OCS Study
MMS 87-0121

Causes of Wetland Loss in the Coastal Central Gulf of Mexico

Volume III: Appendices

MMS U.S. Department of the Interior
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Gulf of Mexico OCS Region

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Volume III: Appendices

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Appendix A

SUMMARY OF HURRICANES AND TROPICAL STORMS IN LOUISIANA

by

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Department of Geography and Anthropology

This list of hurricanes and tropical storms was compiled for each of these three coastal locations to give an inventory of disturbed tropical weather affecting the Louisiana coast. The compilation has been organized into three lists of storms (Tables A-1 through A-3) that directly affected the weather at three locations along the Louisiana coast: Boothville in lower Plaquemines Parish, Morgan City at the center of the coast, and Cameron, near the Texas border.

A unique feature of this appendix is that each storm has been classified according to an estimate of relative intensity at each of the three sites, with "H" representing hurricane intensity storm winds, "TS" tropical storm intensity winds, and "TD" winds associated with tropical depression intensities.

In the first column the dates indicate the total lifespan of the storm as given by the National Weather Service. The second indicates the name of the storm. The practice of naming tropical storms was not done until 1950. The third column shows the maximum intensity that the storm achieved as classified by the National Weather Service.

The intensities given in the fourth column are relative intensities for each of the coastal locations. For example, Audrey, a major hurricane that struck the west Louisiana coast in 1957 caused hurricane force winds at the point of landfall, but only tropical depression force winds at Boothville. It is important to note that these relative intensities are based on sustained wind speeds, not gusts. Intensities are given according to the following scale:

Tropical Depression = winds between 10 and 17 mps
Tropical Storm = winds between 18 and 33 mps
Hurricane = winds greater than 33 mps

The fifth column indicates the dates when the storm was significantly affecting the weather along the Louisiana coast. This is an arbitrary determination usually including the day of landfall, and in many cases the day before. There are a few notable exceptions such as hurricane Juan which affected many coastal locations for four days or more.

Table A-1. Influence of disturbed tropical weather at Boothville.

Date of Storm	Name	Max Intensity of Storm	Rel. Intensity at Coastal Location	Date of Influence On the Coast
1900 Aug 27-Sept 15		H	TD	Sept 8
1900 Sept 10-16		TS	TS	Sept 12-13
1901 Aug 4-17		H	TS	Aug 14-15
1902 Oct 3-13		TS	TS	Oct 9-10
1904 Oct 29-Nov 5		TS	TD	Nov 2
1906 Sept 19-29		H	TS	Sept 26-27
1907 Sept 17-23		TS	TD	Sept 21
1909 Sept 10-21		H	TS	Sept 20
1912 Sept 11-14		H	TD	Sept 13
1915 Sept 22-Oct 1		H	H	Sept 29
1916 June 29-July 10		H	TS	July 5
1917 Sept 21-29		H	TS	Sept 28
1918 Aug 1-6		H	TD	Aug 6
1923 Oct 16-19		TS	TS	Oct 17
1926 Aug 22-27		H	TD	Aug 25-26
1926 Sept 11-22		H	TD	Sept 21
1932 Aug 26-Sept 3		H	TD	Aug 31-Sept 1
1932 Oct 7-18		TS	TD	Oct 15
1934 Aug 26-Sept 1		H	TD	Aug 26-27
1936 July 26-27		TS	TD	July 26-27
1937 Sept 16-21		TS	TD	Sept 18-20
1938 Oct 10-17		TS	TD	Oct 16-17
1940 Aug 2-10		H	TD	Aug 5-8
1941 Sept 11-16		TS	TD	Sept 12-15
1942 Aug 17-22		H	TS	Aug 19-21
1943 July 25-29		H	TD	July 26-27
1944 Sept 8-10		TS	TS	Sept 8-10
1945 Sept 3-6		TS	TD	Sept 6
1946 June 13-16		TS	TD	June 14-16
1947 Sept 4-21		H	H	Sept 19-20
1950 Aug 20-Sept 1	Baker	H	TS	Aug 30-31
1955 July 31-Aug 2	Brenda	TS	TS	July 26-27
1955 Aug 23-29		TS	TS	Aug 26-27
1956 Sept 21-30	Flossy	H	TS	Sept 23-24
1957 June 25-28	Audrey	H	TD	June 27
1957 Aug 8-11	Bertha	TS	TD	Aug 9
1964 Sept 28-Oct 5	Hilda	H	TD	Oct 3-4
1965 Aug 26-Sept 12	Betsy	H	H	Sept 9-10
1969 Aug 14-22	Camille	H	H	Aug 17-18
1971 Sept 5-18	Fern	H	TS	Sept 16
1974 Aug 29-Sept 10	Carmen	H	TS	Sept 7-8
1977 Sept 3-8	Babe	H	TD	Sept 5
1979 July 9-16	Bob	H	TD	July 11
1985 Aug 28-Sept 14	Elena	H	TS	Sept 2
1985 Oct 26-Nov 1	Juan	H	TS	Oct 27-31

