Submerged Lands Productive Capacity

A REPORT OF THE

NATIONAL PETROLEUM COUNCIL

1953

REPORT OF THE
COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

As Adopted By

The
NATIONAL PETROLEUM COUNCIL

May 28, 1953

CHAIRMAN: L. S. WESCOAT

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that five years is an inadequate period in which to evaluate the contribution to future supplies of oil and gas of a major new province, such as the offshore area. Exploration and drilling within five years are likely to be more important in locating resources for future development than in providing immediate availability. In connection with the request that this study be made without regard to ownership or title, it should be noted that the Committee has found it necessary to make the following assumptions: (1) existing leases will be confirmed (2) additional leases will be granted on a basis which will encourage exploration and development of the entire offshore area, and (3) remaining unsettled questions regarding jurisdiction, leasing and other matters will be resolved satisfactorily and promptly. If these matters are not resolved promptly the estimates of availability that may be developed in a five-year period of time should apply from the date on which operations can again be carried on freely throughout the area rather than from today.

The request for this study deals with "offshore submerged lands." As the definition of the shore line is a controversial question, this Committee has not attempted to define precisely where the offshore area begins, nor has the Committee attempted to determine what percent of the estimated available production will be from the area of the shelf restored to the states, or from the area of the shelf placed under the jurisdiction and control of the United States by the Submerged Lands Act. It has, however, excluded from its estimates of availability production from fields considered to be in inland protected waters in Louisiana, such as Breton Sound, Main

Pass, Rabbit Island, and South Pass, and from wells in California that are producing from beneath submerged lands but are located onshore or on piers. The Committee estimates that as of January 1953 about 9,000 barrels daily were being produced in that part of the Gulf Coast which is offshore beyond question, exclusive of about as much more production at Breton Sound, Main Pass, Rabbit Island, and South Pass. In addition, offshore availability in the Gulf Coast in January 1953 included some 1,500 barrels daily of natural gas liquids and between 100 and 135 million cubic feet daily of natural gas from producing wells connected to pipe lines.

OUTLOOK FOR AVAILABILITY

While the entire continental shelf area of the United States, comprising 278,000 square miles, may be considered a prospective petroleum province, existing economic and technology limits prospective drilling within the next five years to water depths of about 60 feet. At the present time, it seems probable that drilling in submerged offshore areas within five years will be limited almost entirely to about 14,000 square miles off the coasts of Texas and Louisiana covered by water depths up to 60 feet and to about 300 square miles off the southern coast of California, extending to the 50 foot water depth contour. Some exploration may be undertaken in deeper waters or in other areas of the continental shelf within the next five years, but the problems involved in such ventures will probably restrict their significance insofar as development of availability is concerned during the next five years.

About 30 percent or more of the wells drilled may be expected to be dry holes. The remaining oil and gas wells drilled in submerged offshore areas might increase availability by about 70-100,000 barrels daily of crude oil and natural gas liquids and 600-800 million cubic feet daily of natural gas by the end of five years with average success. Such drilling activity would represent a resumption of the operations that were brought virtually to a halt in 1950 by the controversy between the Federal Government and the states over the offshore lands. In addition to drilling operations in areas that have already been explored, there will be further exploration and drilling under satisfactory conditions for offshore operations.

In California, petroleum developments beneath submerged lands have been limited thus far to those that can be conducted by directional drilling from shore and from piers extending from shore. Existing state laws in California have not permitted drilling of wells on offshore platforms, although there has been some offshore exploration. It is estimated that around 100,000 barrels daily of availability might possibly be developed from submerged offshore areas of southern California within five years after state laws are modified to permit offshore drilling and after all questions relating to offshore operations are satisfactorily resolved. No estimates have been made of the amount of gas that might become available in this offshore area, as attention will probably be concentrated on developing oil production during the first five years of operation and availability of gas will probably be dependent upon whether a major gas field is discovered.

AVAILABILITY UNDER EMERGENCY CONDITIONS

The request for this study included an inquiry with respect to the amount of availability that might be developed "if a critical and immediate need develops for national security reasons." The Committee has considered this request but is unable to provide a numerical answer. The determining factors with respect to operations under emergency conditions will be the size and quality of proved undeveloped offshore locations at the time, but this cannot be predicted in advance. In the opinion of the Committee, the estimates submitted herein are probably a good measure of the availability that may be developed within five years under either normal circumstances or emergency conditions.

CONCLUSION

Assuming adequate economic incentives, adequate supplies of materials' and manpower, confirmation of existing leases, the granting of additional leases following satisfactory solution of the controversy over submerged lands, and freedom of operators to explore and develop this area, it is estimated that there might be developed with average success an availability from offshore submerged lands of about 170,000-200,000 barrels daily of crude oil and natural gas liquids and 600-800 million cubic feet daily of natural gas in five years of opportunity for experienced operators to conduct offshore activity freely under satisfactory conditions. These estimates are exclusive of production from California wells now producing from beneath submerged waters but located onshore and on piers and of production from wells in protected inland waters along the Gulf Coast.

Because of the time required to study and evaluate a major new petroleum province of the size and importance of the submerged offshore area, it is the opinion of this Committee that the major contribution of the submerged offshore area to the nation's supplies of oil and gas will come beyond the five-year period which it was requested to study. Drilling after the five year period should increase availability rapidly because of additional development on discovered fields, improved techniques, and later discovery and development resulting from continued exploration.

Potential petroleum resources of the continental shelf have been there for countless years without value to anyone. How valuable they can be made in meeting petroleum requirements will depend on the ingenuity exerted and success realized in finding and developing offshore oil and gas at costs competitive with those on land. In any event, great amounts of capital will have to be risked in exploration and drilling and in the case of discoveries, additional sums will have to be spent in carrying on producing operations and paying royalties over many years. These investments and expenditures may be more or less than the value of the oil and gas produced. The idea that the gross value of probable ultimate production is a measure of the worth of offshore petroleum resources is erroneous and should be avoided. Technological limitations may mean that only a part of the potential offshore resources will ever be developed. Even with respect to the part developed, the expenditures for exploration, drilling, production, and royalties will offset the gross income from production and determine whether and how much net income is realized as a return on the risks taken and the investments made in offshore operations.

Respectfully submitted,

/S/ L. S. Wescoat

L. S. Wescoat, Chairman
Committee on Submerged Lands
Productive Capacity

EXHIBIT A.

C
O
P
Y

UNITED STATES
DEPARTMENT OF THE INTERIOR
OIL AND GAS DIVISION
WASHINGTON 25, D. C.

July 16, 1952

Mr. Walter S. Hallanan, Chairman
National Petroleum Council
1625 K. Street, N. W.
Washington, D. C.

Dear Mr. Hallanan:

The National Petroleum Council's report of January 29, 1952, on "Petroleum Productive Capacity" is one of the most thorough-going and important reports the Council has submitted to the Department of the Interior. This report stresses the importance of oil and gas prospects of offshore submerged lands. The President's Material Resources Commission (Paley Commission) report, June 1952, likewise emphasizes the importance of these potential reserves. Both reports indicate that such resources of oil and gas could be critically important to national security and defense.

While both reports point out the potential importance of the oil and gas prospects of offshore submerged lands, it is also important that an authoritative study be made of the availability of these potential reserves in terms of technological aspects. The problems incident to the discovery, development and production of offshore petroleum deposits are different both in magnitude and in character when compared to operations in adjacent onshore areas. It is essential, therefore, that the impact of these new and different problems be studied and their effect estimated with reference to the availability of production from submerged lands.

It is, therefore, requested that the National Petroleum Council appoint a committee to proceed with this study upon the assumption that conditions comparable to those upon which the National Petroleum Council report on productive capacity was based will exist and to evaluate the technological aspects of exploration, development and production with respect to the

availability of production from submerged lands:

1. If a critical and immediate need develops for national security reasons.

2. If no such needs arise but if exploration and development were to be freely conducted over a 5-year period.

It is requested that this study be made on the basis of technological aspects only without regard to ownership or title.

Very truly yours,

Signed: H. A. STEWART

H. A. Stewart
Acting Director

EXHIBIT B

REPORT OF THE
CALIFORNIA SUB-COMMITTEE
OF THE
NATIONAL PETROLEUM COUNCIL'S COMMITTEE ON
SUBMERGED LANDS PRODUCTIVE CAPACITY

May 28, 1953

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distances seaward before plunging off into deeper water. This coastal shelf is narrowest where adjacent to headlands or areas of high relief, and is widest adjacent to the valleys or plains. Its width varies from a minimum of 1 or 2 miles to a maximum of about 14 miles. In some portions the drop off is sharp at the outer margin and in other portions it is merely a gradual steepening of slope.

(2) A basin and range area, which extends from the margin of the coastal shelf outward to the escarpment at the southwest edge of the Continental border, is a region of deep, closed basins and steep-sided, generally flat-topped, submerged ranges, the highest points of which comprise the Channel Islands.

The coastal shelf comprises the area of greater interest as it contains the extension of the producing sedimentary basins of Southern California, together with their structural trends and possibly their reservoir sands. All three of the producing basins of Southern California, that is, the Santa Maria, Ventura, and Los Angeles Basins border the coast line and may continue seaward beneath the ocean for some distance.

The Santa Maria Basin, lying between Point San Luis and Point Arguello, produces principally from fractured Miocene shales with minor production coming from overlying Sisquoc sands. Both the Miocene shales and the overlying Pliocene Sisquoc formation extend seaward together with their structural trends. The coastal shelf out to the depth of 300 feet has a width of 5 to 10 miles opposite this basin.

Drilling depths on shore vary generally between 2,000 and 10,000 feet to the objective zones.

The Ventura Basin, lying broadly in the area between the Santa Monica Mountains and the Santa Ynez Mountains, borders the coast from Point Conception to Point Mugu at the west end of the Santa Monica Mountains. The Ventura Basin is productive from beds of Pliocene, Miocene, Oligocene, and Eocene ages. The Pliocene beds, however, are the most prolific and have yielded the major portion of the oil. These Pliocene beds outcrop only locally along the coast from Point Conception to Carpenteria. Southeast of Carpenteria where the shore line turns more southerly and crosses the Ventura Basin, a thick Pliocene section is exposed, and should extend offshore. A number of producing structures and structural trends of the Ventura Basin extend offshore, and it is reasonable to anticipate that oil fields will be found on the offshore extension of such structures.

The Coastal belt out to the depth of 300 feet has a width of from one and a quarter miles to ten miles adjacent to the on shore portion of the Ventura Basin. Depths to objective zones on shore vary generally between 1,500 and 12,000 feet, but in deeper parts of the basin objectives lie below 20,000 feet.

The Los Angeles Basin, lying between the Santa Monica Mountains and the San Joaquin Hills in the vicinity of Laguna Beach, contains a thick productive Pliocene and Upper Miocene section, which borders the coast line and undoubtedly extends seaward.

The Coastal shelf out to the water depth of 300 feet has a width of from one mile to fourteen miles adjacent to the landward portion of the Los Angeles Basin. Drilling depths to objective horizons on shore vary generally between 1,000 and 12,000 feet.

The area of basins and ranges, which lie seaward from the coastal shelf, is interesting from an exploration standpoint only around the islands and on the banks or flat tops of the submerged mountain ranges where depths are sufficiently shallow so that drilling operations might be possible. These areas and depths are tabulated in Part I of this report. The basins generally extend to depths from 4,000 to 6,000 or 7,000 feet. We know something of the geology of the high areas from the outcrops on the islands. The San Miguel, Santa Rosa, Santa Cruz and Anacapa island chain is the westward extension of the Santa Monica Mountains high or positive area and contains similar rocks. Beds from Eocene to Middle Miocene, underlain by basement complex, outcrop on these islands. On Santa Cataline Island Miocene volcanics lie on metamorphic Franciscan rocks. On the other scattered Channel Islands outcrops of Eocene to Miocene rocks occur. Structure on these islands is complex and typical of the uplifted areas that border the Pliocene basins on the mainland. The rather meager evidence from these island outcrops suggests that the offshore banks generally contain rocks of Miocene and older age. Thus, they do contain sediments, at least in part, of the same age and character as those which produce oil on shore.

2. The Complicated Nature of Geologic Structures.

a. Numerous sand segments (lenticular nature and variable permeabilities of sands).

Our experience with producing structures in the southern district of California indicates that in offshore structures lenticular sands can be expected with multiple zones, and varying permeabilities:

(1) In anticlinal structures on shore productive sands on the flanks and plunges of structures in many cases have shaled out on the axis, so that tests on the axes do not necessarily prove or disprove productive possibilities. This condition may necessitate a number of exploratory wells to test an offshore structure, thereby increasing the cost. Examples are: Castaic Junction, Castaic Hills, West Montalvo oil field, and others.

(2) Productive sands are frequently very lenticular so that numerous small reservoirs of very limited extent are present, each reservoir being productive in only a few wells. The Honor Rancho field is an example. With this type of sand condition several wells are required to test a structure, and an abnormal number of wells must be drilled in order to exploit all of the producing sands. Oil fields in the offshore area of similar type can be expected.

(3) Sand permeabilities vary greatly even in the case of blanket sands so that such sands might be productive in one structure, or portion of a structure and unproductive in an adjacent structure, or a portion of it. Examples are:

   (a) Eocene is commercially productive at Bardsale, but unproductive on closures east and west of it on same uplift;

(b) Sentous zone (Miocene) at Inglewood is productive on the northwest plunge of the field, but the sand is too tight over the balance of the structure to be commercially productive. This situation makes exploration more difficult and expensive.

(4) A transgressive sand, such as the Baqueros sand, which is a prolific producing horizon in coastal oil fields, may shale-out offshore and be absent from an offshore structure. Thus, some of the promising offshore anticlines may be unproductive due to shale-out of the main producing zones.

(5) Fracture reservoirs, such as the fractured chert producing horizon of the Santa Maria Basin, result in a large number of dry holes due to the fact that fracturing is sporadic and unpredictable. This condition can be expected in some of our offshore structures in that area and may result in a high ratio of unproductive wells.

b. Faults and Other Complications.

In the on shore Southern California oil province, faulting is widespread and complex. Faulting is present in every oil field, and in nearly every field it limits production in one or more zones. Thrust, strike-slip, and normal faults of great magnitude are present on land and can be expected in the offshore area. Some of the well-known thrust faults have 15,000 to 20,000 feet of displacement. Some of these thrust faults are known from surface geology, others have been discovered by drilling. An example of a thrust fault penetrated in a well is located in the Ventura Basin north of Montalvo. This well penetrated the Oak Ridge thrust fault and drilled to a depth in excess of 18,000 feet without finding production. There are many other similar cases of expensive, deep, unproductive wells due to thrust faults being encountered. The cost of such wells ranges from one-quarter of a million to a million dollars.

In some cases oil is present in structures beneath thrust faults, as for example, the Aliso Canyon field which produces from a footwall structure below the Santa Susana thrust fault. This footwall structure is also complicated by several thrust faults, unknown before they were discovered by drilling, which control and localize production. Such structures beneath thrust faults must be found by deep exploratory drilling, because seismic data are rarely obtained beneath thrust faults, certainly not in sufficient quantity and not of sufficiently reliable quality to permit one to map a sub-thrust structure. The Ventura Avenue, San Miguelito, and Padre Canyon oil fields are other examples of fields that are complicated by thrust faulting.

Normal and strike-slip faults are to be reckoned with also, as both types of faults often control accumulation of oil and are responsible for numerous dry holes. For example, the San Gabriel strike-slip fault effectively controls oil accumulation in the Placerita and Honor Rancho fields; wells northeast of this fault are unproductive. This fact had to be learned the hard, expensive way by drilling a number of dry holes east of the fault. A few examples of fields in which normal faults affect accumulation in one or more oil zones are Wilmington, Torrance, Huntington Beach, and Inglewood. Examples of normal faults cutting off production in an entire field are at Montebello and Montalvo oil fields.

We must expect similar complex faulting in offshore structures. Offshore seismic work and coring of the ocean bottom have already indicated a very complex fault pattern in this area, consisting of thrust, strike-slip, and normal faults, the details of which cannot be worked out by further seismic shooting or coring because data obtained are not abundant enough or of good enough quality to work out the necessary detail.

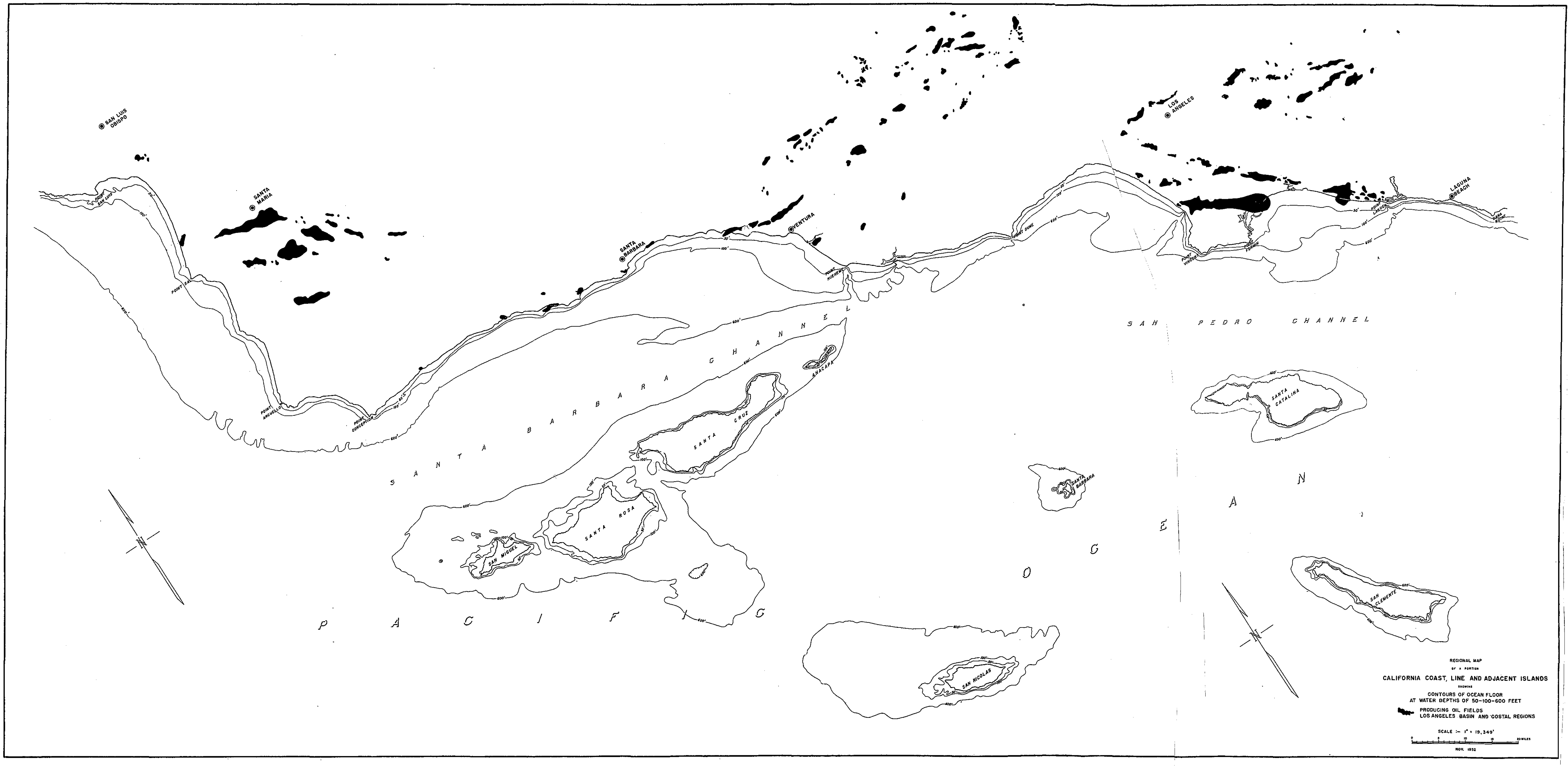
c. Difficulties of Testing and Finding Production under such Conditions.

The preceding discussion indicates some of the difficulties to be expected in exploratory drilling for oil in the California offshore area.

An outstanding example of the hazards encountered in exploratory drilling of a complexly faulted offshore fold is furnished by the exploratory wells that have been drilled off Coal Oil Point near Santa Barbara. Five wells have been drilled and a sixth is now drilling on this structure. This exploratory drilling campaign has cost about $3,000,000 (estimated) and there is no commercial production yet. Unpredictable complex faulting is responsible for this. These are all drilling costs. There is no cost for an island or platform in this case because wells are whipstocked from shore.

The fact that each offshore structure could require several wells to test it, due to fault complications, rapid variations in sedimentation, etc., indicates high drilling costs to test each structure. Drilling costs coupled with construction costs for islands or platforms, plus costs of marine equipment essential for conducting operations, will make offshore exploratory drilling very expensive as well as hazardous.

Every phase of offshore exploration is many times more difficult than on shore exploration as well as being many times more expensive.



REGIONAL MAP

OF A PORTION

CALIFORNIA COAST, LINE AND ADJACENT ISLANDS

SHOWING

CONTOURS OF OCEAN FLOOR
AT WATER DEPTHS OF 50-100-600 FEET

● PRODUCING OIL FIELDS
LOS ANGELES BASIN AND COSTAL REGIONS

SCALE :- 1" = 19,349'

0 5 10 15 20 MILES

NOV. 1952

J. P. Bailey
H. C. Bemis
John Sloat
L. B. Snedden

PART II

SUBMERGED LAND STUDY

PROBLEMS AND COSTS INVOLVED IN OFFSHORE EXPLORATION

1. Differences from Land Operations including New Techniques

Exploration for potential oil producing structures in offshore areas which are entirely overlain by water has posed many problems which are markedly different from land operations. The normally used methods of exploration on land which have been adapted to water work are the reflection seismograph, refraction seismograph, gravity meter, magnetometer, airborne magnetomer, bottom sampling, offshore coring, commercial diving, and ocean bottom photography. In almost every case the frontier of the method has been advanced - in some cases solving what initially appeared to be almost impossible problems. The primary problem has been to apply land developed instruments, techniques and methods to operations both on and in the water. Intensive research and experimental programs at great cost have been carried on to convert from land to water operations. New instruments, new techniques, conversion to boat rather than vehicle transportation, insulation from salt water, depth pressure problems, organization problems, restrictions imposed by state commissions on operation, and public relations problems have all had to be solved with the inevitable compromise which has restricted the full effectiveness of the method which would normally be realized. The cost of each operation has been greatly increased over land work. Specific techniques for the more important exploratory methods are summarized as follows:

a. Reflection Seismograph. Many differences are apparent with new techniques developed, such as:

(1) Use of boats to replace motor vehicles.

(2) Reassembly of recording instruments to be housed on boats.

(3) New developments in seismometers for water work plus the development of special seismometer floats.

(4) Development of new type cables.

(5) Development of new firing techniques and methods.

(6) Development of new explosives to eliminate damage to marine life, and which are reliable under water at variable depths.

(7) The need to obtain two components of the reflected energy so that strike and dip computations can be made is necessitated by the complex geology off the coast of California. This requires special boats and equipment.

(8) Surveying problems for location of shot points at great distance from shore and in foggy and inclement weather requires the use of Shoran.

(9) Development of new and accurate base maps.

(10) Coordination and timing of closely integrated multiple unit operation.

(11) Development of new and streamlined methods of computing and handling seismic records obtained.

In addition to the foregoing differences from land operations, many other problems arise as a result of this type of offshore exploration, such as:

(1) Problem of damage to marine life, which at its worst was very minor.

(2) Short terms and restricted areas of permits.

(3) Provisions for separate boats for the State Lands observer and for the Fish and Game observer

(4) Authority of each observer to approve or shut down operations before the firing of every charge.

(5) Restrictions placed by authorities upon transportation, loading, and quantity of explosives which can be handled at one time.

(6) Resistance and complaints brought to bear by cities, counties, and other groups to the issuance of every permit. (Arguments presented have been frequently lacking in fact and sound judgment.)

The cost per month to operate a seismic offshore crew in California waters varies from $100,000 to $125,000. This compares with a land cost for seismic crews ranging from $15,000 to $30,000 per month. In general the cost of operating a seismic crew in California waters is much higher than it is in the Gulf of Mexico. The following tabulation indicates the approximate cost per month of the various components of a marine reflection seismology crew:

Recording boat	$ 5,000.
Shooting boat	5,000.
Jetting boat	5,500.
Water taxi	1,300.
Other boats and miscellaneous	35,000.
SUB TOTAL	$51,800.

(Balance carried forward)	$ 51,800.
Contract seismic equipment and personnel	30,000.
Powder	20,000.
Shoran surveying	8,000.
Permits	1,200.
TOTAL	$111,000.

The cost per profile, which is the seismic record obtained from each shot, compared with the cost for equivalent onshore data is difficult to compute. In open sea work the cost per profile is less than on shore; but when the crew is working in an area where jetting is required, the cost per profile is much higher than on shore because of the few profiles per day that can be obtained under these conditions.

In general the reflections obtained from offshore seismic work are less abundant and of lower quality than the average of on shore work. Consequently, it requires a greater density in terms of shot points per square mile to obtain comparable information.

b. Other Geophysical Methods. Other methods have been used, but have not been adopted generally for exploration off the California coast. These methods are refraction seismograph, gravity meter, magnetometer and airborne magnetometer.

c. Offshore Coring. A large amount of research work has gone into the development of coring tools to obtain satisfactory samples from the ocean floor beneath the overburden and in depths of water to approximately 600 feet. Representative samples from the formation are a basic requirement with proper orientation for strike and dip control. Four different types of coring instruments have been developed by the industry. Coring operations required the development of:

(1) Special orientation devices.

(2) Methods to drive core barrel into the formation.

(3) Methods to recover core.

(4) Development of special pumps and hoses to jet away the recent overburden and thus penetrate the formation with the core barrel.

(5) Coordination of mechanical work and palentological experts to realize the objectives of the coring.

(6) Conversion of boats to carry and work with this special equipment.

The cost per month to operate an offshore sampling boat is about $15,000, and does not have a large range of variation because only one boat is required. Experience to date indicates that the cost per sample averages about $150 when using equipment that provides data for the orientation of the core. The cost of any individual core varies from this figure materially depending upon the depth of water, thickness of overburden and character of the formation from which the sample is taken. The number of samples per square mile required is variable depending upon the geological structure, the character of the formation, samples and many other factors.

Offshore coring develops information which permits mapping of the geology of the ocean floor. This method endeavors to accomplish what the field geologist accomplishes by surface mapping on shore. Information developed by offshore coring is necessarily greatly restricted and obtained at far greater cost.

Offshore coring is essential and has been of tremendous aid in checking seismic structures, determining faults and unconformities, and the age of formations on these structural highs. To indicate some of the difficulties involved in obtaining offshore cores, the following examples are cited:

420'	water	382'	water	326'	water	264'	water
165'	overburden	276'	overburden	346'	overburden	410'	overburden
585'	sub-sea level	658'	sub-sea level	672'	sub-sea level	674'	sub-sea level

It is apparent from the foregoing tabulation that formation samples cannot be obtained where depth of water or overburden is too great. There are many cases in which much time and equipment are lost when coring under adverse conditions.

2. Experience to Date

A reconnaissance seismograph coverage has been obtained by numerous companies of the area offshore from the coast line between Dana Point and Point San Luis. Many additional crew years of seismic surveying and ocean bottom sampling (the counterpart of surface geology) will be necessary to map the geologic structure in detail. The quality of seismic offshore results in California has been in general, inferior to results obtained in comparable areas onshore because of interfering seismic energy from many sources associated with marine shooting. The interpretation of offshore seismic results is difficult because of lack of well control, the complexity of the geological structure, the poor quality of much of the data, less surface geological control, and inadequate seismic velocity control.

Offshore sampling has been done by various companies, and is in progress at this time. The offshore sampling that will be required to map the geology of the ocean floor will be extensive.

Frank B. Carter
L. H. Metzner
M. J. Hill

PART III - DESCRIPTION OF OFFSHORE AREA

A. The term "Offshore area" is best defined by map accompanying Part I which shows the California coast line from Point San Luis Obispo, San Luis Obispo County to Dana Point in Orange County. This is the area in which some exploratory work has been done and is approximately the offshore complement of the onshore, Los Angeles Basin and Coastal oil producing region.

Contours indicating water depths adjacent to the mainland coast line and to the islands are shown on the map for 50, 100, and 600 foot depths.

The areas contained between the shore line and these various depths, both for the mainland and the islands are shown in the following tabulation.

