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THE OIL AND GAS INDUSTRY OF COASTAL LOUISIANA AND ITS EFFECT ON LAND USE AND SOCIOECONOMIC PATTERNS

By Donald W. Davis and John L. Place

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CONVERSION TABLE

Length

Multiply	By	To Obtain
meters (m)	3.281	feet (ft)
kilometers (km)	0.6214	mile (mi)

Area

Multiply	By	To Obtain
meter^2 (m^2)	10.76	feet^2 (ft^2)
hectare (ha)	2.471	acre
kilometer^2 (km^2)	0.3861	mile^2 (mi^2)

Volume

Multiply	By	To Obtain
meter^3 (m^3)	35.31	foot^3 (ft^3)
cubic meter (m^3)	6.290	barrel (bbl), petroleum, 1 bbl = 42 gal)

Mass

Multiply	By	To Obtain
kilogram (kg)	2.205	pound avoirdupois (lb avdp)
metric ton	1.102	ton, short (2,000 lb)

THE OIL AND GAS INDUSTRY OF COASTAL LOUISIANA AND ITS EFFECT ON LAND USE AND SOCIOECONOMIC PATTERNS

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ABSTRACT

Louisiana's coastal wetlands, along with their well-drained urbanized strips, have been significantly affected by the oil and gas industry.

Onshore, more than 6,300 exploratory wells and more than 21,000 development wells were drilled in Louisiana's eight southernmost parishes between 1937 and 1977. Nearly all those wells were in wetlands or inland water bodies. The wetlands, totaling more than 2 million hectares (ha), extend inland to roughly latitude 30° N, and are about 15 percent forested swamp and 85 percent nonforested marsh. Inland waters within the Louisiana coastal zone total more than 1 million ha. Nearly all these waters are quite shallow. More than 235,000 ha of this coastal area is used for major activities associated with the extraction of oil and gas. Production in the eight southern parishes peaked in 1970 to 120 million m^3 of oil and 172 billion m^3 of gas. Connecting extensive onshore fields--and also servicing offshore fields--are intricate networks of canals for pipelines and maritime traffic related to the oil and gas industry.

Offshore, more than 2,400 drilling and production platforms had been installed by May of 1981. Oil production from wells in both Federal and State waters off Louisiana peaked at 71 million m^3 in 1972. Offshore gas production continues to increase, with 131 billion m^3, in 1979.

Since the early 1950's southern Louisiana's population has shifted from remote rural areas in the marshes to the more densely settled areas on the natural levees and beach ridges where employment is available in oil-field support industries and businesses. In 1975, in the 14 primary settlement clusters within the coastal wetlands, more than 3,600 advertised business activities were connected directly to the oil and gas industry. This compares to about 1,200 such activities in 1955, at the start of offshore development. These businesses are listed as water transportation, transportation equipment, pipelines, chemicals, special trade contractors, and petroleum refining, as well as actual oil and gas extraction.

Area measurements of urban land uses reveal a major concentration of industry and transportation facilities along the navigable waterways. Ship and rig construction are important activities; of 148 fixed drilling platforms under construction in the United States in March 1981, 94 were being built in Louisiana to be barged out into the Gulf of Mexico and beyond. Of the 122 petroleum-industry support boats being built in the United States in 1976, 82 were in Louisiana shipyards; the worldwide total was estimated to be only about 200. In 1980, the Nation's marine contractors were building 129 logistic support vessels. Louisiana-based firms had 98 vessels under construction.

INTRODUCTION

There currently exists a national need to increase our domestic sources of energy by extracting oil and gas from the Outer Continental Shelves (OCS)* along the Atlantic seaboard, Gulf coast, California, and Alaska. To plan for such development, it is necessary to anticipate impacts on land use and land cover and on socioeconomic patterns of the coastal States adjacent to the prospective offshore fields. To benefit from past experience, an investigation was conducted on the development of the hydrocarbon industry in the Louisiana coastal area--the oldest and most complete extraction of offshore petroleum in the United States--and on the associated changes in the economy, employment, and land conditions of that coastal region.

Although the Louisiana experience is unique in having occurred on or near the delta of the Mississippi River with its extensive wetland coast, there are lessons learned from this experience. These lessons might apply in part to the Atlantic seaboard from New Jersey to Georgia where inland waters and broad marshes prevail behind the barrier beaches. Specifically applicable to other areas is the knowledge of the impact that occurred with development of onshore facilities to support offshore oil and gas operations.

Methods

To study onshore impact of petroleum development, available data on areas of land use and land cover were used for 20 parishes of southern Louisiana, with emphasis being placed on the southernmost eight parishes. Primary methods of research included interpretation of aerial photographs and topographic maps available since the early 1930's, literature searches, interviews, and fieldwork. The principal source for current land use and land cover was the maps compiled by the U.S. Geological Survey (USGS) dated 1972 or 1973. The classification system used to code the land use and land cover categories was transitional between the systems described by Anderson and others (1972) and Anderson and others (1976). Fourteen settlement strips on natural levees and old beach ridges were studied in detail (fig. 1). Data on trends in employment and types of business were compiled for both the parishes and the strips.

Several research techniques were used to assess the evolution of Louisiana's coastal settlement patterns leading up to and into the era of oil and gas extraction. Information on early communities was obtained from township plats in the State Land Office and in local courthouses and was compared to information on USGS topographic maps published between 1930-40. Recording past and present coastal settlements required extensive fieldwork. Former residents were contacted and interviewed. From these interviews, researchers discovered that a pattern of out-migration had taken place, with the population moving from isolated marsh settlements onto the natural levees.

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*Federal Outer Continental Shelf (OCS) refers to offshore zone beyond the State's 3-mile limit.

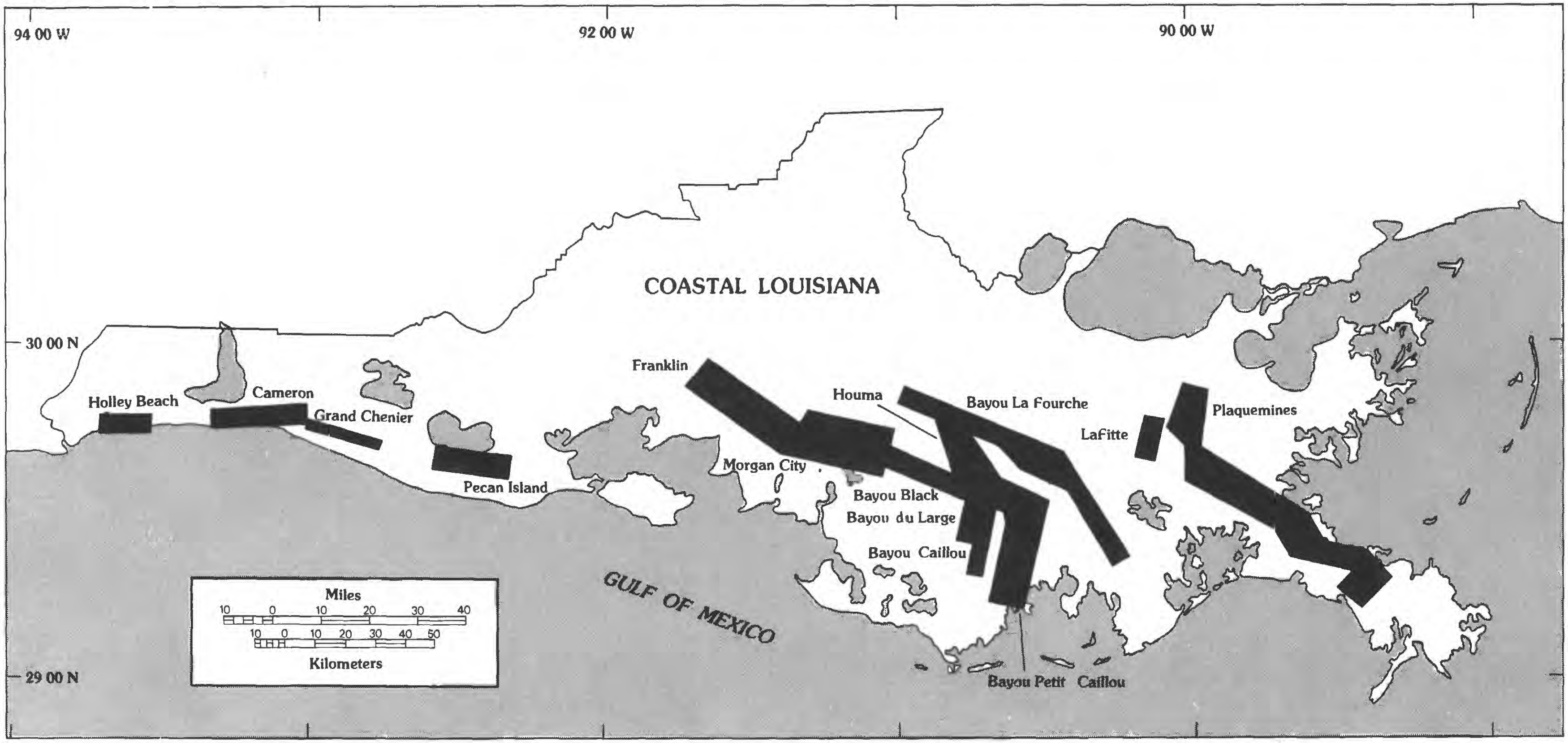


Figure 1.--The 14 settlement strips investigated in this study. The narrow irregular black lines represent the boundaries of coast and inland water bodies, notable that of the Mississippi River Delta on the far right, and the inland boundary of the southernmost 20 parishes of Louisiana.

Geographic Setting

The area investigated extends from the inland edge of Louisiana's coastal wetland seaward, including the Outer Continental Shelf, where petroleum is currently being extracted. The inland edge of the coastal wetland conforms quite closely to latitude 30° N.

Unlike California, which has an easily identified land-water interface, the definition of Louisiana's coastal zone is difficult. In the "Louisiana Wetlands Prospectus," the Advisory Commission on Coastal and Marine Resources has established the "coastal zone" as a region encompassing the coastal water and shorelands influenced by marine processes within the transitional and intertidal basins, marshes, swamps, natural levees, and beaches of the State's "lower" 26 parishes (counties) (St. Amant and others, 1973, p. 8). Although complete, the definition includes considerable land beyond the marsh-swamp complex. This report focusses primarily on the eight parishes in the region known locally as "the marsh" (fig. 2). The marsh has 1.9 million ha of nonforested wetlands and 1.3 million ha of associated water surfaces, much of the total of the Nation's marshlands. These marshes are one of the most productive wildlife habitats on the North American Continent. Each year fishermen catch more than 450 million kg of estuarine dependent fish and shellfish--primarily menhaden, oysters, and shrimp (National Oceanic and Atmospheric Administration, 1980, p. 3). In conjunction with the nonrenewable petroleum resources, this complicated mixture of land and water surfaces has become an exceedingly valuable natural resource.

The coastal lowlands are 24-32 km wide west of Vermilion Bay and increase to 80 km wide south of New Orleans. The mixture of land and water is a result of Mississippi River deposition and shoreline processes during the last few thousand years (Gould and Morgan, 1962, p. 287). For centuries sediment-laden water has fanned out along the coast and created two environments: a deltaic plain and a chenier (from the French chêne, meaning oak) plain (fig. 3). Together, these Recent coastal provinces cover about 36,260 km^2.

The peat accumulations and sedimentary structures of the deltaic and chenier plains have presented no serious problems to the petroleum industry. Exploration of the coastal lowland awaited only the perfecting of equipment capable of operating in wetland regions. Once the technology was developed and improved, exploration, drilling, and production in the deltaic and chenier plains was accelerated.

Deltaic Plain

East of Vermilion Bay, sediment accumulation has resulted in the sequential development of a delta system. Known as the deltaic plain, the area is the site of a series of six major deltaic lobes that extended seaward at different times during the last 7,000 years. Each lobe advanced into the shallow waters of the Gulf of Mexico (Gould and Morgan, 1962, p. 289) and was distinguished by numerous distributaries (figs. 4 and 5). These channels continued to bifurcate aiding the distribution of the river sediments and progradation of the coast. Natural levees formed along the channels and served as favorable settlement sites.

Figure 2.--The parishes of southern Louisiana. The shaded area indicates some of the parishes most often affected by coastal zone problems. The inland boundary is indicated for the eight parishes containing most of the coastal wetlands.

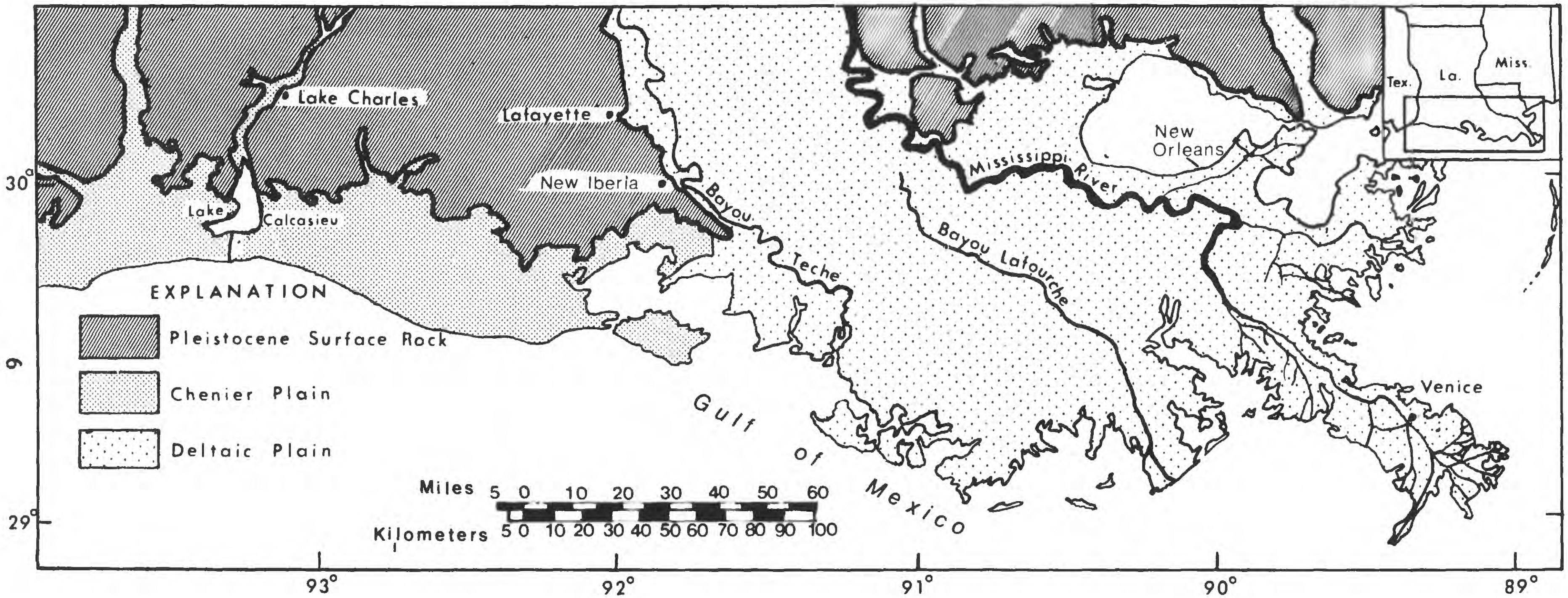


Figure 3.--The deltaic and chenier plains of the coast of Louisiana (Frazier and Osanik, 1968).

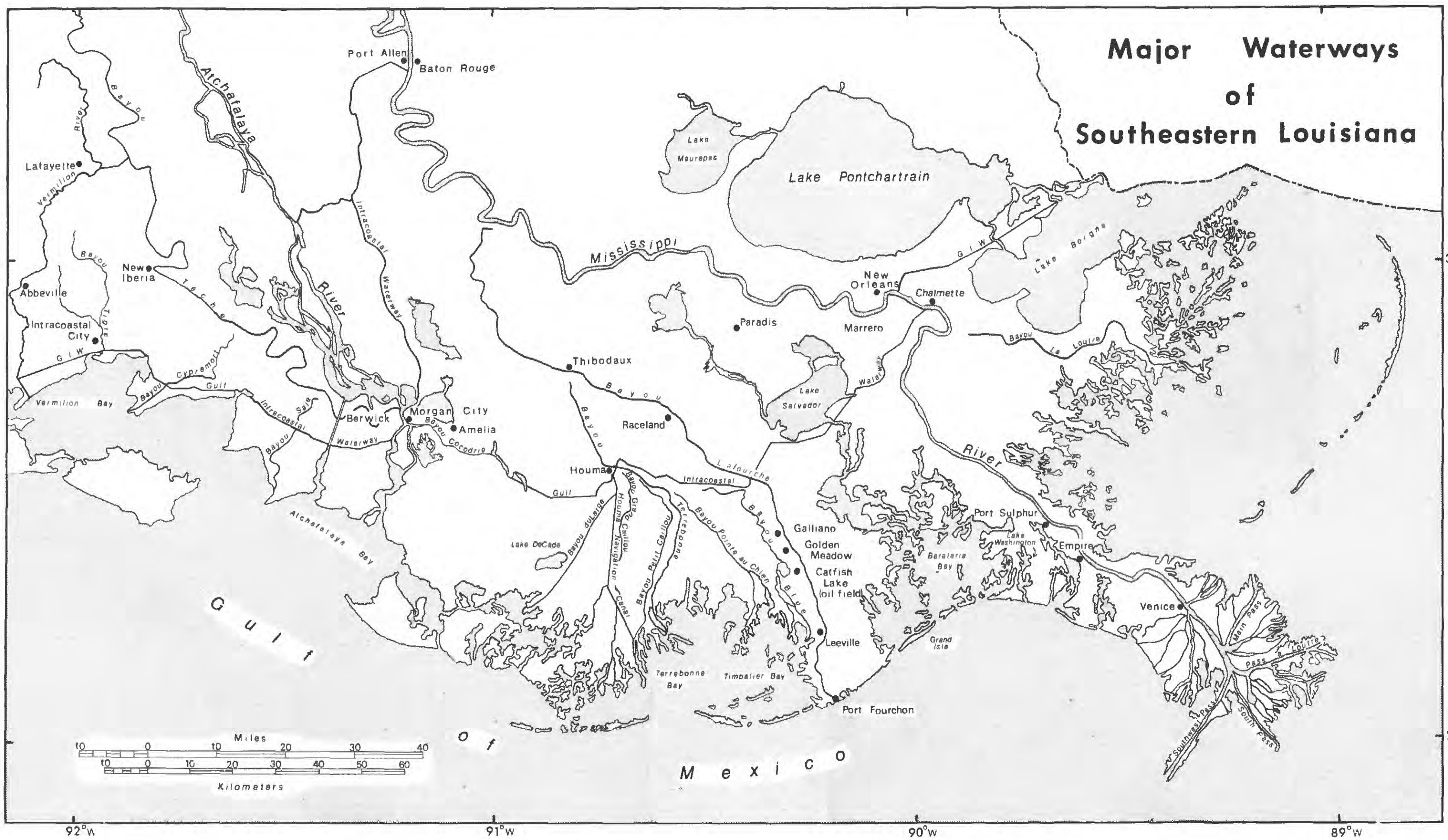


Figure 4.--Major waterways of southeastern Louisiana, primarily on the deltaic plain. Many are or were distributaries of the Mississippi River.

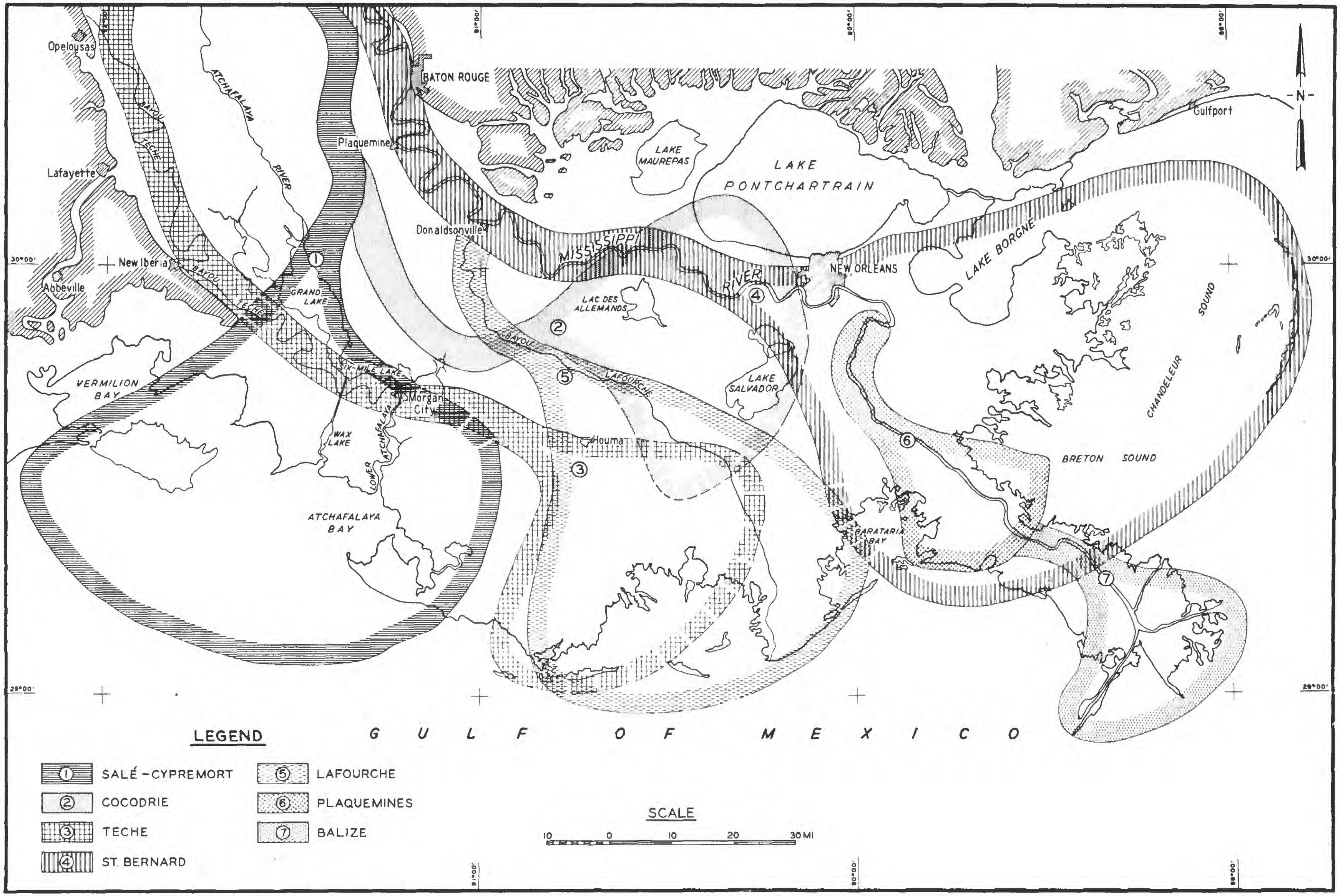


Figure 5.--The deltaic lobes responsible for the creation of the deltaic plain (Kolb and Van Lopik, 1958).

Two distinctive plant communities have influenced development of the deltaic plain by the oil and gas industry--flotant and roseau cane (Chabreck, 1970, p. 7). Flotant communities, distinguished by abundant "plant species tolerant of frequent and sustained flooding," are "anchored in a relatively thin, matted layer of decomposing vegetable debris that is either truly floating on water or supported by highly aqueous organic ooze" (Russell, 1942, p. 78-79). Roseau cane marsh communities, on the other hand, are dominated by tall grasses and reeds and essentially is land; it can support a man's weight (Russell, 1942, p. 77), while flotant "trembling prairie" is a quagmire underfoot. The ease of excavation of flotant marsh has facilitated development of networks of canals associated with the 144,900 ha classified by the USGS as extractive land, a category almost synonymous with the oil industry in coastal Louisiana.

Chenier Plain

West of the Mississippi's postglacial deltaic sequences is the chenier plain. Silts and clays from the various deltas collected in the littoral zone and were stablized by salt-tolerant vegetation to produce a mud coast. Interruptions in the progradation process allowed heavier particles to amass into ridges (cheniers) now covered by tall grasses and hardwoods (Shepard and Wanless, 1971, p. 217). These stranded beach ridges are the sites of four settlement clusters. The linear configuration of the settlements conforms to the "high ground" associated with the former beach ridges, just as the natural levees serve as nuclei for community expansion on the deltaic plain.

Land use and land cover patterns in the low-lying marsh are related to the soils and the couch or wire grass (Spartina patens) that dominate the area. Unlike the deltaic plain, the chenier plain is made up of older, more consolidated sediments and, therefore, is a distinctive physiographic unit.

Current Wetlands Processes

The change having "the most disastrous influence in the general ecology of the Louisiana coast was ... construction of the Mississippi River guide levees to provide flood protection" (Duffy, 1974, p. 7). The Mississippi has historically overflowed its banks infusing nutrient-rich freshwater into the marsh. Present dispersal of water through the leveed channels has terminated this natural process, preventing sediment deposition on the wetlands. Sediment deposition at the river's mouth has extended the modern delta into deep water. Gagliano, Myer-Arendt and Wicker (1981) feel that destructive processes (for example, erosion) outweigh the constructive elements, with the lowland region losing about 104 km^2 of land surface per year. One exception to the loss is a new delta forming in Atchafalaya Bay. Shlemon (1975, p. 209) estimates that although primarily a subaqueous feature, the young delta in the last 20 years has "more than doubled its submarine area and thickness." Unless modified, the delta "could expand across its bay at an approximate rate of 14 to 17 km^2 per year" (Shlemon, 1975, p. 209). Sedimentation will eventually create new land. Water depths will decrease thus affecting the movement of supply boats to Morgan City.

