Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices

Appendix B — Technical Methods

This document is one of three that outline a jointly developed, Federal/State/Local, plan to address Louisiana's massive coastal land loss problem and provide for a sustainable coastal ecosystem by the year 2050. These three documents are:

- Coast 2050: Toward a Sustainable Coastal Louisiana,
- Coast 2050: Toward a Sustainable Coastal Louisiana, An Executive Summary,
- Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices.

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For additional information on coastal restoration in Louisiana: www.lacoast.gov or www.savelawetlands.org.

Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices

Appendix B- Technical Methods

report of the

Louisiana Coastal Wetlands Conservation and Restoration Task Force

and the

Wetlands Conservation and Restoration Authority

Louisiana Department of Natural Resources
Baton Rouge, LA 1999

ACKNOWLEDGMENTS In addition to those named in the various attributions throughout this Appendix, a number of people played key roles in bringing this document together in its current form. This included editing, table development, writing explanatory and transitional text, and general formatting. These people were: Honora Buras, Ken Duffy, Bill Good, Cathy Grouchy, Bren Haase, Bryan Piazza, Phil Pittman, Jon Porthouse, Diane Smith, and Cynthia Taylor.

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SECTION 1

INTRODUCTION

An important contribution of the Coast 2050 planning process was to develop considerable new technical information on several important subjects. The methodologies used to develop this information are summarized in Appendix B. The summaries are intended to provide a brief written record of what was done.

It is assumed that the reader is familiar with important concepts and acronyms that are generally known to coastal managers, scientists, and planners in Louisiana. Persons responsible for the individual appendices are identified for those readers who desire further information or clarification. The overall Appendix B was compiled by Lee Wilson, consultant to the Ecosystems Protection Branch, U.S. Environmental Protection Agency, Dallas, Texas.

The five discussions of technical methods presented in Appendix B are summarized below.

- *Section 2: Methodology for land loss projections*. This section explains the methods used to project wetlands loss between 1990 and 2050, as presented in Figures 1-1 and 1-2 and Chapter 5 in the main Coast 2050 report. The methodology uses recent rates of loss as a starting point for projecting future losses, adjusts these rates where appropriate, and predicts the main locations of loss through an innovative technique based on computerized interpretations of satellite images. For additional information, contact Suzanne Hawes, New Orleans District, U.S. Army Corps of Engineers. The citation for this part of the appendix is as follows.

  Hawes, S. 1999. Methodology for land loss projections. In: Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices. Louisiana Department of Natural Resources. Baton Rouge, La.

- *Section 3: Faulting, subsidence and land loss in coastal Louisiana*. This section provides information on faulting, subsidence and land loss in coastal Louisiana, as a general consideration in restoration planning. This information was also used to prepare Figure 4-4 in the main report, which relates major fault trends to regional subsidence rates and land loss, and Figure 4-5, which presents a map of subsidence rates in coastal Louisiana by mapping unit. The methodology reflects the professional judgment of Sherwood Gagliano, who utilized various data sources to quantify subsidence rates, and information on faults and other geologic structures of the coast in order to map the spatial patterns of subsidence. For additional information, contact Dr. Gagliano at

- Coastal Environments Inc., Baton Rouge. The citation for this part of the appendix is as follows.

  Gagliano, S. M. 1999. Faulting, subsidence and land loss in coastal Louisiana. In: Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices. Louisiana Department of Natural Resources. Baton Rouge, La.

- *Section 4: Methodology for assessment of fisheries*. This appendix explains the methods used to assess existing trends in fisheries production, and projects these trends into the future, as presented in the regional appendices (Appendices C-F) and summarized in Chapter 6 of the main report. The methodology is based on using selected species as indicators of different elements of the fisheries population, and using available data and professional judgments (largely from the Louisiana Department of Wildlife and Fisheries) to characterize the existing and prospective trends. For additional information, contact Dr. Glenn Thomas, Louisiana Department of Wildlife and Fisheries, Baton Rouge. The citation for this part of the appendix is as follows.

  Ruebsamen, R. and Thomas, R. G. 1999. Methodology for assessment of fisheries. In: Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices. Louisiana Department of Natural Resources. Baton Rouge, La.

- *Section 5: Methodology for assessment of wildlife*. This section explains the methods used to assess existing wildlife habitat status and future trends, as presented in the regional appendices (Appendices C-F) and summarized in Chapter 6 of the main report. The methodology is similar to that for fisheries in that it uses representative species, available data and professional judgments. For additional information, contact Quin Kinler, Natural Resources Conservation Service, Baton Rouge, or Gerry Bodin, U.S. Fish and Wildlife Service, Lafayette.

  Bodin, G. and Kinler, Q. 1999. Methodology for assessment of wildlife. In: Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices. Louisiana Department of Natural Resources. Baton Rouge, La.

- *Section 6: The third delta conveyance channel project*. This section explains the rationale and underlying design concept for what is arguably the most dramatic of all the Coast 2050 strategies – to build a third deltaic lobe of the Mississippi Delta by conveying river water to areas of eastern Terrebonne and western Barataria basins, where a once productive marsh is largely gone. For additional information, contact Dr. Sherwood Gagliano or Dr. Hans van Beek, Coastal Environments, Inc., Baton Rouge, Louisiana.

  Gagliano, S. M. and van Beek, J. L. 1999. The third delta conveyance channel project. In: Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices. Louisiana Department of Natural Resources. Baton Rouge, La.

SECTION 2

METHODOLOGY FOR LAND LOSS PROJECTIONS

Calculation of Rate of Land Loss in the Absence of Restoration

There are two databases showing land loss in coastal Louisiana.

- The database developed by the National Wetlands Research Center of the U.S. Geological Survey (USGS) covers the entire coast, indicates habitat types, and shows loss and gain from 1956 to 1990.

- The database developed by the New Orleans District of the U.S. Army Corps of Engineers (USACE) covers the coastal marshes over a 60-year period of record, divided into four time intervals. The product of this database is a set of seven maps depicting the location of land loss per time period. The database is highly consistent, because the same two geologists determined the land/water interface for all periods. However, it does not cover all of the cypress swamps, does not include the drainage of the Sabine River, and does not show habitat types.

In 1991, as part of the CWPPRA planning process, an interagency group of marsh experts gathered to discuss which database to use to project marsh loss for the Louisiana Coastal Wetlands Restoration Plan (published in 1993). The group determined that the USACE database was the most appropriate to use to project future loss because it had the most extensive loss record and the land/water interface had been consistently delineated. Since land gain was infrequent and localized, the group determined that this parameter was not necessary to project future losses.

The 1991 interagency group chose 1974 through 1990 as the most appropriate base period to determine future loss. The average loss statewide was slightly more than 30 square miles per year from 1974 to 1983. The loss dropped to just over 25 square miles per year in the most recently analyzed time period, 1983 to 1990. There are significant uncertainties in any 60-year projection into the future: rate of sea level rise, frequency of hurricanes and floods, rate of development, etc. The group determined that including the higher 1974-1983 loss with the 1983-1990 loss would compensate for a possible increase in sea level rise. They also felt that the 1974-1990 loss rate most accurately reflected the post-1990 loss rate. Thus, this rate was used in the 1993 CWPPRA "Louisiana Coastal Wetlands Restoration Plan" and in subsequent feasibility studies conducted under CWPPRA.

Subsequently, as part of feasibility studies done under CWPPRA, another group of marsh experts (including some members of the 1991 group) analyzed the loss patterns on the USACE land loss maps. The group drew polygons around areas where loss patterns seemed to have the same cause. The acres lost in each polygon of similar loss were determined for each of the four time periods. The annual percent of marsh loss between 1974 and 1990 was determined for each polygon. For projection purposes, these rates were assumed to continue into the future.

During the Coast 2050 planning process, local experts on Coast 2050 Regional Planning Teams adjusted a few of the 1974-1990 loss rates to account for one-time losses and false loss associated with extremely high water levels.

Another adjustment during the Coast 2050 process was done because the USACE database included only land to water changes, and therefore did not show embankments of dredged material along channels as wetland loss. To partially correct this, the most extensive spoil banks, those along the Mississippi River Gulf Outlet, were measured and counted as loss. Since the Louisiana Coastal Wetlands Conservation Plan is now in place, all future loss due to development will be mitigated. Thus, the 1974-1990 loss due to canals, borrow pits, etc., was not included in the rate to be used for projections. Since the Sabine River watershed was not covered by the USACE database, the 1978-1990 loss rate from the USGS database was used in that area.

The USACE database covered all habitats in the coastal area, including the extensive agricultural and residential areas adjacent to the Mississippi River and Bayou Lafourche. The polygons of similar loss included these nonwetland areas. The Coast 2050 experts realized that including these developed areas in the base from which loss was determined produced an inaccurately low loss rate, since the loss rate should apply only to wetlands acreage. Accordingly, the USGS database was used to determine the acres of marsh in 1990 in each polygon. All loss on the USACE loss maps was determined to be in marsh. The adjusted 1974-1990 loss rate was applied to the acres of marsh in 1990 and then to the remaining acres of marsh each year from 1991 through 2050. This determined the acres remaining in 2050 for each polygon, if no restoration occurred.

Adjustment for Restoration Projects

There is one large freshwater diversion from the Mississippi River at Caernarvon and a second under construction at Davis Pond as this document goes to press. There are nearly 60 coastal restoration projects authorized on the first six CWPPRA Priority Lists. All these projects either reduce future marsh loss or create marsh. For CWPPRA projects, the additional acres present in the project area at the end of 20 years (as determined by the Wetland Value Assessment) were used to determine the benefits between 1990 and 2010. Then, the longevity of each project, (as determined by the CWPPRA Environmental Working Group) was used to determine the marsh loss reduction/marsh gain for each project for years 2011 through 2050. If the project had longevity of greater than 50 years, the WVA benefits were continued until 2050. If the longevity was less than 30 years, after year 30, the loss rate was returned to the 1974-1990 rate. For the Caernarvon Freshwater Diversion, the benefits from the EIS were used. For the Davis Pond Freshwater Diversion, the benefits from the March 11, 1998, Fact Sheet were used.

The benefitted acreage in each polygon was calculated as described above. This acreage was then subtracted from the acres projected to be lost. This determined the net amount of marsh to be lost in each polygon.

Location of Lost Land

In order to determine where within each polygon the above loss might be located, the 1993 LANDSAT image was used. The polygon, diversion, and CWPPRA project boundaries were obtained from the Louisiana Department of Natural Resources (DNR). The Natural Systems Engineering Laboratory at LSU developed the prediction maps. They selectively modified parts of the LANDSAT image to reflect the net acreage of marsh lost in each polygon by 2050.

Each 25 m pixel on the image contained brightness based on combining bands from the original LANDSAT data. Each cell was assigned a pseudo color–dark blue for the lowest end of the brightness range and bright white for the highest end. Generally, solid marsh areas had a high brightness while open water had a low brightness. Areas with an intermediate brightness were assumed to be broken marsh with brightness corresponding to the percentage of land. Brightness was then used as land/water boundary criteria. Areas with brightness higher than the criterion was considered land and those with lower brightness were classified as water.

In order to make the image “lose” land, the criterion for land was then adjusted to a higher value that resulted in less land in the image. This was done iteratively until the amount of land in each polygon matched the acreage predicted to remain in that polygon in 2050. Reducing the brightness criterion removed land from the image. The amount of land preserved by CWPPRA projects and the river diversions was then added back to the image in each polygon. In order to clearly indicate the land lost and gained through 2050, maps were printed to show the base marsh in green, the areas to be lost in red, and areas of gain in black. The result is a map of coastal Louisiana that indicates what marsh areas may be lost or gained by 2050. Refer to Figures 1-1 and 1-2 in the Coast 2050 main report. The overall results of the projection also are presented in Chapter 5 of the report.

Prediction of Loss Through 2050 by Mapping Unit

The USGS database was used to determine the acres of swamp and various types of marsh in each mapping unit in 1990 (Table 2-1). The USACE database was used to determine historic losses and the rate of loss from 1974-1990 for each mapping unit. The benefits of the CWPPRA projects and freshwater diversions were also determined by mapping unit and habitat type. The habitat types to be lost were estimated by superimposing the 2050 loss projection maps onto the 1990 habitat maps. This methodology assumes that the location of future habitat zones will not shift. Since these zones have shifted both north and south in the past, the assumption that they will remain as they were in 1990 is simplistic. Since the USACE database did not include swamps, academics with experience in analyzing swamp loss were contacted and their help was used to determine the amount of swamp predicted to be lost in each mapping unit.

The result is a table indicating projected marsh and swamp losses, as well as benefits of CWPPRA projects and river diversions by habitat type and by mapping unit through 2050 (Table 2-1).

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects.