Area Adjacent to Coast	Square Miles	Acres	Interval Area in Acres
Shore to 50' Contour	212.46	135,925	
Shore to 100' Contour	517.32	330,964	195,039
Shore to 600' Contour	1,671.36	1,069,274	738,310
Areas Adjacent to Islands			
SAN CLEMENTE			
Shore to 50' Contour	7.92	5,069	
Shore to 100' Contour	16.38	10,482	5,413
Shore to 600' Contour	96.96	62,034	51,552
SAN NICOLAS			
Shore to 50' Contour	6.70	8,076	
Shore to 100' Contour	29.81	19,074	10,998
Shore to 600' Contour	352.67	225,626	206,552

Areas Adjacent to Islands	Square Miles	Acres	Interval Area In Acres
SANTA CATALINA			
Shore to 50' Countour	2.82	1,804	4,812
Shore to 100' Contour	10.34	6,616	50,005
Shore to 600' Contour	88.49	56,621	
SANTA BARBARA			
Shore to 50' Contour	1.88	1,203	1,031
Shore to 100' Contour	3.49	2,234	3,265
Shore to 600' Contour	8.59	5,499	
SAN MIGUEL *			
Shore to 50' Contour	12.22	7,819	7,904
Shore to 100' Contour	24.58	15,723	
SANTA ROSA*			
Shore to 50' Contour	32.90	21,050	31,963
Shore to 100' Contour	82.86	53,013	
SANTA CRUZ*			
Shore to 50' Contour	14.24	9,108	13,661
Shore to 100' Contour	35.59	22,769	
ANACAPA*			
Shore to 50' Contour	1.88	1,203	1,890
Shore to 100' Contour	4.83	3,093	
* *The same 600' contour encompasses the above four islands and gives the following totals	916.	585,716	491,118
Total Coast and Island Areas			
Shore to 50' Contour	293.02	191,257	272,711
Shore to 100' Contour	725.20	463,968	1,540,802
Shore to 600' Contour	3,134.00	2,004,770	

B. The offshore area described above is subject to moderate wind and wave action a majority of the time Records kept by the Marine Meteorological Station at Los Angeles harbor indicate that during the five year period from June 1, 1935 to June 1, 1939 the maximum wind velocity was 28 miles per hour and that 95% of the time it was less than 13 miles per hour. However, from work published by the Scripps Institution of Oceanography it is shown that during a tropical storm occurring on September 24, 1939 wave heights of 30 to 35 feet were observed with a 14 second period and accompanied by high winds. From the Scripps report it is noted that three storms of this type have reached the area in 50 years but that only one was accompanied by high winds.

Also from studies made by Scripps at La Jolla, California, which is outside of the area described above, but which is believed sufficiently close to be indicative of wave conditions farther up the coast it was noted that waves between 6 to 7 feet in height occurred 2% of the time during June to August, little more than 2% of the time during September to November, 7% of the time during March to May and 10% of the time during December to February. Waves greater than 6 to 7 feet were also observed, the highest being 18 feet with a number of days showing waves between 10 and 12 feet. The figures quoted above are based upon observations covering four years.

Also of interest in the selection of drill sites which are subject to wave action is that ocean bottom topography greatly affects wave heights due to refraction. The refraction factor depends upon the wave period and can be expected to vary between 0 and 3 for periods greater than 12 seconds and 0 and 2 for periods less than 12 seconds. The exact value for a given location can be determined only by construction of a refraction diagram.

James Moon
K. C. Vaughn
B. H. Anderson

PART IV - DRILLING

(1) ERECTION OF OFFSHORE DRILL SITES

The erection of a drill site for drilling for oil in the open sea is a complicated and expensive procedure. The problems encountered are almost entirely different from and foreign to drilling for oil on land. Probably the first consideration is the type of well to be drilled - that is whether it is a 100% exploratory wildcat or a well to be drilled into a known or highly probable producing area. A strictly wildcat well might utilize a more or less temporary structure of lower cost or an easily moved, but more expensive, structure. A well to be drilled in developing a producing area would demand a larger, more expensive and more permanent structure. Such problems are not encountered in conventional land operations. Secondly, the depth of the water would be most influential in governing the design. While it is known from experience that certain types of structures have been used in water up to 50 feet in depth, and assuming that the range of such structures might be extended in some instances to as much as 100 feet, very little actual experience under coastal conditions is available for depths beyond 50 feet. A number of designs have been suggested for deeper water; some for depths as great as 200 feet but none have been built and their erection and handling problems will be complicated and costly.

To date there has been only one drill site constructed off the California coast located 2700' from the shore in 28' of water; so experience off the California coast is limited. Numerous pier installations have been made, however, which have indicated the magnitude of costs in the erection and maintenance of offshore drill sites.

The experience of Gulf Coast operators will be invaluable in the solution of some problems. However, conditions off the California coast are dissimilar to those of the Gulf. Among the conditions which would trouble California operators are:

A) Much deeper water closer to shore. The very gradual shelving of the Gulf Coast is practically unknown in California.

B) A hard shale bottom making it difficult to drive piling to depths greater than about 8 feet.

C) An almost continuous heavy swell condition.

While storm conditions along the California coast are not to be compared with Gulf Coast storms, history has indicated that at least once in 50 years, waves of extreme height can be expected. Therefore, the first deck level for maximum safety should be set at a minimum of 35' above mean high tide line and the entire structure, including derrick, stressed for winds of 75 mph (actual) and wave pressure. The pressure exerted by waves 35' high on a typical self-contained drill site is greater than 1,000,000#, resulting from a pressure of about 1600# per foot of surface exposed.

A drill site to meet the California requirements for drilling in less than 100' of water could be one of several types.

A) A template type with piling driven through the template - probably double deck and completely self-sustaining.

B) A sheet pile, earth-filled coffer dam type with a hard surface top - also self-sustaining.

C) A series of small piling template type platforms equipped with derrick and drawworks and serviced by an attendant barge.

D) One of the proposed submersible barge types - self-sustaining or serviced by attendant barges.

Platforms for drilling in water depths above 100' have not yet been built, but several untried, but preliminary designs, are available, and include:

A) A super piling template structure 80 feet square, weighing 1200 tons and costing $1,000,000 (est.) bare.

B) A three or four leg floating structure with hollow telescoping leveling legs through which piles can be driven, having a deck 120 feet square and weighing an estimated 1784 tons with an estimated cost of over $1,000,000.

C) A single caisson, bottle-like structure having a deck just big enough for one derrick and drawworks and having a net weight of 6500 tons and an estimated cost of $1,500,000.

Selection of any one of the best above designs will be influenced by factors such as depth of water, number of wells to be drilled and whether the project is classed as exploratory or development. The number of wells will influence choice because a multiwell program will allow reasonable amortization of a more elaborate and expensive structure. Wildcat drilling might utilize relatively low cost expendible structures or movable types, with space requirements held to a minimum. Development islands or platforms would incorporate permanence, long life, initial production maintenance and sufficient area to accommodate production facilities. Costs for such islands or platforms run high. An expendible island to accommodate all drilling equipment will cost approximately $400,000 and a small expendible platform for use with an attendant barge is estimated to cost $250,000. Gulf Coast experience indicates that for template type island 126' x 172', having two decks, an expenditure of $1,500,000 would be required. In all instances initial costs for platform and drilling equipment to drill a single well will exceed $1,000,000.

Communications between the drill site and a shore base will have to be established - probably short wave radio-telephone. Cost of such an installation would approximate $30,000.

The erection requirements of the drill site will be determined by the type used, but almost certainly, large barge cranes, pile-driving equipment and possible dredges will be necessary.

Construction time will also be an important item. Swell conditions and the distance from shore will determine the number of hours per day that work can be carried on. There will be periods of days and even weeks when no work can be accomplished and standby time will add materially to costs.

(2) USE OF MARINE VESSELS

In the use of drill sites of any type built for drilling for oil at sea, the employment of several different types of marine vessels will be necessary. Such a requirement for any one island might include the following:

A) Three crew boats, approximately 80 feet long having a 50 ton capacity and costing as much as $60,000 each. These are used for transportation of personnel and small supplies. One boat must be used for standby purposes as long as men are on the platform. In some areas it may be possible to contract for this service, but overall costs would be relatively unchanged.

B) One cargo vessel approximately 135' long with a capacity of 250 tons gross which is used for the transportation of heavy equipment. Approximate cost $100,000. Contract service is again a possibility.

C) One drilling tender, if a self-contained platform is not used, which would be approximately 325 feet long and have a gross capacity of 3800 tons. Cost would be approximately $500,000. This would be a necessary part of the drilling equipment.

D) One sea-going standby tug for the drilling tender which is not self-propelled. Cost approximately $250,000. Contract service may be utilized.

Most operators to date have used War Surplus equipment and modified it to fit their requirements. If in the future such vessels must be built for the particular purpose, the cost would be substantially greater. Using War Surplus equipment requires an investment of from $275,000 to $1,000,000 with a daily standby operating cost of from $1,000 to $2,500.

A transportation fleet of the type described requires the employment of at least 30 to 50 men, depending on whether a self-contained or attendant barge type platform is used. Additional vessels would also eventually be required for such services as cementing, well logging and shooting if these services were not permanently installed on the attendant barge or on the self-contained structure.

Also, the above list does not include the large work barges and floating marine cranes and pile drivers necessary for the island type installation. These would probably be furnished by the construction contractor, but the cost of any and all special equipment must eventually be borne by the operator.

The rules and regulations of the following governmental and marine agencies must be complied with in obtaining and maintaining the drilling site and required transportation facilities:

U. S. Coast Guard
U. S. Customs
American Bureau of Shipping
U. S. Corps of Engineers
State Oil and Gas Conservation Dept.
State Land Dept.
State Fish and Game Commission

Also all marine vessels must be operated and maintained in accordance with all rules governing safe conduct at sea.

(3) DIRECTIONAL DRILLING

Directional drilling will doubtless be used in both exploratory and development drilling. In the case of exploratory drilling from a small platform with attendant barge, a single vertical hole would be drilled. If the vertical hole proved disappointing, it would be plugged back and additional directional exploratory holes drilled from the original location.

In the case of production or development drilling on a larger platform one vertical hole would be drilled and completed; the drilling rig moved a few feet and a directional well drilled. This practice of moving would be continued until all the working space on the platform were used up. The number of wells drilled from any one platform would be determined by the well depth, the well spacing and the deck area of the platform.

It is believed that on a drill site at sea no difficulties in directional drilling other than those usually present would be encountered. Suitable supervision and equipment such as whipstocks, survey equipment, etc. would, of course, have to be kept on hand at all times.

(4) HIGH COSTS OF DRILLING

It has been conservatively estimated, that under present conditions, it will cost four to ten times as much to prepare for drilling an average well at sea as compared to an average well on land. Because basic design factors may be affected, dependent upon whether or not the well is considered development or exploratory, costs are summarized as follows for a well in 50' of water:

BASIC EQUIPMENT COST

	DEVELOPMENT	EXPLORATORY
Platform or Island	$1,500,000	$ 400,000
Drilling Equipment	500,000	500,000
Special Equipment	100,000	100,000
Marine Vessels	280,000	280,000
Shore Base	50,000	50,000
Communications	30,000	30,000
	$2,460,000	$1,360,000

OPERATION (DRILLING) COST

	DEVELOPMENT	EXPLORATORY
(10,000' Well)		
Drilling (120 days)	$ 600,000	$ 480,000
Marine Cost	120,000	100,000
	$ 720,000	$ 580,000

TOTAL COST PER WELL

(10 Wells - 10,000')	DEVELOPMENT	EXPLORATORY
Operation	$ 720,000	$ 580,000
Amortization	246,000	136,000
	$ 966,000	$ 716,000

	EXPLORATORY
(1 Well - 10,000')	
Operation	$ 580,000
Amortization (Equipment)	96,000
Amortization (Platform)	400,000
	$1,076,000
(5 Wells - 10,000' plug and redrill)	
Operating	$ 580,000
Amortization (Equipment)	96,000
Amortization (Platform)	80,000
	$ 756,000

Estimated cost of a drill site for depths up to 200' are $1,500,000 for either a development or exploratory well, since depth places an economic limit on an artificial island. Enlargement to provide space for multiple wells (in excess of 5 or 6) would increase cost to an estimated $2,000,000. The magnitude of the problem is, therefore, apparent. It is probable, based on discovery frequency, that as many as four exploratory locations comprising eight to ten wildcat wells would be drilled before a new pool is discovered. Following discovery, development and operation problems and expense are still to be faced.

All factors necessary for proper engineering design and construction are available or obtainable and therefore the problem is resolved to one of economics. To date, experience has indicated that cost estimates in the Gulf Coast have been consistently low; therefore, it is felt that the above costs, in light of present knowledge, are on the low side.

Successful drilling and producing in waters deeper than 150-250 feet by any method is open to broad engineering conjecture. It is believed that all that can be practically stated at this stage of our knowledge of the subject, and without practical experience, is that these depth limitations will be exceeded only when economically feasible.

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PART V. - OPERATIONAL

THE SUPPORT ACTIVITY FOR THE OFFSHORE OILFIELD OPERATION

An offshore oilfield operation must be supplied and supported in much the same way as a similar operation onshore. Machinery, construction materials, drill pipe, casing, drilling mud, cement, fuel, water, consumable supplies, and personnel must be transported to and from the location, and oil and gas must be processed and transported from the location. The principle difference between the offshore operation and a similar operation onshore is that the majority of the transport to and from the location must be by water. This difference, as compared to operations on land, is reflected in the specialized equipment and facilities needed to fulfill the support functions, the increased susceptibility of the supporting activities to the vagaries of weather, and the greater elapsed time of transportation.

While the marine craft are the core of the fadilities supporting any offshore operation, they are dependent upon a base on shore from which to operate, as an apple is dependent upon its stem. It is the purpose of this report to outline the facilities and equipment, including marine craft, which the onshore base must have, and the services it must provide to properly serve the offshore activity. Because the facilities and services required by a drilling well are considerably different from those needed by a producing well, the requirements for the two bases will be treated separately.

Drilling Base

The essential function of an onshore base in supporting any offshore activity is to furnish the offshore activity with what it needs when it needs it. The base supporting a drilling well should possess or provide the following:

1. Harbor for sheltering small craft engaged in operation.

2. Suitable personnel boats, tugs, and barges or lighters to transport to and from the offshore operation the personnel, construction material and equipment, drilling equipment, tubular goods, etc., used in the construction of the offshore location or drill site, and the drilling and producing of the wells. A typical offshore drill site may contain as much as 600 tons of structural steel, 1700 tons of steel pipe, and 200,000 board feet of heavy timber. The drilling equipment to drill a 15,000 foot well will weigh as much as 650 tons, including drill pipe. The casing, tubing, oil well cement and production equipment used to complete such a well will weigh 500 tons or more. Fuel, dry drilling mud, and miscellaneous supplies may amount to as much as 1000 tons in the course of drilling a deep well. While the current practice is to carry a considerable part of this 4500/ tons of supplies and equipment on an auxiliary drilling barge, there still remains from 1000 to 2000 tons of expendable materials which must be transported to the offshore location for each well drilled.

3. Suitable dock facilities to load the supplies and equipment on the barges or lighters for transport to the offshore locations.

4. Facilities for fueling, servicing, and maintaining the various small craft.

5. Dependable communications between the shore base and the offshore locations and small craft.

6. Equipment to perform various well servicing operations, such as cementing, electric logging, perforating, etc., if such equipment is not included as part of the permanently installed equipment on the offshore drill site.

7. Navigational aids, such as radar, radio direction finders, etc., to facilitate return of small craft to the shore base during periods of fog or rough weather.

8. Supply facilities, such as warehouses, pipe yards, fuel storage, commissary and refrigerated stores, etc. with suitable hauling and handling equipment.

9. Shop facilities, such as machine shop, welding shop, engine overhaul shop, etc., for maintenance and repair of offshore drilling equipment, and possibly marine equipment.

10. Suitable aircraft, such as helicopter, with landing facilities, for fast transport of urgently needed repair parts, critically ill or injured personnel, technical or service personnel, etc.

Harbor

The ideal harbor, obviously, is one in which an anchored or docked ship is completely protected from wind or wave from any direction, but can be entered easily. An examination of the charts and the United States Coast Pilot for the area considered in this report, namely from the vicinity of San Luis Obispo south to the United States - Mexico border, indicates how infrequently these qualifications are met, as follows:

1. There are three harbors, San Diego Bay, San Pedro-Long Beach

Harbor, and Port Hueneme, which provide reasonably complete protection from all directions of wind and weather, are deep enough to accommodate any ship, and have commercial dock facilities available. Port Hueneme has the disadvantage that it is owned and operated by the U. S. Navy, which reserves the right to exclude commercial shipping on immediate notice.

2. Two more harbors, Newport Bay and Morrow Bay provide the same complete protection from the weather, but have water depths of only 16 to 20 feet, and very limited commercial dock facilities.

3. A few more harbors, such as Redondo Beach, Santa Monica Harbor, and Santa Barbara, provide somewhat less protection from the weather, are rather limited in protected area and have very limited pier facilities. These ports are used principally by pleasure and fishing craft, and there may be restrictions limiting commercial traffic at some of them.

4. Finally, there are a number of coves and bays which provide protection from one or more directions of weather, but are vulnerable from other directions, usually the south and southwest. At most of these, pleasure or fishing piers have been built, but there are usually no facilities for small craft to tie up to the dock. Port San Luis is the exception, providing considerable deep water wharf space, but is vulnerable to northerly winds. Such ports might be considered for use as temporary bases, but, with the possible exception of Port San Luis, would probably not be suitable for permanent bases.

5. Lastly, the thought that the offshore operator can develop a suitably protected site for his onshore base from the raw land, as has been done on the Gulf Coast, should be discouraged. Most of the

support bases developed during the Gulf Coast operations have been on rivers several miles upstream from their mouths. At these, protection from the weather was natural, and it was only necessary to do some dredging, and construct the dock facilities. The conditions on the Pacific Coast are far different and more discouraging. With the exception of several shallow lagoons in the coastal plain north of San Diego, and Alamitos and Anaheim Bays in the vicinity of San Pedro-Long Beach Harbor, there are no spots along the coast where the protection now provided from the weather could be substantially augmented without construction of extensive and expensive jetties or breakwaters, at a probable cost of several million dollars. To develop one of the shallow lagoons into a suitable base, including dredging, construction of entrance jetties, and construction of suitable docks or wharves is estimated to cost a million dollars or more.

On the basis of the foregoing, it would appear that, for most operations, the operator should plan to use the ports as they now exist.

As a partial compensation for the relative infrequency of suitably protected port facilities, the weather over much of the area under discussion, particularly from Port Conception south, is mild. From Point Conception, south, gales are noted in only about one percent of the weather observations made during the winter months. Gales occur very infrequently during summer months and the principle hazard occuring then is a heavy swell condition from the south and southwest. A marked change in climate and meterological conditions occurs north of Point Conception, and gales occur much more frequently. This condition may require larger support and service boats for the support operations, and will undoubtedly delay operations offshore much more than farther south. Even so, gale readings probably occur during only five to seven percent of the weather observations, mostly from the northwest.

While the area south of Point Conception is not immune from infrequent severe gales and heavy swell conditions, the predominance of calm weather over much of the area should be considered when selecting the site for the supporting base for an offshore operation, particularly when that operation is of a presumably temporary nature.

The selection of the site for the onshore base to support a specific offshore operation can be made only by the operator after a complete analysis of all the factors involved. In general, if the offshore operation is reasonably permanent in nature, the support base should be located in a well protected harbor, so that supplies can be loaded and unloaded when desired, and to provide protected anchorages from the small craft during storms. For California, this would mean locating the main onshore base at San Diego, Newport Bay, San Pedro-Long Beach, Port Hueneme, or Morro Bay. From these five ports, the maximum distance to any probable offshore work, including around the Channel Islands, would be about 65 miles, or a five to seven hour trip one way. The travel time for personnel and light supplies could be reduced considerably, by operating the service boats carrying them from an auxiliary base located at the port nearest the offshore operation which provided a pier from which personnel and light supplies could be handled. In this situation, the main support base would be at the protected harbor, from which heavy supplies would be shipped, and all small craft would move to the main base during periods of bad weather.

Small Craft

As stated before, the small craft, i.e. personnel boats, tugs, barges or lighters, and special service craft, are the core of the support of an offshore operation. Construction and drilling crews, supervisory and technical personnel, sick or injured men, construction materials, drilling equipment, etc. must be transported to and from the offshore operations. And with rare exceptions of extreme urgency, when use of aircraft of some type may be justified, all of this transportation must be by boat or barge.

The complement of small craft which would be needed to support one offshore operation, are as follows:

	Item	Estimated Initial Cost	Estimated Daily Operating Cost	Estimated Daily Cost If Chartered
A:	3 - Crew Boats			
	2 - Personnel boats, 48 feet long, diesel powered, 400 shaft horsepower, 16 knot speed, 2 man crew, 24 hours per day operation. (These craft are similar to water taxis used on this Coast for many years with good success).	(2 @ $30,000) $60,000	(2 @ $150) $300	(2 @ $185) $370

	Item	Estimated Initial Cost	Estimated Daily Operating Cost	Estimated Daily Cost If Chartered
B:	1 - Combination Crew and utility boat, 60 feet long, diesel powered, 400 shaft horsepower, 14 knot speed, 3 man crew, 8 hours per day operation. (Used as an emergency crew boat in extremely rough weather, for standby boat, and for transporting heavier equipment and supplies, which could not be carried on smaller personnel boats)	$75,000	$150	$250
B:	1 - Tug 80-90 feet long, diesel powered, 500 shaft horsepower, 6 man crew, 8 hours per day operation, plus 16 hours per day standby	$125,000	$220	$450
C:	1 - Barge Combination tank and deck cargo barge, 110 feet long x 30 foot beam, 500 tons capacity, with tanks for water and diesel fuel and to haul heavy equipment, tubular goods, etc., as deck cargo	$70,000	$ 30	$ 40
Subtotals for minimum equipment required:		$330,000	$700	$1110

Item	Estimated Initial Cost	Estimated Daily Operating Cost	Estimated Daily Cost if Chartered
D: 1 - Crane Barge	$150,000	$ 90	$ 120
120 feet long, 750 tons displacement, with 50 ton rotating crane, with auxiliary pile driving equipment, etc., used for drilling structure construction, rigging up operations, etc.			
E: 1 - Auxiliary Personnel Boat	$30,000	$ 60	$ 80
36 feet long, diesel powered, 400 shaft horsepower, 24 knot speed, for emergency trips and staff personnel			
Subtotals for additonal Auxiliary Equipment:	$180,000	$150	$200
Grand Total for all Equipment	$510,000	$850	$1310

As will be noted above, the complement of small craft is segregated into the minimum equipment which is essential to support of the operation, and additional equipment which would be desirable to have but is not essential to conduct the operation. The requirements of the particular operation will determine what equipment will be purchased and operated by the operator, and what will be chartered. Undoubtedly, during the preliminary stages, it will be expedient to charter most of the equipment.

The initial costs noted are for new equipment. Occasionally suitable secondhand equipment is available at a reasonable cost. If such equipment could be obtained, the initial costs could be reduced to about 60 percent of those shown here. Some war-surplus craft are available, but usually they are in poor condition and the prices are not very attractive. In this connection, it should be pointed out that, in the offshore development work conducted in the Gulf Coast since the war, many such operations were economically feasible only because of the availability of war surplus craft of all descriptions, at a small fraction of their replacement cost. As noted, such favorable conditions do not obtain now, and probably will not in the foreseeable future.

The selection of small craft has been made on the assumption that most of the operations will be carried out south of Point Conception. For continuous operations north of Point Conception, it would probably be expedient to replace one or both of the 48 foot personnel boats with 60 foot combination crew and utility boats.

The purchase and operating costs of the drilling tender are not included here, inasmuch as the tender is a vital part of the offshore drilling platform, and its costs are included therein.

Dock Facilities

The most important facility which the main onshore base must provide, next to protection from the weather, is a suitable dock at which heavy equipment and supplies can be loaded on and unloaded from the barges or lighters supplying the offshore activity. The dock should have a suitable crane for lifting the heavy equipment to and from the barges.

At the five harbors along the coast which were considered suitable for the main onshore base, plus one or two others, suitable wharves or docks are available for lease. Lease rates are nominal, and a dock of suitable size would probably cost no more than $500 to $800 per month for the bare dock, depending upon the size of barges used, and the amount of equipment shipped and received. For the initial stages of an operation, the operator would be well advised to operate from a leased dock.

If, at some later time, the operator should want to build his own dock facilities, they will cost him about $10 per square foot of dock area, exclusive of lease or purchase price of the land, dredging of the channel alongside, access roads to the dock, crane facilities, etc. For a dock of suitable size to accommodate the small craft recommended, say 150 feet long by 30 feet wide, the cost of the bare dock alone would be $40,000 to $50,000.

In addition to the bare dock, crane facilities of some sort will be required to load and unload pipe, equipment, and supplies. For a temporary operation, truck cranes could be used, or a locomotive crane, if tracks are available on the dock. For a permanent installation, a 30 to 50 ton dock crane of the gantry or shipyard "whirley" type would be ideal, but a locomotive crane would probably be adequate. Estimated purchase, rental, and operating costs for these various types of cranes are as follows:

	Estimated Rental Including Operators	Estimated Purchase Cost	Estimated Operating Costs
20 ton heavy truck crane; (would need 2 to handle very heavy equipment, as drawworks, pumps, etc.)	$150/8 hr. day	$ 40,000	$1500/month
40 ton Diesel Electric Locomotive crane	$300/8 hr. day If available	$ 70,000	$2000/month
40 ton Diesel Electric Travelling Gantry crane	Not available	$120,000 -$140,000	$2400/month

In addition to the dock facilities to be provided at the main base, some provision may have to be made at the auxiliary base, if the offshore operation is at a considerable distance from the main base, and it is desired to move personnel and light supplies from some point on shore which is closer to the offshore activity. In general, there seem to be fishing or pleasure piers at frequent enough intervals along the coast, where personnel and light supplies could be loaded and unloaded, that the auxiliary base can be located at one of these. If it is felt that none of these can be used satisfactorily, and the operator elects to build his own, it will cost him from $8 to $10 per square foot of area. Depending upon the topography of the shoreline, such a pier could cost $120,000 - $200,000 or more to bring the end beyond the surfline.

Fueling and Service Facilities

Fueling and other service facilities must be available, for both the offshore activity and the small craft supporting it.

With the conditions that exist in the area under consideration, there is no reason to install elaborate or extensive fueling facilities at the operator's shore base. At all five of the harbors recommended as locations for the main onshore base, as well as many points between these harbors there are commercial fuel docks at which diesel fuel, water, lubricating oil, etc. can be obtained. If the operator should elect to establish his main or auxiliary onshore base at some point at which no fueling or other marine service facilities exist, it may be necessary to install limited fuel capacity, to supply the small craft, but the fuel for the offshore activity should be barged from the nearest commercial fuel dock. Under these circumstances, the most that would be needed at the base would be a 2000 bbl. tank, with necessary pump and piping to both receive and discharge fuel, at an estimated cost of about $8000.

Communications

An essential item of equipment in the successful conduct of an offshore operation is a reliable means of communication between the onshore base, the offshore operations and all units of marine equipment offshore. Short wave two-way radio communication is the most practical and suitable way to accomplish this.

Most of the operations in the Gulf Coast have used low power frequency modulated systems, with transmitting and receiving units at the base, at each drilling or production location and on the various small craft. Some of the larger tugs and some drilling barges also have marine radiotelephone installations, for ship-to-ship and ship-to-shore communications through land telephone lines. A low power short wave network linking the offshore activities with its bases and supporting boats will cost about $1000 for each transmitter-receiver unit, or a total of about $8,000 to $10,000 for one offshore operation with its supporting bases and boats. Marine radiotelephone installations will be about the same or a little more in price. These cost estimates apply if the shore installation is placed in existing buildings. If a separate self contained unit is employed a total expense of $30,000 could be anticipated.

Well Servicing Operations

An offshore drilling well will require the same service operations, such as cementing, electric logging, formation testing, side wall sampling, perforating, directional drilling services, etc. as its counterpart on dry land. Some of the equipment for this, such as cementing pumps, electric logging equipment, etc. may be installed on the drilling tender or drilling platform as a permanent part of their equipment. However, it may be necessary to supply such services from shore. In these circumstances, particularly during the initial stages of an operation, the service equipment would be obtained from the service company and transported on the operator's barge to the offshore location, transferred to the drill site, and returned to shore when the job is completed.

Listed below are some typical services which might be performed on a typical 10,000 foot well, listing the price of the service for a similar well onshore, the estimated charge of the service company for marine service, the estimated cost of the barge and tug, and the total cost. As can be seen, the cost for a service operation for an offshore well will average about one and one-half to two times the cost for a similar service onshore.