To overcome the problems associated with land loss or gain, the companies working in the marsh have used their engineering skills to maintain navigable channels, build protective bulkheads, riprap sides of eroding bayous and canals, and establish stable drilling foundations. All of these activities have influenced the wetlands, particularly salinity regimes and land loss associated with canalization, but were required to develop the region's natural resources.

LAND USE PRIOR TO OIL DEVELOPMENT

Archeological artifacts indicate that the Louisiana coastal area has been the site of continuous human occupancy for at least 12,000 years. McIntire (1958) mapped more than 500 early Indian dwelling sites. From pre-Columbian times, man has utilized the wetlands effectively--locating his settlements on protected and well-drained land, near navigable waterways and not too far from his agricultural, fishing, hunting, and trapping areas.

The 14 primary areas of well-drained land are the natural levees along the old distributaries on the deltaic plain and the remnant beach ridges on the chenier plain. They either contain roads or border waterways and are the primary settlement sites. Strips of agricultural land lie between the settlements and the wetland, occupying the remainder of the well-drained land. Virtually all industry in the area, with the exception of the oil and gas fields and other extractive mineral activities, clusters along the waterways and main roads.

Cheniers, natural levees, islands, coteaus (isolated high ground), and hammocks afforded elevated sites suitable for the establishment of permanent communities. These high ground areas supplied farmer, trapper, and fisher folk with most of the essentials for their economic existence, became the nodal points of human occupancy, and thus established the regional pattern of settlement for the petroleum industry's logistic support.

Each immigrant group settled the land according to a pattern that has been described as "marshhufendorf" (Dickinson, 1961). This type of "marsh village," first named by 12th-century Flemish settlers on the coast of northwest Europe, is a settlement form that appears in every area of North American French colonization. In Europe, it emerged in a wetlands environment reclaimed by dikes; in Louisiana, settlements followed the crests of natural levees and cheniers.

Based on the economic activity responsible for their existence, pre-1937 communities may be classified into three categories: agricultural, fishing, and trapping. Whether a single family or a population of 1,000 was involved, the residents supported themeselves directly, or indirectly, by one or more of these occupations. Often there was seasonal overlap; nevertheless, one was always dominant.

The abandoned deltaic plain communities of Mauvais Bois, Camardelle, and Manila Village are examples of marsh occupancy. At Mauvais Bois, the population lived in dispersed farmsteads dependent upon subsistence agriculture, as well as on seasonal fishing and trapping. At Camardelle the natural levee was too narrow for agriculture, so the line of settlement was supported by fishing and trapping. Manila Village was a Barataria Bay shrimp-drying village built on stilts. Until its demise, it served as a major fishing community.

Since the majority of the settlement sites in the deltaic plain were accessible only by water, they were, in a sense, isolated. In most cases, they were connected to resource areas, markets, and sources of supplies by the region's natural and manmade waterways.

The old cheniers were first settled in the 1850's. Unlike their deltaic plain counterparts, early settlers did not scatter throughout the marsh. The strips outlined in figure 1 are essentially the same as those colonized over a century ago.

A survey of USGS topographic maps dated 1930-40 discloses that the alluvial wetlands supported in excess of 350 settlements, ranging from single-family units to large well-organized communities. Like the prehistoric Indian dwelling places (Kniffen, 1935, p. 5-12; 1936, p. 407-418; 1938, p. 189-206; McIntire, 1958), each site indicates the use of the marsh and predates the economic emphasis on exploration of oil and gas resources. They indicate that Louisiana's fishermen and trappers were aware of their environment and developed skills that allowed them to harvest the aquatic-dependent wildlife. Their maritime culture traits proved to be a valuable asset in providing the petroleum industry's logistic support.

LOUISIANA OIL AND GAS INDUSTRY

With the ever-increasing demand for petroleum products, oilmen have been drilling in areas previously considered economicallly unfavorable. Working in coastal marshes and then farther and farther offshore on the Outer Continental Shelf, oilmen are now drilling on leases more than 300 km from logistic support bases, in water more than 300 m deep (Carmichael, 1975, p. 233). From both onshore and offshore fields in 1980, Louisiana supplied 15 percent of the Nation's domestically produced petroleum and 35 percent of the natural gas (U.S. Department of Commerce, 1981, p. 739).

Land use and land cover maps (U.S. Geological Survey Open-File Reports 75-244, 245, and 246) show the location of large industrial sites and principal waterways (fig. 6), and all extractive industrial (fig. 7) areas larger than 4 ha in the center of Louisiana's Gulf Coast in 1972. Figure 6 illustrates the location of industrial buildings and transportation facilities along Louisiana's waterways. A total of 235,500 ha of this onshore district was utilized for mineral extraction, virtually all of it for oil and gas. Such extractive operations have modified the landscape. Overlaying the map of extractive sites with a map of wetlands reveals that 96 percent of the large onshore oil and gas fields (about 226,000 ha) lies within the wetlands.

Onshore Activity

In August 1901, W. Scott Heywood drilled the first producing oil well in south Louisiana (Posgate, 1949, p. 87). Other wildcatters followed, but their interest was short lived. Three years later the search moved to Caddo Lake in extreme northwestern Louisiana; exploration in southern Louisiana was temporarily abandoned (Oil and Gas Journal, 1950, p. 267).

Equipment brought by barge on the Mississippi and Red Rivers was used to explore Caddo Lake. Once towed into position, a piling-supported derrick was used to drill for oil (Londenberg, 1972, p. 56). After numerous dry holes, a major pool was discovered in May 1911; America's

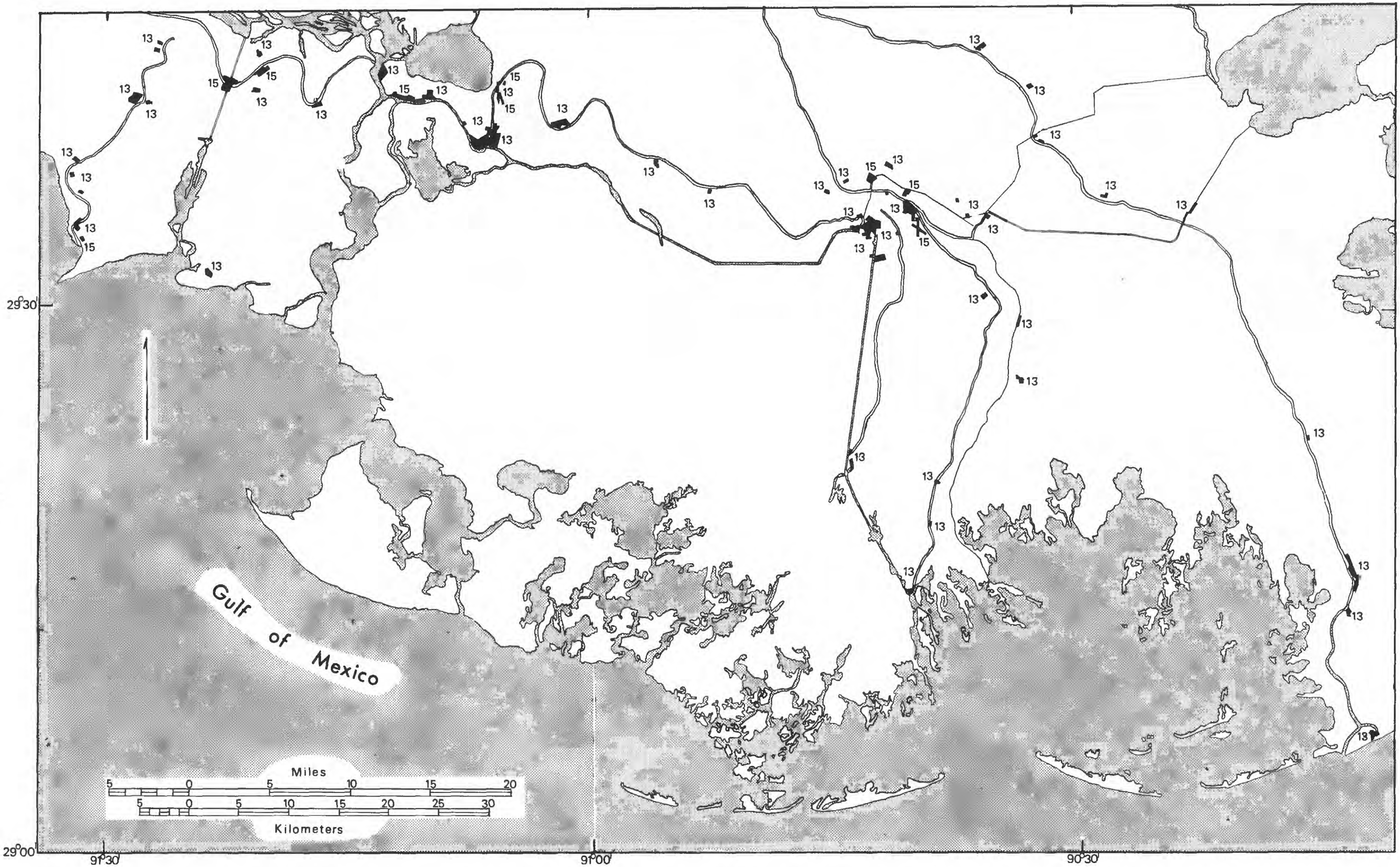


Figure 6.--The 1972 distribution of principal industrial sites (land use categories 13 and 15) in the western part of the deltaic plain, illustrating their proximity to navigable waterways. (Category 13 is Industrial and Category 15 is Transportation, Communications, and Utilities) (from USGS Land Use and Land Cover Map, Open-File Report 75-245).

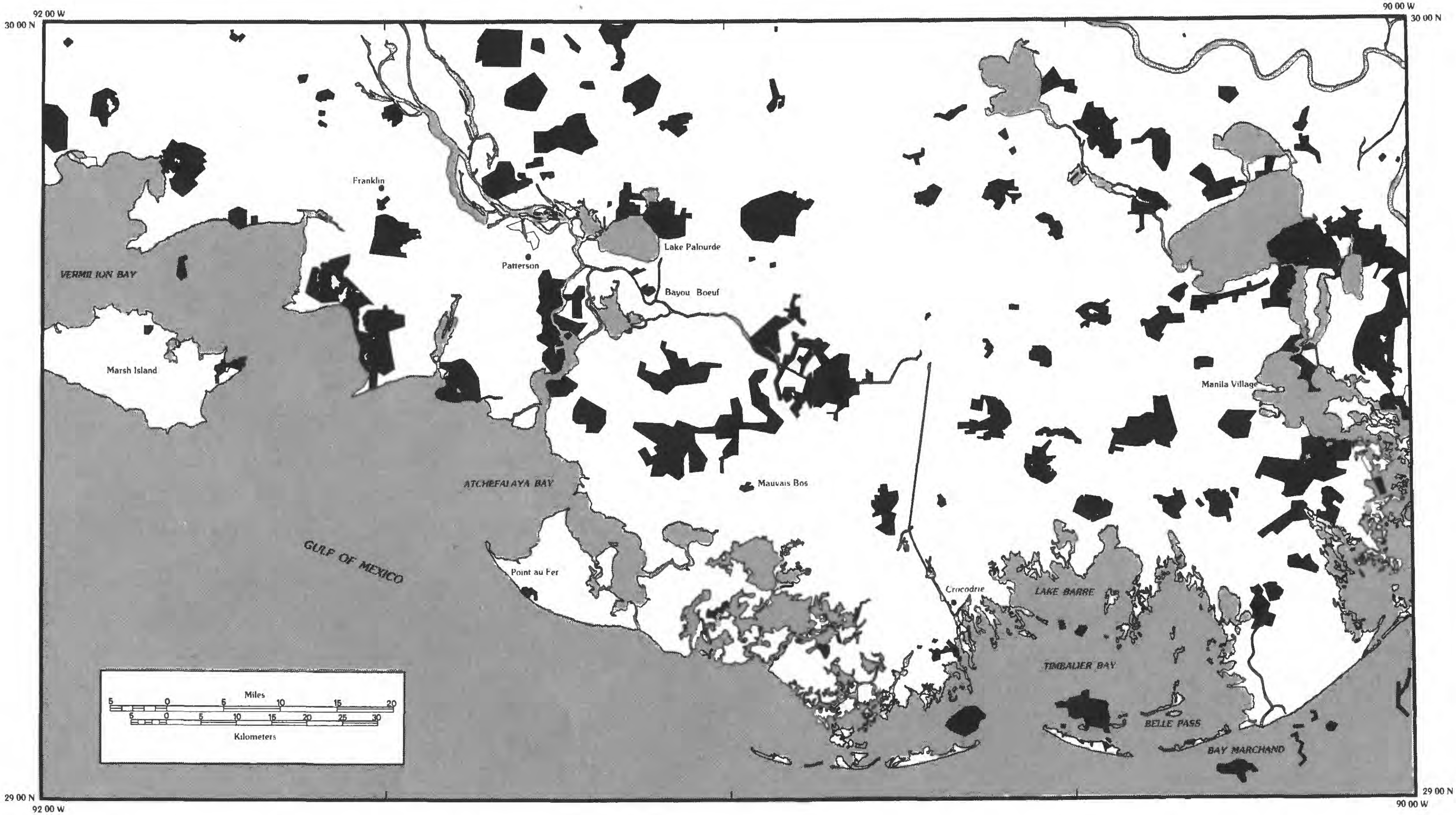


Figure 7.--The 1972 extractive land use. Major oil and gas fields in south-central Louisiana are shown in black. Nearly all of these are in marsh (from USGS Land Use and Land Cover Map, Open-File Report 75-245).

first subaqueous oil well had been completed (Mid-Continent Oil and Gas Association, 1975, p. 6). The Caddo Lake field became the most prolific in Louisiana, setting the pace for exploratory drilling. It was 30 years before southern Louisiana petroleum production exceeded that of the Caddo Lake region.

On the coastal plain, discoveries at Spindletop in Texas and at Jennings, Louisiana confirmed the region's hydrocarbon potential, particularly in stratigraphic traps associated with salt domes. Exploration for and development of these structures was hampered by the logistics and economics of operating in the coastal wetlands. Between 1901 and 1923 only eight discoveries were made. With advances in geophysical exploration in the 1920's, renewed interest was shown in the swamps and marshes. As a result, by 1928, 28 domal features had been mapped using seismic methods (Posgate, 1949, p. 87). Several fields were producing, but only the Lafitte, Big Lake, and Turtle Bay fields were in isolated aquatic areas (Flude, 1936, p. 142).

Wetland exploration requires boats and other floating equipment to gain access to drilling sites. Oilmen needed port facilities to support their waterborne operations, service their fleet, and store other supplies needed to work in the wet areas of south Louisiana.

Drilling firms working in the wetland had to pioneer new exploratory methods. They needed fleets of floating vessels to service their tracts. Where no naturally occurring water routes existed, canals were dug to drilling sites using powerful suction and bucket dredges. More than 50,000 m^3 of material was moved per kilometer of canal. The completed network was worth the expense because the operators were assured lease access (Oil and Gas Journal, 1942, p. 59; and 1955a, p. 122).

Activity in the marshland was handicapped by the lack of a stable derrick support due to the soil's low load-carrying ability. Techniques changed when exploration moved from ground capable of supporting 15,000 kilograms per square meter to water-saturated marshy areas capable of supporting only 1,200 kg/m^2. Flotant is so soft that it functions more like quicksand than soil, intensifying the industry's engineering problems. To compensate for the region's poor load-bearing capacity, two foundation types were initially tried, mats and pilings (Herbert and Anderson, 1936, p. 32, 40).

To eliminate the cost of erecting special foundations, some firms began to use barges. In the Lake Barre area, one company utilized a floating drilling unit (Williams, 1934, p. 14). The creation of submersible barges as mobile drilling platforms signalled a new era of exploration.

By the late 1920's large marsh tracts were under lease to a company that wanted to drill into the subsurface domes from a moveable base. The firms needed "a barge equipped with derrick and equipment, which could be floated to the necessary location, flooded and submerged to rest on the bottom" (Londenberg, 1972, p. 56). The barge provided a stable support that could be refloated and quickly towed to another site reducing nonproductive time. The company discovered a barge invented by Louis Giliasso in 1928 (Londenberg, 1972, p. 56) and patented in the United States and Venezuela (Williams, 1934, p. 14). In 1933, Giliasso's barge was brought down the Ohio and Mississippi to begin drilling in southern Louisiana. Previously, 17 days were required to position a derrick; the barge needed a maximum of 2 days. Once in place, well completion averaged 64 days. From the submersible drilling barge, 5 1/2 wells could be drilled per year.

Drilling

An examination of exploration and development statistics reveals the success of drilling in southern Louisiana. In the 41-year period recorded in figure 8, a total of 27,691 wells were drilled.

The International Oil Scouts Association (1937-78), referenced in figure 8, indicates 28 percent of all wildcat (exploratory) operations have been successful in southern Louisiana in discovering new oil (10 percent) and gas (18 percent) fields (table 1).

Table 1.--Exploratory wells in southern Louisiana by Parish[1/] for selected periods.

OIL

	C	I	J	L	P	S	T	V	Total
Up to 1938	0	0	0	0	0	0	0	0	0
1939-43	0	2	1	1	4	3	3	3	17
1944-48	2	0	5	1	2	1	3	0	14
1949-53	12	7	7	14	32	10	14	1	97
1954-58	11	11	13	22	45	11	41	11	165
1959-63	9	11	9	21	44	19	15	16	145
1964-68	8	2	7	16	24	7	16	9	89
1969-73	7	5	5	14	5	7	7	5	55
1974-77	8	2	3	12	2	0	6	6	39
Total	57	41	50	101	158	58	105	51	621

GAS

	C	I	J	L	P	S	T	V	Total
Up to 1938	0	0	0	0	0	0	0	0	0
1939-43	3	1	0	2	1	1	4	2	14
1944-48	1	1	3	0	2	0	2	0	9
1949-53	11	4	0	10	12	3	32	7	79
1954-58	27	19	8	51	29	13	59	49	255
1959-63	39	9	7	39	18	32	44	52	240
1964-68	27	16	9	28	10	23	34	26	173
1969-73	30	13	5	25	12	25	58	49	217
1974-77	23	12	3	25	19	10	26	63	181
Total	161	75	35	180	103	107	259	248	1,168

DRY

	C	I	J	L	P	S	T	V	Total
Up to 1938	7	1	0	0	0	0	1	2	11
1939-43	16	12	4	9	4	17	18	6	86
1944-48	25	9	7	15	13	15	27	10	121
1949-53	43	16	18	30	91	32	42	32	304
1954-58	105	48	66	181	145	65	163	108	881
1959-63	128	42	63	140	180	99	167	193	1,012
1964-68	120	43	50	117	145	65	144	107	791
1969-73	184	49	40	92	85	66	154	129	799
1974-77	123	42	29	104	60	50	112	57	577
Total	751	262	277	688	723	409	828	644	4,582

C - Cameron Parish
I - Iberia Parish
J - Jefferson Parish
L - Lafourche Parish
P - Plaquemines Parish
S - St. Mary Parish
T - Terrebonne Parish
V - Vermilion Parish

Total exploratory wells --------	6,371
Percent oil wells successful -	10
Percent gas wells successful -	18
Percent dry holes -------------	72
Average number of exploratory wells per year - ------------	155

Source: Data compiled from National Oil Scouts Association of America Year Book, published consecutively from 1937-39, v. VII-IX, and Oil and Gas Field Development: National Oil Scouts and Landsmen's Association Year Book, published consecutively from 1940-59, v. X-XXIX and International Oil and Gas Development: International Oil Scouts Association Year Book, Part I - Exploration, published consecutively from 1960-78, v. XXX-XLVIII.

1/ In addition to these eight parishes, the Parish of St. Bernard also had some exploration, primarily between 1938 and 1940 when drilling produced 7 oil wells, 16 gas wells and 210 dry holes.

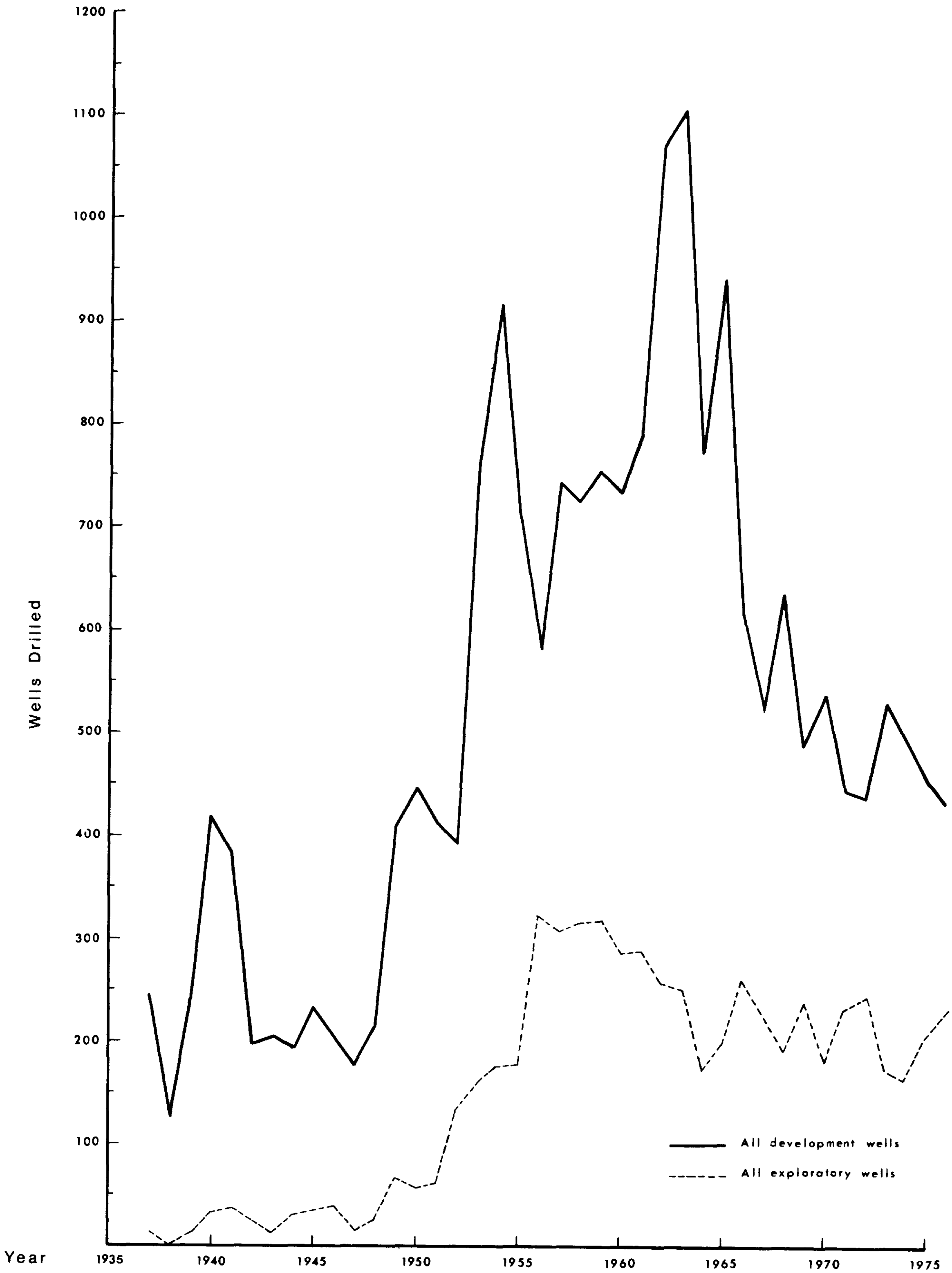


Figure 8.--Exploratory and development wells drilled onshore in southern Louisiana between 1937 and 1977.

Source: Data compiled from National Oil Scouts Association of America Year Book, published consecutively from 1937-39, v. VII-IX, Oil and Gas Field Development: National Oil Scouts and Association Year Book, published consecutively from 1940-59, v. X-XXIX and International Oil and Gas Development: International Oil Scouts Association Year Book, Part I - Exploration, published consecutively from 1960-78, v. XXX-XLVIII.

In developing these new fields, the industry, as of December 1978, had drilled 21,320 wells. Table 2 shows 76 percent were successful field extensions--61 percent associated with oil and 15 percent with gas.

Table 2.--Development wells in southern Louisiana by parish[1/] for selected periods.

