Technical Bulletin of the Louisiana Wild Life and Fisheries Commission

Geology of Rockefeller Wild Life Refuge and Game Preserve, Cameron and Vermilion Parishes, Louisiana

Refuge Division
New Orleans, Louisiana
1959

Louisiana
Wild Life and Fisheries Commission

Technical Report of the
Louisiana
Wild Life and Fisheries Commission

Geology of Rockefeller Wild Life Refuge and Game Preserve, Cameron and Vermilion Parishes, Louisiana

By
LEWIS G. NICHOLS

Refuge Division
New Orleans, Louisiana
1959

Geology of Rockefeller Wild Life Refuge and Game Preserve, Cameron and Vermilion Parishes, Louisiana

ACKNOWLEDGMENTS

The work for this report was done on the Rockefeller Wild Life Refuge and Game Preserve in Cameron and Vermilion Parishes, Louisiana. The facilities and equipment of the Refuge were made available to the writer.

This report was considerably enhanced through the aid of many individuals and firms. Dr. James P. Morgan of the School of Geology, Louisiana State University, made many valuable suggestions. Mr. Edward W. Orton, Mr. H. Tate Ames and Mr. Roger T. Saucier contributed data on the Vermilion Parish portion of the Refuge. The Testing and Research Section under Mr. H. L. Lehmann, Testing and Research Engineer, of the Department of Highways, State of Louisiana, analyzed the soil samples. Mr. Fred Shutts of Shutts' and Sons, Civil Engineers, in Lake Charles, provided information on boundary lines and old maps. The Office of the District Engineer, New Orleans District, of the Corps of Engineers, U. S. Army, provided data on the water level changes in the Mermentau River Basin. Mr. F. J. Ezernack, Mr. W. E. Williams and Mr. Henry Clark of the Soil Conservation Service of the U. S. Department of Agriculture contributed information on marsh soils and plant life. The Gulf Seismic Company of Beaumont, Texas, allowed the writer to accompany their shooting crew and provided borehole data. The Eustis Engineering Company of New Orleans and their field engineer, Mr. E. H. Nettles, made available cores taken from test borings on the Refuge. Mr. Moise Sturlese of Grand Chenier, Louisiana, supplied many place names and early history of the Refuge. Mr. Robert E. Rice, Engineer, Louisiana Wild Life and Fisheries Commission, has assisted in many ways and was especially helpful in giving freely of his time, office facilities and personnel. The final plates were drafted by Mr. David E. Butler. Mrs. Joyce J. Nichols contributed immeasurably in the editing, assembling and typing of the manuscript. Finally, the writer wishes to express his appreciation to the many individuals who have read and criticized this manuscript, particularly Dr. Van T. Harris, U. S. Fish and Wildlife Service, and Mr. William R. Paine, Department of Geology, Southwestern Louisiana Institute.

TABLE OF CONTENTS

ILLUSTRATIONS

INTRODUCTION

At the suggestion of Mr. Ted O'Neil, Chief, Fur Division of the Louisiana Wild Life and Fisheries Commission, a geologic study of the Rockefeller Wild Life Refuge and Game Preserve was initiated. The study follows the basic outline of work as set forth in the contract between the Louisiana Wild Life and Fisheries Commission of the State of Louisiana and Mr. Lewis G. Nichols, contract dated January 11, 1954. Presented here is the final report based on the findings of the study.

Purpose and Scope

The purpose of this study is to delineate all surface geologic features of the Refuge, both past and present, in order that they may be understood and used more advantageously in the Rockefeller Refuge Expansion Program. The scope of the study is restricted to surface and Recent geology. The Recent-Pleistocene contact is mapped in order to present the depth at which firm foundation material is first encountered. The problem of Refuge drainage is presented from the viewpoint of changes in the past, present conditions, and possible future changes. The vegetation of the Refuge is mapped and the vegetative effect of marsh elevation, drainage, and salinity is discussed. Canal levees were studied with the hope of determining the levee size necessary to obtain maximum levee effectiveness in each type of marsh. Preliminary results of the levee study are included in this report.

Previous Investigations

Previous investigations of the geology of this area have been of a general nature. With the exception of Fisk's (1948) investigation of the Lower Mermentau River basin all the reports have discussed Cameron and Vermilion Parishes as a whole or Southwest Louisiana as one unit. Hilgard (1871, 1873 and 1880) presented some of the early descriptions of Southwest Louisiana. The first comprehensive report of Southwest Louisiana was by Harris and Veatch (1899 and 1905). In 1935, Howe, Russell and McGuirt wrote a report on the geology of Cameron and Vermilion Parishes. This was the first paper dealing exclusively with the two parishes and is the best to date. Fisk (1948) in his Mermentau River basin study presents a good discussion of marshland physiography and the sediments that make up the marshland. The latest report dealing with this region is by Jones (1954). This last report covers the geology and ground-water resources of Southwestern Louisiana.

Description of the Area

The Rockefeller Refuge occupies 82,000 acres of marshland of which 49,000 acres are located in the southeast corner of Cameron Parish and the remainder in the southwest corner of Vermilion Parish (Plate I). It is bounded on the south by the Gulf of Mexico and on the north by the Grand Chenier-Pecan Island beach ridge complex. The east boundary follows the section line between R 1 W and R 2 W which is due south from the north end of Pecan Island. The west boundary follows the section line between R 4 W and R 5 W south to the section line separating T 15 S and T 16 S and then follows this line westward to the Gulf. This is near Beach Prong of Hog Bayou.

The only firm land included in the Refuge is along the northern boundary line where a small beach ridge is crossed near the west end of Long Island and again at Josephine Island. Near Tiger Island and Cow Island of the Grand Chenier complex, the north boundary line is at the edge of the marsh or where the firm ridge land begins. The 26.5 miles of Gulf shoreline offers firm land along the beach and for a few hundred feet behind the beach. Throughout the Refuge proper there are four marsh ridges which locally are firmer than the surrounding marsh.

The marshland of the Refuge may be considered as of three types, arranged in belts that parallel the coast. The northern belt is essentially a fresh marsh composed of tall grasses. These grasses require several inches to a foot of water for growth and yearly add much vegetable matter to the subsoil. Consequently this marsh is very soft and unstable. The middle belt, which grades into both its deep marsh neighbor to the north and its shallow and firmer neighbor to the south, is a brackish water marsh. Its grasses are short and it is usually water free several months of each year. This marsh has an unstable subsoil but a thick root mat permits walking in heavily grassed areas. The southern belt is the firmest marsh of the three being higher and more salt tolerant. When compared in size the three belts are not equal. The northern belt is from a mile to a mile and one-half in width and extends from the east boundary almost to Humble Canal. The southern belt reaches from one-half of a mile to a mile north from the beach with the wider end being to the west. The middle belt averaging four miles in width is thus the most extensive of the three and occupies the remainder of the Refuge.

There are six tidal channels that drain and fill the Refuge. The widths of the streams vary from about 100 feet near the beach to a few feet at their distal ends. The longest stream is Constance Bayou which meanders 11.25 miles through the center of the Refuge. However, the average length of the tidal channels is 5.5 miles. The lengths of all the bayous and their tributaries show that there are 60 miles of mapable bayous on the Refuge.

The bayous of the Refuge service some eight major lakes and countless smaller ones. Big Constance is the largest of the lakes and covers approximately 1,080 acres. The next three larger lakes are Deep Lake, 880 acres; Flat Lake, 600 acres and Miller's Lake with 360 acres. Major lakes cover 3,780 acres of land and when the remainder of the lakes drained by the minor tributaries are added to this total, the figure reaches 4,840 acres. There are many other marsh lakes that are ephemeral in nature and are not included in the above figure.

A description of the Refuge could not be complete without taking into consideration the man-made waterways. Rockefeller Refuge has over 36 miles* of canals of which 22.75 are used and maintained by oil companies. The remainder of the canals are Refuge property line canals and Refuge service canals. In addition to the major canals, there are at present 13.5 miles of mudboat ditches. Pirogue trails used in trapping are also present but are of importance only in small and local areas.

* Recent construction has added 46.75 miles of Refuge property line and impoundment service canals to this total.

Techniques and Methods

The study of Rockefeller Refuge was conducted with several distinct, yet related, goals in mind. This necessitated a varied approach to the many problems and the application of a number of techniques and methods. Surveying equipment was used to obtain exact distances and locations and to note elevation changes as small as one-tenth of a foot. Beach samples and cuttings from shallow boreholes were analyzed and interpreted. Water samples were tested as to salinity and soil samples were tested for their hydrogen ion concentration. Marsh vegetation was identified and mapped. Transportation problems, always difficult in a marsh area, were alleviated through the use of mudboats and marsh buggies. Up-to-date maps and aerial photographs were studied, interpreted and used as field guides.

Bayou levees, canal levees, marsh ridges and the present beach were profiled as to their surface configuration by the use of level and level rod.

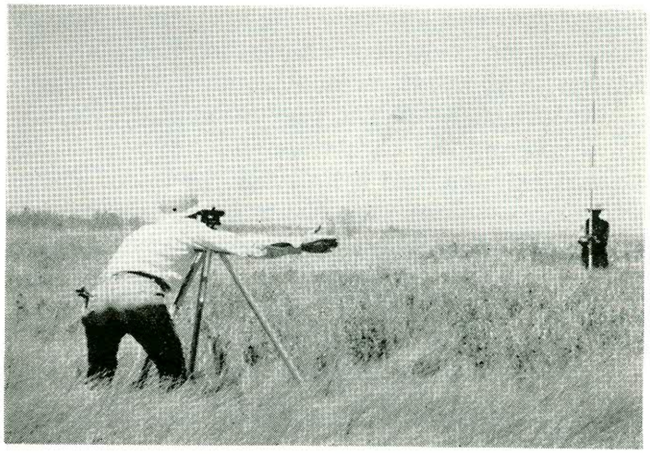

Figure 1. Method used in profiling natural levees and marsh ridges. A natural levee is being profiled here. Note vegetation change as the rod man nears the crest of the levee.

Short distances were measured by steel tape and longer distances, by the stadia method. In conjunction with these profiles, boreholes were drilled to obtain complete cross sections. In the longer marsh traverses it was frequently necessary, where mapable landmarks were absent, to measure distances by the stadia method. (Figure 1).

In the subsurface phase of the Refuge study, boreholes were drilled to a maximum depth of

52 feet. This was done by hand using a 1½-inch diameter carpenter or ship auger welded to ¾-inch galvanized pipe cut in sections four feet in length (Figure 2). Eighteen-inch pipe wrenches were used to rotate the auger and to pull the pipe out of the hole. This type auger secures a suitable sample for analysis from any depth or horizon penetrated. The Research Section of the Louisiana Department of Highways conducted grain size analyses of soil and beach samples.

Figure 2. Examination of soil sample. Auger is the type used for drilling of boreholes.

The salinity of marsh and bayou water samples was obtained by specific gravity type salinity hydrometers. The hydrogen ion concentration in marsh soil and water was measured with a long range slide comparator pH kit and hydrion papers (Figure 3).

Drainage and tidal studies were carried on and aided through the use of two eight-day water level recorders. The recorders were placed in strategic locations selected to record maximum and minimum tidal changes within the same drainage basin.

The field work was accomplished with

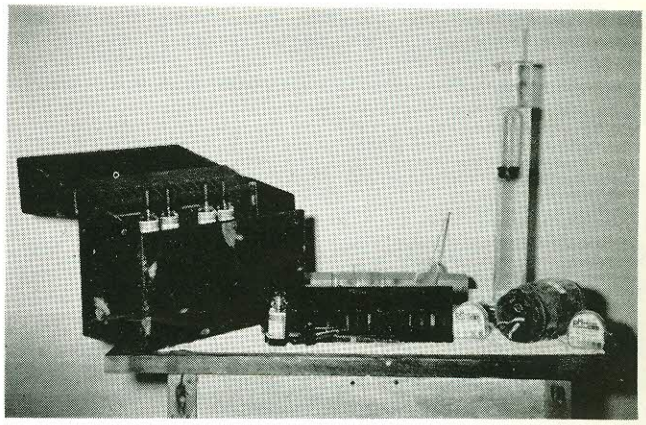

Figure 3. Equipment for measuring pH and salinity. Left, a long range slide comparator kit for measuring pH of water. Right foreground, Hydrion papers at soil sample for measuring pH of soil. Right background is specific gravity type hydrometer for measuring salinity of water.

Figure 4. Marsh buggy bogged in small bayou. This bayou is a tributary of Dyson's Bayou. Vegetation is marshhay cordgrass.

Refuge personnel serving as helpers in drilling boreholes and in servicing and driving mudboats and marsh buggies (Figure 4).

Geologic Setting of Southwest Louisiana

Southwest Louisiana occupies a unique position in the geologic picture of the gulf coastal plain. Therefore a brief summation of the geologic history of Quaternary time, which is composed of the Recent and Pleistocene epochs will be presented. Geologically the Rockefeller Refuge and the whole of Southwest Louisiana are intimately related to the Mississippi River alluvial valley (Russell, 1940). Geologic processes active along the coast today can be directly related to the present Mississippi River. Accordingly, the extensive prairie and marshland of southwestern Louisiana can be traced to an ancestral Mississippi River.

This ancient river received its initial encouragement to flow to the Gulf of Mexico from the advancing ice of the Pleistocene epoch. The glacial ice in taking its water from the ocean lowered sea level approximately 400 feet (For discussion and bibliography, see Kuenen, 1950). The Mississippi River thus had to adjust itself to a new base level and in doing so cut a valley across the coastal plain. As the ice retreated and the sea regained its former level, the entrenched river alluviated its valley. Since the beginning of Pleistocene time the glaciers waxed and waned four and probably a fifth time and the ancestral Mississippi River cut and then filled its valley each time. The Recent epoch of geologic time began when sea level started to rise after the last glacial advance.

The geologic history of this area can be interpreted by understanding three processes: the method whereby the river fills its valley, the sedimentation of the areas adjacent to the valley, and the overall effect of the successive cuttings and fillings as related to the Gulf Coast Geosyncline (Howe, 1931; Barton, 1933). When sea level began to rise the valley was at its maximum depth and width and the shoreline was south of the present-day coast. As the seas advanced upon the land the river's gradient decreased forcing it to deposit its heavy load of sediments. Thus the river filled its valley, first with cobbles and coarse gravels, then sands, and finally silts and clays as it adjusted itself to a rising sea level. After sea level reached its present position the river began building great deltas and extending out into the Gulf of Mexico (Russell, 1936; Fisk, 1944). During this time the river frequently changed courses leaving abandoned deltaic plains (Barton, 1930) to be eroded away by waves. The material eroded from these deltaic plains was in part carried along shore to the west and redeposited to form a marginal deltaic plain.