Service	Cost on Shore	Extra for Marine Service	Est.Cost of Barge and Tug	Total Cost for Offshore
Cementing*				
Surface Pipe 100 ft.w/1000 sax.	$1192	$705		$1897
Water String 10,000 ft.w/1000 sax.	$1717	$705		$2422
Plug Job 10,000 ft.w/1000 sax.	$ 567	$225		$ 792
Squeeze Job 10,000 ft.w/1000 sax.	$ 592	$225		$ 817
Electric Log				
8,000 ft.	$ 770	$288	$500	$1558
10,000 ft.	$ 910	$228	$500	$1698
Sidewall Sampling	$ 700	$288	$500	$1488
Formation Tester 10,000 ft.	$ 261	$288	$125	$ 774
Gun Perforating 4-1/2" holes/ft. 200 ft.	$3545	$288	$500	$4333
Directional Drilling Service 120 days	$16,800	$6480	-	$23,280

*Prices for cementing are for marine, self-propelled equipment as used on Gulf Coast which would probably not be available during initial stages of California operations. Truck mounted units will cost a little less, but are not so convenient.

Navigational Aids

In addition to adequate radio communications, consideration should be given to equipping the shore base with such navigational aids as radar and radio direction finder if it is not already so equipped, to facilitate the return to base of the various small craft during foggy or heavy weather. At the larger harbors, such as San Pedro-Long Beach and San Diego, radar has been or probably will be installed before long. Radio beams and radio direction finders are more common still. There is a general feeling among small craft operators along the Coast that they can operate successfully in thick weather with the navigational aids now available. If a radar installation at the shore base should prove desirable, it would cost from $8000 to $10,000 for a suitable unit. A radar unit for a small craft, requiring a shorter range, will probably cost $2500 - $5000.

In addition to radar, operators on the Gulf Coast have found it desirable to employ meteorological consulting services to augment the information they receive from the U.S. Weather Bureau, particularly for the prediction of occurrence and probable path of hurricanes. In view of the relative clemency of the weather in this area, such refinements do not appear justified, although certainly both meteorologists and oceanographers should be consulted when the location of an offshore operation or onshore base is being determined.

The foregoing seven items outline the minimum essentials which the onshore base must have to adequately do its job. The following three are refinements which may improve its efficiency in performing its tasks.

Supply Facilities

As the base is now set up, it makes no provision for storing any of the items which it ships or receives, either at the dock or elsewhere nearby. As it must operate now, supplies must be delivered, probably by truck immediately prior to being loaded on the barge, and trucked away immediately they are loaded on the dock from the barge. This will occasion no particular difficulty if the operator's pipe yards and supply warehouses are sufficiently close to the dock, so that there is a minimum of delay in shipping some urgently needed item to the offshore rig. In other words, if the operator's present source of supply is within one to two hours travel by truck from his dock, there is little need to have any storage at or near the dock. If, on the other hand, the supplies must come 100 miles or more to the point of shipment, and the operator is engaged in a fairly extensive and permanent program of development, he is probably justified in building covered warehouses and open storage racks, with adequate materials handling equipment at or near the dock. In some harbors, covered storage space can be rented at $.15 per square foot per month, and uncovered storage at half this price. If warehouses or pipe yards are built, they will cost about $5.00 per square foot for warehouses, exclusive of the cost of the land, and $.50 per square foot for open pipe storage yards. Refrigerated warehouses for perishable commissary stores will cost roughly twice the cost of a plain warehouse, including cost of refrigeration equipment. Materials handling equipment to move material between warehouse or pipe yard and dock, including trucks, crane, fork lift truck, etc., will cost from $20,000 up, depending upon the amount desired.

Shop Facilities

The necessity for adding shop facilities, such as a machine shop, welding shop, engine overhaul shop, etc., must be determined on the same basis as the necessity for storage warehouses and yards. It is assumed that light shop facilities, such as welding equipment, engine lathe, drill press and the like will be installed on the drilling tender or platform. If there is excessive delay in accomplishing urgent repairs because there are no shops near at hand, either the operator's own shop or commercial job shops, which can accomplish the work, then the operator may be justified in setting up his own shops at the shore base. A modestly equipped heavy machine shop will cost between $50,000 and $100,000, with a welding shop about ten percent of that.

Aircraft

Aircraft, mostly of the float plane type, have been used to a limited extent in the Gulf Coast operations. Such aircraft types do not appear feasible for California offshore operations because of the general choppiness of the water.

However, there does appear to be a promising field for the helicopter, with its ability to land and takeoff from a small platform, as on the deck of a drilling tender. The use of the helicopter for transfer of critically ill or injured personnel, delivery of critical repair parts, transportation of staff or urgently needed technical personnel, would be invaluable in expediting the offshore operation.

At present, all new helicopter production is being taken by the Armed Forces. When units are available for commercial use, a suitable one will probably cost $80,000 to $100,000, with maintenance and operating costs of $3000 - $5000 per month. Rental on currently available machines is $75 per hour. Suitable landing facilities, both offshore and onshore could probably be provided for $5000.

There are two major points which must be emphasized in discussing the support of the offshore operation. One is the slowness of the marine transportation which must be used, and the second is the degree to which operations are subject to the whims of the weather.

Depending upon the type of boat considered, whether tug with barge in two or personnel boat, an increase of 4 to 7 miles in distance from the onshore base to offshore operation will increase the round trip travel time by about one hour. In general, average speed on the water will be about one-fourth of that on land.

The generally mild weather experienced over much of the area off the Southern California Coast indicates that there will be little interference with the operations on the drilling platforms and tenders. However, the transfer of personnel and supplies between small boat and platform is another matter. Operators in the Gulf Coast have noted it is difficult to transfer personnel from boat to drill site in calm weather, very difficult in choppy weather, and practically impossible in moderately rough weather. This means that the drilling operation may be held up more by an inability to supply it during choppy weather, than by the effect of the weather on the operation itself.

Production Base

The problems involved in the support of an offshore producing oil field are similar in many respects to those involved in the support of the offshore drilling activity. Most of what has been said about the support of the drilling activity applies with equal validity here, as follows:

1. A sheltered base with dock facilities is needed if heavy well servicing equipment must be sent to the well occasionally, or if the oil is shipped from the platform by barge.

2. A less sheltered base in closer proximity to the platform can be utilized for the personnel boats used by the pumpers and gaugers for periodic trips to the platform.

3. Various small craft must be provided and maintained, including a personnel boat for pumpers and gaugers; tug and barge if heavy well servicing equipment must be transported to and from the platform; and a sufficient number of tugs and oil tank barges, if oil is to be transported to shore by barge.

4. Suitable communications, navigational aids, etc. must be provided to ensure safe movement of all small craft.

In addition to these requirements, which have been discussed in detail, and need not be reviewed here, facilities must be provided on shore to receive, process and ship the oil and gas produced at the offshore locations, and shipped by barge or pipeline to the onshore base. These facilities will be identical in most respect with those presently installed for processing oil produced from wells on shore.

The cost of the facilities, in terms of cost per barrel of oil received, processed, and shipped per day, depends, of course, on their size, although as the size increases, the cost of the facilities per barrel handled per day will tend to level off. Assuming 10,000 barrels per day production from each of ten fields, for a total daily production of 100,000 barrels, with a gas-oil ratio of 500 cubic feet per barrel of oil produced, and with the production from each field going to a separate shore base, either by barge or pipe line, the average cost of the necessary facilities to receive, process, and ship the oil will be as follows:

Item	Estimated Capital Cost Per Bbl/day Processed	Estimated Capital Cost for 100,000 Bbl/day
1. Oil and Gas separators, including piping, oil meters, and gauging tanks. (These may be installed on offshore platform, with separate oil & gas lines to shore, or with oil barged to shore and gas flared. However, it may be desirable to ship oil & gas to shore in common line)	$1.00	$100,000
2. Dehydration equipment, including tanks, oil heaters, injector pumps, shipping pumps, and piping. (Based on assumption that only 10% of production will have to go through electric dehydrators, and that remainder does not need treatment, or can be treated with chemical)	$6.00	$600,000
3. Unloading pumps for unloading oil when barged to base. Includes pumps, motors, piping, and manifolding	$1.00	$100,000
4. Shipping facilities, including tanks, shipping pumps, and pipelines:		
A. For shipping via pipeline		
a. Storage tanks	$7.00	$700,000
b. Shipping pumps	$4.50	$450,000
c. Pipe lines	8" - $23,000/mile	in place

ITEM	Estimated Capital Cost Per Bbl/day Processed	Estimated Capital Cost for 100,000 Bbl/day
B.* For shipping via tanker		
a. Storage tanks	$21.00	$2,100,000
b Shipping pumps (may be possible to install tanks high enough to gravitate oil to tanker)	$12.00	$1,200,000
c. Submarine loading line includes moorings	$15.00	$1,500,000
5. Natural Gasoline Plants Assuming 500 cubic feet of gas per barrel of oil produced	$100/MCF/day	$5,000,000

*Item 4-B assumes shipping facilities installed at production base for each offshore field. The same facilities, with possibly more tank space, would serve to ship four or five times the production of one field, at a corresponding reduction of one-fourth or one-fifth of the estimated capital cost per barrel per day and per 100,000 barrels per day, as shown.

The same comments that were made in discussing the support of the offshore drilling operation, with regard to slowness of water transportation, and its susceptibility to the weather, apply to the support of the offshore production operation, but with less force. This is because the operation of the offshore producing well will not be so dependent upon receipt of supplies and personnel from the shore. Unless the well is in need of repair, which should occur infrequently with flowing wells, particularly, it should be able to function satisfactorily with no attention for a week or more. This will be particularly so if individual well flowlines are laid to shore, and the separating and gauging operations performed on shore. In these circumstances, the well can probably be left unattended for a month or more, using recording or transmitting gauges to obtain such information as is needed at the well head.

PART VI - PRODUCTION

C. W. Dawson
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PROBLEMS AND COSTS INVOLVED IN OFFSHORE DEVELOPMENTS

Production (General)

In general, the cost of offshore production operations will range from 3 to 7 times that of comparable onshore production operations. It has also been found that any production of less than 1,000 barrels per day of oil which must be barged a distance greater than 10 to 15 miles to onshore storage or handling facility would very probably be an uneconomical venture. These generalizations have been made as a result of the experience in the Gulf Coast area.

(1) Production Difficulties of Maintaining Operations Against Wave Action

All offshore structures and facilities must be designed for severe storms which, on the Pacific Coast, usually occur during the winter and early spring. The Northern Coast of California experiences storms of greater severity than does the Southern California coast.

Although the Pacific Coast area does not experience hurricanes, as does the Gulf Coast area, it is to be expected that storms will occasionally develop which will have winds up to 100 miles per hour and wave heights in excess of 20 feet. These wind velocities and wave heights are only slightly less than those experienced in the Gulf Coast area and it is believed that producing structures located offshore will be nearly comparable in design and cost for an equivalent depth of water to those in the Gulf Coast area.

The greatest hazard to either a drilling structure or a producing structure exists in water 35 to 40 feet deep due to the prevalence of breaking waves at this depth. The pressure or drag exerted by 20-foot waves on circular piles supporting a typical offshore structure is over 500 pounds per square foot of area affected. To this force must be added the wind pressure that normally accompanies a storm. If the wind reached 100 miles per hour, the additional force on the structure would amount to approximately 13.5 pounds per square foot of exposed surface.

While only two or three offshore platforms in the Gulf Coast have been wrecked by storms, nonproductive time resulting from adverse weather conditions may range from 10 to 25 percent, the range resulting from differences in exposure to the open sea, water depth, amount of travel time required between shore base and offshore platform, and type of operation underway. Operators in the Gulf Coast area have experienced difficulty in maintaining routine operations when wave heights exceed four feet. Here in California we can expect that at least 20 percent of the time wave heights will exceed four feet. Gulf Coast operators have also found that transfer operations of personnel and equipment are usually suspended when the wave heights exceed nine feet. Here in California we can expect wave heights in excess of nine feet at least 2.5 percent of the time. Operators in the Gulf Coast have found that in marine pipe line construction, loading oil from platform to barge, chain handling, transfer of personnel, etc., a combination of wind and wave action may reduce the above figures to one-half of those shown.

(2) Difficulty and Expense of Moving Oil

In any offshore venture, the handling of oil is an expensive process. The reasons for this are the costs of tankage on platforms (approximately $50 per barrel capacity), the cost of barges and tugs and the cost of laying submarine pipe line. All of these costs will vary, dependent upon how far off shore this oil is located, how close to existing onshore handling facilities and many others. As previously mentioned, experience gained by Gulf Coast operators has indicated that any production less than 1,000 B/D of oil, which must be barged a distance greater than 15 miles, would probably be an uneconomical venture.

(a) Gathering Oil By Barge

In the Gulf Coast, the predominant method of collecting and moving oil from platforms to onshore facilities is by barge and tug. These barges range in capacity from 3,500 to, say, 10,000 barrels and cost between $9 and $12 per barrel of capacity. The tugs used generally can be rented, but if purchased, will cost in the neighborhood of $250,000 each. One operator is experiencing transportation costs approximating $.85 per barrel of oil moved by barge and tug.

Some of the disadvantages to using barges are:

Weather - Wind, wave, and fog on the Pacific Coast can be expected to preclude the movement of barges at least 25% of the time. To minimize this lost time necessitates much careful forward planning. Some of this planning includes careful monitoring of all weather information to anticipate adverse conditions, being able to shut-in production if there is possibility of overflowing barge, and protecting platform from damage by barge during storms.

Oil-water-gas Separation -If water is produced with oil, it must be separated prior to collecting and transporting oil to onshore facilities, if transportation costs are to be held to a minimum. Also, since barges are not pressure vessels, all gas must be separated from production. These separation facilities must be located on the platform and will cost at least three times the cost of comparable facilities onshore.

Even though separation facilities can be located on the producing platform, exacting controls must be maintained to insure that all water separated is free from oil and there is no oil spillage into the ocean. If only small quantities of oil are contained in the waste water or are spilled, the prevailing westerly wind will drive this oil to the beaches. Because of the tremendous investment and interest in California beaches, the deposition of only small quantities of oil will precipitate considerable adverse publicity and possibly court action to discontinue operations.

Personnel - When barges are used to collect as well as transport oil, it is necessary to have personnel on or near the platform at all times to maintain the exacting control of oil handling and cleaning facilities required. This man or men must be on the platform day and night through good weather and bad. It is a rigorous life and dangerous existence, particularly if there must be travel back and forth between platforms or from platform to a barge where the oil is being collected. Moving from one object to another under normal wave conditions is not the simple matter of stepping in and out of a truck on land.

(b) Laying Gathering Lines to Shore

Any marine gathering line requires automatic control equipment to shut the line in should a break or fire occur. Also, lines must be buried to avoid fishermen and other marine craft from fouling lines, nets, and anchors. To protect the pipe line from corrosion, wrapping and cathodic protection is required.

The economics of installing a buried-marine pipe line is dependent of course, on the amount and value of the oil produced. Since these pipe lines and allied control facilities can cost as high as $300,000 to $500,000 per mile, the value of such a transportation method must be carefully compared with that of barging.

Marine pipe lines should be designed so that they are free of obstructions that would prevent the pumping of paraffin and bitumen removing equipment through the line. If possible, long radius bends should be incorporated in the line at points where the line changes direction.

Two typical areas connected to onshore terminals by marine gathering lines are represented by the Bay Marchand Field, off the coast of Louisiana in the open Gulf, and the Smith Point in Galveston Bay, Texas. The former, producing 7,500 barrels of oil per day with very little water is connected to shore with three four-inch lines extending through some three miles of open water. Low tubing pressure necessitates supplementary pumping equipment on the platforms (6 in number of which 5 support 28 producing wells). Electric power is provided via submarine cable and in addition to supplying the pumps, provides electricity for the type of workover equipment required in the maintenance of any producing field. Marine pipe line construction effected a $.50 per barrel reduction in field production cost for this installation.

The Smith Point Field, an older development in the 10-foot deep waters of Galveston Bay, produces about 1,150 barrels of oil per day plus 3,000 barrels of water. High pressure gas is available, however, to supply pump motive power to transport the unseparated oil-water-gas mixture through 11 miles of six-inch line to onshore heater-treater and separator facilities at the local Pasotex Pipe Line Terminal. This field, in an unusually favorable location from the standpoint of offshore operations, produces and transports oil to pipe line terminals at a cost of some $.30 in excess of comparable onshore development.

(3) High Cost of Offshore Producing Operations

Offshore production costs may be defined to include the cost of artificially lifting the oil to the platform or controlling the rate of flowing wells, treating and separating the oil-gas-water mixture, transporting the oil and gas to the nearest onshore terminal, servicing the wells and maintaining the various offshore facilities. Some other costs that might be included are pressure maintenance and secondary recovery operations.

As previously indicated, the experience of Gulf Coast operators has been that costs of offshore producing operations range between 3 and 7 times those of onshore operations. Although the literature does not break down the costs for any of the component parts of producing operations an attempt is made here to discuss briefly the approximate cost and problems to be expected.

(a) Artificial lifting - No great problem is anticipated if conventional pumping units are used, since this equipment does not require much space. There will be some problem in protecting the pumping units from corrosion, but use of plastics and enamels should provide the necessary protection at relatively low cost. Power for the pumping units can either be with gas engines or electric motors. In the former case, fuel gas must be available on the platform and in the latter case, electric power would probably be supplied from shore by a steel armored submarine cable. There are advantages to both means of power supply and only an economic study will reveal the better method.

If gas lift is used for artificially lifting the wells, it may be possible to use available high pressure gas from another producing formation. This is being done in a few instances on the Gulf Coast and is working quite satisfactorily. If gas for gas lifting must be compressed, the compressors can either be located on or adjacent to the offshore structure or onshore with main gas lift line laid on the ocean floor. Gulf Coast operators in shallow protected waters have successfully used compressors mounted on barges. These barges are so constructed they may be ballasted to rest on the bottom and thereby have a firm-spread foundation eliminating the effect of tidal movement on connections from compressors to wells. For the Pacific Coast it is believed that only platform mounted compressors and onshore compressors will be applicable because of the greater tides in the Pacific Ocean and we do not have the bayou country with protected waters.

All things considered, it would probably cost at least 1-1/2 times and possibly as much as 5 times the normal onshore costs for any method of offshore artificial lifting. The former cost is in all probability using conventional pumping units; the latter in using an offshore compressor plant.

(b) <u>Oil cleaning and separating</u> - The experience of Gulf Coast operators is that offshore tankage costs as much as $50.00 per barrel of capacity. This cost is so much more than comparable onshore facilities it is obvious that wherever practicable these offshore facilities should be held to an absolute minimum. If oil must be barged, certain offshore facilities will be required. The amount of equipment required is dependent upon the volume of gas and water produced with the oil and the method of well gauging to be used. Also, if oil is to be barged, it is almost mandatory that personnel live on the platform to control wells, gauge oil, load oil on barge and maintain equipment. As mentioned previously, exacting control will have to be maintained on any oil and water separation process to preclude oil disposed of with waste water being washed up on beaches. It is conceivable the costs for oil, water and gas separation in an offshore structure will range anywhere from 3 to 10 times that for onshore facilities.

If there is sufficient production to warrant pipe line construction from the platform to onshore facilities, it is possible to hold platform facilities to a minimum. The amount of facilities required are dependent, of course, upon many variables, such as whether wells are flowing or pumping, amount of water produced with oil, the method of gauging, the amount of gas available and if it can be economically conserved, the type of control equipment to be used to shut in the wells or pipe lines should a break or fire occur. One Gulf Coast operator set up the following desired characteristics for his offshore oil and gas separation and handling.

1. Adequate pump capacity and power.
2. The physical size and weight be such that it could be placed on space available on the existing structures so as not to require erection of additional offshore structures. It was further desirable that the size be such that it could be in place on the structures during drilling or workover operations and thus be available to handle the production of the completed wells on that structure.
3. The equipment should remove sand, gas, and free water from the oil before it leaves the structure so that the oil will enter the pipe line in a form which will least damage the line and which will require a minimum line capacity.
4. The equipment should provide a means of producing weak wells against a minimum back pressure.
5. The equipment should make gas available from high pressure wells for gas lifting purposes.

6. The equipment should make a continuous record of its production including water cuts.
7. The equipment should provide a means for testing wells under their normal operating conditions without interfering with the production of other wells.
8. Malfunctioning of the equipment should initiate corrective action to prevent damage and the creation of hazards. The corrective action should be such as to, at the same time, maintain normal production rates.
9. The equipment should be prefabricated on shore into a unit capable of being installed on the offshore structure in one lift.
10. The equipment should not involve the storage of oil at atmospheric pressure in order to reduce fire hazard.
11. Any abnormal operating conditions or malfunctions should automatically be reported to an operating attendant located on shore.
12. The equipment should provide for shutting in the wells from a location on shore to eliminate the necessity of personnel going out to offshore locations during adverse weather for the purpose of shutting in the wells.

To provide the desired onshore control and to provide power for his platform operations, he installed a steel armored submarine cable capable of transmitting 2500 horsepower. Incorporated in this cable were three pairs of small wires for use in telephone communication, remote control and supervision of offshore producing facilities.

No cost data is available on the above type of minimum offshore facilities but it is not inconceivable they cost at least 3 and possibly 4 times that of comparable onshore facilities.

(c) Well servicing - Because Pacific Coast operations will be carried on in generally unprotected waters, it is believed that well servicing equipment will have to be located on the platform. This will necessitate a derrick on skids or tracks which can be moved from well to well. The draw-works will have to remain at the platform because of the expense in barging such equipment and installing it each time a well needs servicing. Power for the draw-works can be supplied either with gas engines or by electric motors. The supply of rods, tubing, well pumps and other replacement parts can either be stored on the platform or barged to the platform as required. Since personnel and supplies will have to be moved by boat and barge, it can safely be assumed that servicing costs will be at least 3 times that for onshore operations.

(d) Maintenance of Offshore Structures and Equipment - As on a ship, maintenance of these structures and equipment is a continual and costly expense. Most Gulf Coast offshore platforms are cathodically protected with costs for the protection running into thousands of dollars per year. Protection of equipment on the structure as well as the structure itself is necessary if it is to be continued in serviceable and operable condition. No cost data was found in the literature on this problem, but it is assumed that at least $25,000 (and probably more) per year is spent for this work on a typical platform.

(e) Transportation of Personnel and Equipment - Crew boats which are seaworthy in the worst kind of weather are required for any offshore production platform. Crew boats used in the Gulf Coast are usually about 80 feet long and cost \$50,000 to \$60,000 each. It is probably desirable to have at least two boats to assure one is always available. Other equipment needed that may be rented or purchased are tugs, barges and floating cranes. Gulf Coast operators engaged in offshore Development and Producing operations are able to use their marine equipment for both operations and have an investment in this type of equipment ranging from \$275,000 to \$1,000,000.

(f) Pressure Maintenance and Secondary Recovery Operations- No literature could be found regarding the problems and costs of such operations, but when considering the cost of compressors, water filtering and treating equipment, pumps, etc., and the area required to set up such equipment, it can readily be seen that millions of dollars would be required for equipment and platforms alone, to say nothing about the increased operating and maintenance costs.

EXHIBIT C

REPORT OF THE
GULF COAST SUB-COMMITTEE
OF THE
NATIONAL PETROLEUM COUNCIL'S COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

May 28, 1953

FOREWORD

The following report on the technological aspects of offshore operations on the Gulf Coast Continental Shelf was compiled by the Gulf Coast Subcommittee of the National Petroleum Council Committee on Submerged Lands, Petroleum Productive Capacity at the request of Mr. H. A. Stewart, Acting Director of the Oil and Gas Division of the Petroleum Administration for Defense, United States Department of Interior. Mr. Stewart requested that the report should include detailed discussions of offshore problems and that these discussions should be phrased in terms that will convey a clear understanding of the problems to uninformed persons, outside of the oil industry. We have attempted to follow these instructions by submitting a non-technical summary along with a technical report. We hope that both the summary and the technical report will contribute to an understanding of exploratory and developmental operations on the Gulf Coast Continental Shelf.

SUMMARY

The spectacular, industrial growth of the Gulf Coast area during recent years is due mainly to the discovery and the development of large reserves of oil and gas on geologic structures beneath the Coastal Plains of Texas and Louisiana. Many of the major structures in the area beneath the Coastal Plains have now been found, so the search for additional fuel reserves to sustain industrial growth has shifted in part to the Continental Shelf off Texas and Louisiana where favorable structures for the accumulation of oil and gas have been located by geophysical surveys - a method of investigation which will reveal favorable structures.

Exploratory and developmental work on these structures has been carried on by several operators since the end of World War II. These were pioneering operations in every respect, as there were no precedents to follow in planning exploratory operations in open waters. Nevertheless, these pioneering operations were successful in demonstrating that substantial reserves of oil and gas are present on some structures in the Gulf of Mexico, and that both exploratory and developmental operations in open waters are entirely feasible from a technical viewpoint. They have demonstrated also that offshore operations are expensive, due to the large initial capital investments in geophysical surveys, shore base, vessels for transporting men, equipment and supplies, platforms for drilling rigs and drilling tenders, as well as the high, daily operating cost for drilling units working in offshore areas. Some of these costs will be reduced by the economies resulting from large scale operations and by the development of more efficient equipment for offshore drilling. Nevertheless,

the costs of offshore operation will always be relatively high as compared to operations on land.

Capital expenditures for equipment and installations required for offshore, exploratory work are about five times greater than those required for onshore operators. For example, the estimated expenditures for equipment and installations required for drilling 10 wells in 60 feet of water from 6 platforms with one drilling rig total $5,713,000 (see Tabulation 2). This cost is based on the assumption that 6 platforms will be required and that at least one well on each platform is productive so that there is no opportunity to reduce costs by salvaging and re-erecting a platform at another location. Installations and equipment for a similar exploratory program on land would cost about $1,000,000. The costs of drilling, geophysical surveys and leasing are not included in these estimates.

The costs of operating the equipment are also two to three times higher in the offshore area due to the higher charges for labor, transportation, maintenance of equipment, depreciation of equipment, etc. For example, the total cost of drilling 5 vertical and 5 directional holes to depths ranging from 10,000 to 12,000 feet will be $6,700,000 plus $1,500,000 for 5 platforms in 60 feet of water, or a total cost of $8,200,000 assuming that there is at least one productive well on each platform thereby eliminating the possibilities of using the same platform in two locations. Ten onshore, exploratory wells drilled to the same depth will cost about $3,200,000.

This is not the entire story as an operator will almost certainly want to acquire several prospects in order to reduce the risks inherent to all exploration. There is no definitive method of determining reserves on a structure short of drilling expensive tests and the only method of recovering expenditures for unsuccessful tests on structures that are barren or have low reserves is by remunerative operations on structures with large reserves of oil and gas (please refer to pages 8-10 in the technical report). Consequently the prudent operator is faced with the necessity of obtaining several prospects. The first step towards this goal is to decide on the area or the areas where geologic conditions appear to be most favorable for the accumulation of oil. Then, geophysical surveys will be made in the selected areas in order to locate favorable structures. These surveys will cost up to several million dollars depending on the size of the area selected for investigation, the amount of detailed information on individual prospects required by the operator for purposes of evaluation and selection, the type of geophysical surveys that are used, etc. After the locations of favorable prospects have been established by these surveys, the operator must obtain leases on several of these prospects and this may involve substantial expenditures.

The total expenditures required for the discovery of a major oil field on the Continental Shelf are difficult to predict. The first structure that is selected for testing may turn out to be a major oil field in which case the total expenditures will be much lower than if four, low-reserve structures are tested before discovering a major oil field on the fifth prospect. An operator must be prepared financially for disappointments.

All operators that plan to engage in offshore exploration are well aware that these operations are very expensive at the present. Their decision to explore on the Continental Shelf is based on the conviction that onshore exploratory work along the Gulf Coast is reaching the point of diminishing returns and that offshore costs will be reduced materially by utilizing the technical "know how" gained from large scale operations particularly in the developmental phases of offshore operations.

Successful exploratory operations on a structure are normally followed by development of the oil and gas reserves on the structure. The purpose of this work is to drain reservoirs (the oil bearing sands) in an efficient and economical manner, and to recover as large a percentage of the oil and gas as is possible under the conditions existing in the field. Drilling operations of this nature, commonly designated as development drilling, are generally 15 to 25 per cent less expensive (compare Figures 18 and 19) than exploratory drilling, as depths to reservoir sands, and to zones where difficult drilling conditions may exist, are partially known, thereby reducing the charges for casing, auxiliary well logging services and geologic supervision. Furthermore, several drilling rigs are generally in operation in the field thus reducing unit costs for transportation, supervision, etc. For example, the daily cost for transportation of men, equipment and supplies to one drilling installation consisting of a drilling tender moored to a small platform is about $1350 (please refer to page 31 in the technical report). The daily cost for transportation to three, similar drilling installations operating on the same structure would not be materially greater than $1350. Therefore, substantial savings in the costs of transportation are possible where large scale drilling operations are in progress in the same general area.