OIL

	C	I	J	L	P	S	T	V	Total
Up to 1938	44	45	12	36	9	54	40	9	249
1939-43	131	86	55	241	155	218	60	67	1,013
1944-48	34	19	69	184	169	68	99	78	720
1949-53	68	149	104	386	565	104	239	25	1,640
1954-58	186	166	121	506	689	242	428	66	2,404
1959-63	164	120	223	536	877	320	625	61	2,926
1964-68	133	28	102	321	799	231	464	41	2,119
1969-73	104	50	95	171	270	222	249	23	1,184
1974-77	104	44	19	107	180	122	153	19	748
Total	968	707	800	2,488	3,713	1,581	2,357	389	13,003

GAS

	C	I	J	L	P	S	T	V	Total
Up to 1938	0	0	0	0	0	3	0	0	3
1939-43	9	2	2	11	3	14	5	10	56
1944-48	4	1	5	17	14	11	16	13	81
1949-53	47	23	9	45	45	21	72	31	293
1954-58	103	42	13	95	47	59	149	74	582
1959-63	70	49	13	116	107	84	212	71	722
1964-68	78	31	8	63	54	79	120	55	488
1969-73	64	29	36	75	80	71	194	55	604
1974-77	55	35	21	55	64	56	120	43	449
Total	430	212	107	477	414	398	888	352	3,278

DRY

	C	I	J	L	P	S	T	V	Total
Up to 1938	33	17	0	7	28	22	9	6	122
1939-43	71	48	17	78	24	71	37	26	372
1944-48	10	10	21	59	26	28	45	17	216
1949-53	59	69	51	130	202	50	99	25	685
1954-55	90	63	37	151	130	61	121	46	699
1959-63	122	36	67	160	148	55	170	96	854
1964-68	138	44	47	156	143	82	170	109	889
1969-73	106	61	42	98	99	58	139	47	650
1974-77	84	38	38	65	104	53	96	74	552
Total	713	386	320	904	904	480	886	446	5,039

C - Cameron Parish
I - Iberia Parish
J - Jefferson Parish
L - Lafourche Parish
P - Plaquemines Parish
S - St. Mary Parish
T - Terrebonne Parish
V - Vermilion Parish

Total development wells -------	21,320
Percent oil wells successful --	61
Percent gas wells successful --	15
Percent dry holes ------------	24
Average number of development wells per year --------------	520

Source: Data compiled from National Oil Scouts Association of America Year Book, published consecutively from 1937-39, v. VII-IX, Oil and Gas Field Development: National Oil Scouts and Landsmen's Association Year Book, published consecutively from 1940-59, v. X-XXIX and International Oil and Gas Development: International Oil Scouts Association Year Book, Part I - Exploration, published consecutively from 1960-78, v. XXX-XLVIII.

1/ In addition to these eight parishes, the Parish of St. Bernard also had some development, primarily between 1938 and 1940 when drilling produced 80 oil wells, 16 gas wells and 26 dry development wells.

Between 1937 and 1970, well output generally increased, but since 1970, it shows a definite downward trend (tables 3 and 4). The coastal parishes, in 1970, produced 120,757 thousand m^3 of oil and 172,845 million m^3 of gas (table 4). By 1980, production had dropped drastically to only 20,774 thousand m^3 of oil and 52,283 million m^3 of natural gas--reductions of 83 and 70 percent, respectively.

Louisiana's coastal lowlands are now in a mature stage of oil and gas development, and significant new discoveries are becoming a rarity. Woltz (1979, p. 1360-1361) reports that in 1978 field extensions dominated south

Table 3.--Crude oil, including condensate, production, in thousands of m^3, southern Louisiana by parish for selected years.

YEAR	CAMERON	IBERIA	JEFFERSON	LAFOURCHE	PLAQUEMINES	St. MARY	TERREBONNE	VERMILLION	TOTAL
1938	1,075	852	932	659	316	620	1,421	60	5,935
39	1,013	693	758	730	465	463	1,030	69	5,521
1940	1,350	569	803	1,260	831	761	846	87	6,507
41	1,507	566	905	1,424	1,313	632	790	176	7,313
42	1,352	476	796	1,279	1,346	654	633	249	6,785
43	1,407	554	975	1,384	1,693	818	940	372	8,143
44	1,374	620	940	1,437	1,998	985	1,162	1,165	9,731
45	1,198	607	980	1,561	2,096	984	1,218	1,588	10,232
46	1,128	631	1,156	1,577	2,152	1,177	1,199	1,667	10,687
47	1,160	720	1,329	1,766	2,483	1,475	1,336	1,623	11,892
48	1,186	951	1,458	2,268	2,802	1,673	1,610	1,585	13,533
49	1,004	1,197	1,629	2,533	2,955	1,784	1,759	1,309	14,170
1950	1,004	1,605	1,521	3,271	3,669	1,762	2,054	1,252	16,138
51	1,042	2,155	1,653	3,524	4,839	2,036	2,480	1,390	19,119
52	1,164	2,560	1,644	3,717	5,352	2,144	2,705	1,343	20,629
53	1,334	2,733	1,623	4,067	6,237	2,191	3,265	1,312	22,762
54	1,333	2,351	1,451	4,036	6,832	2,054	3,263	884	22,204
55	1,537	2,402	1,729	4,433	8,243	2,280	3,577	894	25,095
56	1,870	2,523	1,802	4,854	10,865	2,751	3,872	937	29,474
57	2,128	2,593	1,867	5,663	12,625	3,148	4,464	1,101	33,589
58	1,972	2,141	2,124	5,425	12,073	3,243	4,690	1,162	32,830
59	2,052	2,330	2,673	6,353	14,207	3,975	6,136	1,306	39,032
1960	2,158	2,655	3,065	7,396	15,680	4,655	7,223	1,465	44,297
61	2,156	2,618	3,254	8,546	16,605	5,412	7,870	1,674	48,135
62	2,499	2,633	3,952	10,451	18,952	5,861	9,656	2,083	56,087
63	2,973	2,496	4,314	11,999	21,018	6,096	10,383	2,179	61,458
64	3,137	2,500	4,699	12,229	23,454	6,439	11,377	2,304	66,139
65	3,159	2,639	5,056	13,123	27,121	7,251	12,089	2,437	72,874
66	3,394	3,007	5,539	15,062	32,783	8,322	13,518	3,088	84,713
67	3,539	4,310	6,336	17,795	38,108	9,989	15,569	3,536	99,182
68	3,543	4,867	7,282	18,706	41,075	10,255	16,800	4,056	106,584
69	3,877	5,389	8,000	18,931	41,405	10,727	18,354	4,332	111,015
1970	4,147	5,396	8,437	20,025	45,805	11,760	20,501	4,686	120,757
71	3,544	4,349	8,395	15,322	41,352	9,057	13,975	3,058	99,052
72	2,708	4,101	3,078	10,280	26,989	6,909	11,431	2,879	68,375
73	2,340	3,611	2,535	9,389	24,234	5,504	9,872	2,925	60,511
74	2,112	2,993	1,853	8,114	20,157	4,888	7,523	2,410	50,050
75	1,894	2,331	1,778	6,343	15,475	3,696	6,391	1,958	39,866
76	1,742	2,151	1,593	5,420	12,172	2,900	5,714	1,612	33,304
77	1,684	2,142	1,335	4,604	10,958	2,436	5,206	1,483	29,848
78	1,548	1,693	1,258	4,323	10,075	2,063	4,477	1,417	26,854
79 1/	1,502	1,355	1,071	3,669	8,958	1,672	3,684	1,388	23,299
1980 1/	1,444	1,138	901	3,107	8,274	1,393	3,140	1,377	20,774

1/ Not official--subject to audit.

Source: Data was compiled from the 14-21st Biennial Reports published consecutively from 1938-53, and the Annual Oil and Gas Reports published consecutively from 1953-78 by the State of Louisiana Department of Conservation, New Orleans. Data for 1979 and 1980 are from the State of Louisiana Department of Conservation's open file reports.

Louisiana's exploration pattern, with only seven new field discoveries. Not only has drilling activity declined, but onshore leases have also decreased (Woltz, 1979, p. 1365).

Pipeline Networks

The historical expansion of the network of oil and gas pipelines affecting the coastal wetlands have been studied for the years 1941, 1951, 1964, and 1973. Most of these pipelines connect the fields with the processing and transportation centers.

The 1941 record reveals only a few kilometers of pipelines. The most notable are those extending from Raceland through the Paradis field to the Mississippi River and the 80-km gas line extending from Lake Washington, in Plaquemines Parish, through Lafitte to Marrero. In the

Table 4.--Gas including casinghead, production, in millions of m^3 in southern Louisiana by parish for selected years.

YEAR	CAMERON	IBERIA	JEFFERSON	LAFOURCHE	PLAQUEMINES	St. MARY	TERREBONNE	VERMILLION	TOTAL
1938	56	25	179	80	21	27	69	11	468
39	89	25	164	155	39	45	131	38	686
1940	150	28	170	202	52	67	200	56	925
41	253	33	201	383	195	32	263	129	1,489
42	249	51	155	585	250	359	618	136	2,403
43	223	56	179	887	306	438	885	207	3,181
44	356	66	172	983	345	474	1,114	1,647	5,157
45	412	90	200	1,003	398	552	1,231	2,313	6,199
46	458	111	241	813	465	897	1,108	2,501	6,594
47	503	141	295	827	560	975	1,264	2,747	7,312
48	604	184	429	971	606	1,018	1,503	25,316	30,631
49	543	204	453	1,047	603	1,084	1,394	2,526	7,854
1950	586	280	392	1,164	766	1,037	1,644	2,433	8,302
51	978	404	385	1,253	1,041	1,381	1,735	7,884	15,061
52	1,744	560	370	1,389	1,273	2,316	2,413	1,819	10,884
53	1,891	953	404	1,969	1,438	1,629	3,810	1,988	14,082
54	1,185	1,036	449	2,155	1,759	2,180	4,009	2,251	15,924
55	3,397	1,180	562	2,814	2,191	2,941	4,830	3,109	21,024
56	4,513	1,447	623	2,732	2,990	2,972	5,710	3,682	24,669
57	5,895	1,586	667	3,846	3,811	2,868	6,283	4,754	29,710
58	7,326	1,453	813	4,499	4,643	3,235	6,880	5,932	34,781
59	9,394	1,942	953	5,322	5,619	3,548	8,198	6,819	41,795
1960	10,568	2,655	926	5,932	6,728	4,628	9,266	7,560	48,263
61	10,227	2,624	1,011	6,502	7,446	5,320	9,670	8,939	51,739
62	11,000	2,973	1,468	7,237	8,771	6,217	11,792	11,287	60,745
63	12,450	3,005	1,550	7,797	10,547	7,444	13,666	12,339	68,798
64	13,247	3,196	1,511	8,008	11,842	8,709	15,958	13,149	75,670
65	12,981	3,224	1,512	8,371	15,856	11,727	17,378	13,785	84,834
66	15,108	3,706	1,878	9,574	20,997	13,814	21,427	15,581	102,145
67	15,534	6,355	2,125	10,844	24,592	16,336	23,085	19,452	119,323
68	18,154	8,542	2,272	12,447	29,773	17,464	25,342	22,192	136,186
69	22,606	11,527	2,304	13,119	29,455	20,492	33,874	24,397	157,744
1970	5,642	11,391	2,004	12,336	29,193	24,372	38,974	27,953	172,845
71	16,223	8,094	3,333	11,270	28,366	19,265	30,264	23,455	140,270
72	11,601	9,505	2,379	10,037	23,847	17,943	28,745	20,883	124,940
73	10,112	8,722	2,156	9,273	21,828	16,846	27,025	20,594	116,556
74	8,794	8,478	1,652	7,975	18,731	15,101	23,262	15,844	99,837
75	7,511	8,876	1,517	6,651	14,052	12,602	19,485	12,180	82,875
76	5,740	9,527	1,450	6,087	10,368	12,502	17,267	9,549	72,490
77	5,734	8,635	1,362	5,956	9,054	12,365	16,564	8,299	67,970
78	5,507	8,458	1,400	5,767	8,127	11,793	15,201	7,470	63,723
79 1/	5,886	8,265	998	4,779	7,646	11,324	13,265	7,740	59,904
1980 1/	5,208	6,996	993	4,340	7,070	9,269	11,290	7,117	52,283

1/ Not official--subject to audit.

Source: Data was compiled from the 14-21st Biennial Reports published consecutively from 1938-53, and the Annual Oil and Gas Reports published consecutively from 1953-78 by the State of Louisiana Department of Conservation, New Orleans. Data for 1979 and 1980 are from the State of Louisiana Department of Conservation's open file reports.

industry's infancy, pipelines began to replace the region's natural waterways in moving petroleum and natural gas (Oil and Gas Journal, 1937, p. 183).

Murchison and Patton (1951, p. 1338) reported the discovery of 6 fields, 9 important extensions, and 31 new pools by 1950 (p. 1341-1342). Within Plaquemines, St. Mary, Terrebonne, and Lafourche Parishes, the 1951 pattern of nearly 100 km of marsh pipelines had become particularly intricate. A 145-km gas line connected oil wells at the mouth of the Mississippi River to Chalmette (Petroleum Engineer, 1951a, p. D-40). The longest line crossing the marsh is the 570-km "Muskrat Line" going through "swamps, bays and marshland for 80 percent" of its length (Resen, 1956, p. 188). The 12-m wide, 2.4-m deep canal that follows the pipeline right-of-way is a prominent landscape element.

By 1960 the petroleum industry had demonstrated renewed interest in southern Louisiana, primarily because 34 percent of the wildcatting operations between 1952 and 1960 had been successful (Jarrell, 1960, p. 221). Large and small operators were continuing to drill in the wetlands. The pipeline network began to have a definite pattern with numerous lines sharing the same rights-of-way. When compared to the 1941 network, it is apparent that the 1950's and early 1960's were years of intensified exploration and development activity. The chenier plain became at that time a significant source of natural gas with 10- to 40-cm pipelines for transport. On the deltaic plain the principal resource is oil and an extensive pipeline network connects the production sites to the market.

From the mid-1960's through the early 1970's, the oil and gas fields of Louisiana's coastal zone were extended. By 1973, pipeline patterns had coalesced to form a complicated array of lines. Between 1964 and 1973, onshore drilling had declined compared with the previous period, but the success rates for both exploratory and development wells remained relatively constant. Between 15 and 25 percent of the exploratory wells, and from 65 and 82 percent of the development wells were successful (Eldred and Johnson, 1965, p. 711; Johnson and Boutte, 1980, p. 1445).

Pipelines now commonly share rights-of-way. A major concentration extends from Franklin through Morgan City, Houma, and Raceland to the Mississippi. Several gas transmission lines, 51 to 86 cm in diameter, parallel the coast from the delta across Lake Pontchartrain. On the chenier plain, the network connects the offshore fields to lines extending north.

Canal Network

A detailed map of the Louisiana marsh-swamp complex shows the intricacy of the pattern of artificial waterways. Some are wide and some narrow, but they have in common a straightness of course that distinguishes them from natural waterways. Too small to be recorded on the USGS maps of land use and land cover published at a scale of 1:250,000, the petroleum-related canal network nevertheless has great significance in southern Louisiana. The "one well, one canal" technique enlarged the fields and intensified the canals' regional impact.

Resulting from the intensity of construction activities, a region nearly the size of New Jersey has been crisscrossed and ringed by a massive network of manmade waterways. These routes are a cohesive, regionally organized system, constructed to meet local needs. New channels have been added continually, but old ones were rarely filled-in; thus, the complex network continued to interwine and expand into a complicated web. Once a canal was cut, it endured. Theoretically, its duration was finite, but some have enlarged into straight-channeled bayous.

Cutting of canals into the wetlands began with the earliest European settlers and continues to the present. Canals are necessary because of the difficulty, and often impossibility, of building roads in such an area. If the canals have been a boon to transport, they have also created problems, such as altering wetland flow regimes, water chemistry, and increasing saltwater intrusion into previously freshwater areas. A most conspicuous effect is the decrease in land area, permanently altering the coastal zone's natural appearance. In one 43-km^2 area, there are 68 km of petroleum-related canals. Excavation of this system required the removal of at least 3,400,000 m^3 of material. The new channels represent a significant change in the land to water ratio.

Barrett (1970, p. 1) measured more than 7,300 km of canals south of the Intracoastal Waterway in Louisiana, a network larger than the entire United States had in 1860. His computations of the length multiplied by an average width of 23 m indicate that 171 km^2 of land area were lost to canalization. Gagliano (1973, p. 5), using a series of historical maps to assess change in land/water ratios, determined that land loss amounted to 490 km^2. Although the calculations differ due to techniques and area studied, the figures show the magnitude of land lost to excavation.

To understand the geographic growth and development of the canals associated with this land loss, the manmade channels may be classified into five categories according to principal function or use: (1) drainage and reclamation, (2) trapping, (3) logging, (4) petroleum exploration and development, and (5) general transportation.

Drainage, Trapping, and Logging Canals

Marsh and swamp drainage ditches were excavated by French planters as early as 1720 to drain potential crop and pasture land. In many cases, drainage canals also served as transportation routes as flood- and water-control methods extended cultivation beyond the limits of natural levees and into the wetlands. Today, several drainage canals are major transportation arteries, thus transcending their original function.

Early drainage programs were limited to small areas. Technological problems precluded large reclamation projects. Such projects were not initiated until after 1900 when enterprising investors purchased extensive tracts for polderization; their efforts, however, were unsuccessful (Harrison and Kollmorgan, 1947, p. 668). Of approximately 50 attempted projects (Okey, 1914, p. 3), only five are still utilized for agriculture. The distinctive canal patterns remain as sole evidence of the abandoned farms.

Even though marsh reclamation was a failure, water levels are still being controlled from pumping stations. With new agricultural or urban and built-up land being cleared, diked, and drained, engineers are continuing the process begun in the 1700's. As the region's population was expanded by the "transients" attracted to the oil fields, new subdivisions were required. Between 1940 and 1970, the populations of Houma, Morgan City, New Iberia, and Thibodaux increased significantly, with most of this expansion occurring in the "boom years" of offshore exploration and development. Houma, for example, had a 96-percent increase in its population between 1950 and 1960 (Bobo and Charlton, 1974, p. 37-38). To accommodate this growth, new land had to be cleared, often requiring drainage or flood-control projects.

Not only have the large cities benefited from drainage projects, but so have the 14 settlement strips shown in figure 1. The unique, often linear, agricultural patterns of the strips are a product of drainage reclamation programs (fig. 9). The canals included in each strip have been equally important in protecting many low-lying communities from the

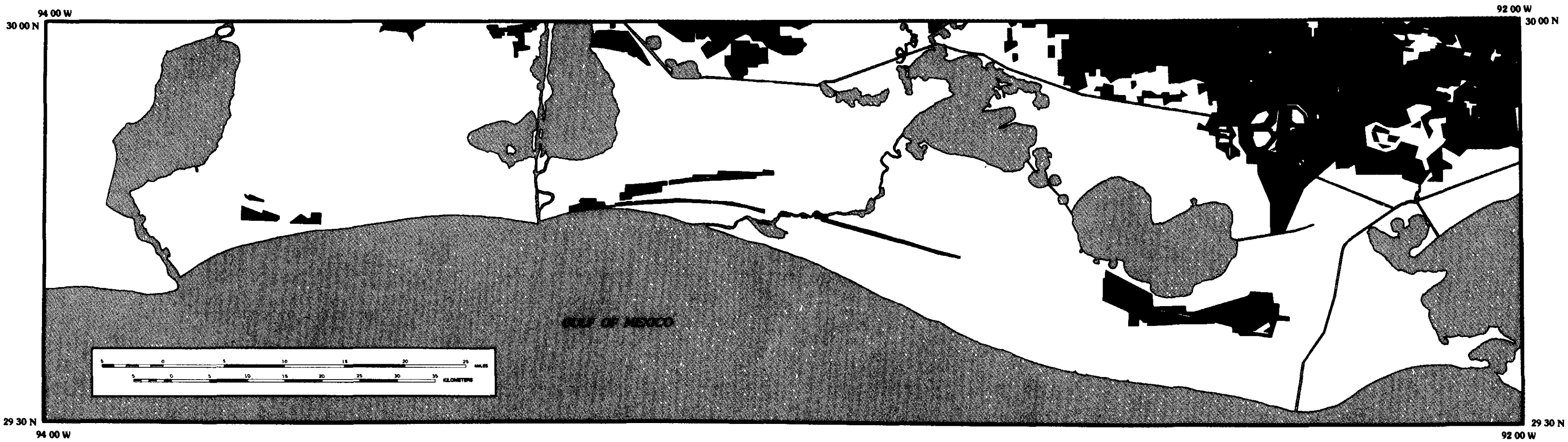


Figure 9.--Agricultural land use (black areas) in southwestern Louisiana in 1972. The coastal wetland of the chenier plain is unfavorable for agriculture except on the old beach ridges and the higher, better-drained inland areas. (From USGS Land Use and Land Cover Map, Open-File Report 75-244).

flooding which often accompanies summer thunderstorms. Flood control, or "guide levees," provide an easily identified boundary between agricultural land and marsh. Whatever the purpose, canals and ditches have contributed to the extension, in length and width, of these linear features.

A unique canal type is the traînasse, a term derived from a French word meaning "to drag," but used locally as a "trail cut through the marsh grass for the passage of a pirogue" or shallow-draft canoe (Read, 1937, p. 74). These pirogue trails, 1-1/2 m wide and 15 to 30 cm deep, provided sufficient access for trapping of muskrat and other animals. Although small, and therefore not shown on land use and land cover maps, these trails are more than channels used for irrigation or drainage, they are a significant factor in the marsh dweller's systematic exploitation of the environment.

To trap efficiently, a large number of traînasse were hacked through the marsh, resulting in an impressive network of manmade waterways. The traînasse pattern created by these trapper-fisher folk represents the first large-scale marsh canalization, often providing the only access routes to potential drilling sites. The trails, at times, were used by seismic crews searching for hydrocarbon traps in the subsurface structure.

Many channels began as small traînasse, which, through repeated use, storms, and current flow, enlarged into permanent features having a unique impact on the wetland's landscape. Many have become important transportation arteries for the petroleum industry's fleet. Any indication of their manmade origin lies only in their straightness and relationship to the natural waterways (Davis, 1976, p. 359).

The swamp, unlike the marsh, was significant for its forest resources, particularly cypress. In harvesting the region's timber, lumber companies were confronted with the problems of access to, and removal of timber, which were solved by excavating canals (Davis, 1975, p. 34-35). As relict waterways, logging canals are still a part of the landscapes of Iberia, Lafourche, St. Mary, and Terrebonne Parishes. For over 50 years, logging channels were essential to the forest industry, but as the cypress was depleted, logging operations ceased. Only the canals and pull-boat scars remain.

The persistence of the logging canals is a visible example of what will happen when southern Louisiana's hydrocarbon resources are exhausted. The canals may then have little commercial value other than to serve the region's sportsmen.

Petroleum Canals

Near the end of the logging period, oilmen began to consider seriously the coastal zone's potentials. The success of the barge Giliasso marked the start of expanded exploration activity and set the pattern of wetland drilling. By 1940, coastal Louisiana "showed an advance in both the number and quality of new petroleum areas uncovered," particularly in the unexplored delta territory (Brace, 1941, p. 1004).

To maximize the submersible drilling barge's potential, the industry needed to provide more access canals. In 1938 a barge-mounted dragline went into the marsh and dug "the first drilling site ever prepared by floating equipment" (McGhee and Hoot, 1963, p. 150), thus opening the coastal lowlands to petroleum development. Actually, the oldest petroleum-related canal was built 12 years earlier at Venice in Plaquemines Parish, an event that went virtually unnoticed (W. P. Villere, oral commun., 1971). The Venice field is now identified by a 13-km canal, outlining a circle 4 km in diameter and encompassing more than 4,000 ha. More than 50 branch canals join the circle, each representing a drilling site. The pattern outlines a subsurface salt dome (Oil and Gas Journal, 1955a, p. 122), and has become one of the coastal zone's best examples of canalization.

Four types of equipment are used in petroleum-related dredging: hydraulic or suction dredges; bucket dredges; spud barges outfitted with portable draglines; and dragline-equipped marsh buggies.

Hydraulic dredges are the most familiar type of excavator used in dredging. This efficient dredge not only cuts into the bottom with large rotating cutterheads, but discharges the material into spoil areas parallel to the channel. The artificial levees are covered eventually by trees, giving the canal a distinct appearance.

Access canals are excavated almost exclusively by bucket dredges and spud barges. The bucket dredge consists of a bucket or clamshell dragline mounted on a barge-type hull. In digging a pipeline or location canal, the operator leaves a continuous embankment of soil on one or both sides of the excavation, far enough from the cut to prevent sliding and heaving. Wave wash from boat traffic erodes the banks, altering the channel's profile. Maintenance work is then required. Oil companies contract for a 2.4-m channel depth, but will pay for a 0.6-m "overdepth." Siltation, slipping and bank collapses are difficult to predict; consequently, 50 percent of some dredging firm's business involves redredging access canals.

Spud barges provide the versatility necessary in cleaning swamp locations, pipeline river crossings, and improving levees. On a spud barge, unlike a bucket dredge, the dragline is not mounted permanently to the barge; it can, in fact, be outfitted with a crawler undercarriage to operate on land. The dragline is particularly useful because it can handle wet and dry soils successfully. When excavating a canal the dredge places a continous spoil mound adjacent to the channel. These artificial ridges eventually become vegetated, thus outlining the canals and altering the land cover.

Two types of marsh buggies have been developed, wheeled and tracked. Tracked vehicles are preferred, due to their versatility. Although buggies are used primarily to make seismic profiles, they can be equipped with small draglines for excavating for small-diameter pipelines, thus eliminating the necessity of dredging a full-scale canal when only a small ditch is required. The technique reduces environmental damage.

Where practical, pipeline "ditches" are cut with draglines, provided the surface can support the heavy timber mats, or rip-rap used underneath the equipment (Reed, 1951, p. 77; Bilbo, 1957, p. D-26; Ebdon, 1958, p. 89). The ditches are actually part of a canal, excavated so that the pipe can be floated, laid, or pushed into place. The ditch is dug to position the pipe properly, and the canal allows the "lay barge" to move along the right-of-way (Ivey, 1958, p. 37). Working in the excavated right-of-way, the barge moves out from under the pipeline as sections are welded together on its deck (Williams, 1936, p. 39; Ivey, 1958, p. 36; Myers, 1962, p. 52-54).