REGION 1	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
UPPER BASIN								
Amite/Blind	3,440	0	0	0	3,440	138,930	40	0
Tickfaw River Mouth	2,350	0	0	0	2,350	22,840	35	0
Manchac Land Bridge West	2,950	0	0	0	2,950	8,550	60	0
Tangipahoa River Mouth	4,000	390	0	0	4,390	21,310	0	1,670
UPPER BASIN TOTAL	12,740	390	0	0	13,130	191,630	135	1,670
MIDDLE BASIN								
Tchefuncte River Mouth	4,390	380	0	0	4,770	4,020	3,320	0
Manchac Land Bridge East	850	11,620	0	0	12,470	4,490	0	7,350
Bonnet Carre'	1,170	0	0	0	1,170	2,120	0	0
La Branche	980	2,530	3,720	0	7,230	10,020	0	1,130
North Shore Marshes	120	3,580	5,800	0	9,500	0	0	960
Pearl River Mouth	7,280	7,970	6,960	0	22,210	880	410	410
East Orleans Land Bridge	60	22	25,380	0	25,462	0	0	0
Bayou Sauvage	5,110	1,220	110	0	6,440	320	730	200
MIDDLE BASIN TOTAL	19,960	27,322	41,970	0	89,252	21,850	4,460	10,050
LOWER BASIN								
South Lake Borgne	0	0	7,080	9,510	16,590	0	0	0
Central Wetlands	1,000	0	20,510	90	21,600	90	0	0
Biloxi Marshes	50	0	36,000	50,950	87,000	0	0	0
Eloi Bay	990	0	5,320	19,160	25,470	0	0	0
LOWER BASIN TOTAL	2,040	0	68,910	79,710	150,660	90	0	0
REGION 1 TOTAL	34,740	27,712	110,880	79,710	253,042	213,570	4,595	11,720

Acres in 1990 from DNR GIS.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 1	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
UPPER BASIN							
Amite/Blind	0	0	40	40	69,460	0	0
Tickfaw River Mouth	0	0	35	35	11,420	0	0
Manchac Land Bridge West	0	0	60	60	4,270	0	0
Tangipahoa River Mouth	0	0	1,670	1,670	10,655	0	0
UPPER BASIN TOTAL	0	0	1,805	1,805	95,805	0	0
MIDDLE BASIN							
Tchefuncte River Mouth	0	0	3,320	3,320	2,010	0	0
Manchac Land Bridge East	0	0	7,350	7,350	2,250	0	0
Bonnet Carre'	0	0	0	0	0	0	0
La Branche	680	0	1,810	2,070	5,010	60 % I, 40 % B	260 B
North Shore Marshes	510	0	1,470	1,470	0	35% B, 65% I	0
Pearl River Mouth	1,660	0	2,480	2,690	0	70% B, 15% I, 15% F	210 B
East Orleans Land Bridge	3,550	0	3,550	3,550	0	100 % B	0
Bayou Sauvage	0	0	930	3,550	0	80% F, 20% I	2,100 F, 520 I
MIDDLE BASIN TOTAL	6,400	0	20,910	24,000	9,270	50% I, 30%B, 20% F	2100 F, 520 I, 470 B
LOWER BASIN							
South Lake Borgne	660	1,990	2,650	3,310	0	70 % S, 30% B	330 B, 330 S
Central Wetlands	1,010	0	1,010	1,980	0	100 % B	970 B
Biloxi Marshes	2,410	13,670	16,080	16,080	0	85% S, 15% B	0
Eloi Bay	470	2,680	3,150	3,150	0	85% S, 15% B	0
LOWER BASIN TOTAL	4,550	18,340	22,890	24,520	0	80% S, 20% B	1300 B, 330 S
REGION TOTAL	10,950	18,340	45,605	50,325	105,075	40% S, 25% B, 25% I, 10% F	2100 F, 520 I, 1770 B, 330 S

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 2 **BARATARIA BASIN**	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
Baker	640	0	0	0	640	32,760	230	0
Des Allemands	18,520	0	0	0	18,520	44,560	5,840	0
Lake Boeuf	20,420	0	0	0	20,420	45,980	6,425	0
Gheens	12,500	0	0	0	12,500	6,910	2,250	0
Cataouatche/Salvador	90,550	5,110	0	0	95,660	11,850	6,415	0
Clovelly	15,670	19,040	500	0	35,210	0	1,080	3,170
Perot/Rigolettes	2,830	12,180	13,490	0	28,500	0	530	2,080
Jean Lafitte	1,000	450	0	0	1,450	2,920	0	0
Naomi	1,530	13,810	4,770	0	20,110	1,380	0	675
Myrtle Grove	370	0	46,630	1,890	48,890	0	0	0
Little Lake	70	3,890	12,030	10,640	26,630	0	0	900
Caminada bay	0	0	2,230	34,290	36,520	0	0	0
Fourchon	0	0	0	6,770	6,770	0	0	0
Barataria Bay	0	0	0	800	800	0	0	0
W. Pt a la Hache	60	0	8,300	0	8,360	0	0	0
L. Washington/Grand Ecaille	180	0	9,270	27,120	36,570	0	0	0
Bastion Bay	0	0	1,820	2,390	4,210	0	0	0
Cheniere Ronquille	0	0	0	6,530	6,530	0	0	0
Grand Liard	1,440	3,860	4,090	5,840	15,230	0	0	300
BARATARIA TOTAL	165,780	58,340	103,130	96,270	423,520	146,360	22,770	7,125

Acres in 1990 from DNR GIS.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 2 BARATARIA BASIN	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
Baker	0	0	230	230	16,380	100% F, lose 50% swamp	0
Des Allemands	0	0	5,840	6,730	26,740	100 % F, lose 60% swamp	890 F
Lake Boeuf	0	0	6,425	8,040	27,580	100 % F, lose 60% swamp	1,615 F
Gheens	0	0	2,250	2,250	3,460	100 5 F, lose 50% swmap	0
Cataouatche/Salvador	0	0	6,415	16,735	5,930	100 % F, lose 50% swmap	10,320 F
Clovelly	0	0	4,250	5,635	0	70% I, 30% F	770 I, 615 F
Perot/Rigolettes	3,190	0	5,800	10,370	0	50% B, 45% I, 5% F	1,990 B, 2,580 I
Jean Lafitte	0	0	0	0	0	0	0
Naomi	450	0	1,125	7,075	0	60 % I, 40 % B	2,650 B, 3,300 I
Myrtle Grove	5,080	780	5,860	10,220	0	90 % B, 10 % S	4,140 B, 220 S
Little Lake	4,190	1,820	6,910	14,330	0	50 % B, 25% I, 25% S	2,690 I, 3,050 B, 1,680 S
Caminada bay	1,880	17,080	18,960	19,560	0	90 % S, 10 % B	480 S, 120 B
Fourchon	0	1,460	1,460	1,790	0	100 % S	330 S
Barataria Bay	0	330	330	520	0	100 % S	190 S
W. Pt a la Hache	2,360	0	2,360	4,500	0	100 % B	2140 B
L. Washington/Grand Ecaille	280	8,480	8,760	9,500	0	95 % S, 5% B	200 B, 540 S
Bastion Bay	500	3,490	3,990	3,990	0	85 % S, 15 % B	0
Cheniere Ronquille	0	4,400	4,400	5,980	0	100 % S	1,580 S
Grand Liard	3,300	3,600	7,200	7,200	0	50 % S, 45 % B, 5 % I	0
BARATARIA TOTAL	21,230	41,440	92,565	134,655	80,090	45% S, 25% F, 20% B, 10% I	13,440 F, 9,340 I, 14,290 B, 5,020 S

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 2	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
BIRDSFOOT DELTA								
West Bay	4,660	2,220	340	760	7,980	0	gain 7120	0
East Bay	3,450	1,340	0	0	4,790	0	1,500	370
A Loutre	23,970	3,850	0	0	27,820	0	4,280	1,070
Cubits Gap	16,790	2,170	0	0	18,960	0	2,960	1,830
Baptiste Collette	2,210	1,900	390	0	4,500	0	1,460	40
BIRDSFOOT TOTAL	51,080	11,480	730	760	64,050	0	3,080	3,310
BRETON SOUND BASIN								
American Bay	2,090	2,320	11,470	26,460	42,340	0	0	700
Caernarvon	100	840	48,390	10,160	59,490	0	0	0
River aux Chenes	250	0	18,500	0	18,750	0	0	0
Lake Lery	210	0	12,410	0	12,620	0	0	0
Jean Louis Robin	570	0	19,880	17,490	37,940	0	0	0
BRETON SOUND TOTAL	3,220	3,160	110,650	54,110	171,140	0	0	700
REGION 2 TOTAL	220,080	72,980	214,510	151,140	658,710	146,360	25,850	11,135

Acres in 1990 from DNR GIS.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 2	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
BIRDSFOOT DELTA							
West Bay	0	0	gain 7120	7,250	0	80 % F, 20 % I	14,370 F
East Bay	0	0	1,870	1,870	0	80 % F, 20 % I	0
A Loutre	0	0	5,350	6,340	0	80 % F, 20 % I	790 F, 200 I
Cubits Gap	0	0	4,790	6,370	0	70 % F, 30 % I	1,500 F, 80 I
Baptiste Collette	0	0	1,500	2,900	0	60 % F, 40% I	1,120 I, 280 F
BIRDSFOOT TOTAL	0	0	6,390	24,730	0	50% F, 50% I	16,940 F, 1,400 I
BRETON SOUND BASIN							
American Bay	9,860	2,080	12,640	13,880	0	80 % S, 15 % B, 5 % I	1,240 B
Caernarvon	1,980	1,700	3,680	13,280	0	80 % B, 20 % S	7,680 B, 1,920 S
River aux Chenes	4,320	0	4,320	4,870	0	100 % B	550 B
Lake Lery	1,020	0	1,020	3,110	0	100 % B	2,090 B
Jean Louis Robin	1,180	3,740	4,920	9,340	0	60 % B, 40 % S	4,420 B
BRETON SOUND TOTAL	18,360	7,520	26,580	44,480	0	70% B, 25% S, 5% I	15,980 B, 1,920 S
REGION TOTAL	39,590	48,960	125,535	203,865	80,090	40% S, 30% B, 20% F, 10% I	30,380 F, 10,740 I, 30,270 B, 6,940 S

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 3	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
TERREBONNE BASIN								
Black Bayou Wetlands	160	0	0	0	160	16,270	0	0
Chacahoula Swamps	270	0	0	0	270	37,300	0	0
Verret Wetlands	250	0	0	0	250	57,700	0	0
Pigeon Swamp	10	0	0	0	10	5,500	0	0
Fields Swamp	20,730	0	0	0	20,730	580	3,010	0
Devils Swamp	1,370	0	0	0	1,370	200	865	0
St. Louis Canal	8,030	4,570	1,830	0	14,430	1,090	2,510	1,255
Savoie	2,600	0	0	0	2,600	340	860	0
Bully Camp South	0	0	440	31,110	31,550	0	0	0
Bully Camp North	2,260	2,640	13,080	1,200	19,180	0	1,580	695
HNSC Marshes	840	2,440	120	0	3,400	6,034	0	1,990
Caillou Marshes	50	0	11,100	29,300	40,450	0	0	0
Montegut	120	1,260	4,360	0	5,740	10	0	1,200
Terrebonne Marshes	0	0	4,220	26,210	30,430	0	0	0
Boudreaux	2,095	5,680	9,740	0	17,515	1,910	2,030	3,580
Pelto Marshes	150	1,230	5,580	34,555	41,515	0	0	0
GIWW	22,970	0	0	0	22,970	22,620	9,940	0
Penchant	100,150	4,040	2,120	0	106,310	1,250	13,160	5,170
Mechant de Cade	4,200	14,950	31,150	4,280	54,580	280	4,460	4,350
Avoca	2,630	0	0	0	2,630	1,180	1,850	0
Atchafalaya Marshes	30,310	10,950	1,420	0	42,680	135	3,310	370
Isles Dernieres Shoreline	0	0	0	0	0	0	0	0
Timbalier Island Shoreline	0	0	0	0	0	0	0	0
Point au Fer	0	4,490	21,550	4,010	30,050	0	0	0
TERREBONNE TOTAL	199,195	52,250	106,710	130,665	488,820	152,399	43,575	18,610

Acres in 1990 from DNR GIS.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 3	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
TERREBONNE BASIN							
Black Bayou Wetlands	0	0	0	0	6,510	25% swamp to marsh, 10% to OW	0
Chacahoula Swamps	0	0	0	0	14,920	25% swamp to marsh, 10% to OW	0
Verret Wetlands	0	0	0	0	23,080	25% swamp to marsh, 10% to OW	0
Pigeon Swamp	0	0	0	0	2,200	25% swamp to marsh, 10% to OW	0
Fields Swamp	0	0	3,010	3,210	0	100% F	200 F
Devils Swamp	0	0	865	865	0	100% F	0
St. Louis Canal	1,255	0	5,020	5,020	0	50% F, 25%B, 25% I	0
Savoie	0	0	860	860	0	100% F	0
Bully Camp South	440	12,550	12,990	12,990	0	97% S, 3% B	0
Bully Camp North	6,310	0	8,585	10,495	0	70% B, 15% I, 15% F	1,030 B, 880 I
HNSC Marshes	0	0	1,990	1,990	0	100% I	0
Caillou Marshes	7,970	1,990	9,960	9,960	0	80% B, 20% S	0
Montegut	2,800	0	4,000	4,000	0	70% B, 30% I	0
Terrebonne Marshes	3,920	15,700	19,620	19,620	0	80% S, 20% B	0
Boudreaux	3,940	0	9,550	10,130	0	40% B, 40% I, 20% F	470 I, 110 B
Pelto Marshes	1,460	13,140	14,600	14,600	0	90 % S, 10% B	0
GIWW	0	0	9,940	9,940	0	100% F	0
Penchant	1,030	0	19,360	20,670	0	70% F, 25% I, 5% B	1,310 F
Mechant de Cade	2,100	0	10,910	11,150	0	40% F, 40% I, 20% B	130 B, 110 I
Avoca	0	0	1,850	1,850	0	100% F	0
Atchafalaya Marshes	0	0	3,680	3,680	0	90% F, 10% I	0
Isles Dernieres Shoreline	0	0	0	0	0	1358 s	0
Timbalier Island Shoreline	0	0	0	0	0	1228 s	0
Point au Fer	3,180	110	3,290	4,220	0	80% B, 15% I, 5% S	660 I, 170 B, 100 S
TERREBONNE TOTAL	34,405	43,490	140,080	145,250	46,710	30% F, 30% S, 25% B, 15% I	1,510 F, 2,120 I, 1,440 B, 100 S