The fixed charges for operation and maintenance of the shore base will be divided among a larger number of wells as exploratory operations are replaced by developmental operations. Thus, charges per well for the facilities provided by the shore base will be lowered. It may be necessary to enlarge the shore base in order to accommodate the increase in traffic, but the costs of this work will not be excessive when divided among a large number of wells.

The costs for drilling platforms will be about the same as for exploratory wells. Additional platforms will be needed for producing equipment, oil storage and field housing.

Facilities for handling the production of oil will be provided. Flow lines will be laid from the wells to gathering stations where the oil will be stored while awaiting transportation to land. A pipe line from the field to shore will probably be laid when sufficient reserves of oil have been developed on the structure.

Gas reserves developed in offshore areas can be operated efficiently despite high costs. A wide spacing pattern designed to recover the maximum volume of gas and condensate with a minimum number of wells can be developed for each structure. The well will be shut in until the proven reserves are large enough to justify the expense of a pipe line to shore. Once this pipe line is laid, it will, of course, provide an outlet for any minor gas fields located along the pipe line.

A discussion of offshore operations would be incomplete without mention of operational planning and the men that are responsible for this work. Since the end of World War II, many of the most competent men in the oil industry have been engaged in planning for offshore operations on the Gulf Coast Continental Shelf. Most of these men had little or no previous experience with marine operations in open waters, so their assignment involved considerable research in order to determine the most economical methods of finding and producing oil from structures located in offshore areas. Their work is far from complete - in fact, the applications of many of their ideas have yet to be tested under field conditions. Their goal is to develop large reserves of oil and gas at unit costs that are comparable with those on land. Most of them believe that this goal can be realized if offshore operations are conducted on a large scale and all facilities and equipment are fully utilized. If this is the case, it will be a noteworthy achievement that will benefit the industrial economy of the United States for many years.

INTRODUCTION

The following technical report is a factual description of the technological aspects of offshore operations on the Gulf Coast Continental Shelf. The problems associated with these operations are outlined, and estimates of the capital expenditures required for entry into these operations are presented.

The report is divided into four parts. Part I includes a brief, geographic description of the Gulf Coast Continental Shelf, as well as some observations concerning exploratory operations on the Shelf; Part II is a generalized, geologic description of the Gulf Coastal Plain between the Mississippi Delta and the Rio Grande; Part III deals with offshore, exploratory methods; and Part IV deals with development.

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PART I

THE GULF COAST CONTINENTAL SHELF

The arcuate segment of the Continental Shelf lying between the Florida Keys and the Rio Grande is herein designated as the Gulf Coast Continental Shelf. It covers an area of about 132,000 square miles and reaches a maximum width of about 175 miles off the west coast of Florida. Its seaward limit is arbitrarily defined in this report as the 100 fathom depth contour, although the actual break in slope at the outer margin of the Shelf ranges in depth from 40 fathoms to over 100 fathoms (see Figure 1).

The evaluation of prospective areas on the Gulf Coast Continental Shelf shown on Figure 1 is based on one or more of the following:

(1) Geologic comparison with coastal sectors of the Gulf coastal states.

(2) Geologic information from offshore wells.

(3) Geophysical surveys.

(4) Integration of data from the sources of information listed above.

The geologic hazards of wildcatting on the Continental Shelf are significantly higher in most areas than on the adjacent coastal plain. This is due mainly to the lack of reliable stratigraphic information in areas that have not been tested by drilling. Structural conditions can be determined by geophysical surveys in advance of leasing and drilling, but stratigraphic conditions cannot be predicted with accuracy beyond 10 or 15 miles from the nearest well. Consequently, stratigraphic information adequate for the evaluation of prospects is available for only about 5% of the total area of the Shelf.

The generally favorable area for exploration extends westerly from the Mississippi Delta to the Rio Grande (see Figure 1). It is a submerged extension of the productive, coastal plain of Texas and Louisiana, and it is a structurally favorable area for accumulation of oil and gas. Production has been obtained from 25 structures off the coast of Louisiana and from one structure off the coast of Texas. Stratigraphic conditions off Louisiana are generally favorable out to a depth of at least 10 fathoms, so the geologic hazards of wildcatting in this area are not significantly higher than on the adjacent, coastal plain. Stratigraphic conditions off Texas appear less favorable at the present time, but as very few wells have been drilled in the area, there is little reliable information on which to base an evaluation of stratigraphic conditions. (Note: please refer to Part II of this report for a more complete discussion of stratigraphic factors localizing accumulations of oil and gas along the Gulf Coast).

The Continental Shelf off Mississippi, Alabama, and Florida is virtually unknown insofar as geological conditions are concerned. There are a few scattered tests located on land along the coast, but no production has been found adjacent to the coast with the exception of the Sunniland Field in Florida (see Figure 1). The thick assemblage of Miocene and younger beds comprising the productive sequence in southern Louisiana thins markedly to the east and becomes calcareous. The regional trend of the beds is southeastward, and they dip to the southwest along the coast of Mississippi and Alabama, thus bringing the underlying Mesozoic beds within reach of the drill in the coastal plains to the east of the Mississippi Delta. The prospects of finding large accumulations of oil and gas on the adjacent Continental Shelf are less encouraging than to the west of the Mississippi Delta. Consequently, exploratory work will probably be concentrated largely in the favorable area for the next 5 or 10 years.

PART II

GENERAL GEOLOGY OF THE GULF COASTAL PLAIN BETWEEN THE MISSISSIPPI DELTA AND THE RIO GRANDE

Oil finding in the Gulf Coastal Plain requires both knowledge and understanding of regional and local geological factors controlling accumulation of oil and gas. The following notes, in part from the 1953 Guidebook prepared for the annual meeting of the American Association of Petroleum Geologists in Houston, provide useful background material for an appreciation of exploratory problems, both on the Coastal Plain and on its submerged continuation offshore.

The Gulf Coast petroliferous province is unique in North America in that most of the productive structures were formed either directly or indirectly by movement of salt that underlies most of the productive Cenozoic sequence. The age of the salt has not been definitely established in the coastal sector of the province where the salt layer or layers are well beyond the reach of the drill. However, many geologists believe that it is the stratigraphic equivalent of the Louann salt of Permian age which is recognized in the subsurface along the northern margin of the province.

Nearly all of the oil from the Gulf Coast is produced from beds of Cenozoic age. Beds of Cretaceous age, which have been drilled and produced along the northern and eastern margins of the productive, Cenozoic province, may constitute important targets for exploration on the Continental Shelf off Mississippi, Alabama, and Florida, but this is pure speculation until such time as more geologic information is available on this sector of the Shelf.

Stratigraphy

The clays, sands, and shales of the entire Cenozoic have a similar origin. Southward flowing rivers, comparable with those of today, brought great volumes of sediment from the same general area around the interior of the continent. The sediments were deposited on flood plains crossing coastal plains, massed in dunes and bars near the beaches, and spread over the floor of the Gulf throughout the entire era. Periods of regressive seas with growth and seaward extension of the land area alternated with shorter periods of transgression when the sinking and tilting of the land brought marine deposits over earlier, continental sediments. Sediments deposited during different phases of the regressions and transgressions vary in lithology and in their faunal content. Commonly, tongues of marine shale containing relatively deep water faunas thin updip where they interfinger with sands deposited in near-shore and continental environments. In general, these zones of transition from marine to continental sediments migrate seaward in successively younger, formational units up to the Pleistocene.

This seaward migration of the transition zones has determined the positions of productive trends or "fairways" which are located slightly seaward of the transition zone in each formational unit. Favorable conditions for accumulation of oil and gas along these productive trends are due partly to the mutual proximity of source and reservoir rocks. Sands suitable for reservoirs are rare to absent farther downdip where the sediments consist chiefly of shale; and source beds for oil are rare farther updip in the predominantly continental assemblage of sediments.

The productive trends for individual stratigraphic units along the Gulf Coast are delineated in Figure 2. The Miocene trend, extending along the coast of Texas and Louisiana, includes more than 20,000 feet of Miocene and younger sediments in southern Louisiana. It will probably be subdivided into several productive trends when the productive limits of the various stratigraphic units comprising the Miocene and Pliocene are established by drilling on the Continental Shelf.

The formational units thicken as they are traced in the subsurface from their updip, continental facies to their downdip, marine facies. The rate of thickening, which is fairly constant for individual stratigraphic units in their continental and near-shore, marine facies, increases rapidly in their deeper,marine facies. Seaward dips also steepen as the rate of thickening increases, thus forming a flexure that is often aptly described as a "hinge line". These structures, like the closely associated transition zones between marine and continental facies, migrate seaward in successively younger formations.

Various views are held on the origin of the "hinge lines". Some geologists, impressed by the similarities between these structures and breaks in slope at the margins of Continental Shelves, consider them to be buried margins of ancient shelves. Others, impressed by the changes from sand to shale facies along the "hinge lines" and by changes in rates of thickening at the "hinges", believe that the structures resulted from differential compaction in sediments and differential subsidence in response to excess loading seaward of the "hinge". Still other geologists, impressed by the close, spatial association of "hinge lines" and regional, seaward dipping, gravity faults, suggest that the "hinge" may have originated as the result of movement along these faults. The various views are not mutually exclusive and probably they will all be incorporated in the final story of the origin of these interesting structures.

A definite description of a stratigraphic column will not apply to all of the Gulf Coast. Through long periods and over a wide expanse, the flood plains and deltas of several rivers may merge to give a certain uniformity. At other times, the variations in amount and type of sediments that different portions received from their local sources have resulted in marked changes in the character of sediments - thus introducing lateral variations in lithologic facies. Although the major transgressions were effective on a sufficiently uniform scale so that they are readily recognized throughout the region, there were also local basins created by differential subsidence.

These restricted embayments were filled with relatively thick sedimentary deposits that thin towards the margins of basins where they merge with deposits having normal, regional thicknesses. Furthermore, changes in thickness and lithology of sedimentary units are encountered on many structures, particularly where sediments are pierced by salt. These changes are due to several factors including the following: (1) uneven bottom topography as the result of vertical movements accompanying salt emplacement; (2) faulting concurrent with deposition; and (3) structural disturbances adjacent to the salt plug. Their role in localizing accumulations of oil and gas on structures is becoming apparent as correlations become more reliable.

The maximum thickness of all stratigraphic units of the Cenozoic can not be accurately determined. An arbitrary thickness of 30,000 feet is sometimes adopted as a working figure, but this seems overly conservative, especially in southern Louisiana where wells have been drilled to 17,000 feet without reaching the middle of the Miocene.

Regional Structure

The arcuate homocline forming the northern limb of the Gulf of Mexico geosyncline is the major structure along the Gulf Coast. Its general, structural characteristics are well portrayed on Figure 3, showing the structure of the Upper Texas Gulf Coast Area. Seaward dips on this structure are the sum of original seaward slopes of surfaces on which sediments were deposited, plus crustal subsidence during development of the geosynclinal trough, plus the effects of differential compaction in sands and muds. Steepening of seaward dips occurs along "hinge lines" that migrate seaward in successively younger, formational units (see Figures 4 and 5).

The position or positions of the Gulf of Mexico geosynclinal trough during the Cenozoic can not be determined from existing subsurface geologic data, as nearly all formational units continue to thicken seaward to the deepest positions penetrated by the drill. Thus, all exploration up until the present has been on the homoclinal, northern limb of the geosynclinal trough.

Numerous gravity faults, some of which are traceable for over 100 miles in the subsurface, interrupt the homoclinal structure. Their trends are generally parallel to the present coast line; they dip seaward at angles ranging from 40° to 60°; stratigraphic throws up to 3,000 feet have been reported; displacements increase with depth;

and stratigraphic units are thicker on the downthrown block than they are on the upthrown, thus indicating that the faults were active during deposition. Anticlinal folds are closely associated spatially with these regional faults. They are generally located on the downthrown block; and their axes are generally parallel to the trend of the fault.

Differential, crustal subsidence has been the dominant process in the structural evolution of the Gulf Coastal area during the Cenozoic. The only structure that originated from tectonic forces appears to be the Gulf Coast geosyncline. Subsidence and loading on the flanks of this structure have been directly or indirectly responsible for the almost infinite variety of complex, fault patterns that interrupt the continuity of both local and regional structures.

Structures Controlling Accumulation

Structural and stratigraphic factors controlling accumulation on domal structures along the Gulf Coast are complex due mainly to domal growth during deposition. As a result, the ratios of dry holes to productive wells on most of the structures are generally high when compared to other petroliferous provinces. Similar conditions exist on the Continental Shelf off Louisiana where the ratios of dry holes to productive wells are relatively high on structures that are now under development.

Classification of structures

Structures along the Gulf Coast may be classified in various ways. The following classification, based on depths to salt and shapes of structures, was adopted by W. W. Patrick in his paper on "Salt Dome Statistics", appearing in the Guidebook prepared for the 1953 Annual

Meeting of the American Association of Petroleum Geologists in Houston. It is relatively simple and is well adapted for the purposes of this report.

1. SALT DOMES - structures on which salt has actually been penetrated by the drill. These structures are subdivided on the basis of depths to salt into:
   - (a) shallow salt domes - salt 2,500 feet or shallower.
   - (b) intermediate salt domes - salt 2,500 - 6,000 feet.
   - (c) deep salt domes - salt 6,000 feet or deeper.

2. DOMAL TYPE STRUCTURES - salt has not actually been penetrated by the drill. However, the general, structural characteristics of these domes are similar to deep salt domes, thus suggesting that they were also formed by movement of salt.

3. ANTICLINAL FOLDS - salt has not been encountered. These structures are commonly associated with regional down-to-the-coast gravity faults, as was mentioned under the heading of "Regional Structure" in this report.

4. FAULTED ANTICLINAL FOLDS - the basic symmetry of the fold has been modified by faulting.

Patrick has also listed cumulative productions from structures in Texas along the prolific, Gulf Coastal productive trends. The following tabulation based on his figures shows average cumulative productions for all salt domes and a limited number of non-salt dome fields. The latter were selected from well-known fields of more than average importance.

SHALLOW DOMES
(Salt encountered at depths less than 2,500 feet)

No. of domes	33
Average cumulative production	28,000,000 bbls.
No. of domes having less than 10,000,000 bbls.cum.prod.	17 - - - -51%
No. of domes having more than 20,000,000 bbls.cum.prod.	10 - - - -33%

INTERMEDIATE DOMES

(Salt encountered between 2,500 feet and 6,000 feet)

No. of domes	8
Average cumulative production	12,000,000 bbls.
No. of domes having less than 10,000,000 bbls.cum.prod.	6 - - - -75%
No. of domes having more than 20,000,000 bbls.cum.prod.	2 - - - -25%

DEEP DOMES

(Salt encountered at depths greater than 6,000 feet)

No. of domes	10
Average cumulative production	31,000,000 bbls.
No. of domes having less than 10,000,000 bbls.cum.prod.	5 - - - -50%
No. of domes having more than 20,000,000 bbls.cum.prod.	4 - - - -40%

DOMAL TYPE STRUCTURES

(Salt has not been encountered to date)

No. of domes	19
Average cumulative production	67,000,000 bbls.
No. of domes having less than 10,000,000 bbls.cum.prod.	3 - - - -16%
No. of domes having more than 20,000,000 bbls.cum.prod.	11 - - - -58%

ANTICLINAL FOLDS

No. of structures	26
Average cumulative production	36,000,000 bbls.
No. of fields having less than 10,000,000 bbls.cum.prod.	8 - - - -30%
No. of fields having more than 20,000,000 bbls.cum.prod.	14 - - - -54%

FAULTED ANTICLINAL FOLDS

No. of structures	16
Average cumulative production	17,000,000 bbls.
No. of fields having less than 10,000,000 bbls.cum.prod.	5 - - - -31%
No. of fields having more than 20,000,000 bbls.cum.prod.	6 - - - -37%

Structures with cumulative productions ranging from a few barrels to over 300,000,000 barrels are included in the foregoing tabulation. These structures are located in Texas on the Gulf Coastal Plain which merges with the adjacent Continental Shelf at the shoreline. Therefore, it is reasonable to assume that exploration and development on similar structures located in the Gulf of Mexico will repeat the experience on land, that is, some structures having large reserves will be discovered and developed while other structures having small reserves will be tested and abandoned. Exploratory operations on the low-reserve structures will be discontinued as soon as the disappointing facts are established, but nevertheless these operations will have involved heavy expenditures (see Summary of Wildcat Drilling Costs in Part III of the report) which can be recovered only by remunerative operations on structures with large reserves. The minimum requirement for self supporting operations in the Gulf of Mexico is to conduct exploratory operations on a large scale by leasing and testing a number of promising prospects. The overall exploratory program will be successful only if major oil fields are discovered.

PART III

OFFSHORE EXPLORATORY OPERATIONS

These operations, which are generally far more expensive than on land, are divisible into three categories: (1) stratigraphic investigations based mainly on seaward projection of stratigraphic data from wells located along the coast or on the Continental Shelf, (2) structural investigations based on geophysical surveys, and (3) wildcat drilling. Inexpensive methods of exploration such as interpretation of aerial photographs, surface mapping, etc., can not be used to define favorable areas on the Continental Shelf, and stratigraphic investigations are hampered by the paucity of wells. Thus, most exploratory operations consist of geophysical surveys and wildcat drilling.

Geophysical Operations

Structures favorable for the accumulation of oil on the Continental Shelf off Texas and Louisiana have been located and mapped by gravimetric and seismic surveys. Most of these structures can be classified as salt domes .

Gravimetric Surveys

The salt in these domes is lighter than most of the adjacent sediments, thus causing a local decrease in the earth's gravitational field. These local variations in the earth's gravitational field can be located by a gravimeter - an instrument which is an extremely sensitive weighing device. Gravimeters have been developed to the point where those used on land are very light and compact, and thus they can be carried without difficulty anywhere a man can go. No auxiliary equipment is necessary, and any convenient method of transportation is satisfactory. In contrast to this, a gravimeter for offshore operations has to be mounted in a waterproof housing which will withstand water pressures of several hundred pounds per square inch. Special motors are mounted in the waterproof housing to level and adjust the instrument. In operation, the meter is lowered over the side of a boat to the bottom, then leveled and read by remote control. Rough water or a soft sea bottom hampers the leveling and reading operations and sometimes prevents the obtaining of useful data. A land party consisting of from six to ten men will average 600 stations per month at a cost of about $20 per station, whereas a water party, consisting of perhaps twelve men, including boat personnel, will average less than 250 stations per month at a cost of about $120 per station.

Seismic Surveys

Seismic methods of surveying are based on accurate timing of artificially generated, elastic waves or sound waves that are transmitted through rocks. These waves are initiated by the explosion of a small amount of dynamite at a shot point. They spread radially outward from the shot point - some of the energy being reflected back toward the surface of the earth by reflecting horizons, i. e.: contacts between sedimentary layers having different speeds of transmission of sound, whereas other portions of the energy are refracted or bent on passing into a high velocity bed. They travel along the upper surface of this bed where they initiate secondary sound waves that return to surface where they are picked up by instruments known as detectors.

Both reflected and refracted sound waves furnish information that is useful in determining subsurface, structural conditions. Seismic reflection surveys utilize reflected sound waves to determine the depth to a reflecting interface. The round trip time required for energy to travel from the point of explosion downward to the bed and back to the surface is recorded accurately. The depth of the bed below the surface can be determined from this if the speed of transmission in the intervening beds is known or can be computed. Structural uplifts and depressions involving the reflecting bed are thus apparent from increases and decreases in travel times of the sound wave.

Seismic, refraction surveys utilize the travel time of a refracted sound wave to determine (a) depths to high speed beds and (b) horizontal discontinuities in rocks, such as occur where sediments are pierced by a salt plug. Detectors are generally placed up to several miles away from the shot point. The time of explosion and the time of arrival of the first sound waves are recorded accurately, and by comparing travel times recorded by the various detectors, it is possible to compute depths to high speed beds. A special application of the refraction method is based on the difference in speed of transmission of sound waves in sediments and in salt. This method is used to delineate the shapes of salt domes. It is applied by lowering one or more detectors into a bore hole in the salt in order to record travel time from shot points some distance away - usually several miles. The observed time consists of two separate components, travel time in low velocity sediments and travel time in high velocity salt. The problem is to determine the length of the wave path in each medium. This can be done either mathematically or graphically, and the position of salt-sediment interface along one wave path can be determined. Finally, the shape of the dome can be determined fairly accurately by recording travel times from shots in many locations around the periphery of the dome.

Refraction, seismic surveys are generally more expensive and their results are generally less precise than those obtained by reflection surveys. They are therefore used mainly in areas where the reflection method fails to obtain useful data. They have not been used to any extent in offshore areas because of the disadvantages mentioned above and because of the difficulty in obtaining precise, distance measurements between shot points and detectors in marine operations.

The costs of offshore, seismic surveys are relatively high. This is due to the specialized equipment and the size of the crew that are required. A reflection, seismic crew working on the Continental Shelf uses from two to five boats ranging in length from 85 to 160 feet. These vessels are expensive, as they must be well constructed in order to withstand the heavy seas that are encountered. The equipment used by the crew is also more expensive than that used on land, and the crew is, of course, much larger.

The monthly costs for a reflection seismic party engaged in offshore work range from $35,000 to $80,000 in contrast to the monthly cost for similar operations along the coastal plains which average about $15,000. However, the cost per linear mile of survey line is not greatly different if long, continuous lines in offshore areas can be run without interruption. This is due to the speed of marine operations when weather and other conditions are favorable.

Surveying Operations

Precise, positional surveys with an average error of about 100 feet are required for both gravimetric and seismic surveys on the Continental Shelf. There are four principal methods of obtaining this order of accuracy - the Sonobuoy Method, the Shoran Service, the Lorac Service and the Raydist Service. These services, developed during and since World War II, are described briefly in the following pages.

The Sonobuoy Method utilizes the speed of transmission of sound in water to determine locations. It consists of a buoy, known as a Sonobuoy, to which a radio transmitter and antenna are attached. The buoy is attached to an anchor by means of an electrical conducting cable. A detector, actuated by sound waves in water, is also attached to the anchor. Several Sonobuoys are dropped in water close enough to shore so that their positions can be determined by triangulation from stations on shore. The ship may then proceed to a nearby point from which the seismic survey will start, and the location of the first shot point will be determined in the following manner. Sound waves set up in water as the result of the dynamite explosion radiate outward from the shot point towards the Sonobuoys. They are picked up by the detector attached to the Sonobuoy and the detector initiates a radio pulse which is transmitted back to the ship. The time of transmission of the sound wave through water can then be determined from accurate recording of the time of dynamite explosion and the time of reception of the radio signal - the time of transmission of radio signals can be neglected. This difference in time multiplied by the speed of sound in water gives the distance from the shot point to the Sonobuoy. The position of the shot point is then determined by swinging three or more arcs whose radii are proportional to distances from the shot point to the various Sonobuoys.

The Sonobuoy Method may be extended seaward by dropping Sonobuoys at shot points in positions that have been determined by the technique outlined in the previous paragraph. The Sonobuoy Method is used mainly by reflection, seismograph crews, but it could be used by gravity crews if they were equipped to generate miniature explosions in water at points where gravity observations are to be made.

The Shoran Method of surveying was developed during the war as a useful and highly precise method of measuring distance. The basis of the surveying technique is simple. The round-trip, travel time of a radio pulse between two points is measured with high precision. The distance can then be readily determined, as the speed of transmission is known. By setting up two or more Shoran transmitters along the coast or on boats anchored in the water at known positions, the location of a Shoran receiver can be determined accurately with respect to the Shoran transmitters. The effective range of the Shoran system appears to be about 25 miles, that is, roughly the distance to the horizon. The signal is propagated in a straight line due to the relatively short wave length of the signal.

The Lorac system makes use of longer, electromagnetic waves than the Shoran, with the consequence that the waves tend to follow along the surface of the earth and thus they can be received beyond the horizon. Several Lorac transmitters are located on shore and spaced at adequate intervals to provide suitable base lines. The signals are transmitted on three wave lengths that are not greatly different. The signals are transmitted continuously and an interference pattern is established over the entire area within range of the transmitters. Positions are determined from these interference patterns by the use of complex, electronic equipment setups. Precalculated charts show the relation of the interference pattern with respect to a known grid, such as latitude or longitude or the Lambert coordinate system. Experience has indicated that this system is adequate and gives a precision with an accuracy of the order of 100 feet when due care is used. The present Lorac equipment appears to have an effective range of almost 100 miles.

The Raydist system is similar to the Lorac in that an interference pattern of electromagnetic waves is set up in space. This system also makes use of several transmitters on shore and has receivers aboard ship. The two systems, that is, the Lorac and the Raydist, differ in some important details, but the precision and range attained are comparable.

The cost of the Shoran, the Lorac, and the Raydist systems is considerable, and the user pays some \$7,500 or \$8,500 per month if he is a single user, to \$5,000 or \$5,500 per month, if he is one of four or more clients. The cost of the Sonobuoy system appears to be appreciably less, but it is not of such universal application as the other three systems. It seems improbable that the cost of adequate surveying service in the Gulf of Mexico can be reduced appreciably in the future, and it is therefore necessary in estimating the cost of geophysical operations in the Gulf of Mexico to assume that the cost of the operation will be increased on an average by $6,000 or $7,000 per month due to these services. These figures contrast with the cost of surveys on land which range from $1,000 to $1,500 per month, depending on the size of the survey party.

Wildcat Drilling

Most companies classify their drilling operations under the headings of exploration and development. An exploratory or wildcat well is one that is drilled for the purpose of locating a new oil or gas field or for the purpose of extending the productive limits of a field. In contrast, a development well is one which is located within the productive limits of a field for the purpose of draining a known reservoir.

Wildcat drilling in offshore areas has proven to be markedly more expensive than on land. The actual costs of some exploratory wells drilled by various companies are listed below. The figures in two cases are incomplete in that they do not include expenditures for platforms which vary in cost depending upon the type of platform, the depth of water, etc. For instance, a small platform constructed in 20 feet of water costs $200,000, whereas the same platform in 60 feet of water costs $300,000. About 40% of these expenditures are non-recoverable in the event that wells drilled from the platform are dry and the platform is then salvaged and moved to another location.

A major oil company actively engaged in offshore exploration until these operations were curtailed, estimates that an 8,000 foot, wildcat well costs about $400,000, and a 13,000 foot, wildcat well costs about $700,000. Platform costs are not included in these figures.

A major oil company drilled a 12,600 foot, wildcat well located 3 miles off the coast of Louisiana in 15 feet of water at a cost of $652,000, excluding the cost of a platform.

Another major oil company drilled an 8,500 foot, vertical well located 1½ miles off the coast of Louisiana in 20 feet of water at a cost of $360,000 and a 10,000 foot, directional well from the same platform at a cost of $700,000. The platform was constructed for $250,000, thus the total expenditure for the platform and drilling of two wells was $1,310,000.

The more important factors contributing to the high cost of offshore drilling operations are:

Capital Investments

1. Shore Base

The first step in offshore work is to provide a base of operations on land. This shore base will be located on a navigable channel with access to the open waters of the Gulf of Mexico (see Figure 6). The base must be large enough to accommodate crewboats up to 110 feet in length, tugboats up to 90 feet in length and barges up to 170 feet in length. A land base will generally have the following facilities: a mooring basin approximately 300 feet square, individual harbors within the basin for the crewboats, a dock and wharf at least 120 feet long, a loading hoist, and a loading ramp to allow wheeled loads to be driven on to the barges. As the operations increase in scope, it will be necessary to add pipe racks, a warehouse, a material platform and an office. Living quarters may be added as a final facility. A typical base constructed for offshore operations will cost from $150,000 for the bare essentials to $400,000, depending on the natural terrain at the site, the facilities provided and the scope of the offshore operations. Some reduction in cost may be realized where existing shore installations designed for bay and marsh work can be enlarged to accommodate the equipment which will be used in the Gulf of Mexico.

In the event that offshore operations are curtailed for any reason, the minimum facilities of the shore base can be maintained for about $40,000 per year, including rental fees for the land.

2. Platform

(a) Self-Contained Drilling Platform

The name of this type of structure aptly describes its function - the platform being large enough to accommodate all rig equipment, auxiliary apparatus, supplies of various kinds, living quarters for 40 to 60 crew members, galley, recreational room for men not on duty, sanitary facilities, etc. This type of structure (see Figure 7) has been constructed on a single, double-decked platform located in 48 feet of water for $1,230,000.