The push-flotation technique requires a channel only large enough to permit the lay barge to assemble the pipeline and float it in the narrow pipeline cut. As each new section is launched the completed string is floated down the canal, guided by marsh buggies. Many kilometers of pipeline can be shoved along the route without moving the lay barge (Oil and Gas Journal, 1958, p. 81), thus reducing dredging costs.

Transportation Canals

People have long depended on the intricate network of rivers, bayous, lakes, and deep channels as routes for moving their commodities to market. Natural water bodies were traditional shipping routes. To reduce travel time, rivers, bayous, and canals were dredged to expand the transportation system. All manmade waterways are potential arteries of commerce; however, only a few were built exclusively for commercial traffic. With bank stabilization, channel alinement, and the maintenance of uniform channel depth, southern Louisiana is now served by 19 major transportation canals, rivers, or bayous.

Between 1880 and 1945, numerous waterways were built or improved. Accompanying the increased demand for petroleum in World War II, Congress approved the financial support necessary to complete the Gulf Intracoastal Waterway--the Nation's most important canal system. This system, in conjunction with the Mississippi River, made Louisiana the center of wartime Gulf Coast petroleum traffic. The 19 waterways listed in table 5 serve as tributary feeders; they are the principal transportation canals and significant additions to the State's commercial watercourses.

The World War II experience demonstrated the value of the country's navigable waterways. Bulk shipping industries have continued to utilize these routes in the low-cost movement of their commodities, with crude and refined petroleum products dominating the statistics. Of the 152 million metric tons moved in 1978, 89 million (tables 6 and 7) or 59 percent, are related to the petroleum industry (U.S. Army Corps of Engineers, 1978). Chemical and allied products, along with nonmetallic ores, are a distant second and third. Together these categories accounted in 1978 for 84 percent of the commerce shipped on the region's major waterways. Since 1955, there has been a 153-percent increase in tonnage of commodity movements. Traffic peaked in 1970-71 (table 7). Since 1971, petroleum and petroleum products shipments have declined 15 to 20 percent.

Waterway tonnage statistics (table 5) reveal that in 1970 and 1978 the commerce moving on Louisiana's waterways was about equal. Petroleum and petroleum product tonnages have changed, however. In 1970, there were 4,142 thousand metric tons of these commodities shipped by way of the Atchafalaya River (table 6); in 1976 only 3,280 thousand metric tons were reported. The same is true on all but six routes. Increases were noted only on Bayou Lafourche, on Calcasieu River and Pass, on Empire to the Gulf of Mexico, on Gulf Intracoastal Waterway to Bayou Dulac, on the Gulf Intracoastal Waterway between Morgan City and Port Allen, and on the Mermentau River (table 6).

Although the shipping volume has changed, southern Louisiana's waterways continue to be important adjuncts to the region's pipelines. The canals represent flexibility because barge traffic can be directed to

Table 5.--Waterway shipments, in thousands of metric tons, in southern Louisiana.

Waterways	Thousands of metric tons shipped 1955	1960	1965	1970	1975	1978
Atchafalaya River above Morgan City	489	5,503	4,112	4,449	2,683	5,950
Atchafalaya River, Morgan City to the Gulf of Mexico	911	2,885	4,307	3,761	3,442	3,266
Barataria Bay	767	1,646	3,657	4,621	2,958	1,374
Bayou Lafourche	1,069	2,093	2,123	2,204	1,452	1,272
Bayou Little Caillou	31	54	88	650	756	727
Bayous Petit Anse, Tigre and Carlin	445	795	1,107	1,346	1,234	1,838
Bayou Teche	293	445	639	589	552	572
Bayou Teche and Vermilion River	188	641	837	1,087	1,221	1,065
Bayou Terrebonne	1,165	1,624	648	472	504	415
Calcasieu River with Pass	13,964	15,821	13,123	16,032	15,838	24,131
Empire to Gulf of Mexico	125	463	750	162	1,000	283
Freshwater Bayou	2/	2/	2/	31	264	163
GIWW1/ to Bayou Dulac	267	390	406	335	676	567
GIWW, Mississippi River to Sabine River	24,301	32,898	43,611	59,072	51,472	56,010
GIWW, Morgan City to Port Allen	2,265	2,515	8,548	15,637	15,492	16,386
Houma Navigation Canal	2/	2/	1,059	2,427	2,201	1,614
Lake Charles Deep Water Channel	12,828	17,670	24,462	33,890	29,420	34,591
Mermentau River	400	436	1,078	764	1,212	855
Mermentau River, Bayous Nezpique and Des Cannes	1,624	2,742	1,977	1,575	675	1,466

Source: U.S. Army Corps of Engineers, 1955; 1960; 1965; 1970; 1975; and 1978

1/ Gulf Intracoastal Waterway

2/ No data

refineries operating below capacity, and petroleum can be shipped according to industrial demands. Pipelines are unidirectional, and once the product is pumped, its destination cannot be changed easily.

All commodities recorded on table 7 are bulk cargoes that are difficult to ship as profitably by alternate methods, hence the use of channelized waterways.

Transportation waterways are easily identified by their wide, straight, spoil-laden banks. They provide open-ended links between points, and extend for many kilometers along well-defined courses. Each transportation artery influences the regional economy, attracting industry and affecting land use patterns parallel to the right-of-way.

Canal Growth in Four Areas

Four areas--Barataria, Bayou du Large, Pecan Island, and West Delta were selected for detailed review of canal growth (figs. 10-13) (Davis, 1973, p. 154-167). Representative examples of all canal types appear on these maps. Each was chosen because it illustrated a different canal pattern or several canal types; each was characterized by canal extension since 1950.

Table 6.--Waterway petroleum shipment, in thousands of metric tons, in southern Louisiana.

Waterways	1967	1970	1973	1976	1978
	Crude Petroleum with Petroleum Products[1/]				
	Thousands of metric tons shipped				
Atchafalaya River above Morgan City	2,547	3,210	1,691	2,613	3,012
Atchafalaya River, Morgan City to the Gulf of Mexico	1	932	1,440	667	297
Barataria Bay	2,078	2,758	1,135	187	131
Bayou Lafourche	510	588	376	646	312
Bayou Little Caillou	9	616	943	802	791
Bayous Petit Anse, Tigre and Carlin	259	116	93	72	110
Bayou Teche	353	240	176	65	259
Bayou Teche and Vermilion River	986	834	426	422	305
Bayou Terrebonne	229	122	95	93	126
Calcasieu River with Pass	10,604	11,711	10,764	13,726	19,313
Empire to Gulf of Mexico	504	70	53	683	147
Freshwater Bayou	3/	13	473	164	162
GIWW[2/] to Bayou Dulac	51	24	43	54	34
GIWW, Mississippi River to Sabine River	34,666	37,213	34,399	31,228	32,249
GIWW, Morgan City to Port Allen	4,576	6,635	6,390	8,247	7,116
Houma Navigation Canal	652	1,720	1,677	1,161	919
Lake Charles Deep Water Channel	20,812	23,134	29,699	20,400	21,940
Mermentau River	815	707	1,304	884	684
Mermentau River, Bayous Nezpique and Des Cannes	1,669	1,417	541	540	1,178
Total	81,321	92,060	91,718	82,671	89,063

Source: U.S. Army Corps of Engineers, 1967; 1970; 1973; 1976; and 1978

1/ Includes: Gasoline; jet fuel; kerosene, distillate fuel oil; residual fuel oil, lubricating oils and greases; Naphtha, mineral spirits and solvents; asphalt, tar, and pitches; coke, including petroleum coke; liquified petroleum gases, coal gases, natural gas, and natural gas liguids, asphalt building materials; petroleum and coal products, not elsewhere classified.

2/ Gulf Intracoastal Waterway

3/ No data

4/ Total represents Group 13 - Crude petroleum and Group 29 - Petroleum and Coal Products

Topographic maps were used to compile the sequential growth of canals in the four areas. After 1968, only petroleum-related waterways were shown. Drainage, logging, and trapping channels were too complex to interpret from the available 1968 photomosaic. For each area, three periods were selected to trace the history of the region's canalization. Each period reveals man's ability to change the landscape to meet his resource needs.

Canals excavated for hydrocarbon developments are the most visible manmade element on the landscape. Each of the four case studies reveals the extent of the various canal types and indicates the significance of canals as landscape elements.

Barataria.--In 1939, there were 87 km of drainage, reclamation, and trapping canals in the Barataria area on the deltaic plain. Nine years later 74 km of petroleum-related waterways had been excavated. By 1962 the system had enlarged into a 251-km network of interconnecting channels, an increase of more than 300 percent over 1948. In addition, 24 km of drainage canals were cut to meet the local demand for dry land along the narrow natural levees of Bayou Barataria. Interpretation of

Table 7.--Waterway commodity shipments, in thousands of metric tons, in southern Louisiana.

Commodity	Thousands of metric tons 1973	1976	1978
Farm Products	1,047	1,979	2,152
Fish and Other Marine Products	13,317	9,411	8,869
Metallic Ores	80	251	478
Coal	1,023	744	576
Crude Petroleum	45,841	38,236	40,968
Nonmetallic Ores, except fuels	10,148	11,185	11,862
Food and Kindred Products	819	1,065	998
Basic Textiles	-	-	7
Lumber and Wood Products	62	114	148
Pulp, Paper and Allied Products	95	169	219
Chemicals and Allied Products	19,904	23,370	25,176
Petroleum and Coal Products	36,240	43,901	48,429
Rubber and Miscellaneous Plastics	2	4	3
Building Products	608	393	535
Primary Metal Products	3,507	3,746	3,925
Fabricated Metal Products	137	73	71
Machinery	266	248	307
Transportation Equipment	80	37	15
Miscellaneous itmes not classified elsewhere 1/	5,039	6,270	7,807
Total	138,215	141,196	152,545

Source: U.S. Army Corps of Engineers, 1973, 1976, and 1978.

1/ Includes ballast water.

the 1972 land use and land cover map (U.S. Geological Survey, 1975c) reveals that the ring levee around Lafitte has stimulated the development of 47 ha of strip and clustered settlement.

By 1968, the area's 12 oil and gas fields were accessible; dredging by the petroleum firms was reduced to about 8 km per year, considerably below the 18 km dredged annually before 1962. Only 51 km of well-access and pipeline routes were added between 1968 and 1972, bringing the total to about 377 km of manmade waterways related to petroleum extraction on 17,880 ha. In addition to the petroleum-related canals, there are 111 km of smaller channels, which represent 23 percent of the area's artificial watercourses.

Bayou du Large.--In this deltaic plain marsh, the 1944 topographic map shows 47 km of transportation channels, 32 km of traînasses, and 6 km of petroleum canals. Over the next two decades, 105 km of well-access canals were dredged. Four years later, 47 km had been added to the system, representing about 29 percent of the example area's waterways.

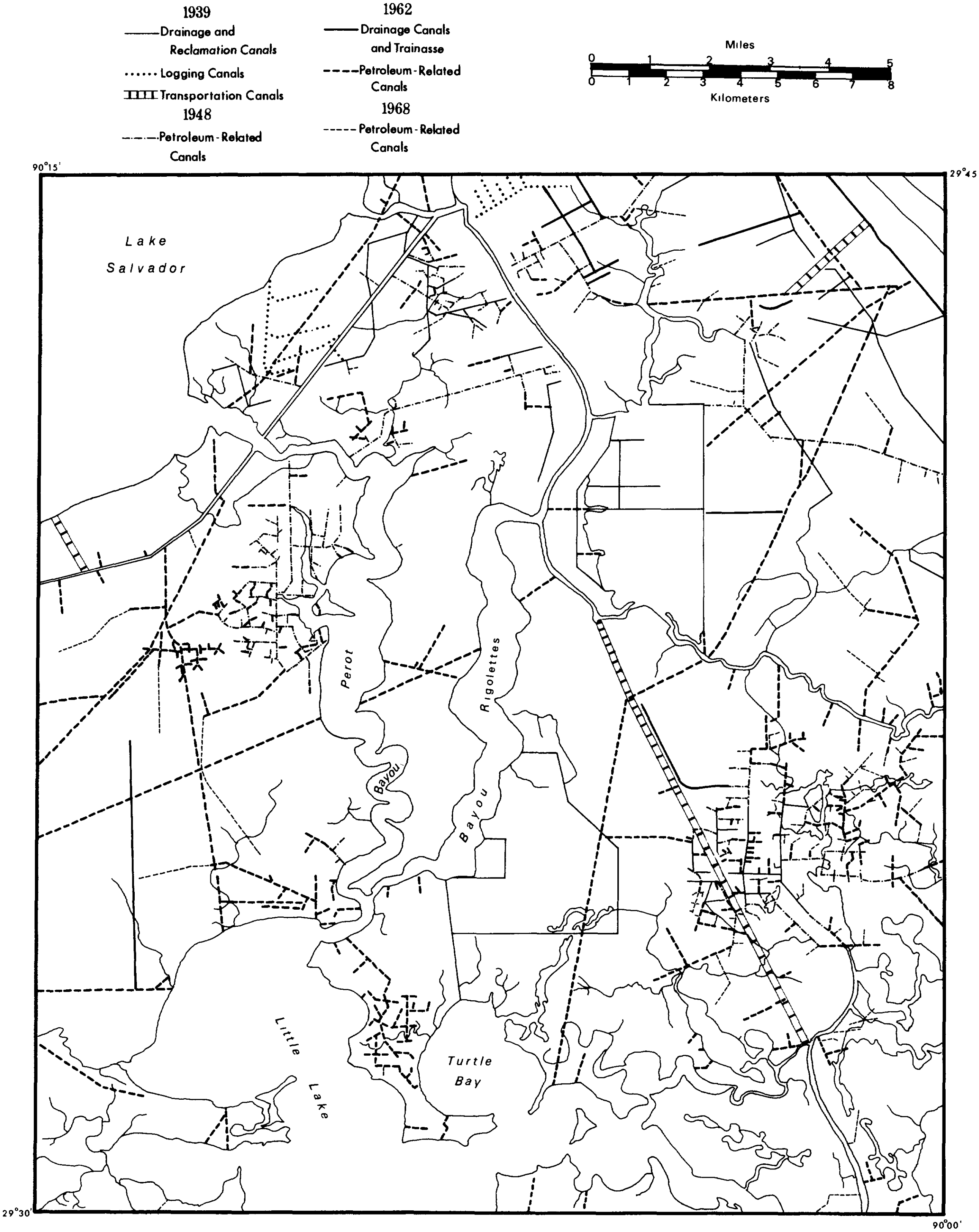


Figure 10.--Canal networks serving Barataria region in 1939, 1948, 1962, and 1968. Planimetry is from the USGS Barataria 1:24,000-scale topographic map.

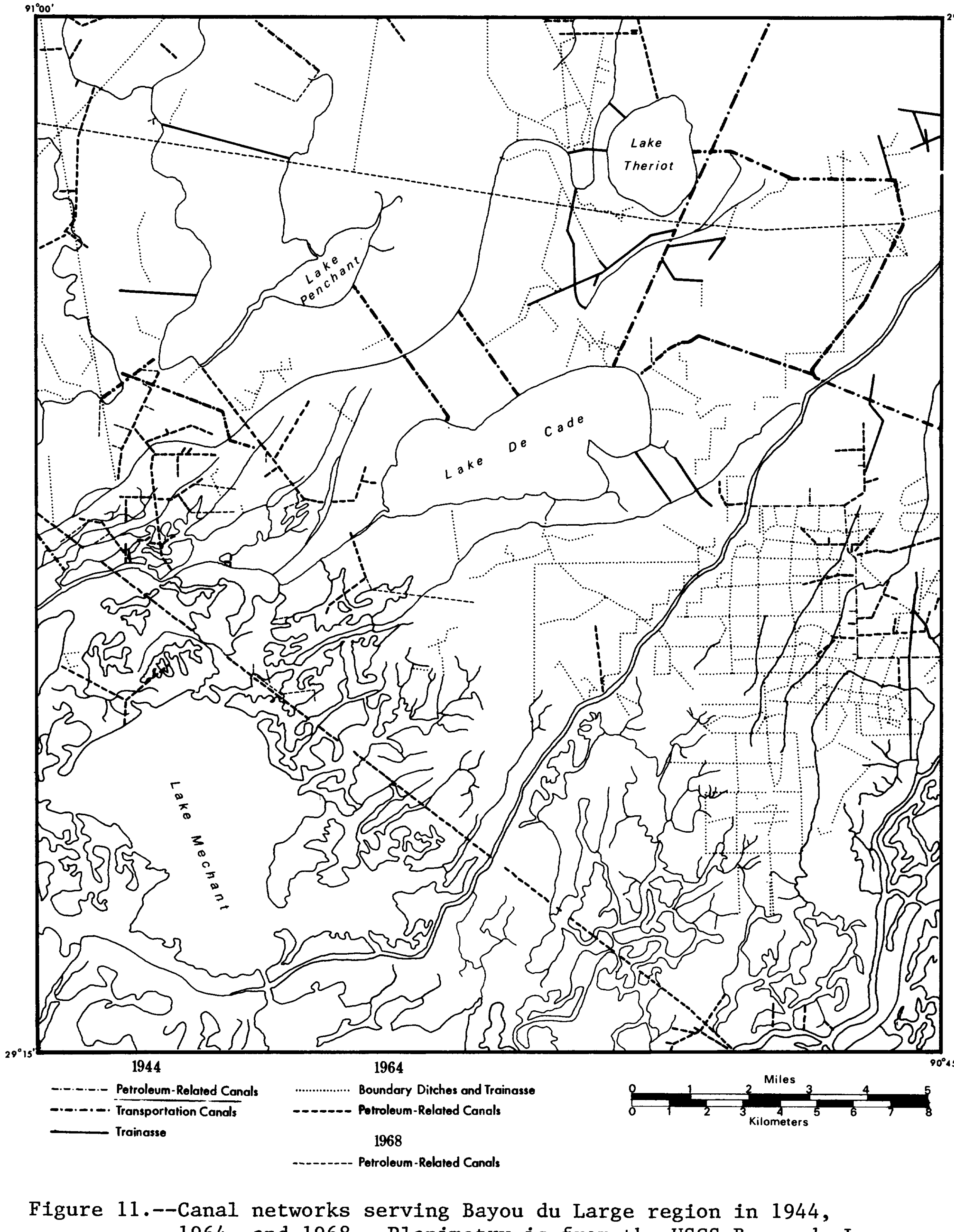


Figure 11.--Canal networks serving Bayou du Large region in 1944, 1964, and 1968. Planimetry is from the USGS Bayou du Large 1:24,000-scale topographic map.

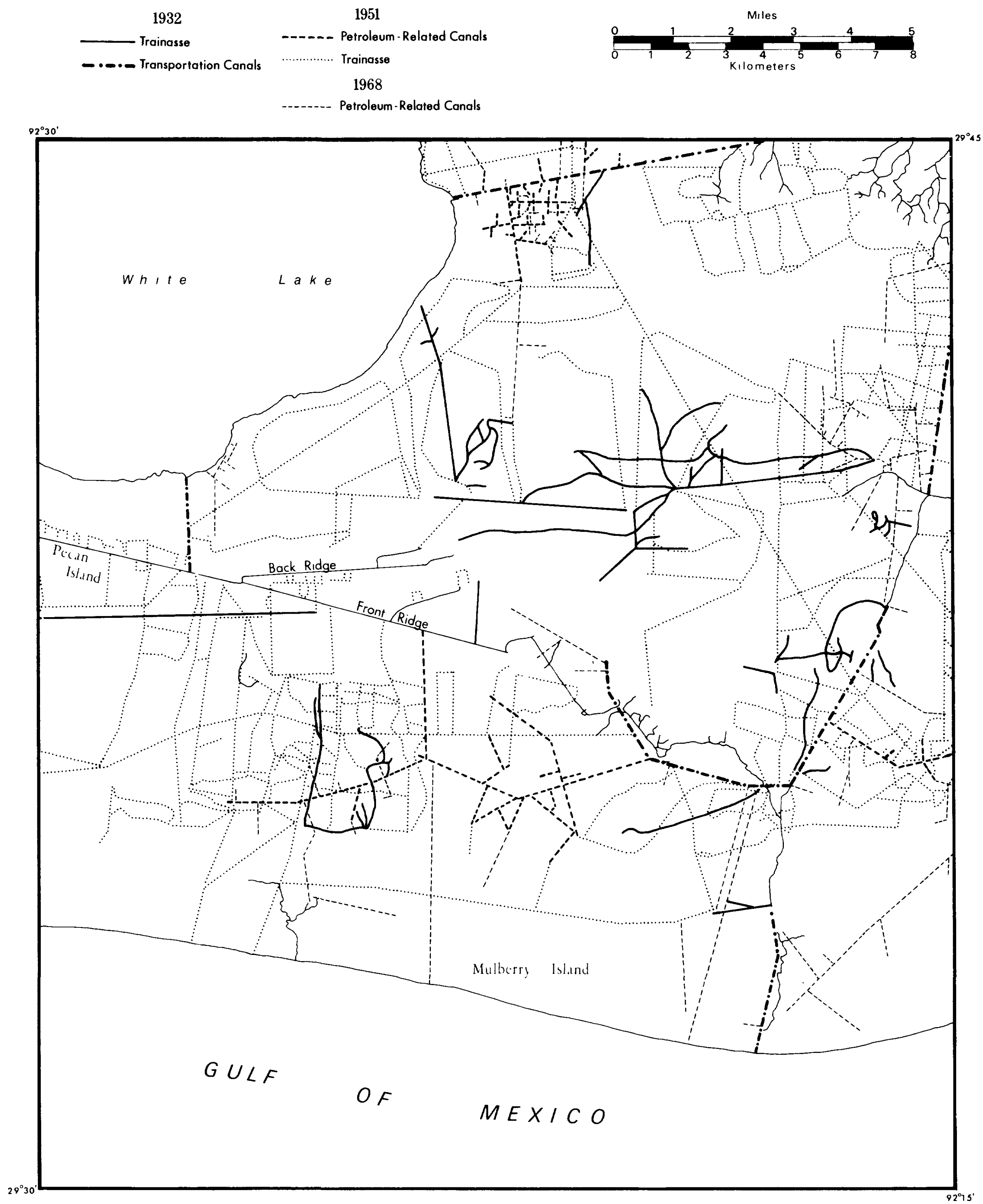


Figure 12.--Canal networks serving the Pecan Island region in 1932, 1951, and 1968. Planimetry is from the USGS Pecan Island 1:24,000-scale topographic map.

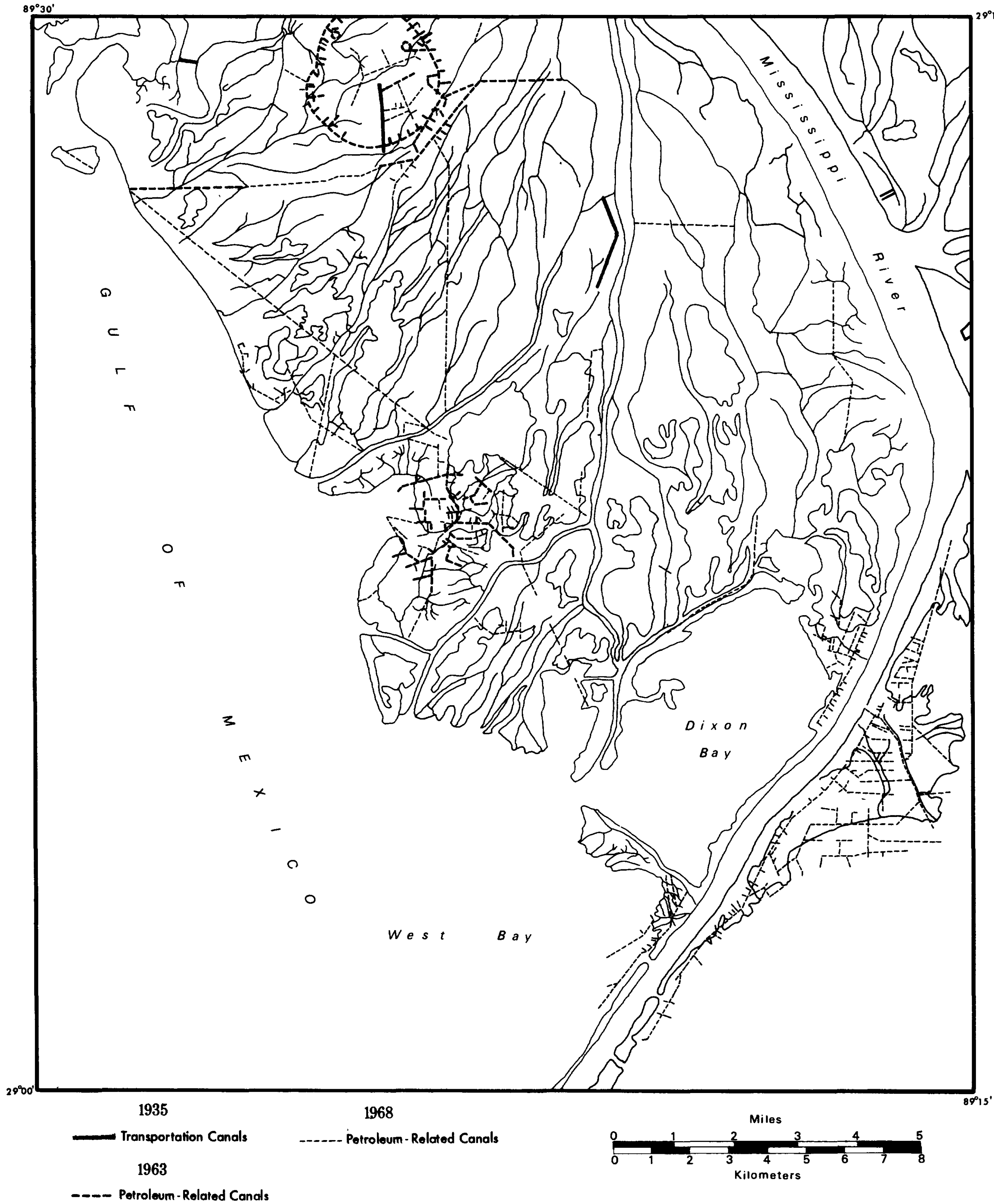


Figure 13.--Canal network serving the West Delta (south of Venice) region in 1935, 1963, and 1968. Planimetry is from the USGS West Delta 1:24,000-scale topographic map.