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 3	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
ATCHAFALAYA BASIN								
N. Wax Lake Wetlands	2,770	0	0	0	2,770	2,340	460	0
Wax Lake Wetlands	43,610	0	0	0	43,610	10,255	5,860	0
Atchafalaya Bay Delta	2,430	0	0	0	2,430	0	gain 44,430	0
ATCHAFALAYA TOTAL	48,810	0	0	0	48,810	12,595	gain 38,110	0
TECHE/VERMILION BASIN								
Cote Blanche Wetlands	43,470	2,690	0	0	46,160	12,430	510	250
Vermilion Bay Marsh	6,610	29,970	36,660	0	73,240	5,960	0	3,950
Marsh Island	0	0	49,390	7,080	56,470	0	0	0
Rainey Marsh	245	7,770	47,990	2,410	58,415	0	0	780
TECHE/VERMILION TOTAL	50,325	40,430	134,040	9,490	234,285	18,390	510	4,980
REGION 3 TOTAL	298,330	92,680	240,750	140,155	771,915	183,384	5,975	23,590

Acres in 1990 from DNR GIS.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 3	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
ATCHAFALAYA BASIN							
N. Wax Lake Wetlands	0	0	460	460	0	100% F	0
Wax Lake Wetlands	0	0	5,860	5,860	0	100% F	0
Atchafalaya Bay Delta	0	0	gain 44,430	gain 36,350	0	100 % F	8,080 F
ATCHAFALAYA TOTAL	0	0	gain 38,110	gain 30,030	0	100% F	8,080 F
TECHE/VERMILION BASIN							
Cote Blanche Wetlands	0	0	760	3,470	0	85% F, 15% I	2,440 F, 270 I
Vermilion Bay Marsh	9,610	0	13,560	13,560	0	75% B, 25% I	0
Marsh Island	4,800	1,840	6,640	7,290	0	70% B, 30% S	350 S, 300 B
Rainey Marsh	7,060	0	7,840	7,840	0	90% B, 10% I	0
TECHE/VERMILION TOTAL	21,470	1,840	28,800	32,160	0	75% B, 20% I, 5% S	2,440 F, 270 I, 300 B, 350 S
REGIONAL TOTAL	55,875	45,330	130,770	147,380	46,710	40% B, 35% S, 20% I, 5% I	12,030 F, 2,390 I, 1,740 B, 450 S

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 4	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
MERMENTAU BASIN								
Cameron Prairie	9,680	0	0	0	9,680	0	1,995	0
Lacassine Pool only	5,570	0	0	0	5,570	0	0	0
Lacassine south and east	9,570	0	0	0	9,570	0	1,820	0
Big Burn	40,330	2,600	50	0	42,980	0	3,330	2,220
Middle Marsh	1,360	10,260	560	0	12,180	0	460	1,110
Grand Cheniere Ridge	2,730	2,960	560	20	6,270	0	0	0
Oak Grove	560	20,880	3,600	10	25,050	0	0	890
Lower Mud Lake	40	20	0	2,780	2,840	0	0	0
Hog Bayou	1,270	0	7,610	5,900	14,780	0	480	240
North Grand Lake	10,640	0	0	0	10,640	50	1,700	0
Little Pecan	46,270	160	2,470	0	48,900	0	3,670	0
Rockefeller	12,750	11,770	25,780	12,480	62,780	0	2,610	3,920
Grand Lake East	6,970	0	0	0	6,970	0	2,200	0
Grand/White Land Bridge	7,090	0	0	0	7,090	0	1,030	0
Amoco	16,500	0	0	0	16,500	300	6,000	0
South White Lake	29,950	240	80	0	30,270	0	4,220	0
South Pecan Island	550	2,590	29,990	1,720	34,850	0	0	0
North White Lake	38,830	0	0	0	38,830	0	3,560	0
Little Prairie	10,620	50	0	0	10,670	0	740	0
Big Marsh	21,360	9,330	1,180	0	31,870	0	450	80
Locust Island	2,160	7,530	3,020	0	12,710	20	620	620
MERMENTAU TOTAL	274,800	68,390	74,900	22,910	441,000	370	34,885	9,080

Acres in 1990 from DNR GIS.
Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.
Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 4	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
MERMENTAU BASIN							
Cameron Prairie	0	0	1,995	2,115	0	100 % F	120 F
Lacassine Pool only	0	0	0	0	0	0	0
Lacassine south and east	0	0	1,820	1,820	0	100 % F	0
Big Burn	0	0	5,550	5,550	0	60 % F, 40 % I	0
Middle Marsh	0	0	1,570	1,570	0	70 % I, 30 % F	0
Grand Cheniere Ridge	0	0	0	0	0	0	0
Oak Grove	0	0	890	890	0	100 % I	0
Lower Mud Lake	0	525	525	525	0	100 % S	0
Hog Bayou	480	0	1,200	1,200	0	40 % F, 40 % B, 20 % S	0
North Grand lake	0	0	1,700	1,700	0	100 % F	0
Little Pecan	0	0	3,670	3,670	0	100 % F	0
Rockefeller	6,530	0	13,060	13,060	0	50 % B, 30 % I, 20 % F	0
Grand Lake East	0	0	2,200	2,200	0	100 % F	0
Grand/White Land Bridge	0	0	1,030	1,030	0	100 % F	0
Amoco	0	0	6,000	6,000	0	100 % F	0
South White Lake	0	0	4,220	4,225	0	100 % F	5 F
South Pecan Island	6,980	0	6,980	6,980	0	100 % B	0
North White Lake	0	0	3,560	3,560	0	100 % F	0
Little Prairie	0	0	740	740	0	100 % F	0
Big Marsh	0	0	530	3,000	0	85% I, 15% F	2,470 I
Locust Island	630	0	1,870	1,870	0	30% F, 30 % I, 35% B	0
MERMENTAU TOTAL	14,620	525	59,110	61,705	0	60% F, 25% B, 15% I	125 F, 2,470 I

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 4	Fresh Marsh acres in 1990	Intermediate Marsh acres in 1990	Brackish Marsh acres in 1990	Saline Marsh acres in 1990	Total Marsh acres in 1990	Swamp acres in 1990	Fresh Marsh lost by 2050	Intermediate Marsh lost by 2050
CALCASIEU/SABINE BASIN								
Hackberry Ridge	520	0	2,400	0	2,920	0	0	0
Choupique Island	410	0	340	0	750	0	0	0
Big Lake	19,095	0	0	0	19,095	0	720	1,090
Sweet/Willow Lakes	6,240	20	0	0	6,260	0	1,860	0
Cameron Creole	10	13,170	17,890	0	31,070	0	0	1,110
Cameron	5,900	6,820	4,220	1,940	18,880	0	360	435
Clear Marais	4,650	10	120	0	4,780	0	300	0
West Black Lake	2,240	1,190	140	0	3,570	0	640	320
Black Lake	230	910	1,920	0	3,060	0	0	315
Brown Lake	2,570	1,870	11,660	0	16,100	0	0	865
Hog Island Gully	0	0	1,330	2,130	3,460	0	0	0
West Cove	2,810	0	0	0	2,810	0	280	0
Mud Lake	0	0	14,040	0	14,040	0	0	0
Martin Beach/Ship Channel	20	2,760	2,170	570	5,520	0	0	250
Southeast Sabine	10	12,430	6,590	0	19,030	0	0	100
Second Bayou	0	11,150	2,300	0	13,450	0	0	620
Gum Cove	1,230	0	0	0	1,230	0	0	0
Southwest Gum Cove	5,840	3,510	1,120	0	10,470	0	520	320
Sabine Lake Pool 3	15,980	20	10	0	16,010	0	0	0
Willow Bayou	0	2,500	18,960	0	21,460	0	0	0
Johnson's Bayou East	1,840	21,380	280	0	23,500	0	0	5,790
Perry Ridge	7,820	7,370	0	0	15,190	170	gain 2040	0
Sabine Lake Ridges	1,810	8,300	12,100	3,800	26,010	0	0	340
Johnson's Bayou Ridge	0	0	1,290	1,830	3,120	0	0	0
Johnson's Bayou West	0	430	11,060	0	11,490	0	0	0
Black Bayou	600	9,480	13,750	0	23,830	0	0	0
CALCASIEU/SABINE TOTAL	79,825	103,320	123,690	10,270	317,105	170	2,640	11,555
REGION 4 TOTAL	354,625	171,710	198,590	33,180	758,105	540	37,525	20,635

Acres in 1990 from DNR GIS.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

Table 2-1. Acreage and loss of different wetland types in the coastal zone of Louisiana, including benefits of CWPPRA projects (Cont.).

REGION 4 CALCASIEU/SABINE BASIN	Brackish Marsh lost by 2050	Saline Marsh lost by 2050	Net Marsh loss by 2050	Marsh lost without any restoration	Swamp acres lost by 2050	Approximate type of habitat lost	Acres preserved by CWPPRA and USACE marsh creation
Hackberry Ridge	0	0	0	0	0	0	0
Choupique Island	0	0	0	0	0	0	0
Big Lake	1,750	0	3,560	3,620	0	50%B, 30%I, 20%F	60 B
Sweet/Willow Lakes	0	0	1,860	2,100	0	100%F	240 F
Cameron Creole	1,110	0	2,220	7,370	0	50%I, 50% B	2,575 I, 2,575 B
Cameron	95	0	890	890	0	50% I, 40% F, 10% B	0
Clear Marais	0	0	300	1,060	0	100% F	760 F
West Black Lake	0	0	960	960	0	67% F, 33% I	0
Black Lake	195	0	510	1,050	0	70 % B, 30 % I	540 B
Brown Lake	2,740	0	3,605	4,325	0	80 % B, 20 % I	720 B
Hog Island Gully	gain 490	0	gain 490	550	0	70% S, 30 % B	385 S, 655 B
West Cove	0	0	280	600	0	100 % F	320 F
Mud Lake	1,850	0	1,850	2,660	0	100 % B	810 B
Martin Beach/Ship Channel	380	0	630	630	0	60% B, 40 % I	0
Southeast Sabine	390	0	490	890	0	80 % B, 20 % I	400 B
Second Bayou	160	0	780	780	0	80 % I, 20 % B	0
Gum Cove	0	0	0	0	0	50 % F, 30 % I, 20 % B	0
Southwest Gum Cove	210	0	1,050	1,070	0	50 % F, 30 % I, 20 % B	20 F
Sabine Lake Pool 3	0	0	0	0	0	0	0
Willow Bayou	5,190	0	5,190	5,190	0	100 % B	0
Johnson's Bayou East	0	0	5,790	5,790	0	100 %I	0
Perry Ridge	0	0	gain 2040	gain 2040	0	0	0
Sabine Lake Ridges	3,020	0	3,360	3,360	0	90 % B, 10 % I	0
Johnson's Bayou Ridge	640	430	1,070	1,070	0	60% B, 40% S	0
Johnson's Bayou West	2,510	0	2,510	2,510	0	100 % B	0
Black Bayou	4,020	0	4,020	6,400	0	90%B, 10% I	1,740 B, 640 I
CALCASIEU/SABINE TOTAL	23,770	430	38,395	50,835	0	60% B, 30% I, 10% F	1,340 F, 3,215 I, 7,500 B, 385 S
REGION 4 TOTAL	38,390	955	97,505	112,540	0	40% F, 40% B, 20% I	1,465 F, 5,685 I, 7,500 B, 385 S

F=Freshwater Marsh; I=Intermediate Marsh; B=Brackish Water Marsh; S=Saltwater Marsh; OW=Open Water.

Projected loss is the COE loss rate from 1974-1990 applied to DNR acres in 1990.

Projected loss is net loss and includes benefits of CWPPRA projects on PL #1-6 and COE marsh creation.

SECTION 3

FAULTING, SUBSIDENCE AND LAND LOSS IN COASTAL LOUISIANA

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Introduction

The passive appearance of Louisiana's coastal lowlands masks the intensity of the region's dynamic geological processes. The Mississippi River Deltaic Plain and Chenier Plain natural systems, which occupy coastal Louisiana (Figure 3-1), lie above a sediment-filled trough called the Gulf Coast Salt Basin (Figure 3-2). The trough was created 225 million years ago when the super continent called Pangea began to pull apart during the Late Triassic Period. In the trough that was created, a great thickness of sedimentary rock has accumulated (Spearing 1995). The Earth's movements associated with the geological structures of the trough are forces that direct and shape the landforms and processes of the two natural systems. These tectonic movements strongly influence where the rivers flow and deposit sediment and where the land sinks and erodes away. Sediment deposition and other processes associated with the natural systems may in turn affect subsidence and earth movement resulting in an inseparable interplay of cause and effect between the geologic setting and the active natural systems. Natural and manmade ridges form the skeletal framework to which the coastal wetlands are attached. They form a divide between the estuarine basins. Chains of barrier islands mark the seaward boundary of the estuarine basins (after Gagliano and van Beek 1993).