An alternative method is to place all of the drilling equipment and supplies on one platform and the living quarters on a separate platform with the two platforms connected by a steel foot bridge (see Figure 8). An installation of this type located in 43 feet of water was constructed for $775,000. The actual costs for this installation are outlined below:

MAIN PLATFORM (26,750 sq. ft.)		
Cost of material	$200,000	
Cost to prefabricate	$150,000	
		$350,000
QUARTERS PLATFORM (7,850 sq. ft.)		
Cost of material	$ 30,000	
Cost to prefabricate	$ 25,000	
Cost of quarters (48 men)	$ 90,000	
		$145,000
SPECIAL DOLPHINS		
Cost of material	$ 30,000	
Cost to prefabricate	$ 25,000	
		$ 55,000
TRANSPORTATION AND INSTALLATION		$225,000
TOTAL COST OF PLATFORM		$775,000

These cost figures, $775,000 for the two-platform installation and $1,230,000 for the double-decked platform, are the actual amounts spent on two platforms several years ago. The present day costs for a self-contained platform with living quarters in different depths of water are shown on Figure 9. Actual costs will vary from these estimates, depending on the operator's requirements, but otherwise, the estimates are reasonably accurate.

Self-contained platforms are expensive to move or to salvage in the event that wildcat wells drilled from the platform are abandoned for any reason. The estimated costs of moving the platform to another location total $405,000 or roughly 50% of the cost of the original platform.

Cost to remove structure	$175,000
Cost to repair structure	$ 45,000
Cost to re-install structure	$185,000
TOTAL	$405,000

In the event that all offshore operations are abandoned so that the platform could not be sold to another operator, it could be salvaged, reduced to its original pieces and sold. This operation would cost about $100,000 more than the value of the steel in the platform.

(b) Platform for use with drilling tender

The high initial cost and the low salvage value of the self-contained drilling platform led to the development of a more economical drilling method utilizing an auxiliary drilling tender moored to a small platform (see Figures 10 and 11).

The small platform (See Figure 12), which is about 50 feet in width and 100 feet in length, supports the substructure, derrick, drawworks, engines, rotary, one mud pump, small mud pit, and other miscellaneous equipment that is necessary for limited operations during short periods of time when the tender is pulled away from the platform.

All equipment that is not essential on the platform is placed on the drilling tender, thereby reducing the size of the platform required for the operation. These drilling tenders are converted, war surplus vessels designated as LST's and YF barges. Their functions in drilling operations are discussed in the following pages under the heading of "Floating-Drilling-Tender".

In all areas of the Gulf of Mexico the weather conditions are such that the drilling tender is forced to stay away from the platform from 30 to 60 days per year. In order not to lose this valuable time, some operators have installed a pipe rack platform adjacent to the drilling platform with a modified mud system so that limited drilling operations can continue when the tender is pulled away.

A small platform erected in 60 feet of water and completely prepared for drilling equipment will cost about $300,000 (see Figure 13). The platform can be salvaged, moved and re-erected in another location for about $175,000 or roughly 60% of the cost of the original installation. The platform can be salvaged for steel for about $50,000 - the cost of salvage being estimated at $100,000 and the value of the steel being only about $50,000.

3. Equipment for Offshore Wildcat Drilling

Perhaps the most significant difference between onshore and offshore exploration lies in the cost of the specialized equipment needed for offshore exploration. On land a company may lease one or two tracts during the year and then engage the services of a drilling contractor for several exploratory wells. This procedure can not be followed in the offshore area where a company must either purchase the necessary equipment for drilling or guarantee a contractor sufficient work to repay the cost of equipment over a period of several years. Except for drilling rigs, most of the equipment, because of its size and specialized nature, can not be used for purposes other than drilling in offshore areas, so it must remain idle, if offshore operations are curtailed for any reason.

(a) Floating-Drilling Tender

If the platform floating tender method of drilling is used, a suitable vessel must either be constructed or converted to a drilling tender. This vessel must be large enough to withstand normal wind and wave conditions while anchored at the platform, provide space for all drilling equipment and supplies not absolutely necessary on the platform and provide facilities for housing and feeding 45 to 70 men.

All supplies and equipment are transferred from the tender to the platform as they are needed. Drill pipe, casing and other large items are transferred from the tender to the platform over a flexible bridge that allows the tender to roll and pitch within reasonable limits. Liquids, such as mud, fuel and water, are transferred through rubber or flexible steel hose, and the return mud from the well is transferred through a large swinging rubber hose.

Some companies have converted war surplus YF barges (see Figure 14) into drilling tenders. These barges were originally designed and constructed for the Navy to be used in the Pacific theatre during World War II for the transportation and storage of supplies and equipment. Their overall dimensions are 48 x 260 feet, with a weathered deck 15 feet above the bottom of the hull and a deck house 13 feet above the weathered deck. They were selected for conversion because of their moderate cost and the large open spaces above and below deck which are necessary for storage of supplies and the installation of equipment. These barges having a cargo capacity of 2,300 tons, were converted at a cost of from $700,000 to $1,000,000 each, including the installation of equipment.

Other companies have converted used, war surplus LST's (see Figure 10) into self-propelled, drilling tenders. These vessels, designed and constructed for the Army, were used to transport men and material across the ocean and to land them directly on hostile beaches. Their overall dimensions are 50 x 327 x 27 feet with large open spaces above and below deck. The costs of conversion ranged from $750,000 to $1,500,000, including the installation of equipment.

The supply of these surplus vessels is now exhausted, and companies planning to start an offshore drilling program in the future must build new vessels designed as drilling tenders. One of these vessels that is now under construction will cost about $2,700,000. Fourteen months were spent in design work on this new tender and another nine months will be required to construct and equip the vessel before it will be ready to begin operations.

These vessels become a liability when not engaged in drilling operations, as they are not useful for any purpose other than offshore drilling. They require constant maintenance regardless of whether they are standing idle or on a location. Consequently, drilling programs should be planned well in advance in order to utilize the vessels as completely as possible.

(b) Crew and Cargo Vessels

Crew and cargo vessels for the transport of men and supplies to one offshore, wildcat well will cost about $1,000,000.

Three crewboats are needed: one will transport personnel from the base to the offshore rig in the morning and will relieve the boat that has been standing by at the rig since the previous day; the second boat will then return to base. A third boat is required as a replacement in case of a breakdown, or when one of the other crewboats is in for maintenance and repairs. It is also used for unscheduled trips and for transporting equipment and supplies in case of an emergency.

War surplus vessels formerly used for crewboats are no longer available, so oil companies are planning to construct new vessels designed for this service. They will cost from $125,000 to $200,000 each, depending on their length, type of construction, etc.

Self-propelled, cargo boats and conventional barges towed by tugs are used to transport supplies from the shore base to the offshore rig. The most economical, self-propelled, cargo boat has been the war surplus LCT's (see Figure 15) that were converted for offshore use at a cost of $25,000 to $50,000. They are no longer available, so cargo vessels designed especially for this service will be built at an estimated cost of $150,000 to $200,000 depending on their size and speed.

Barges that will transport loads that can not be handled by self-propelled vessels are being constructed at a cost of approximately $50,000 each.

SUMMARY OF TRANSPORTATION EQUIPMENT COST

NO.	TYPE VESSEL	SIZE	APPROXIMATE COST
3	Crewboats	63' - 136'	$375,000 - $600,000
1	Cargo Boat	115'	150,000 - 200,000
1	Cargo Barge	110' - 170'	40,000 - 70,000
1	Small Tug	65' - 90'	100,000 - 200,000
1	Large Tug	90' - 120'	200,000 - 500,000
			$865,000-$1,470,000

Crewboats designed for offshore operations may be diverted to marsh operations if they do not have too deep a draft for marsh canals and shallow bays. Their resale value is small if they can not be used for either offshore or marsh operations. Cargo boats are only suitable for offshore operations. The large and small tugs could be used for other work in the event that offshore operations were curtailed.

Large derrick barges, capable of handling loads up to 200 tons, are required for the erection of platforms in waters greater than 60 feet in depth. Their dimensions are 300 x 100 x 17 feet. The barge and the derrick will cost about $1,000,000. The number of barges required by oil companies will depend on the number of platforms that will be erected in deep water and the number of offshore drilling units that are available for work in deep water. The derrick barges, because of their size, can be used only for offshore work or for work along the larger, navigable rivers.

(c) Mooring Equipment

Mooring and maintaining a drilling tender in close proximity to a drilling platform requires an expensive anchorage system that was designed and developed by oil companies engaged in offshore exploration. The mooring equipment in use at the present time is adequate under normal weather conditions, but would not be strong enough to withstand the full force of a tropical hurricane. All personnel and equipment will be moved to safer waters when a hurricane approaches the offshore, drilling unit.

Several different methods of mooring are used by companies operating in the Gulf. One of the anchorage systems favored by several companies is shown in Figure 16. This system consists of the following components.

A 2 1/16" stud link, anchor chain with a strength of 500,000 lbs. is used to connect the ship to spud piling driven until the top of the piling is below the ocean floor. It became necessary to use this spud piling after experience indicated that the conventional anchors would not seat themselves firmly in the unconsolidated floor of the Gulf of Mexico. Some chain is stored in chain lockers on the ship and handled by special windlasses capable of developing a pull of 120,000 lbs. and with brakes tested to 200,000 lbs. The four chains on the stern are approximately 1,200 feet long and allow for maneuvering the ship to face heavy season the bow or stern. Three of the bow anchor chains are approximately 1,000 feet long and the fourth is 2,000 feet or longer and is used to swing the ship in a complete circle, 360 degrees, if it becomes necessary to drop all other mooring lines and pull away from the platform.

The cost of installing this mooring equipment on a tender and furnishing the chain for one location is approximately $200,000. Additional expenses include spud piling and one or two shots of chain on each piling. It is uneconomical to recover these pilings and chain upon completion of operations.

(d) Communications Equipment

An offshore, drilling program would be impossible without dependable and efficient communications. Practically all companies have their own FM radio installations and Radio Marine Telephones. Their FM installations consist of a powerful transmitting station at the main operating base and mobile units on all platforms, tenders, service vessels and crewboats. Radar is used by some companies operating offshore and has proved extremely useful in navigating during fog or at night. The value of this communication and radar equipment becomes apparent during times of emergency, such as squally weather and hurricanes. During the hurricanes of 1948, several boats were guided into protected waters by the shore based radar at Grand Isle and two way FM radio communication. Other radar sets are placed on drilling tenders, platforms, and boats for their own protection as well as for guiding vessels not equipped with radar.

Itemized costs for communications equipment totalling $28,515 are shown in Tabulation 1. This equipment is sufficient for the shore base and one offshore drilling unit.

(e) Drilling Equipment

The drilling equipment used in offshore operations to date has been standard rigs modified for the exacting requirements of offshore operations. Heavy duty rigs are normally used, as a large percentage of the wells are expected to be drilled below 10,000 feet. Large pumps capable of developing 600 horsepower or more are used with jet bits in drilling the sand and shale sections typical of the Gulf Coast.

The drilling equipment is skid mounted in large units in order to reduce to a minimum the number of lifts to and from the platform. Stand-by equipment for all critical items must be provided to prevent the expensive delays that would result if the rig was shut down. In addition, a large stock of spare parts is carried for all equipment on the tender and platform. Additional blow out preventers are installed on most offshore wells to guard against a possible blowout that can occur in this area at any time.

Drilling equipment for offshore use costs slightly more than similar equipment on land due to the costs of modification and of mounting the equipment on skids. However, as larger derrick barges are constructed for offshore operations, this equipment can be unitized in even larger and heavier sections, thereby reducing the time and cost of loading and unloading the equipment on the platform as well as reducing the rig-up time required. This will result in a considerable reduction in offshore drilling cost.

(f) Offshore vs. Onshore Expenditures for Equipment and Installations

The estimated expenditures for platforms, equipment, etc., that are required for drilling 10 wells in 60 feet of water with one rig total $5,713,000 (see Tabulation 2 for itemized costs). This cost is based on the assumption that six platforms will be required and that at least one well on each platform is productive so that there is no opportunity to reduce costs by salvaging and re-erecting a platform at another location.

The cost of equipment, preparation of sites, etc. for a similar, wildcat program on land is about $1,000,000 (see Tabulation 2), so the ratio of expenditures is roughly 5:1. Some reduction in costs of offshore, wildcat operations will result from large scale operations when two or more drilling units are working on the same structure. Additional reductions in cost should be realized as operational crews gain experience in the construction of platforms.

Operating Conditions and Problems

1. Planning

Planning of exploratory operations on the Gulf Coast Continental Shelf has been the task assigned to a large number of competent men in the oil industry since the end of World War II. Most of these men had little or no previous experience with marine operations in open waters, so their assignment involved considerable research in order to determine the most economical methods of finding and producing oil from structures located in offshore areas. Their work is far from complete -- in fact, the applications of many of their ideas have yet to be tested under field conditions. Their goal is to develop large reserves of oil and gas at unit costs that are comparable with those on land. It is a difficult but not impossible goal if operations are conducted on a large scale and all facilities and equipment are thereby utilized fully.

The salaries of all supervisory and technical personnel engaged in planning are, of course, charges against the production that will be developed in offshore areas and in their aggregate amount, they represent substantial expenditures for the various companies engaged in planning.

2. Personnel

Competent supervisors and highly skilled labor are required for offshore, drilling operations. The problem is to assemble crews by careful screening of qualified men and then to retain these crews more or less intact. This can be accomplished by providing safe working conditions, adequate wages, dependable transportation, comfortable living quarters and wholesome meals - all of which increase the cost of offshore, drilling operations.

Overtime pay is much higher due to the work-schedule adopted by most companies. Two crews are on location working 12 hour tours for 7 to 10 days before returning to shore where they have 5 to 7 days off. The cost of labor on an offshore rig is about $3,800 per week as compared to $2,300 on land.

3. Directional Drilling

The high cost of drilling platforms is responsible for the large number of directionally drilled holes in offshore areas. It is not economically feasible to erect a platform for each wildcat well, so several wells are directionally drilled from a single platform. The cost of these holes is from 25% to 100% higher than vertical holes, depending on the problems that are encountered. Their relatively high cost is a serious disadvantage on the flanks of salt domes where many wildcat wells are needed before the limits of the productive segments of the dome can be determined. However, their cost will be reduced materially as crews gain experience in drilling directional wells and as more efficient equipment for this work is developed.

4. Danger of Fire and Blowout

Blowouts and fire (see Figure 17) are serious hazards on offshore installations, and every precaution must be taken in order to avoid disasters of this nature. The precautions include an additional blowout preventer and an accumulator that are not used in standard, onshore hookups, and careful checking of all equipment by well trained supervisors. Fire drills are conducted at regular intervals, and all men are trained to recognize troubles that may terminate in fire and blowout so the appropriate emergency action can be taken.

5. Weather

Drilling operations are curtailed about 10% of the time due to inclement weather conditions. Storms of moderate intensity are relatively common during the winter months, and tropical hurricanes occur from July to November. Most of the "shut-downs" are due to storms of moderate intensity when the seas are high enough to prevent drilling yet weather conditions are not severe enough to evacuate men and equipment.

Many oil companies operating in the Gulf retain weather consultants to supplement the general forecasts supplied by the United States Weather Bureau. These detailed forecasts expedite operational planning and make it possible to carry on critical operations during relatively favorable weather.

6. Corrosion

Salt water and salt spray have corrosive effects on the steel used in drilling platforms, drilling tenders, boats, equipment and machinery. Many types of protective coatings and corrosion preventative measures have been used to protect metal above the water line, but they have not been in use long enough to evaluate their effectiveness. However, machinery that has been galvanized or metal sprayed is still in good condition after six or seven years of exposure. Cathodic protection is used on all structures for protection below the water line.

The cost of preventative measures adds greatly to the initial investment, but it reduces maintenance expenses and thus is a sound investment.

7. Depreciation and Obsolescence

The useful life of vessels, structures and equipment is shortened as the result of damage attributable to one or more of the following: wave action, wind, corrosion and collision. Furthermore, the rate of obsolescence of vessels and equipment is high as compared to land operations where the companies have a wealth of experience to guide their selection of drilling equipment. Drilling methods used in offshore operations will be improved and more efficient equipment will be designed and constructed as the companies gain experience in the Gulf. The useful life of equipment will be increased, thereby reducing the charges for depreciation and obsolescence. However, at the present time, five years appears to be a reasonable estimate for the useful life of equipment. Consequently, this figure is used to determine charges for depreciation in estimating operating costs.

Operating Costs

1. Transportation

The daily operating costs for crewboats, cargo vessels, etc., are:

NO. OF VESSELS	TYPE OF VESSEL	UNIT COST/DAY	NON-SELF PRO-PELLED TENDER	or	SELF-PRO-PELLED TENDER
3	Crewboats	$250	$750		$750
1	Self Propelled Cargo Boat	$250	$250		$250
1	Cargo Barge	$50	$50		$50
1	Small Tug	$300	$300		$300
1	Large Tug	$500	$500		-
	TOTAL DAILY COST		$1,850		$1,350

These cost figures include charges for depreciation, maintenance, fuel, crew, etc.

These vessels could service more than one rig in areas where several drilling operations are in progress on the same structure or on contiguous structures. This would reduce the cost of transportation for each wildcat operation.

2. Platform Maintenance

The maintenance of offshore installations is difficult and expensive. Inspections of the underwater components of the platform must be made periodically, and the magnesium or zinc blocks used for cathodic protection must be replaced as they are depleted. Similarly, the protective coatings used on the superstructure must be renewed as they are removed by corrosion and abrasion.

3. Drilling

The daily operating cost for the drilling equipment on a platform is estimated to range from $1,000 to $1,500, depending on the size and nature of the equipment. Charges for depreciation and maintenance are included in these estimates which are approximately 25% higher than for the same equipment on land. The increase in cost is due to the high expenditures for labor as the result of overtime rates of pay for the 12 hour tour for 7 days per week, the extra supervision required and the extra labor engaged in maintenance of equipment.

The daily operating cost for the drilling tender ranges from $1,200 to $2,500 per day, depending on the size of the vessel, the size of the crew and the type of drilling operation.

These relatively high costs are due to the facilities that must be provided on the tender. It is a combination of a seagoing vessel, an auxiliary to the drilling rig, a warehouse for storage of supplies and equipment such as the Halliburton Cementing Unit and a hotel equipped to serve four meals a day to a large number of men (40-75) and to provide them with comfortable sleeping quarters and recreational facilities.

Summary of Wildcat Drilling Costs

Offshore, wildcat drilling costs vary widely, depending on the depth of water, depth of well, number of wells drilled from the same platform, type of well, etc. However, these costs are generally from two to five times higher than costs for onshore, wildcat wells as is shown on Figure 18.

For example, the cost of an 8,000 foot, exploratory well on land is about $130,000 (see Figure 18) while the cost of an 8,000 foot, vertical well on the Continental Shelf is $290,000 and an 8,000 foot directional hole from the same platform is $410,000. These figures do not include the cost of a platform which amounts to $300,000 if the platform is erected in 60 feet of water (see Figure 13). The cost of the platform is non-recoverable if one or both wells are producers, whereas only the non-salvagable cost of the platform, or about $200,000, will be charged against the wells in the event that they are both dry.

The costs of both onshore and offshore wells increase markedly with the depth of the well. A 14,000 foot, onshore, exploratory well will cost about $515,000 compared to $940,000 for a 14,000 foot, offshore, vertical well and $1,090,000 for an offshore, directional well to the same depth. The cost of platform ($300,000) raises the cost for a single, vertical well to $1,240,000. This figure is reduced slightly if three wells (1 directional and 2 vertical) are drilled from the same platform to a depth of 14,000 feet - the average cost of each well being $1,140,000.

Ten exploratory wells will be required for definitive tests of some large structures where several segments of the dome are barren of oil and gas. The cost of drilling 5 vertical and 5 directional holes to depths ranging from 10,000 to 12,000 feet will be $6,700,000 (see Figure 18) plus $1,500,000 for five platforms in 60 feet of water (see Figure 13) or a total cost of $8,200,000, assuming that there is at least one productive well on each platform thereby eliminating the possibilities of using the same platform in two locations. Ten onshore, exploratory wells drilled to the same depths will cost $3,200,000.

All charges for material, labor, construction, depreciation, maintenance of equipment, outside services, etc., are included in these figures; however, they do not include expenditures for geophysical surveys or leasing.

All companies that plan to engage in offshore work are well aware that these operations are very expensive at the present time. Their decision to explore on the Continental Shelf was based on the conviction that these costs will be reduced materially by utilizing the technical "know how" gained from large scale operations.

PART IV

OFFSHORE DEVELOPMENT OPERATIONS

Successful exploratory operations on a structure are normally followed by development of the oil and gas reserves on the structure. The purpose of this work is to drain reservoirs in an efficient and economical manner and to recover as large a percentage of the oil and gas as is possible under the conditions existing in the field. Drilling operations of this nature are generally 15 to 25 per cent less expensive (compare Figures 18 and 19) than wildcat drilling, as subsurface geological conditions are partially known, thereby reducing the cost of casing program, auxiliary logging services, etc. Furthermore, several drilling rigs are generally in operation in the field, thereby reducing unit costs for transportation, supervision, etc. However, the cost of offshore development drilling is high when compared with similar operations on land, as will be apparent from the following notes:

A major oil company operating three miles off the coast of Louisiana drilled 5 wells from a platform erected in 48 feet of water. These wells, ranging in depth from 5,000 to 7,200 feet, cost $1,540,000, excluding the expenditures for the platform which was about $250,000. Thus, the total cost for the five wells was almost $1,800,000 or roughly $360,000 for each well.

A major oil company developing a field located near the mouth of the Mississippi River drilled a 6,300 foot, development well for $382,000 and a 9,450 foot development well for $523,000. These costs include expenditures for the platform which in this case amount to $83,000 for each well - a total of five wells having been drilled from the same platform which cost $422,000.

Another operator working from a platform located 15 miles offshore in 60 feet of water drilled three wells costing $1,773,000, excluding expenditures for the platform. This development work consisted of a 9,300 foot well costing $389,000, a 10,500 foot well costing $585,000 and a 14,000 foot well costing $800,000. The platform cost for these wells is estimated at $300,000 (see Figure 13), thus adding $100,000 to the cost of each of the three wells.

These high costs for development work present a challenge to the oil industry. They may be reduced substantially by large scale operations and by the design of more efficient drilling equipment - this, at least, is the conviction shared by many technical men who are familiar with offshore operations. For example, one operator has already devised a method of reducing the drilling costs for development wells. Two drilling rigs are operated on a single platform serviced by one drilling tender; thus the daily operating costs for the tender are divided between two wells. Other ingenious methods of reducing costs will be developed in the future as operators become more experienced in offshore operations.

Capital Investments

Shore Base

The shore base used during exploratory work will probably be enlarged by constructing additional boat stalls, bulk heads, and pipe racks. Office buildings and possibly a company camp may be provided, depending on the size of the operation and facilities that are available in nearby towns.

Six or eight drilling rigs may be handled from the enlarged shore base during a large scale development program. The fixed charges for operation and maintenance of the base will thus be divided among a larger number of wells, thereby reducing the charge per well for the facilities provided by the shore base.

Platforms

The cost of drilling platforms will be about the same as for wildcat wells. Additional platforms will be needed for producing equipment, oil storage and field housing.

Production

Facilities for handling the production of oil and gas must be provided. Flow lines will be laid from the wells to the gathering stations where the oil is stored while awaiting transportation to land; the wells will be equipped with expensive, automatic equipment to minimize the danger of fire and blowout as the result of hurricanes or collisions; living quarters for production personnel must be provided, and both pumper's boats and work boats must be purchased and maintained in the field for routine production work. Finally, a pipe line to shore will probably be laid in order to transport oil by the most economical method.

Gas reserves developed in offshore areas can be exploited in an efficient and economical manner. A wide, spacing pattern designed to recover the maximum volume of gas and condensate with a minimum number of wells can be developed for each structure. The wells will be shut in until the proven reserves are large enough to justify the expense of a pipe line to shore. Once this pipe line is laid, it will, of course, provide an outlet for any minor gas fields located along the pipe line.

Summary Showing Estimated Costs

These may be divided into drilling and production costs, and an estimate can then be made of the probable cost of a 20 well program on an offshore structure in 60 feet of water. The cost of a similar development program on land is included in order to provide a basis for comparison of onshore and offshore costs.

Drilling Costs	Offshore	Land
Base of operation (expansion)	$ 250,000	$ 80,000
Platforms (see Figure 13) 4 platforms in 60 feet water	1,200,000	200,000
Drilling (see Figure 19)		
5 - 8,000' wells	2,090,000	500,000
5 - 10,000' wells	2,640,000	800,000
5 - 12,000' wells	3,210,000	1,300,000
5 - 14,000' wells	4,655,000	2,100,000
TOTAL COST	$14,045,000	$4,980,000

Production Costs	Offshore	Land
Flow lines	$ 105,000	$ 118,000
Production Equipment	287,000	63,000
Housing and warehouse	375,000	50,000
Pipe line to shore (30 miles)	1,920,000	---
Tank battery	250,000	300,000
Transportation equipment	450,000	25,000
Roads	---	200,000
Salt water disposal	---	750,000
TOTAL	$ 3,387,000	$ 906,000

MAP OF THE GULF COAST CONTINENTAL SHELF

CLASSIFICATION OF PROSPECTIVE AREAS ON THE GULF COAST CONTINENTAL SHELF BETWEEN SHORELINE AND 20 FATHOM DEPTH CONTOUR

FAVORABLE AREAS

▤ Mississippi Delta to Texas-Louisiana border. Geological conditions appear to be favorable for accumulations of oil and gas in Miocene and younger beds.

▨ Texas-Louisiana border to near Red Fish Bay Field—the area may be favorable if adequate reservoir sands are present in Miocene and younger beds.

▧ Near Red Fish Bay Field to Rio Grande. Reservoir sands are probably present in the Frio (Oligocene) adjacent to the coast and possibly present in Miocene and younger beds.

UNKNOWN AREAS

▥ Mississippi Delta to Florida Keys. Geological conditions on the Continental Shelf are practically unknown.

