disadvantage or an advantage. For instance, deep water over an offshore dome is an advantage if the storage cavity is to be serviced



Cavity	Diam.	Volume - million barrels
A	100	1.40
B	250 ft.	8.76
C	500 ft.	35.00

FIGURE 5

RELATIVE SIZE OF DOME AND CAVITIES

by supertankers but is a disadvantage when considering the cost of constructing a service platform. The location of an onshore dome near a developed refining complex is advantageous from a transportation point of view but again from the cost view it is a disadvantage when considering acquisition of land. The cheapest land is usually furthest from developed areas. A location serviceable only by tanker might be useless if all sea traffic were halted. On the other hand a site serviceable only by pipeline may be disadvantageous if the lines are operating at maximum capacity when the reserve of oil is needed.

The salt dome areas were divided into regions based on location (on or offshore), proximity to refining centers and ocean ports, and or proximity to large rivers offering potential solution water sources and transportation media (Figure 6). All the salt domes meeting the depth to top of salt requirement were considered. The features of each dome are listed in the Appendix and at least one dome in each area was selected as best for that area. Pipeline and refinery data were taken from the Oil and Gas Journal's 1971 Crude Oil Pipeline Atlas. Depth refers to top of salt, volume is estimated to a depth of 10,500 feet, and all distances are straightline distances

unless otherwise indicated. Points considered in the selection of the best domes were as follows:

1. Depth relative to the other domes in the group.
2. Volume in relation to potential expansion of storage and in relation to the volume of the other domes in the group. (No size was considered disqualifying.)
3. Distance to large rivers. This includes intercoastal waterways.
4. Location in respect to land acquisition cost and construction difficulties.
5. Possible conflicts with other commercial operations such as LPG storage, commercial salt mining operations, or sulphur production.

The best domes were then used to develop a program for construction of the proposed one billion barrel storage capacity. It was assumed that dispersal would be beneficial for physical security reasons, transportation availability and flexibility. The best domes for each area are indicated by ⊕ in the following figures.

From the ten regions thirty-two domes were chosen as being the best for storage sites and are summarized below:

Region	Dome
Arizona	Luke
North East Texas	Oakwood, Brooks, and Steen
South Texas	Gyp Hill
Texas Coastal	Boling, Damon Mound, Hawkinsville, Moss Bluff, South Liberty, and Davis Hill
Texas Offshore	Block 144
North Louisiana	Rayburns, Crowville, and Bruinsburg
Louisiana Coastal	Vinton, Avery Island, Weeks Island, Cote Blanche Island, and Napoleonville
Louisiana Offshore	Blocks 386, 164, 115, 175, 126 and Rabbit Island
Mississippi	McBride, Leedo, Lampton, and Richton
Alabama	McIntosh

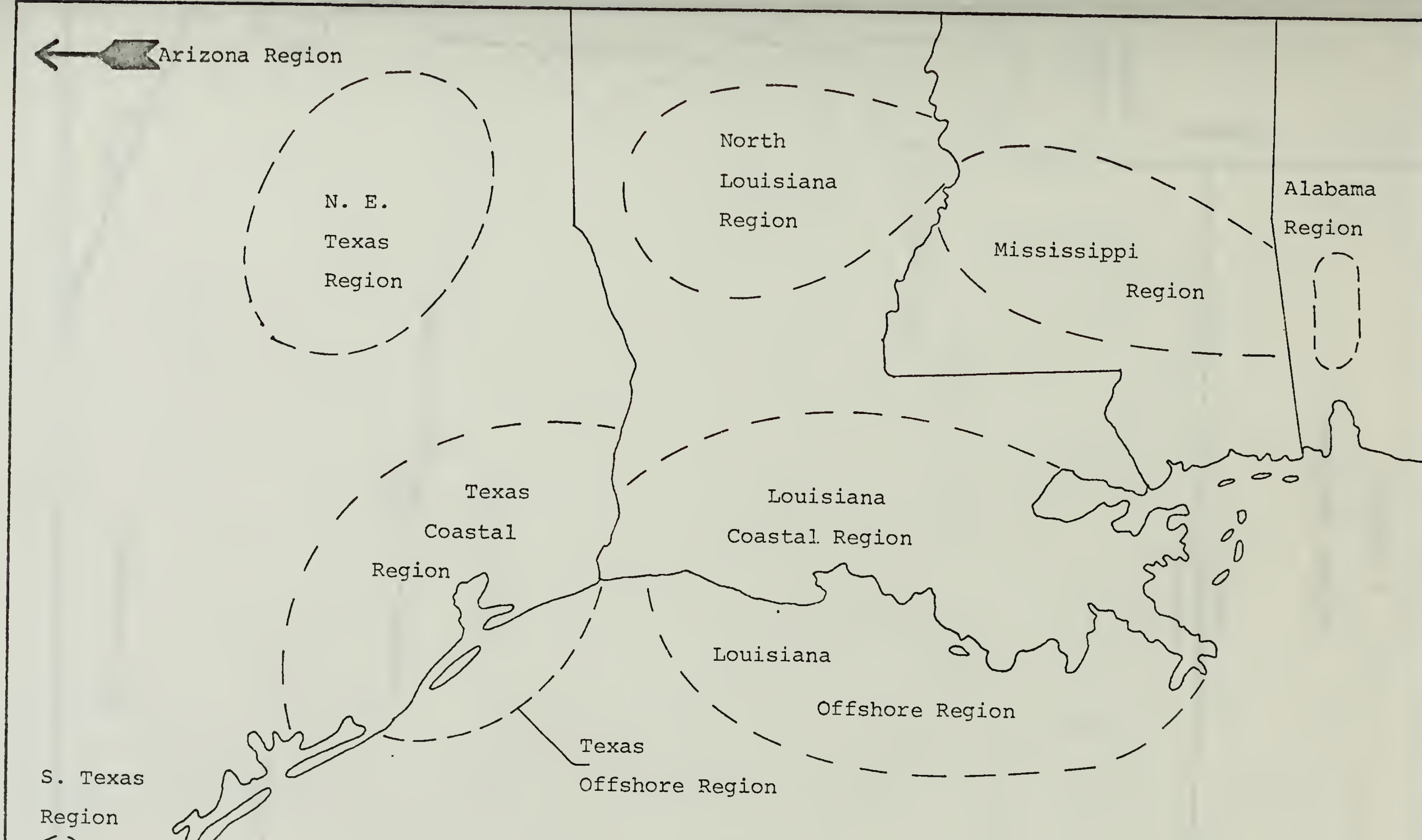


FIGURE 6

SALT DOME REGIONS

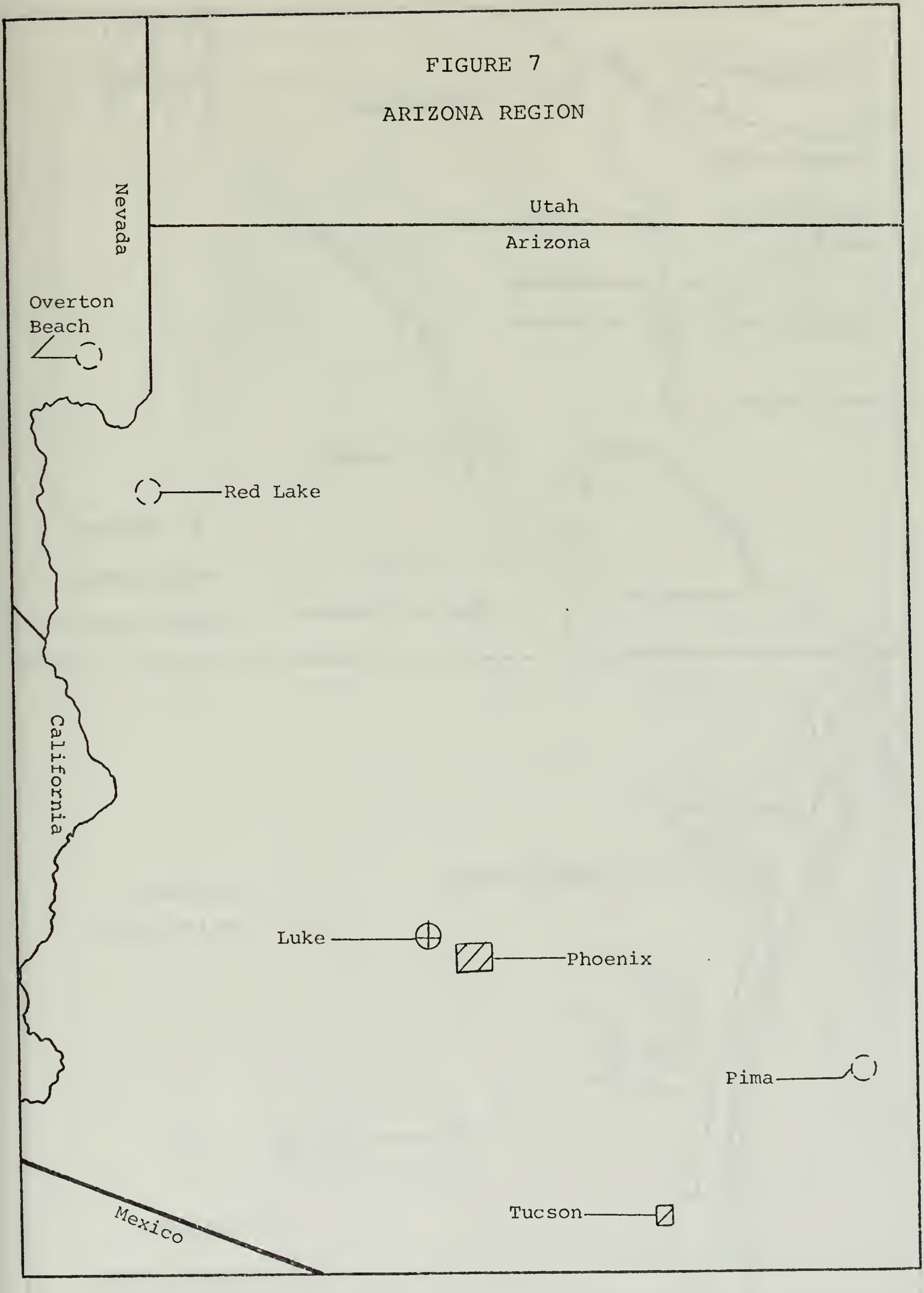


FIGURE 7
ARIZONA REGION
Utah
Arizona
Nevada
Overton Beach
Red Lake
California
Luke
Phoenix
Pima
Tucson
Mexico