For millions of years the Mississippi and other rivers have delivered sediment from the heart of the continent to the continental margin along the Gulf of Mexico. Particle by particle the sands, silts and clays have been carried and dropped. The weight of the deposited

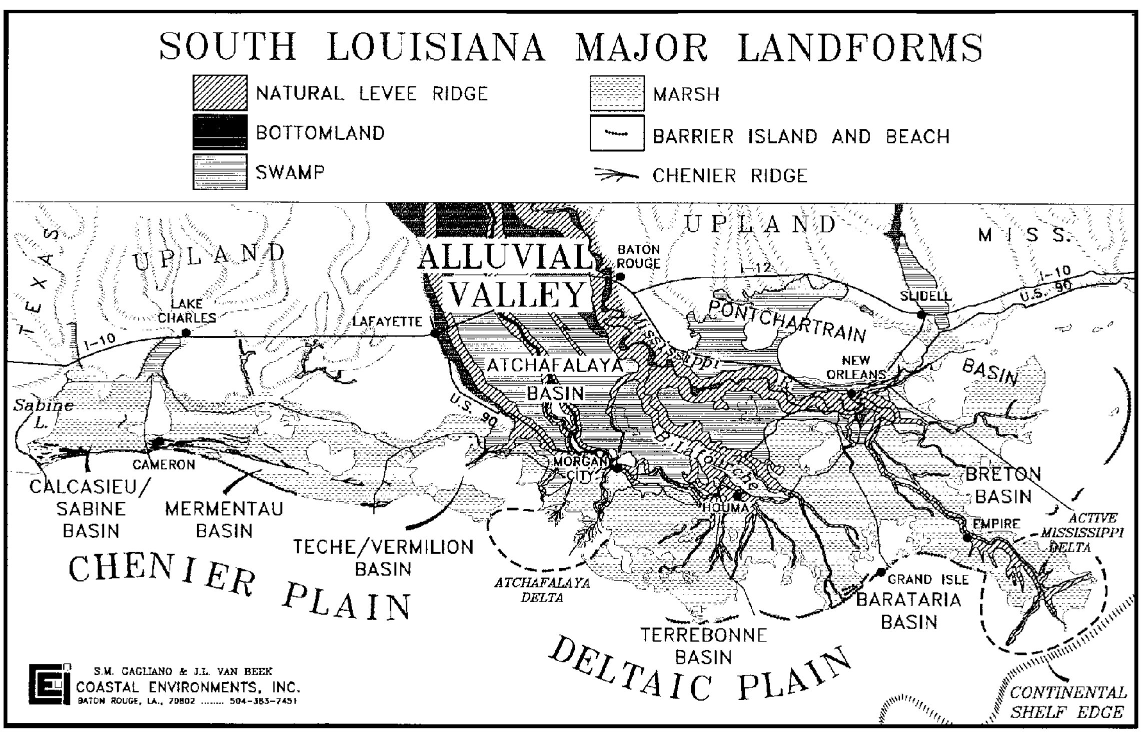


Figure 3-1. Major landforms of coastal Louisiana (after Gagliano and van Beek 1993).

sediment has pushed down the Earth's crust causing both the trough and the gulf to deepen (Figure 3-2). The crust, and thus the sediment that overlays it, continues to sink as more deposits are constantly added to the top of the sequence. When most of the sediment that now fills the trough was deposited, it was deposited in shallow marine and coastal environments. Today, even though some oil wells in south Louisiana have been drilled to depths of more than 25,000 ft, the sedimentary deposits in the deepest part of the trough have not been penetrated. The sediment pile is 40,000 ft thick at the coast and may be as much as 60,000 ft thick offshore (Spearing 1995).

While the weight of the sediment

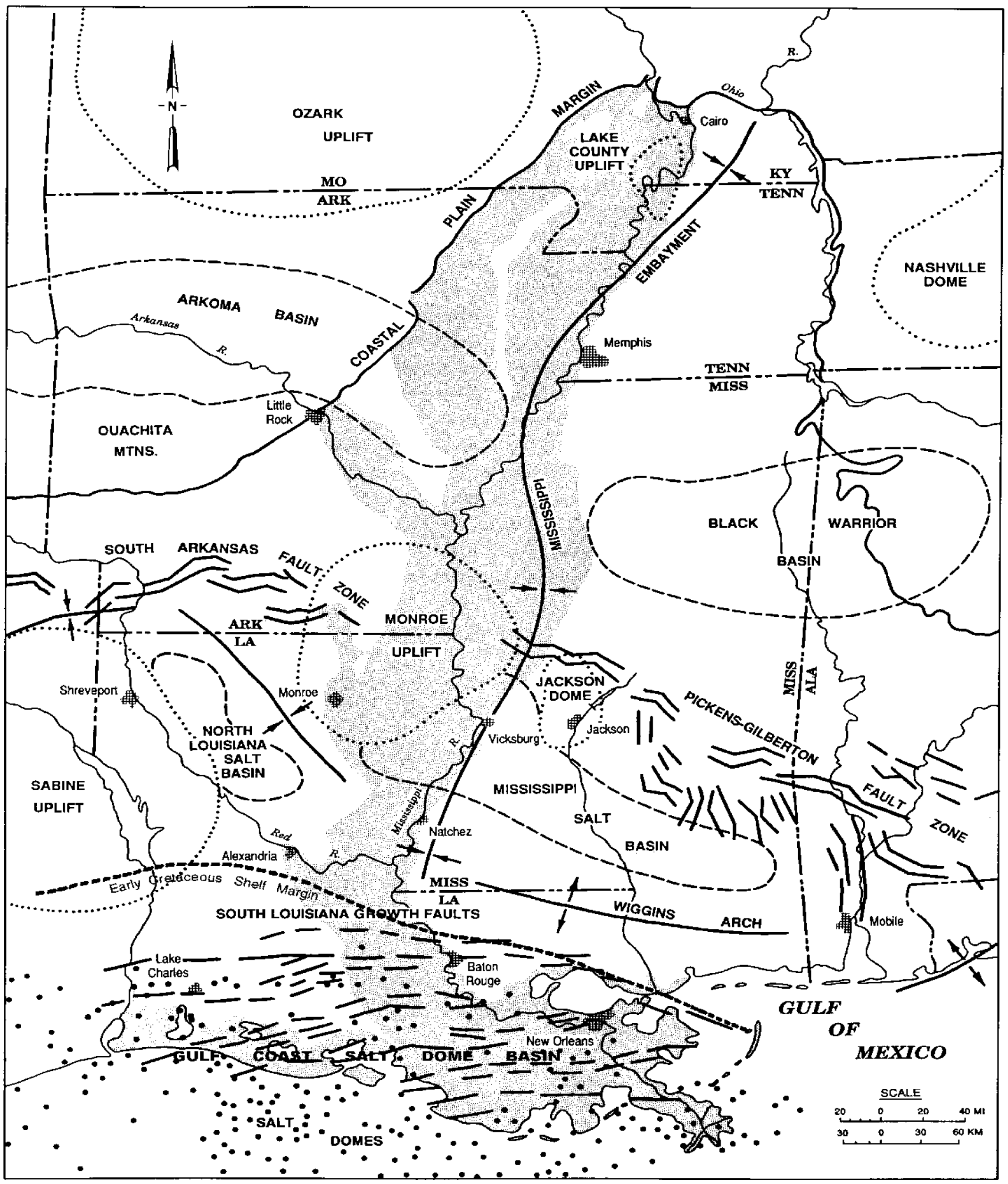


Figure 3-2. Major structural features of Louisiana (after Saucier 1994).

dumped by the rivers causes the crust to bend (down-warping), there is also a compensation effect causing inland areas to be uplifted. The land surface of south Louisiana is like a see-saw. Geologists have identified hinge lines, analogous to fulcrums of see-saws, that run through the coastal lowlands of Louisiana. North of these lines the land is rising (Uplands), and south of them it is sinking (Deltaic and Chenier Plains, see Figure 3-3). The cities of Lake Charles, Lafayette, Baton Rouge and Slidell are landward of the hinge lines and are on blocks that are being uplifted. New Orleans, Houma, Golden Meadow, and Empire are on blocks that are subsiding. In addition to the north-south variations, there are also variations in down-warping and uplift from east to west. The rates of east-west down-warping change abruptly at faults running through the St. Bernard area.

Earth movement in the Gulf Coast region takes on a variety of forms. In some areas where the near-surface deposits are soft and poorly consolidated they squeeze and flow under the weight of sedimentary loading and even some man made structures. In some areas the foundation beds warp and bend, and in others the effects of sedimentary loading cleave the earth, resulting in faults.

There is a thick bed of pure salt underlying much of south Louisiana, adjacent areas of Texas and the

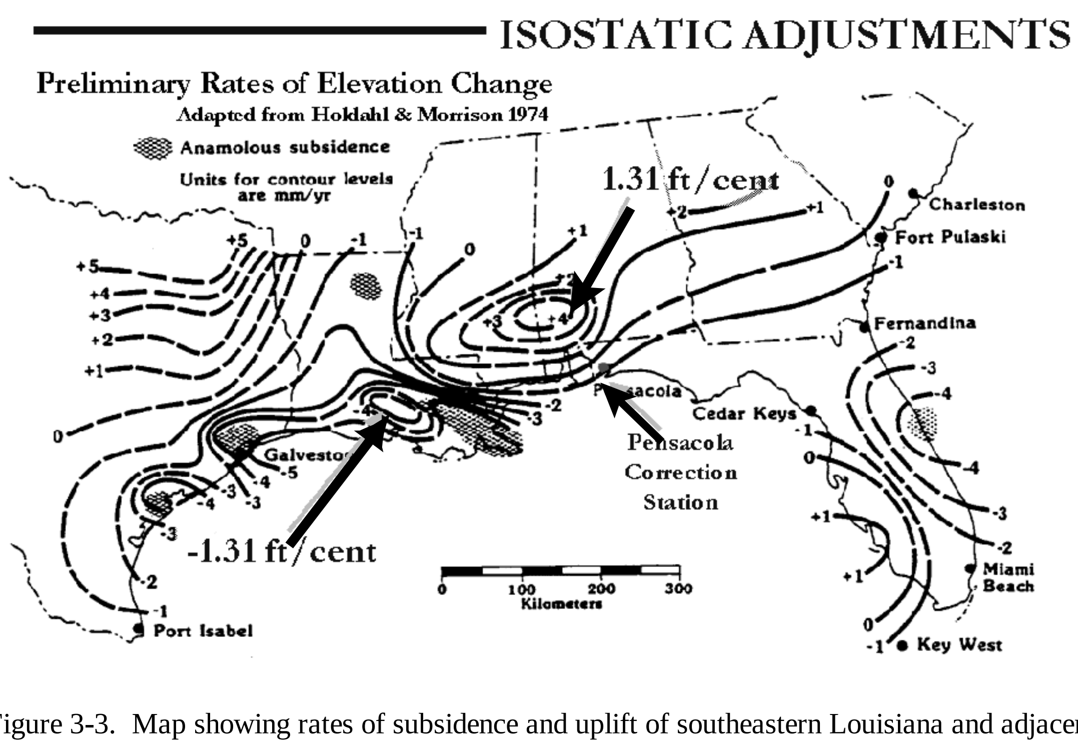


Figure 3-3. Map showing rates of subsidence and uplift of southeastern Louisiana and adjacent areas of Mississippi. Rates in millimeters per year and based on analysis of comparative geodetic leveling measurements (after Penland et al. 1988; adapted from Holdahl and Morrison 1974).

continental shelf. This salt bed, called the Louann Salt, formed in an inland-sea 145 million years ago. Because the salt has a low density, when heavier sand, silt, clay and limestone were deposited above it, the intense pressure and heat caused giant bubbles to form in the salt. Like a mixture of oil and water, the salt bubbles slowly pushed their way upward through the sedimentary sequence (Figure 3-4). Some actually reached the surface and created topographic bulges or domes. Well-known examples of salt domes with surface expression are found in the Five-Island Chain and include Jefferson Island, Avery Island, Weeks Island, Cote Blanche and Belle Isle. There are numerous other salt domes in the subsurface. Most earth movement in the region occurs as slippage along faults. Faults can be traced by topographic displacements on the surface of older uplands, but are not readily visible in the lowlands where movement is masked by

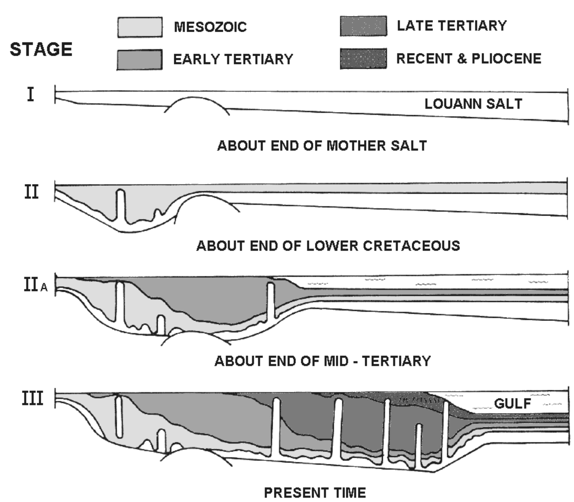


Figure 3-4. Development stages of the Gulf of Mexico showing subsidence, sequential sediment fill, and salt dome development (after Halbouty 1979).

contemporaneous sediment deposition. Most faults in coastal Louisiana show little if any surface expression, and have been mapped primarily by petroleum geologists working with seismic data and correlation of oil well boring logs.