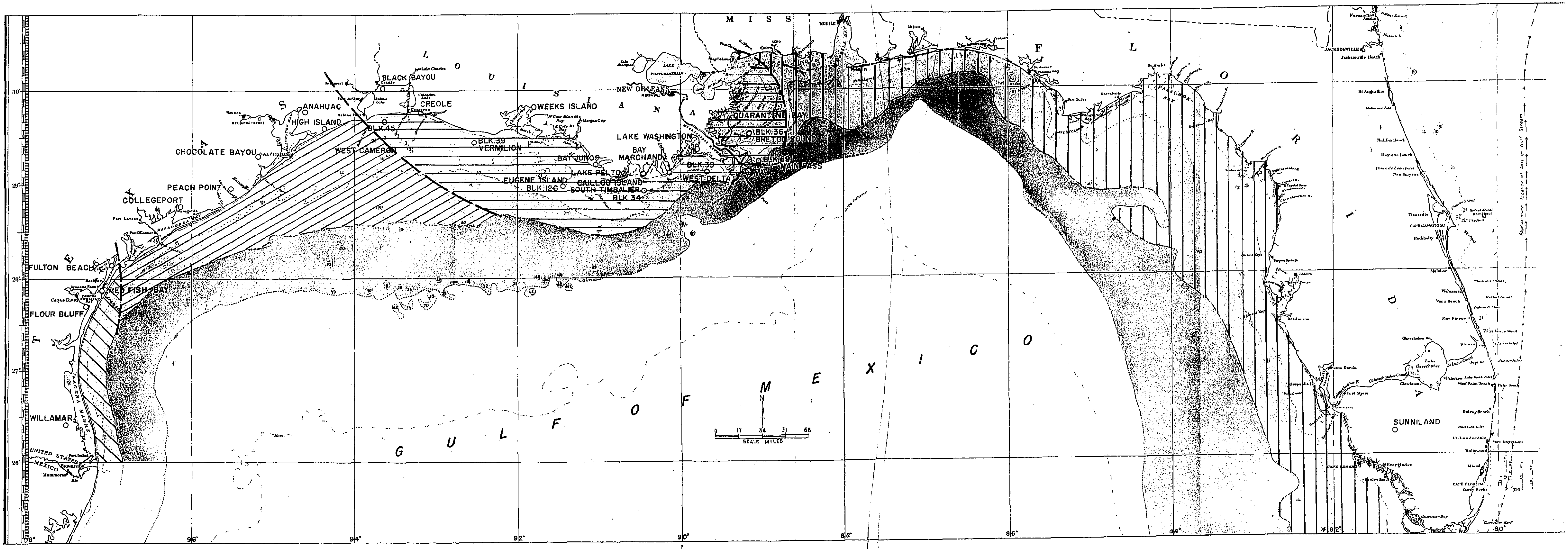
DEPTH OF WATER

□ 0–10 Fathoms (0–60 Feet)

□ 10–20 Fathoms (60–120 Feet)

░ 20–100 Fathoms (120–600 Feet)

FIGURE 1


T E X A S
L O U I S I A N A
M I S S
F L O R I D A
G U L F O F M E X I C O
BLACK BAYOU
Lake Charles
Orange
Beaumont
Port Arthur
Sabine Lake
Calcasieu Lake
CREOLE
Cameron
ANAHUAC
HIGH ISLAND
Houston
CHOCOLATE BAYOU
GALVESTON
PEACH POINT
COLLEGEPORT
Port Lavaca
Port O'Connor
MATAGORDA BAY
FULTON BEACH
Rockport
Aransas Pass
RED FISH BAY
Corpus Christi
FLOUR BLUFF
LAGUNA MADRE
WILLAMAR
UNITED STATES
MEXICO
Port Isabel
Brownsville
Matamoras
BLK.45
WEST CAMERON
BLK.39
VERMILION
WEEKS ISLAND
Morgan City
BAY JUNOP
EUGENE ISLAND
BLK.126
LAKE PELTO
CAILLOU ISLAND
SOUTH TIMBALIER
BLK.34
LAKE WASHINGTON
BAY MARCHAND
BLK.30
WEST DELTA
NEW ORLEANS
LAKE PONTCHARTRAIN
Lake Maurepas
QUARANTINE BAY
BLK.36
BRETON SOUND
BLK.69
MAIN PASS
Bay St.Louis
Gulfport
MOBILE
MOBILE BAY
Milton
St Andrew
Panama City
Port St. Joe
Carrabelle
St Marks
APALACHEE BAY
Tarpon Springs
TAMPA
Bradenton
Punta Gorda
Fort Myers
CAPE ROMANO
Everglades
Whitewater Bay
Fernandina
JACKSONVILLE
Jacksonville Beach
St Augustine
Halifax Beach
Daytona Beach
Ponce de Leon Inlet
New Smyrna
Titusville
CAPE CANAVERAL
Rockledge
Malabar
Wabasso
Vero Beach
Fort Pierce
Stuart
Okeechobee
Lake Okeechobee
St Lucie Canal
Jupiter
Caloosahatchee Canal
Clewiston
Pahokee
West Palm Beach
Palm Beach
Delray Beach
SUNNILAND
Ft.Lauderdale
Port Everglades
Hollywood
Miami
CAPE FLORIDA
Fowey Rocks
Carysfort Reef
Approximate location of axis of Gulf Stream
1000
0 17 34 51 68
SCALE MILES
N
30°
29°
28°
27°
26°
98°
96°
94°
92°
90°
88°
86°
84°
82°
80°

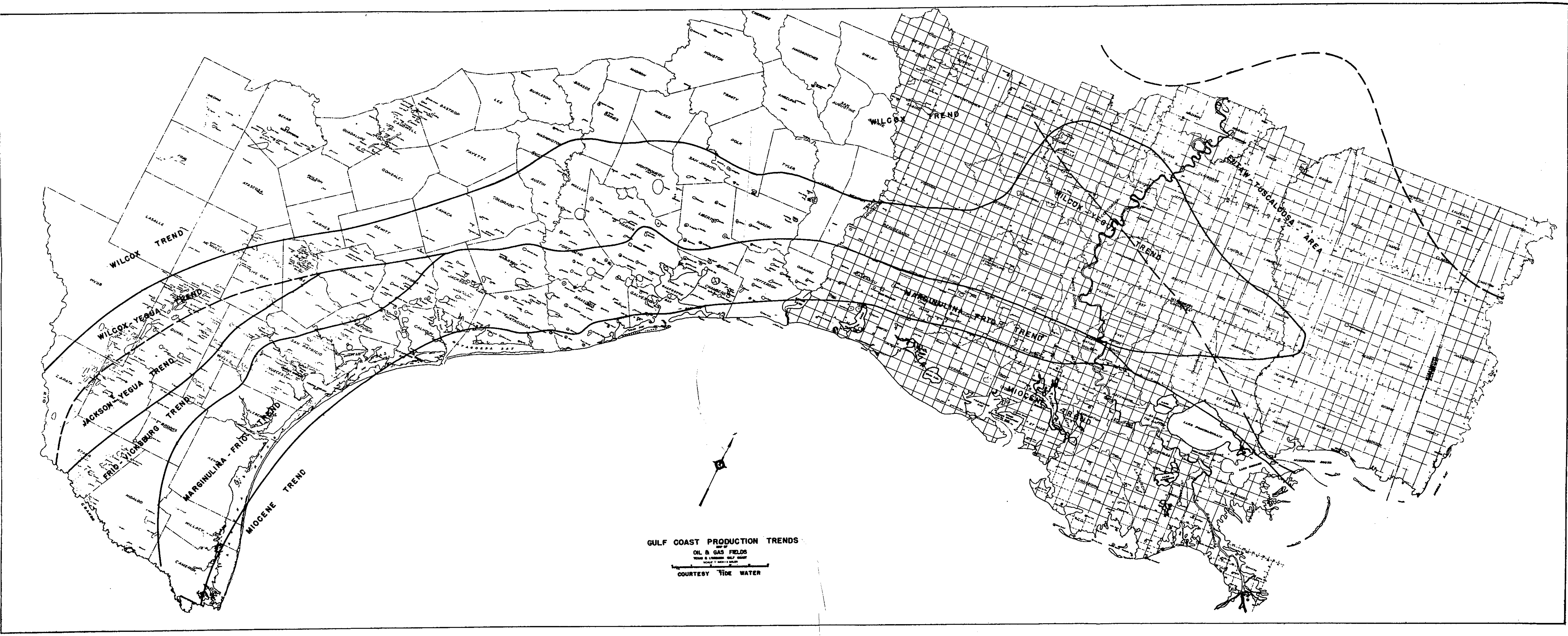

GULF COAST PRODUCTION TRENDS
MAP OF
OIL & GAS FIELDS
TEXAS & LOUISIANA GULF COAST
COURTESY TIDE WATER
WILCOX TREND
WILCOX - YEGUA TREND
JACKSON - YEGUA TREND
FRIO - VICKSBURG TREND
MARGINULINA - FRIO TREND
MIOCENE TREND
EUTAW - TUSCALOOSA AREA

FIGURE 2

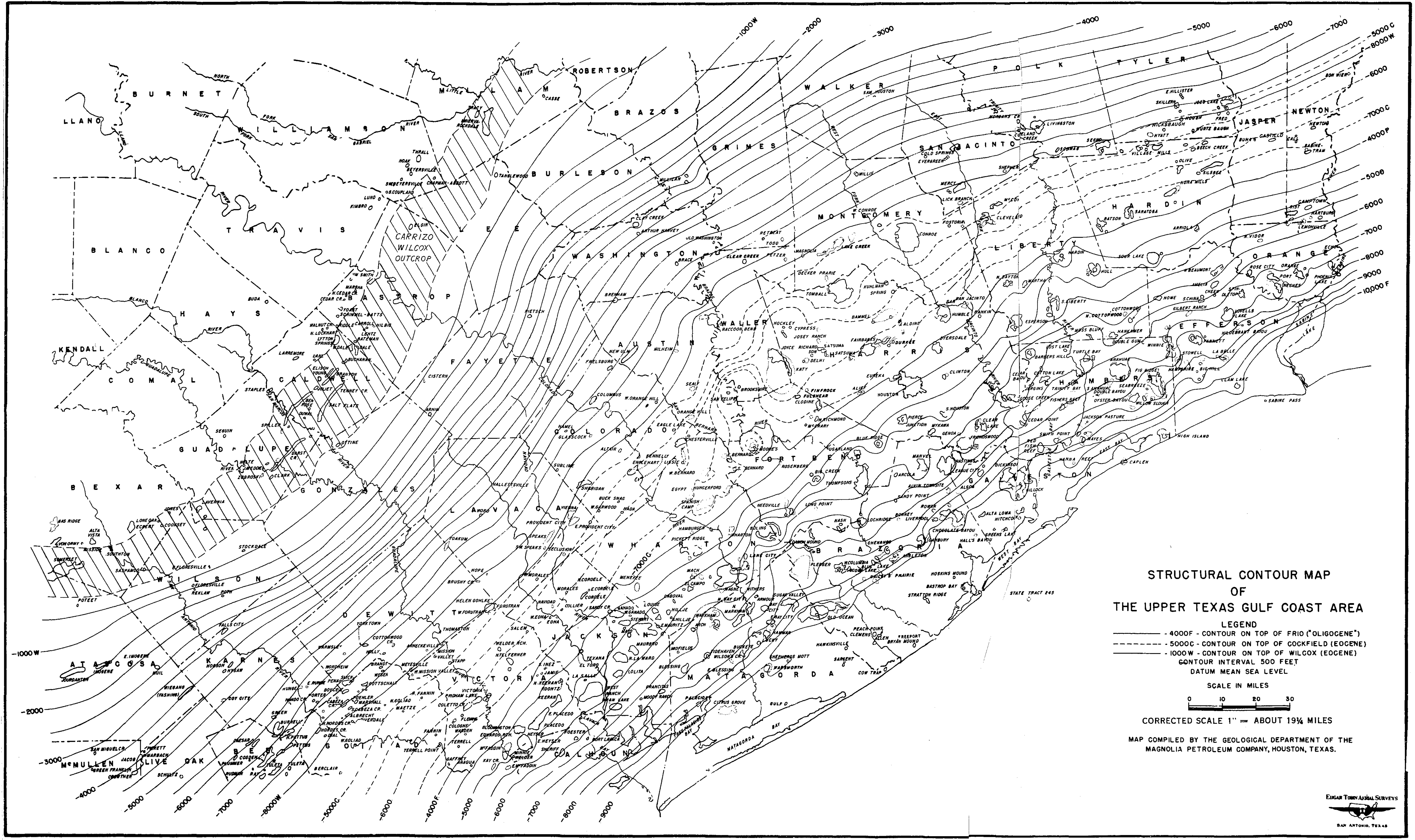

STRUCTURAL CONTOUR MAP
OF
THE UPPER TEXAS GULF COAST AREA
LEGEND
- 4000F - CONTOUR ON TOP OF FRIO ("OLIGOCENE")
- 5000C - CONTOUR ON TOP OF COCKFIELD (EOCENE)
- 1000W - CONTOUR ON TOP OF WILCOX (EOCENE)
CONTOUR INTERVAL 500 FEET
DATUM MEAN SEA LEVEL
SCALE IN MILES
0
10
20
30
CORRECTED SCALE 1" = ABOUT 19¼ MILES
MAP COMPILED BY THE GEOLOGICAL DEPARTMENT OF THE MAGNOLIA PETROLEUM COMPANY, HOUSTON, TEXAS.
EDGAR TOBIN AERIAL SURVEYS
SAN ANTONIO, TEXAS
BURNET
LLANO
WILLIAMSON
MILAM
ROBERTSON
BRAZOS
WALKER
POLK
TYLER
JASPER
NEWTON
GRIMES
SAN JACINTO
BURLESON
MONTGOMERY
HARDIN
LIBERTY
ORANGE
JEFFERSON
CHAMBERS
HARRIS
WALLER
WASHINGTON
LEE
TRAVIS
BLANCO
HAYS
BASTROP
CARRIZO WILCOX OUTCROP
KENDALL
COMAL
CALDWELL
FAYETTE
AUSTIN
COLORADO
FORT BEND
GALVESTON
BRAZORIA
WHARTON
MATAGORDA
JACKSON
LAVACA
GONZALES
GUADALUPE
BEXAR
WILSON
DEWITT
VICTORIA
CALHOUN
GOLIAD
KARNES
ATASCOSA
BEE
LIVE OAK
McMULLEN
HOUSTON
SABINE PASS
HIGH ISLAND
STATE TRACT 245
MATAGORDA BAY
WEST BAY
EAST BAY
-1000W
-2000
-3000
-4000
-5000
-6000
-7000
-8000W
-5000C
-6000
-4000F
-5000
-6000
-7000
-8000
-9000
-7000C
-1000W
-2000
-3000
-4000
-5000
-6000
-7000
-5000C
-8000W
-6000
-7000C
-4000P
-5000
-6000
-7000
-8000
-9000
-10,000F

FIGURE 3

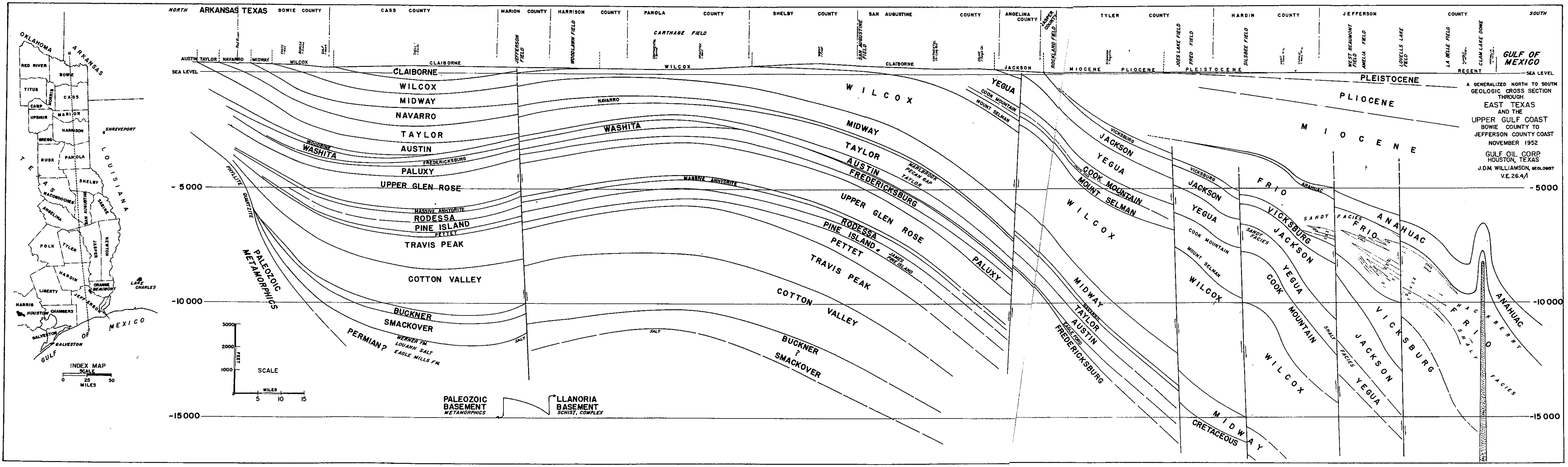

A GENERALIZED NORTH TO SOUTH GEOLOGIC CROSS SECTION THROUGH EAST TEXAS AND THE UPPER GULF COAST
BOWIE COUNTY TO JEFFERSON COUNTY COAST
NOVEMBER 1952
GULF OIL CORP.
HOUSTON, TEXAS
J.D.M. WILLIAMSON, GEOLOGIST
V.E. 26.4/1
NORTH
ARKANSAS
TEXAS
BOWIE COUNTY
CASS COUNTY
MARION COUNTY
HARRISON COUNTY
PANOLA COUNTY
SHELBY COUNTY
SAN AUGUSTINE COUNTY
ANGELINA COUNTY
JASPER COUNTY
TYLER COUNTY
HARDIN COUNTY
JEFFERSON COUNTY
SOUTH
JEFFERSON FIELD
WOODLAWN FIELD
CARTHAGE FIELD
SAN AUGUSTINE FIELD
ROCKLAND FIELD
JOES LAKE FIELD
FRED FIELD
SILSBEE FIELD
WEST BEAUMONT FIELD
AMELIA FIELD
LOVELLS LAKE FIELD
LA BELLE FIELD
CLAM LAKE DOME
GULF OF MEXICO
SEA LEVEL
- 5000
-10 000
-15 000
AUSTIN
TAYLOR
NAVARRO
MIDWAY
WILCOX
CLAIBORNE
JACKSON
MIOCENE
PLIOCENE
PLEISTOCENE
RECENT
WASHITA
WOODBINE
FREDERICKSBURG
PALUXY
UPPER GLEN ROSE
MASSIVE ANHYDRITE
RODESSA
PINE ISLAND
PETTET
TRAVIS PEAK
COTTON VALLEY
BUCKNER
SMACKOVER
SALT
PERMIAN?
WERNER FM.
LOUANN SALT
EAGLE MILLS FM.
PHYLLITE
QUARTZITE
PALEOZOIC METAMORPHICS
PALEOZOIC BASEMENT METAMORPHICS
LLANORIA BASEMENT SCHIST, COMPLEX
MARLBROOK
PECAN GAP
JAMES
YEGUA
COOK MOUNTAIN
MOUNT SELMAN
VICKSBURG
FRIO
ANAHUAC
SANDY FACIES
SHALY FACIES
HACKBERRY
EAGLE FORD
CRETACEOUS
SCALE
FEET
3000
2000
1000
MILES
5
10
15
INDEX MAP
SCALE
0
25
50
MILES
OKLAHOMA
ARKANSAS
TEXAS
LOUISIANA
RED RIVER
BOWIE
TITUS
MORRIS
CAMP
CASS
UPSHUR
MARION
HARRISON
GREGG
RUSK
PANOLA
SHELBY
NACOGDOCHES
SAN AUGUSTINE
SABINE
ANGELINA
POLK
TYLER
JASPER
NEWTON
HARDIN
LIBERTY
ORANGE
BEAUMONT
JEFFERSON
HARRIS
HOUSTON
CHAMBERS
GALVESTON
SHREVEPORT
LAKE CHARLES
GULF OF MEXICO

FIGURE 4

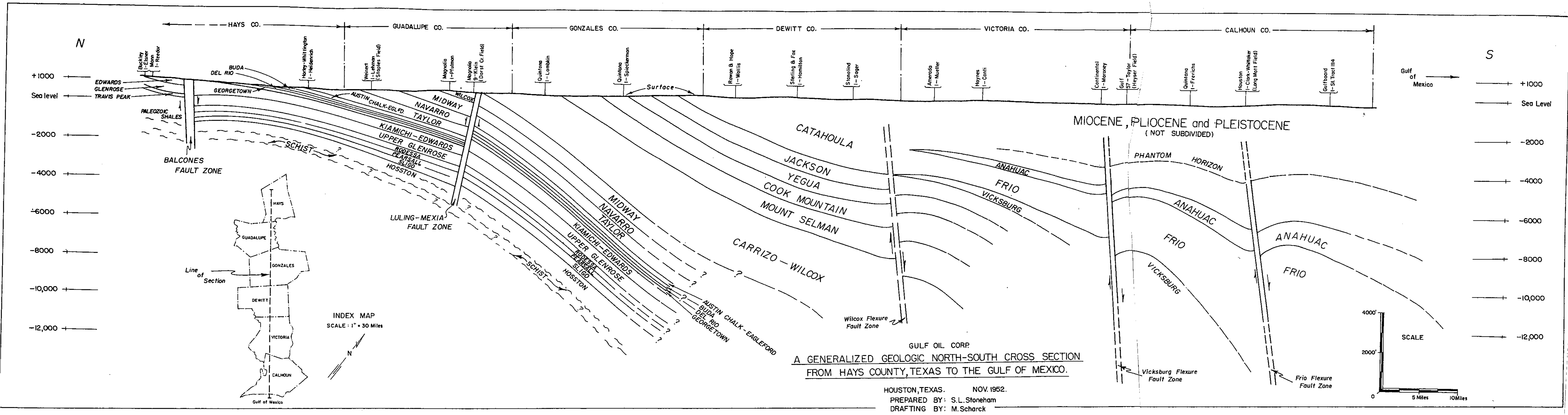

N
S
HAYS CO.
GUADALUPE CO.
GONZALES CO.
DEWITT CO.
VICTORIA CO.
CALHOUN CO.
Buckley 1-Elsner
Mann 1-Reedor
Harley-Whittington 1-Heidenrich
Weinert 1-Lehman (Staples Field)
Magnolia 1-Pfulman
Magnolia 9-Klein (Darst Cr. Field)
Quintana 1-Lambkin
Quintana 1-Spieckerman
Surface
Rowan & Hope 1-Wallis
Sterling & Fox 1-Hamilton
Stanolind 1-Sager
Amerada 1-Mueller
Haynes 1-Conti
Continental 1-Moroney
Gulf 57-Taylor (Heyser Field)
Quintana 1-Frerichs
Houston 1-Clark-Whittaker (Long Mott Field)
Gulfboard 1-St. Tract 114
Gulf of Mexico
+1000
Sea level
-2000
-4000
-6000
-8000
-10,000
-12,000
EDWARDS
GLENROSE
TRAVIS PEAK
PALEOZOIC SHALES
BUDA
DEL RIO
GEORGETOWN
AUSTIN CHALK-EGLFD.
MIDWAY
NAVARRO
TAYLOR
WILCOX
KIAMICHI-EDWARDS
UPPER GLENROSE
RODESSA
PEARSALL
SLIGO
HOSSTON
SCHIST
BALCONES FAULT ZONE
LULING-MEXIA FAULT ZONE
AUSTIN CHALK-EAGLEFORD
BUDA
DEL RIO
GEORGETOWN
CATAHOULA
JACKSON
YEGUA
COOK MOUNTAIN
MOUNT SELMAN
CARRIZO-WILCOX
Wilcox Flexure Fault Zone
MIOCENE, PLIOCENE and PLEISTOCENE
(NOT SUBDIVIDED)
ANAHUAC
FRIO
VICKSBURG
PHANTOM HORIZON
Vicksburg Flexure Fault Zone
Frio Flexure Fault Zone
HAYS
GUADALUPE
GONZALES
DEWITT
VICTORIA
CALHOUN
Gulf of Mexico
Line of Section
INDEX MAP
SCALE: 1" = 30 Miles
N
SCALE
4000'
2000'
0
5 Miles
10 Miles
GULF OIL CORP.
A GENERALIZED GEOLOGIC NORTH-SOUTH CROSS SECTION
FROM HAYS COUNTY, TEXAS TO THE GULF OF MEXICO.
HOUSTON, TEXAS. NOV. 1952.
PREPARED BY: S.L. Stoneham
DRAFTING BY: M. Scharck