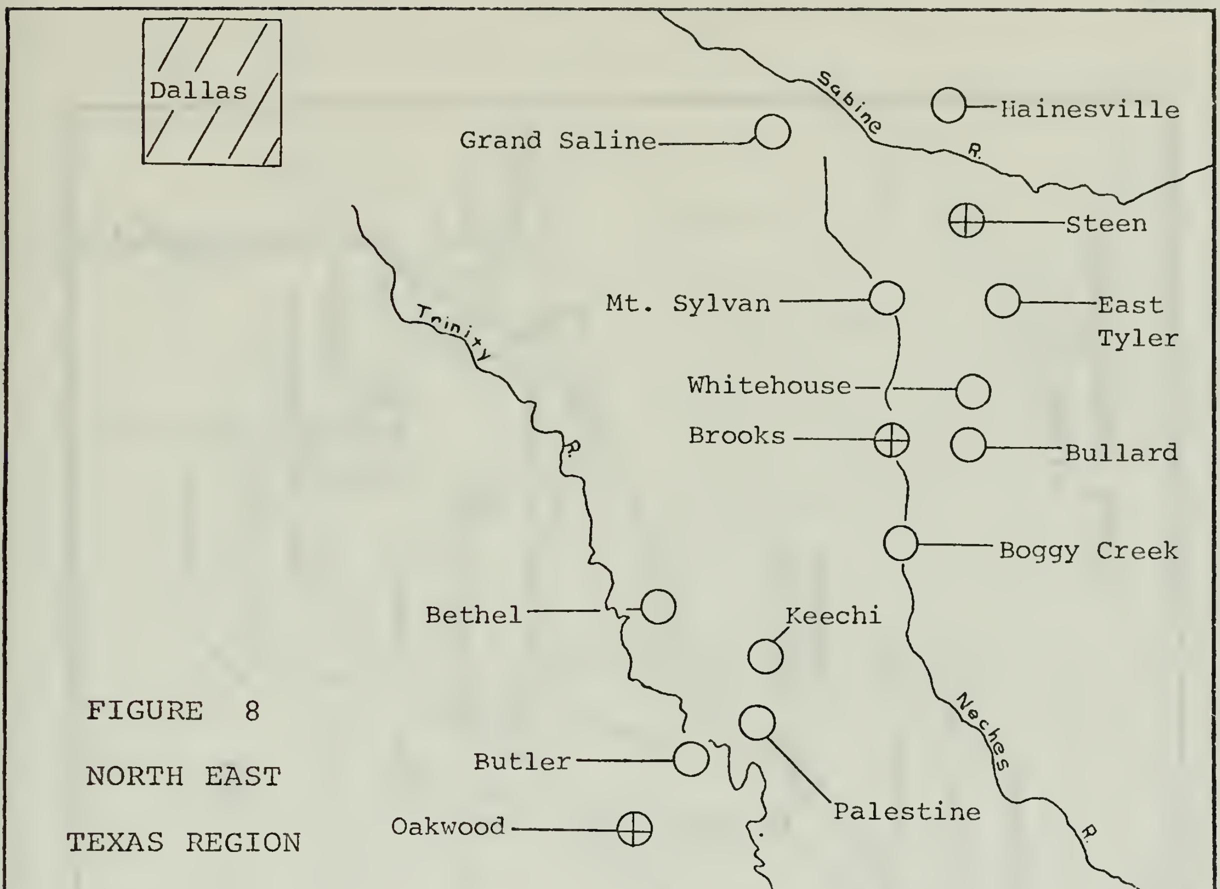


FIGURE 8

NORTH EAST TEXAS REGION

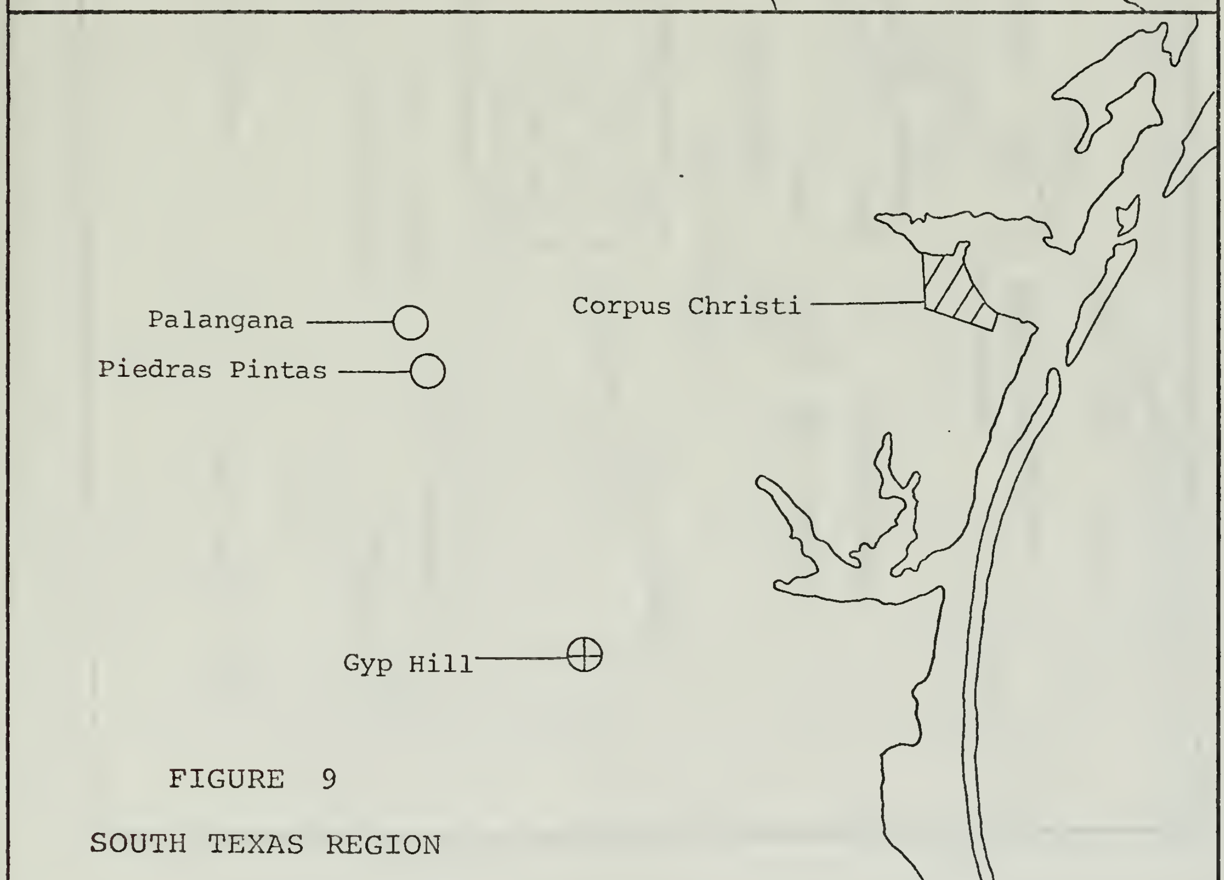


FIGURE 9

SOUTH TEXAS REGION

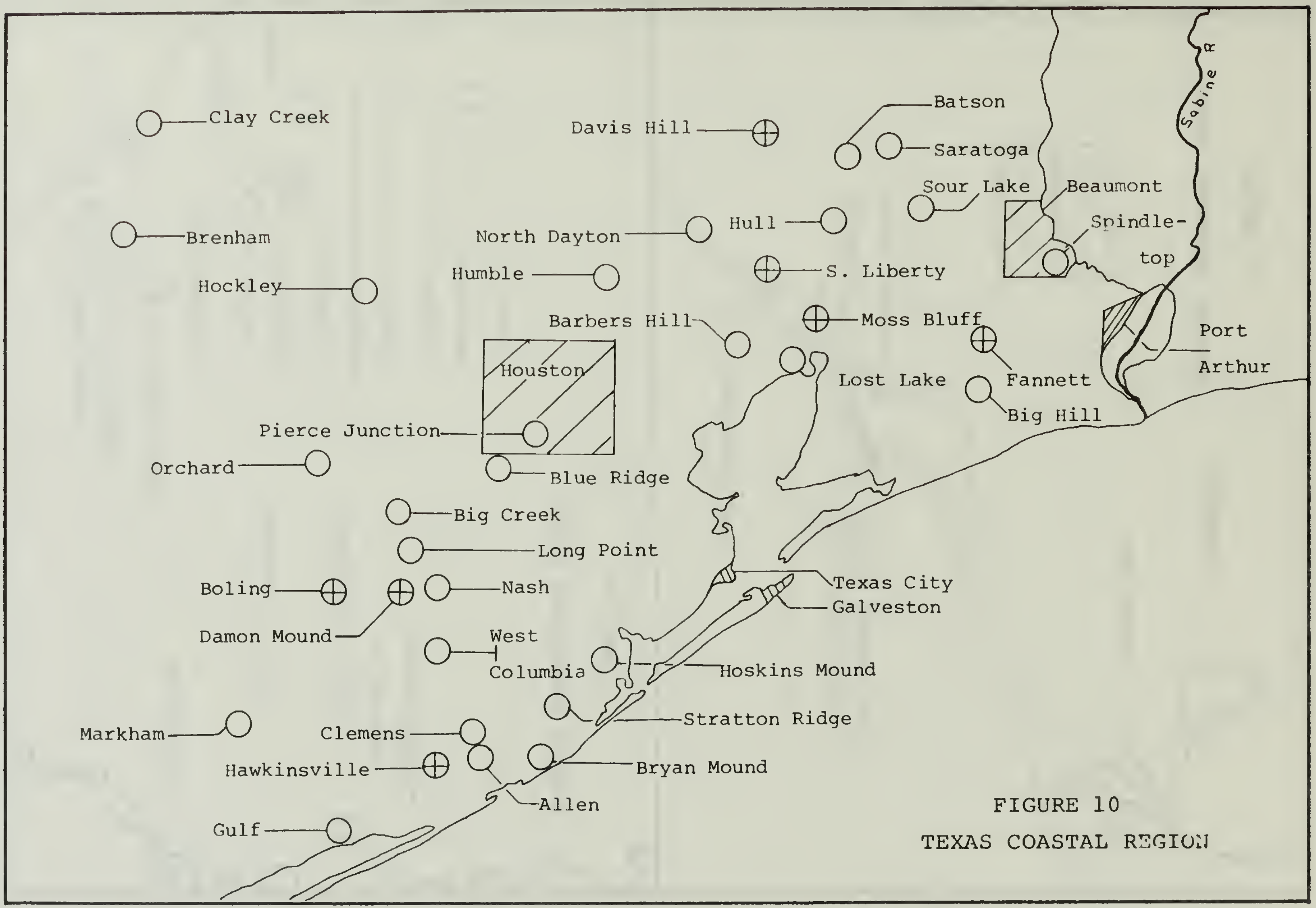
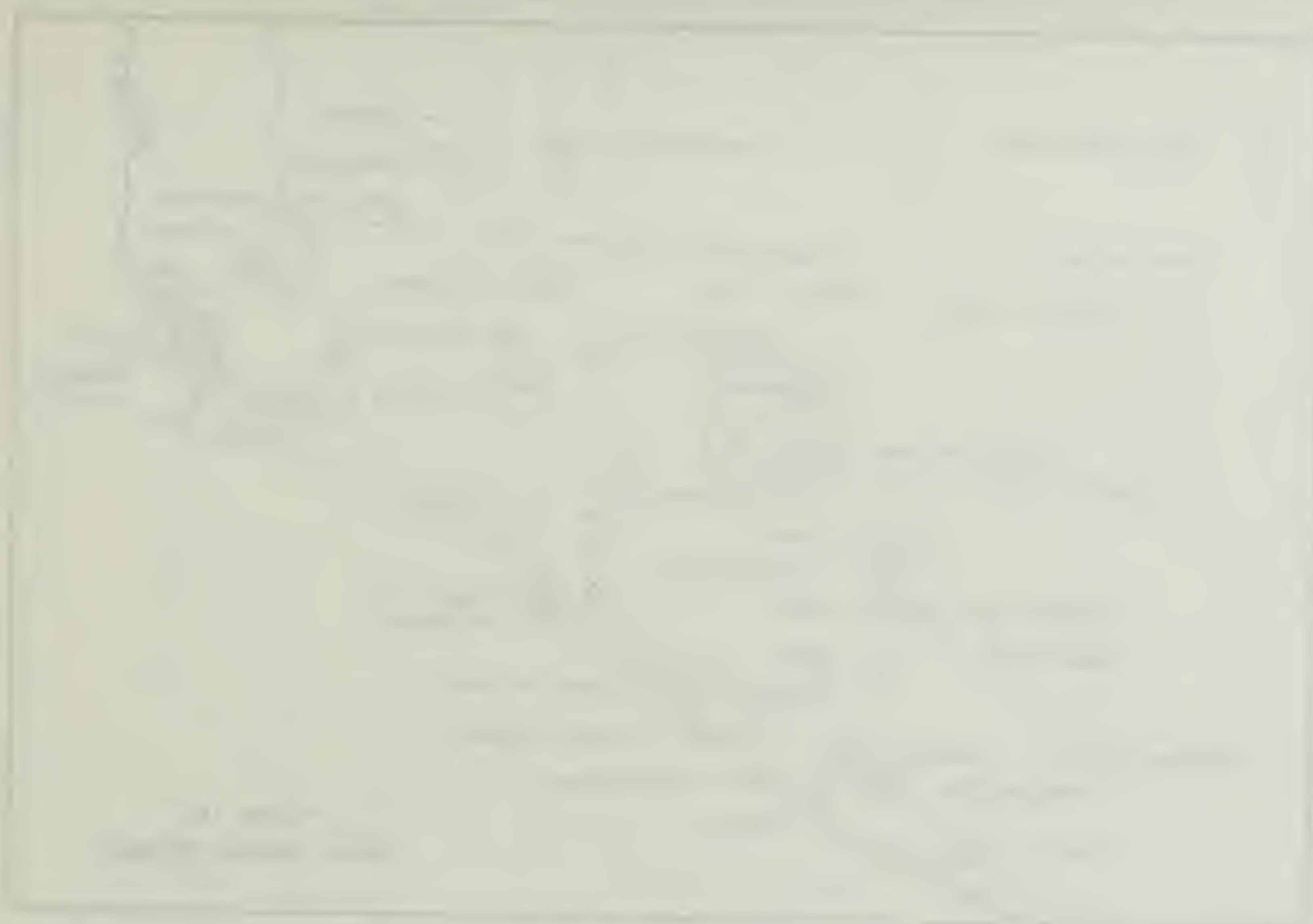