Most south Louisiana faults are "normal faults," found where hanging blocks have moved down the slopes of fault planes. Most are also "growth faults," found where sedimentary beds on the down-dropped (hanging) blocks are thicker than comparable beds on adjacent up-thrown blocks, providing evidence that the faults have continued to move through time. Growth faults are established initially along zones of weakness, such as places where growing delta fronts extend beyond the continental shelf edge. Once established, such weak zones generally persist as more sediment is deposited above them. Thus, the amount of cumulative displacement on a growth fault increases with time and depth.

Major fault systems can be delineated within the maze of faults that snake their way across coastal Louisiana. These fault systems break the region into giant polygonal blocks. Each polygon may move independently of its neighbors, as might ice cubes floating in a pitcher. An individual block may move up, down, and/or tilt; each at a different rate than neighboring blocks.

Blocks with low topographic surface elevation are invaded by the sea as they sink (Figure 3-5). One measure of the degree of marine invasion is the rate of relative sea level rise that occurs on the blocks. A part of this rise rate is related to the worldwide increase in the level of the sea (eustatic rise), which has accelerated during recent decades as a result of glacial melting. The rise rates in coastal Louisiana have also accelerated, and are in some areas as much as 8 to 16 times greater than the worldwide rate.

The existence and location of the fault systems underlying the region have been recognized by geologists for many years, but their significance in relation to the land loss and system collapse phenomena is only now being understood. A better understanding between the relationships of fault bound blocks and other neotectonic activity, land loss and shoreline change is fundamental to long term restoration and multiple use management of the Louisiana coast. For an outstanding synthesis of the geology of coastal Louisiana the reader is referred to Spearing (1995).

In this paper, rates of vertical movement have generally been converted to feet per century (ft/century). English measures are used because they are currently the standard for engineering planning and design in the region. To facilitate conversion to other units of measure, a conversion table is available on the concluding page of this paper.

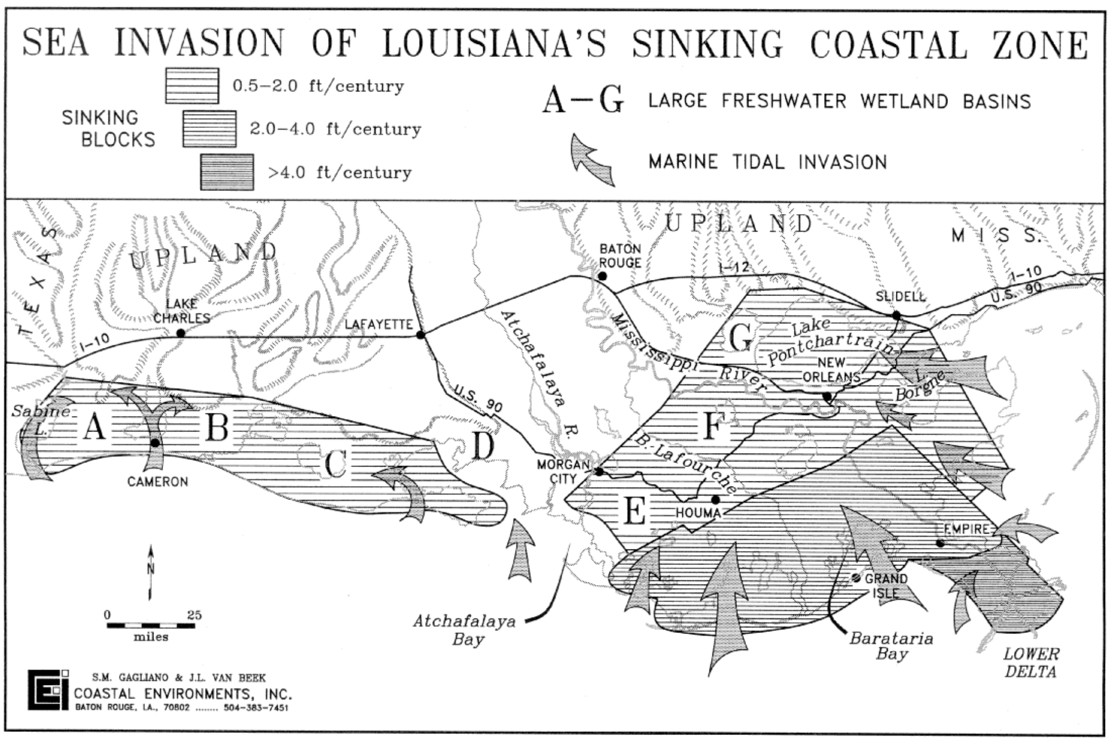


Figure 3-5. Sinking blocks and rising sea. Rates of land sinking can be related to large fault bound blocks. As the blocks subside, the sea invades the land. The marine invasion is accelerated by canals. Salt-sensitive vegetation and fragile organic soils of freshwater basins in the landward ends of the estuaries are highly vulnerable to marine tidal invasion (after Gagliano and van Beek 1993).

The 20th Century Transgression

The landmass occupied by the Mississippi River Deltaic Plain and the Chenier Plain natural systems is the result of 7,500 years of progradation (Figure 3-1). The sediment prism deposited during this progradation is the most recent addition to the top of the Gulf Coast Basin's thick sedimentary sequence. Land building has not been constant for the last 7,500 years; rather, it has been cyclic and related to the process of upstream diversion or delta switching (Fisk 1944; Frazier 1967; Gagliano and van Beek 1970; Coleman et al. 1998). Five major episodes or cycles of delta building have unfolded during this time interval, and a sixth is presently in progress (Roberts 1998). Each cycle lasted 1,000 years or more and progressed through stages of growth of the landmass into the sea (the sea regressed from the land) followed by stages of deterioration and coastal erosion (the sea transgressed onto the deltaic landmass). Even though there have been periods of transgression, the net result has been a building process, the result of which is the Deltaic and Chenier Plains.

Judging from maps of the Louisiana coast made by European explorers and settlers, the coast was in a condition of net gain during the sixteenth, seventeenth and eighteenth centuries. This condition lasted until the late nineteenth century, when a long interval of land building was interrupted and reversed. During the past hundred years there has been an invasion of the land by the sea, the results of which have been catastrophic land loss and wetland deterioration. This paper particularly examines the relationships between growth fault movement and this Twentieth Century Transgression. The geological record indicates that growth fault movement has always been a driving force for deltaic transgression. The twentieth century event is special in that the land sustaining forces that in the past offset transgressive impacts have been stifled, hence the land loss.

In these coastal lowlands, changes of a fraction of an inch per year in the relative elevation between land and sea can upset long-term natural system equilibrium and cause major environmental change. Massive coastal erosion, which began in the late nineteenth century (Gagliano et al. 1981) and peaked during the early 1970's (Britsch and Kemp 1990), has resulted in loss and deterioration of wetlands, barrier islands and ridges (Figure 3-6). During a period of little more than 100 years, more than 1,600 square miles, or about 20% of Louisiana's coast (mostly wetlands), have eroded away. Since it took 7,500 years for the coastal lowlands to form, it follows that 1,500 years of natural land building has eroded away in about 100 years. As a result, both the Deltaic Plain and Chenier Plain systems are badly degraded. The Deltaic Plain in particular has lost, and continues to lose, subsystem components and is approaching a condition of system collapse (Figure 3-7).

The distribution of the land loss sheds light on the causes (Figure 3-6). The losses are not uniformly distributed; rather, high loss is concentrated in four areas: 1) the Calcasieu-Sabine Basin;

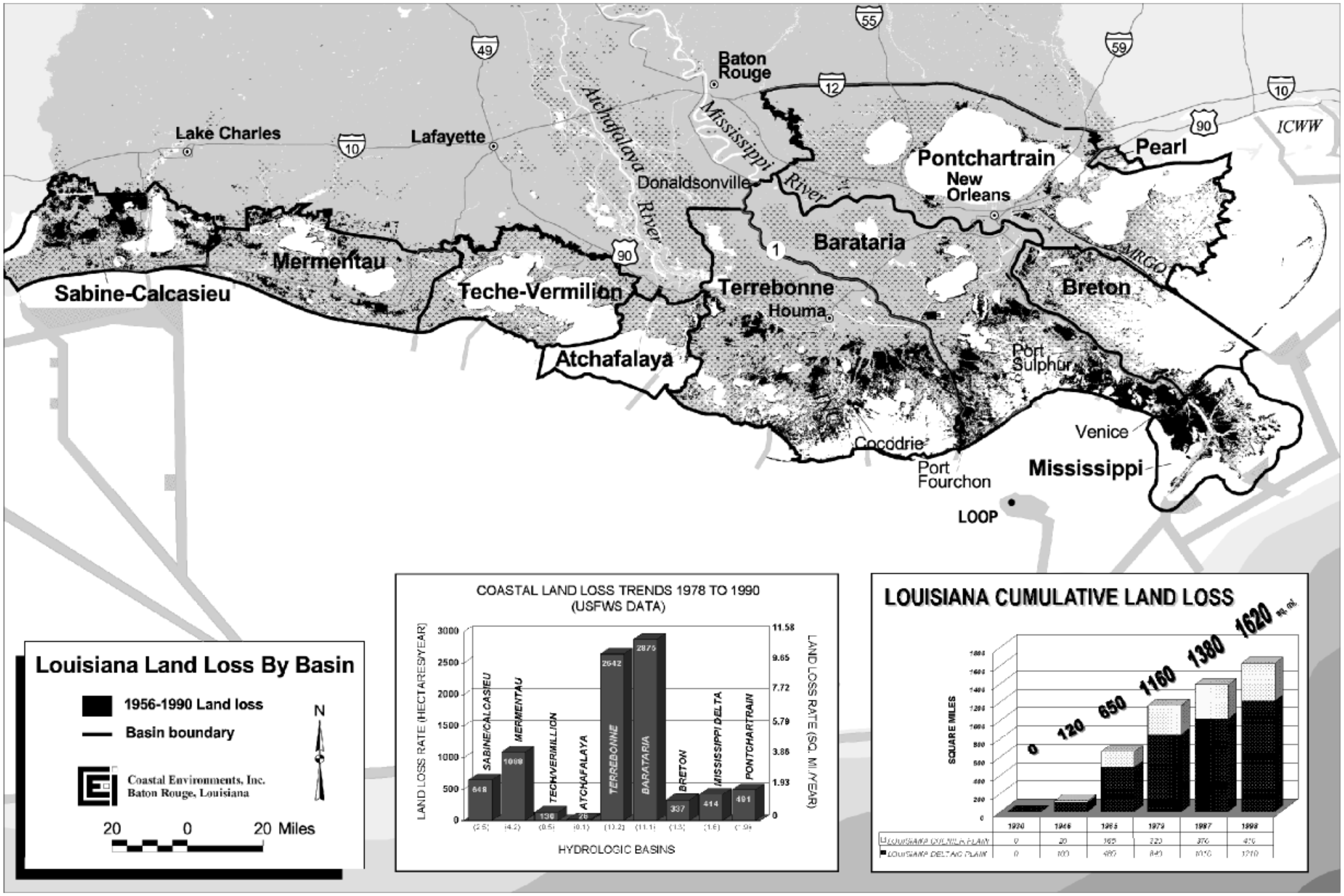


Figure 3-6. Map showing land loss in coastal Louisiana for the period 1956 - 1990 (adapted from Barras et al. 1994). Inset graphs show distribution of loss by hydrologic basins and cumulative land loss.

2) the Pontchartrain Basin; 3) the Terrebonne and Barataria basins; and 4) the Mississippi Basin. It has been determined that losses in the Calcasieu-Sabine Basin are related primarily to marine process invasion of fresh marshes through the Calcasieu and Sabine ship channels. Likewise, losses in the Pontchartrain Basin cluster around the Mississippi River Gulf Outlet, a navigation channel dug in the 1960's.

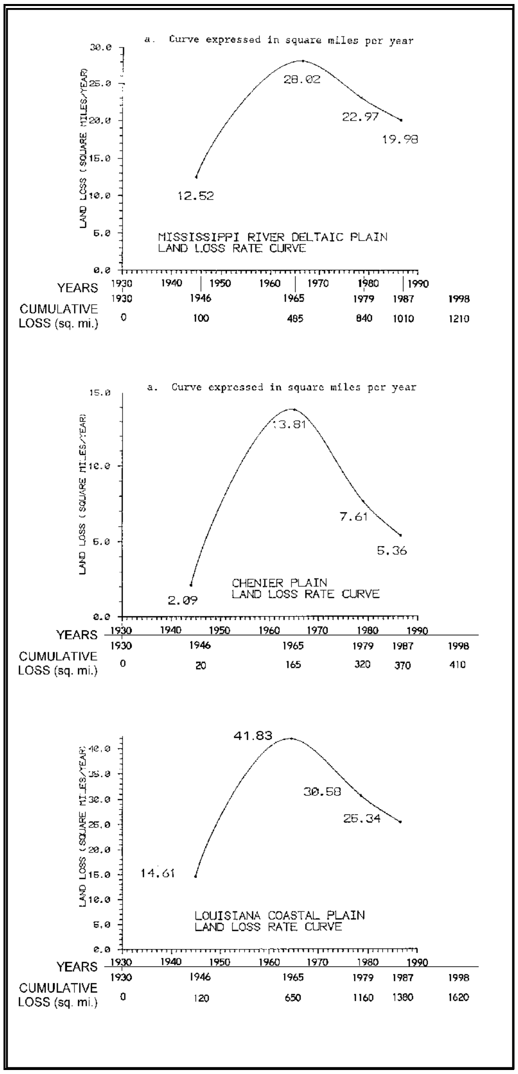


Figure 3-7. Graphs showing land loss curves and cumulative loss in coastal Louisiana (adapted from Dunbar et al. 1992).