FIGURE 5

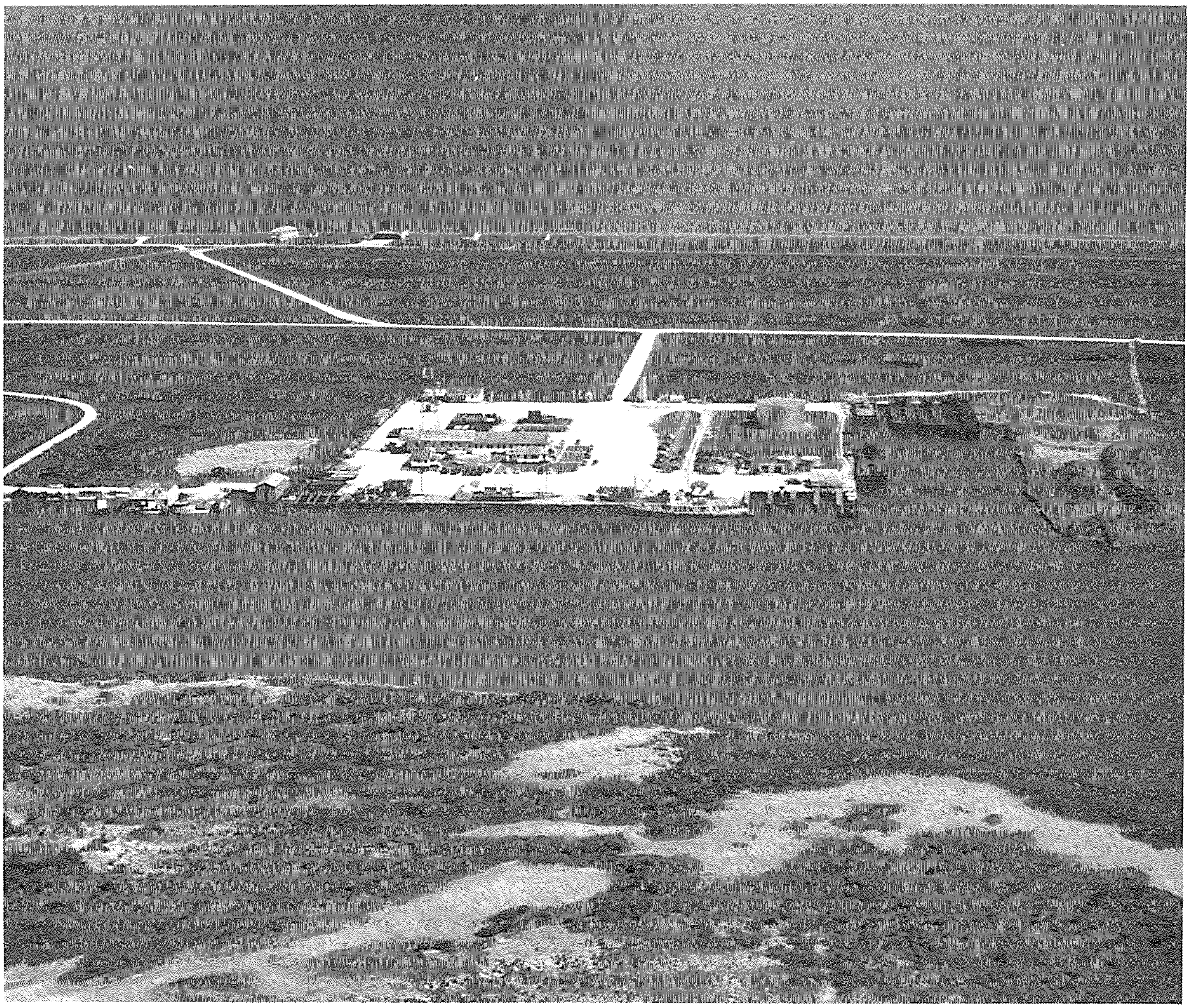


FIGURE 6

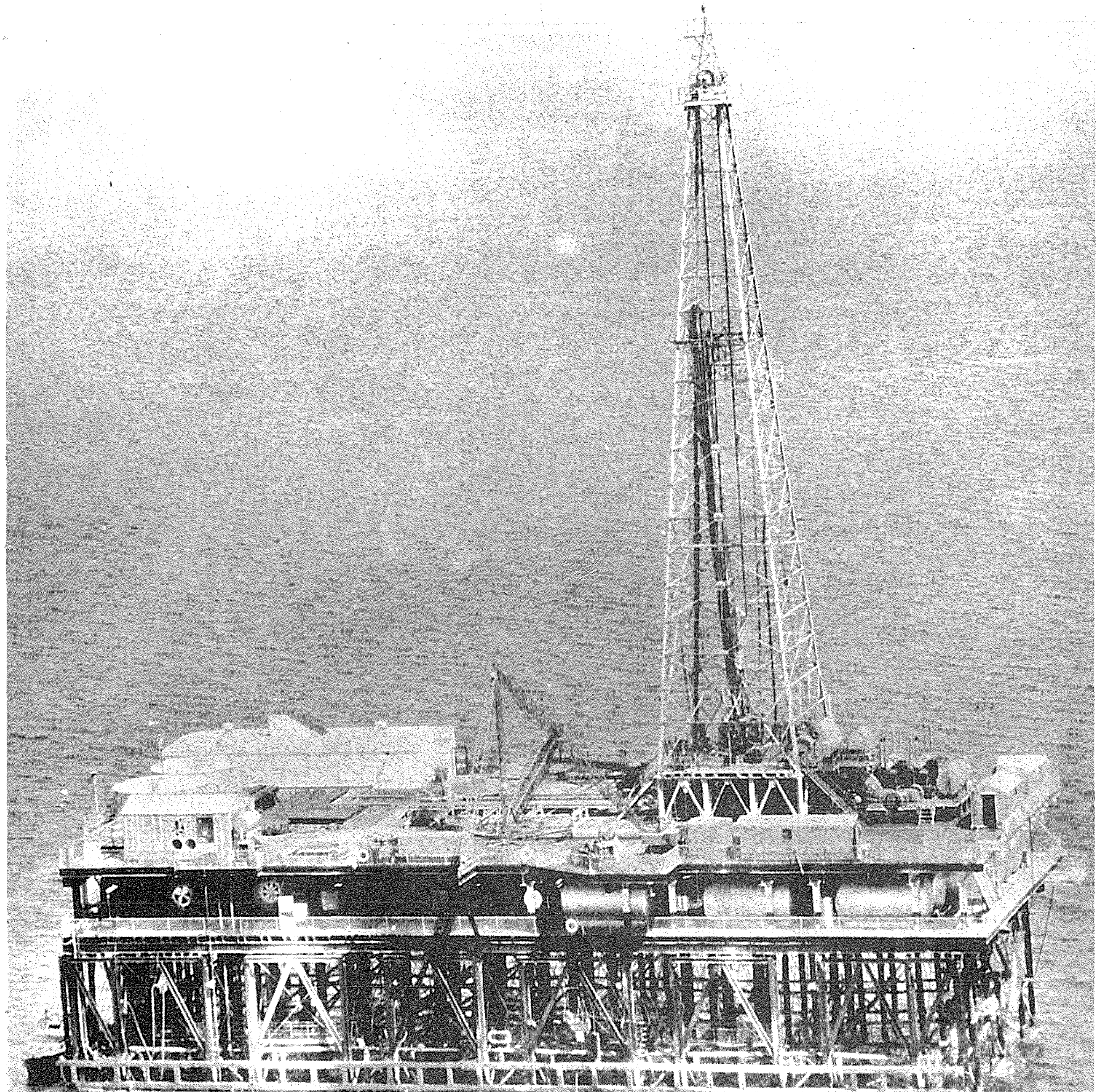


FIGURE 7

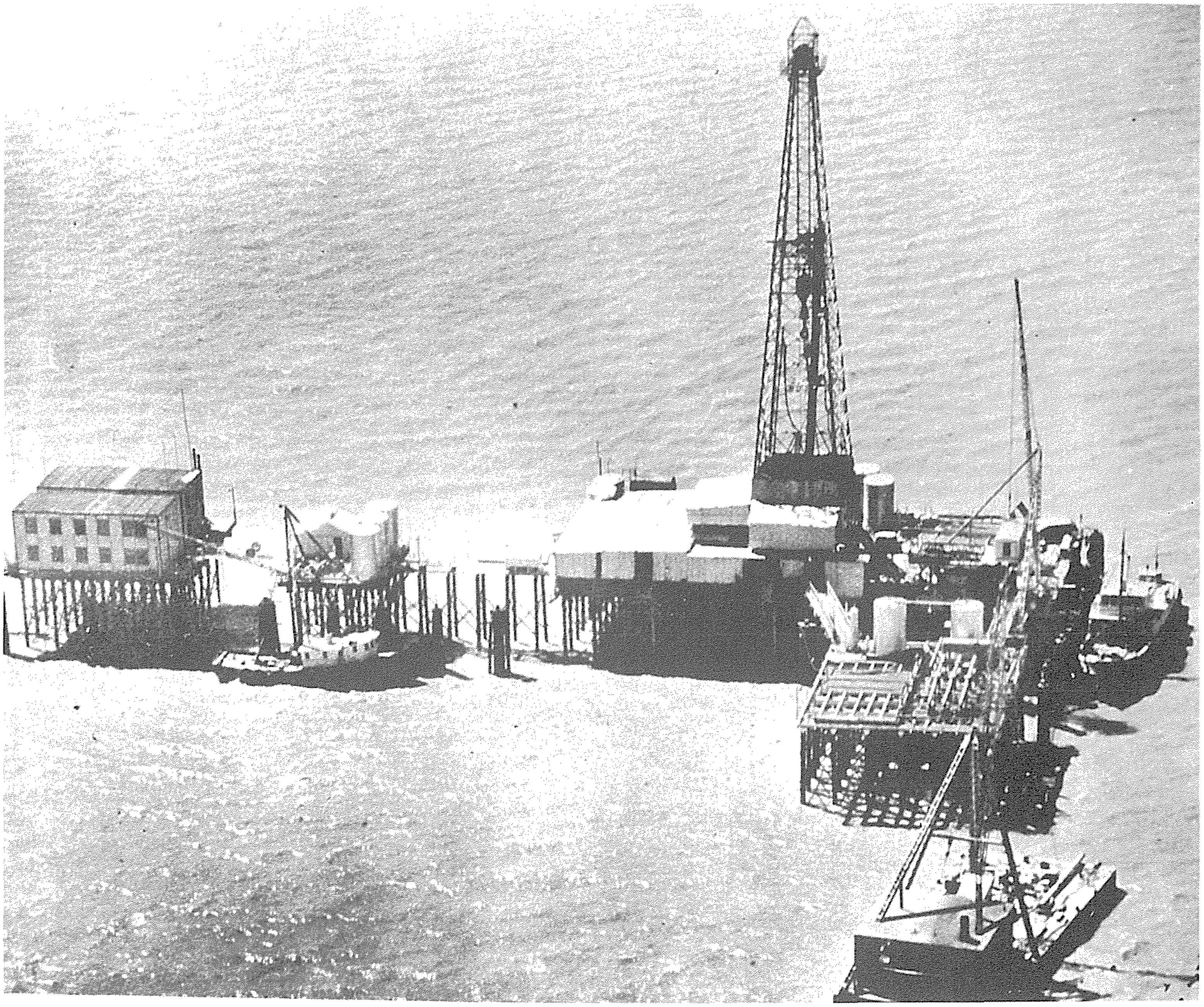


FIGURE 8

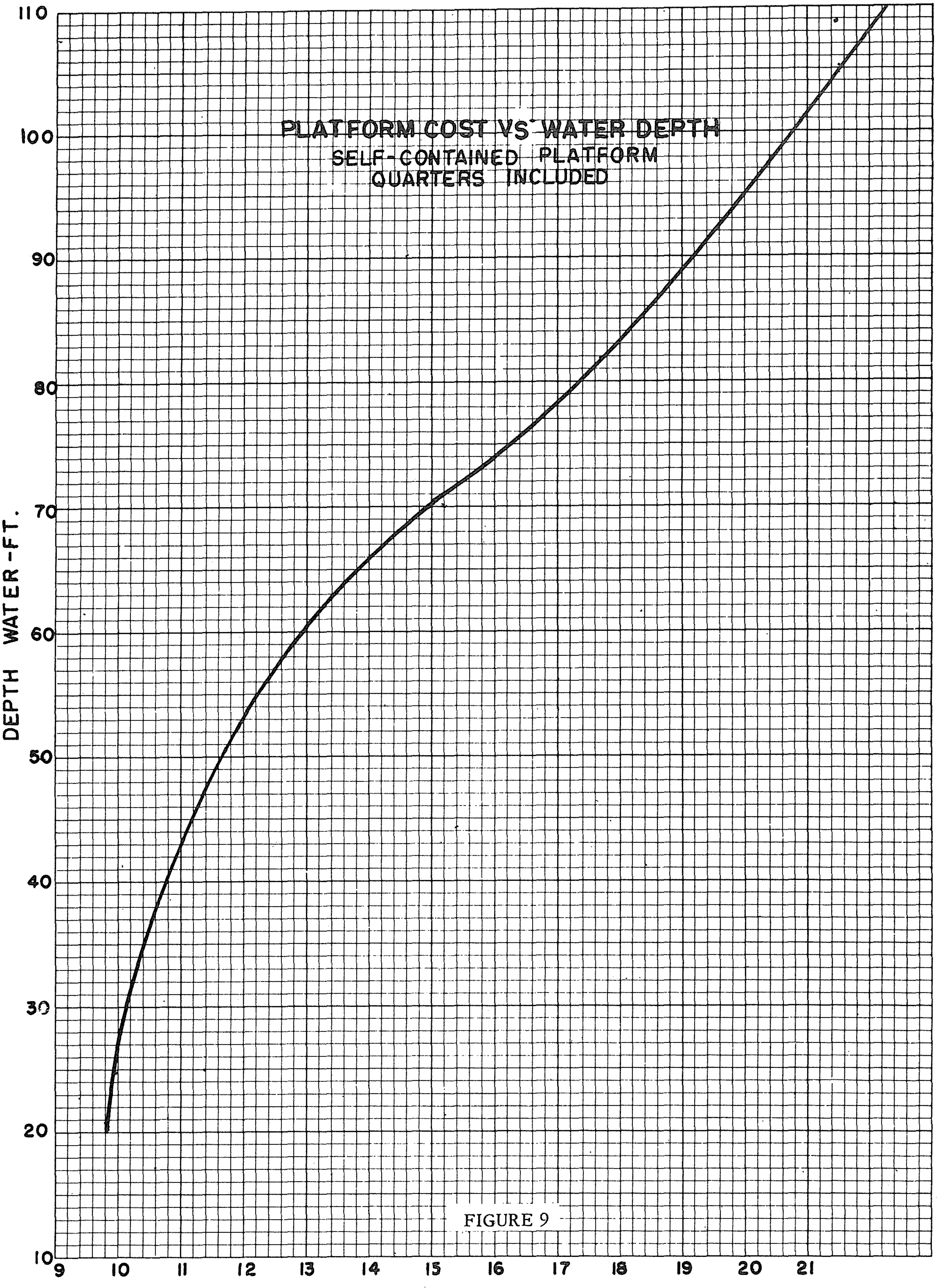

PLATFORM COST VS WATER DEPTH
SELF-CONTAINED PLATFORM
QUARTERS INCLUDED
DEPTH WATER-FT.
110
100
90
80
70
60
50
40
30
20
10
9
10
11
12
13
14
15
16
17
18
19
20
21
PLATFORM COST-DOLLARS X $100,000

FIGURE 9

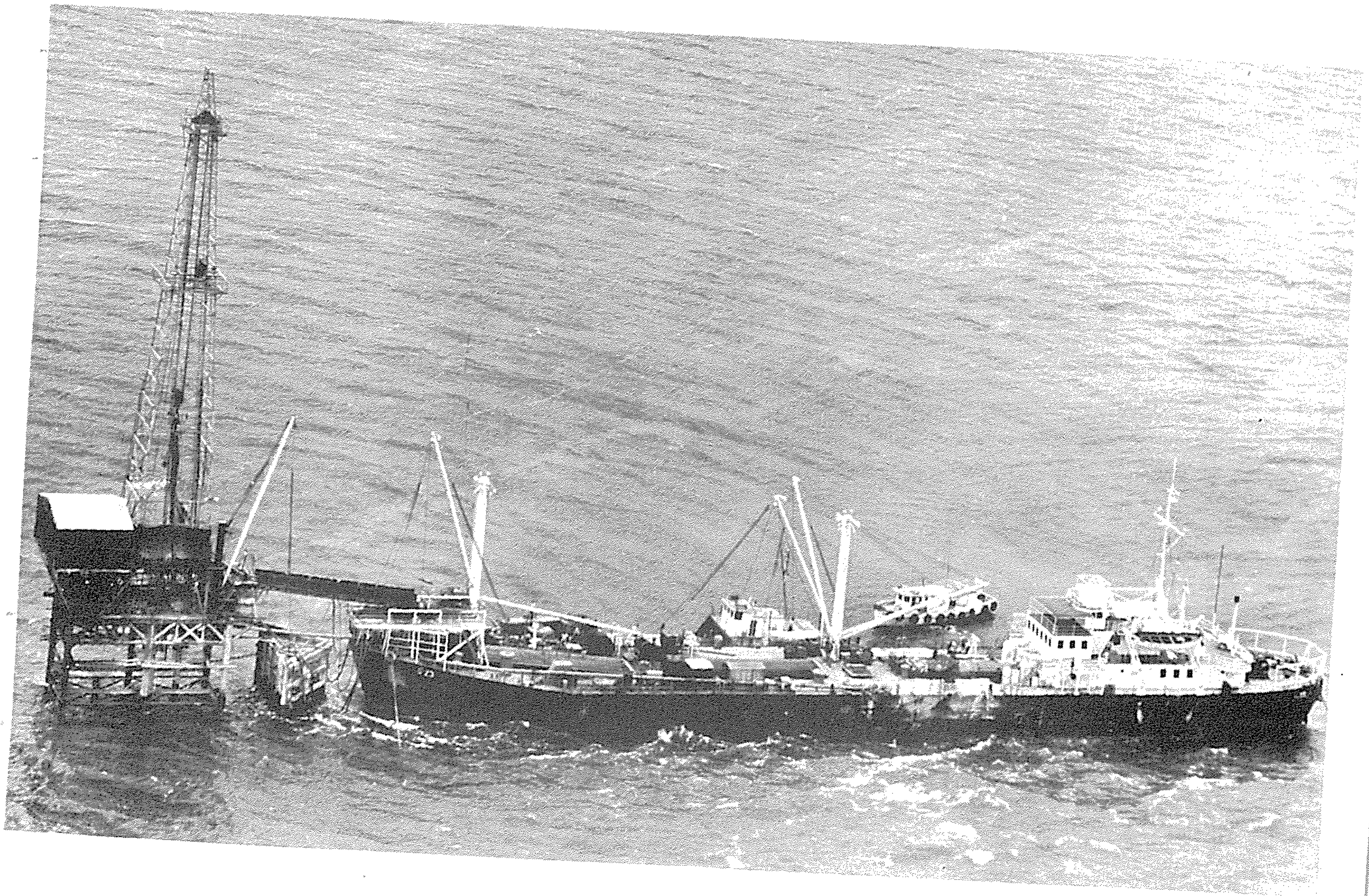


FIGURE 10

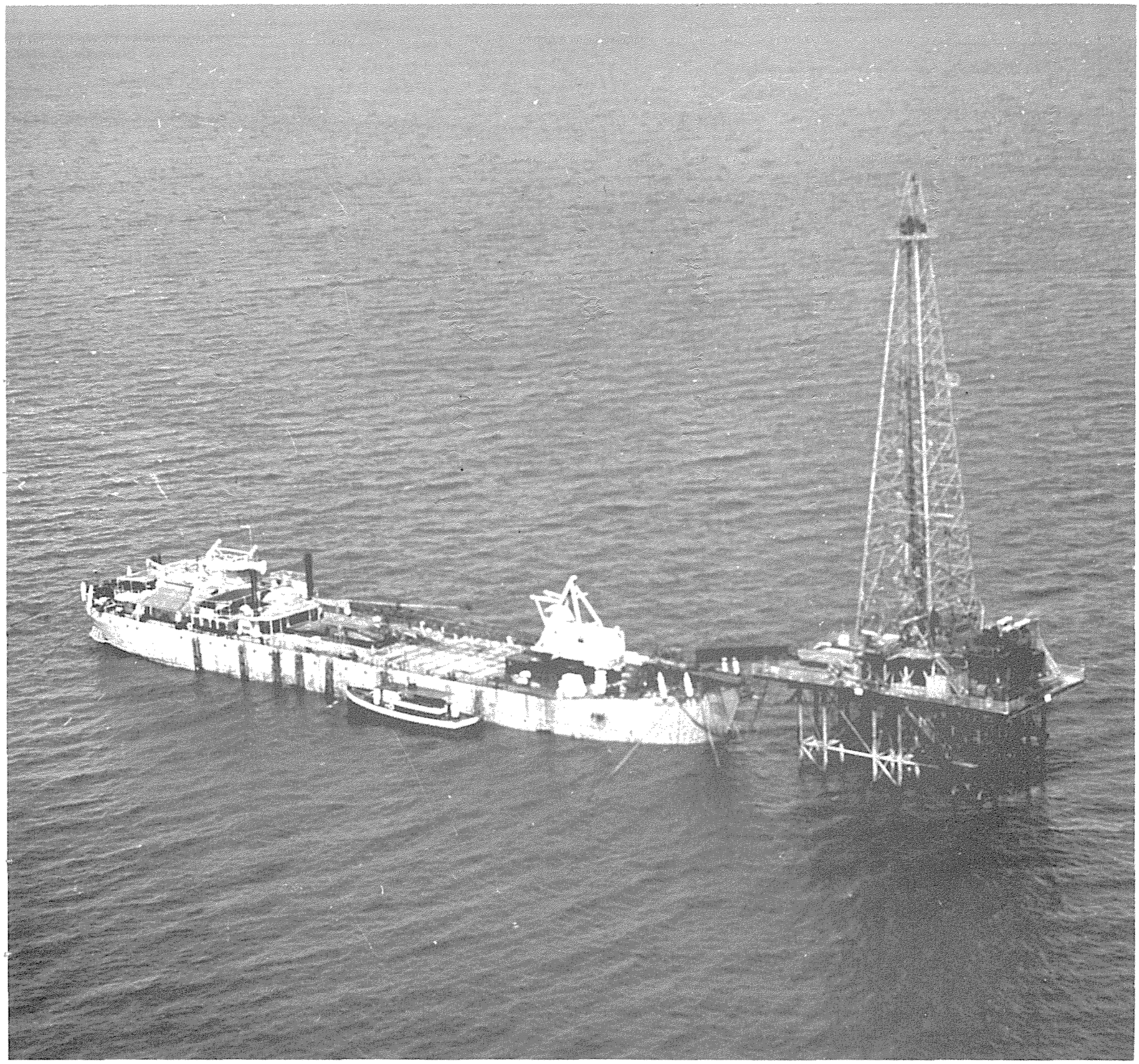


FIGURE 11

FIGURE 12

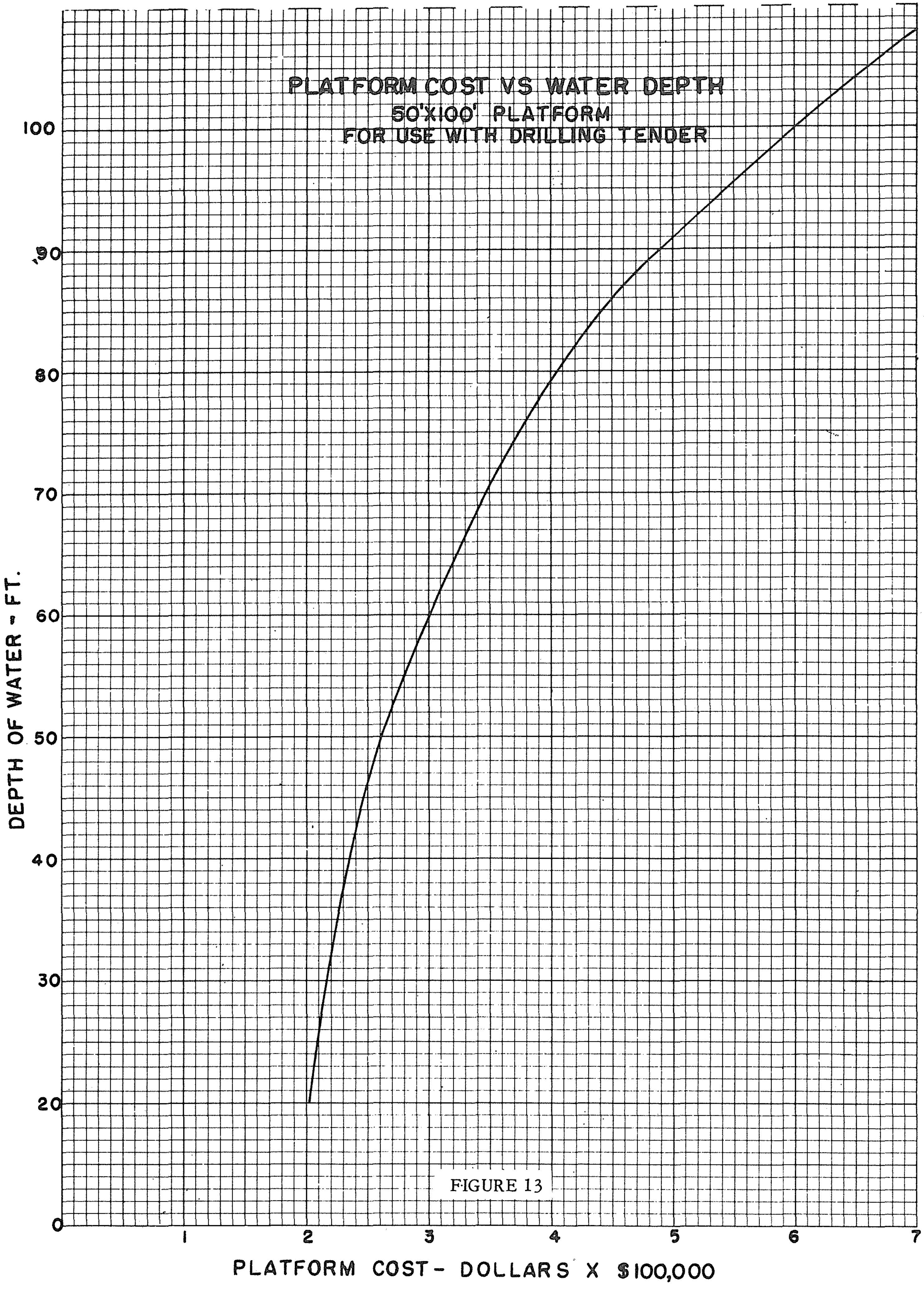

PLATFORM COST VS WATER DEPTH
50'X100' PLATFORM
FOR USE WITH DRILLING TENDER
DEPTH OF WATER - FT.
100
90
80
70
60
50
40
30
20
0
1
2
3
4
5
6
7
PLATFORM COST - DOLLARS X $100,000

FIGURE 13

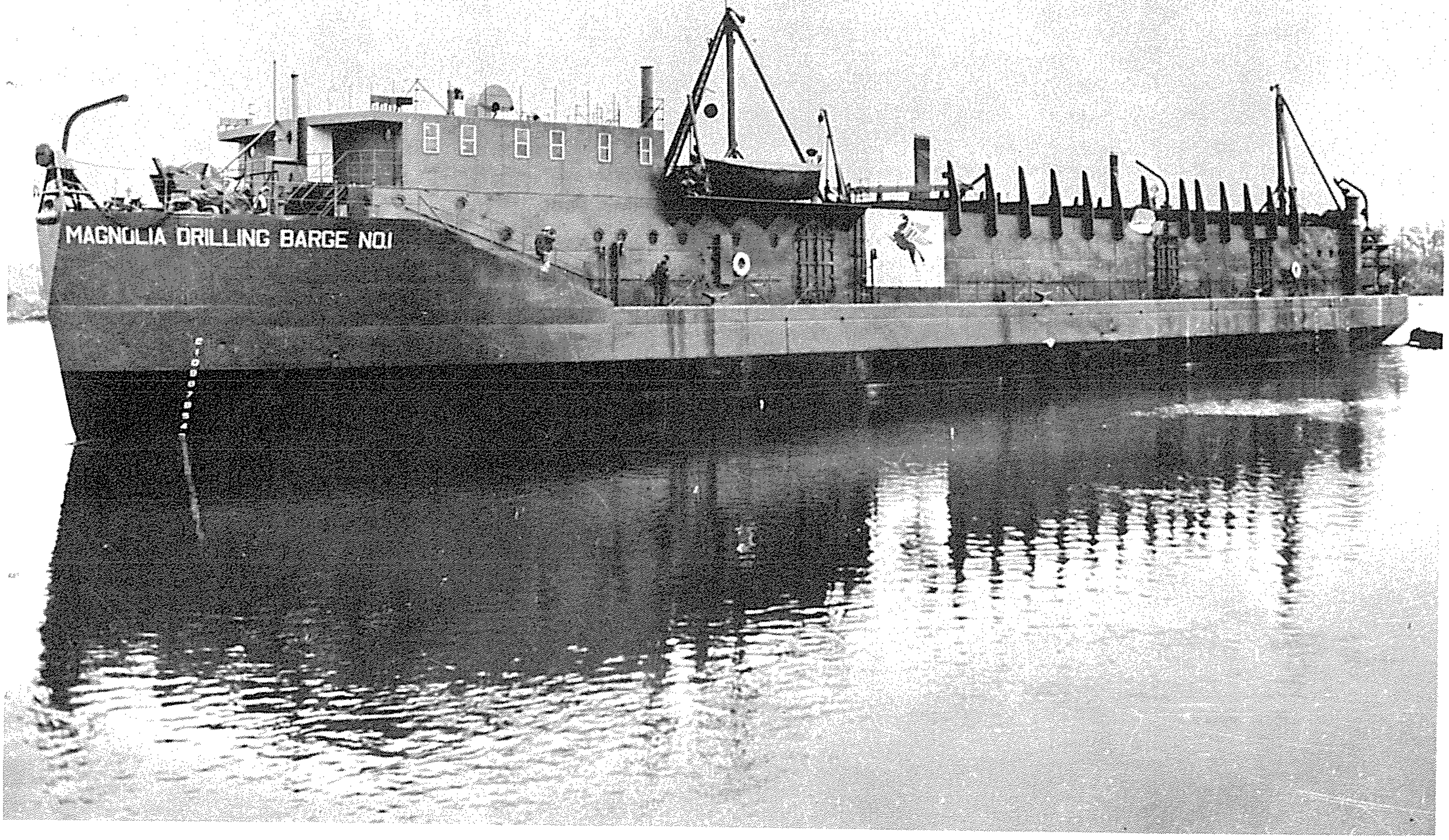
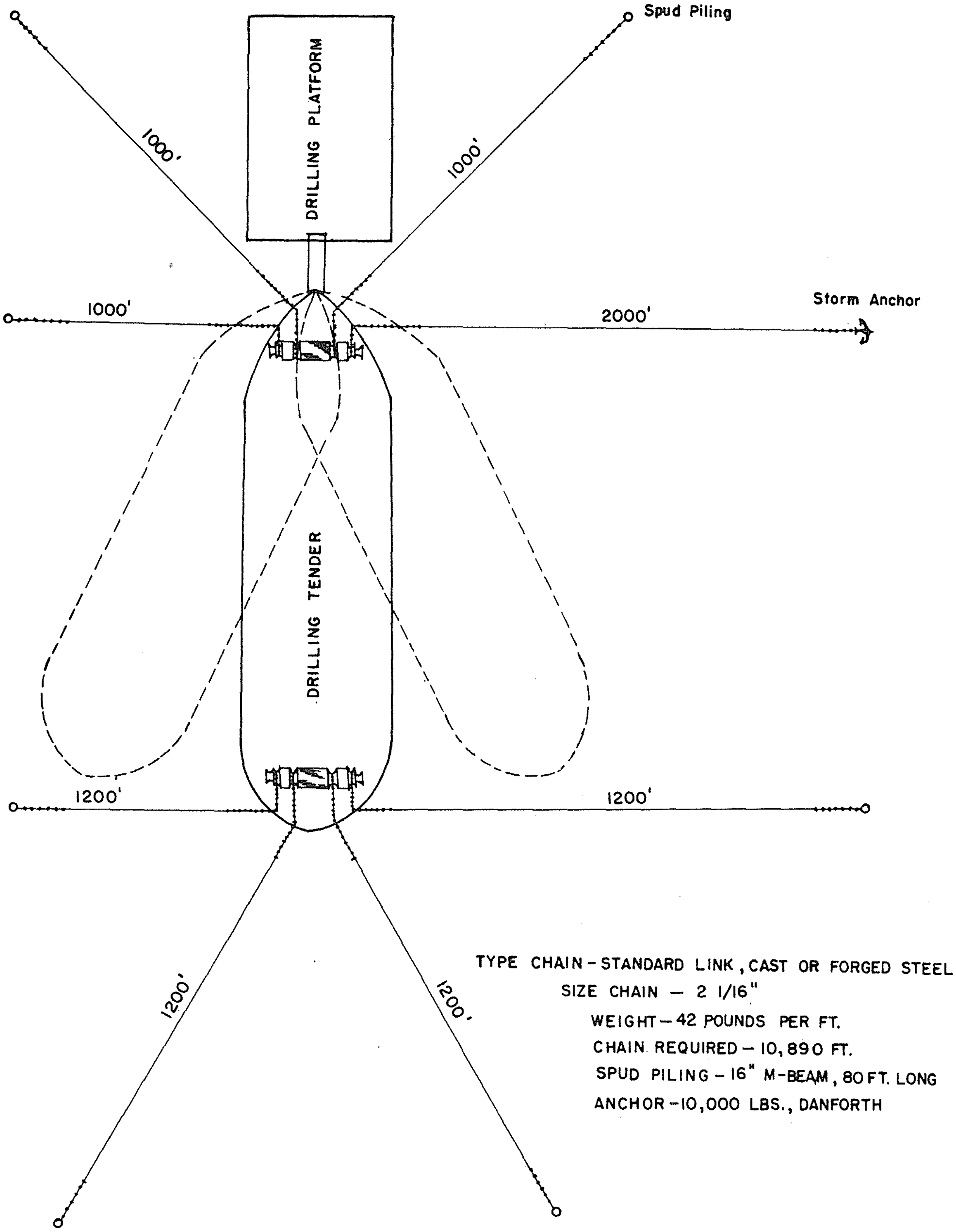


FIGURE 14

FIGURE 15



TYPE CHAIN - STANDARD LINK, CAST OR FORGED STEEL
SIZE CHAIN — 2 1/16"
WEIGHT - 42 POUNDS PER FT.
CHAIN REQUIRED - 10,890 FT.
SPUD PILING - 16" M-BEAM, 80 FT. LONG
ANCHOR - 10,000 LBS., DANFORTH