Although no major canals were excavated, the total number of petroleum-related waterways increased due to the appendages connected to the principal routes.

Pecan Island.--In 1951 the traînasse was the leading canal type in the Pecan Island portion of the chenier plain, with a total length of 499 km. More than 30 km of the oilfield canals appear on the 1951 map. Seventeen years later the system has increased to 135 km, an average addition of 6 km per year. Unlike flotant marsh, the chenier plain's soils can support drilling equipment. Canals are not a necessity. Exploratory and development wells can be drilled from board roads laid to the drilling site, thus reducing the region's petroleum-related canals. Concomitant with the lesser density, compared with Barataria, in manmade canals is the smaller area devoted to extractive industries. Maps of the land use and land cover of the chenier plain in 1972 show 3,450 ha of extractive land with four fields accounting for 1,690 ha, or 49 percent.

West Delta.--In the West Delta section of the Mississippi delta, petroleum canals are highly visible landscape elements. The terrain is dominated by these features; four petroleum fields account for 13,760 ha of extractive industries. The development of these canal patterns began in the 1930's when only 5 km of petroleum-access routes were excavated. By 1953, dredging contractors had added 51 km of new canals. In the next 15 years, the system was enlarged by 162 km. The 1950's and 1960's were periods of extensive hydrocarbon-related activity, not only in the West Delta region, but throughout the marsh, where the landscape reflects the accelerated drilling.

OFFSHORE PETROLEUM INDUSTRY

Drilling in Louisiana's wetlands served as a training ground for successful drilling on the Outer Continental Shelf. Many facilities had already been established to serve onshore oil and gas fields accessible only by boat and barge in the canalized coastal wetlands. Operations on a sea of mud are not too different from those used on a sea of water. From a rather quiet beginning, the search for hydrocarbons on the OCS grew rapidly, far exceeding early expectations. By 1981, a total of 2,433 structures had been installed off Louisiana's coast--1,162 of these were classified as major structures (Don Giror, USGS Conservation Division, oral commun., 1981). Of these, the available data indicate that 17 had been claimed by hurricanes (table 8) (Carmichael, 1975, p. 231) and between 1964 and March 1981 there were 73 major accidents (defined as a spill of 7.95 m^3 or more) associated with fires, blowout, or other unusual occurrences resulting in 53,360 m^3 of petroleum spilled on the Outer Continental Shelf (U.S. Geological Survey, 1979, p. D-2 - D-15; U.S. Geological Survey, 1981, p. D-1 - D-2).

Construction and maintenance of production platforms, and subsequent extraction and handling of subsea oil and gas requires an extensive array of onshore facilities. Refineries, terminals, boat docks, airports, helicopter bases, repair facilities, shipyards, and pipe storage areas are essential to offshore operations. Property demands for these facilities influence coastal land use patterns. Some firms have located at remote points on the coast, such as Port Fourchon or Venice, and their

Table 8.--Major petroleum development in Federal waters off Louisiana through May 1981[1/].

	Platforms		Damaged by	Damaged by	Destroyed by	
	Installed	Salvaged[2/]	hurricanes	fire[3/]	fire[3/]	
Active						
Prior to 1954	277	74	-	4	-	199
1954-59	112	30	8	1	2	71
1960-64	251	23	7	3	1	217
1965-69	67	2	2	5	3	55
1970-74	80	2	-	3	5	70
1975-79	447	N/A	N/A	9	4	434
1980-81	99	N/A	N/A	4	-	95
Total	1,316	131	17	6	-	1,162[4/]

1/ Major platforms are supported by at least four pilings, have two or more pieces of production equipment and/or six completed wells.

2/ For use elsewhere

3/ No distinction is made between drilling rigs and platforms in the USGS Conservation Division's accident reports. This problem inflates the numbers slightly. Data reflects only "Major Accident." Since 1958, 177 fires have been reported. Most were extinguished with hand fire extinguishers.

4/ As of May 31, 1981, there were an additional 1,271 minor structures, an increase of 134 since April 30, 1978, for a total of 2,433 offshore platforms in Federal waters off Louisiana.

Source: Carmichael, 1975
Kent Stauffer, USGS Conservation Division provided the 1975-1978 update (oral communication).
Don Giroir, USGS Conservation Division provided the 1979-1981 update (oral communication).
U.S. Geological Survey, Conservation Division, 1979, 1981a, with supplements for 1981b.

land area requirements, for example, land used for transportation facilities, reflect the significance of maritime transportation to and from the oil and gas fields. Cities on well-developed traffic corridors serve as nodal points, attracting all types of businesses involved in meeting the logistic needs of the offshore contractors. Expansion of these support facilities stimulates the local economy and marked changes in urban and built-up land uses occur. Demands are increased for land to be used for residential, commercial, service, industrial, transportation, communications and utilities, institutional, and other types of intensive use. In nearly all places on this coast, the natural environment limits or confines urban growth. Support industries, therefore, are agglomerated or confined within the few areas of dry land. These areas, shown as 14 separate settlement sites in figure 1, are relatively well-defined in nature.

In assessing changes in land use and land cover on the Louisiana coast, this analysis will focus on the historical development of the oil and gas industry, along with the ancillary services contributing to the developing socioeconomic patterns.

Lease History

Drilling on the submerged continental margins off Louisiana and Texas opened a new era in marine/oil operations. Within the first 20 years, the search covered 487,000 km^2 of leases later identified as excellent producing areas (Weeks, 1965, p. 129). Between 1954 and 1979 the petroleum industry invested nearly $14 billion to explore 36,907 km^2 of untested Gulf of Mexico leases (Harris, McFarlane, Williams, and Hammersley, 1980, p. 8).

In 1954, 90 tracts were leased in offshore Louisiana, 58 of these were productive. Ten years later 735 blocks were under lease (table 9). Early exploration was erratic. High development costs and legal problems led to offshore uncertainties that dominated the 1950's (McCollum, 1960, p. 28) However, in the 1960's the petroleum industry had accelerated its development in the Gulf of Mexico. By 1979, the rights to 2,075 oil and gas tracts in the waters off Louisiana had been obtained through competitive bidding (Harris, McFarlane, Williams, and Hammersley, 1980, p. 9-11). Although most blocks are located in less than 180 m of water, eight firms have invested more than $400 million to explore 32 blocks beyond this contour (Offshore, 1975b, map). Exploratory drilling has extended into water more than 300 m deep (Caugney and Stuart, 1976, p. 68).

Table 9.--Louisiana's producing and nonproducing offshore wells.

Year	Tracts Leased	Number of Producing Wells	Number of Nonproducing Wells	Total Wells	Percent Producing
1954	90	58	295	353	16.4
55	94	102	356	458	22.3
56	1/	167	265	432	38.6
57	1/	210	176	386	54.4
58	1/	226	136	362	62.4
59	19	259	85	344	75.3
1960	99	285	94	379	75.2
61	1/	294	85	379	77.6
62	410	311	475	786	39.6
63	1/	342	441	783	43.7
64	23	357	422	779	45.8
65	1/	406	335	741	54.8
66	41	469	303	772	60.7
67	158	506	293	799	63.3
68	16	518	276	794	65.2
69	36	531	265	796	66.7
1970	138	557	254	811	68.7
71	11	596	303	899	66.3
72	178	636	234	870	73.1
73	10	660	309	969	68.1
74	244	668	519	1,187	56.3
75	120	725	521	1,246	58.2
76	57	749	489	1,238	60.5
77	97	780	509	1,289	60.5
78	109	786	475	1,261	62.3
79	125	849	457	1,306	65.0

1/ No Louisiana lease sale

Source: Harris, McFarlane, Williams, and Hammersley, 1980

Moving from the first site in water 5 m deep to water depths 50 times as great was a challenging task. Exploration activities in the open sea required considerable research and development time. Petroleum and service company engineers had to design exploration and production equipment capable of meeting the rugged, self-imposed standards established by the expanding industry. To meet the challenges of working offshore, drilling contractors have available 461 mobile drilling units capable of working in from 10 m to 300 m of water, with 140 new rigs on order or under construction (Trafford, 1980, p. 19).

Technical Support

Numerous technical advances have been made, but of particular importance is the development of a drillship that could be precisely positioned. When equipped properly, the marine-service fleet can operate in water out to a depth of 6,000 m (Tubb, 1977, p. 39).

Even though deep-water drilling and production is a reality, there are problems related to developing the sites. During the development phase a fixed platform is fabricated and placed over the discovery well. From this base as many as 50 directionally-oriented production wells may be drilled.

Whatever may be the outcome of testing the offshore frontier basins of the United States, increases in reserves off southern Louisiana and the upper Texas Gulf Coast may be found during the next few years (King, 1976, p. 42). To locate these potential reserves the petroleum industry annually drills an average of 197 exploratory wells. Only 27 percent on the average are successful. Of an annual average of 543 development wells drilled, 424 wells or 78 percent are successful.

To service these offshore wells requires extensive onshore facilities. Louisiana's pioneer role offshore resulted in many of the State's cities acquiring the necessary infrastructure to meet the needs of the offshore industry. Most of the settlement strips outlined in figure 1 have experienced the economic impact from the work offshore. For example, 76 percent of the logistic support craft being built in the United States in 1980 were in Louisiana shipyards. Ninty-eight of the 129 boats being fabricated in the United States in 1980 were under contract to Louisiana shipbuilders (table 10). The State's iron and sheet metal welders have been producing between 63 and 85 percent of the country's fixed production platforms (table 11). All of this activity requires space and influences local industrial land use and land cover patterns. Transportation facilities are equally important since 40 percent of the world's crewboats, supply vessels, and tugs are owned by Louisiana-based firms (Ocean Industry, 1981, p. 51-80). To dock and service this marine fleet involves the need for land.

Post War Exploration and Development Offshore

In 1947 some companies began to drill on two leases off Point au Fer totalling more than 160 km^2. Before the Point au Fer leases could be drilled, a considerable amount of planning was required in order to meet any contingency. The problem was not drilling the well per se, but devising a method that was safe, portable, and relatively inexpensive (Seale, 1948, p. 114). To meet the first and second requirements a

Table 10.--Petroleum industry boats being built by Gulf coast logistic support firms.

State	1977 1/		1978 2/		1979 3/		1980 3/		Average Boats Built	Average Percent
	Boats	Percent of total	Boats	Percent of total	Boats	Percent of total	Boats	Percent of total	1977-1980 4/	1977-1980
Louisiana	30	35.3	95	77.2	60	53.1	98	76.0	70.1	60.4
Texas	18	21.2	13	10.6	9	8.0	14	10.9	13.5	12.7
Other U.S.	37	43.5	15	12.2	44	38.9	17	13.1	27.5	26.9
Total	85	100.0	123	100.0	113	100.0	129	100.0		

1/ Tubb, 1977a
2/ Tubb, 1978s
3/ Tubb, 1979
4/ Ocean Industry, 1980

Table 11.--Fixed platforms under construction in the United States, January 1975[1], March 1978[2], and March 1981[3].

State	Total			Percent United States			Change		Percent Worldwide			Change	
	1975	1978	1981[4]	1975	1978	1981	1975-78	1978-81	1975	1978	1981	1975-78	1978-81
California	1	0	2	1.4	0	1.4	-1.4	+1.4	0.6	0	0.6	-0.6	+0.6
Louisiana	61	55	94	85.9	73.3	63.5	-12.6	-9.8	37.4	37.4	30.4	0	-7.0
Texas	9	20	52	12.7	26.7	35.1	+14.0	+8.4	5.5	13.6	16.8	+8.1	+3.2
United States Total	71	75	148	100.0	100.0	100.0			43.5	51.0	47.8	+7.4	-3.2
Outside of the United States	92	72	161				-20.0	+69.0	56.4	49.0	52.1	-7.4	+3.1
Worldwide Total	163	147	309				-16.0	+162.0	100.0	100.0	100.0	0	0

1/ Ocean Industry, 1976a
2/ Cashman, 1978
3/ Cashman, 1981
4/ Of the 303 structures scheduled for 1981 installation, 112 (37%) will be in the Gulf of Mexico.

compromise between and all-rigid and all-floating structure was considered most practical. Once the equipment was assembled, drilling began. Two months after a Block 32 well was started, a commercial reservoir was discovered. The first truly offshore well was a reality (Seale, 1948, p. 116; Barnes and McCaslin, 1948, p. 97-98). The coastal zone was affected by both the onshore impacts and cumulative effects of drilling offshore.

To develop the leases required a radio-equipped fleet. Sixteen boats and barges were assembled to shuttle men, equipment, and supplies to the drilling site (Barnes and McCaslin, 1948, p. 96). For safety, one boat was stationed permanently near the rig to evacuate the crew in an emergency, a practice still utilized. The rest of the flotilla was based at the supply depot in Berwick. From this beginning, the Berwick waterfront grew and in 1973 contained 75 ha of support facilities, alined along approximately 3 km of the Atchafalaya River.

The supply depot was literally the base of operations, because success depends on the prompt arrival of men, equipment, and materials. As the industry developed, naval architects designed vessels with greater speed, draft, and endurance (Goldman, 1949, p. 276, 281-282).

Getting the petroleum to shore was a problem requiring considerable planning. The oil initially was pumped into barges and transported to an 11-ha site on Bayou Boeuf near Morgan City. The facility was designed to store 5,700 m^3 of crude oil (McCaslin, 1948, p. 107-108).

In the rush that followed the discovery off Point au Fer, petroleum firms began to investigate intensively the Gulf of Mexico's subsurface geology. In 1948, geophysical data gave a "definite indication of the existence of upwards of 90 salt domes or other structures within the 50.5-km zone (31.4 mile) off the Louisiana coast" (Williams, 1948, p. 154). Breton Sound, Eugene Island, Grand Isle, Ship Shoal, South Pelto, and West Cameron tracts were being explored (fig. 14). To keep pace with the consumption of oil and gas, exploration and development would have to extend seaward across the continental shelf (Logan and Smith, 1948, p. 39-40); Atwater, 1956, p. 2624-2634). By 1955 more than 40 rigs were in operation up to 80 km offshore (Oil and Gas Journal, 1955b, p. 126). The instability of the sea floor, supply distances, winds, corrosion, and anchor chain fatigue were contributing to increased costs (Resen, 1955, p. 87). These and other problems slowed exploration and development in the 1950's. By 1963 the offshore recession was over (fig. 15). Offshore petroleum production statistics reveal several years of increased output after 1965 (table 12). Offshore oil production began to decline in 1973, but gas yields continue to increase.

If the 1940's can be characterized as the beginning of the offshore era of petroleum development, then the 1950's should be considered the beginning of the marine technological revolution. In this period, boat builders installed diesel, rather than gasoline engines, and designed steel, rather than wooden-hulled support craft. Shipyards were fabricating vessels capable of operating in the Gulf of Mexico. In 1976, 105 Louisiana shipyards were working to meet the needs of the offshore operators. The marine service industry has been responsible for establishing Louisiana as a world leader in building thousands of supply boats, towing-supply vessels and large utility craft operating around the world (Ocean Industry, 1974, p. 44-51; Ocean Industry, 1975, p. 36-50F; Tubb, 1978, p. 51-65). A trend has developed whereby boats double as

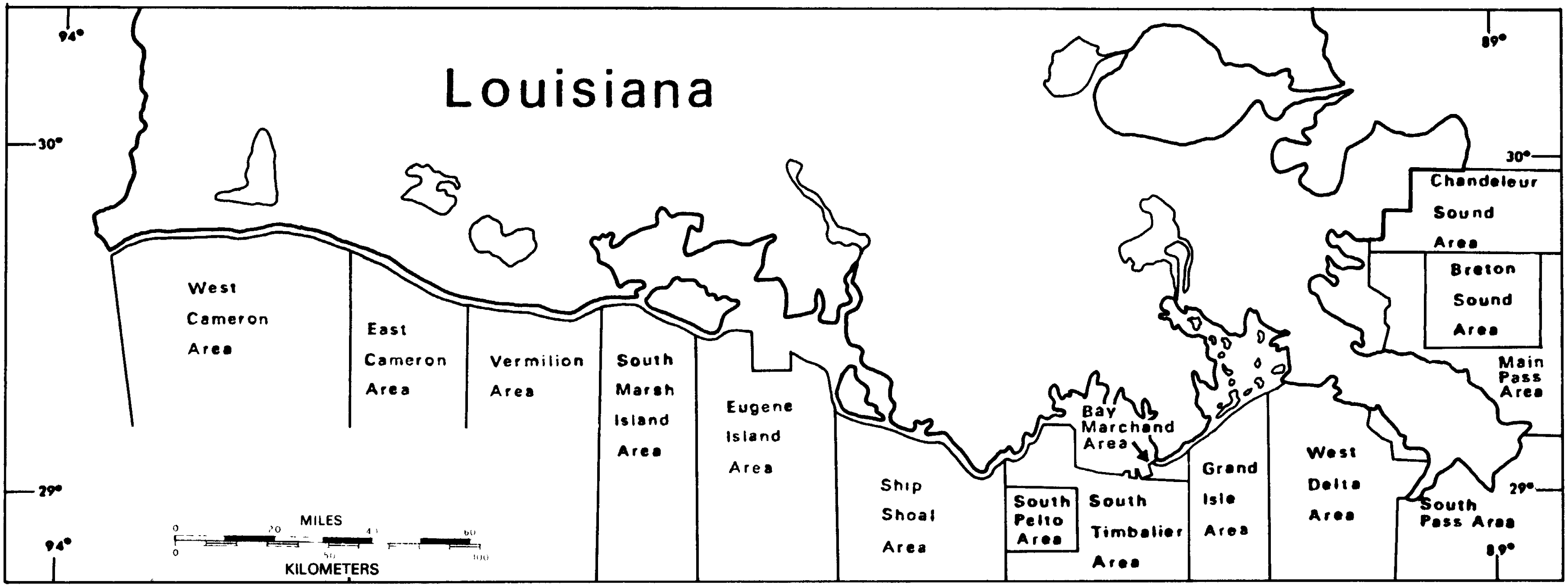


Figure 14.--Petroleum lease areas off the Louisiana coast as of 1973.

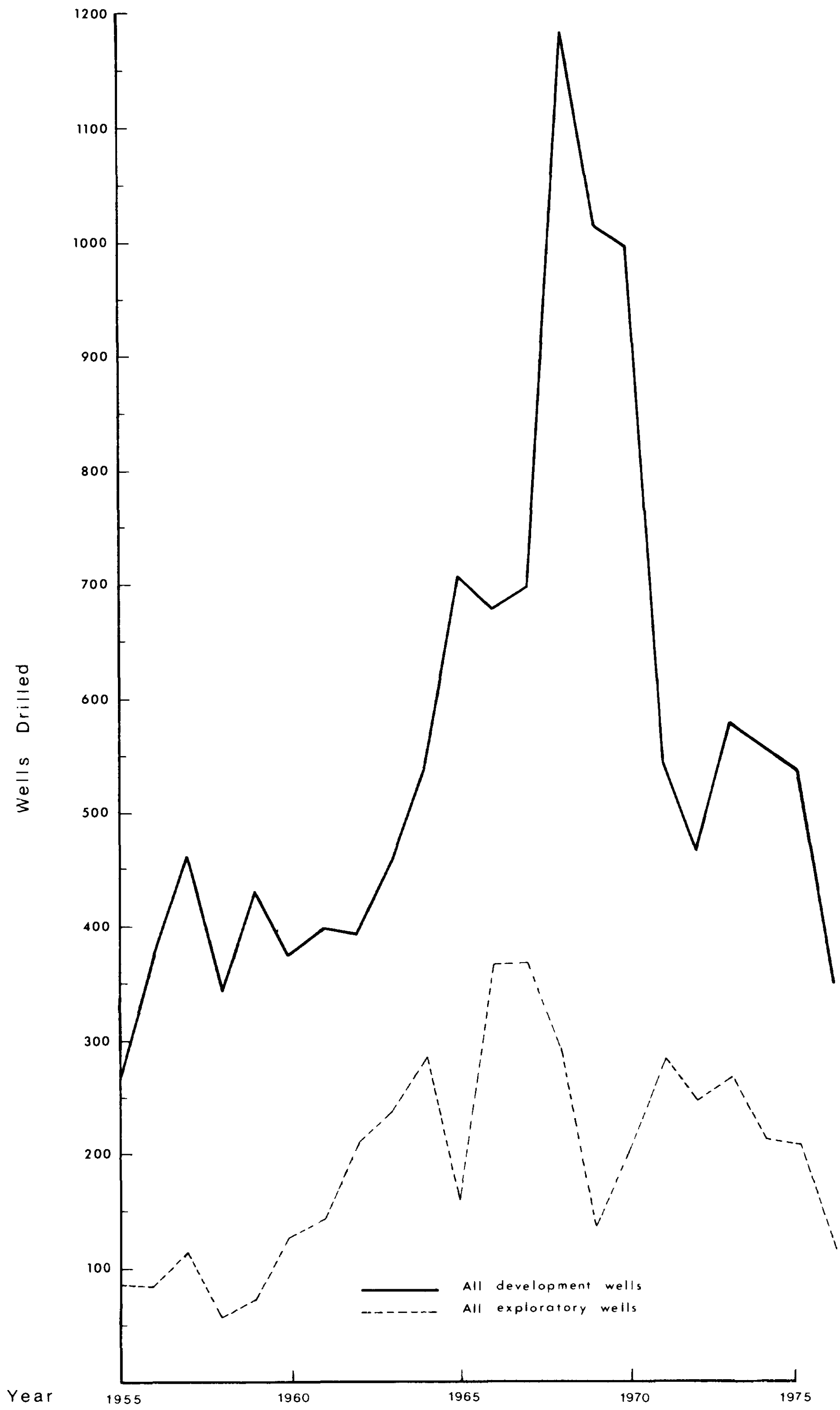


Figure 15.--Number of exploratory and development wells drilled offshore between 1955-77.

Source: Data compiled from National Oil Scouts Assocition of America Year Book, published consecutively from 1937-39, v. VII-IX, and Oil and Gas Field Development: National Oil Scouts and Landsmen's Association Year Book, published consecutively from 1940-59, v. X-XXIX; and International Oil and Gas Development: International Oil Scouts Association Year Book, Part I - Exploration, published consecutively from 1960-78, v. XXX-XLVIII.

Table 12.--State and Federal OCS petroleum production off Louisiana.

Year	OIL Thousands of m3	OIL Percent State	OIL Percent OCS	GAS Millions of m3	GAS Percent State	GAS Percent OCS
Prior to 1954	8,714	98	2	2,596	78	22
1954	2,532	79	21	2,303	31	69
55	4,091	74	36	3,435	33	67
56	6,504	73	27	3,866	39	61
57	8,401	70	30	4,545	49	51
58	9,123	57	43	6,626	45	55
59	11,574	51	49	9,325	37	63
1960	14,012	44	56	11,566	33	67
61	16,408	38	62	12,982	31	69
62	20,161	29	71	16,662	23	77
63	23,705	30	70	20,009	20	30
64	27,620	29	71	22,188	21	79
65	31,688	27	73	24,670	26	74
66	38,650	23	77	35,850	24	76
67	45,161	23	77	46,876	34	66
68	52,458	20	80	58,263	31	69
69	58,145	18	82	70,198	26	74
1970	63,342	16	84	79,299	19	81
71	70,654	13	87	91,168	18	82
72	71,961	14	86	98,577	17	83
73	68,285	13	87	102,374	15	85
74	61,892	12	88	109,654	14	86
75	56,218	11	89	108,232	13	87
76	53,958	11	89	113,388	13	87
77	51,609	10	90	115,964	11	89
78	49,369	10	90	131,371	11	89
79	47,754	10	90	131,305	10	90
Total	973,989	15	85	1,433,294	17	83

Source: Harris, McFarlane, Williams, and Hammersley, 1980

tug-supply, crewboat-research, and supply-support. In 1975, nearly 300 workboats were reported operating in the Gulf of Mexico (Ocean Industry, 1976, p. 49-66). A 1981 survey of the marine transportation fleet recorded 589 support vessels stationed in the Gulf of Mexico. The region's 1,660 ha of transportation space must dock and service this fleet.