This area is complicated by the presence of the Gulf Coast Geosyncline. This geosyncline is essentially a downwarping of the earth's crust due to a vast accumulation of sediments. It is estimated that the Gulf Coast Geosyncline has a maximum thickness of over 40,000 feet. It is still growing and very active. The accumulated weight of great amounts of deltaic sediments causes subsidence and a resultant tilting on the flanks of the geosyncline. This tilting makes possible the preservation of portions of the deltaic surfaces or terraces of each of the interglacial periods of filling.

In Louisiana the Pleistocene is represented by four terraces (Fisk, 1938) which can be differentiated superficially by the degree of slope, dissection and weathering. The last terrace formed in the Pleistocene epoch is the Prairie terrace which is exposed immediately to the north of the coastal marshes. The Recent which is represented by the present alluvial valley of the Mississippi River and the coastal marshes is an outgrowth of the current period of valley filling.

PHYSIOGRAPHY

Physiographic Setting of Rockefeller Refuge

Rockefeller Refuge is situated in a distinct physiographic unit of Southwest Louisiana known as the coastal marshland (Doering, 1935). The physiographic unit immediately to the north of the coastal marshland is the prairie. These two units although very unlike physically have origins related to an ancestral Mississippi River and reflect many of the physiographic features and geologic principles pertinent to a clear understanding of this region. Before discussing the Refuge itself, the prairie and coastal marshland will be presented in their broader aspects in order to give the proper perspective to Southwest Louisiana.

The Prairie. The prairie is one of several topographic belts that roughly parallel the gulfshore of Southwest Louisiana. The prairie is a flat, slightly undulating plain sloping gently gulfward at a rate of 1½ to 2 feet per mile (Fisk, 1938). It is essentially a grassland with concentrations of trees being found in flood plains of streams and marginal to streams. Drainage is poor, a result of the nearly flat nature of the surface. The most conspicuous features of the prairie surface, with exception of the active streams, are the abandoned Pleistocene streams which are indicated by meander scars showing former river courses to the Gulf (Fisk, 1944 and 1948). Meander scars of an ancient Mississippi River may be seen near Abbeville where the present Vermilion River flows in this old channel. Farther to the west much smaller scars of an ancient Red River meander across the prairie surface (Plate II). The prairie is the youngest of four such physiographic units of fluviatile origin. Surface features that separate these units are: (1) the amount of stream dissection, (2) the regional slope of the surface gulfward, and (3) the depth of weathering. Since the prairie is the youngest, it shows these features in their smallest degree.

Major streams flowing across the prairie point out a physiographic feature that is prominent in the gulf coast area. This is the drowning of river valleys (See Howe, 1935 for discussion and bibliography). The Mermentau River shows this feature quite well. The wide flood plain of the river bounded by scarps and the widening of the river into Lake Arthur are evidence of this fact. This will also be pointed out in the section on coastal marshland. The drowning of river valleys is only one of several features which reflect the presence of the Gulf Coast Geosyncline. This phenomenon is caused by the subsidence of this region under the tremendous weight of sediments that have been deposited in southern Louisiana and adjacent areas. This process has been in operation for many millions of years. The fact that Rockefeller Refuge is within the area of an actively sudsiding geosyncline will explain many of the above physiographic features.

The Coastal Marshland. The general physiographic features of the coastal marshland will be discussed in this section while the bulk of the marshland features will be brought out in detail when the Refuge itself is outlined. Marsh, by definition, is an area where the water table is coexistent with the land surface and supports a prolific growth of water tolerant grasses. The coastal marshland is therefore a near sea level grassland with an unstable subsoil. The marshland is broken by shallow lakes and bayous and a series of abandoned beach ridges called cheniers (Russell and Howe, 1935). The cheniers represent the only relief of the area. Locally some cheniers reach an elevation of 16 feet. In cross section the cheniers show the steep fore slope and gentle back slope of present day beaches. They are composed of fine sand and marine shells and shell fragments. The cheniers mark the farthest retreat of the shoreline during periods when coastline erosion was dominant over deposition. When deposition became dominant extensive mudflats were built in front of the Cameron and Vermilion Parish beaches. This sediment was derived from deltaic masses to the east. This balance between erosion and deposition shifted many times in the late Recent geologic history leaving a complex of cheniers. Some were abandoned as ridges in the marsh while others were worn away or truncated by the formation of younger beaches later to become cheniers themselves. At the present time the Mulberry Beach and Chenier au Tigre area of the Vermilion Parish gulf coastline is receiving sediment and building mudflats. In contrast, the coastline of Rockefeller Refuge is retreating (Plate II, in envelope). The present beach in the Refuge area reaches an elevation of five feet.

The Mermentau River is the only stream in the immediate vicinity of Rockefeller Refuge that drains the prairie surface and then flows across the coastal marshland to empty into the Gulf. This stream as it enters the marshland widens into Grand Lake, one of the largest marsh lakes in the state. The origin of Grand Lake is related to the presence of several factors working or occurring together. Paramount of these is the general sudsidence of the whole area which causes rivers to widen into lakes and form estuaries at their mouths. Secondly, the small degree of compactness of the marsh and the ease with which it erodes make the marsh subject to the formation of lakes. Grand Lake is at present enlarging to the east and south at an average of 10 feet a year (Shutts, personal communication). The dominant cause of this enlargement is erosion of the shores by wind driven waves.

Small tidal channels drain the marshland within the limits of the Rockefeller Refuge. They will be discussed in a following section.

The contact between the soft marshland and the firm prairie is very distinct. The identifying feature is the tall marsh grasses as compared to the short prairie grasses. In some locals the marsh deposits onlap the prairie land and lense out to a final thickness of only a few inches. Nearby old streams may have cut the prairie surface back to the extent that the marsh literally abuts against the prairie, and reaches a thickness of 10 to 20 feet within a few feet of the contact. The marsh is dominantly a fresh marsh from the contact with the prairie to the ridge complex and is brackish or salty from the ridges to the beach.

Climate

The climate of Southwest Louisiana is determined in part by its location in a semi-tropical latitude and its proximity to the Gulf of Mexico. This humid, temperate climate can be pictured by some average precipitation and temperature figures (Climate and Man, 1941). The average annual precipitation for Cameron Parish is 52.91 inches. This is slightly under the statewide average of 55.45 inches. The maximum rainfall for Cameron Parish occurs in the months of July and September with approximately eight and seven inches respectively. The minimum months are November and January when approximately two and one-half inches of rainfall are recorded each month. However, these figures may be misleading in that the localized nature of storms frequently cause many areas to receive much more rainfall. The mean temperature for Cameron Parish is 68.2 degrees which is a little warmer than the 67.4 degrees mean for the state. In Cameron Parish, July is the warmest with an average of 81.1 degrees and January, the coldest averaging 51.8 degrees.

In summer the prevailing southerly winds provide a moist tropical climate. The atmospheric pressure usually decreases westward from the Atlantic Ocean and produces a condition favorable for afternoon thundershowers provided the ocean high pressure area is not too far west. If this pressure distribution condition is altered to bring westerly to northerly winds then periods of hotter and drier weather interrupt the prevailing moist condition.

In the winter high winds preceding areas of high barometric pressure are experienced. These high pressure areas coming from the northwest rotate in a clockwise direction. This results in the wind shifting from the south by way of the west to the north. The fall of temperature is most noticeable when the wind shifts to the northwest.

Occasionally tropical storms with strong cyclonic winds, high tides, and torrential rain visit this area from July through early October. These storms normally approach Louisiana from the southwest and strike the coast every four or five years. Really dangerous storms with winds of 100 miles per hour or more strike the coast once in 10 years.

Physiographic Features of Rockefeller Refuge

Tidal Channels. An examination of the gulf shoreline of Cameron and Vermilion Parishes will show that all but one of the tidal channels occur in the coastal area included within Rockefeller Refuge. The tidal channels of the Refuge do more than just flood and drain the marsh as the tides rise and fall. They aid in the drainage of flood waters from the high lands during seasons of heavy rainfall. It is this fact that helps explain the grouping of the tidal channels along the coast. The cheniers serve as natural barriers to the run-off of water and it is only where they are broken that the tidal channels have formed, that is, between Grand Chenier and Pecan Island. The one exception to this grouping of tidal channels is found southeast of Pecan Island.

More than seasonal high water is necessary to maintain a tidal channel the year round and here Rockefeller Refuge is well situated to supply these intangibles. After the initial beach breakthrough by a marsh stream, the newly forming tidal channel quickly cuts through the soft marsh material to the gray clay, which is five to six feet deep in this area, making the outlet hard to close. In addition, the rapidly retreating coastline does not have enough coastwise moving sediment which is so necessary to seal off breakthroughs. The marsh in which the tidal channel is forming is relatively new and unstable and therefore allows numerous marsh lakes to form and store water. These lakes serve as reservoirs and insure a greater two-way flow of water.

It should be emphasized that additional tidal channels are not apt to form on Rockefeller Refuge. The existing channels and their lakes may be tapped at a new location by the retreating coastline thus making channels out of former tributaries

Figure 5. Dorcelie Bayou truncated by beach deposits. The flow in this bayou was captured by an oil company canal and consequently beach deposits sealed the bayou's mouth.

but no new and distinct channels will form. Plate I (In Envelope) shows that in 1888 there were three outlets in this area where there are now seven. All of which were formed by the above method. Figures 5 and 6 show abandoned tidal channels resulting from coastal retreat.

A brief resumé of the tidal channels of Rockefeller Refuge will be presented at this time. Plate I should be consulted in reference to the size and drainage area of these bayous. Beach Prong of Hog Bayou has been closed and opened many times in the past. It is now in a position to gain prominence. Joseph Harbor Bayou and Little Constance Bayou at one time had a common pass to the Gulf. Joseph Harbor is now declining in its distal drainage area due to the tidal flow being taken over by the Humble Canal. Little Constance Bayou is in a stable condition. Constance Bayou formerly included East Constance Bayou and East Little Constance Bayou. All three now have individual mouths. Constance Bayou and East Constance Bayou are in a stable condition. East Little Constance Bayou has closed naturally from the lack of tidal flow and the excessive accumulation of beach material between the mouth of East Constance Bayou and its own mouth. Wave attack from the southeast swept the beach material into the mouth of East Little Constance Bayou and thus closed it. Rollover Bayou apparently has served as a tidal channel for this area a long time, being mentioned along with Constance Bayou in the earliest reports of coastal explorers (Hackett, 1931). In recent years Rollover Bayou has carried more water to a wider area because of the many ditches and canals connecting with it.

Natural Levees. Natural levees are strips of slightly higher and firmer land that flanks aggrading streams. These alluvial deposits are formed when the current velocity is checked as a stream overflows its banks. Thus a natural levee is no higher than the flood water stage of the river. The natural levee is composed of material that is carried in suspension by the river.

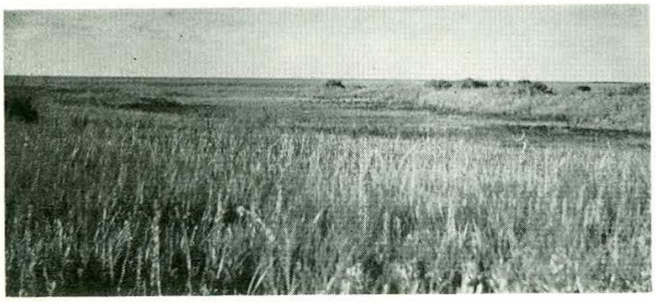

Figure 6. Abandoned channel of Joseph Harbor Bayou. This portion of the bayou was cut off by the retreat of the coastline. Channel is marked by high levees as opposed to a low channel and the accompanying vegetation changes.

The coarsest particles carried are the first to be dropped when the current velocity is suddenly slowed as the stream leaves its channel. Therefore the crest of the levee is composed of the coarsest material and as one transverses the levee at right angles to the stream, finer material is encountered until the levee loses its identity.

The natural levees present in the area studied flank tidal channels. Although these natural levees were formed under slightly different conditions, the basic principles involved are essentially the same. Tidal channels are characterized by two-way flow: the flood and ebb of the tide. In rainy seasons and periods of high water in the adjacent upland areas, the tidal effect may be curtailed until the freshwater level is lowered to that of the current high tide level. During this period, the flow of water is one way, that is, gulfward. The sediments that comprise the tidal channel natural levees come from two main sources; marsh waste products such as organic debris and marsh soil that is broken loose by fauna activity, and secondly the fine material carried by the longshore current and subsequently washed into the mouths of the tidal streams. In this area the material carried in the flood waters of upland floods must be considered negligible due to the great marsh distance and lack of through-flowing streams.

The height to which a natural levee can be built is dependent upon the continued increase in flood stage concomitant with the building up of the stream bed. It can readily be seen that the natural levee flanking a tidal stream soon reaches a height which is in equilibrium with tidal action. Further levee building depends upon the frequency and severity of storm tides. The occurrence of storm tides coinciding with upland floods may also cause levee building by aiding the tidal water to reach greater heights. Flood water from upland floods draining across the marsh does not in itself constitute a levee building feature as this water has slowed and dropped its load in the first open water or marsh encountered. Furthermore it approaches the tidal stream area from an inland direction and first fills inter-stream or marsh areas. Therefore the normal flood waters can only gain entrance to the tidal stream on a falling tide.

As is expected, levees built by tidal streams are only a few tenths of a foot above the marsh. The supply of sediment used for building levees is small and is frequently neither available nor carried by the overflowing tide water. The water rises slowly and when the crest of the levee is reached very little current is present to carry sediment, except near the mouth where the water is churned up by the breakers along the shore. Nevertheless the water carries material in suspension and solution and the levee, greatly aided by vegetation, retains a thin layer of sediment. The levees are most frequently topped during vernal and autumnal tides and by storm tides.

The part played by vegetation in the building of natural levees along tidal streams is very great. As soon as the levee is higher than the surrounding marsh, new conditions in the height of the water table, salinity and aeration are brought into play and thus a different type vegetation is supported by the levees. This vegetation is bigleaf sumpweed (*Iva frutescens*) ; big cordgrass (*Spartina cynosuroides*) ; and sea-oxeye (*Borrichia frutescens*). The above conditions and plants improve the levee by building better soil through a balance between organic products and bacterial action.

Tidal Channel Levees. The tidal channel levees as found on the Rockefeller Refuge may be as high as one foot above the surrounding marsh.

The height as does the width of a levee decreases as one moves inland from the gulf shoreline. The width of the levees varies from 500 feet near the coast to a few feet at the inland ends.