FIGURE 16

MOORING SYSTEM FOR DRILLING TENDER

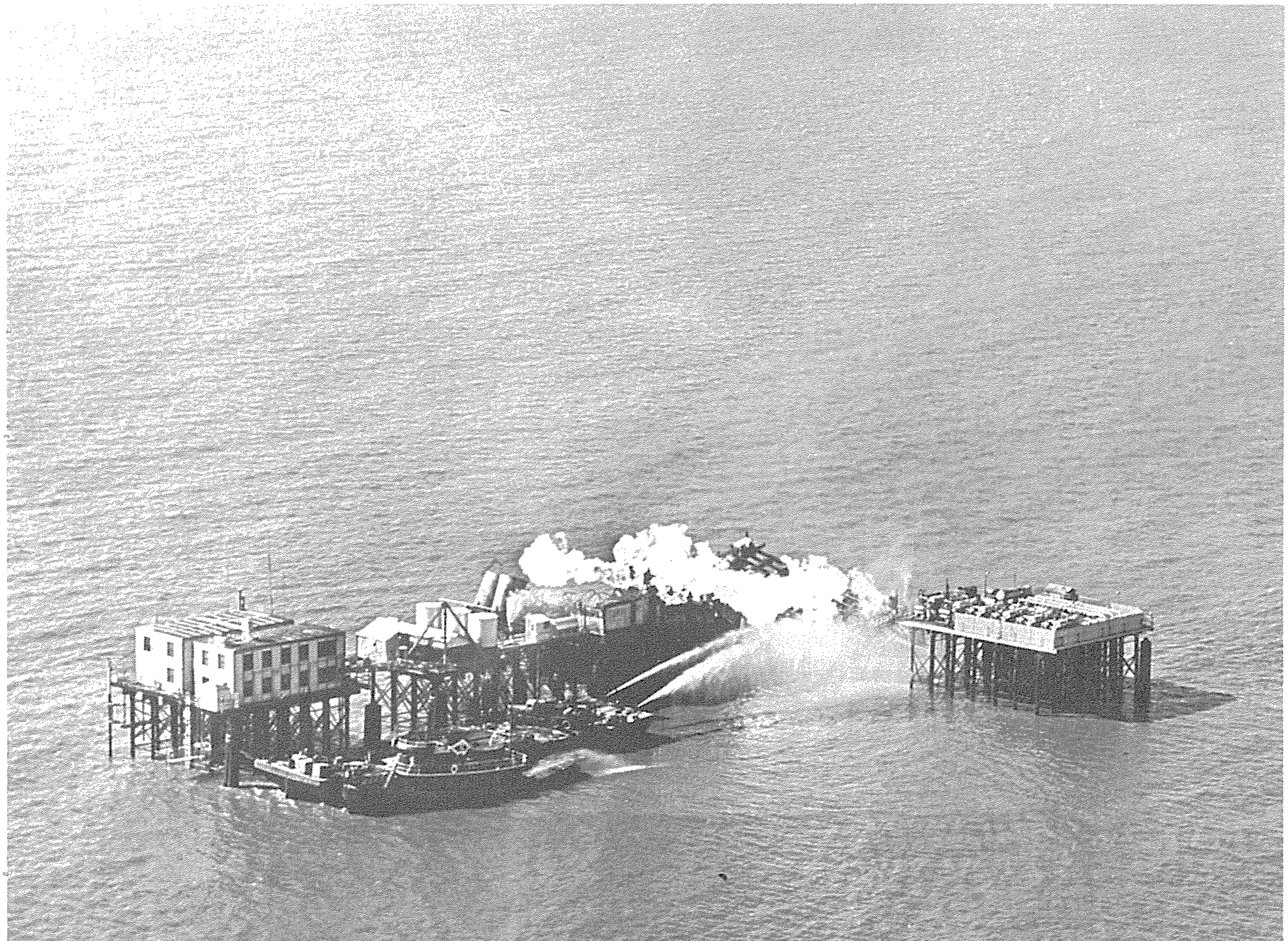


FIGURE 17

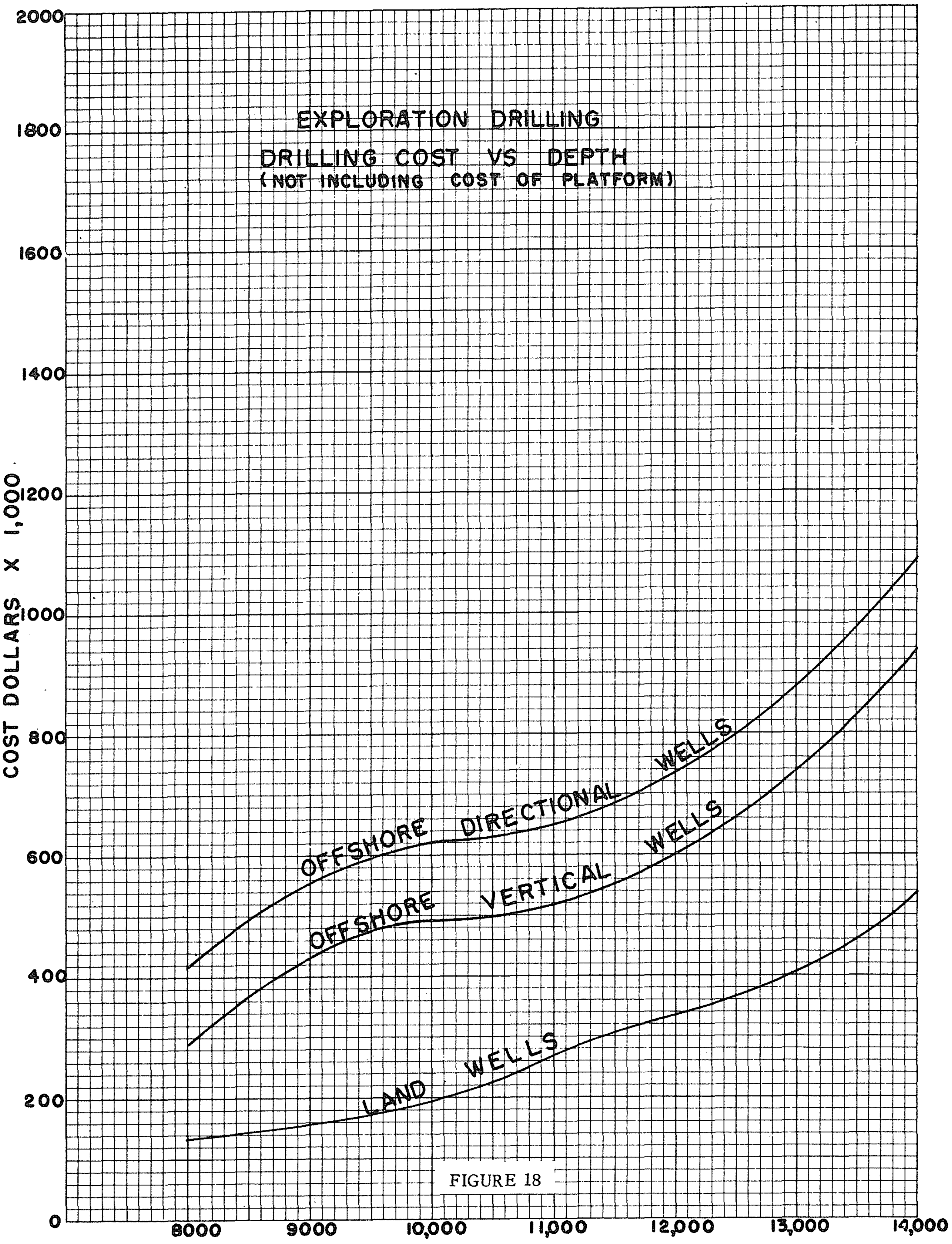

EXPLORATION DRILLING
DRILLING COST VS DEPTH
(NOT INCLUDING COST OF PLATFORM)
COST DOLLARS X 1,000
2000
1800
1600
1400
1200
1000
800
600
400
200
0
8000
9000
10,000
11,000
12,000
13,000
14,000
DEPTH, FT.
OFFSHORE DIRECTIONAL WELLS
OFFSHORE VERTICAL WELLS
LAND WELLS

FIGURE 18

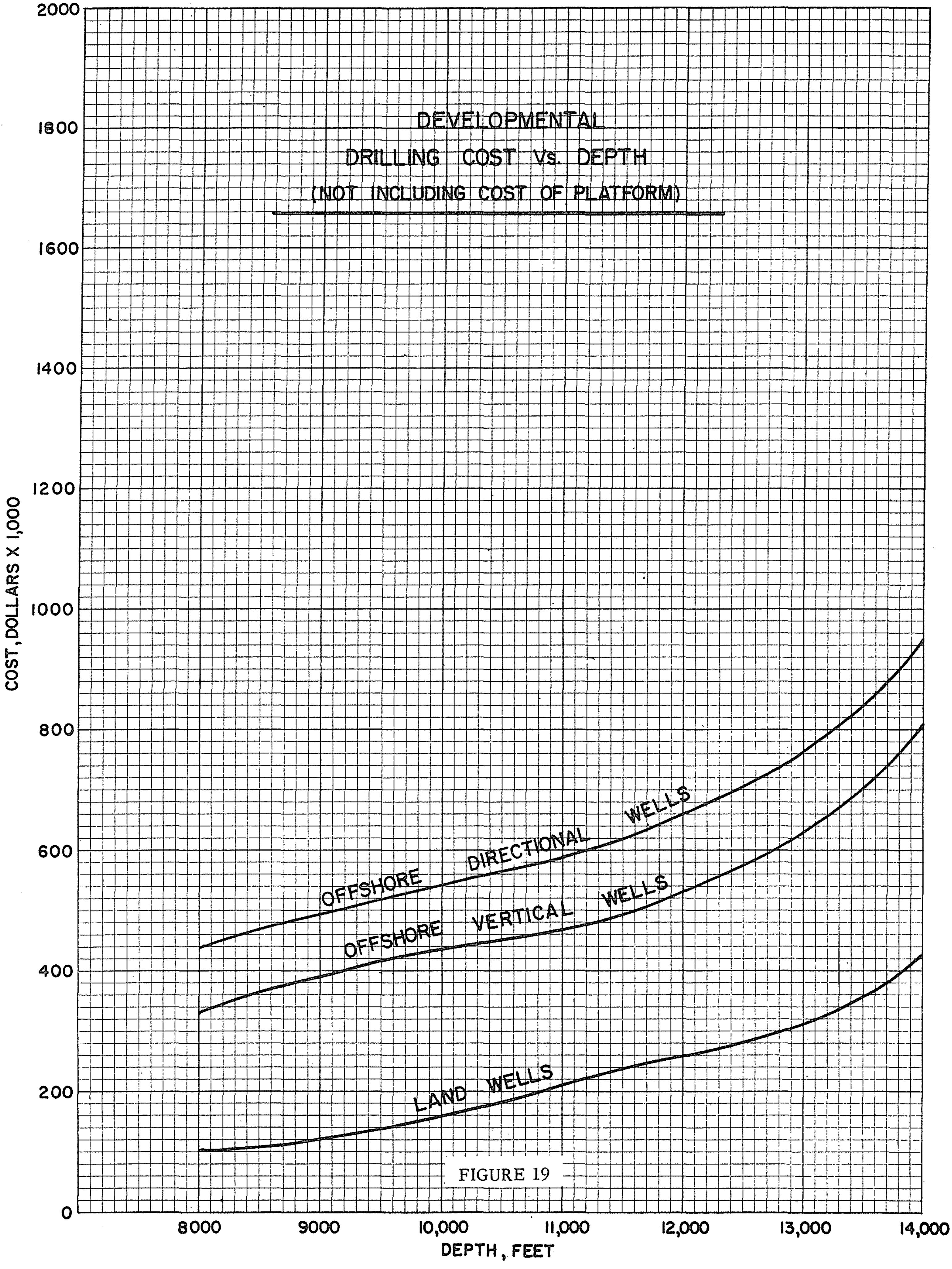

DEVELOPMENTAL
DRILLING COST Vs. DEPTH
(NOT INCLUDING COST OF PLATFORM)
COST, DOLLARS X 1,000
2000
1800
1600
1400
1200
1000
800
600
400
200
0
8000
9000
10,000
11,000
12,000
13,000
14,000
DEPTH, FEET
OFFSHORE DIRECTIONAL WELLS
OFFSHORE VERTICAL WELLS
LAND WELLS

FIGURE 19

COST OF COMMUNICATIONS EQUIPMENT

Tender or Platform - Radar		
1 RCA CR-104 Radar Set	$ 9,200.00	
Installation	850.00	
Misc. Material	100.00	
SUB TOTAL	$10,150.00	$10,150.00
Small Boats - Crew or Work - Radar		
1 RCA CR-103 Radar Set	$ 5,005.00	
Installation Cost	750.00	
Misc. Material	50.00	
SUB TOTAL	$ 5,805.00	$16,000.00
Base Station - Radar		
Same as above for Tender		
Tender or Platform Radio		
1 RCA CT 11A Radio	$ 2,096.00	
1 RCA CC 4C1 Remote Control	268.00	
1 RCA 1A Antenna	105.00	
Cable, fittings, transformer, etc.	470.00	
Misc. Mat'l. and Co. Labor	185.00	
SUB TOTAL	$ 3,124.00	$19,124.00
Small Boats - Crew or Work - Radio		
1 RCA CMV3 Radio	$ 576.00	
1 RCA 1A Antenna	105.00	
Antenna and Charging Unit	275.00	
Misc. Expense and Co. Labor	140.00	
SUB TOTAL	$ 1,096.00	$20,220.00
Cars - Radio		
1 RCA CMV3 Radio	$ 576.00	
1 Charging Unit	175.00	
Misc. Expense and Co. Labor	75.00	
SUB TOTAL	$ 826.00	$21,046.00
Base Station Radio		
1 RCA CT 11A Radio	$ 2,096.00	
1 RCA CCHC1 Remote Control	268.00	
1 RCA 1A Antenna	105.00	
Antenna Tower	4,500.00	
Cable, fittings, transformer	345.00	
Misc. Mat'l. and Co. Labor	200.00	
SUB TOTAL	$ 7,514.00	
GRAND TOTAL		$28,560.00

TABULATION 1

WILDCAT DRILLING

CAPITAL EXPENDITURES

	LAND	OFFSHORE
1 Shore Base	$ 20,000	$150,000
6 Platforms and preparation of site	102,000	$1,800,000
1 Drilling Tender		$2,300,000
3 Crew Boats		$385,000
1 LCT		$150,000
1 Barge		$ 50,000
1 Small Tug		$150,000
Mooring Equipment		$200,000
Communications Equipment		$ 28,000
1 Rig	$750,000	$500,000
	$872,000	$5,713,000

TABULATION 2

EXHIBIT D

MEMBERSHIP OF THE COMMITTEE AND
ITS SUBCOMMITTEES
COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

May 28, 1953

EXHIBIT D

NATIONAL PETROLEUM COUNCIL
COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

CHAIRMAN: L. S. Wescoat, President
The Pure Oil Company

SECRETARY: Richard J. Gonzalez
Humble Oil and Refining Company

Hines H. Baker, President
Humble Oil and Refining Company

Paul G. Benedum, President
Hiawatha Oil and Gas Company

Bruce K. Brown, President
Pan-Am Southern Corporation

Russell B. Brown, General Counsel
Independent Petroleum Association of America

E. F. Bullard, President
Stanolind Oil and Gas Company

H. S. M. Burns, President
Shell Oil Company

Robert H. Colley, Chairman of the Board
The Atlantic Refining Company

Howard A. Cowden, President and General Manager
Consumers Cooperative Association

J. C. Donnell II, President
The Ohio Oil Company

J. Frank Drake, Chairman of the Board
Gulf Oil Corporation

Paul Endacott, President
Phillips Petroleum Company

R. G. Follis, Chairman of the Board
Standard Oil Company of California

B. A. Hardey
Independent Producer

B. Brewster Jennings, President
Socony-Vacuum Oil Co., Inc.

Charles S. Jones, President
Richfield Oil Corporation

William M. Keck, Sr., President
The Superior Oil Company

Richard Gray Lawton, President
Lawton Oil Corporation

A. C. Mattei, President
Honolulu Oil Corporation

L. F. McCollum, President
Continental Oil Company

N. C. McGowen, President
United Gas Corporation

S. B. Mosher, President and General Manager
Signal Oil & Gas Company

Henry L. Phillips, President
Sinclair Oil & Gas Company

E. E. Pyles, Vice-President
Monterey Oil Company

W. S. S. Rodgers
The Texas Company

Reese H. Taylor, President
Union Oil Company of California

C. H. Wright, Chairman of the Board
Sunray Oil Corporation

GULF COAST SUBCOMMITTEE
OF THE
COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

CHAIRMAN:	A. E. Chester Magnolia Petroleum Company
VICE CHAIRMAN:	D. V. Carter Magnolia Petroleum Company
SPECIAL ASSISTANT:	Ben C. Belt, Vice President Gulf Oil Corporation

Ira H. Cram
Continental Oil Company

Morgan J. Davis
Humble Oil & Refining Co.

E. R. Filley
The Texas Company

Edgar Kraus
Atlantic Refining Company

George B. Lamb
Gulf Oil Corporation

Marvin Lee
Consumers Cooperative Producing Association

Buford Miller
Melben Oil Company

S. C. Oliphant
Stanolind Oil & Gas Company

John Payne
Shell Oil Company

D. R. Pflug
United Gas Pipe Line Company

Tom Seale
Kerr-McGee Oil Industries

M. H. Steig
Phillips Petroleum Company

C. E. Sutton
Pure Oil Company

Harold C. Teasdel, President
The California Company

W. A. Thomas
Ohio Oil Company

SUBCOMMITTEES APPOINTED BY THE GULF COAST SUBCOMMITTEE OF THE COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

STEERING

CHAIRMAN: D. V. Carter
Magnolia Petroleum Company

Stuart Buckley
Production Research Division
Humble Oil & Refining Company

Ira H. Cram, Vice-President of Exploration
Continental Oil Company

E. M. Kipp, Manager
Engineering Department
The California Company

John M. Payne
Shell Oil Company

Tom Seale
Kerr-McGee Oil Industries

Chase E. Sutton, Division Manager
The Pure Oil Company

H. C. Teasdel, President
The California Company

EXPLORATION

CHAIRMAN: Ira H. Cram, Vice-President of Exploration
Continental Oil Company

J. A. Harris
The California Company

Marvin Lee
Consumers Cooperative
Producing Association

Roy A. Payne
Gulf Oil Corporation

M. H. Steig
Phillips Petroleum Company

PRODUCTION AND ENGINEERING

CHAIRMAN: E. M. Kipp, Manager
Engineering Department
The California Company

B. K. Ayers
Stanolind Oil and Gas Company

Tom H. Cobb
Kerr-McGee Oil Industries, Inc.

D. L. Harlan *
The Texas Company

*(Alternate)
J. A. Battle, Jr.
The Texas Company

John M. Payne
Shell Oil Company

Fred Wilson
Magnolia Petroleum Company

ECONOMICS

CHAIRMAN: Stuart E. Buckley
Humble Oil & Refining Company

T. W. Johnson
United Gas Pipe Line Co.

Shirley L. Mason
Stanolind Oil & Gas Company

W. F. Maxwell *
Atlantic Refining Company

W. A. Thomas
Ohio Oil Company

AVAILABILITY

CHAIRMAN: Chase E. Sutton **
The Pure Oil Company

Stuart E. Buckley
Humble Oil & Refining Company

E. P. Hayes
The Texas Company

E. M. Kipp, Manager
Engineering Department
The California Company

D. R. Pflug, Chief Engineer ***
United Gas Pipe Line Company

* (Alternate)
R. W. Dorsey
Atlantic Refining Company

** (Alternate)
I. W. Alcorn
The Pure Oil Company

*** (Alternate)
L. A. Meltzer
United Gas Pipe Line Company

WEST COAST SUBCOMMITTEE
OF THE
COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

CHAIRMAN: Floyd S. Bryant, Vice President
Standard Oil Company of California

VICE CHAIRMAN: E. E. Pyles, Vice President
Monterey Oil Company

Paul Andrews
Signal Oil & Gas Company

S. F. Bowlby, Vice-President
Shell Oil Company

L. A. Cranson
Executive Vice-President
Honolulu Oil Corporation

Olen Lane
Continental Corporation

G. W. Ledingham
Western Gulf Oil Company

Frank A. Morgan
Vice President
Richfield Oil Corporation

J. R. Puls
The Texas Company

A. C. Rubel
Vice-President
Union Oil Company of California

R. O. Swayze
General Petroleum Corporation

T. L. Wark
Vice-President
Tide Water Associated Oil Co.

SUBCOMMITTEES APPOINTED BY THE WEST COAST SUBCOMMITTEE OF THE COMMITTEE ON SUBMERGED LANDS PRODUCTIVE CAPACITY

EXPLORATION AND GEOLOGY

CHAIRMAN: Rollin Eckis
Richfield Oil Corporation

James P. Bailey
Standard Oil Company of California

H. C. Bemis
Standard Oil Company of California

Vincent W. Finch
Shell Oil Company

G. W. Ledingham
Manager of Exploration
Western Gulf Oil Company

John Sloat
Union Oil Company

Loring B. Snedden
The Texas Company

DRILLING AND PRODUCTION

CHAIRMAN: Paul Andrews
Chief Production Engineer
Signal Oil and Gas Company

B. H. Anderson
Continental Oil Company

H. Bassler
Standard Oil Company of California

Frank B. Carter
General Petroleum Corporation

O. W. Chonette
The Texas Company

C. W. Dawson
Standard Oil Company of California

Melvin James Hill
Western Gulf Oil Company

R. J. Kettenburg
Shell Oil Company

Loyde H. Metzner
Signal Oil and Gas Company

James Moon
Consulting Mechanical Engineer

R. O. Pollard
Richfield Oil Corporation

R. D. Townsend
General Petroleum Corporation

K. C. Vaughn
Union Oil Company

EXHIBIT E

NATIONAL PETROLEUM COUNCIL

MEMBERS

May 28, 1953

EXHIBIT E

NATIONAL PETROLEUM COUNCIL

1953

MEMBERSHIP LIST
(As of May 28, 1953)

OFFICERS

Walter S. Hallanan, Chairman
R. G. Follis, Vice-Chairman
James V. Brown, Secretary-Treasurer

HEADQUARTERS

601 Commonwealth Building
1625 K Street, N.W.
Washington 6, D.C.

COUNCIL MEMBERS

Robert O. Anderson, President
Malco Refineries, Incorporated

Hines H. Baker, President
Humble Oil & Refining Company

Max W. Ball
Oil and Gas Consultant

Munger T. Ball, President
Sabine Transportation Co., Inc.

T. H. Barton, Chairman of the Board
Lion Oil Company

Paul G. Benedum, President
Hiawatha Oil & Gas Company

Fred E. Bergfors, President and Treasurer
The Quincy Oil Company

Jacob Blaustein, President
American Trading & Production Corporation

Paul G. Blazer, Chairman of the Board
Ashland Oil & Refining Company

William R. Boyd, Jr.
Managing Partner
Boyd, Hardey & Wheelock

Reid Brazell, President and General Manager
Leonard Refineries, Inc.

J. S. Bridwell
Bridwell Oil Company

F. W. Brigance, President
American Association of Oil-well Drilling Contractors

Bruce K. Brown, President
Pan-Am Southern Corporation

Russell B. Brown, General Counsel, Independent Petroleum Association of America

M. D. Bryant, President
Texas Independent & Royalty Owners Association

H. S. M. Burns, President
Shell Oil Company

J. P. Coleman, President
National Stripper Well Association

Robert H. Colley, Chairman of the Board
The Atlantic Refining Company

Howard A. Cowden, President and General Manager
Consumers Cooperative Association

Stuart M. Crocker, Chairman of the Board
The Columbia Gas System, Inc.

John F. Cummins, President
Cumberland Oil Company

E. DeGolyer, Geologist,
Oil Producer

J. C. Donnell, II, President
The Ohio Oil Company

Fayette B. Dow, General Counsel
National Petroleum Association

Warwick M. Downing
Independent Oil Producer

Wesley E. Downing, President
Independent Oil Men's Association of New England, Incorporated

J. Frank Drake, Chairman of the Executive Committee
Gulf Oil Corporation

Gordon Duke
Oil Marketer

James P. Dunnigan, President
Producers Refining, Inc.

Paul Endacott, President
Philips Petroleum Company

Max M. Fisher, Executive Vice President
Aurora Gasoline Company

R. G. Follis, Chairman of the Board
Standard Oil Company of California

Clyde T. Foster, President
The Standard Oil Company (Ohio)

Stark Fox, Executive Vice President
Oil Producers Agency of California

Hial B. Gernert, President
Rocky Mountain Oil and Gas Association

B. C. Graves, President
Union Tank Car Company

B. I. Graves
Petroleum Consultant

Walter S. Hallanan, President
Plymouth Oil Company

Jake L. Hamon
Oil Producer

George J. Hanks, President
South Penn Oil Company

B. A. Hardey
Independent Producer

R. H. Hargrove, President
Texas Eastern Transmission Corporation

John Harper, President
Harper Oil Company, Inc.

I. W. Hartman
Oil Producer

Harry B. Hilts, Secretary
Atlantic Coast Oil Conference, Incorporated

Eugene Holman, President
Standard Oil Company (N.J.)

D. A. Hulcy, President
Lone Star Gas Company

A. Jacobsen, President
Amerada Petroleum Corporation

B. Brewster Jennings, President
Socony-Vacuum Oil Co., Inc.

Carl A. Johnson, President
Independent Refiners Association
of California

Charles S. Jones, President
Richfield Oil Corporation

Mason B. Jones, President
Petroleum Equipment Suppliers
Association

W. Alton Jones, President
Cities Service Company

Paul Kayser, President
El Paso Natural Gas Company

William M. Keck, Sr., President
The Superior Oil Company

Richard Gray Lawton, President
Lawton Oil Corporation

J. Sayles Leach, President
The Texas Company

John M. Lovejoy, President
Seaboard Oil Company of Delaware

Charlton H. Lyons, President
Independent Petroleum Association
of America

L. F. McCollum, President
Continental Oil Company

R. W. McDowell, President
Mid-Continent Petroleum
Corporation

N. C. McGowen, President
United Gas Corporation

William G. Maguire, Chairman
of the Board
Panhandle Eastern Pipe Line Co.

B. L. Majewski, President
Great American Oil Company

J. Howard Marshall, Vice President
Signal Oil and Gas Company

A. C. Mattei, President
Honolulu Oil Corporation

Nelson Maynard, President
National Congress of Petroleum
Retailers, Incorporated

S. B. Mosher, President and
General Manager
Signal Oil and Gas Company

Glenn E. Nielson, President
Husky Oil Company

S. F. Niness
National Tank Truck Carriers,
Incorporated

Maston Nixon, President
Southern Minerals Corporation

J. L. Nolan, Manager
Oil Department
Farmers Union Central Exchange,
Incorporated

John F. O'Shaughnessy
Vice-President
The Globe Oil & Refining Co.

J. R. Parten, President
Woodley Petroleum Company

William T. Payne, President
Mid-Continent Oil & Gas
Association

Frank M. Perry, President
Natural-Gasoline Association
of America

Joseph E. Pogue
Petroleum Consultant

Frank M. Porter, President
American Petroleum Institute

E. E. Pyles, Vice-President
Monterey Oil Company

Walter R. Reitz, President
Quaker State Oil Refining Corp.

Sid W. Richardson, President
Sid W. Richardson, Inc.

A. S. Ritchie
Independent Producer

M. H. Robineau, President
The Frontier Refining Company

J. French Robinson, President
Consolidated Natural Gas Company

Roland V. Rodman, President
Anderson-Prichard Oil Corporation

A. H. Rowan, President
Rowan Oil Company

A. W. Scott, President
National Petroleum Association

R. S. Shannon, Director
Pioneer Oil Corporation

W. G. Skelly, President
Skelly Oil Company

P. C. Spencer, President
Sinclair Oil Corporation

D. T. Staples, President
Tide Water Associated Oil Co.

Clarendon E. Streeter, President
Pennsylvania Grade Crude Oil
Association

Reese H. Taylor, President
Union Oil Company of California

Roy J. Thompson, Chairman
National Oil Jobbers Council

W. W. Vandeveer
Oil Producer

W. G. Violette, President
Standard Oil Company (Kentucky)

S. M. Vockel, President
The Waverly Oil Works Company

Wm. K. Warren, Chairman of
the Board
Warren Petroleum Corporation

L. S. Wescoat, President
The Pure Oil Company

John H. White, President and
General Manager
Hewitt Oil Company

Robert E. Wilson, Chairman of
the Board
Standard Oil Company (Indiana)

John Wrather
Independent Oil Operator

C. H. Wright, Chairman of
the Board
Sunray Oil Corporation