The greatest losses have occurred in the Barataria and Terrebonne Basins flanking Bayou Lafourche, and in the Active Mississippi Delta (Mississippi Basin). One of the primary purposes of this paper is to investigate the causes of this loss.

Structural Elements

The major structural features of Louisiana and adjacent areas are shown in Figure 3-2. Louisiana is found in a geologically active, fault lined basin that makes constant vertical and horizontal adjustments. The discussion that follows identifies some of the major geological classifications, features and trends that are represented in the region.

Gulf Coast Salt Dome Basin

The Early Cretaceous Shelf Margin defines the northern boundary of the Gulf Coast Salt Dome Basin (Figure 3-2; Salvador 1991; Saucier 1994; Spearing 1995). As discussed previously, the Louann Salt lies near the base of the 10-or-more mile-thick sequence of sedimentary deposits. This bed of pure salt, which accumulated in an inland-sea during the middle Jurassic period, was originally deposited to a thickness of about 13,000 ft. The salt bed is the mother bed of the salt domes within the basin. The domes of coastal Louisiana are actually the northern part of a broad zone extending under much of the northern and western Gulf of Mexico.

Onshore and beneath the continental shelf the domes are mostly isolated diapiric structures. They are typically mushroom-shaped columns which may be from 2 to 20 miles in diameter. A few have surface expression, but the tops of most are situated from 2,000 to 10,000 ft below the surface. In the deeper offshore areas the salt diapirs are mostly tongue-like masses squeezed out toward the deep gulf along the continental margin. Salt spines in some domes are known to be still rising. Movement is episodic and at an almost imperceptible rate in the probable order of 0.01 in/yr or less (Saucier 1994).

Collapse Features

The domes occur in waves or bands, which are related to deep-seated basement topography (Adams 1997). Between some bands, where salt development has been most intense, the Louann Salt bed has been reduced in thickness, causing collapse of overlying beds (Seglund 1974). These depletion areas result in distinctive circular fault patterns (Figure 3-8). Subsurface faults in the Active Mississippi River Delta area exhibit the characteristic circular pattern of a collapse feature. This delta feature coincides with an area of intensive sediment loading associated with the Balize Delta lobe, a depositional event that occurred during the last 1,000 years (Frazier 1967). This apparent relationship between sediment loading and faulting raises a question of cause and effect. Does the circular fault pattern in the Balize Delta lobe represent a collapse feature over a salt depletion area that was filled by active delta deposition, or does the circular fault system represent vertical movement around an area of intensive sediment loading? These collapse areas are large and scattered across the coast, some coinciding with areas where modern subsidence and erosion rates are high.

South Louisiana Fault Systems

The effects of fault movement on stream patterns and landforms have long been a topic of interest to students of Louisiana geology. Harold N. Fisk (1944) illustrated a pattern of northwest-southeast and northeast-southwest trending faults, fractures, and alignments of streams and water bodies that criss-cross the Mississippi Valley and Deltaic Plain. Ellis Krinitzsky (1950) studied this pattern and concluded that it was related to a shift in the position of the equatorial bulge, which in turn resulted from a shift in the angle or position of the Earth's rotational axis. Saucier (1994) discussed the theory and concluded that more detailed studies have failed to verify fault movement on many of the alignments and therefore largely discarded the Fisk-Krinitzsky hypothesis. However, it should be pointed out that fractures and lateral movement faults are difficult to identify on well logs and seismic records. Such features, which are more subtle, may be defined on the basis of surface expression and/or relationships with other structural features or trends, and despite being difficult to detect, may constitute important structural elements.

Fisk (1994) also believed that in many instances faults influenced the locations and trends of Mississippi River bends, distributary channel alignments and nodes of distributary branching. He postulated, for example, that the Mississippi River bend called English

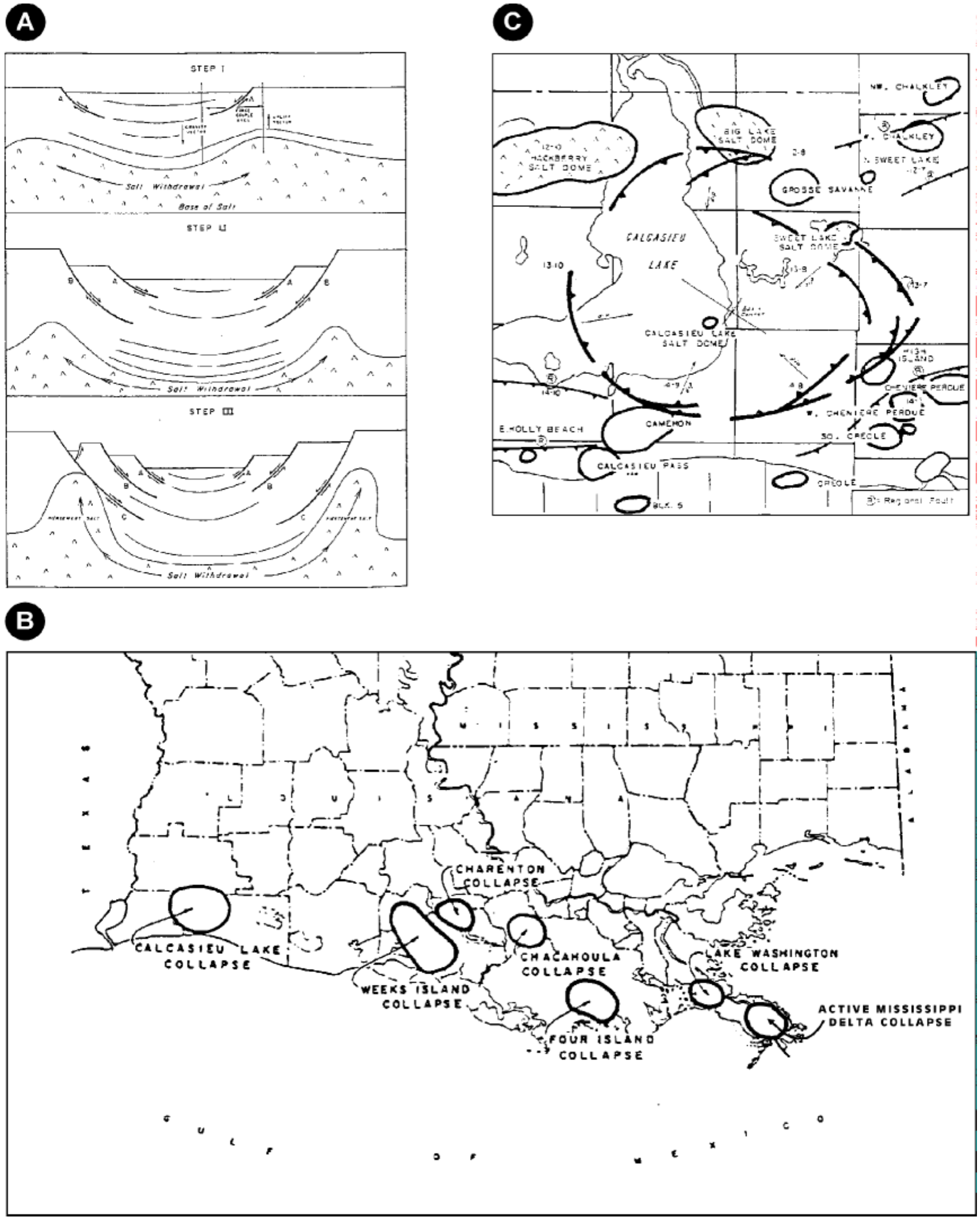


Figure 3-8. Salt depletion areas.

A. Schematic diagram of formation of collapse-fault system over salt-withdrawal basin.

B. Map showing location of selected collapse-fault systems in coastal Louisiana.

C. Calcasieu Lake collapse-fault system. High historic land loss around the lake occurs over the collapse area. (Maps and diagrams adapted from Seglund, 1974. The active Mississippi Delta collapse was added by the author.

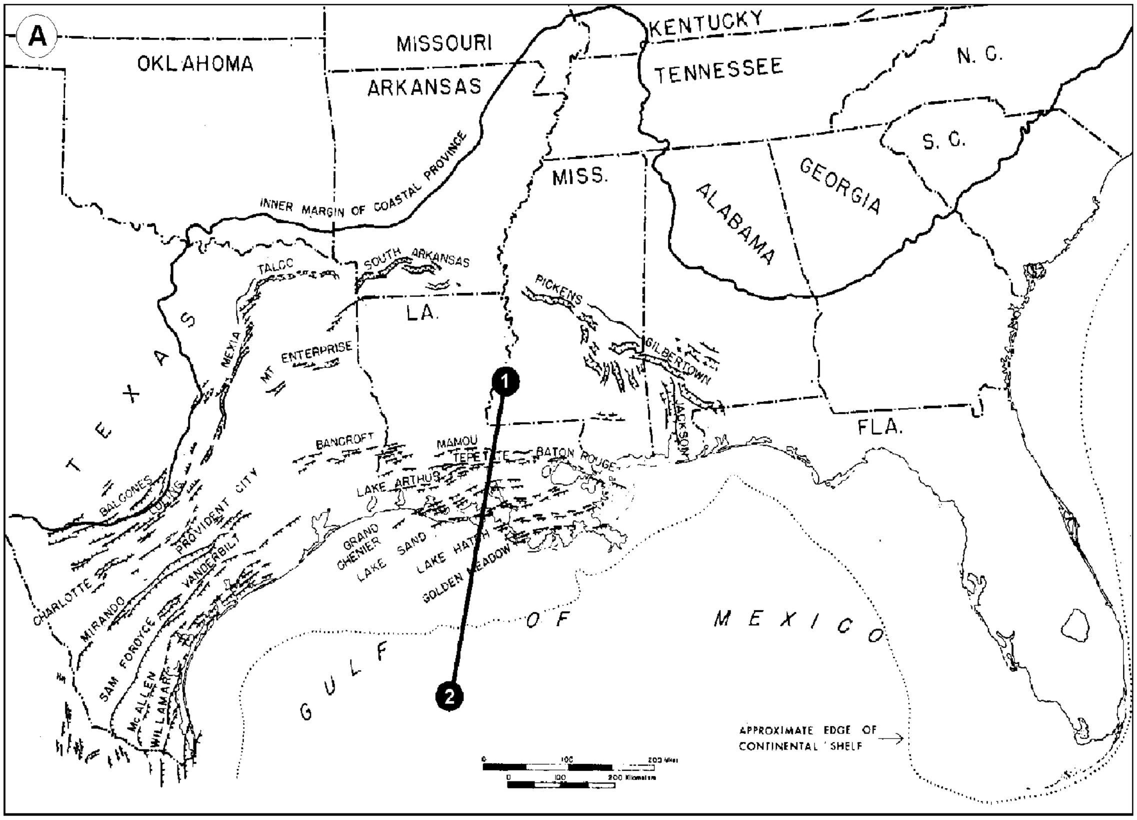
Turn, just downstream from New Orleans, lies within a graben. Work by Saucier (1994), Kolb et al. (1975), and others have verified such relationships. In a comprehensive study of the geology of the Deltaic Plain, Kolb and van Lopik (1958) cited abrupt narrowing of natural levee ridges and sharp changes in the Mississippi River south of New Orleans as probable indications of fault effects on landforms. Watson has demonstrated the relationships between faults, subsidence and uplift and changes in stream morphology and hydrology along the Mississippi River (Watson 1982). Fisk has been proven to be correct in his hypothesis that major fractures and both near surface and deeper subsurface fault movements are fundamental driving process for delta system dynamics, configuration and change.

Growth Faults

Grover Murray (1960) identified major structural features in Louisiana and adjacent areas, including fault trends (Figure 3-9). Growth faults in south Louisiana occur along the margin of, and within the Gulf Coast Salt Dome Basin. Murray (1960) identified eight major fault systems in south Louisiana: the 1) Mamou, 2) Tepetate-Baton Rouge, 3) Lake Arthur, 4) Scott, 5) Grand Chenier, 6) Lake Sand, 7) Lake Hatch and 8) Golden Meadow. These occur within zones of limited width and extent. Within each zone there is typically a series of en echelon normal faults. The zones are generally subparallel to the strike of the younger coastal strata, are about 8 to 20 miles apart and can be traced for distances of 100 miles or more. Displacements on individual faults are typically, but not always, normal faults, taking place contemporaneously with deposition and vertical displacement and generally increasing with depth. The faults are steeply dipping (50 to 60 degrees) in the upper near-surface but flatten out with depth. Displacement in the deeper sections may be in the order of several thousand feet. The earliest dates of fault movement are older inland (Paleocene and Eocene) and become progressively younger toward the coast (Miocene).