The levee height near the mouth of Little Constance Bayou is found to be one foot higher than near Deep Lake (Figures 7 & 8). A similar comparison of the levee height with respect to the marsh level shows a decrease of levee height as the bayou is traced inland. Two factors which complement each other are responsible for this feature. Wash-over deposits along the coastline build up the marsh immediately behind the beach and secondly there is increased levee building activity near the coastline. Of the two, wash-over deposits are more important in accounting for the greater elevation near the coast. This elevation change is graphically shown on Plate III of Little Constance Bayou and Plate IV of Constance Bayou. These stream and levee profiles were taken and water levels checked at a time of normal high tide. By comparing Section Number III with Section Number I of Little Constance Bayou (Plate III) the above mentioned facts are readily apparent. There is more levee near the beach or at Section III (see legend for identification of levee deposit) and the water level does not reach the marsh level. At Section I the levee is much smaller and the water level is above the marsh level. A similar comparison of Constance Bayou can be made.

Figure 7. Little Constance Bayou levee near Deep Lake. This location is three miles inland and here the levee is barely perceptible. The marsh burned a few days before this photograph was taken. Water is at high tide level.

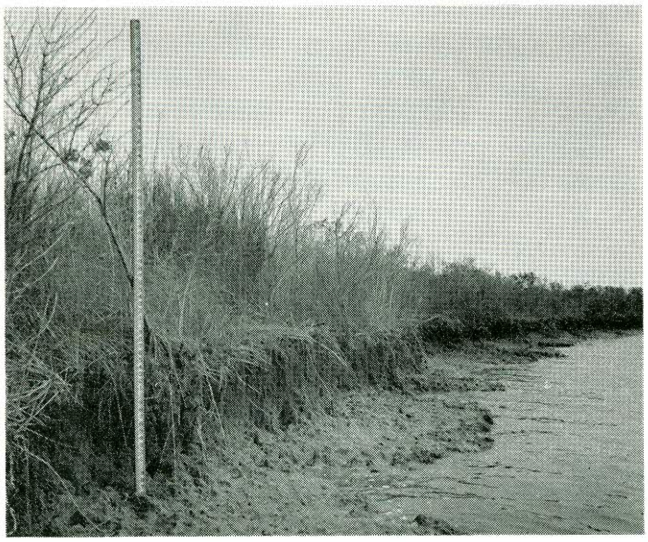

Figure 8. Natural levee of Little Constance Bayou exposed at low tide. This photograph taken one quarter mile from the beach. Note thickness of levee and lush vegetation growth.

Technically, levee height is defined as the difference between low water stage and flood water stage. Accordingly the levee of a tidal channel should be as thick but no thicker than the difference between low and high tide. This however is not entirely correct. Marsh elevation and mean high tide are approximately one foot in elevation, based on mean gulf level, and the levee sets upon the marsh. Thus the levee height is more closely related to the balance between the extreme high tide and the level of flood water draining through the marsh.

The levee can be identified by its material. A borehole through the crest of the levee shows the presence of oxidized gray-brown organic clay. Near the beach where oxidized clay also occurs as a wash-over deposit, the levee merely adds to the overall thickness. In inland areas where the wash-over zone is absent the levee is distinguished by oxidized gray-brown organic clay. This material is actually immature soil being formed from the mineral and organic matter collecting there a few inches above the water table.

Tidal channel levees as found on Rockefeller Refuge are a very distinct physiographic feature when viewed in their proper perspective. They supply firm footing for walking, a varied vegetation assemblage, and help to regulate the run-off of water (Figures 9 and 10).

Lakes. The lakes found on Rockefeller Refuge are readily divided into two types. The

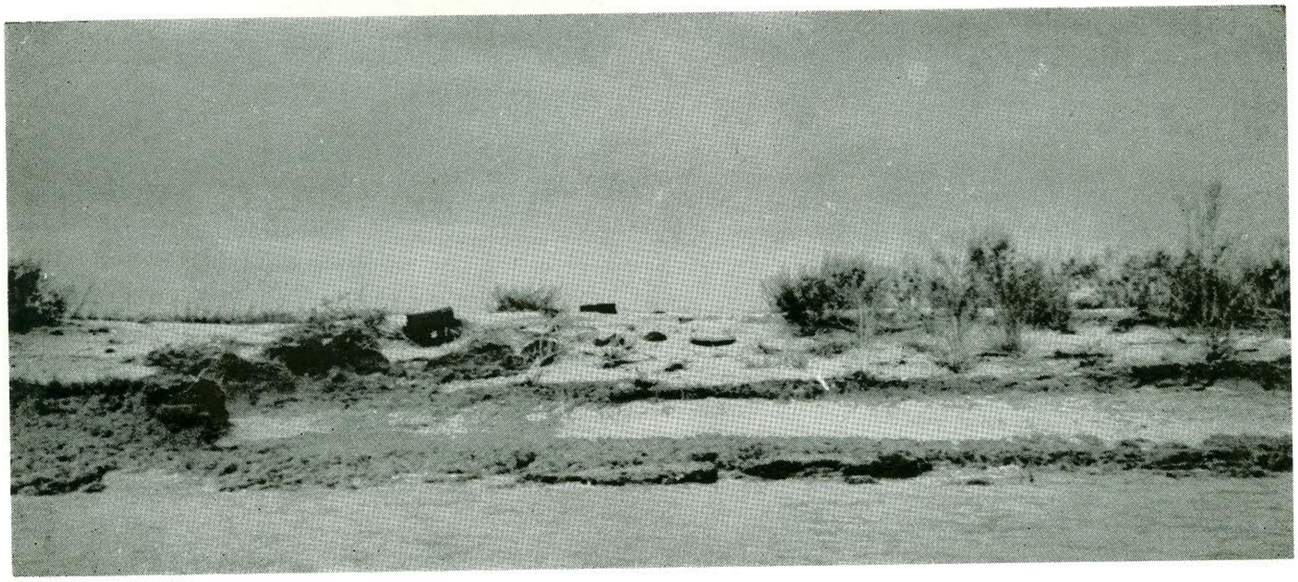

Figure 9. Natural levee and shell deposits at mouth of Joseph Harbor Bayou. This location is 1/8 mile inland from the coast. The mouth of the bayou is being widened and shell deposits are accumulating on the crest of the levee. Note the three distinct levels: the lower is the bottom of the organic layer, the middle is the old levee surface, and the top is the crest of the shell deposits.

first and more prominent is the tidal channel lake, covering several hundred acres, averaging two feet in depth, and fed by a major tidal channel. There are several such lakes on the Refuge. The second type lake, a marsh lake, is much smaller and more shallow than the tidal channel lake. The marsh lake is maintained by very minor tributaries or by ground and surface water. These lakes are too numerous to be referred to individually.

The presence of tidal channel lakes can not be related to any one cause but rather a combination of allied causes. No matter what initiates lake formation there must be some additional feature or natural barrier to retain the water and maintain the lake. On Rockefeller Refuge the high area immediately behind the beach supplies the main barrier, thus forming a slight trough at the edge of the wash-over deposits. Miller's Lake, Big Constance Lake, and Flat Lake are located a short distance back of the shoreline as indicated on Plate I (In Envelope). Ironically the very factor that has helped to sustain these lakes may eventually cause their destruction, that is, the retreat of the shoreline. Little Constance Lake, Big Constance Lake, and Flat Lake show evidence of this today. The retreat of the shoreline not only fills up the lake bed but also forces the water farther inland and makes the tidal stream assume a channel through the lakes. Once a channel is established in the lake and the thread of current follows it, the filling of the lake is virtually assured.

The location of the tidal channel lakes has another controlling factor and this is the presence

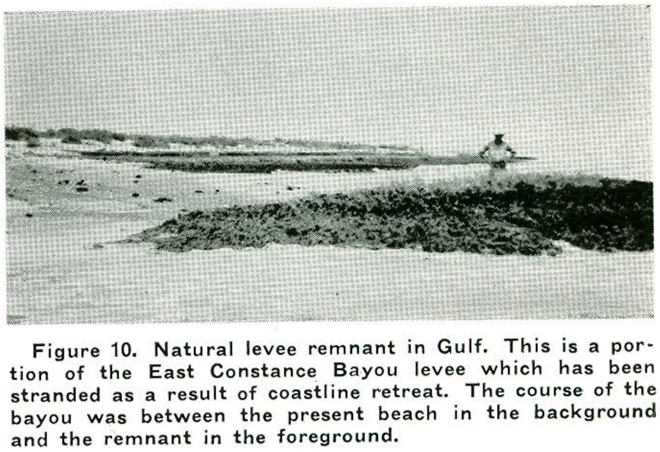

Figure 10. Natural levee remnant in Gulf. This is a portion of the East Constance Bayou levee which has been stranded as a result of coastline retreat. The course of the bayou was between the present beach in the background and the remnant in the foreground.

of marsh ridges that bear approximately northwest-southeast across Rockefeller Refuge. Plate I shows the alignment of the lakes in the inter-ridge areas. Although these ridges have little or no relief above the marsh surface they do have enough consistency both in extent and firmness to help initiate the formation of lakes. Little Constance Lake, East Little Constance Lake, and Rollover Lake are located just back of ridges and are good illustrations of this feature.

Marsh lakes may have their origin in one or a combination of ways. Marsh fires that burn into a peat layer, which is frequently found just under the surface of the marsh, are a common cause of lakes (Figure 11). In extremely dry periods the water table drops down below this peat layer, drying it and allowing the peat to be subject to burning. When this happens a new lake is created in the burned out area. Animal "eat-outs" are another means whereby marsh lakes are formed. Heavy concentrations of geese may completely denude an area in a short time. When the root matter which binds the surface soil together is gone, the next high water period may create another lake. Over population of muskrats may cause a similar situation. Price Lake is a good example

Figure 11. Marsh fire.

of a series of marsh lakes, resulting from "eat-outs", which have enlarged into a major lake.

Animal runs between lakes may establish a connection to a tidal channel tributary. In this way marsh lakes become a part of a drainage system. However, they may remain isolated and reflect the water conditions in the marsh. In the summer of 1954 many of the marsh lakes completely dried up, even to the extent that marsh buggies driving across them kicked up dust in the process. Figure 12 shows mud cracks in a dry marsh lake.

Figure 12. Dry marsh lake. Note mud cracks in lake floor. Vegetation is marshhay cordgrass.

Present Coastline. The 26.5 miles of the Rockefeller Refuge coastline are distinctive in their consistency and similarity. The entire coastline has been retreating across the marshland for a great many years. This is reflected in the beach deposit rimming the coast (Figure 13). Plate I

Figure 13. Coastline looking east from Beach Prong of Hog Bayou. Note beach deposits encroaching upon the marsh and leaving exhumed marsh to face the attack of the waves.

(In Envelope) shows the relative positions of the coastline at the times of three surveys: 1888 (United States Coast and Geodetic Chart Number 201), 1932 (United States Geological Survey

Quadrangle Sheets), and 1954 (Shutts' and Sons Survey). In the interval between 1888 and 1932 the coastline within the boundaries of Rockefeller Refuge has retreated on the average of 24 feet a year. Between 1932 and 1954 the coastline has retreated on the average of 30 feet a year. This latter increase in coastline retreat should be explained, though it may be partly false due to the more accurate methods of surveying and the use of aerial photographs in map making. It is doubtful that the marsh is any less resistant to erosion now than in the past. A severe storm or a concentration of storms has not occurred in the interval between 1932 and 1954, therefore they could not account for the increase. It seems logical to assume that offshore shoal areas have been sufficiently eroded through wave attack to allow the storm waves to reach the coast with increasing force. This may account for the increase in the rate of retreat.

The present rate of retreat will not slacken until a definite depositional change occurs along the coast. This depositional change is now taking place along the Chenier au Tigre-Mulberry Beach area (Morgan, Van Lopik and Nichols, 1953). Mudflats are being deposited in the above mentioned region and are being reported farther west each year. These mudflats are directly related to the increasing amount of flow and sediment carried by the Atchafalaya River and are extending their limits westward. If this natural changeover of flow from the Mississippi River to the Atchafalaya River is allowed to continue, the coastline of Rockefeller Refuge will shift from one of retreat to one of advance.

Plate V is composed of a series of beach profiles taken at intervals along the present coast. A study of them will reveal that they are very similar in surface configuration. The beach deposit will average 100 feet in width and the average height above marsh level is three feet. An additional 1.5 feet of marsh is exposed above mean water level making the overall height approximately 4.5 to 5 feet. The actual beach deposit is from 10 to 20 feet back of the water line. In front of the beach the marsh over which the beach has retreated is undergoing wave attack (Figure 14). A short time ago this surface was under the beach. The steep fore slope of the beach reflects the erosive force with which the waves strike the beach and carry material up and over the crest. The relatively gentle back slope of the beach and the gradual thinning of the wash-over deposits reflect the less determined manner in which the deposits are spread over the marsh by water that has lost its transporting power in striking the beach. Due to the irregular habits of storms some areas have a greater concentration of beach material than others.

Figure 14. Exhumed marsh being destroyed by waves. Note area scoured out by log. Photograph taken west of Joseph Harbor Bayou.

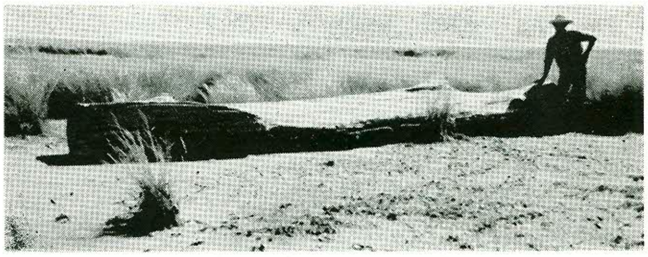

Figure 15. Log in marsh. This log has been washed one mile inland during a severe gulf storm. Vegetation is marshhay cordgrass.

Marsh Ridges. A series of marsh ridges with an approximate bearing of northwest-southeast are present on the Rockefeller Refuge. These ridges are four in number and are more prominent in the western half of the Refuge (Plate I, In Envelope). Plate VI presents for comparison cross sections of the various ridges. The maximum elevation above the marsh of the largest ridge is 0.4 foot and the maximum width of this ridge is 1800 feet. From this maximum size the ridges grade downward until they are flush with the marsh surface and cannot be identified by relief. The ridges might not be detected visibly if it were not for the vegetation change brought about by the greater elevation. Unfortunately the ridges are not continuous. In many areas particularly in the eastern and southern portions of the Refuge the ridges are absent for distances exceeding one mile. When the ridges are present in this area, there is no superficial evidence of the fact and they must be found by probing and identified by boreholes. They are identified by their firm nature which is brought about by a slight increase in fine sand and silt content. Where the ridges have been above the marsh level, as they are in the western half of the Refuge, they show oxidation, nodules, and more humus and organic material in the mineral soils. Where the ridges have never maintained a position above marsh level the only means of identification is by their grain size variation. Plate VI shows a typical columnar section through a ridge as compared to a marsh sequence.