Off Louisiana's coast, petroleum operators have leased more than 2,000 blocks (Harris, McFarlane, and Hammersley, 1980, p. 9-11). To explore the 36,907 km^2 leased on the OCS has required offshore contractors to build giant mobile drilling units. The technology and innovations developed by the United State's rig builders have been tested worldwide. These firms will be involved in fabricating the three types of drilling equipment: the self-elevating or "jack-up," the semisubmersible, and the drillship (Booth, 1974, p. 38) (table 13). In 1980, there were 140 mobile drilling units under construction worldwide, of which 43 were in Gulf of Mexico shipyards (see table 13). For more information on rigs and platforms, see Adams and others (1975).

If a well is located in relatively shallow water, a self-elevating or jack-up drilling unit is commonly utilized. Once towed to the drilling site, the rig's long self-elevating legs are lowered and planted firmly in the seabed. The drilling deck is then jacked up to a safe level (Leavens, 1976, p. 95). If geophysical and geological data indicate possible hydrocarbon traps in water deeper than 90 m, a semisubmersible rig is likely to be used. The advantage of this rig is the stability obtained by partially flooding the hull and anchoring the vessel over the

Table 13.--Drilling units under construction in the United States, 1976[1/], 1977[2/], 1978[3/], 1979[4/], and 1980[5/].

State	Jack-ups					Semisubmersible					Drillships					Total Units Under Construction				
	1976	1977	1978	1979	1980	1976	1977	1978[6/]	1979[6/]	1980[6/]	1976	1977	1978	1979	1980	1976	1977	1978	1979	1980
Alabama	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1	0	0	0
California	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1	0	0	0
Illinois	-	-	-	-	-	-	-	-	1	-	-	-	-	-		-	-	0	1	0
Indiana	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1	0
Louisiana	-	-	-	-	-	4	-	-	-	-	3	-	-	-	-	7	0	0	0	0
Maryland	-	-	1	-	3	-	-	-	-	4	-	-	2	3	1	-	-	3	3	8
Mississippi	3	1	8	7	15	-	-	-	-	-	-	-	-	-	-	3	1	8	7	15
Texas	11	-	12	15	27	2	-	1	-	1	4	2	-	-	-	17	5	13	15	28
Washington	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	0	0	0	0
U.S. Total	14	1	21	22	45	9	2	2	2	5	7	2	2	3	1	30	8	24	25	51
Outside of the U.S.	29	18	18	35	70	34	16	5	4	13	21	8	2	4	6	84	42	25	43	89
Worldwide Total	43	19	39	57	115	[7/]59	[8/]27	7	6	18	28	10	4	7	7	130	56	49	68	140

1/ Ocean Industry, 1976a
2/ Ocean Industry, 1977
3/ Tubb, 1978b
4/ Tubb, 1979
5/ Trafford, 1980
6/ The 1978-1980 data in the United States represents submersibles, no semisubmersibles were under construction.
7/ Total includes 16 submersibles built outside the United States.
8/ Total includes 19 submersibles built outside of the United States.

drilling site. Floating drillships are designed to operate in deep water and can best be described as a ship with a hole cut through the hull for drilling.

If exploratory drilling discovers economically recoverable hydrocarbons, stationary platforms are installed to drill the development wells. From fabricating facilities in Louisiana and Texas more than 2,400 structures have been established in the Gulf of Mexico. The platform must be assembled according to rigid standards in order to protect it from hurricane-induced winds and waves. Often as tall as a skyscraper, the complete fabrication process can take from 4 to 36 months, depending on the structures, size, steel requirements, and equipment.

In 1955 at Bayou Boeuf, the first fabrication yard solely for construction of fixed drilling platforms was established. This yard along with 13 others has produced most of the platforms placed in leases off Texas and Louisiana. Since 1954 oil operators have installed about 90 structures yearly. To meet the demand the Bayou Boeuf yard has expanded into an industrial complex involving more than 420 ha. Near this facility, another firm has built a yard encompassing more than 115 ha. These areas, along with two others in Houma, were fabricating 66 structures in 1977, 39 percent of the 169 units then under construction worldwide (Ocean Industry, 1977, p. 28-34).

Since relatively early in the offshore drilling era, helicopters have been a standard transportation tool (Wilson, 1965, p. 46). Drilling rigs and production platforms have helipads included in their design, since no other transportation can match the speed of moving personnel to rigs as far as 160 km out into the Gulf or back to shore in medical emergencies.

Louisiana's offshore experience has produced some highly skilled maintenance personnel who work not only in the Gulf of Mexico, but in offshore regions around the world. Many men living in the communities that comprise the 14 major strips of settlement in southern Louisiana have worked in foreign areas. The removal of these men from the local labor pool necessitates the training of new people, a continuous process. The industry is always looking for skilled maintenance personnel. To assist in the educational process, one local university has established a unique program. The curriculum permits offshore personnel to attend school during their alternate week ashore. Many short courses are offered in safety, well-logging, and maintenance. To meet the manpower shortages in the marine services industry, the State Department of Education, through its vocational division, has established a maritime school to train people in obtaining licenses to operate offshore vessels (Offshore, 1975a, p. 37). Training, at all levels, is required to meet the needs of all companies involved in the effort to exploit the offshore energy resources.

Oil and Gas Districts

Jurisdiction of the natural resources of the Outer Continental Shelf were defined by the Submerged Lands Act in May 1953 and the Outer Continental Shelf Lands Acts in August 1953 (Weaver, Jirik, and Pierce, 1969, p. 2). With passage of these acts, the industry expanded its offshore activity. By 1977 more than 17,000 wells, of all types, had been drilled off the Louisiana coast (tables 14 and 15). By far the most productive area is south and west of the Mississippi Delta. Nearly

Table 14.--Offshore exploratory wells, by lease area, off Louisiana.

OIL

	BM	BS	CE	CW	CS	DW	EI	GI	MP	MI	PS	SS	SP	TS	VO	Total
1955-59	2	1	0	1	0	17	25	12	7	1	2	14	4	10	4	100
1960-64	4	2	3	2	2	29	13	16	19	14	7	22	11	15	3	162
1965-69	2	12	1	3	7	18	12	13	10	18	0	26	12	13	8	155
1970-73	0	4	5	4	0	5	8	2	6	5	0	10	1	1	2	53
1974-77	0	1	0	1	0	2	5	0	2	5	0	2	1	2	3	24
Total	8	20	9	11	9	71	63	43	44	43	9	74	29	41	20	494

GAS

	BM	BS	CE	CW	CS	DW	EI	GI	MP	MI	PS	SS	SP	TS	VO	Total
1955-59	5	1	11	17	0	10	19	3	9	6	0	10	7	4	12	114
1960-64	2	3	15	27	1	25	13	5	8	26	1	15	5	1	35	182
1965-69	2	6	15	62	3	11	9	7	5	11	0	25	1	26	13	196
1970-73	0	4	12	20	0	0	8	5	13	14	0	13	0	4	6	99
1974-77	0	2	16	42	5	2	26	0	4	24	5	14	2	4	27	173
Total	9	16	69	168	9	48	75	20	39	81	6	77	15	39	93	764

DRY

	BM	BS	CE	CW	CS	DW	EI	GI	MP	MI	PS	SS	SP	TS	VO	Total
1955-59	14	7	23	19	0	15	13	11	9	2	0	21	25	21	23	203
1960-64	10	25	39	69	21	46	78	34	43	73	7	70	21	36	86	658
1965-69	5	51	55	51	49	78	70	45	163	48	8	116	81	84	67	971
1970-73	0	23	124	136	20	25	101	31	63	70	1	67	67	27	86	841
1974-77	4	8	48	110	15	25	102	3	60	64	2	20	43	21	86	611
Total	33	114	289	385	105	189	364	124	338	257	18	294	237	189	348	3,284

BM - Bay Marchand
BS - Breton Sound
CE - Cameron East
CW - Cameron West
CS - Chandeleur Sound
DW - Delta West
EI - Eugene Island
GI - Grand Isle
MP - Main Pass
MI - Marsh Island South
PS - Pelto South
SS - Ship Shoal
SP - South Pass
TS - Timbalier South
VO - Vermilion Offshore

Total exploratory wells -------	4,542
Percent oil wells successful --	11
Percent gas wells successful --	17
Percent dry holes ------------	72
Average number of exploratory wells per year --------------	197

Source: Data compiled from National Oil Scouts Association of America Year Book, published consecutively from 1937-39, v. VII-IX, Oil and Gas Field Development: National Oil Scouts and Landsmen's Association Year Book, published consecutively from 1940-59, v. X-XXIX and International Oil and Gas Development: International Oil Scouts Association Year Book, Part I - Exploration, published consecutively from 1960-78, v. XXX-XLVIII.

one-third of the 12,494 development wells were in the Main Pass, South Pass, and West Delta lease areas, indicating the importance of these tracts in oil and gas production (see fig. 15). They are also responsible for 22 percent of the exploratory activity. Each year, oil men drill an average of 197 exploratory and 543 development wells. These 740 efforts comprise 65 more than the average number of wells drilled onshore each year.

Pipelines

Pipeline networks have been studied for 1941, 1951, 1964, and 1973. This sequence indicates the historic growth and development of Louisiana's oil and gas industry. In a larger sense, it documents the

Table 15.--Offshore development wells, by lease area, off Louisiana.

OIL

	BM	BS	CE	CW	CS	DW	EI	GI	MP	MI	PS	SS	SP	TS	VO	Total
1955-59	124	4	2	10	0	177	126	108	155	6	3	37	426	52	6	1236
1960-64	169	49	3	20	10	290	122	153	108	49	24	68	234	137	1	1437
1965-69	94	26	7	11	36	310	254	316	277	94	19	313	315	332	55	2459
1970-73	24	14	8	17	8	172	248	57	186	20	6	228	183	82	37	1290
1975-77	16	13	8	19	19	24	50	4	38	110	3	47	152	9	6	518
Total	427	106	28	77	73	973	800	638	764	279	55	693	1310	612	105	6940

GAS

	BM	BS	CE	CW	CS	DW	EI	GI	MP	MI	PS	SS	SP	TS	VO	Total
1955-59	10	0	36	40	0	18	22	5	14	6	0	19	19	5	31	225
1960-64	14	6	27	22	3	52	18	16	10	37	0	19	10	2	48	284
1965-69	6	8	35	139	2	58	75	56	69	123	7	134	24	68	56	860
1970-73	5	3	87	93	1	31	182	19	31	43	1	101	6	58	58	719
1975-76	6	12	80	160	3	18	112	16	10	83	1	55	33	23	79	691
Total	41	29	265	454	9	177	409	112	134	292	9	328	92	156	272	2779

DRY

	BM	BS	CE	CW	CS	DW	EI	GI	MP	MI	PS	SS	SP	TS	VO	Total
1955-59	20	2	12	16	3	53	73	31	36	1	7	60	48	36	20	418
1960-64	34	37	7	20	4	56	72	31	22	21	17	33	32	34	18	438
1965-69	38	19	37	49	10	98	132	64	74	111	17	96	86	65	73	969
1970-73	19	8	48	43	4	39	85	20	52	16	1	85	59	36	49	564
1975-77	9	13	32	58	1	17	61	11	9	57	14	28	34	12	30	386
Total	120	79	136	186	22	263	423	157	193	206	56	302	259	183	190	2775

BM - Bay Marchand
BS - Breton Sound
CE - Cameron East
CW - Cameron West
CS - Chandeleur Sound
DW - Delta West
EI - Eugene Island
GI - Grand Isle
MP - Main Pass
MI - Marsh Island South
PS - Pelto South
SS - Ship Shoal
SP - South Pass
TS - Timbalier South
VO - Vermilion Offshore

Total development wells ---- 12,494
Percent oil wells successful -- 56
Percent gas wells successful -- 22
Percent dry holes ------------ 22
Average number of development wells per year ------------- 543

Source: Data compiled from National Oil Scouts Association of America Year Book, published consecutively from 1937-39, v. VII-IX, Oil and Gas Field Development: National Oil Scouts and Landsmen's Association Year Book, published consecutively from 1940-59, v. X-XXIX and International Oil and Gas Development: International Oil Scouts Association Year Book, Part I - Exploration, published consecutively from 1960-78, v. XXX-XLVIII.

expansion of the logistic support facilities. Within each period, the region's service centers have been influenced by the increased drilling activity.

In 1951, 4 years after the Block 32 find, there was only modest offshore development. Twenty-four blocks were producing hydrocarbons. With the exception of West Cameron Block 45 and West Delta Block 69, all other leases were relatively small. Due to the industry's infancy, large logistic support facilities and pipeline networks were not an absolute requirement.

Further inspection of the 1951 map reveals that one pipeline crosses the offshore region. This line, 20 cm in diameter, connects the Vermilion area Block 39 gas field to a line onshore. The 14-km underwater pipeline, along with an independent line into Bay Marchand (McCaslin, 1949, p. 70) marked the beginning of the pipelines that now crisscross the offshore leases. Prior to construction of the pipelines, moving offshore oil to land was a major operation using fleets of barges (Oil and Gas Journal, 1949, p. 324).

In November 1951, a large-diameter gas line was extended into Ship Shoal Blocks 32 and 51 (Petroleum Engineer, 1951b, p. D-21). It was the longest line of any kind offshore. Stringing the ponderous, cement-coated pipe seaward was a forerunner of the intensified growth to be recorded on the 1964 map. In addition, the need was established for pipe-lay barges, ocean-going tugs, and pipe-fabrication yards, along with the rig manufacturing and support services. A new industry developed. The coastal zone's ports and development corridors became industrial foci, meeting the offshore needs of the early 1960's.

In the early 1960's, work offshore was progressing at a frantic pace, with some phenomenal discoveries (Limes and Stripe, 1959, p. 126; Wilson, 1959, p. 66; McGhee and Lawrence, 1961, p. 59; McGhee, 1962, p. 105). Two mammoth fields, South Pass Block 24 and Bay Marchand (now South Timbalier), were recognized as among the State's largest.

Off the deltaic and chenier plains most pipelines are for the movement of natural gas, with the greatest concentration west of the South Timbalier leases. Toward the Mississippi delta, oil lines dominate the pipeline pattern. In 1979 there were 849 producing leases off Louisiana's coast, nearly 15 times the number in 1954 (Harris, McFarlane, Williams, and Hammersley, 1980, p. 9-11). To collect the recovered hydrocarbons for the onshore markets required more than 6,400 km of pipeline.

IMPACT ON THE LAND, LAND USE, AND SOCIETY

The low-lying coastal plain of southern Louisiana encompasses more than 3 million ha, an area where wetlands and water bodies are dominant (fig. 3). Included in this region are all or parts of the eight southernmost parishes of Louisiana, shown in figure 2. These eight parishes are generally the ones most heavily impacted by the development of that part of the oil and gas industry that is served by boat, either on inland waterways or offshore.

The Canal Builders' Effect on the Land

The combined work of the dredging contractors has produced a canal system that in effect opened the coastal zone to hydrocarbon development. In the process the petroleum industry added a large number of canals to the wetlands. The interconnecting network of transportation routes has become a permanent landscape feature, and through additions, the system expands into a complicated pattern. Densities are intensified, affecting land-water ratios, flow regimes, and saltwater intrusion. With increased densities, these waterways coalesce into small lakes and bays. Unless sediment or fill is added, the land is lost. The manmade canal networks expand as tenacious features across the landscape, becoming patterns of extractive land use covering up to 16,000 ha per site.

Well locations are controlled by seismic evidence, not surface morphology; consequently, the canal network rarely has any logical or orderly relationship with the natural landscape.

In older fields, such as Catfish Lake, a 1,353-ha site (located west of Golden Meadow), the pattern is well defined with over 56 km of canals. In developing a field, the oil company first cuts a series of primary service routes, then adds supplementary channels as needed for site access. Through time the expanded canal pattern dominates the landscape, with each appendage representing a new well; it is a one-well--one-canal system. The pattern grows rapidly. In 17 years, the canal network of the Leeville fields increased from 49 to 105 km which, along with spoil banks, accounted for 15 percent of the region's 59 km^2 of surface area in 1969 (Gagliano, 1973, p. 78). The same is true throughout the marsh.

Initially, well access routes are 21 to 27 m wide and 2.4 to 3.0 m deep. Each additional kilometer of length adds more than 83,000 m^3 of spoil, initially creating considerable new dry land (Oil and Gas Journal, 1942, p. 59). Once in use, the distinctive straight channel side often erodes into a cuspate form. Gagliano, Meyer-Arendt, and Wicker (1981) concluded that approximately 104 km^2 of coastal Louisiana's land is lost each year to erosion. About 25 percent of this loss can be accounted for as a direct result of petroleum industry dredging (S.M. Gagliano, oral commun., 1981).

One immediate effect of canalization is change in salinity regimes. Changes in surface runoff, tidal exchange, and water circulation alter the chemistry and floral and faunal characteristics. Lake DeCade (Terrebonne Parish) was at one time well stocked with catfish, but canalization modified the lake's salinity level. Shrimp now breed in the lake and, according to the local fishermen, the catfish are gone.

As pipelines cut through the marsh, their routes cross the region's natural waterbodies. To reduce the environmental impact of these linear features, dams, weirs, and other protective measures are being erected.

The wetlands are no longer considered "worthless," but instead an important aquatic habitat. Gosselink, Odum, and Pope (1974, p. 21) calculate that 1 ha of marsh returns more than $10,000 annually. The region is therefore worth protecting. The marsh-estuary complex generates the largest amount of revenue from its hydrocarbon products, a nonrenewable resource. Aquatic life utilizes the estuaries as a nursery ground. The "estuarine dependent" species have an annual dockside value of more than $150 million (Ringold and Clark, 1980, p. 100), and are a renewable resource that can be managed to increase in value. To minimize saltwater intrusion and circulation changes, water control structures built by the petroleum companies are designed to preserve this valuable wildlife habitat. Gusey and Maturgo (1971, p. 5) report that during development of the region's subsurface resources the wildlife and fisheries harvest showed an almost steady increase.

Changes in Land Use

A better understanding of this onshore impact of the maritime-oriented hydrocarbon industry can be obtained through a brief review of land use in this coastal region. Successful development of the region's petroleum resources attracted numerous industries to the coastal zone.

In the mid-1950's in southern Louisiana, there were 1,187 principal businesses serving the petroleum industry. By the early 1970's this figure increased to 3,591, an increase of more than 100 businesses per year. When located in the major cities, these firms have consolidated into industrial complexes or development corridors. They have come together into distinct patterns, typical of the petroleum industry's regional impact. The patterns are likely to continue to expand. Throughout the area, development wells are being added to existing fields, and there is a definite trend to move into deeper water. Meeting the economic demands of these activities requires extensive onshore services amid often enlarged facilities.

To maintain production schedules in the delta's fields, 44 firms had established offices at Venice, an increase of 28 firms over the early 1950's. To serve the Grand Isle, Ship Shoal, and Timbalier tracts, the communities along Bayou Lafourche began to attract service facilities. South of Larose there were 94 businesses, 62 percent of which were in Golden Meadow and Leeville. The limited land on the natural levees was being transformed into commercial, industrial, and transportation corridors.

Telephone directories recorded 3,625 business activities engaged in 36 petroleum-related enterprises within the coastal zone during 1975. Land use and land cover maps revealed that most of these firms were served by 11,450 ha of commercial, industrial, and transportation land. These patterns have evolved with the petroleum industries' expansion offshore; they provide all the essential services required to maintain more than 2,000 offshore structures.

By 1955, 10 refineries, 14 petrochemical plants, and 3 carbon black firms had located in southern Louisiana, with 29 pipeline companies involved in the movement of petroleum and natural gas (Dowdy, 1955, p. A43-A44). Employment and population patterns were also being established. Between 1950 and 1960, the population in seven parishes (Cameron, Iberia, Lafourche, Plaquemines, St. Mary, Terrebonne, and Vermilion) increased an average of 30 percent or about 7,800 people per parish (Bobo and Charlton, 1974, p. 14-19). Port and logistic support facilities showed considerable expansion. Abbeville, Houma, Morgan City, New Iberia, and Thibodaux had an aggregated growth between 1940 and 1960 of 45 percent (Bobo and Charlton, 1974, p. 37-38). From 1959 to 1969, the new jobs created by the petroleum industry increased the median income of families in urban areas of 2,500 or more inhabitants by several thousand dollars per year (Bobo and Charlton, 1974, p. 179-180).

The cities of New Iberia and New Orleans are inland from the 14 settlement strips identified in figure 1. They collectively have 1,090 businesses related to the petroleum industry. As might be expected, these firms have played a major role in the economic structure of the two areas.

Within several of the strips outlined on figure 1 there are companies that cater to every aspect of the offshore petroleum industry. They have turned the 18,020 ha of the settlement clusters into major logistic centers. There are engineering firms, chemical distributors, mud companies, hardware outlets, shops specializing in marine engines, ship builders, boat repair services, towing contractors, log libraries, heliports and aircraft maintenance facilities, boat rental firms, structural fabricators, and many others. Mud, casing, cement, and other expendables are transported from onshore bases to the job site by a continuous ferry service. In the linear communities flanking the region's principal waterways, the boat industry has become an intricate part of the region's economy.

Along with the economic effects of the petroleum industry, a considerable demand for land was having a decisive and cumulative impact on the land use and land cover patterns. The exploration and development phases changed the region's rural character and attracted primary and secondary industries to the logistic support centers.

Currently, in the coastal wetlands of the eight southernmost parishes, there are more than 18,000 ha of strip and clustered settlements, divided into the 14 major strips of intensively used land. Each is expanding into the adjacent wetlands through land reclamation projects, thus allowing the communities to accommodate an enlarged population.

Land use maps prepared by the U.S. Geological Survey (selected representative settlement strips appear in figures 16 and 17) show the areal extent of the various land uses associated with the settlements in 1972. From these maps the area in each use was calculated. Such maps revealed the settlement pattern; 14 areas can be easily identified (fig. 1). The two maps, figures 16 and 17, were selected to illustrate examples of a chenier plain strip and a strip in the southwestern part of the deltaic plain. These maps mainly utilize the classification system from Anderson and others (1972), but the wetland categories, Forested and Nonforested Wetlands, are from the classification system presented by Anderson and others (1976).

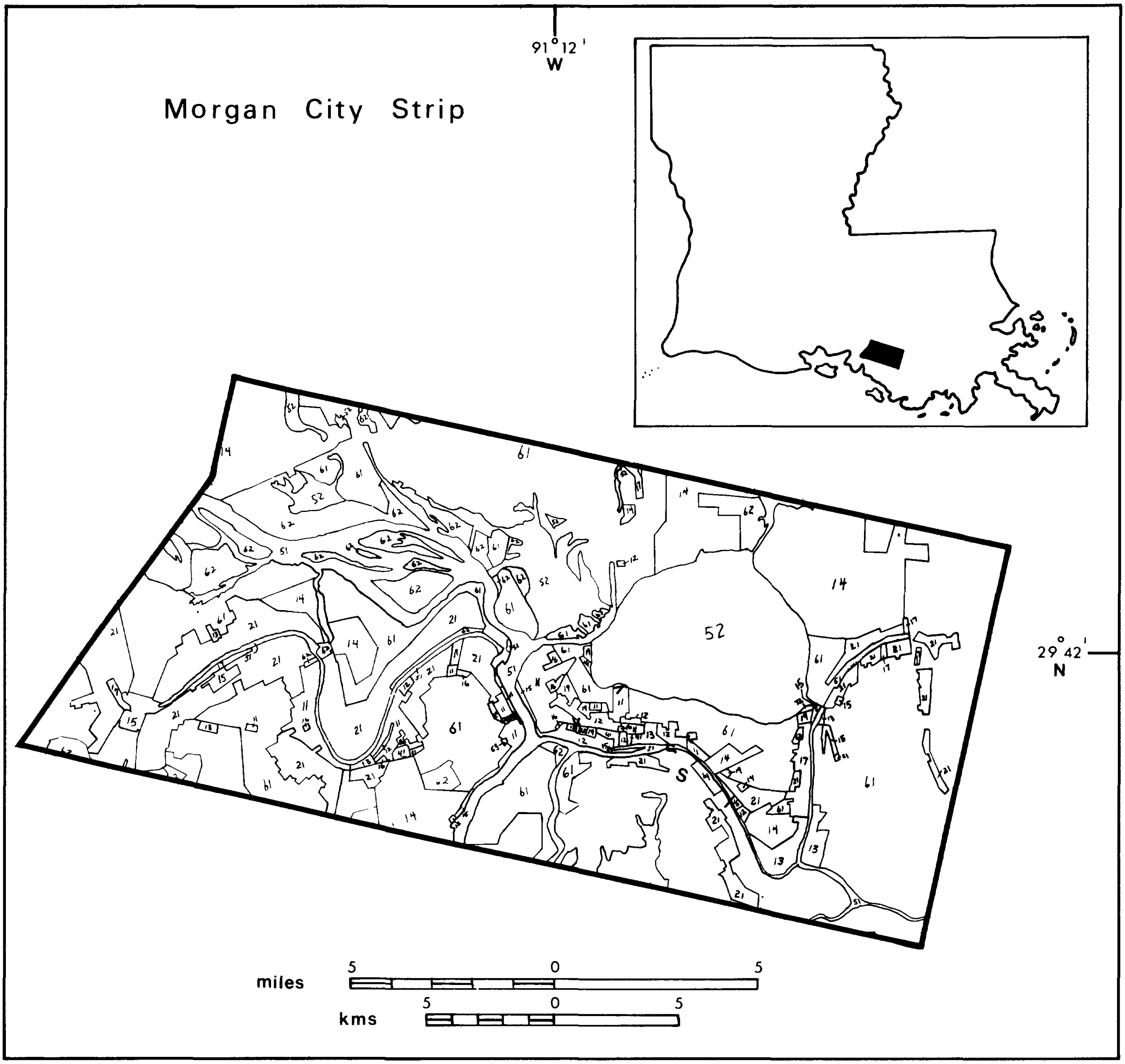
The distribution of all types of land use and land cover for southern Louisiana in 1972 is shown in table 16, which lists the total areas of each use or cover type by parish. Map analysis of all types of land use and land cover indicates that the large oil and gas fields on the deltaic plain have, in nearly all cases, been drilled in wetland areas. On the chenier plain, patterns show extractive industries to be relatively small and widely spaced and found mostly in the coastal marshes. The totals listed by parish in table 16 show more clearly the great amount of land (184,200 ha) devoted to intensively-developed oil and gas fields (Category 14, Extractive) in southern Louisiana. Also, figure 7 shows an example map of the impact of drilling in the wetland areas. The 20 parishes of table 16 contained, in 1972, approximately 588,700 ha of forested wetland and 1,312,100 ha of non-forested wetland.