FIGURE 10

TEXAS COASTAL REGION



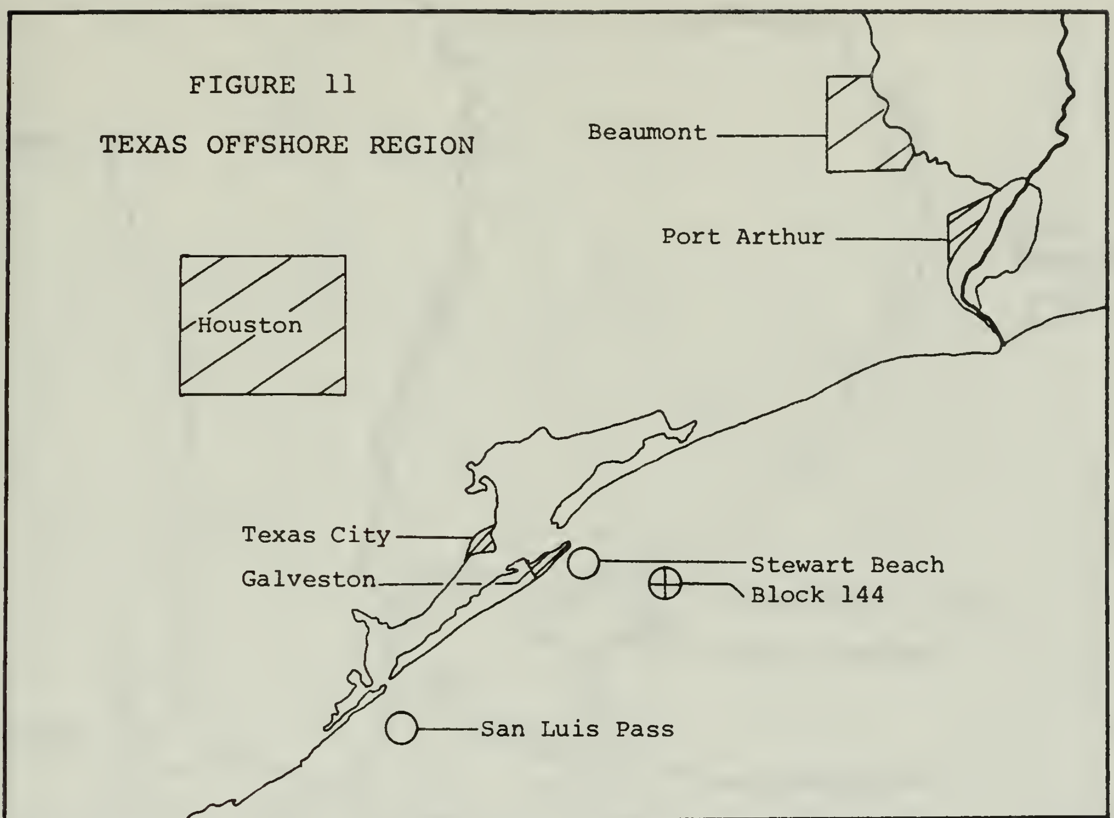


FIGURE 11

TEXAS OFFSHORE REGION

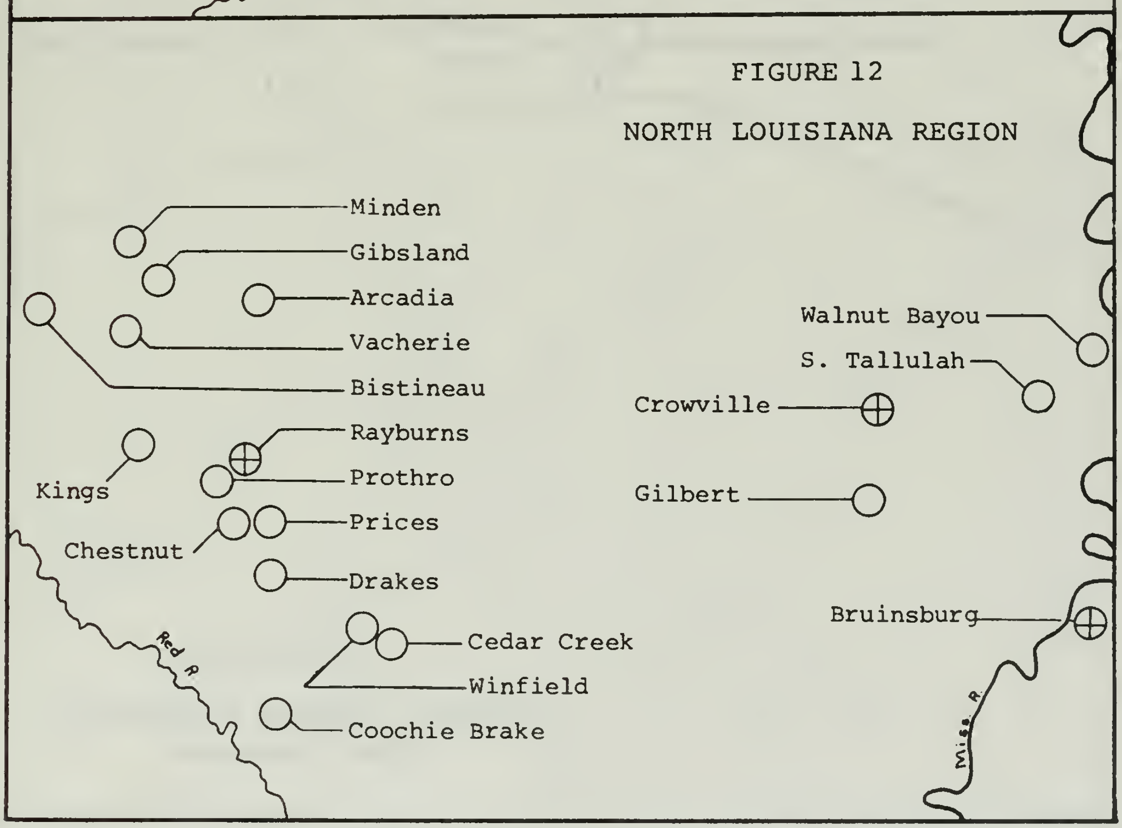


FIGURE 12

NORTH LOUISIANA REGION

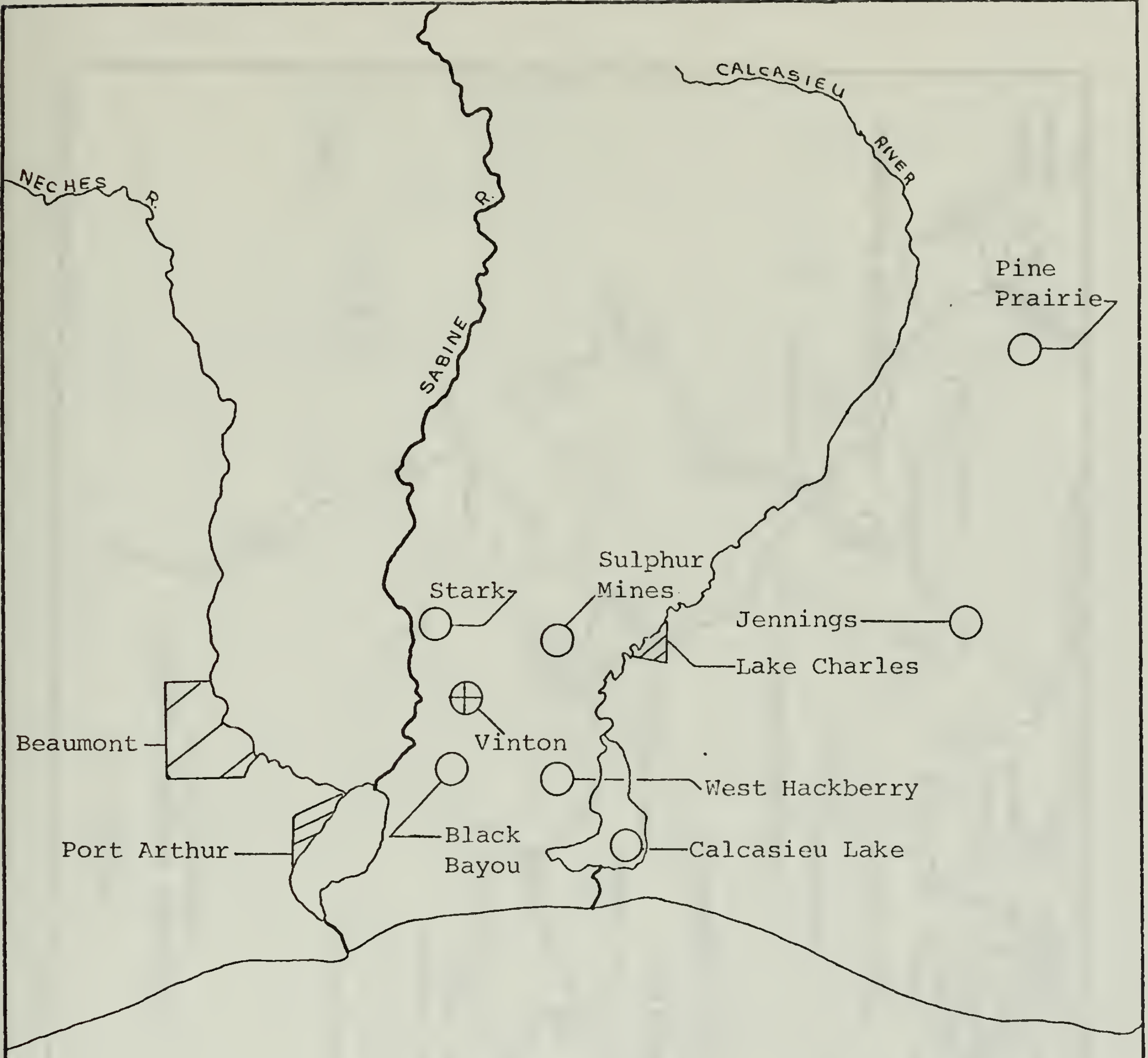


FIGURE 13

LOUISIANA COASTAL REGION
(western half)