Ridge I as shown on Plate I (In Envelope) begins near Tiger Island. It is continuous to Superior Canal but from there on to the eastern boundary it is broken. Ridge II enters the Refuge just south of the northwestern corner of the Refuge and is continuous to a point just short of Humble Canal. In this area the ridge is prominent as shown by the cross sections on Plate VI but the remainder of the ridge is broken and has been identified in only four other places as it continues on to the southeastern corner of the Refuge. Ridge III enters the Refuge two miles south of Ridge II and is truncated by the present beach just west of Big Constance Lake. This ridge is the largest on the Refuge, notably between the west boundary and Humble Canal. The remainder of its course is broken and indistinct. The final ridge is at the extreme west end of the Refuge. Here as is the case with all the ridges as they near the beach, the ridge is soon masked by the wash-over deposits.

The alignment of the ridges with the present day coastline and with the former beach ridges is shown on Plate II (In Envelope). This alignment along with the analysis of the material forming the ridges points out that the ridges owe their origin to the geologic processes responsible for the coastal advance, i.e., mudflat deposition. This will be discussed more fully in the section covering stratigraphy and sedimentation.

Canals and Canal Levees. The last feature to be discussed in this section is man made. Canals and canal levees make up an important part of the Refuge and should not be neglected. The 22.75 miles of oil company canals, when originally dredged, averaged 65 feet in width and nine feet in depth. These canals have since enlarged their surface width by about 20 per cent while their depth has decreased approximately the same amount (Figure 16). Levees averaging 70 feet in width and five feet in height were built on both sides of the canals. These levees have since subsided and decreased in height by approximately 40 per cent. These figures are variable depending

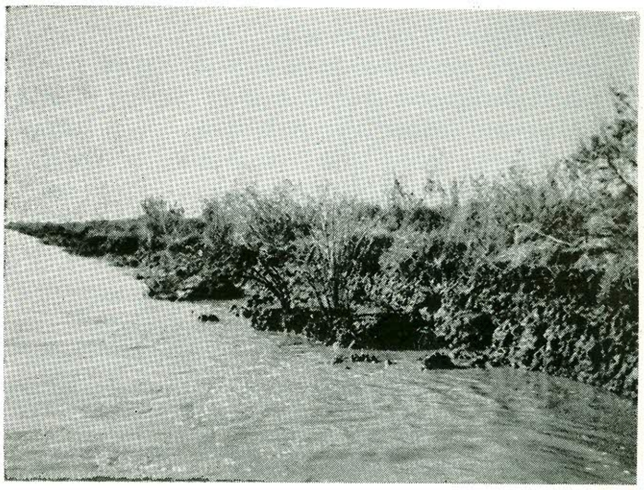

Figure 16. Humble Canal levee slumping into canal. Waves created by passing boats destroy canal berms and eventually the levees.

upon the length of time the levees have been undergoing subsidence and erosion. For a complete discussion see the section on canal levee study. In addition to the oil company canals there are 10 miles of property line canals and a little more than four miles of Refuge service canals that have levees. Along the property line canals the levee is placed on only one side, that side being the south or Refuge side. At present the property line canal is complete from the new headquarters site east to Superior Canal. The service canal runs west from the Humble Canal to the new headquarters site. The location of these canals and the oil company canals can be better visualized by reference to Plate I (In Envelope).

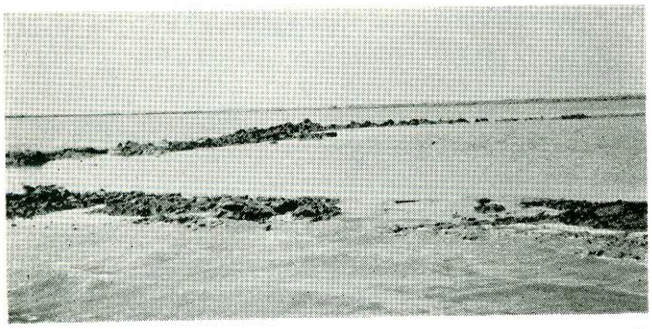

Figure 17. Levee in Deep Lake. This levee surrounds oil well location. Levee is breached in center foreground by high water.

Drainage

The natural drainage of the Refuge is facilitated by six tidal channels. These channels aid drainage by allowing the surface water of the marsh to drain to the Gulf and by permitting the marsh to be flooded by high tides. Tidal conditions directly control the amount of water that drains from the marsh. The amount of water on the marsh depends upon climatic forces. Heavy rains in the neighboring high lands to the north and on the Refuge itself fill the marshland. Strong southerly winds will force sea water over the marsh and conversely, strong northerly winds will lower the water level along the coast and literally blow the water out of the marsh.

Normal tidal action regulates the amount of run-off. The tortuous course followed by the tidal channels slows the rise and fall of tides to the extent that the water level change in the inland lakes is only a few inches. Straight deep canals have the opposite effect. A balance between the amount of water on the marsh and the tidal change is soon reached and subsequent lowering of the water level is gradual and in keeping with the evaporation-transpiration cycle. Under drought conditions the marsh will dry up and the water table will be lowered as much as two feet below the marsh surface. Normal tidal action under drought conditions merely fills and drains tidal lakes that have direct access to the tidal channels.

The location of the water on the marsh is controlled by marshland physiography. The controlling features are the high marsh that rims the coast, marsh ridges, natural levees, and the Grand Chenier-Pecan Island ridge complex to the north of the Refuge. These features point out two important facts: the relatively closed nature of tidal channels except in the distal ends and the drainage of marsh surface water to the central portion of the Refuge. Following heavy rains and high tides the drainage of the water into low areas is restricted by the tidal channel levees. The levees are highest near the coast and decrease in height in an inland direction. It is in the low central portion of the marsh that the levees disappear and permit the marsh water to enter otherwise closed drainage systems. Plates III and IV (In Envelope) illustrate this decrease in levee height.

The six tidal channels that drain Rockefeller Refuge will be discussed as they occur in the four drainage basins that comprise the Refuge.

Joseph Harbor-Price Lake Drainage Basin. This area is in the inter-ridge area between Ridge III and Ridge IV. Joseph Harbor Bayou is the main tidal channel. Minor ones are Beach Prong of Hog Bayou and Dorcelie Bayou. Joseph Harbor Bayou and Beach Prong of Hog Bayou are both connected to the Price Lake area by mudboat ditches and both serve in filling and draining the area. Dorcelie Bayou will soon be closed artifically by an oil company canal which will cross the bayou near its mouth. Dorcelie Bayou drains the area west of Deep Lake. Joseph Harbor Bayou has been deepened artificially up to Humble Canal. The ease of flow up the Humble Canal has resulted in flooding of the region near Nigger Ditch. Miller's Lake shows evidence of accretion around the edges and is also decreasing in depth. Beach Prong is at present uncontrolled and is increasing its tidal effect in the Price Lake area.

Little Constance Bayou Drainage Basin. This drainage basin is between Ridge II and Ridge III. Little Constance Bayou drains Little Constance Lake which is rapidly closing and Deep Lake which is almost stable. Little Constance Bayou has established a channel through Little Constance Lake and is building a levee along this channel. With each overflow this levee becomes higher and soon will isolate all but a small portion of the lake. Deep Lake now absorbs most of the tidal action of Little Constance Bayou. Deep Lake shows accretion in the northwestern portion and is enlarging along the north and south shores. The rate of enlargement in a north-south direction is 1.5 to 4 feet per year. In a northwest-southeast direction Deep Lake shows 15 feet of accretion in the last 20 years. Under present conditions this rate of enlargement is not expected to change. North Island Canal enters Deep Lake on the north side and drains the marsh to the north of the lake.

Constance Drainage Basin. This is the largest basin. It covers most of the Refuge east of Little Constance Bayou. Constance Bayou and East Little Constance Bayou drain this area. At the present time East Little Constance Bayou is closed and unless extreme high water conditions return it is likely to remain closed (Figure 18). Constance Bayou is the longest bayou on the Refuge with its distal end at a point north of Deep Lake. The network of marsh streams that service this basin reach from the junction of North Island Canal and Nigger Ditch to East Little Constance Lake. Big Constance Lake is filling along its south shore. The other lakes in this system are relatively stable. Superior Canal has truncated many of the tributaries of this system and has effectively closed some drainage bayous.

Figure 18. East Little Constance Bayou closed by beach deposits. A large supply of beach material deposited near the former mouth of East Constance Bayou has sealed up East Little Constance Bayou. This occurred during a minor storm.

Rollover Drainage Basin. This basin comprises the area of East Constance Bayou, Rollover Bayou and the area to the east. Rollover Bayou is the larger and carries more water. It drains Rollover Lake and much of the area to the north as well as the marshland to the east. Flat Lake absorbs much of the flow of East Constance Bayou and is filling with sediment. An artificial cut into Flat Lake from East Constance Bayou is causing the cut off portion of that bayou to fill with sediment. Recently enlarged canals and ditches have caused Rollover Bayou to flood and drain large marsh areas formerly unaffected by tidal action.

Water Level Study of Little Constance Bayou Drainage Basin. Water level changes in the marsh reflect tidal changes and the influx of rain water and run-off water from neighboring areas. The tidal effect is by far the most important from the stand point of day by day changes. In the Gulf of Mexico the tidal range is small and winds cause a much greater sea level variation than the moon. However when not considering the wind, tides follow the moon very closely and as the lunar or tidal day is 50 minutes longer than the solar day, tides occur later each day. On certain days of each month the normal two high and two low waters a day will be replaced by a single high and low water a day. Along the Louisiana and Texas coasts the lunar tidal variations are due to the changing declination of the moon. The tides are semidiurnal around the times when the moon is on the Equator but become diurnal around the times of maximum north or south declination of the moon.

Little Constance Bayou Drainage Basin was selected for the water level study because of its relatively closed nature with respect to neighboring basins. Two water level recorders were placed in this basin. Gauge I was located one mile from the mouth of Little Constance Bayou to record maximum water level changes and Gauge II, inland in a small bayou on the southwest side of Deep Lake to record the minimum changes. See Plate I (In Envelope) for locations of gauges. In addition to the tidal variations, the time interval between high and low tides at the coast and the high and low tides inland were measured.

The Stevens Type F Recorder was used. In this recorder a horizontally supported chart drum is turned by the four inch float proportional to changes in water levels. A pen traverses the chart at a constant speed controlled by an eight-day clock. The combined movement of the chart drum and pen produces a graphic record of water levels against time. The recorders were installed in housings on wells made from 55 gallon oil drums. These wells, placed in the bayous, served to dampen waves produced by boats and currents. Figure 19 shows a recorder installed at its bayou location.

The data gained from these recorders is incomplete in that it was not possible to keep the gauges in operation for a long enough period of time. Seasonal variations are important in this portion of the coast and frequently overshadow the small lunar tide. Since tide tables are published by the United States Coast and Geodetic Survey for Louisiana, it is the irregularities of meteorological conditions that are important. Another failing of this data is the lack of correlation with mean sea level. At each gauge a mean water level was established and variations recorded from this mean.

At Gauge I, located near the gulf, the tidal variations are regular and closely correspond to the published predictions. During the period of observation the highest level above a calculated mean water level was 1.71 feet. The lowest level below the calculated mean water was 1.19 feet. The greatest daily variation was 2.1 feet and the greatest variation during the period of observation was 2.8 feet. In periods of diurnal tides, the daily variation is the largest and averages 1.5 feet. These periods slowly give way to semidiurnal tides and the daily variation gradually decreases to 1 foot. The minor tidal variation averages 0.6 feet. There is great variation in the time required for the tide to flood. The average time is seven hours with a high water stand of approximately seven hours. Flood and ebb tides normally begin later at Gauge II. The time interval between the beginning of flood tide at Gauge I and the corresponding beginning of flood tide at Gauge II varies from two to four hours. The time interval between the beginning of ebb tide at Gauge I and the corresponding beginning of ebb tide at Gauge II varies from two to six hours. These figures show great variation during semidiurnal tides. During diurnal tides the time intervals are more regular.

At Gauge II, which is located inland, the variations are uniformly small. During the period of observation the highest level above a calculated mean water level was 0.83 feet, the lowest level below the calculated mean was 0.53 feet. The greatest daily variation was 0.60 feet and the greatest variation during the period of observation was 1.36 feet. In periods of diurnal tides the daily variation is the largest averaging 0.35 feet. The semidiurnal periods have a smaller variation which averages 0.18 feet. Figure 20 shows the daily variations of the water level as recorded at Gauge II. The period illustrated is from July 13 to August 13. The charts are correlated with the phases and declinations of the moon to show the lunar effect. Smaller two-a-day tides will be noted when the moon is on the Equator and larger one-a-day tides as the moon nears its southernmost and northernmost declinations. The high level reached July 29-30 is a result of a minor tropical storm in the gulf. This high level partially masks a larger cyclic change in the water level. During the diurnal or one-a-day tides, there is a general rise in the water level while during the semidiurnal tides there is a compensating decline.

The results from the tidal study show that meteorological conditions are the controlling factor in determining the amount of water found in the marsh. Normal tidal changes can be contained within the tidal channels themselves and their community of tidal lakes. During droughts when there is little or no water on the marsh this is readily shown. Seasonal changes in tides and

Figure 19. Tide Gauge II. This gauge is in a small bayou at the southwest edge of Deep Lake.

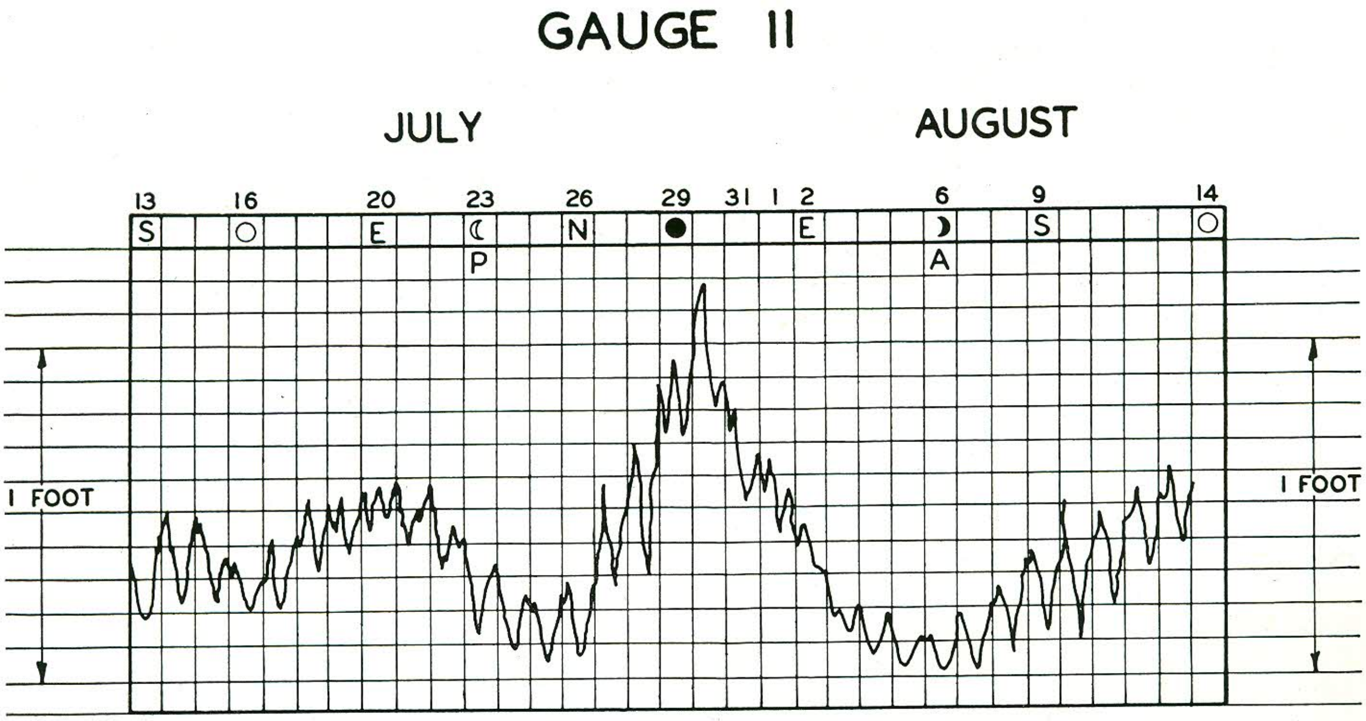

Figure 20. Tide Chart. This chart depicts one month's water level changes at Gauge 11, inland near Deep Lake. The daily variations are on the order of 0.2 feet while the greatest variation during the interval covered by this chart is one foot. The phases of the moon and the date on which they occurred are indicated across the top of the chart. ◉, new moon; ☽, first quarter; ☺ full moon; ☾, last quarter; E, moon on the Equator; N, S, moon farthest north or south of the Equator; A, P, moon is apogee or perigee.

weather bring abnormal high tides that overflow into the marsh and subnormal low tides that drain the marsh. Water on the marsh resulting from rains and freshets account for sustained high water levels.