Settlement Patterns

Settlements continue to this day to aline along natural levees and beach ridges within the 14 easily-defined strips (fig. 1) appearing on the maps of land use and land cover prepared by the U.S. Geological Survey. Each strip is characterized by elongated patterns of settlement, ranging from 20 ha at Holly Beach to 4,040 ha strung out along Bayou Lafourche. In all strips, more than 18,000 ha (table 17) of land use and land cover types associated with strip settlement existed in 1972.

The hamlets of the 1930's have coalesced into continuous linear settlements. They have grown to the point where boundaries between communities are no longer well defined. Some people have referred to the urbanization along Bayou Lafourche as "the longest main street in the World." Settlement density along the highways on the crests of the "levees" approaches that of urban row housing.

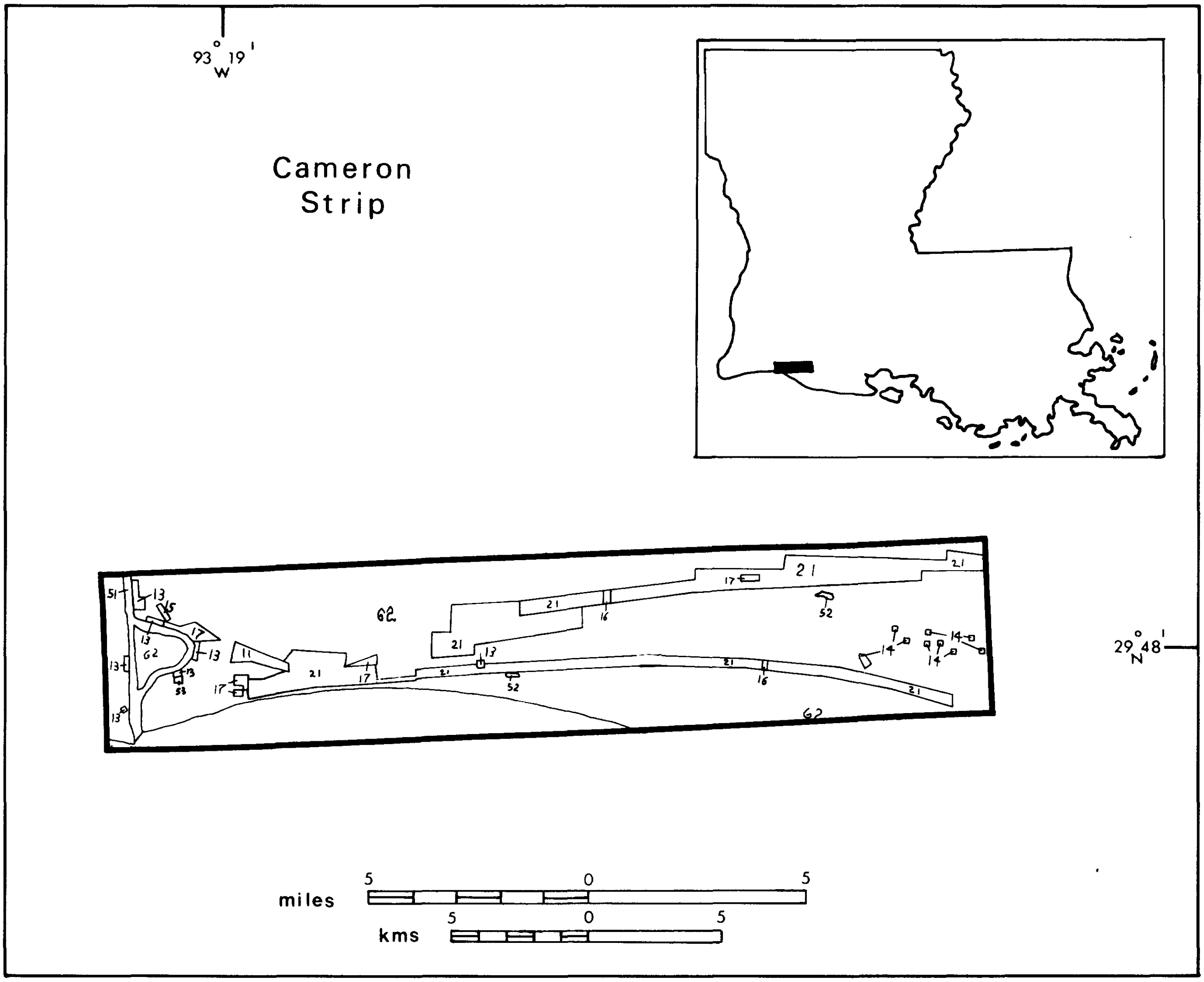
Utilizing most of the 6,030 ha classified as industrial and transportation land within the strips on the USGS maps of land use and land cover, the petroleum industry has been responsible for the construction



Category Code

11 Residential	17 Strip and Clustered Settlement
12 Commercial	19 Open and other
13 Industrial	21 Cropland or Pasture
14 Extractive	51 Stream or Waterway
15 Transport./Commun./Utility	52 Lake
16 Institutional	61 Forested Wetland

Figure 16.--Example of a settled strip, Morgan City, located on the deltaic plain of Southern Louisiana. Data are from the USGS land use and land cover map of New Orleans, Louisiana, 1:250,000-scale quadrangle, 1972, Open-File Report 75-245.



Category Code

11 Residential
12 Industrial
14 Extractive
15 Transport./Commun./Utility
16 Institutional
17 Strip and Clustered Settlement
21 Cropland or Pasture
51 Stream/Waterway
52 Lake
62 Nonforested Wetland

Figure 17.--Example of a settled strip, Cameron, located on the chenier plain of southern Louisiana. Data are from the USGS land use and land cover map of Port Arthur, Texas, Louisiana, 1:250,000-scale quadrangle, 1972, Open-File Report 75-244.

Table 16.--Land use and land cover in hectares for the parishes of southern Louisiana, 1972.

	Ascension	Assumption	Cameron	East Baton Rouge	Iberia	Iberville	Jefferson	Lafayette	Lafourche	Orleans
Urban or Built-up Land										
11 Residential	800	100	200	13,900	900	600	11,300	4,400	1,200	10,700
12 Commercial and Services	200	0	0	2,300	300	100	1,100	600	200	1,300
13 Industrial	800	200	100	1,900	300	800	2,200	300	400	2,000
14 Extractive	900	6,600	3,700	700	7,800	2,100	18,100	200	37,300	400
15 Transportation, Communications and Utilities	0	0	100	400	600	0	700	500	100	1,100
16 Institutional	0	0	100	1,100	100	500	300	300	200	500
17 Strip and Clustered Settlement	500	2,000	300	400	1,500	900	900	800	3,700	500
18 Mixed	0	0	0	0	0	0	0	0	0	0
19 Open and Other	200	0	0	2,200	200	100	2,400	200	200	2,000
Agricultural Land										
21 Cropland and Pasture	37,000	30,800	43,200	53,200	49,300	42,300	1,500	55,300	48,900	100
22 Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas	0	0	0	100	100	0	0	100	0	0
23 Feeding Operations	0	0	0	0	0	0	0	0	0	0
24 Other	0	0	0	100	200	0	0	0	0	0
Rangeland - Not Applicable										
Forest Land										
41 Deciduous	9,200	0	0	1,200	200	1,800	1,500	400	1,400	2,300
42 Evergreen (Coniferous and Other)	800	0	0	3,000	100	1,700	0	0	0	0
43 Mixed	4,200	0	0	33,400	500	1,800	0	1,200	0	0
Water										
51 Streams and Waterways	2,000	0	6,900	2,400	1,500	4,500	1,700	0	700	3,300
52 Lakes	100	5,600	73,100	300	9,100	400	38,600	100	23,500	35,900
53 Reservoirs	100	0	0	0	0	0	0	0	2,300	0
54 Bays and Estuaries	0	0	0	0	39,100	0	19,000	0	42,500	400
55 Other	0	0	75,800	0	210,500	0	87,800	0	199,800	0
Wetland										
61 Forested	20,400	47,400	700	2,300	32,500	110,000	10,700	1,300	49,600	2,700
62 Nonforested	700	0	340,600	700	49,700	2,000	32,900	100	144,500	23,600
Barren Land										
71 Salt Flats	0	0	0	0	0	0	0	0	0	0
72 Beaches	0	0	0	0	0	0	0	0	0	0
73 Sand Other than Beaches	0	0	0	0	0	0	0	0	0	0
74 Bare Exposed Rock	0	0	0	0	0	0	0	0	0	0
75 Other	0	0	1,800	200	4,300	0	5,900	0	5,600	300
Total Hectarage	77,900	92,700	546,600	119,800	408,800	169,600	236,600	66,000	562,100	87,100

Table 16.--Land use and land cover in hectares for the parishes of southern Louisiana, 1972 (con't).

	Plaquemine	St. Bernard	St. Charles	St. James	St. John The Baptist	St. Martin	St. Mary	Terrebonne	Vermilion	West Baton Rouge
Urban or Built-up Land										
11 Residential	600	1,800	900	500	600	400	1,700	2,200	1,400	300
12 Commercial and Services	100	100	100	0	0	100	1,000	600	100	0
13 Industrial	1,200	300	1,400	600	0	100	500	700	200	300
14 Extractive	21,300	0	8,800	300	200	12,900	22,000	38,700	2,100	100
15 Transportation, Communications and Utilities	600	0	0	0	0	2,500	2,200	300	200	0
16 Institutional	300	0	100	100	300	0	0	0	0	0
17 Strip and Clustered Settlement	2,500	800	700	1,100	500	500	1,800	3,200	800	500
18 Mixed	0	0	0	0	0	0	0	0	100	0
19 Open and Other	200	300	200	0	100	0	500	100	0	100
Agricultural Land										
21 Cropland and Pasture	8,800	900	8,800	22,500	11,300	54,700	34,700	22,400	173,700	20,800
22 Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas	900	100	0	0	0	0	0	0	0	0
23 Feeding Operations	0	0	0	0	0	0	0	0	0	0
24 Other	0	0	0	0	0	0	0	0	0	0
Rangeland - Not Applicable										
Forest Land										
41 Deciduous	2,700	4,200	200	3,000	200	3,200	300	8,600	2,900	100
42 Evergreen (Coniferous and Other)	0	0	100	0	300	200	0	0	0	0
43 Mixed	0	0	500	200	1,300	1,900	0	0	100	14,500
Water										
51 Streams and Waterways	21,800	2,400	2,500	2,700	1,500	3,600	5,500	3,000	2,200	3,000
52 Lakes	50,000	47,600	35,100	0	39,900	5,200	8,400	27,300	63,400	300
53 Reservoirs	700	900	100	100	100	0	0	100	0	0
54 Bays and Estuaries	92,000	138,700	0	0	0	0	28,400	97,100	31,900	0
55 Other	745,400	301,500	0	0	0	0	191,800	121,700	158,700	0
Wetland										
61 Forested	5,200	1,700	22,000	32,300	33,000	115,400	41,800	36,500	11,500	11,700
62 Nonforested	177,300	105,800	29,600	0	7,100	8,900	53,500	226,500	108,600	0
Barren Land										
71 Salt Flats	0	0	0	0	0	0	0	0	0	0
72 Beaches	600	1,000	0	0	0	0	0	300	0	0
73 Sand Other than Beaches	0	0	100	0	0	0	0	0	0	0
74 Bare Exposed Rock	0	0	0	0	0	0	0	0	0	0
75 Other	6,400	10,300	0	0	0	0	5,000	6,300	100	0
Total Hectarage	1,138,700	618,400	111,200	63,400	96,400	209,600	399,100	595,500	558,000	51,700

Computer listing prepared by the Louisiana Office of State Planning, Baton Rouge, La., from data compiled by the U.S. Geological Survey.

Table 17.--Urban and Built-up land use in hectares by settlement strips in the chenier and deltaic plains, 1972.

Name of Strip	Residential	Commerical and Services	Industrial	Extractive	Transportation Communication, and Utilities	Institutional	Strip and Clustered Settlement	Mixed	Open and Other	Total
Code:	11	12	13	14	15	16	17	18	19	
Chenier Plain										
Cameron	120	-	100	50	20	10	170	-	-	470
Grand Chenier	-	-	40	10	30	110	40	-	-	230
Holly Beach	20	-	30	230	-	10	20	-	-	310
Pecan Island	-	-	-	4-	-	-	90	-	-	130
Total (chenier)	140	-	170	330	50	130	320	-	-	1,140
Deltaic Plain										
Bayou Black	-	90	150	630	-	-	560	-	-	1,430
Bayou du Large	-	-	-	-	-	-	150	-	-	150
Bayou Grand Caillou	170	10	50	-	-	-	500	-	-	730
Bayou Lafourche	2,020	170	290	3,460	10	250	4,040	-	140	10,380
Bayou Petit Caillou	90	20	150	6,930	70	30	1,630	-	-	8,920
Franklin	800	50	170	840	-	60	2,460	-	10	4,390
Houma	2,050	900	430	60	180	140	1,590	-	320	5,670
Lafitte	-	50	20	-	-	10	420	-	-	500
Morgan City	1,550	30	1,140	7,690	580	120	450	-	210	11,770
Plaquemines	810	70	1,980	6,410	590	360	6,220	-	90	16,530
Total (deltaic)	7,490	1,390	4,380	26,020	1,430	970	18,020	-	770	61,470
Total (14 strips)	7,630	1,390	4,550	26,350	1,480	1,100	18,340	-	770	62,610

From data on land use and land cover compiled by the U.S. Geological Survey.

of extensive fabrication and support facilities. Two platform construction sites cover a total of 540 ha and represent an important addition to the local economy. In addition, other tracts have been developed to build, service, and dock the marine fleet required by the offshore platforms. The industrial and transportaton uses of land are commonly related to the petroleum industry (table 17).

Some sites outside the strips are highly specialized. They are either related to the petroleum industry or serve as recreation centers. For example, the two individual tracts south of Golden Meadow encompass 183 and 28 ha of industrial land parallel to Bayou Lafourche. These are multifunctional services centers, established by the petroleum industry to meet their needs.

One noteworthy pattern that is revealed in table 17 is the very large area devoted to extractive use compared to other urban or built-up uses. In the deltaic plain it comprises more than 40 percent of the urban or built-up land in that plain. In the chenier plain, it is about 30 percent of the urban or built-up.

The land use and land cover map of the New Orleans Quadrangle (USGS Open-File Report 75-245) also records a 62-ha industrial complex between Belle Pass and Pass Fourchon, both distributary channels of Bayou Lafourche. An enlarged facility, proposed for completion in 1985, will occupy more than 688 ha for industrial expansion and 202 ha for port space. The long-range uses of the "Port Fourchon development" include terminal and docking facilities and fabrication yards for the offshore rigs. The multi-use area will also play a prominent part in the proposed superport off the coast of Lafourche Parish, a facility that may, in time, affect land values, industrial development, and the region's and State's economy (Gulf South Research Institute, 1974, p. 18-20; Irvin Melancon, General Manager, Greater Lafourche Port Commission, Galliano, La., oral commun., May 25, 1975).

Deltaic Plain Settlement

The impact of urbanization is still developing. In 1940 the communities of Houma, Morgan City, and Thibodaux each had less than 10,000 inhabitants. In recent decades the impact of urban influences continues to be light for coastal Louisiana as a whole. Within the 14 settlement strips, however, the factors contributing to urbanization are more apparent. The population clusters within these intensively used strips, with the exception of Houma, Morgan City, New Iberia, and Thibodaux, are a heterogeneous mix of residential, commercial, industrial, and transportation areas. Intensive uses are related to the economic independence associated with the oil and gas industry and the historical involvement with fish and wildlife exploitation.

Development along the natural levees was facilitated by improvements in the small marine engine. From levee communities, one could harvest marsh resources and enjoy the benefits of rapid transportation as well as the conveniences associated with the linear settlements.

The pattern of settlement shifted from small, often isolated sites, to more permenent, structured communities. Mass out-migration has consolidated the deltaic plain's urban-rural pattern. No longer is the marsh dotted by small subsistence hamlets. Fishing and hunting camps represent the sole survivors of isolated settlement within the alluvial wetlands. Now occupation of the marsh is a matter of choice, primarily being carried on to exploit the recreation potential.

In the deltaic plain, 10 settlement strips listed in figure 17 help to support the approximately 331,000 people that live in Iberia, Lafourche, Plaquemines, St. Mary, and Terrebonne Parishes, (Jefferson is not included, as it is part of the New Orleans metropolitan area) (State Planning Bulletin, 1981, p. 4). More than 98 percent of the study area's linear settlements are in the deltaic plain. From table 17 it is clear that land categorized as strip and clustered settlements is relatively extensive along the Mississippi River, Bayou Lafourche, and Franklin strip. In addition, more than 3,000 ha in this plain are devoted to the land-based firms and businesses associated with the industrial and transportation impact of the petroleum industry.

In all 10 settlement strips, there are 4,378 ha of industrial land, with individual sites ranging from under 4 ha to more than 400 ha. When coupled with the region's 1,430 ha of transportation-oriented businesses, these two land use categories cover an area of about 7,808 ha.

To appraise the regional economic structure of the 14 strips, telephone directories and State Employment Security records were utilized extensively (tables 18 and 19). These sources provide a means to assess the cumulative impact and relative magnitude of the petroleum industry's support services within the 14 strips of intensive settlement. A slow transition has facilitated industrial growth, meeting the needs of the expanding offshore development.

Businesses and employment statistics for 1974 reveal that about 25 percent of the labor force is involved in petroleum-related extractive and transportation occupations. Eighty percent of the individuals employed in extractive industries work for 167 firms in Lafourche, Iberia, St. Mary, and Terrebonne Parishes, with an average of about 50 employees per business. Transportation-oriented occupations account for 7,588 jobs, indicating the importance of the marine-service industry. Equally significant is the high proportion of jobs in the transportation equipment category, essentially boat building and repair. Sixty-two firms were reported in this category. The land use data for the 20 southern parishes tabulated on table 16 reveals 9,300 ha being used for activities related to transportation, communications and utilities, which includes port facilities and boatyards. The figure is understated due to the large number of activities that occupy less than 4 ha, the minimum unit recorded. The boatbuilding industry is scattered throughout the wetlands and involves only a small area, but produces 40 percent of the world's oil logistic support craft for the offshore petroleum industry.

Due to the importance of logistic support bases and ancillary services, all 10 settlement strips of the deltaic plain have profited from hydrocarbon exploration and development. Dock and storage facilities within the strips is often confined to small sites, which are too small to show on the USGS land use and land cover maps. Because of their number they have a cumulative impact. Along the Bayou Grand Caillou strip, there are several service centers, but the sites were not recorded. Compilations in table 17 indicated no transportation development, but within the strip and clustered settlement category, there are numerous water-related support services. In the Petit Caillou strip, there are 70 ha of transportation-oriented land. One site encompasses 48 ha. The strip's 150 ha of industrial land are scattered throughout the region. Sites vary from the 28-ha facility at Cocodrie to numerous other facilities farther north along the bayou.

Table 18.--Business and employment by parish in 1974 (From data compiled by the State of Louisiana Department of Commerce and Industry, Baton Rouge, La., A, Number of businesses; B, Number of persons employed).

Standard Industrial Classification	Cameron		Lafourche		Iberia		Plaquemines		St. Mary		Terrebonne		Vermilion		Total		Percent	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Agricultural Production - Crops	-	-	2	4	1	13	2	32	1	4	2	13	-	-	8	66	.12	.08
Agricultural Services	-	-	4	37	8	53	1	-	4	13	5	5	9	28	31	136	.48	.17
Forestry	-	-	-	-	-	-	1	8	-	-	-	-	-	-	1	8	.02	.01
Fishing, Hunting, Trapping	14	217	153	282	28	51	22	313	44	249	103	186	20	157	384	1,455	5.93	1.83
Oil and Gas Extraction	14	413	33	1,117	37	1,142	22	961	36	3,648	61	2,421	17	661	220	10,363	3.40	13.01
Nonmetalic Mining	-	-	1	2	3	972	-	-	1	118	1	30	-	-	6	1,122	.09	1.41
Building Construction	-	-	29	175	24	145	9	402	41	978	38	232	6	106	147	2,038	2.27	2.56
Other Construction	4	148	16	161	16	225	19	660	17	382	23	542	6	18	101	2,136	1.56	2.68
Special Trade Contractors	-	-	76	492	58	484	43	614	45	580	78	710	39	255	339	3,135	5.24	3.94
Food and Kindered Products	6	129	25	1,801	20	1,018	5	158	12	670	29	1,156	11	666	108	5,598	1.67	7.03
Apparel Manufacturer	-	-	4	6	-	-	-	-	-	-	-	-	1	87	5	93	.08	.12
Lumber and Wood Products	-	-	1	13	2	231	-	-	-	-	4	31	1	38	8	313	.12	.39
Furniture and Fixtures	-	-	-	-	2	58	1	47	-	-	-	-	-	-	3	105	.05	.13
Paper and Allied Products	0	0	1	239	1	95	-	-	-	--	-	-	-	-	2	334	.03	.42
Printing and Publishing	-	-	3	52	6	98	-	-	7	82	6	112	5	20	27	364	.42	.46
Chemicals and Allied Products	-	-	1	12	2	12	3	659	1	339	-	-	1	12	8	1,034	.12	1.29
Petroleum Refining	-	-	1	0	-	-	1	2	1	2	-	-	1	9	4	13	.06	.02
Rubber and Plastics	-	-	2	8	-	-	--	-	-	-	1	0	-	-	3	8	.05	.01
Building Products	-	-	4	37	5	41	3	50	8	96	1	9	2	18	23	251	.36	.32
Primary Metal Industries	-	-	-	-	-	-	1	367	-	-	-	-	-	-	1	367	.02	.46
Fabricated Metal Products	-	-	5	27	1	6	3	216	22	604	7	1,023	3	5	41	1,881	.63	2.36
Machinery, Except Electrical	2	4	8	567	20	816	1	30	-	-	10	103	1	6	42	1,526	.65	1.92
Electrical Machinery	-	-	1	4	-	-	-	-	1	21	-	-	-	-	2	25	.03	.03
Transportation Equipment	1	4	17	529	6	241	6	368	15	378	11	539	6	91	62	2,150	.96	2.70
General Measuring Instruments	-	-	-	-	-	-	1	30	-	-	-	-	-	-	1	30	.02	.04
Miscellaneous Manufacturing	-	-	2	-1	-	-	-	-	1	3	-	-	-	-	3	4	.05	.01
Local and Suburban Transit	-	-	2	4	6	31	2	9	5	17	3	49	-	-	18	110	.28	.14
Motor Freight Transportation	1	3	14	160	18	367	14	264	9	115	19	426	11	47	86	1,382	1.33	1.73
Water Trnasportation	20	537	237	2,254	44	476	133	1,094	142	2,452	151	1,312	27	284	754	8,409	11.65	10.56
Air Transportation	-	-	1	1	1	26	-	-	1	58	7	61	1	2	11	148	.17	.19
Pipelines, Not Natural Gas	1	18	-	-	-	-	1	1	-	-	1	16	-	-	-3	35	.05	.04
Transportation Services	-	-	-	-	1	3	1	24	-	-	2	5	-	-	4	32	.06	.04
Communication	2	17	5	140	4	49	6	45	5	97	5	78	3	59	30	485	.46	.61
Electric, Gas, Sanitary Services	1	5	5	59	3	38	1	20	1	2	1	74	1	2	13	200	.20	.25
Wholesate Trade--Durable Goods	7	21	64	714	66	727	39	697	78	1,220	120	2,154	30	287	404	5,820	6.24	7.31
Wholesale Trade--Nondurable Goods	-	-	-	-	-	-	-	-	1	4	-	-	-	-	1	4	.02	.01
Building Materials	3	30	26	217	25	238	11	67	25	169	27	251	33	321	150	1,293	2.32	1.62
General Merchandise Store	4	11	17	206	13	301	6	37	19	260	17	585	11	91	87	1,491	1.34	1.87
Food Stores	6	53	54	202	47	311	21	295	51	429	55	446	40	219	274	1,955	4.23	2.45
Auto Dealers, Gas Stations	11	25	82	539	61	537	28	135	79	618	103	689	49	282	413	2,825	6.38	3.55

Table 18.--Business and employment by parish in 1974 (From data compiled by the State of Louisiana Department of Commerce and Industry, Baton Rouge, La., A, Number of businesses; B, Number of persons employed). (Con't)

Standard Industrial Classification	Cameron		Lafourche		Iberia		Plaquemines		St. Mary		Terrebonne		Vermilion		Total		Percent	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Apparel Stores	1	1	29	132	18	179	3	27	18	67	23	83	20	73	112	562	1.73	.71
Furniture Stores	-	-	28	163	24	97	2	18	18	95	25	185	17	46	114	604	1.76	.76
Eating and Drinking Places	11	48	71	399	70	382	36	193	64	589	92	1,200	54	220	398	3,031	6.15	3.80
Miscellaneous Retail	3	7	44	240	43	225	12	72	46	231	56	305	45	237	249	1,317	3.85	1.65
Banking	1	14	7	281	6	215	1	55	6	263	5	386	7	140	33	1,354	.51	1.70
Credit Agencies	-	-	16	121	14	77	7	15	11	49	18	89	8	31	74	382	1.14	.48
Security Brokers	-	-	2	10	1	-	-	-	1	3	1	2	-	-	5	15	.08	.02
Insurance	-	-	1	14	2	21	-	-	-	-	-1	3	-	-	4	38	.06	.05
Insurance Agents	1	4	28	88	15	52	2	8	16	104	20	63	17	51	99	370	1.53	.46
Real Estate	2	7	16	37	19	83	7	18	35	93	59	155	14	39	152	432	2.35	.54
Combination of Real Estate	-	-	-	-	-	-	-	-	2	5	2	6	-	-	4	11	.06	.01
Holding and Investment Offices	-	-	3	8	1	2	-	-	4	17	7	36	-	-	15	63	.23	.08
Hotels and Motels	7	44	12	69	8	57	5	29	15	238	8	106	6	13	61	556	.94	.70
Personal Services	2	11	29	107	43	154	6	23	41	146	39	140	20	52	180	633	2.78	.79
Business Services	2	31	15	351	28	139	15	451	74	1,701	52	580	12	41	198	3,294	3.06	4.14
Auto Repair and Garages	2	2	17	51	19	58	7	24	12	44	39	145	15	21	111	345	1.71	.43
Miscellaneous Repair Shops	5	107	26	114	35	207	8	296	34	380	33	420	14	119	155	1,643	2.39	2.06
Motion Pictures	-	-	4	52	1	17	1	3	5	36	2	41	4	16	17	165	.26	.21
Amusement Services	8	51	13	65	9	48	8	108	9	61	7	86	4	34	58	453	.90	.57
Health Services	2	16	67	703	73	571	8	131	53	321	49	889	32	484	284	3,115	4.39	3.91
Legal Services	1	3	26	68	23	68	6	17	18	69	33	120	17	55	124	400	1.92	.50
Educational Services	1	22	3	4	7	60	1	4	8	43	5	12	5	44	30	189	.46	.24
Social Services	-	-	-	-	1	7	-	-	-	-	1	2	-	-	2	9	.03	.01
Membership Services	-	-	7	27	2	3	-	-	6	77	11	61	2	10	28	178	.43	.22
Private Households	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	.02	.00
Miscellaneous Services	1	4	23	78	21	172	4	118	16	73	28	208	9	58	102	711	1.58	.89
Public Order and Safety	1	1	8	537	2	28	3	337	5	42	4	21	4	31	27	997	.42	1.25
Public Finance	-	-	1	12	1	6	-	-	3	10	1	12	3	7	9	47	.14	.06
TOTAL	148	2,008	1,392	13,793	1,015	11,733	549	9,552	1,194	18,366	1,512	18,614	664	5,593	6,474	79,659	100.00	100.00

Table 19.--Economic activities related to the petroleum industry by settlement strip or city, 1955, 1965, 1975.