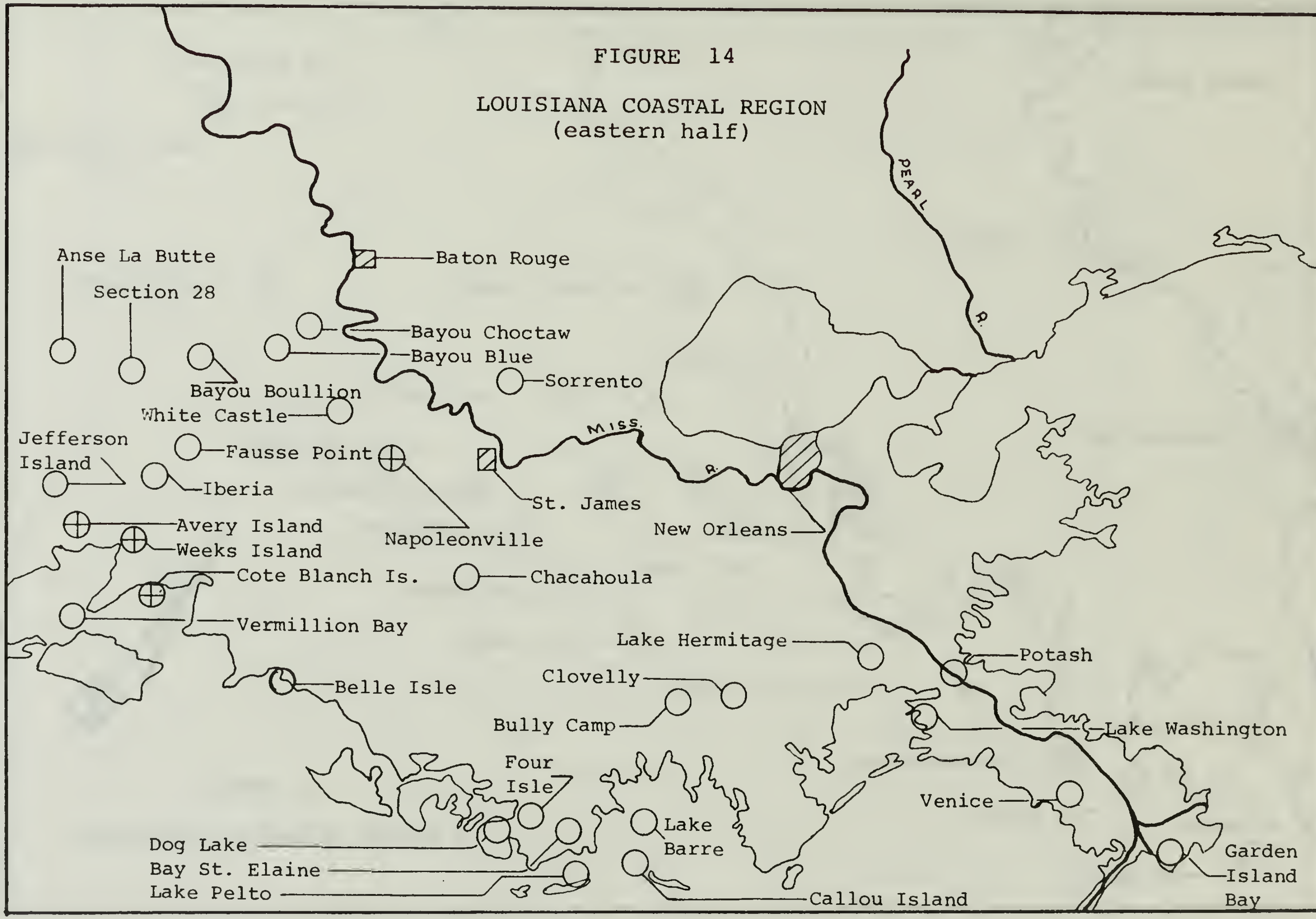


FIGURE 14

LOUISIANA COASTAL REGION
(eastern half)

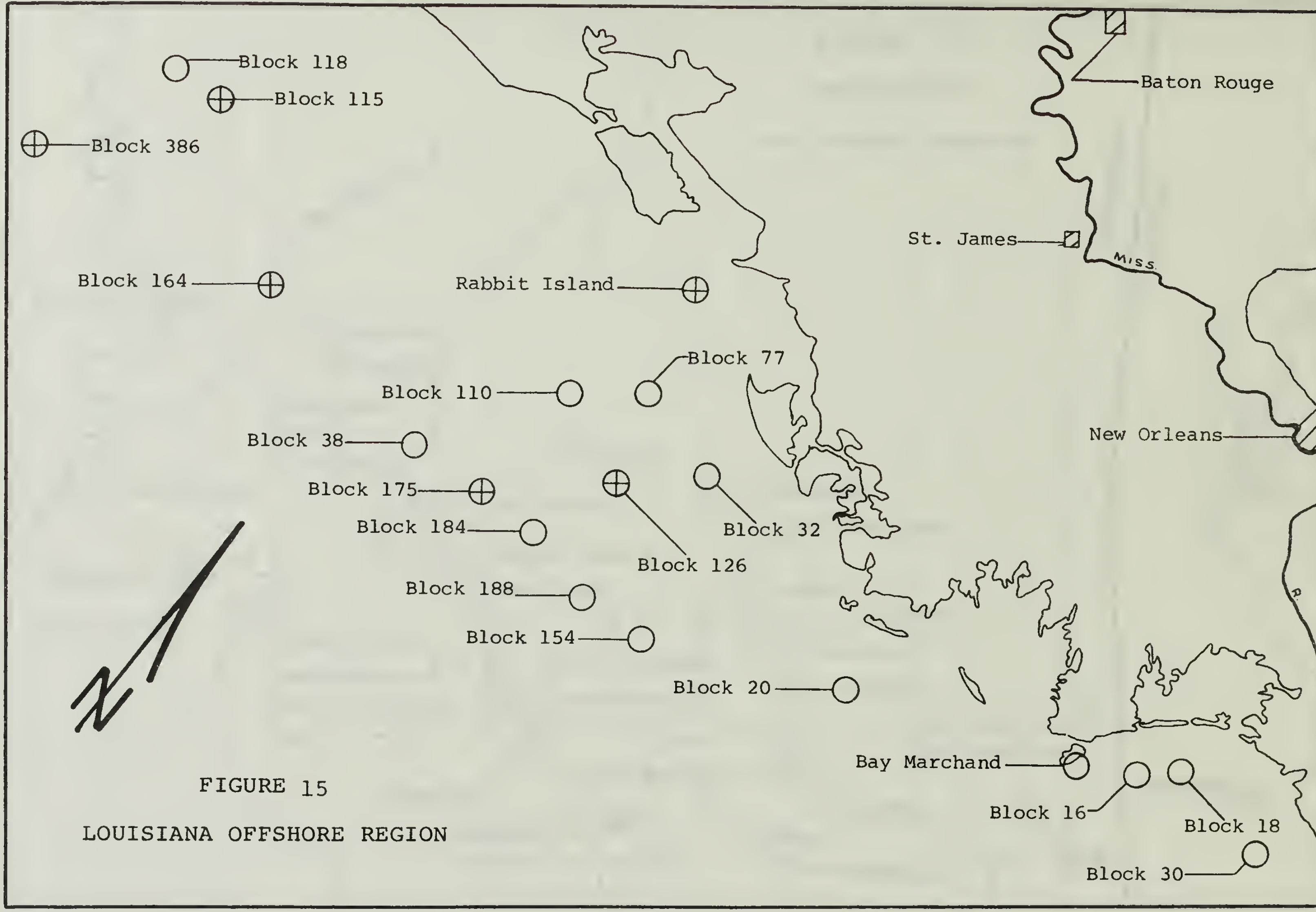


FIGURE 15

LOUISIANA OFFSHORE REGION

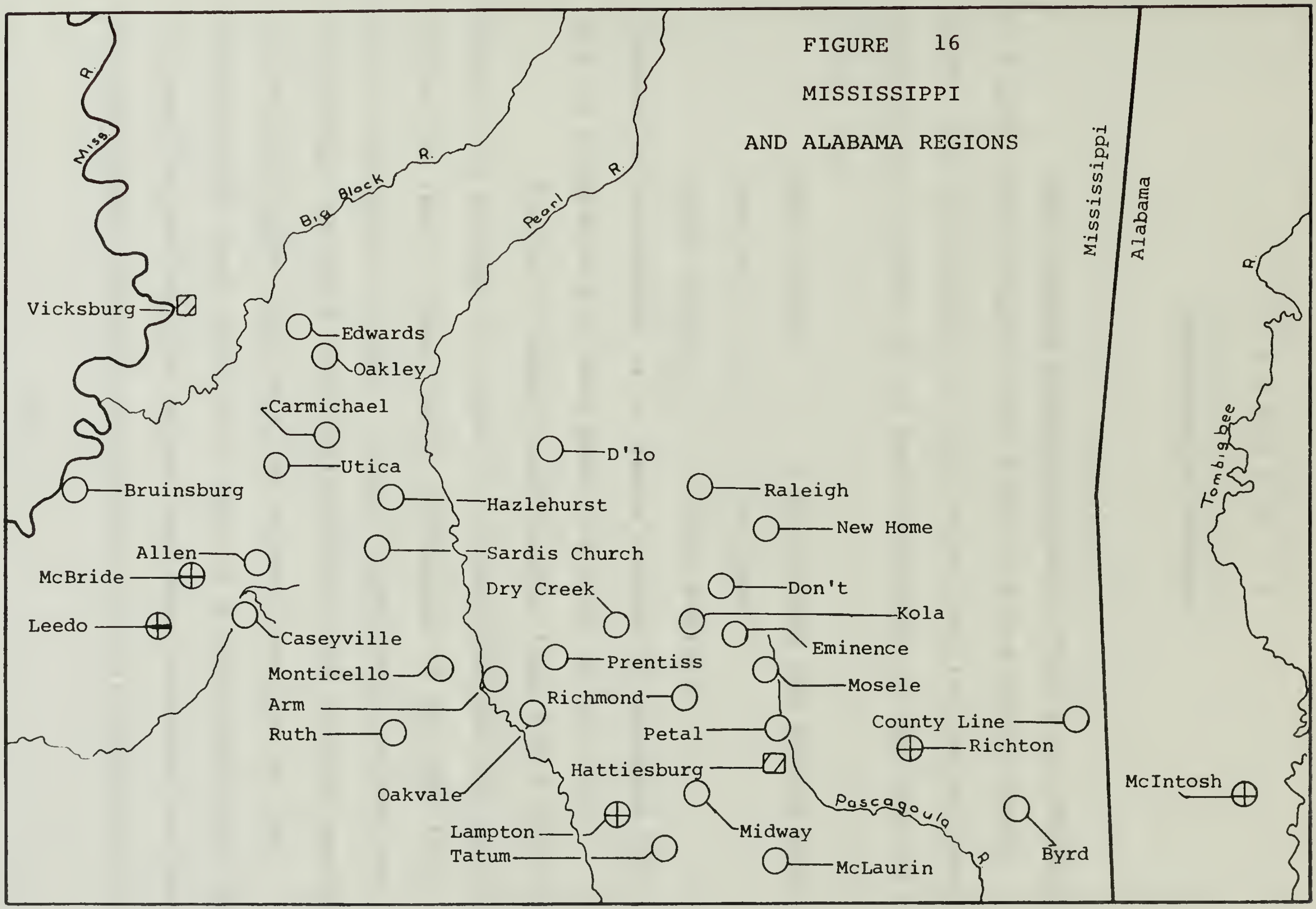


FIGURE 16

MISSISSIPPI AND ALABAMA REGIONS

CHAPTER V

CONSTRUCTION PROGRAM

Any storage program sequence should accommodate the most likely import loss first and the least likely last. For the purpose of this study the following import regions are classed as to the likelihood of the loss of their oil.