Gravity Tectonics Model: South Louisiana Slumping into the Gulf

Models developed by petroleum geologists show delta thickening on the basin side of major fault zones (Galloway 1986; Adams 1997; and others). Richard L. Adams (1997) relates these growth faults to basement topography of the Salt Basin. Using gravity and magnetic mapping, Adams prepared a "basement pseudo-structure map," which he used to develop a model (Figure 3-10). From the model Adams concluded that, "...basement horsts, grabens, and counter-rotated half-grabens influence the location of major growth fault regimes and production trends. Growth faults are preferentially found over the leading edge of high basement blocks, and major fields are often associated with these growth faults" (Adams 1997:6). He also states that, "...growth fault locations are controlled by basement structures and salt movements forming inherent zones of weakness," and that, "...these growth faults are usually found near the shelf break and are most active near the mouths of rivers where the thickest sands are deposited in the delta front... ." Adams further concludes, "...since most salt domes are formed near the corners



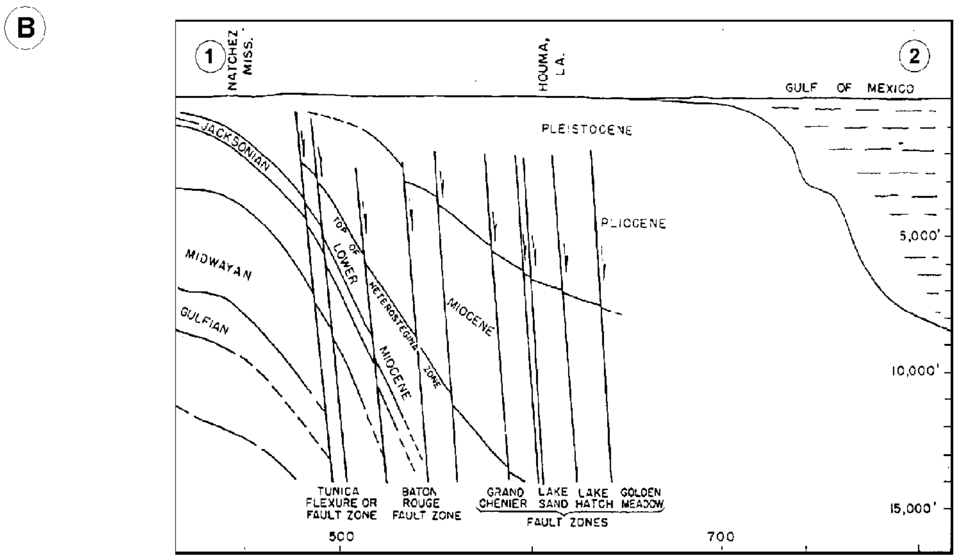


Figure 3-9. Principal fault systems of Gulf Coastal Province.

A. Map showing faults and other structural features.

B. North-South regional cross-section though southern Louisiana showing major stratigraphic units and fault zones. This drawing was published in 1960, when there were no wells below 15,000 feet (after Murray 1960).

of basement blocks, the major growth faults are also often associated with salt domes. The growth faults sole out at depth into decollement zones interpreted to be deep water shales (i.e. maximum flooding surfaces or condensed sections) or remobilized salt."

The sedimentary rocks, which have accumulated on the continental margin are subject to "gravity tectonics," one manifestation of which is a system of growth faults, between which are blocks that slump down and seaward into the Gulf (Figure 3-11; Winker 1982; Galloway 1986). These faults, many of which underlie the Deltaic Plain, remain active for long periods of time. "Extension and faulting is triggered by gravitational sliding and spreading" (Galloway 1986:123). The fault bound blocks characteristically rotate and tilt as they slump down the fault planes. The surfaces on the inland sides of the blocks are reduced in elevation more than on the seaward sides. Water bodies and areas of high land loss frequently occur in the resulting surface depressions. A contemporary example of the formation of a growth fault zone is found in the Active Mississippi Delta where the Birdfoot Delta has extended beyond the continental shelf edge and is building a thick sedimentary platform into deep water. Here a zone of diaipiric clay structures (mud lumps), faults, and

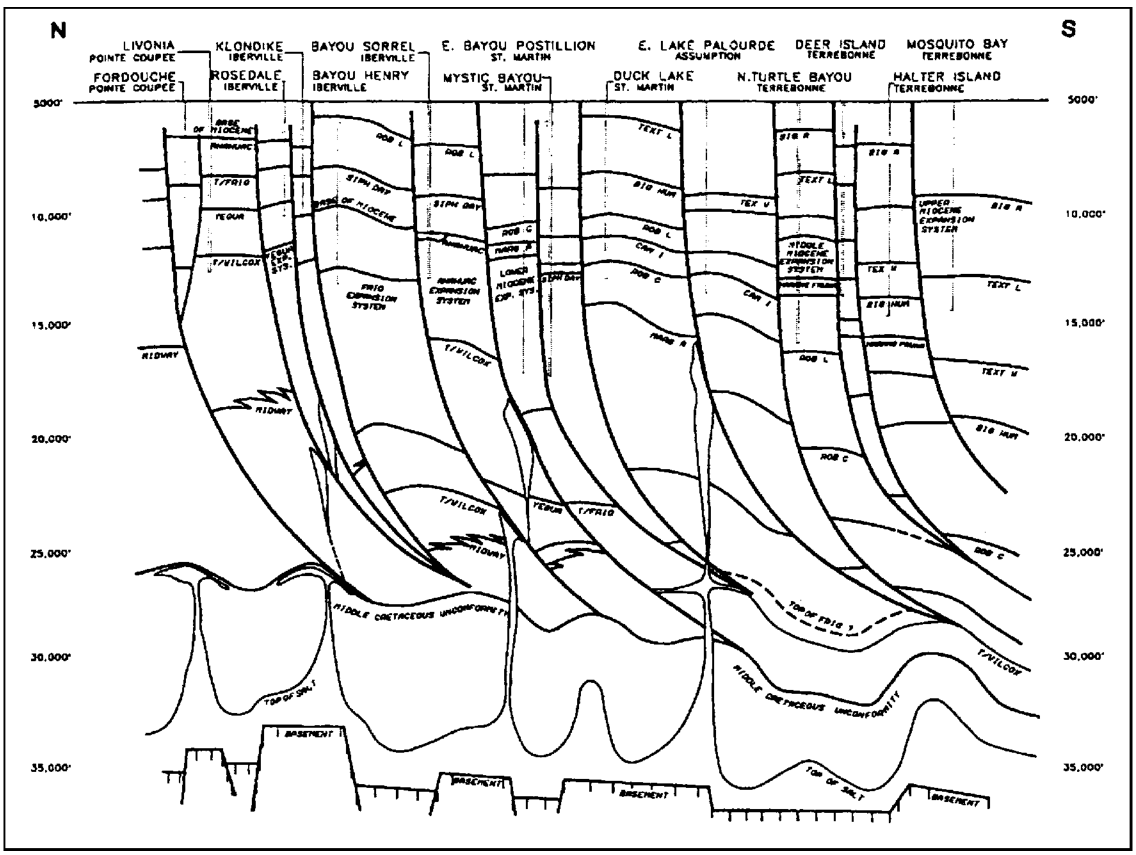


Figure 3-10. Cross-section through Gulf Coast Salt Dome Basin showing successively younger growth fault systems from north to south. Section also shows inferred basement-salt-decollement surface relationships (after Adams 1997).

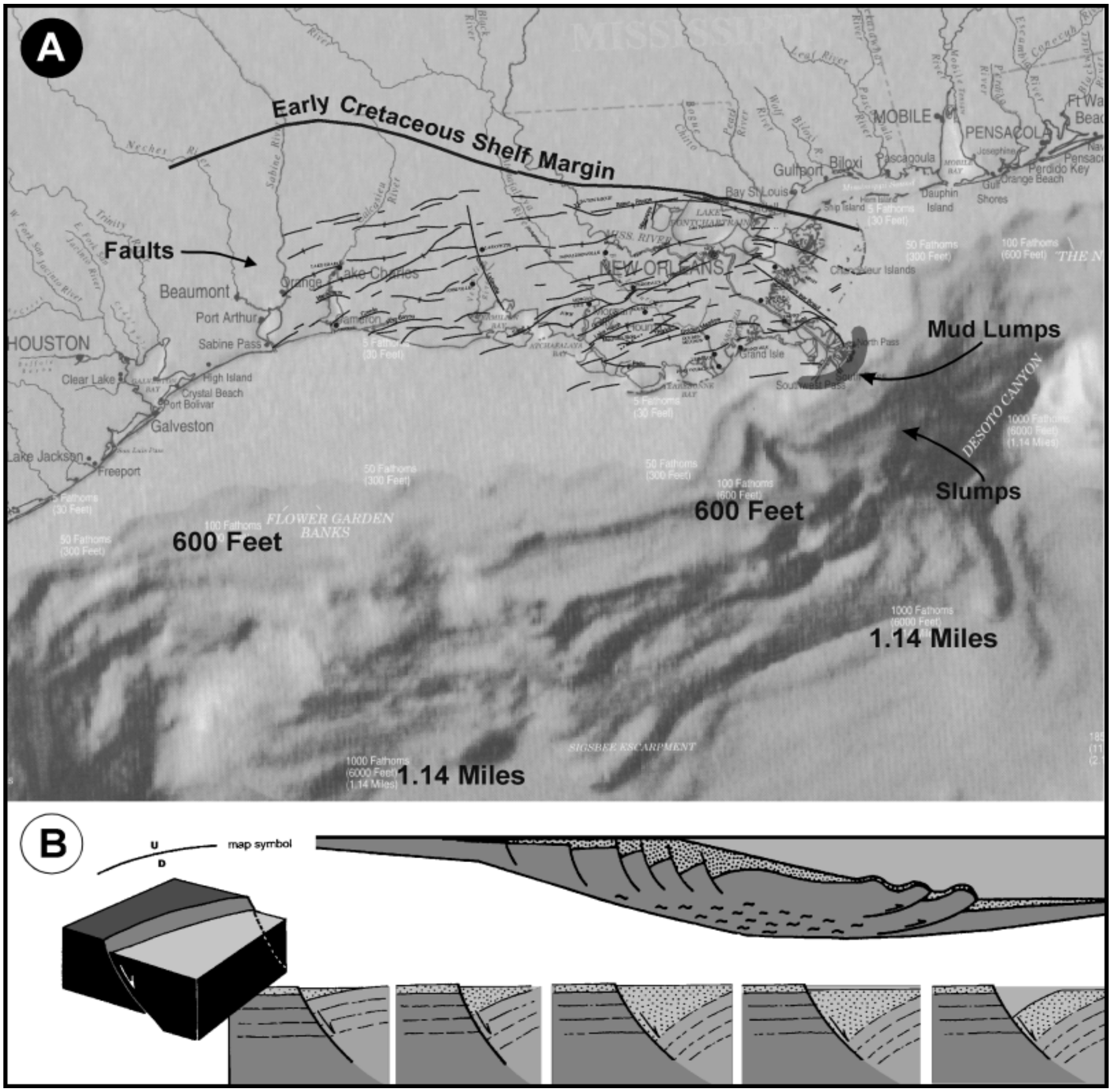


Figure 3-11. Continental margin slumping in south Louisiana.

A. Growth faults indicate lines of instability. Faults are progressively younger in a seaward direction.

B. Stress and strain domains of a prograding clastic continental margin. Diagrammatic cross-section illustrates continental margin gravity slumping model (cross-section after Winker 1982).

massive gravity slumps have developed along the sloping delta front (Figure 3-12). (Morgan et al. 1968; Gagliano and van Beek 1973; Coleman et al. 1980).

The Wallace Fault and Salt Dome Map

In 1966 the Gulf Coast Association of Geological Societies published the "Fault and Salt Map of South Louisiana." The map was compiled by W. E. Wallace, who listed himself as editor, and was the then most current

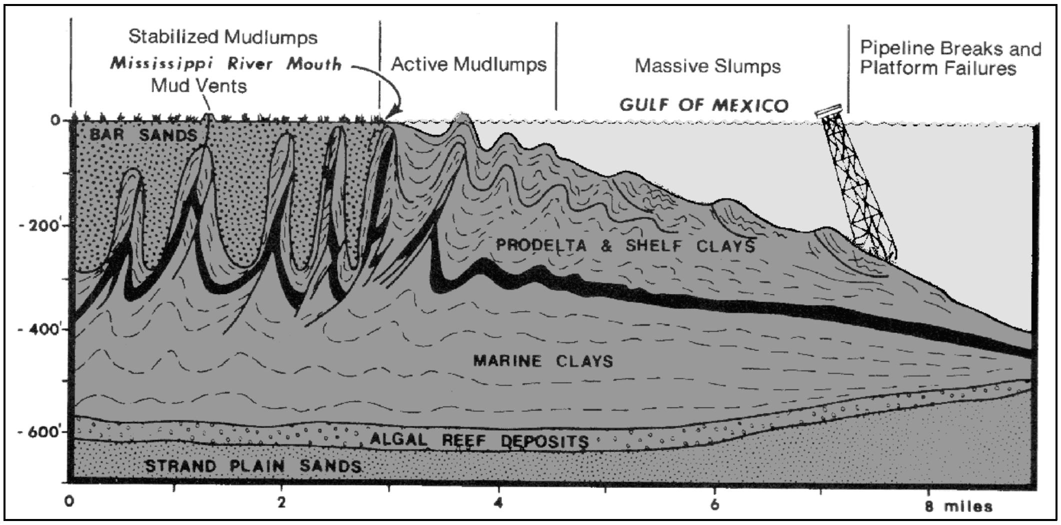


Figure 3-12. A cross-section in the vicinity of South Pass illustrates the manner in which relatively dense river mouth deposits on unstable clays initiate mudlump folding, thrust faulting and massive sea bottom slumps. Vertical displacements along faults of 350-ft or more have been documented. Major fault movement and slumping occur episodically and almost instantaneously (after Gagliano and van Beek 1973).

version of a series commenced by Wallace in 1943. This remarkable map resulted from the compilation of subsurface data from oil and gas fields scattered across south Louisiana, and remains one of the best sources of such data. The original map was at a scale of 1 inch to 4 miles. At the time the map was developed, most of the data were above 10,000 ft; data below 15,000 ft were sparse. The fault traces are probably not corrected to the land surface (map legend and text do not indicate the datum to which the traces are projected). The data points and lines from which the faults are drawn are concentrated around known oil and gas fields. The Wallace salt and fault map takes on new meaning when interpreted in reference to the gravity tectonics model.