Vegetation

Introduction. The coastal marshlands came into being with the first vegetation coverage of the newly formed mudflats. In the exposed mud and shallow water, grasses began growing and forming soil with their organic debris. The type of vegetation found in a marsh depends upon the water level, salt content in the water, and soil properties. As the marshland develops, these factors are subject to small changes and with them the type vegetation changes.

The water level is dependent upon variables such as meteorological conditions, tidal conditions, and elevation of marsh with respect to surrounding physiographic features. The salt content of the surface water is also dependent upon the above conditions. The soil properties which affect vegetation in a marshland are the type parent material and the salt content.

Rockefeller Refuge. Rockefeller Refuge has several distinct vegetational zones that can be related to the above conditions. The coastal area with its high beach and wash-over deposits is slightly higher than the center of the Refuge. The resultant slope of the marshland is toward the center of the Refuge. Opposed to this is the reservoir of fresh water in the Grand Lake-White Lake area which overflows into the Refuge from the north.

A fresh marsh is maintained along the northern boundary of the Refuge by rain water and a continual replenishing of the freshwater by drainage from the north. The daily saltwater tide is counter-balanced by the quantity of freshwater available. The tide, even when exceptionally high, does not entirely displace the freshwater. The ground water remains fresh and the invading saltwater will soon be drained off by tidal action and diluted by freshwater from the north. The tidal change allows the freshwater to flush out the saltwater and the percentage of salt is eliminated or lowered to a compatible vegetative position while at the same time the proper water depth is maintained. The result is a deep water fresh marsh complex on the north (Figure 21). At the center of the Refuge where the freshwater meets the saltwater there is a shallow brackish to saltwater marsh (Figure 22). Marginal to the beach there is a saltwater marsh that is free from standing water a portion of each year.

Figure 21. Deep marsh vegetation complex. This is a freshwater marsh south of Josephine Island.

Figure 22. Marsh meadow vegetation in a shallow, brackish to saltwater marsh. This vegetation is marshhay cordgrass, approximately two feet tall.

Within the general setting as outlined above there is a vegetation change that accompanies the tidal channel levee systems. The maximum levee height is at the bank of the tidal channel and from this point the surface slopes inward to low areas between the tidal channels (Figure 23). This creates a change in plant types based on elevation. The above occurs only in saltwater zones as the tidal channels do not reach the freshwater areas. A similar change takes place from the beach northward.

Other vegetation differences in the Refuge area are found along the marsh ridges and in the extreme west portion of the Refuge. In several places the marsh ridges are slightly higher in elevation than the surrounding marsh and are characterized by a different type vegetation (Figure 24). The ridges are not high enough nor are the inter-ridge areas low enough to influence the overall vegetation picture. In the extreme west portion of the Refuge the salt marsh that is marginal to the beach is more extensive. This is probably due to the better drainage conditions of the marshlands immediately to the north of this area.

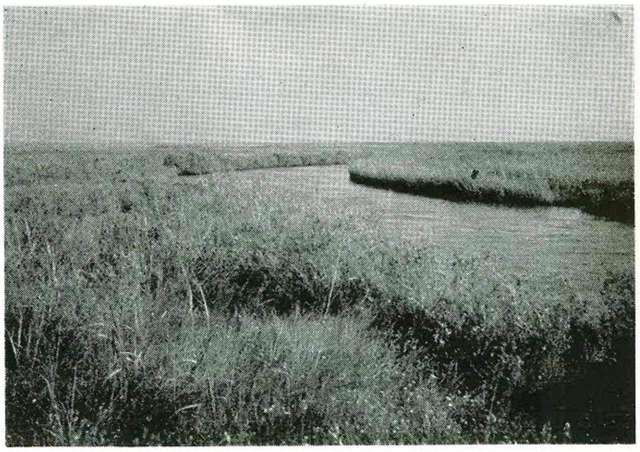

Figure 23. Natural levee vegetation complex. The tall leafy, woody plant at the bayou bank is bigleaf sumpweed. In the center foreground is sea-oxeye.

Vegetation Survey of the Refuge. The survey of the Refuge was conducted from marsh buggies and mudboats. Dominant plants were mapped and subdominant ones were noted in each vegetation zone. In borderline areas and transition zones, the vegetation was mapped as a com-

Figure 24. Common reed or roseau cane. This vegetation is frequently found on marsh ridges in the western portion of the Refuge. The roseau cane pictured here is eight feet tall.

plex and all prominent plant types indicated. The area affected by severe saltwater intrusions was not type mapped. Table I shows the marsh plants mapped and the zones in which each plant may be found. The common name marked by an asterisk is the one recommended by the Soil Conservation Service of the United States Department of Agriculture and used in this report.

The vegetation type map of Rockefeller Refuge, Plate VII (In Envelope), is divided into six zones: three major zones, a transition zone, a highland complex, and the saltwater intrusion area. Of the major zones the fresh marsh is listed as deep marsh complex, the brackish marsh as marshhay cordgrass zone, and the salty zone as the seashore saltgrass zone. The transition zone between the fresh marsh and the brackish marsh is listed as intermediate marsh complex. The highland complex is listed as gulfshore and levee complex. The area affected by saltwater burn is listed as saltwater intrusion area.

The deep marsh complex is found along the northern boundary of the Refuge. It is predominantly a fresh marsh. For a normal growing season there should be approximately a foot of water over this type marsh. It is particularly susceptible to destruction from saltwater invasion. The marsh is low and if it is reached by straight canals having access to the gulf, the repeated floodings by saltwater would convert the marsh to a salt marsh. These straight canals provide rapid drainage of the freshwater and allow maximum tidal change in inland areas. The meandering nature of tidal channels inhibit a rapid change. During drought years this area is invaded by many annuals.

The intermediate marsh complex is a transition zone between the fresh marsh on the north and the brackish to salt marsh to the south. This transition zone may have characteristics of both a fresh marsh and a brackish marsh. This complex is found in the western portion of the Refuge where the marsh ridges are more prominent. The slightly higher elevation of the ridges provide a habitat that permits fresher plant types to grow.

The southern three-fourths of the Refuge is comprised of a brackish to salty type marsh called marsh meadow (Report on the relation of wildlife to agricultural drainage. . . , 1951). It is broken only by the high beach and levee zone. The marsh meadow is divided into two zones, the marshhay cordgrass zone and the seashore saltgrass zone. The marshhay cordgrass tolerates slightly fresher water and makes up the larger portion of this type marsh. The seashore saltgrass is dominant marginal to the gulfshore zone. This marsh is normally dry a portion of each year and is a firmer marsh than the deep marsh. A higher water level would convert this marsh to a good wildlife habitat. Better drainage would make it a firmer, higher marsh of little use for wildlife.

The gulfshore and levee complex is found on the high areas immediately behind the beach, on bayou levees, lake shores, and along old canal levees. A type vegetation that requires more elevation and yet is tolerant of a high salt content in the soil is found in this complex. This complex is only a few hundred feet wide at its widest point yet its prominence and extensive nature give it an important position (Figure 25).

The saltwater intrusion area is not type mapped. This area is undergoing an extensive change. It was formerly a deep marsh with the dominant plant being saw grass. This vegetation

Table I.

A PARTIAL LIST OF MARSH PLANTS USED IN TYPE MAPPING, ROCKEFELLER REFUGE

		Type Marsh in Which Species Occur			
Scientific Name	Common Name	Deep Marsh 0-1.68% salinity FRESH	Intermediate Marsh 0-2% salinity BRACKISH	Marsh Meadow .8-5% salinity SALT	Gulfshore and Levee
Acnida alabamensis	chou-gras, gulfcoast waterhemp*	x	x		
Baccharis halimifolia	eastern baccharis*, marsh elder, manglier		x (ridges)		x
Batis maritima	maritime saltwort*, glass wort				x
Borrichia frutescens	sea-oxeye*				x
Cladium jamaicense	saw grass*	x			
Distichlis spicata	seashore saltgrass*, saltmarsh grass			x	x
Daubentonia drummondi	rattlebox*, coffee bean	x			
Eleocharis (species)	spikesedges*	x	x		x
Iva frutescens	bigleaf sumpweed*, marsh elder, buckbrush		x (ridges)		x
Juncus effusus	common rush*, soft rush	x			
Juncus roemerianus	needlegrass rush*, black rush			x	x
Lycium halimifolium	matrimonyvine*				x
Phragmites communis	common reed*, roseau cane	x	x (ridges)		
Sagittaria lancifolia	bull tongue arrowhead*	x	x		
Scirpus californicus	california bulrush*, giant bulrush	x	x		
Scirpus olneyi	olney bulrush*, three square			x	
Scirpus robustus	saltmarsh bulrush*, leafy three-cornered grass, coco			x	
Spartina alterniflora	smooth cordgrass*, seacane, oyster grass			x	x
Spartina cynosuroides	big cordgrass*, hogcane	x	x (ridges)		x
Spartina patens	marshhay cordgrass*, wiregrass, couch grass			x	
Typha angustifolia	narrow leaf cattail*	x			
Typha latifolia	common cattail*, broad leaf cattail	x			
Zizaniopsis miliacea	giant cutgrass*	x			

* Name recommended by the U. S. Soil Conservation Service.
Salinities from Penfound and Hathaway (1938).

Figure 25. Gulfshore complex showing sea-oxeye back of beach. Immediately beyond the sea-oxeye is smooth cordgrass and seashore saltgrass.

was killed by frequent saltwater floodings brought about by Humble Canal. Saltwater tolerant plants such as smooth cordgrass are beginning to invade this area. However present impoundments and drainage restrictions have stopped the saltwater and following a flushing out of the salt, freshwater plants will again thrive in this area (Figure 26).

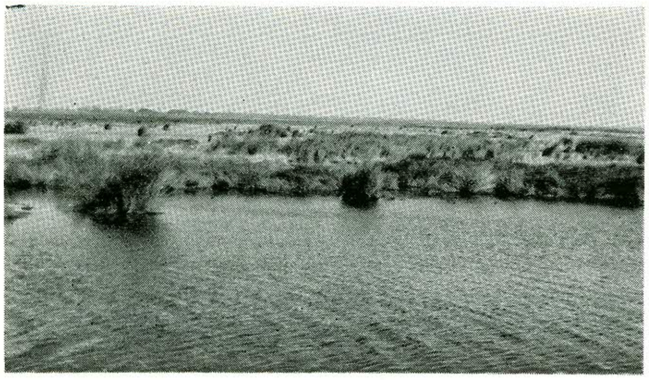

Figure 26. Saltwater intrusion area. The vegetation (mashhay cordgrass) is being destroyed by saltwater intrusion, south of Nigger Ditch.

Significance. In the introduction to this section it was pointed out that the type vegetation is dependent upon three things: water level, salinity of water, and soil properties. The type map of the Refuge ably depicts the plants reaction to these variables. Of the above, water level and salinity of the water are the most important in a coastal marsh environment. Soil is important in that it is being formed by the grasses from the parent mudflat material.

Marsh plants respond as rapidly to water level changes as they do to salinity changes. Under certain conditions of water level and salinity, one plant will tend to be dominant over all others (Allan, 1950). For instance saw grass grows best when there is from six inches of water over its roots to when the water table is within two inches of the ground surface. Any radical changes from these limits will result in saw grass being replaced by another grass more suited to the conditions. Marshhay cordgrass grows best in three inches of water to when the water table is five inches below the surface. These limits are also dependent upon the salinity and become narrower or closer to the ground surface as the salinity increases. In a fresh marsh covered with approximately six inches of water, cattails, sawgrass, and california bulrush dominate. If the water conditions vary between two inches of surface water and a water table six inches below the surface while the salinity is less than one per cent, then common reed, big cordgrass, and some marshhay cordgrass would dominate. Further increase in salinity while the water level remains near the ground surface results in seashore saltgrass and smooth cordgrass. These facts help point out the necessity of controlling water levels as well as salinities.

In conjunction with this study, salinities of surface water was recorded. Rockefeller Refuge suffered a severe drought during the summer and fall of 1954. During the first four months of 1954 the inland lakes and distal bayous and mudboat ditches remained fresh. However, from May until November there was little rain, and lakes and small bayous dried up and tidal channels were as salty as the current gulf salinity (Figure 27). By the end of the summer, Superior Canal was actually draining much of the deep marsh along the north boundary line. This was a direct result of the drought conditions and the lowering of the water level in the Mermentau River Basin reservoir by the withdrawal of the water for rice farming.

Coastal marshland soils are poorly drained and consist of or develop from the accumulation of plant remains. Peat, muck, and a mineral soil are the types that develop in a marshland. On Rockefeller Refuge each of these types can be found. However, the development is not complete and they occur in conjunction with each other. When the soil is greater than 60 per cent organic matter, it is peat. Muck is peat in a more advanced stage of decomposition and has more mineral matter. Mineral soil has very little organic matter and may be oxidized and mottled with iron stains. The parent material for the Refuge is the soft gray clay mudflat material. The above incipient soil types are built up over this parent material.