Most likely . . . . Africa and the Middle East

Possible . . . . . Far East

Least likely. . . . Latin America

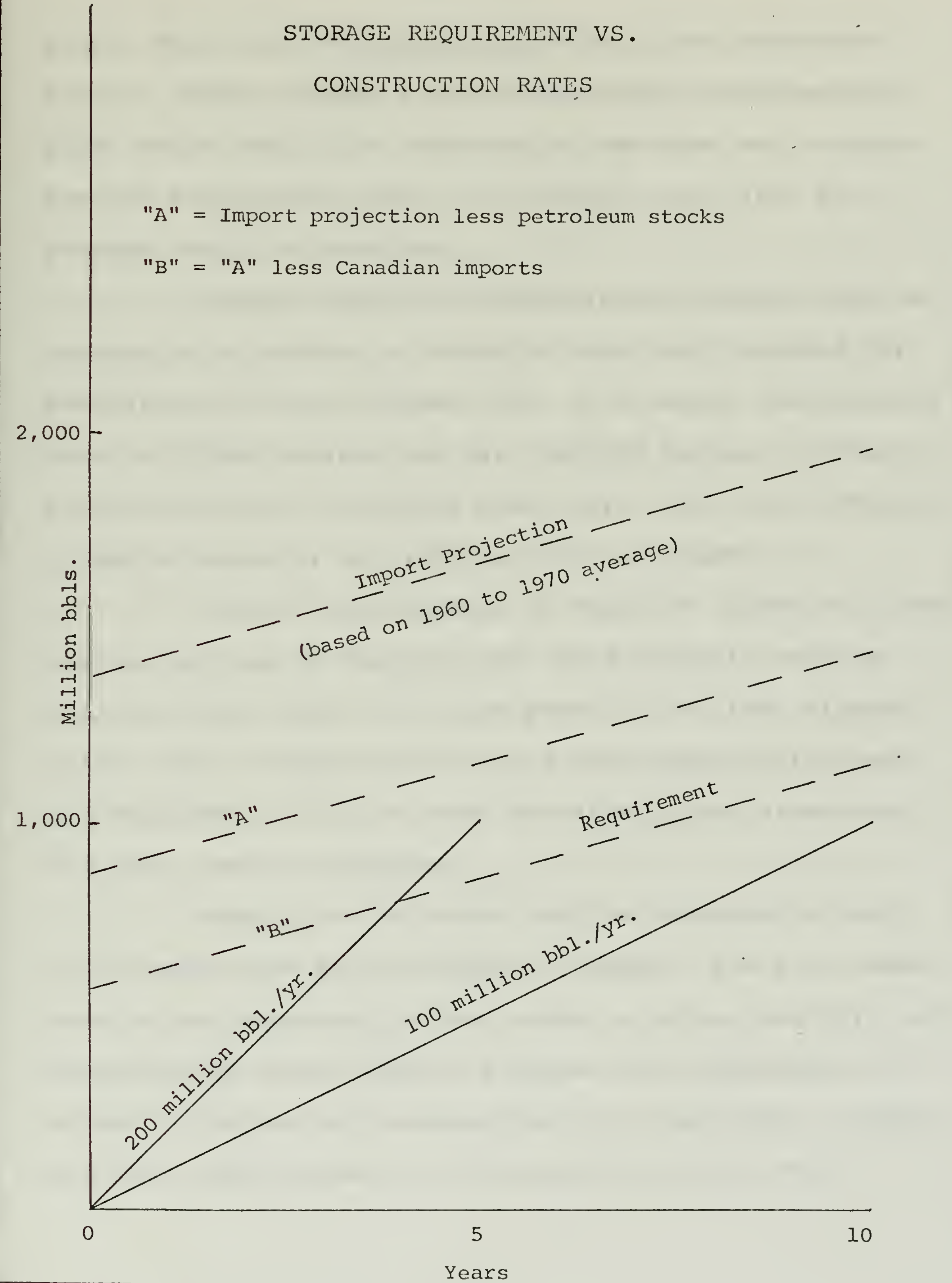
Canada is considered as a stable source of imported oil and no provision has been made for loss of its oil.

Figure 17 shows construction time for a billion barrels of storage at rates of 100 million and 200 million barrels a year. These rates correspond to ten and five year construction times. Actual construction rates for individual cavities have varied from 1,235 barrels per day at the Sour Lake dome to 8,430 barrels per day at the Barbers Hill dome. (5) At a rate of 1,000 barrels per day to meet the 200 million barrel per year construction rate, 548 individual projects would have to be in operation at a

FIGURE 17

STORAGE REQUIREMENT VS.

CONSTRUCTION RATES



time. This would be impractical from a cost standpoint. Even at 10,000 barrels a day 55 individual solution projects would have to be operating at one time and increasing the construction rate to 20,000 bbl. per day, 28 projects would be required.

Actual construction experience indicates that an average of 10 barrels of solution water are required for each barrel of salt removed. (5) At a cavity construction rate of 20,000 barrels per day, 200,000 barrels of fluid would have to be circulated every day. This would require a pumping capacity of 5,830 gallons per minute.

Onshore construction at rates of 10,000 to 12,000 barrels per day is feasible but would probably require multiple fresh water wells and possibly multiple disposal wells. (6) If large cavities and high construction rates are required, it will be more feasible to use sites near the Gulf Coast or offshore.

The oil to be stored will be imported oil and will come to the United States by tanker. Where it comes from is not pertinent to this study as price, quality, and availability at the time of purchase will determine its origin. The cost of transporting it is pertinent. Standard size tanker rates in 1971 were $13 per ton while

supertanker rates were approximately one-half of this amount. (14) Assuming an average transportation cost of $1.00 per barrel based on standard tanker rates, as much as $500 million could be saved if the one billion barrels of crude were shipped by supertanker. However, at the end of 1971 there were no port facilities capable of handling supertankers on the East or Gulf Coasts. (23) Proposals for building or at least interest in building such facilities were made by two state governments in early 1972. (21)

There is a possibility of combining an offshore system to serve a salt dome cavity with a commercial off-load facility for supertankers. There are three different schemes of varying costs for servicing tankers at offshore domes. They are a floating platform costing $80 million, a fixed platform costing $50 million, and a single point moor system costing $35 million. A fourth consideration has been a large port facility, basically an artificial island offshore, costing up to $300 million. (14) This system does not lend itself as well to application to the salt dome storage project as only one facility of this type would probably be constructed off the Gulf Coast. The other three lend themselves to multiple sites because of their small size and relative low cost.

This concept of joint use can be carried even further. So as not to restrict tanker offloading to pipeline capacity, refinery requirements, or limited storage the tankers could be offloaded directly into the cavities which could be constructed with excess capacity to handle tanker shipments. Faster turn around times for tankers would decrease import costs and the large storage capacity would allow firmer shipping schedules.

Onshore, in most cases, the land and mineral rights will be privately owned and since salt does have commercial value it will have to be purchased from its owner at a relatively high cost. Use of an offshore dome will eliminate the cost of land and acquisition of salt and/or storage rights in these areas controlled by state or the federal governments should be more easily obtainable.

It was previously theorized that there could develop a naval conflict or confrontation of such possible magnitude that worldwide shipping would be halted entirely or at least restricted so as to halt a large portion of our imported oil. If this situation should occur, an offshore storage site, unless also connected by a transmission line to the shore, might prove to be at a disadvantage.

This is not to say that the supposed situation was such that even coastal shipping would be stopped but the possibility of such a situation developing at a time when a small number of tankers were in U.S. coastal waters where they would be in a position to move oil from the Gulf to the East Coast refineries is possible. For instance, it would take 20 to 25 70,000 dwt. tankers (standard size) to move one million barrels of oil a day from Louisiana to New York assuming a round trip time of 10 days. The East Coast refineries have an approximate capacity (1971 figures) of 1,335,000 barrels per day not including the 550,000 barrel refinery center at Montreal, Canada, which receives imports via pipeline from the port at Portland, Maine. If one studies the crude transmission pipeline system of the United States, it becomes apparent very quickly that our East Coast refineries are isolated from our domestic crude supplies except by ocean routes. There are a number of gas transmission lines to the East but converting these to crude lines, if it were feasible, could result in a natural gas shortage in lieu of a crude shortage. Product transmission lines, however, may be idle without a flow of crude to refineries and do offer a possible means of assisting in transporting crude to the East. No matter how

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unpredictable the availability of ocean transportation may be, it will have to be the means of supplying the East Coast with the bulk of its crude requirements.

Sites close to a salt water source are best suited to fast construction rates. The first and most critical storage will be constructed in the Louisiana Coastal region at the Avery Island site. By constructing five 300 foot diameter by 1,000 foot cavities simultaneously at 12,000 barrels per day per cavity, a 60 million barrel capacity can be reached in two years and nine months. Oil from this site can be moved by barge on the Intracoastal Waterway system to New Orleans or Port Arthur, Texas, for transfer to tankers and shipment to the East Coast or through a nearby 22 inch transmission line to Port Arthur or Houston.

Keeping in mind the need for a supertanker off-load facility, an offshore site should be developed at the same time. The Block 175 salt dome off the Louisiana Coast can accommodate five cavities which can be constructed at the same rate as the group at the Avery Island dome. A drilling platform could be converted to a service platform for filling the cavity from tankers. The platform can also be connected to the existing 12 inch offshore line

that is nearby and by cross connecting to the Texas 22 inch line on shore, the Avery Island dome cavities can be filled with oil at the same time as the Block 175 cavities. The Block 175 location will accommodate supertankers. Both storage areas would be ready for filling at the same time.

As soon as the Block 175 storage site is completed, a second offshore project, identical to Block 175, can be started at Block 184 which also can be serviced by supertanker. The same procedure can be followed for this site as was followed on the Block 175 site. Concurrently, a project can be started onshore at the Napoleonville dome in Louisiana. Cavities for this dome will be reduced to a 250 foot diameter but the 1,000 foot length will be retained for an installed capacity of 40 million barrels. A slower construction rate of 10,000 barrels per day per cavity will be set for this site since fresh water will probably have to be used. Reducing the finished size of the five cavities will allow this site to be completed at the same time as the Block 184 site. Block 184 lies near an existing offshore pipeline leading to the Texaco refinery near St. James, Louisiana. This line can be connected to the storage site at the Napoleonville dome and the cavities filled in the same manner as at the Avery dome.

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Oil stored at the Napoleonville dome can be transported by tanker from the St. James tanker terminal to the East Coast or sent to the Great Lakes area refineries through the nearby 40 inch Capline. Block 184 can service tankers for East Coast shipments or augment the onshore pipeline system through cross connections to existing lines.

At the same time that the Avery Island and Block 175 projects are started, a third project can be started on shore at the Vinton dome in Western Louisiana. Cavities with 300 foot diameters will be formed but solution rates will be limited to 10,000 barrels per day. Again, five cavities will be formed for a site capacity of 60 million barrels. Construction time will be three and a half years. This dome can be connected to the same 22 inch transmission line that the Avery Island and Block 175 sites were connected to and filled from this line by supertanker shipments through the Block 175 tanker facility. Once filled, the facility can supply oil to the nearby refineries at Port Arthur, Lake Charles, Beaumont, Houston or to the East Coast. It has available to it for transportation a major pipeline, the Sabine River, the Intercoastal Waterway, and the port at Port Arthur.

At this point, as indicated in Figure 18, there have been established two facilities to offload supertankers,

a sizeable storage capacity, and an interconnected system of pipelines for dispersing the stored oil to ports and refineries in Texas and Louisiana. It is not necessary that the oil actually stored be imported oil but every barrel of domestic oil stored must be replaced by an imported barrel. Since the capability of importing and dispersing oil is now available, the rest of the storage sites may use domestic oil diverted from refining centers and replaced by equal imports.