	Bayou Black			Bayou dularge			Bayou Grand Caillou			Bayou Lafourche			Bayou Petit Caillou			Cameron			Franklin			Grand Chenier		
Year	55	65	75	55	65	75	55	65	75	55	65	75	55	65	75	55	65	75	55	65	75	55	65	75
Aircraft Charter and Rental																				1				
Boat Charter and Rental		3	5					1	8		20	35	3		4		2		1		4			
Helicopter Service											1	2						1						
Oil Field Equipment		2	2									1						1	1					
Oil Field Equipment Rental		3	7									1									1			
Oil Field Equipment Repair																								
Oil Field Hauling			2																					
Oil Field Service	1	3	14				1	3	5		25	16		1	1		7	11	8	5	3		1	1
Oil Field Specialities																								
Oil Field Supplies			3								7	5					2	2	2	2	1			
Oil and Gas Exploration																					1			
Oil Land Leases																				1				
Oil Operators																								
Oil Producers		3	3				5	2	8		9	14		3	2		11	14	4	7	9		8	8
Oil Properties																								
Oil Property Management																								
Oil Refiner																								
Oil Reports																								
Oil Royalities																								
Oil Well Cementing																					1			
Oil Well Chemical Service																		1						
Oil Well Casing Fulling																								
Oil Well Core Analysis																								
Oil Well Core Service																								
Oil Well Directional Drilling																			1	1	3			
Oil Well Drilling		4	2					2	3		5	1								1				
Oil Well Drilling Mud		2	2						3		5	3					8	5		1	3			
Oil Well Equipment and Supplies			1								1	1								1	5			
Oil Equipment Rental			1																					
Oil Well Fishing Tools											3	3									1			
Oil Well Log Libraries																								
Oil Well Logging and Perforating												1	1											
Oil Well Service		1	2						2		3	2			1		2	1		2	3			
Oil Well Tools and Rental																				1				
Oil Well Surveyors		1																			2			
Oil Well Wire Line Service																								
Ship Building			3						2		7	11			1						2			
Towing, Marine		1	5				1	5			8	20	2	1					3	6	8			
TOTAL	1	23	52				7	13	31		95	116	5	5	9		32	36	20	29	47		9	1

TOTAL 1955 = 1,209
1965 = 2,664
1975 = 3,625

Source: A count of advertised activities in telephone directories for 1955, 1965, 1975.

Table 19.--Economic activities related to the petroleum industry by settlement strip or city, 1955, 1965, 1975 (con't).

	Holley Beach			Houma			Lafitte			Morgan City			Pecan Island			Plaquemines		
	55	65	75	55	65	75	55	65	75	55	65	75	55	65	75	55	65	75
Aircraft Charter and Rental					8	7				3	3	3					1	3
Boat Charter and Rental				7		15				29	46	49				5	7	17
Helicopter Service				2		2					2	2					1	2
Oil Field Equipment				25	43	51			3	1	8	20					3	7
Oil Field Equipment Rental				1	26	40					7	17					1	13
Oil Field Equipment Repair				4	7	9					2						1	1
Oil Field Hauling					8	14					3	10						5
Oil Field Service				38	93	166		1		9	29	60				9	25	83
Oil Field Specialities					11					1	3							
Oil Field Supplies				12	27	40				5	24	32				2	4	10
Oil and Gas Exploration				3	6	4				7	1							2
Oil Land Leases				2	2	2												
Oil Operators				4	1						2							
Oil Producers		7	8	14	14	18	6	4	3	5	13	15				3	11	15
Oil Properties																		
Oil Property Management																		
Oil Refiner										1								1
Oil Reports																		
Oil Royalities																		
Oil Well Cementing					4	4				1	3	4					1	4
Oil Well Chemical Service											1							
Oil Well Casing Fulling					1													
Oil Well Core Analysis					2						1							
Oil Well Core Service					1													
Oil Well Directional Drilling				2	3	3					2	1						2
Oil Well Drilling					13	10	1		1		10	8					7	3
Oil Well Drilling Mud				7	12	17				7	6	13				8	1	6
Oil Well Equipment and Supplies				26	13	16				2	5	4						8
Oil Equipment Rental						7										2		
Oil Well Fishing Tools					14	14					3	6					2	12
Oil Well Log Libraries																		
Oil Well Logging and Perforating				13	7	8				1		1				1	3	4
Oil Well Service				20	35	41				2	2	11				2	8	25
Oil Well Tools and Rental					13												2	
Oil Well Surveyors				1	2	2												
Oil Well Wire Line Service					2												1	
Ship Building				3	3	7	5	3	3	10	8	19				4	22	3
Towing, Marine				4	11					9	10	34				5	66	14
TOTAL		7	8	188	382	497	12	8	10	93	204	309				39	103	242

Figure 19.--Economic activities related to the petroleum industry by settlement strip or city, 1955, 1965, 1975 (con't).

	Lafayette			New Iberia			New Orleans Area			Other		
	55	65	75	55	65	75	55	65	75	55	65	75
Aircraft Charter and Rental	3	3	3	1	1	1	6	14	18	2	1	2
Boat Charter and Rental	1	3	3	1	6	11	4	2	40	3	9	13
Helicopter Service	1	1	3			1	1	1	1		2	4
Oil Field Equipment	27	78	97	14	13	25	25	47	68	3	2	6
Oil Field Equipment Rental	8	31	61	6	16	18	8	13	21			1
Oil Field Equipment Repair	2	6	9	2		10	5	25	9	1		
Oil Field Hauling		10	16		5	8		10	14			2
Oil Field Service	70	160	239	18	36	62	32	81	137	10	33	59
Oil Field Specialities	3	19		4	7		2	22	13			
Oil Field Supplies	14	30	55	10	20	19	15	43	51	1	3	7
Oil and Gas Exploration		9	47	4	2	1	3	13	48	13	7	3
Oil Land Leases	25	33	50	1	1	1	11	18	23	2	3	3
Oil Operators	16	52	61				10	51	44			
Oil Producers	47	78	79	3	2	3	64	133	933	13	29	36
Oil Properties	1	13	6				1	22	8	1		
Oil Property Management			2									
Oil Refiner			1				1	3	4		2	1
Oil Reports	1		2				4	3	2			
Oil Royalities		3	5				5	5	6			
Oil Well Cementing	2	8	9	2	4	1	3	9	5		1	
Oil Well Chemical Service	1	10					1			2	2	3
Oil Well Casing Fulling		2										
Oil Well Core Analysis	3	6	3				2	4				
Oil Well Core Service	4	3						2	1			
Oil Well Directional Drilling	7	12	25		3	5	2	2	4			
Oil Well Drilling		23	23		7	4		41	25	1	5	8
Oil Well Drilling Mud	5	14	22	7	11	5	12	7	9	5	11	15
Oil Well Equipment and Supplies	12	21	22	22		1	38	33	35			2
Oil Equipment Rental			3									1
Oil Well Fishing Tools	1	7	8	5	11	9	4	7	8			
Oil Well Log Libraries			1						3			
Oil Well Logging and Perforating	7	23	16	4	3	4	8	12	11	1		1
Oil Well Service	27	49	88	12	10	21	18	21	34	8	6	7
Oil Well Tools and Rental	1			2		1	6	8				
Oil Well Surveyors	2	4	6					2	4			
Oil Well Wire Line Service		1						2	2			
Ship Building		1		1	1	11	18	20	28	6	8	15
Towing, Marine	1	1	3	2	2	5	47	74	96		7	12
TOTAL	292	714	968	121	160	227	358	750	863	72	130	201

In the deltaic plain, marine-related businesses have been established in all of the settlement areas listed in table 17. Shipbuilding and towing are particularly noteworthy. The strip settlements and the New Orleans Standard Metropolitan Statistical Area have developed into important marine-service centers. People living in these settlement areas have been responsible for the design, construction, operation, and maintenance of drilling rigs, production platforms, crewboats, barges, pipelines, pipe-lay barges, and service vessels. They have witnessed the regional transition to labor-intensive or capital-intensive occupations and the associated changes in the landscape. The equipment used in working offshore had to be constructed to meet local needs. There was no precedent. Louisiana was the worldwide leader in offshore hydrocarbon exploration and had to learn from its mistakes and successes.

Jobs were created for individuals living in the linear communities by the firms established to fabricate the equipment needed to work in deep water. Within the southernmost five parishes of St. Mary, Terrebonne, Lafourche, Jefferson, and Plaquemines, there were in 1973 an estimated 12,400 individuals employed in manufacturing, and the average unemployment rate was about 5 percent (Bobo and Charlton, 1974, p. 198-199). Jobs are available for skilled craftsmen, with virtual full employment for welders, drilling crews, pilots, ship fitters, and other construction-related trades. Hence, as of 1973 more than 24,000 people were engaged in mineral extraction and transportation occupations (Bobo and Charlton, 1974, p. 198-199). Thirty-five percent of the civilian labor force earned a living in manufacturing, mining, and transportation industries.

Of the 6,474 businesses recorded in table 18, slightly over 200 are grouped in the oil and gas extraction category, with an additional 754 in water transportation. All but 78 of 974 businesses established to service the more than 2,400 offshore structures have located principally within the deltaic plain. Collectively these businesses have been responsible for the majority of the jobs associated directly with the onshore and offshore extractive industries. These two job categories support many other businesses shown in table 18. Ancillary services are part of the heterogeneous blend of companies occupying the 1,390 ha of land in commercial and service activities in the 14 settlement strips.

The region supports 322 commercial fishing boats that discharge their catch at the many processing plants within the five southern delta parishes; fishing was an occupational speciality that in 1974 provided more than 1,000 people with jobs and in the past trained many of the people presently working offshore (table 18). Experience obtained in the fishing industry is a valuable asset in learning how to cope with rough water to keep the rigs supplied. An attitude has developed that emphasizes maintenance of oil production schedules. An ill-equipped rig may have to shut down at a cost in excess of $100,000 per day. The logistic support firms have learned how to keep the rigs working under the most adverse conditions.

Fishing and food processing, when tabulated with oil and gas extraction and water transportation, account for more than 30 percent of the approximately 80,000 people employed in the seven parishes listed in table 18. With nearly one out of every three jobs associated with these four categories of employment, it is apparent that marine and petroleum-related industries are a critically important part of the economic well-being of the seven parishes. As dominant landscape elements, these industries are strung out along the crest of the natural levees. Although not a part of the petroleum industry, the fishing fleets line the lower course of Bayous du Large and Grand Caillou. On the deltaic plain, the fishing and petroleum industry have developed a symbiotic relationship beneficial to both sectors of the economy in that they both use maritime facilities and boats.

Chenier Plain Settlement

The chenier plain's four settlement strips have expanded because of the accessibility provided by the region's three major highways. Completion of these routes in the 1930's furnished the basis for community development. The settlements at Pecan Island, Grand Chenier, Chenier Perdu, Little Chenier, Oak Grove, and Creole were no longer isolated. "Outsiders" were attracted to the area, thus extending the communities' linear configuration in four well-defined settlement strips, encompassing about 1,140 ha of land. Parallel to the Cameron, Grand Chenier, Holly Beach, and Pecan Island settlements are 15,390 ha of cropland and pasture. The first settlers established the region's ranching and agricultural tradition. Of the more than 15,000 ha used for the production of food and fiber, more than 65 percent borders the Pecan Island strip. All available land is used as pasture or has been drained to be used in the production of rice.

After 100 years, the occupational structure of the chenier plain has not changed significantly. Yet within this plain more than 3,400 ha has been mapped as extractive areas. Unlike the deltaic plain, the land area modified by the development of oil and gas fields is small; temporary board roads are used rather than an extensive canal network. Instead of fields encompassing more than 18,000 ha, the chenier plain's extractive sites are generally less than 20 ha. Some canals are excavated, but their patterns do not approach the complicated assemblages found on the deltaic plain.

The absence of notable settlement and industrial activity is indicated by the fact that within the eight southernmost parishes only 5 percent of the strip and clustered settlements, 3 percent of the transportation facilities, and 3 percent of the residential areas are located in the chenier plain (table 16). Although the Creole field discovered in 1933 was supplied from the port of Cameron, the region's settlement strips never developed into important logistic support centers; they have been little influenced by the petroleum industry. Thirty-six firms in the Cameron strip serve the petroleum industry--less than 1 percent of the 3,625 advertised activities shown in table 19.

The four strips on the chenier plain have not experienced the full impact of the offshore industry partly because they are overshadowed by the city of Lafayette. The city is a regional center for the petroleum industry. Located inland from the areas covered by the 14 settlement strips, Lafayette evolved into the single most important community in the State for petroleum-related activities. One out of every four advertised activities recorded in table 19 are in Lafayette. Oil field equipment and services, oil producers, and oil well services account for 52 percent of the 968 activities.

In Cameron Parish, only 2,008 people of the total population (1970) of 8,192 work in businesses covered by the Standard Industrial Classification code, and 950 (47 percent) of them are employed in oil and gas extraction and water transportation. The pattern of land use reflects this. Within the Cameron and Grand Chenier strips, there are only 190 ha devoted to industrial, and transportation, utilities and communication land uses. The sites are small. The 43-ha logistic support center at Cameron is the largest tract. When combined with the other sites around Cameron, the city's regional importance is apparent. Fifty percent of the area associated with fishing, mineral extraction, and logistic support is within six areas comprising about 110 ha. Of the remainder, roughly 70 ha are concentrated in three sites along the Mermentau River at Grand Chenier, and 40 ha are at two isolated sites in the Cameron and Grand Chenier strips.

Although according to State of Louisiana statistics (table 18) for 1974, 5,593 people were employed by 664 businesses in Vermilion Parish, the figures need explanation. Most of these jobs are in and around Abbeville and Intracoastal City, not in the Pecan Island strip. Inhabitants of the Pecan Island ridge have been little affected by industrialization and associated urbanization. The strip is essentially agricultural with only 90 ha devoted to the strip and clustered settlement pattern. The ridge's development corridor is bordered by 9,900 ha of crop and pasture land. The region has not been drastically altered by the commercial and industrial impacts associated with petroleum development.

By contrast, Intracoastal City serves the offshore oil industry. Two land use patterns are dominant--areas used for transportation, utilities, and communication form a central core of activity, and strip and clustered settlement is widespread. Over 10 ha of transportation land have been established at Intracoastal City to serve the marine fleet working the Eugene Island to West Cameron areas. This site fills a service void between Cameron and Morgan City and is beginning to expand along the Vermilion River. Fifty-four petroleum-related firms operate in the city. Three categories are apparent: oil field services, oil producers, and oil well drilling-mud firms. They account for 29 of the businesses. The city's linear character is an outstanding example of the marschhufendorf form with a contemporary purpose.

On the chenier plain, the Cameron strip has become a principal service center with 470 ha recorded as land use of an urban or built-up type other than extractive industry. Within the strip, there are 36 oil- and gas-related activities (table 19).

Land Use Summary

The distribution of all types of land use and land cover for southern Louisiana as of 1972 is shown in table 16 which lists the total areas of each land use and land cover type by parish. The patterns of extractive industries more than 4 ha in size are illustrated in figure 7 for the southwestern part of the deltaic plain. Map analysis of all categories of land use and land cover reveals the deltaic plain's extractive oil and gas fields. Wells located on the natural levees are small in area and do not need to be connected by canals because roads provide access. It was the wetlands, both forested and nonforested, that were mapped as containing extensive oil and gas fields onshore because of the extent of their associated network of canals. Patterns created by these coalescing, intertwined channels range in size from 4 ha to continuous extractive areas covering nearly 18,000 ha, or 180 km^2. Due to this type of activity, the deltaic plain's wetlands are interlaced by the angular designs of the extractive industrial sites.

On the chenier plain, the land areas modified by extractive industry are small, rarely larger than 40 ha, and are widely spaced. The narrow cheniers have been utilized as access routes to the board roads connecting the drilling sites. In the chenier plain's four intensively-used strips, there are more than 300 ha of extractive land. Outside of these four strips, 3,120 ha were identified as extractive sites, and these fields are confined to small plots in the coastal marshes. In contrast, the chenier plain contains more than 225,000 ha of extractive land.

The strips of intensive land use were selected for special investigation because of the large concentration of settlement along these development corridors. Land immediately adjacent to the settlement strips is the better drained land utilized for agriculture.

In the process of servicing offshore structures, the cities of Houma, Lafayette, Morgan City, and New Orleans as well as the 14,690 ha of strip and clustered settlements of Lafourche, Plaquemines, and Terrebonne Parishes have become important onshore support districts for all aspects of the offshore industry. Through study of southern Louisiana's pattern of residential and industrial growth, other potential logistic support cities can project their land requirements and plan accordingly.

The strips are important, not in extractive land use, but as sites for the industries and ancillary services associated with developing the region's mineral resources. Each area, with the exception of Pecan Island, has experienced the economic and demographic impact of the petroleum industry. In 1974, for example, in Lafourche, St. Mary, and Terrebonne Parishes, 7,186 people worked for 130 oil and gas extraction firms. Since the mid-1950's the communities of Houma and Morgan City have each experienced the positive economic impact of the petroleum industry. Between 1955 and 1975, a total of 373 new businesses were added to the list of firms located in these communities each year. In some cases, land necessary to meet the demand has been reclaimed from the wetlands. Industries are limited by the availability of suitable, firm land; they must select sites that are not subsiding or subject to flooding. Hence, one observes the agglomeration of industries along the natural levees and to a lesser degree along the chenier ridges.

Some aspects of these impacts are manifested in the maps of land use and land cover for the strips (see figs. 16 and 17), particularly in the deltaic plain. At the beginning of the era of oil and gas extraction, the natural levees were covered with cropland and, in some places, orchards. Land ownership patterns were in long narrow strips having one end fronting on the bayou in the French manner.

Figure 6 shows numerous industrial patterns bordering the bayous. However, many sites are less than 4 ha and, hence, were not mapped by USGS. For example, a shipyard, catering firm, propeller repair service, and others are important, but simply are too small in area to be shown.

The identified industrial and transportation patterns are associated with the logistic support and fabrication facilities required by the petroleum industry. More than 2,000 petroleum-related industries are located within the coastal zone. Almost continuous urban or built-up patterns border the bayous including in 7,450 ha of industrial and 1,660 ha of transportation land within and outside of the strips.

In the four strips selected on the chenier plain for detailed study, cropland conforms to the characteristic linear form of the chenier ridges. The urban or built-up features are distributed more randomly, but continue to be associated with the highway and waterway transportation net. Petroleum-related firms at Cameron, Creole, Grand Chenier, Hackberry, Johnson's Bayou, and Intracoastal City have established 115 offices within these communities.

Table 18 reveals that 3 percent of southern Louisiana's businesses are associated with oil and gas extraction, but employ 13 percent of the area's work force; they are the largest employer. To provide access to the extractive sites, more than 750 firms are involved in water transportation, continuing a tradition begun by the early French settlers. The marine-service industry operates from only 1,660 ha, less than 1 percent of the 14 strips land use base (table 17), and only 0.1 percent of the land area illustrated on table 16. These companies, however, employ 10 percent of the labor force (table 18). From these statistics, it is clear that the wetland areas have been influenced significantly by the various industries associated with petroleum production.

Not only has the natural landscape been altered, but strip and clustered settlement patterns are now a dominant land use feature. The region's linear communities have developed into one of the most densely settled rural areas in the United States (Carter, 1968, p. 129). Population statistics reveal the wetland parishes had a net population increase between 1950 and 1970 of 31.2 percent (Bobo and Charlton, 1974, p. 22-27). In addition, for much of the population, average income has increased (Bobo and Charlton 1974, p. 22-27). This rapid growth in population and income is a product of the regional dependence on hydrocarbon exploration, development, and services.

Despite the importance of extractive industries and the compaction of the linear settlement form into truly agglomerated communities, a large percentage of the population continues to devote a portion of its time to fishing, hunting, trapping, and garden agriculture. The people think of themselves as belonging to a rural society.

CONCLUSIONS

Among the lessons learned from the study of Louisiana's coastal petroleum industry is that land use and other economic patterns are significantly modified by such developments. Since maritime transportation is the primary link to wells drilled in water-covered sites, the industry's support businesses have been developed lining the available waterfronts. There is a pronounced shift of population from scattered rural homesites to the urbanized strips where higher-paying jobs are available. In addition, there is an influx of skilled labor from other regions. The businesses needed to support hydrocarbon extraction include: (1) boat and helicopter transportation to and from the oil and gas wells; (2) manufacture of support boats; (3) manufacture or supply of well platforms, equipment, and pipe; (4) catering of food and other services; and (5) special repair, rescue, and training facilities.

The lessons learned from the Louisiana experience will be helpful to planners and managers involved with preparations to bring oil and gas ashore from the Outer Continental shelf along most of the Atlantic seaboard of this country. Not only is the knowledge of what happened in Louisiana useful, but the methods used in this kind of study would also be transferable. For example, this study could not have been done without adequate maps of land use or land cover, aerial photographs, or topographic maps showing the coastal plain as it existed at frequent intervals over the past fifty years. Similar baseline information is already available for nearly all of the Atlantic shoreline sectors close to proposed offshore oil or gas developments. If and when we need to study changes in these new areas continued mapping and aerial surveys will of course be necessary.

A major activity that both employs workers and impacts the natural environment is the moving of oil and gas by pipeline inland to refineries or other processing plants. Where these pipelines cross the marshy or swampy coastal plain, it is easier to excavate or dredge canals in which to lay and maintain pipe than to bear the high cost of road building in the wetlands. This canal network inevitably affects the hydrologic, vegetative, and wildlife environment. During the extraction and transfer of large quantities of oil, leakage occasionally occurs, and this pollution persists with possible long-term consequences. Heavy traffic by boat and ocean-going ships in the coastal and inland waters results in chemical pollution of the water and broadening of the channels as erosion of the banks occurs. This is especially significant where oil and gas wells are drilled in wetland or very shallow water and are served by a network of canals. Without question, the economy of the Louisiana coast has been stimulated at least temporarily by extraction of oil and gas. Much of the Nation's need for energy has been assuaged. Major changes, however, in land surface configuration and in land use have resulted, with direct and indirect effects on the water, flora, fauna, and social structure of the coastal parishes.

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