The majority of the Refuge has organic matter or peat at the surface. This grades into a muck which in turn grades into the soft gray clay. The marsh ridges and the gulfshore and levee areas exhibit incipient soil profiles of mineral soil (For marsh ridge sequence see Plate VI, In Envelope). These areas have the highest elevation and consequently support a great variety of plants. They are better drained and the water table drops to several inches below the ground surface each year. This permits oxidation to take place by aeration, bacterial decomposition, and respiration of higher organisms. Oxidation products and humus serve to make better soil (Byers, 1938).

Figure 27. Dry marsh bayou. This bayou is located west of Deep Lake and is a tributary of Dorcelie Bayou. Note the dead fish in the dry channel bed.

The depth to the soft gray clay or parent material is shown by a contour map (Plate VIII). At the same time the thickness of the marsh soil can be noted. The marsh ridges show a greater soil development while a greater thickness of marsh muck and peat is indicated in the Constance Bayou area.

The hydrogen ion concentration in the marsh soil proved to be very consistent. Peat and muck were acid (4.5 to 7.0) while the mineral soil and gray clay were slightly basic (7.0 to 7.5). The organic acids in the peat and muck are the deciding factor. The pH of gulf water is basic and tends to increase slightly with salt concentration (7.0 to 8.5), but in isolated marsh lakes where organic acids are present it is definitely acid (4.5 to 7.0).

Canal Levee Study

The study of canal levees in the marsh was instigated with the idea of determining the most practical sized levee for each type of marsh found on Rockefeller Refuge. This problem is important, for the improvement of marshlands is dependent upon a sound levee system. Levees must be constructed to maintain an effective height and width for a great number of years. To achieve this, careful consideration must be given to the effect of subsidence, dessication, and erosion of the initial levee. The Refuge is well suited for a study of this type as old canal levees are present for study and new canal levees are constantly being constructed for comparison.

The field work involved in the study consisted of a profile of the levee and the marsh. Coordinated with this profile were two detail boreholes, one on the crest of the levee and the other in the undisturbed marsh. Samples were collected from each borehole and tested for moisture and organic content. The various horizons or contacts in the marsh and under the levee were then correlated and the amount of subsidence of the levee measured. At the same time the amount of compression and depression of each individual horizon within the marsh was determined. One big factor not readily measured was the erosion of the levee and the resultant loss of height. This might be ascertained in part by the amount of material washed into the adjacent marsh but measuring would be difficult with little hope of a reliable result. There was no way of knowing original heights of old levees as no measurements were taken, therefore old canals were of little help in this place. However, the new canals offer excellent opportunities for a continued study of this type.

The resultant height of every canal levee can be related to a number of component causes. The greatest apparent loss of levee height can be correlated with compaction of the marsh surface. This takes place rapidly in the first few days following the completion of the levee and then proceeds more slowly. In the months that follow, a slow dessication and disintegration of the levee proceed hand in hand. As the surface dries, it is at first blocky but soon crumbles into tiny fragments susceptible to removal by gravity, running water, and animal activity (Figure 28). This is a continuous process and unless checked by an erosion inhibiting medium will eventually destroy the effectiveness of the levee.

Figure 28. Nutria hole in berm of new headquarters canal. This hole is burrowed into the soft organic layer The lighter area at water level is oxidized gray clay of a marsh ridge.

Plate IX (In Envelope) presents in graphic form a compilation of data derived from the canal levee study. One levee cross section is included to illustrate the data and its application. For example, the following information can be gained from a study of the bar graphs. With reference to cross section V, the age of the levee is 12 months. The marsh surface under the levee is depressed two feet. The organic layer is compressed 75 per cent which means that the original thickness of two feet is now 0.5 foot thick. The gray-black clay layer is compressed 30 per cent or an original thickness of 1.75 feet is now 1.25 feet thick. The upper contact of the gray clay is depressed three inches. The depth to the gray clay is four feet.

In the process of drilling the boreholes, representative samples of the levee material and the various horizons in the marsh were analyzed to determine the per cent moisture by weight. Two graphs based on the moisture content plotted against depth are presented on Plate IX. One graph gives the results of the samples taken from the levee and the underlying marsh. The second graph shows the results from undisturbed marsh. The first graph indicates that the levees are driest near the surface with the moisture content increasing with depth. The organic material of the marsh surface layer is indicated by the reversal of the curve which points out the maximum moisture content. The moisture content then decreases until the gray clay is encountered and a norm established. The second graph shows the moisture content in an undisturbed marsh sequence as reaching its maximum in the highly organic layers near the surface and then decreasing to the gray clay layer. Comparison of the two graphs shows the amount of moisture lost through compaction, and the depth at which compaction ceases to be effective. This depth is at the gray clay horizon. Plate VIII (In Envelope) is a contour map of the top of the gray clay.

Presented below are conclusions based on the data compiled to date. These conclusions are presented with the qualification that additional information may necessitate changes.[1]

a. The paramount factor in the permanence of a levee is the type marsh upon which the levee is placed. Two complementary facts are immediately apparent, namely the more fluid the type

[1] For a comprehensive study of the behavior of levees constructed on marsh, refer to the Louisiana Wild Life and Fisheries Commission Technical Bulletin, Rockefeller Refuge Levee Study by Lewis G. Nichols.

marsh the less weight it will support, and correspondingly the less solid spoil material available to make up the final levee.

b. The condition of the marsh at the time the levee is placed is of great importance. During dry periods when there is no water on the marsh the moisture content of the near surface material is low. This results in greater strength in the top two feet of the marsh. Equally important is the better formed and higher levee that results from this drier and more compact spoil. When water is over the marsh the surface material is supersaturated and becomes very weak and almost fluid. Poorly shaped levees that spread and sink into the marsh result from this condition.

c. The thickness of the surface organic layer controls the amount of immediate subsidence. This layer compacts to approximately 60 per cent of its original thickness. The compaction is readily explained in that the organic layer is made up almost entirely of water and root material.

d. The gray clay horizon shows very little depression even after an interval of two years has elapsed. The largest levees on the Refuge show this horizon to be depressed only a few tenths of a foot. The depth of the gray clay is significant in that most of the compaction takes place above this horizon.

e. The compaction of the intermediate layers between the organic layer and the gray clay is dependent upon the amount of organic matter present.

f. Moisture content can be correlated with the amount of vegetable matter present and may prove to be a reliable key to the approximate amount of compaction.

g. Dessication of the newly formed levee is preliminary to the eventual erosional destruction of valuable levee height. As the surface of the levee dries, it disintegrates and is then in an acceptable form to be transported away by rain water. Loss of levee height in this manner may become critical unless checked by soil binding vegetation.

h. Marsh spoil when used as levee building material is naturally saturated with water and dries very slowly. A crust forms on exposed surfaces of the levee. This crust soon crumbles and disintegrates allowing deeper drying as cracks form in the levee material. Capillary action brings water from the water table into the levee and maintains a high moisture content (Olmstead, 1938). Only in extended dry periods may the water table be expected to lower enough for deep drying to occur in the levee.

STRATIGRAPHY AND SEDIMENTATION

Introduction

The stratigraphy and sedimentation are treated together in this section due to the nature of this investigation. Stratigraphically the deposits found on the Refuge are all Recent in age. These deposits have been studied in detail as well as the Recent-Pleistocene contact. The Recent deposits can be related to several distinct environments of deposition and these deposits are described in light of their environments and age. The history and early work done on the Recent and Pleistocene deposits of Louisiana will not be discussed as it is not deemed necessary for this report. However, references to original papers in which formation names were introduced, will be given. In addition references to early work in this area will be included in the bibliography.

Pleistocene Deposits

Pleistocene deposits are found in the subsurface of Rockefeller Refuge at depths varying from 15 to 40 feet. In the extreme western corner of the Refuge a Pleistocene Red River channel has cut a deep trench in this surface. The depth to the bottom of this trench from the marsh surface is greater than 52 feet. Another trench of a smaller nature is found near the mouth of East Constance Bayou. The Pleistocene deposits encountered under the Refuge all belong to the Prairie formation (Fisk, 1938). This is the same formation that is at the surface just north of the coastal marshland in Cameron and Vermilion Parishes.

Prairie Formation. The Prairie formation can not be discussed in detail here as only the top few feet of the formation were penetrated in this study. The Prairie formation at the Recent contact shows evidence that it has been sub-areal for an undetermined interval of time. It is deeply oxidized and has an eroded surface quite like its emergent counterpart. In general, the deposits are gray, green, tan to buff colored silty clays and silty sands. The oxidation has produced soft ferruginous nodules of a deep rust to red color. These deposits are most distinctive by their color and stiff tenacious nature as compared to the overlying soft gray clays, silts and sands. Occasionally the top two to four feet will show deposits of an environment of reduction such as in a low swale or abandoned stream channel. These deposits are darker, frequently gray-black with a purplish cast. They are composed of highly organic clays but within a few feet grade into the oxidized deposits described above. This darker, unoxidized clay is also very stiff.

The following is a lithologic analysis of the top few feet of the Prairie formation. The location of the boreholes from which this data was taken is at the new headquarters site on Rockefeller Refuge. Depth listed is from the top of the Prairie formation:

0 - 1½′	Stiff gray-black organic clay some oxidization nodules
1½- 6½′	Stiff oxidized gray clay mottled yellow and tan from oxidation
6½-10 ′	Stiff oxidized gray silty clay with silt lenses and shell fragments
10 - ′	Stiff oxidized gray clay with concretions

This borehole was drilled by the Eustis Engineering Company of New Orleans (Figure 29).

Figure 30 is a photograph of cores of the Pleistocene and Recent deposits. The red color found in many of these silts and clays is indicative that they were deposited by distributaries of the Red River (Fisk, 1948).

Environment of Deposition. The deposits of the Prairie formation penetrated in this study are stream, lake, and bay deposits laid down under a deltaic environment. The finely laminated silty clays indicate frequent floodings by small alluviating streams building levees into shallow lakes and bays. Thicker sections of clays indicate a backswamp type deposition where the very fine material settled out of the more stagnant water bodies at a leisurely rate. In the lake deposits of

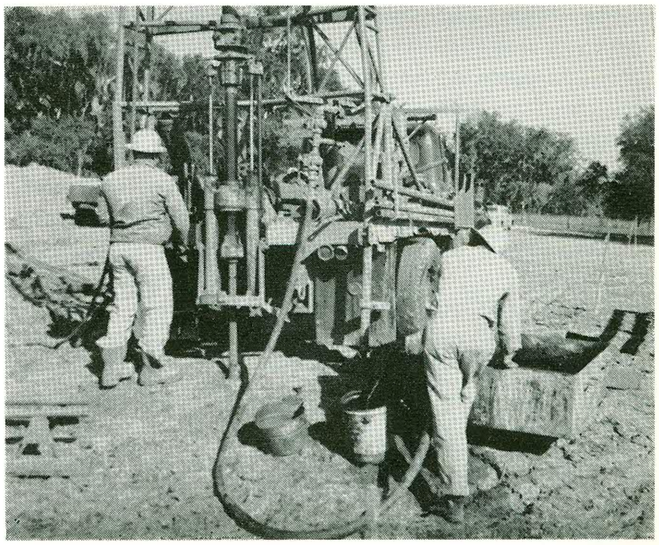

Figure 29. Eustis Engineering Company drilling rig making test borings at Rockefeller Refuge new headquarters site.

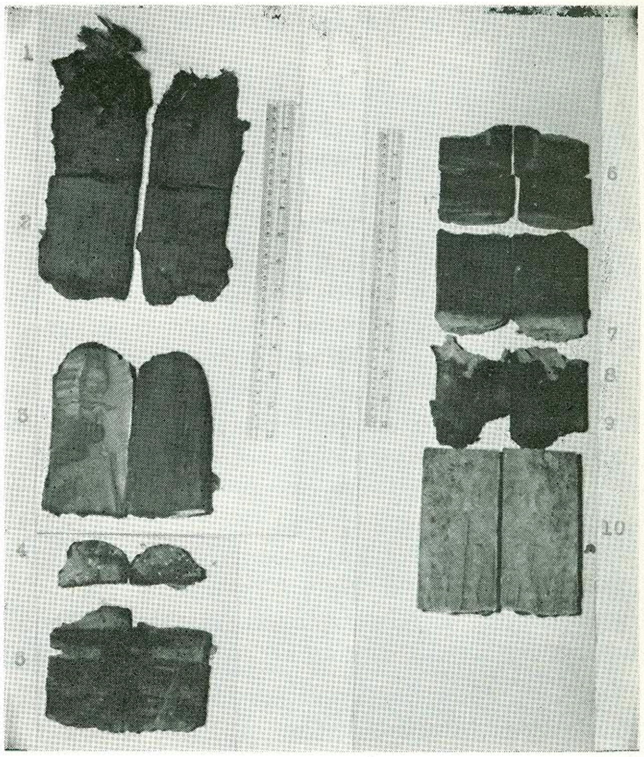

Figure 30. Cores showing composite sequence from marsh surface to Pleistocene contact. 1. organic matter; 2. oxidized gray organic clay; 3. soft gray clay; 4. fine sand and shell fragments; 5. and 6. alternating layers of silty sand and clay; 7. fine sand with shells; 8. Recent-Pleistocene contact; Note sand-filled boring; 9. stiff gray black organic clay; 10. stiff oxidized gray silty clay.

clays and silty clays the brackish water clam *Rangia cuneata* is frequently found indicating the nearness of the gulf. Stratigraphically near will be found *Crassostrea virginica,* a salt water oyster, pointing out the vicissitudes of the Gulf and the River.

Recent-Pleistocene Contact

The Recent-Pleistocene contact is very distinct whether encountered in a borehole or at the surface. As has been previously mentioned this contact is in the subsurface on Rockefeller Refuge. It is delineated principally by color and the decidedly stiffer nature of the Pleistocene deposits. The Pleistocene deposits are oxidized tan to buff color or are characterized by soft yellow to red nodules. Occasionally the deposits are darker and not oxidized. In all instances the Pleistocene deposits are very stiff and compact when compared to the soft gray to black clays, silts and sands of the Recent.

Relatively speaking the Pleistocene surface is a flat, featureless plain. With few exceptions its surface depth in a designated area can be predicted on the basis of a few boreholes. In the Refuge area the Pleistocene surface slopes gulfward at a rate of about four feet to the mile. Immediately to the north of the Refuge the normal rate of slope is one to two feet per mile for the Prairie surface. If the contour map of Plate X is studied these features will be evident. This map also shows to a small degree a slight reversal of the expected south-southeast dip of the Prairie surface to one of south-southwest in the eastern portion of the Refuge. This feature is probably a portion of the large Pleistocene Mississippi River system indicated on Plate II (In Envelope). The possibility of a minor structural feature should not be ruled out.