Although not chosen as best in its group, the dome at Lake Washington will be developed because of its proximity to a major pipeline leading to the New Orleans port and refining facilities. The dome will be developed using the same program as at Avery Island and will start when the Avery project is complete. This storage will be filled with domestic crude.

When the Vinton project is completed, a project can be started at the Hawkinsville dome in Texas. This project will use salt water from the Gulf for solution and brine will be dumped into the Gulf through temporary pipelines. The planned solution rate will be 12,000 barrels per day in five cavities having a combined storage of 60 million barrels. An identical project at the Moss Bluff

site, northeast of Houston, can start as soon as the Napoleonville project is completed.

As soon as the Block 184 project is completed, an identical project can be started at Block 164. This site will not have a platform but only a floating moor system for tanker service as there are no existing transmission lines within a reasonable distance at the present time.

When the Block 184 project is complete a fifth offshore project can commence at Block 144 off the Texas coast at Galveston. The project will be identical to the other four. There are no offshore lines in this area at this time and to construct an expensive offshore line to connect to shore facilities for standby purposes only would be impractical. To facilitate filling the storage cavities and to provide the Texas refining centers around Houston with a supertanker offload facility a fixed platform can be constructed in deeper water and in line with Block 144 and Galveston. An offshore line connecting these three sites can be used to service the storage site and to offload supertankers on a regular basis.

In the interests of dispersal, six sites were chosen for projects to be constructed after the fifth year

of the program. Each site will have two 10 million barrel capacity cavities to be constructed consecutively at a rate of 10,000 barrels per day. The sites will be at the Gyp Hill dome in South Texas, the Boling dome southwest of Houston, the Steen dome in Northeast Texas, the Rayburns dome in North Louisiana, and the Leedo and Richton domes in Mississippi. Construction will take two years and nine months for each cavity or five and a half years for each site and result in a total of 120 million barrels storage capacity.

The program as outlined to this point will not reach the previously projected one billion barrel capacity. At the end of five years the capacity will be 310 million barrels and at the end of ten years it will be 680 million barrels with a final capacity of 700 million barrels at the end of the eleventh year of the program.

The bases of this program are assumptions, projections and possibilities. If such a program were instituted, it would have to be reviewed after each five years of construction to account for changes in these uncertainties and revisions made accordingly. The reviews should be made to include not only changed supply, demand, and political conditions, but more importantly the availability

of useable storage space in commercial salt mine cavities. Hawkins and Jirik reported that in 1964 10 million short tons of salt were produced by solution mining in Texas, Louisiana, and Alabama. This represents about 23 million barrels of storage capacity. Since solution cavities have limits to their size, salt solution mining cavities must ultimately be abandoned. The potential storage space is highly significant as shown by the 1964 rate of salt removal. If the cavities are also near crude oil transport media, they could be used for storage. Sixteen of those domes listed in the Appendix have or have had solution mining projects in them. It is entirely feasible that the remaining 300 million barrels of storage capacity could be obtained from existing salt mine solution cavities. The approximate total volume thus obtainable may suffice to complete the one billion barrel originally conceived project goal within a shorter period of time.

Providing the West Coast refineries with crude oil is a problem in itself. California can be considered as the importer for the West Coast since the refineries in Washington are supplied principally from Alaska and Canada. Net foreign imports to the West Coast were approximately 325,000 barrels per day in 1971. (8) The solution as to

how to make up for this import loss is more difficult and less certain than that proposed for the East Coast. Reliance on transportation by tanker from Gulf Coast storage sites is ruled out as in all probability the available tankers would be in use supplying the East Coast, the blockage of the Panama Canal during the hypothetical world-wide crisis is highly probable, and if oil could be moved from the Gulf Coast to California, then it could in all probability also be moved from Venezuela. There is only one crude transmission line from the oil producing Central United States and transmission of oil by this means is basically limited to present pipeline capacity. The best available solution under these conditions is to store the oil as close as possible to California and rely on railroad, truck and unused pipeline capacity to move the oil the rest of the way to California.

The closest storage site to California is the Luke dome in Arizona. To completely offset California's import losses for a year would require over 100 million barrels of oil. The Luke dome could accommodate this quantity of storage space but construction may be quite difficult in this water scarce state. Even at the maximum construction rate and forming eight cavities simultaneously,

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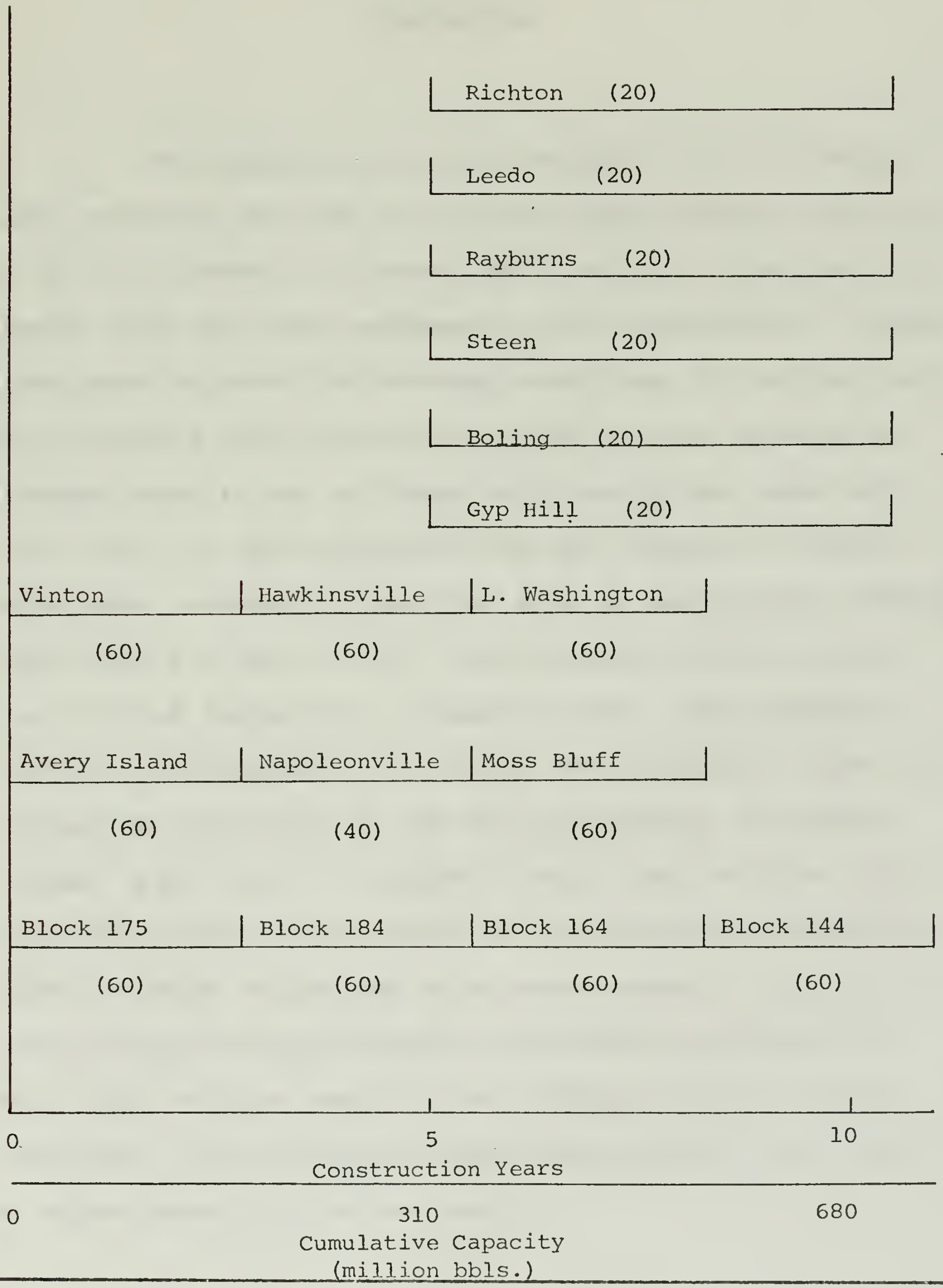
it would take almost three years to construct a 100 million barrel capacity.

Considering the availability of Alaskan North Slope oil three to five years away, the development of import sources on the west coast of South America, the probable construction difficulties in Arizona, and the paucity of large bulk transportation media to California from Arizona it is considered impractical and unwarranted to undertake a storage project for the West Coast at this time.

FIGURE 18

CAVITY CONSTRUCTION PROGRAM
(size in million bbls.)



CHAPTER VI

CONCLUSION

The question as to the feasibility of storing a large quantity of crude oil in salt dome solution cavities so as to be useable in case a restriction in imported oil should occur has been answered in the affirmative. Sixteen sites were selected for storage totalling 700 million barrels assuming that the remaining 300 million barrels of storage capacity can be found in solution salt mine cavities. Four of the selected sites are offshore of which three were intended to function also as supertanker offload facilities not only to fill the storage cavities but to also offload tankers on a regular basis. The proposed construction program will require ten to fifteen years to accomplish; ten years if 300 million barrels of useable storage space can be obtained in salt mine solution cavities and fifteen years if all of the proposed one billion barrel storage volume has to be constructed. The cost of such a project would probably not exceed $2 billion of which $185 million would be for offshore tanker offload facilities. The actual storage construction costs would be approximately $1.85 per barrel.

R E F E R E N C E S

REFERENCES

1. Allen, Kermit, "Eminence--Natural Gas Storage in Salt D mes Comes of Age." A.I.M.E. Transactions, Vol. 250, No. 4, (December, 1971), pp. 276-279.

2. Brown, K. E., "Pressure--Temperature Effect on Salt Caviti s and Survey of Liquified Petroleum Gas Storage." M. S. Thesis. (University of Texas, 1959).

3. "Caverns Prepared for Crude Storage." The Oil and Gas Journal, December 21, 1970, p. 19.

4. Crude Oil Pipeline Atlas, The Oil and Gas Journal, October 11, 1971.

5. Dommers, O. B., et al., "Feasibility of Creating Spherical Cavities in Underground Salt Domes," The University of Texas, Department of Petroleum Engineering Report to the Atomic Energy Commission, June 30, 1963.

6. Fenix and Scisson, Inc., Tulsa, Okla., Private Communication.

7. "Flow of Oil Through Capline Growing," The Oil and Gas Journal, October 18, 1971, p. 46.

8. Gardner, F. J., " Price, Nationalization Jitters Plague International Oil World," The Oil and Gas Journal, December 27, 1971, pp. 67-106

9. Halbouty, Michel T., Salt Domes Gulf Region, United States and Mexico, Gulf Publishing Co., Houston, Texas, 1967.

10. Harr, H. R. Jr., "Red River Waterway Project," The Military Engineer, Vol. 63, No. 414, July-August 1971, p. 249.

11. Hawkins, M. E. and Jirik, C. J., "Salt Domes in Texas, Louisiana, Mississippi, Alabama and Offshore Tidelands," Bureau of Mines Information Circular 8313, U.S. Department of Interior, 1966.

12. Kennedy, J. L., "Tank of One Million Barrel Capacity is Being Readied for Ekofisk," The Oil and Gas Journal, February 14, 1972, p. 73.

13. Kidd, Isaac C. Jr., Admiral, U.S. Navy, "View From the Bridge of the Sixth Fleet Flagship," U.S. Naval Institute Proceedings, Vol. 98, No. 2/828, February, 1972, p. 19.

14. Kinney, Gene, "Watching Washington," The Oil and Gas Journal, November 1, 1971, p.27

15. Koester, Edward A., "Salt Domes in Arizona," Oil and Gas Conservation Commission of the State of Arizona, Geological Report No.1, November 1971.

16. "Outlook for Energy in the United States," The Chase Manhattan Bank, N.A., October, 1968.

17. Petroleum Facts and Figures. (American Petroleum Institute Washington, D.C., 1971)

18. Proceedings of the 1967 Symposium on the Geology and Technology of Gulf Coast Salt, Louisiana State University, 1970.