An adaptation of the Wallace map showing faults and salt domes in south central Louisiana is shown in Figure 3-13, and a classification of fault patterns identified on the Wallace map is shown in Figure 3-14. The Wallace map illustrates the intimate relationship between fault zones and salt domes. The domes occur in alignments along the major fault zones. These rows of domes could be barriers to the slumping process, however, additional research is needed to determine if this is the case. Another possibility is that slump blocks displace the domes, and/or slumping material moves through gaps, over the tops of and in between the domes (see Figure 3-13).

Major Fault Systems

Using the Wallace map as a primary source, a fault trend map was developed for the purpose of this study (Figure 3-15). This map connects discontinuous subsurface fault traces into trends. The major fault systems are punctuated by strings of salt domes. The domes result in distinctive radial fault patterns around

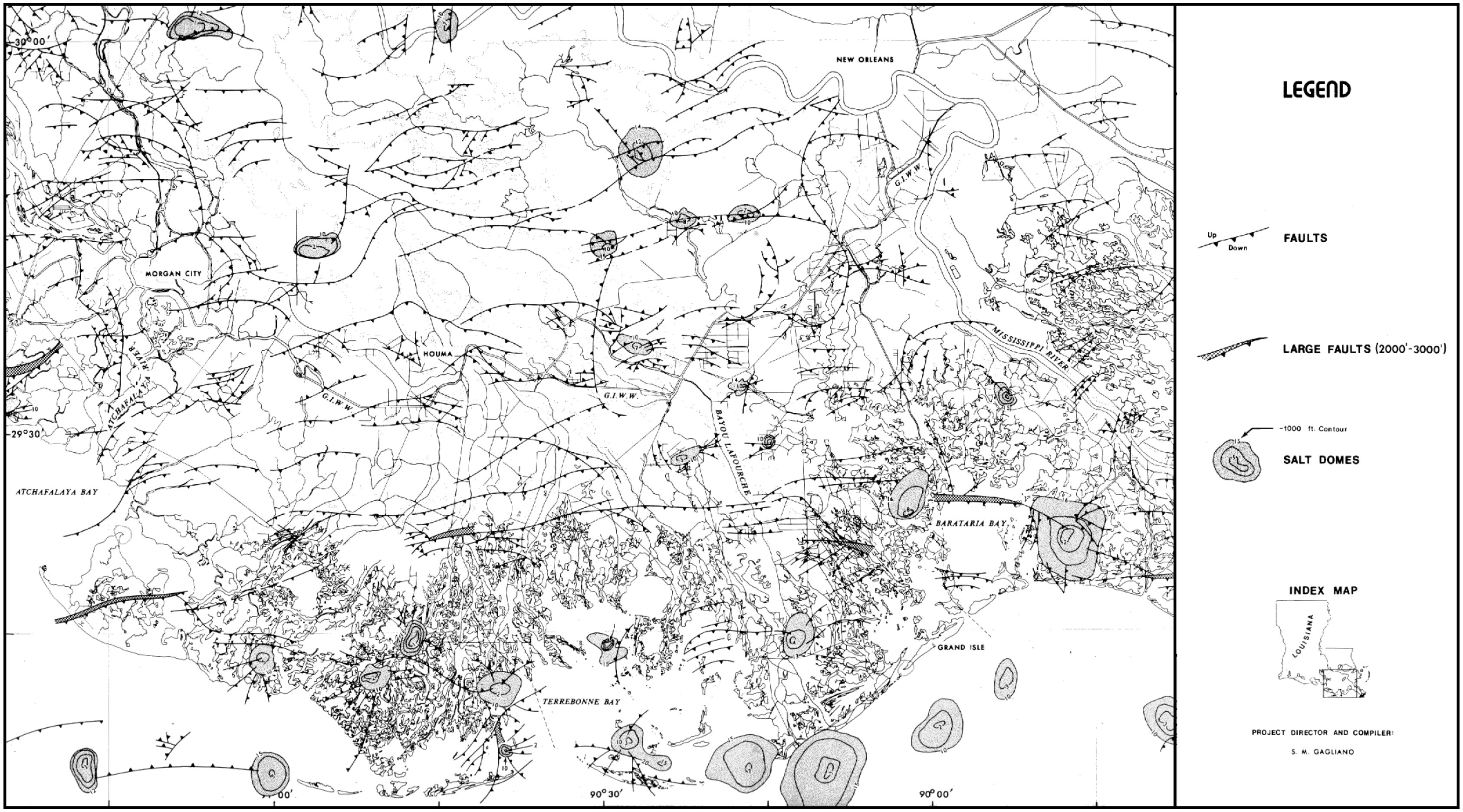


Figure 3-13. Excerpt from the 1966 Wallace Salt Dome and Fault map (adapted by Gagliano et al. 1972).

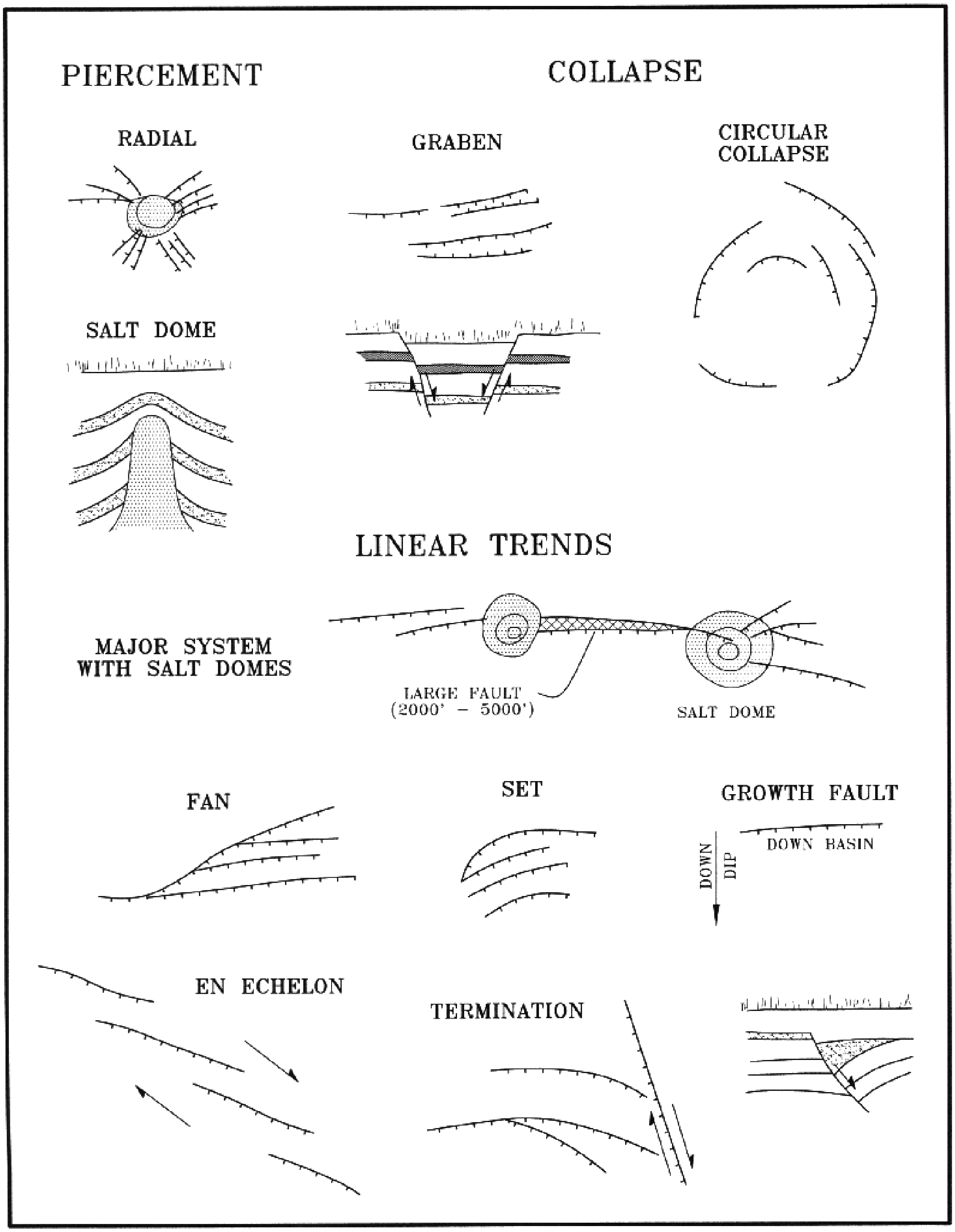


Figure 3-14. Fault patterns and types identified on the Wallace map.

their periphery. Shorter, apparently minor faults are not shown. The major fault systems and alignments are grouped into four categories: Basin Margin Fault Systems; SW-NE Fault Systems and Alignments; NW - SE Alignments or Shear Faults; and, E-W Growth Fault Systems. A discussion of the fault systems that are the most relevant to the study area follows.

Basin Margin Fault Systems

These fault systems are located along the Early Cretaceous Shelf Margin, which defines the northern extent of the Gulf Coast Salt Dome Basin. They include the Bancroft-Mamou fault systems, which extend westward from Baton Rouge across Louisiana and into Texas, and the Baton Rouge fault system.

One of the most prominent fault zones identified by Grover Murray (1960) is the Tepetate-Baton Rouge fault zone, which is referred to in this paper as the Baton Rouge Fault System. This system, extending for more than 200 miles from west of the Mississippi River to the mouth of the Pearl River, has been the topic of a number of studies. Faults in this system are marked by topographic escarpments and displacements of relict late Pleistocene stream scars on the Pleistocene Terrace surface in the Baton Rouge area (Durham and Peeples 1956; Durham 1963). Rolland (1981) also reported cracks and displacements of roads and buildings along this fault in

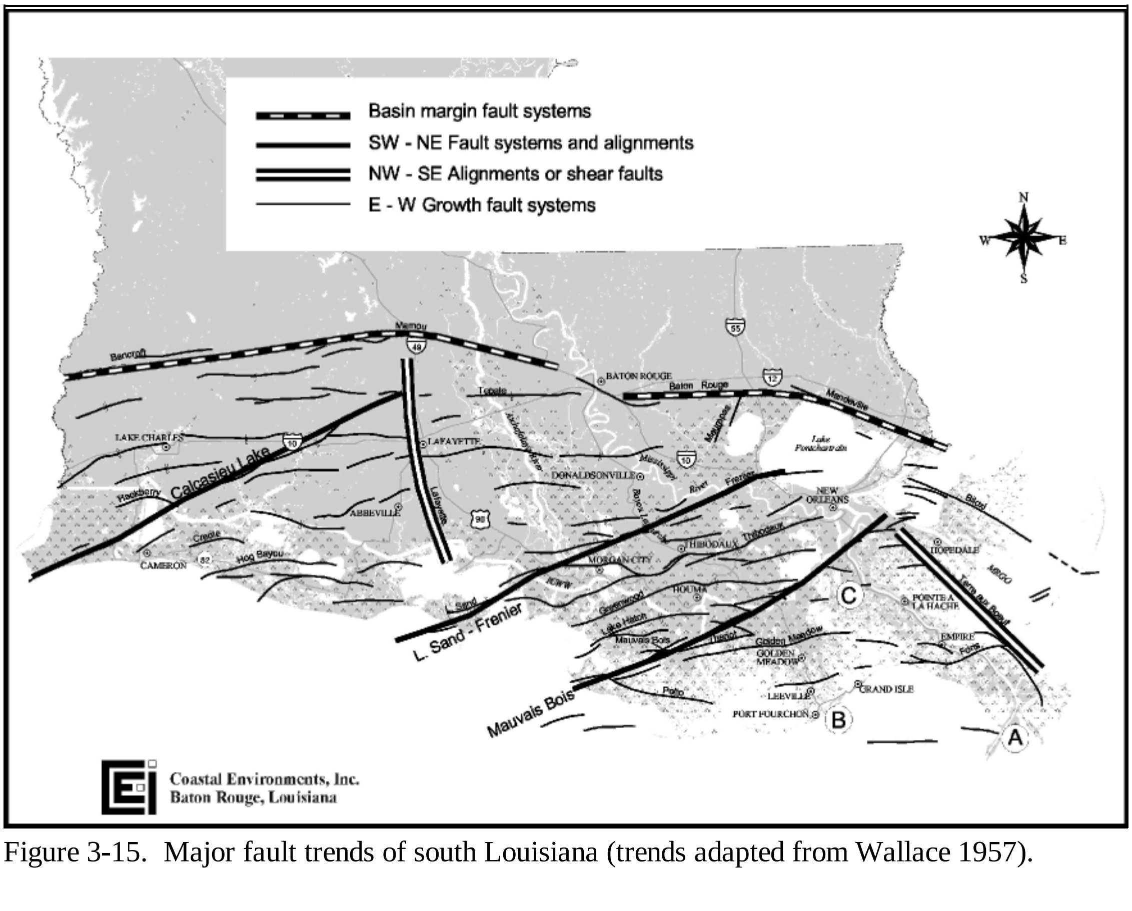


Figure 3-15. Major fault trends of south Louisiana (trends adapted from Wallace 1957).