The gulfward slope of the Pleistocene surface can be seen in cross section on Plate XI. Section A-A′ along the Cameron-Vermilion Parish line shows two terraces, one near the northern boundary of the Refuge and the other near the coast. Section B-B′, along Humble Canal, shows a more nearly constant rate of slope. Frequently in the northern portions of the Refuge the Pleistocene surface is composed of a buried soil complex. It is highly organic, has a dark color and lacks distinct oxidation nodules. Since this sequence is encountered exclusively in the northern part of the Refuge it is suggested that wave erosion during periods of coastline retreat may have partially removed the top few feet of the Prairie surface. This supplies the source area for much of the fine sands that make up the bulk of the cheniers. The erosion occurred very late in Recent time and a sea level change is not postulated for this action.

The nature of the Recent-Pleistocene contact indicates that an unconformable condition existed. The interval between the deposition of the unconformable Recent and the Pleistocene beds is small and although the Pleistocene surface is eroded, little record is missing. The situation is much like the interval between tides. The contact itself frequently has a thin layer of fine sand and shells as a veneer over the surface. Animal borings into the Pleistocene are filled with this sand (Figure 30, Page 29). Small calcarious nodules are also found at this contact. The factors indicating an eroded surface, a reworking of material, and the basal sand of a new deposit all confirm the Recent-Pleistocene contact.

Recent Deposits

Recent deposits make up the entire surface area of Rockefeller Refuge. They belong to the Mermentau member of the Le Moyen formation as defined by Jones (1954). The thickness varies from 15 to 20 feet along the northern boundary to 35 to 40 feet along the gulf coastline. The deposits are interbedded fine sands, silts and clays. Organic clays and peats are prominent as is the beach material of sand and shell along the coastline. Recent deposits also fill scour channels cut into the Pleistocene by streams draining the Prairie surface. These trenches frequently allow Recent deposits to exceed 52 feet in thickness. One such trench courses across the far western edge of the Refuge. At the boundary line this trench is cut more than 25 feet into the Pleistocene surface. A trench of a more minor nature is found near the mouth of East Constance Bayou. Reference to Plate X (In Envelope), a contour map of the Pleistocene surface, will give a comparison of these two trenches. The Recent deposits form a wedge thickening to the south and east. This wedge is suggested by the contour map of Plate X, which is also an isopachous map of the Recent deposits.

Mermentau Member (Le Moyen Formation). The Mermentau member of the Le Moyen formation as found on Rockefeller Refuge is composed of a sequence of interlaminated beds of fine-sands and clays. The thicker clay beds owe their origin to marine mudflat deposits. Organic clays are the marsh and lake deposits while the thin lenses of silts and sands are gulf bottom or bay bottom and nearshore deposits. Along the coastline the present beach deposits are of sand and shell. At the marsh surface thin linear lenses of tidal stream levee deposits and marsh ridge deposits are present.

The sediments making up the various facies of the Mermentau member are gray to gray-black in color. They are very soft and have a variable amount of organic matter. The grain size ranges from the very fine clays and colloids to fine sand. The included beach deposits are a mixture of fine sand, shells, and shell fragments. The clay sequences are occasionally interrupted by sand and silt lenses with tiny shells, whole and in fragments. In the deposits near the cheniers the first 12 feet is made up of alternating layers of clay, silty clay, and silty sand with shell. This sequence indicates both mudflat and nearshore deposition.

The cross sections of Plate XI (In Envelope) are made from borings that include the Rockefeller Refuge section of the Mermentau member. A study of the above plate will be helpful in the understanding of the deposits. Refer to Figure 30 (page 29) for a picture of these sediments.

Environments of Deposition

Gulf Deposits. These deposits are the oldest deposits described and make up the bulk of the Recent material found at Rockefeller Refuge. The gulf deposits are made up of mudflat and nearshore bottom sediments. The mudflat material consists of reworked deltaic deposits that were carried westward along the coast by longshore currents. This occurred during periods when great quantities of sediment were available near the western front of the Mississippi Alluvial Valley. Extensive mudflats were then deposited along the coast in front of the beaches of Cameron and Vermilion Parishes thus stranding them. These mudflats are composed of loosely consolidated gray clays interlaminated with thin lenses of silt. The gray clays represent rapid uninterrupted deposition and the lenses of silt indicate intervals during which the very fine material was winnowed away.

The second gulf deposit to be discussed is the nearshore bottom deposit. This deposit is the offshore facies of beach deposits and accumulates during periods when the shoreline is stable or slowly retreating. The sediments are soft silty clays and silty sands with shells. These lense shaped deposits are finely interbedded. The normal nearshore, marine faunal assemblage thrives in this environment. Mollusks frequently found in these beds are: *Anadara*, sp., *Atrina serrata, Barnea costata, Busycon spiratum, Mercenaria campechiensis, Mulinia lateralis, Polinices duplicatus, Spisula solidissima raveneli, Strombus alatus.*

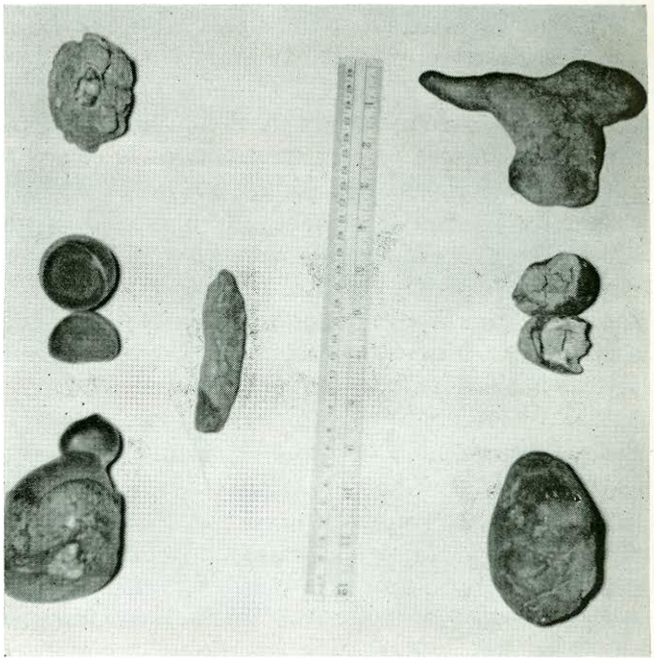

Figure 31. Concretions. These concretions form in nearshore bottom deposits. They were found in spoil dredged up to build levees near Cow Island. Upper left-hand corner, a conglomerate of case hardened clay balls, (note small oyster shell attached to this concretion); upper right-hand corner, a flat anvil-shaped siltstone slab.

A feature of these deposits is the presence of concretions. The concretions measure up to two inches in diameter. They are solid, dark colored and composed of silt and clay. The cementing material or materials have not been established although calcium carbonate is identified in one concretion. Some of the concretions are a conglomerate of case hardened clay balls. One is a flat anvil shaped silt and clay stone similar to cemented sandstone slabs of the Chandeleur Islands, Louisiana (Morgan and Treadwell, 1954). The concretions are beach worn and are unearthed by canal dredgings on the gulf side of old beach ridges or cheniers. Figure 31 shows these concretions.

Levee Deposits. The levee deposits present on Rockefeller Refuge are predominantly along currently active tidal channels. However, there are a few abandoned stream channels with accompanying levees to mark their courses. These are Floating Turf Bayou, the old Josephine Bayou and portions of the present tidal channels that have been cut off by the retreating coastline. The levee deposits are composed of gray to brown to black fine to very fine sand, silt, and clay. The sand is concentrated in the upper few inches of the deposit which is seldom more than two feet in thickness. On Plate XII samples 11 and 12 of the grain size analysis graph of marsh sediments are levee samples. Levee prominence is accentuated by the presence of a more woody type organic matter in the top few inches. This is because of the greater height and the subsequent woody vegetation of the levee. The greater elevation above the marsh level also allows aeriation of the sediment and active bacterial action. The end product is a firmer, compact deposit, which is oxidized and contains humus. Organic material has masked any semblance of bedding.

The mechanics of levee deposition is discussed in the natural levee section of the Physiography of the Refuge. The source of the coarser levee material is important and will be discussed here. A second look at the analysis of the levee samples on Plate XII will show that the sediments are definitely finer grained in the sample taken the greater distance from the beach. It has also been emphasized that the levees are higher and more extensive near the beach. All this points to the source of sediment as being in the direction of the beach. This indicates that the sediment is carried along shore and swept into the tidal channels on a flooding tide, especially during storms originating in the gulf. During periods of strong offshore winds the water in the tidal channels is muddy for several miles inland.

A macrofauna occasionally observed in the levee deposits is the gastropod *Littorina irrorata.*

Marsh Deposits. The marsh deposits are fresh to brackish along the northern boundary of the Refuge and brackish to salty in the remainder of the Refuge. These sediments are soft to soupy organic clays and gray to brown to black in color. Frequently beds of peat will be included with them. The marsh deposits vary in thickness from a few inches to five feet. Plate VI (In Envelope) shows a typical marsh sequence. Marsh deposits accumulate from organic debris and from the very fine material carried in suspension by the flood waters and high tides that spread over the marsh. The faunal content is largely limited to microfauna and a few macrofauna of which *Littorina irrorata* and *Neritina reclivata* are the most abundant.

Lake Deposits. The lake deposits are confined to marsh lakes which make these sediments similar to the marsh sediments. They are dark gray to black organic clays, frequently silty and with shells. The silt concentrations are laminar and it is in these layers that the shells are found. The lakes are brackish to salty. The sediment is brought into the lakes by the flood waters and tides. The deposits consist of sediments derived from the destruction of the marsh and sediments that are already in suspension prior to the waters entry into the marsh area. The fauna content is considerably larger than the assemblage of marsh fauna. It is augmented by many more bottom dwelling mollusks such as: *Brachidontes recurvus, Crassostrea virginica, Mulinia lateralis,* and *Rangia cuneata.* The salt content controls the assemblages.

Marsh Ridge Deposits. These deposits like the other deposits discussed here are facies of the Mermentau member of the Le Moyen formation. These ridges are stratigraphically higher or younger than the cheniers and their offshore facies. They represent minor lithologic changes and are of little importance to this member as a whole but the principles employed here can be applied toward a clear understanding of formations in the geologic past. The marsh ridges lithologically are quite similar to levee deposits. They differ in the amount of organic matter at the surface and have lesser amounts of fine to very fine sand. Otherwise they are a gray to brown to black oxidized clay with varying amounts of silt and fine sand. Organic matter is concentrated in the top of the section changing to humus in the oxidized zone. Plate VI (In Envelope) presents a series of diagrammatic cross sections of the ridges that are found on the Refuge. Included with this plate are two borehole sequences for comparison: one, through the center of a ridge and the other in a marsh area.

The origin of the marsh ridges can best be explained after Plate XII has been studied. The right half of this plate compares graphically the grain sizes of ridge sediments and marsh sediments. The outstanding feature at first glance will be the similarity of the samples. This indicates that the conditions of deposition must have been much the same. However, a closer look at the samples of each ridge separately and according to depth shows a slightly different condition of deposition prevailed. A greater quantity of fine sand is in the upper portions of the ridges. This fact coupled with the alignment and extension of the ridges gives a solution to their origin. (Refer to Plate II, (In Envelope), for a comparison of the alignment of the ridges with the old beach ridges and the present coastline). During the period of extensive mudflat accretion along the coast there were times when the conditions of deposition were more or less stagnant. This allowed a winnowing of the outermost mud. This winnowing left an unusually large amount of fine sand to be either deposited with the next invasion of mud or thrown up on the exposed mudflats by the breaking waves should this period be an extended one. When this happened the current strandline was marked by a slightly coarser and higher deposit. This same thing could happen another way. If excessive quantities of fine sand should be made available for transportation by the longshore current they would be distributed along the coast and deposited in much the same way as described above. The source for the sand could be from the destruction of deltaic masses to the east and offshore shoal areas. Following deposition, the greater ridge elevation supplied the remainder of the conditions necessary for their preservation. Soil development is more advanced on the ridges due to greater aeriation of the sediments and a greater variety of plant life. The ridges are thus slightly oxidized and firmer.

Figure 32. Indurated beach material. This indurated beach material was uncovered after the beach moved inland across it. It is predominantly shell, and formed at the base of the beach deposit.

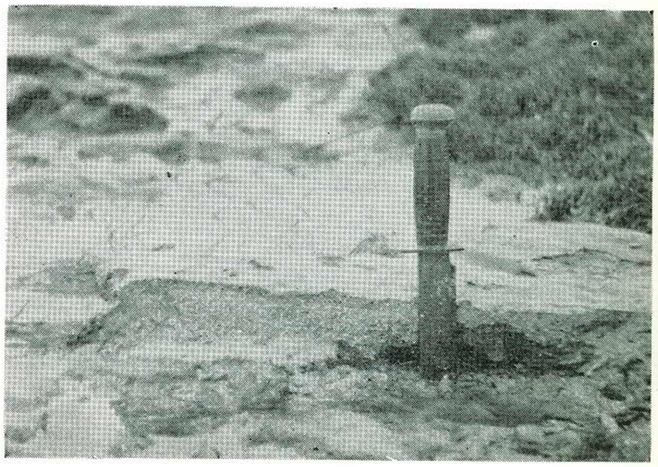

Figure 33. Indurated beach material in cross section. The darker area around the edge of the exposed section is an organic stain.

Beach Deposits. The beach deposits that rim the present coastline are predominantly silt, sand, and shell. The sand varies in grain size from fine sand to very fine sand. Occasionally thin layers of indurated shell or coquina are formed by the shells and shell leached calcium carbonate (Figures 32 and 33). The shell content of the deposit is variable depending upon the position of the sample with respect to the beach deposit. The overall shell content might run as high as 50 per cent, whereas the samples taken at the low tide swash line average 10 per cent shell. Plate V (In Envelope) shows a series of beach cross sections. The outstanding feature is their similarity. Plate XII (In Envelope) contains a grain size analysis of the beach sediments, and here too, they appear to be very similar. However, a slight tendency for the sediments to become finer may be indicated in the western portion of the Refuge. The coefficient of sorting shows the material to be well sorted. Four samples ranged from 1.22 (Beach profile H) to 1.64 (Beach profile I). The highest coefficient of sorting recorded is Beach profile F at 3.13. Included for comparison is a sample taken from the nearshore beach material of Cow Island. It is slightly coarser but the coefficient of sorting compares favorably at 1.75. The coarseness is explained by the samples slightly downslope position on a larger beach deposit In all cases shell content makes up the coarser fractions of each sample.