19. "Soviet Fleet Building Up in Indian Ocean Area," U.S. Naval Institute Proceedings, Vol. 98, No. 3/829, March 1972, p. 124.

20. "Summary, Conclusions, and Recommendations From Cabinet Force's Import Study," The Oil and Gas Journal, March 2, 1970, p. 20-A.

21. "Super Port," The Austin American Statesman, February, 1972, p. 1

22. "Underground Storage of Liquid Hydrocarbons in the United States," The Research and Coordinating Committee of the Interstate Oil Compact Commission, April, 1956.

23. "U.S. Energy Outlook," The National Petroleum Council, Vol. 1, July, 1971.

24. "U.S. Petroleum Statistics," The Independent Petroleum Association of America, 1972.

25. "United States Petroleum Through 1980," U.S. Department of Interior, July, 1968.

APPENDIX

SALT DOME DATA

ARIZONA REGION

At the present time there is only one identified salt dome in Arizona although the existence of other domes is highly probable. (15) The Luke dome is 15 miles northwest of Phoenix and based on present data has a volume of approximately 2.8 cu. mi. to a depth of 3,000 feet. The depth to the top of the salt is 850 ft. The dome is 120 miles south of a 16 inch crude transmission line.

A possible second dome is located 160 miles northwest of the Luke dome and, if determined to be an actual dome, lies in a better position in relation to the 16 inch transmission line. Two other possible domes have been indicated near Overton Beach in Nevada and near Pima, Arizona. Neither is in as favorable a position as the possible Red Lake dome.

NORTHEAST TEXAS REGION

This region is subdivided into groups according to their proximity to large rivers. It is assumed that the primary source of solution water and brine disposal for this group of domes will be wells and the rivers only offer an alternate source of water and in some cases a possible transportation medium.

Sabine River Group

The Grand Saline dome is at a shallow depth, has a large volume, and lies on or near a 20 inch diameter crude line feeding the Chicago and Detroit area. The dome is being used for salt mining and brine production. The Steen dome although having comparable depth is much smaller in size and offers much less potential storage volume. It is near a large transmission line to the Houston area. The Hainseville dome has an existing LPG storage cavity which might conflict with any crude storage operations. The Steen dome with no conflicting operations is the best site for a crude storage operation in this group.

Neches River Group

The Mt. Sylvan, East Tyler, Brooks, and Bullard domes are all relatively shallow. The E. Tyler Dome has an existing LPG storage cavity. The Brooks Dome has the largest useable volume and is only 10 miles from a 20 inch crude pipeline feeding the Port Arthur and Beaumont refining centers. The best of the six domes is the Brooks Dome.

Trinity River Group

The Palestine, Butler, and Oakwood domes are all relatively shallow. The latter two are on or near large pipelines. The Oakwood dome offers a larger potential storage volume and is the best dome of this group for a storage site.

It should be noted that in 1962 Congress authorized a project to make the Trinity River navigable from Dallas, Texas to the Mississippi River. This project was partially funded in 1968 and if completed will provide a second transport media for any crude oil stored in this group of domes.

NORTH EAST TEXAS REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles) to			Pipe Diameter (in.)
			River	Refining Center	Pipeline	
			SABINE RIVER GROUP			
Grand Saline	212	7.6	5	200	on	20
Hainesville	1,155	8.3	5	200	on	8
Steen	300	1.9	5	200	10	20
			NECHES RIVER GROUP			
Mt. Sylvan	613	2.9	on	180	10	10/20
East Tyler	890	4.3	10	180	5	12/20
Whitehouse	2,000	2.5	10	170	5	12
Brooks	220	5.5	on	160	5	10/12
Bullard	527	3.0	10	160	10	10/12
Boggy Creek	1,829	11.0	on	150	on	8/12
			TRINITY RIVER GROUP			
Bethel	1,660	8.0	5	150	5	12
Keechi	2,162	1.1	10	140	5	8
Palestine	122	3.1	5	130	5	8
Butler	312	1.5	5	130	on	20
Oakwood	800	2.9	10	130	on	26

SOUTH TEXAS INLAND REGION

All three domes of this region are on or near crude pipelines feeding into the Corpus Christi area and are in undeveloped areas. There are no large rivers in the immediate area and in all probability solution water would have to be obtained from wells and brine disposed of in the same manner. The Palangana dome has a salt brine production operation. The Gyp Hill dome, although farther from the refineries and port facilities at Corpus Christi by pipeline miles than the other two domes, is closer to an alternate water source and disposal area, Baffin Bay. Based on this difference, the Gyp Hill dome is considered best for a storage site.

SOUTH TEXAS INLAND REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles) to			Pipe Diameter (in.)
			Water Source	Refining Center	Pipe Line	
Palangana	500	3.6	40	60	on	6
Piedras Pintas	1,205	2.6	40	60	on	6
Gyp Hill	1,140	2.3	25	60	10	8

TEXAS COASTAL REGION

This region was divided into four groups on the basis of distance to a salt water source and proximity to two major rivers.

Ten Miles or Less to Salt Water

The Barbers Hill dome is relatively shallow, has a large volume, lies on or near several transmission lines, is only 15 miles from the Baytown refineries and 25 to 30 miles from the refineries and port at Houston. Its disadvantages are that it lies in a developing area where acquisition of land will be expensive and it is already being used as an LPG storage site. The Moss Bluff dome is 15 miles farther from the refining and port facilities but offers a much better prospect in terms of land acquisition costs. Moss Bluff is also very large in size and on or near a large transmission line.

The first seven domes listed above lie south of Houston and on the Gulf Coast itself as opposed to the last four domes which lie northeast of Houston and on an embayment with the exception of the Big Hill dome. The first group of seven lies in a relatively undeveloped area. The

Hawkinsville dome is the best dome of the first group being shallow and of relatively large size. In addition, it is only 10 miles from the Intercoastal Waterway running north to the port of Freeport.

All of the three domes discussed are good sites for storage. The Hawkinsville dome is the best site from the point of land acquisition.

Between Ten and Twenty Miles to Salt Water

The Hull and South Liberty domes offer the best two possibilities based on depth and size. The Hull dome has an existing LPG storage cavity which might conflict with a crude oil storage facility. The South Liberty dome lies closer to Houston and the land acquisition costs would probably be higher. This dome lies across the Trinity River and is closer to Galveston Bay. The South Liberty dome is the best site for a crude storage project.

Trinity River Group

The Humble dome is at a distinct disadvantage in that it lies in a very highly developed area and land acquisition would be costly. The North Dayton and Davis Hill

domes lie in the least developed areas. The Davis Hill dome although 400 feet deeper has a large volume, is on a crude transmission line and is only 5 miles or less from the Trinity River. The Trinity River offers not only a source of solution water but a possible future transportation medium.

Brazos River Group

Ten of this group are relatively shallow but only three of the ten have relatively large volumes. These are the Hockley, Boling and Damon Mound domes. The Hockley dome has a salt mine operation and is in a developing area north west of Houston. The Boling dome is at about the same depth but has 6 times the volume of the Hockley dome and is in a less developed area southwest of Houston. The Boling dome lies on or near an eight inch transmission line compared to the eighteen inch line that passes over the Hockley dome. The Boling dome lies ten miles from the Colorado River and on the smaller San Bernadino River. The Damon Mound dome has similar characteristics except that it is shallower by 400 feet and much smaller in size. Because of their locations in undeveloped area, the Boling and the Damon Mound domes are the best of this group for possible storage sites.

TEXAS COASTAL REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles) to			Pipe Diameter (in.)
			River	Refining Center	Pipeline	
TEN MILES OR LESS TO SALT WATER						
Gulf	1,100	0.7		80	20	-
Hawkinsville	450	4.4		60	15	-
Allen	1,380	0.8		50	15	-
Clemens	1,380	1.9		50	10	-
Bryan Mound	1,112	1.5		45	20	-
Stratton Ridge	1,250	9.6		40	10	-
Hoskins Mound	1,150	0.8		30	10	-
Lost Lake	3,617	1.5		10	on	20
Barbers Hill	1,000	5.1		15	on	20
Big Hill	1,300	2.6		20	on	-
Moss Bluff	1,160	11.2		25	on	20
BETWEEN TEN AND TWENTY MILES TO SALT WATER						
Markham	1,417	1.9		80	on	-
South Liberty	480	5.4		20	on	-
Fannett	2,200	1.0		15	5	20
Hull	595	2.6		30	on	-
Spindletop	1,200	1.8		5	on	-
TRINITY RIVER GROUP						
Humble	1,214	9.8	25	20	on	20
North Dayton	800	1.7	10	20	5	10/12
Batson	2,050	3.2	10	30	on	20/26
Davis Hill	1,200	5.5	5	50	on	10
Saratoga	1,900	2.1	15	30	on	20/26
Sour Lake	719	1.8	25	20	on	25

TEXAS COASTAL REGION (continued)

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles) to			Pipe Diameter (in.)
			River	Refining Center	Pipe-Line	
		BRAZOS RIVER GROUP				
Clay Creek	2,400	2.2	10	80	25	18/8
Brenham	1,150	1.3	20	80	on	18
Hockley	1,010	5.9	20	40	on	18
Orchard	369	1.2	5	45	on	10
Blue Ridge	230	1.3	10	20	on	8
Pierce Junction	860	1.3	15	5	on	8
Big Creek	635	1.8	10	35	on	8
Long Point	868	2.8	10	35	on	8
Boling	975	33.3	10	50	on	8
Nash	950	2.0	5	35	on	-
Damon Mound	529	4.3	10	40	on	-
West Columbia	768	0.8	5	40	on	-

TEXAS OFFSHORE REGION

San Luis Pass and Block 144 have sufficient water depth to be serviced by standard tankers (less than 40 feet of draft). Stewart Beach and McFadden Beach would have to be serviced by barges or new offshore crude lines as there are no existing crude lines off the Texas coast. Based on its nearness to the port of Galveston and the refining complex at Texas City, Block 144 is the best of these four domes for a storage site.

TEXAS OFFSHORE REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance to (miles)				Pipe Diameter (in.)	Depth of Water (ft.)
			Shore	Port	Refining Center	Pipeline		
San Luis Pass	358	-	10	20	25	25	-	40
Stewart Beach	2,640	-	5	5	10	10	-	20
Block 144	1,741	-	15	15	15	15	-	40
McFaddin Beach	2,603	2.4	5	30	30	15	10	20

NORTH LOUISIANA REGION

This region is divided into two groups based on proximity to two major rivers.

Red River Group

The volumes of this group of domes are unknown. Nine of these domes are shallow, less than 1,000 ft., and are 130 to 160 miles from a refining center. The Rayburns dome is the shallowest, is only 5 miles from an existing crude line and is the best site for a crude storage project in this region. The slightly deeper Prices and Drakes domes are equally suited as to location near an existing crude line and offer alternate storage sites.

The Red River offers a potential transportation medium. The River and Harbor Act of 1968 authorized the construction of the Red River Waterway Project which would make the river navigable from Shreveport, Louisiana, to the Mississippi River. (10)

Mississippi River Group

The Crowville Dome has two advantages over the other domes of this group, it is shallow and is on or near

an existing crude line to Baton Rouge. It is relatively far from the Mississippi River but does lie within 5 miles of the Bayou Macon River. If the Mississippi River were considered the transportation media for this group of domes, the Bruinsburg Dome would be the best choice.

NORTH LOUISIANA REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles to) Refining Center	Pipe-Line	Pipe Diameter (in.)
RED RIVER GROUP					
Minden	1,912	30	160	on	6
Bistineau	1,500	15	160	10	3
Gibsland	885	30	160	on	6
Vacherie	777	20	160	10	6
Arcadia	1,400	35	160	10	6
Kings	172	20	150	10	6
Prothro	600	25	150	on	6
Rayburns	115	25	150	5	6
Chestnut	2,450	20	150	on	6
Prices	700	20	150	5	6
Drakes	850	15	150	5	6
Winfield	200	20	130	15	8
Cedar Creek	750	20	130	15	8
Coochie Brake	2,388	5	130	15	20
MISSISSIPPI RIVER GROUP					
Walnut Bayou	2,740	5	130	20	12
South Tallulah	3,023	15	120	20	12
Crowville	800	35	120	on	8
Gilbert	1,778	25	110	5	8
Bruinsburg (Mississippi)	800	5	100	15	8

LOUISIANA COASTAL REGION

This region was divided into three groups based on distance to a salt water source. Those domes within 10 miles of a salt water source are considered within practical reach as far as solution water and brine disposal are concerned. Those domes between 10 and 20 miles from a salt water source are within reach only as an alternate source. Those over 20 miles away are beyond practical reach under ordinary conditions.

Ten Miles or Less to Salt Water

The domes at Avery, Weeks, and Cote Blanche Islands are all shallow, have relatively large volumes, and are within 5 miles of a large crude transmission line. This line feeds into the Port Arthur, Beaumont and Houston areas. In addition all three are in undeveloped areas where acquisition of land would be inexpensive. At the same time construction costs in this swampy area would be high. Of additional significance is the fact that all three domes lie on or very near the Intercoastal Waterway. All three of these domes are well suited for storage sites.

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Between Ten and Twenty Miles to Salt Water

Although the volume of the Vinton dome is unknown, its shallow depth and location make it the best of these 4 domes. It is within 5 miles of a 20 inch and a 22 inch transmission line. It is less than 10 miles east of the navigable Sabine River, 10 miles north of the Intercoastal Waterway, 30 miles from the Port Arthur refineries, and 20 miles from the St. Charles, Louisiana, refineries.

Over Twenty Miles to Salt Water

The Napoleonville dome, located in Assumption Parish, although not the shallowest of this group, has the largest volume. The dome is also 20 miles west of the St. James refineries and port on the Mississippi River and 10 miles east of the Intercoastal Waterway. The St. James port is also the terminus of the 40 inch Capline.(7) The closest crude transmission line to the dome runs north to the Baton Rouge refineries. The dome is in a moderately developed area and is the best of this group for a storage site.

LOUISIANA COASTAL REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles to) Refining Center	Pipe-Line	Pipe Diameter (in.)
TEN MILES OR LESS TO SALT WATER					
Black Bayou	1,035	2.8	15	5	22
West Hackberry	1,790	11.5	20	10	22
Calcascieu Lake	2,345	3.1	25	10	-
Jefferson Island	31	2.4	65	10	22
Avery Island	8	4.0	65	on	22
Weeks Island	43	6.1	55	5	10/22
Cote Blanch Is.	298	6.8	55	5	10/22
Vermillion Bay	265	2.9	65	5	10/22
Bell Isle	137	1.9	45	5	10
Four Isle	1,305	3.1	50	10	22/16
Dog Lake	1,725	-	55	10	22/16
Bay St. Elaine	1,200	6.7	55	on	16
Lake Pelto	1,982	1.7	65	on	16
Lake Barre	758	1.3	60	5	16
Callou Island	2,740	2.3	65	10	16
Chacahoula	1,100	9.1	15	on	20
Bully Camp	1,296	2.7	40	on	12
Clovelly	1,168	.6	40	on	12
Lake Hermitage	1,400	.9	35	on	8
Lake Washington	1,500	14.5	50	on	18
Potash	1,300	1.0	40	on	12
Venice	1,320	3.7	65	on	-
Garden Island Bay	2,041	6.3	80	5	12
BETWEEN TEN AND TWENTY MILES TO SALT WATER					
Vinton	700	-	20	5	20/22
Sulphur Mines	1,460	1.1	15	5	20/22
Iberia	805	2.1	45	on	12
Fausse Point	823	7.9	40	on	12

LOUISIANA COASTAL REGION (continued)

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles to) Refining Center	Pipe-Line	Pipe Diameter (in.)
OVER 20 MILES TO SALT WATER					
Starks	1,538	2.2	30	5	20
Pine Prairie	346	2.9	50	5	8
Jennings	2,400	1.5	40	5	8
Anse La Butte	137	3.1	50	10	12
Section 28	1,181	2.3	40	on	12
Bayou Bouillion	1,261	4.5	30	10	12
Bayou Blue	2,801	4.6	20	10	12
Bayou Choctaw	629	1.3	10	5	12
White Castle	2,313	1.3	25	10	12
Napoleonville	657	7.7	20	10	12
Sorrento	1,717	5.1	15	5	40

LOUISIANA OFFSHORE REGION

This region was subdivided on the basis of possible methods of servicing the storage cavity; supertanker, standard tanker, offshore pipeline, barge and combinations of these. It was assumed that no long distances of offshore pipeline would be constructed specifically for a storage cavity.

Supertanker Service

It is not practical to connect either of these domes to an existing offshore crude line. Except for the unknown volume of Block 386, the two domes have equal characteristics and either could be used for a storage cavity to be serviced by tankers having drafts up to 75 feet.

Standard Tanker Service

Connecting either of these two domes to an existing offshore crude pipeline is not practical. Block 115 has a distinct advantage over Block 118 in its shallowness, 378 feet as compared to 2,930 feet, and is considered the better of the two domes for a storage cavity.

Supertanker or Pipeline Service

Block 175 has the advantage of being at a shallow depth of 201 feet, however, its volume is unknown. Assuming it has an adequate volume, it would be the best of the five domes. Should this dome prove to have a volume insufficient to store the quantity of oil desired, then Block 184 with a volume of 3.2 cubic miles would be the next best choice.

Standard Tanker or Pipeline Service

Based on depth to top of salt, Block 126 is the better of the two domes for a storage site.

Barge or Pipeline Service

Based on depth to top of salt, the Rabbit Island dome is the best but the volume of the dome is unknown. With a volume of over 20 cubic miles, the Bay Marchand dome offers the largest potential storage volume but is at a depth of over 2,000 feet. Assuming an adequate volume, the Rabbit Island dome is the best of this group for a storage site.

LOUISIANA OFFSHORE REGION

Dome Name	Depth (ft.)	Volume (cu. mi.)	Distance (miles) to Shore	Port	Refining Center	Pipeline	Pipe Diameter (in.)
SUPERTANKER SERVICE (depth of water 75 ft. or greater)							
Block 386	800	-	60	85	85	85	10
Block 164	573	9.4	50	110	110	35	10
STANDARD TANKER SERVICE (depth of water at least 40 feet)							
Block 118	2,930	-	40	75	75	70	10
Block 115	338	-	35	85	85	60	10
SUPERTANKER OR PIPELINE SERVICE							
Block 38	2,278	-	60	140	100	10	10
Block 175	201	-	50	150	100	10	10/12
Block 184	1,156	3.2	40	160	90	15	12
Block 188	2,180	13.4	40	170	90	10	16
Block 154	2,916	13.8	35	180	85	10	6/16
STANDARD TANKER OR PIPELINE SERVICE							
Block 110	2,610	17.1	35	150	80	10	12
Block 126	275	3.0	35	170	80	15	12/16
BARGE OR PIPELINE SERVICE (depth of water 20 feet or less)							
Rabbit Island	15	--	10	150	60	on	12
Block 77	1,685	5.2	25	160	70	10	12
Block 32	2,375	4.6	20	170	70	10	16
Block 20	549	3.5	20	80	80	15	16
Bay Marchand	2,114	20.3	5	60	60	on	18
Block 16	1,780	11.0	10	60	60	on	18
Block 18	2,265	4.7	10	55	55	on	18
Block 30	2,778	10.0	20	65	65	10	12

MISSISSIPPI REGION

This region was divided into three groups based on proximity to two major rivers and to the 40 inch Capline transmission line. None of the domes in this region have known salt volumes.

Capline Group

The McBride and Leedo domes have a distinct depth advantage over the other six domes and both are in the same proximity of the Capline. Either of these two domes would be well suited for a crude storage site.

Pascagoula River Group

Based on its proximity to a pipeline and depth, the Richton dome is the best of this group.

Pearl River Group

The Hazlehurst, Arm, Lampton and Tatum domes all have a depth advantage being at a depth less than 2,000 ft. Lampton, having slight advantages over the others in its proximity to a pipeline and the Pearl River, is the best dome in this group for a storage project.

MISSISSIPPI REGION

Dome Name	Depth (ft.)	Distance (miles to)			Pipe Diam- (in.)
		River	Refining Center	Pipe Line	
CAPLINE GROUP					
Edwards	3,026	10	130	5	40
Oakly	2,634	15	130	5	40
Carmichael	2,966	15	100	5	40
Utica	3,135	15	100	5	40
Allen	2,774	5	85	5	40
Caseyville	3,035	5	80	5	40
McBride	2,205	10	85	10	40
Leedo	2,065	10	80	15	40
PASCAGOULA RIVER GROUP					
Raleigh	2,140	20	140	10	10
New Home	2,595	15	140	on	8
Don't	2,200	5	120	10	8
PEARL RIVER GROUP					
Hazlehurst	1,850	10	110	10	40
Sardis Church	2,000	10	100	10	10/40
D'Lo	2,250	20	120	10	8
Ruth	2,700	15	70	10	10
Monticello	2,757	5	90	10	10
Prentiss	2,800	10	100	10	10
Arm	1,930	5	90	10	10
Oakvale	2,696	5	90	10	10
Drycreek	2,100	20	110	10	10
Richmond	1,954	25	110	10	10
Lampton	1,647	5	90	5	10
Midway	2,205	15	100	10	10
Tatum	1,516	10	90	10	10

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MISSISSIPPI REGION (continued)

Dome Name	Depth (ft.)	Distance (miles to)			Pipe Diameter (in.)
		River	Refining Center	Pipe-Line	
PEARL RIVER GROUP (continued)					
Kola	3,048	5	120	15	8
Eminence	2,440	5	120	20	8
Mosele	2,200	5	120	20	10
Petal	1,739	5	120	10	10
Richton	722	10	130	10	10
County Line	1,343	25	160	20	10
Byrd	2,058	10	150	20	10
McLaurin	1,933	10	110	on	10

ALABAMA REGION

Alabama has only two identified salt domes and only one which meets the 3,000 foot depth criteria with a depth of 400 feet. The McIntosh dome is located 45 miles north of the seaport of Mobile and 10 miles west of the Tombigbee River. The nearest crude transmission line is 25 miles south of the dome and runs west to the 40 inch Capline. The nearest large refinery center is at Pascagoula, Mississippi. The Tombigbee River is under development as a navigable waterway and offers a potential transportation link to the port at Mobile.

V I T A

Anthony Edward Corcoran was born in Ottawa, Kansas, on 6 September 1941, the son of Thomas L. and Mildred I. Corcoran. He attended Lincoln and Sacred Heart elementary schools and graduated from Ottawa High School in 1959. He received his B. S. degree in Geological Engineering in August 1964 from the University of Kansas. From this time until January 1965 he was employed by the Atlantic Refining Company as a field party engineer on a seismograph crew in Rockdale and Georgetown, Texas.

On 25 January 1965 he enlisted in the United States Navy as an Officer Candidate and received his commission in June of that year. After attending the Civil Engineer Corps Officer School at Port Hueneme, California, he was assigned to the U.S. Naval Station, Midway Island as the Utilities Officer. Subsequently he served tours as the Assistant Public Works Officer at the U.S. Naval Ammunition Depot, Earle, New Jersey; Assistant Public Works Officer for Antarctic Support Activities; Public Works Officer for the winter over detachment at McMurdo Station, Antarctica;

Resident Officer in Charge of Construction, Laos; and in 1971 was selected for post graduate training in petroleum engineering.

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