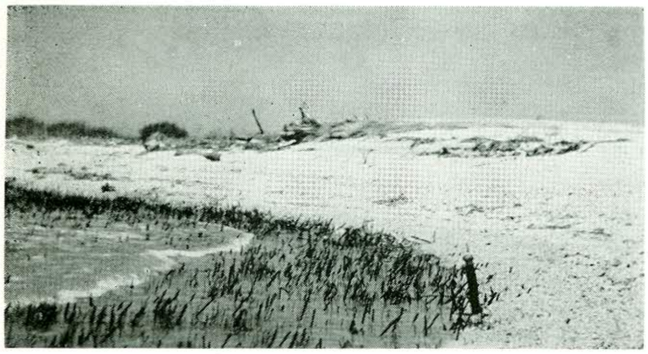

Figure 34. Exhumed marsh and beach deposit. Photograph taken east of Joseph Harbor Bayou.

The beach material is deposited by the gulf waves (Figure 34). The relentless attack of the waves erodes away the marsh and gulf bottom and throws the coarsest material back up on the marsh. This deposit steadily grows as the coastline retreats. Due to the generally east and southeast winds that drive the waves and the longshore current, there is a slight coastwise movement of the beach deposits and sediments to the west. This would explain the finer material being farther from the source area. The shells of marine mollusks found in the beach deposits include the following: *Anadara*, sp., *Atrina serrata, Barnea costata, Busycon contrarium, Busycon spiratum, Callocardia texasiana, Crassostrea virginica, Dinocardium robustum, Donax*, sp., *Dosinia discus, Mercenaria campechiensis, Mulinia lateralis, Noetia ponderosa, Oliva*, sp., *Polinices duplicatus, Spisula solidissima raveneli, Strombus alatus, Tellina*, sp., and many others.

In addition to the present beach deposit there are portions of the Grand Chenier-Pecan Island chenier included on the Refuge at Long Island and Josephine Island. Near Tiger Island and Cow Island of the Grand Chenier complex there is encountered at depth the nearshore facies of these beach deposits. These deposits are essentially the same as the present beach material although considerably older. This offshore facies of these ridges can be traced approximately a quarter of a mile gulfward from the chenier. They lense out at approximately 12 feet in depth.

STRUCTURE

Structural features prominent in the region including the area under study are controlled and dominated by the Gulf Coast Geosyncline. This deep structural trough whose axis roughly coincides with the coastline of Southwest Louisiana and then maintains an east-west course across the state of Louisiana, is reflected on Rockefeller Refuge by the southward dip of the Pleistocene surface. Regional faults accompanying the subsidence and compaction of the sediments related to this geosyncline are also present in the vicinity of Rockefeller Refuge although none can be identified in a restricted study such as this (Fisk, 1948).

The Gulf Coast Geosyncline was first defined according to its relative size and importance by Howe (1931). It has since been treated in many bulletins of the Louisiana Geological Survey and by many students of gulf coast geology. In spite of this intense research using all the methods known to geologists and geophysicists the emmencity of this feature is still not established.

Present figures set the accumulation of sediments in its thickest portions as something over 40,000 feet. Deep well and geophysical data supplies subsurface information. Physiographic evidence based on subsidence dominates the surface information. Features such as: drowned river valleys, receding shoreline, trees killed by saltwater encroachment, buried surfaces formerly at sea level, and the submergence of Indian mounds and occupation sites, are all marshland features that point out the subsidence of this area. The above features are not found on Rockefeller Refuge because of the recent age of the sediments. However, the present coastline and the Grand Chenier-Pecan Island chenier sequence along the northern boundary confirms the fact that the gulf coastline retreats when deposition is not the predominant feature. It should be remembered that in recent geologic time the coastline of Southwest Louisiana is building out as deposition is maintaining its superiority over erosion.

GEOLOGIC SIGNIFICANCE OF ROCKEFELLER REFUGE

Rockefeller Refuge owes its very existence to an ancient change in the course of the Mississippi River. A change much the same as it has been making for many thousands of years and will continue to make if allowed to do so by man. This change brought the River to the west side of its valley and as a consequence great quantities of sediment were available to build out the coastline of Southwest Louisiana. Prior to the change, erosion was the dominant factor as the coastline was retreating to the north under the attack of the Gulf and the effect of subsidence of the Gulf Coast Geosyncline. At the time of this change, only a few thousand years ago, the Grand Chenier-Pecan Island beach ridge was the coastline. After the change, expansive mudflats isolated this beach ridge as the balance shifted from a coastline of retreat to one of advance. The sediments were deposited out from the shoreline and up from the bottom always maintaining an equilibrium of the angle of repose between sediment and the water. Minor vicissitudes in the supply of sediment and the erosive action of the waves produced small lenses of silt and sand in the clay deposits. Just how far out into the Gulf the new land was built can not be determined. From the amount of beach deposit along the present Refuge coastline, it seems logical to assume that this present coast has retreated no more than a mile from its greatest point of advance.

As soon as the new mudflats were exposed to the elements, grasses began converting them to marsh. The loose, saturated, unconsolidated clays slowly settled leaving it up to the marsh sediments to maintain a positive elevation. Tidal channels formed to drain off water accumulations from storm tides and inland flood waters and soon the marsh assumed a form which evolved into today's marshland.

In the near future it is possible that the coastline of Southwest Louisiana will undergo another geologic change. At present the coastline is retreating at a rate averaging 30 feet a year. Yet even now a few miles to the east along the Vermilion Parish coast mudflats are beginning to form. The increase of flow and sediment carried by the Atchafalaya River is responsible for this and if allowed to continue the coast of Rockefeller Refuge will again advance.

Rockefeller Refuge is thus a product of the unending strife between the River and the Gulf. In general the River is winning the battle; this fact is attested by the advanced position of the coast today. Nevertheless, the Gulf has made great inroads into the marshland in the past. Evidence of this is found in the inland position of the cheniers, and the Gulf is constantly ready should the River slow its flow of sediments.

BIBLIOGRAPHY

Abbott, R. Tucker
1954 *American Seashells,* New York, D. Van Nostrand Company, Inc., 541 pp., 40 pls.

Allan, Phillip F.
1950 "Ecological Bases for Land Use Planning in Gulf Coast Marshlands," *Journal of Soil and Water Conservation,* vol. 5, no. 2, pp. 57-62 and 85.

Baldwin, M., Kellogg, C. E., and Thorp, J.
1938 "Soil Classification," *Soils and Men, Yearbook of Agriculture 1938,* U. S. Dept. of Agriculture, Washington, D. C., Government Printing Office, pp. 979-1001.

Barton, D. C.
1930 "Deltaic Coastal Plain of Southeastern Texas," *Bull. Geol. Soc. America,* vol. 41, no. 3, pp. 359-382.
1933 "Mechanics of Formation of Salt Domes with Special Reference to Gulf Coast Salt Domes of Texas and Louisiana," *Bull. Am. Assoc. Petroleum Geologists,* vol. 17 no. 9, pp. 1025-1083.

Bowman, Isaiah
1911 *Forest Physiography . . .* New York, John Wiley and Sons, pp. 529-30.

Byers, H. G., Kellogg, C. E., and others.
1938 "Formation of Soil," *Soils and Men, Yearbook of Agriculture 1938,* U. S. Dept. of Agriculture, Washington, D. C., Government Printing Office, pp. 948-978.

Cameron Parish Resources and Facilities
1947 Cameron Parish Planning Board, State of Louisiana Dept. of Public Works Planning Division.

Climate and Man, Yearbook of Agriculture, 1941
1941 U. S. Dept. of Agriculture, Washington, D. C., Government Printing Office, 1248 pp.

Doering, John
1935 "Post-Fleming Surface Formations of Coastal South-East Texas and South Louisiana," *Bull. Am. Assoc. Petroleum Geologists,* vol. 19, no. 5, pp. 651-688.

Dyke, R. A.
1941 "Climate of Louisiana," *Climate and Man, Yearbook of Agriculture 1941,* U. S. Dept. of Agriculture, Washington, D. C., Government Printing Office, pp. 894-903.

Fenneman, N. H.
1938 *Physiography of Eastern United States,* New York and London, McGraw-Hill Book Co., Inc., 714 pp.

Fisk, H. N.
1938 *Geology of Grant and LaSalle Parishes,* Dept. of Conservation, Louisiana Geol. Surv. Bull. 10, 246 pp.
1944 *Geological Investigation of the Alluvial Valley of the Lower Mississippi River,* Vicksburg, Miss., Mississippi River Comm., 78 pp.
1947 *Fine-grained Alluvial Deposits and Their Effects on Mississippi River Activity,* Vicksburg, Miss., Mississippi River Comm., 82 pp.
1948 *Geological Investigations of the Lower Mermentau River Basin and Adjacent Areas in Coastal Louisiana,* Vicksburg, Miss., Mississippi River Comm., 41 pp.

Frink, J. W.
1941 "Subsurface Pleistocene of Louisiana," *Dept. of Conservation,* Louisiana Geol. Surv. Bull. 19, pp. 369-419.

Hackett, C. W.
1931 *Pichardo's Treatise on the Limits of Louisiana and Texas,* The University of Texas Press, Austin.

Harris, G. D.
1902 *The Geology of the Mississippi Embayment,* Dept. of Conservation, Louisiana Geol. Surv. Spec. Rept. 1, 39 pp.
1905 "Underground Waters of Southern Louisiana," *Dept. of Conservation,* Louisiana Geol. Surv. Bull. 1, part 1, pp. 1-77.

Harris, G. D. and Veatch, A. C.
1899 "A Preliminary Report on the Geology of Louisiana," *La. St. Exp. Sta.,* Geol. and Agri. pt. 5, sec. 2, pp. 52-138.

Hilgard, E. W.
1871 "Geological History of the Gulf of Mexico," *Am. Journal of Science, Third Series,* vol. 2, December, pp. 391-404.
1873 *Supplementary and Final Report of a Geological Reconnaisance of the State of Louisiana,* New Orleans Picayune Steam Job Press, 44 pp.
1880 "Physico-geographical and Agricultural Features of the State of Louisiana." *10th Census of the U. S.,* vol. 5, pp. 109-193.

Hitchcock, A. S.
1950 *Manual of the Grasses of the United States,* U. S. Dept. of Agriculture Misc. Pub. No. 200, Washington, D. C., Government Printing Office, 1051 pp.

Howe, H. V. and Moresi, C. K.
1931 *Geology of Iberia Parish,* Dept. of Conservation, Louisiana Geol. Surv. Bull. 1, 182 pp.
1933 *Geology of Lafayette and St. Martin Parishes,* Dept. of Conservation, Louisiana Geol. Surv. Bull. 3, 238 pp.

Howe, H. V., Russell, R. J., and McGuirt, J. H.
1935 *Reports on the Geology of Cameron and Vermilion Parishes,* Dept. of Conservation, Louisiana Geol. Surv. Bull. 6, 242 pp.

Jones, P. H., Turcan, A. N., and Skibitzke, H. E.
1954 *Geology and Ground-Water Resources of Southwestern Louisiana*, Dept. of Conservation, Louisiana Geol. Surv. Bull. 30, 285 pp.

Kuenen, Ph. H.
1950 *Marine Geology*, New York, John Wiley and Sons, Inc., pp. 532-551.

Louisiana, Guide to the State
1941 American Guide Series, New York, Hastings House.

Morgan, J. P., and Treadwell, R. C.
1954 "Cemented Sandstone Slabs of the Chandeleur Islands, Louisiana", *Journal of Sedium. Petrol.*, vol. 24, no. 2, pp. 71-75.

Morgan, J. P., Van Lopik, J. R., and Nichols, L. G.
1953 "Occurrence and Development of Mudflats Along the Western Louisiana Coast," *Trafficability and Navigability of Delta-Type Coasts, Trafficability and Navigability of Louisiana Coastal Marshes*, Louisiana State University, 34 pp.

Olmstead, L. B., and Smith, W. O.
1938 "Water Relations of Soils," *Soils and Men, Yearbook of Agriculture 1938*, U. S. Dept. of Agriculture, Washington, D. C., Government Printing Office, pp. 897-910.

O'Neil, Ted
1949 *The Muskrat in the Louisiana Coastal Marshes*, La. Dept. of Wild Life and Fisheries, New Orleans, 152 pp.

Orton, E. W., Ames, H. T., and Saucier, R. T.
1954 *Report on Proposed Locations for Water Control Structures, Rockefeller Refuge, Vermilion Parish, Louisiana*, 12 pp. (unpublished).

Penfound, W., and Hathaway, E. S.
1938 "Plant Communities in the Marshlands of Southeastern Louisiana," *Ecol. Mono.*, vol. 8, pp. 1-56.

Report on the Relation of Wildlife to Agricultural Drainage and Economic Development of Coastal Marshes, Cameron Parish, Louisiana,
1951 U. S. Dept. of Interior, Fish and Wildlife Service, Office of River Basin Studies, Washington, D. C., 78 pp.

Russell, R. J.
1936 "Physiography of Lower Mississippi River Delta," *Dept. of Conservation*, Louisiana Geol. Surv. Bull. 8, pp. 3-199.
1939 "Louisiana Stream Patterns," *Bull. Am. Assoc. Petroleum Geologists*, vol. 23, no. 8, pp. 1199-1227.
1940 "Quaternary History of Louisiana," *Bull. Geol. Soc. America*, vol. 51, pp. 1198-1234.
1948 "Coast of Louisiana," *Societe Belge Geologic Bull.*, vol. 57, fasc. 2, pp. 380-394, December.

Russell, R. J., and Howe, H. V.
1935 "Cheniers of Southwestern Louisiana," *Geog. Rev.*, vol. 25, no. 3, pp. 449-461.

Russell, R. J., and Russell, R. D.
1939 "Mississippi River Delta Sedimentation," *Recent Marine Sediments*, Am. Assoc. Petroleum Geologists Symposium, pp. 153-177.

Thorp, James
1948 "How Soils Develop Under Grass," *Grass, Yearbook of Agriculture 1948*, U. S. Dept. of Agriculture, Washington, D. C., Government Printing Office, pp. 55-66.

Tide Tables, East Coast North and South America
1954 Coast and Geodetic Survey, U. S. Dept. of Commerce, Washington, D. C., Government Printing Office, 275 pp.

United States Coast Pilot—Gulf Coast, Third Edition
1949 Coast and Geodetic Survey, U. S. Dept. of Commerce, Washington, D. C., Government Printing Office, 505 pp.

Wolff, S. E.
1954 *A Guide to Plant Names in Texas, Oklahoma, Louisiana, Arkansas*, Revised, Soil Conservation Service, U. S. Dept. of Agriculture, 91 pp.

Maps of Cameron and Vermilion Parishes Used in Study

United States Coast and Geodetic Survey, Louisiana, West End of Pecan Island to Mermentau River, Chart No. 201, 1892. Scale 1:80,000. Topography executed 1888.

Department of the Interior, United States Geological Survey, Louisiana, Quadrangles, Scale 1:31,680.
Cameron Parish:
Hog Bayou, NE and NW Quarters, 1932
Cameron and Vermilion Parishes:
Constance Bayou, SE and SW Quarters, 1932

Shutts' and Sons Survey of Rockefeller Wild Life Refuge and Game Preserve, 1954.