Table A-2. Influence of disturbed tropical weather at Morgan City.

Date of Storm	Name	Max. Intensity of Storm	Rel. Intensity at Coastal Location	Date of Influence On the Coast
1900 Aug 27-Sept 15		H	TD	Sept 8
1900 Sept 10-16		TS	TD	Sept 12-13
1901 Aug 4-17		H	TS	Aug 14-15
1902 Oct 3-13		TS	TS	Oct 9-10
1904 Oct 29-Nov 5		TS	TD	Nov 2
1905 Sept 24-30		TS	TD	Sept 28-29
1905 Oct 5-10		TS	TD	Oct 8-9
1906 Sept 19-29		H	TD	Sept 26-27
1909 Sept 10-21		H	H	Sept 21
1912 June 7-16		TS	TS	June 12-13
1915 Aug 5-23		H	TD	Aug 16
1915 Sept 22-Oct 1		H	H	Sept 29
1916 June 29-July 10		H	TD	July 5
1917 Sept 21-29		H	TD	Sept 28
1918 Aug 1-6		H	TS	Aug 6
1920 Sept 16-23		H	H	Sept 21
1923 Oct 12-17		H	TS	Oct 15
1926 Aug 22-27		H	H	Aug 25-26
1926 Sept 11-22		H	TD	Sept 21
1931 July 11-17		TS	TS	July 15
1932 Sept 18-21		TS	TD	Sept 19
1932 Oct 7-18		TS	TD	Oct 15
1934 June 4-21		H	TS	June 16
1934 Aug 26-Sept 1		H	TD	Aug 26-27
1938 Aug 9-14		H	TD	Aug 14
1938 Oct 10-17		TS	TD	Oct 16-17
1939 Sept 23-26		TS	TS	Sept 25-26
1940 Aug 2-10		TS	TS	Aug 5-8
1941 Sept 11-16		TS	TD	Sept 12-15
1942 Aug 17-22		H	TS	Aug 19-21
1943 July 25-29		H	TD	July 26-27
1943 Sept 15-19		TS	TD	Sept 19
1944 Sept 8-10		TS	TD	Sept 9-10
1946 June 13-16		TS	TD	June 14-16
1947 Sept 4-21		H	TS	Sept 19-20
1948 Aug 28-Sept 6		H	TS	Sept 3-4
1949 Sept 3-5		TS	TS	Sept 4
1949 Sept 27-Oct 6		H	TS	Oct 3-4
1954 July 27-30	Barbara	TS	TD	July 28-29
1956 June 12-14		TS	TS	June 13
1957 June 25-28	Audrey	H	TS	June 27
1957 Aug 8-11	Bertha	TS	TS	Aug 9
1957 Sept 16-19	Esther	TS	TS	Sept 17-18
1959 May 28-June 2	Arlene	TS	TS	May 29-31
1964 Sept 28-Oct 5	Hilda	H	H	Oct 3-4
1965 Aug 26-Sept 12	Betsy	H	H	Sept 9-10
1969 Aug 14-22	Camille	H	TD	Aug 17-18
1971 Sept 3-13	Edith	H	TD	Sept 4-16
1971 Sept 5-18	Fern	H	TS	Sept 16
1974 Aug 29-Sept 10	Carmen	H	H	Sept 7-8
1977 Sept 3-8	Babe	H	TS	Sept 5
1979 July 9-16	Bob	H	TS	July 11
1985 Aug 12-20	Danny	H	TD	Aug 15-16
1985 Oct 26-Nov 1	Juan	H	TS	Oct 27-31

Table A-3. Influence of disturbed tropical weather at Cameron.

Date of Storm	Name	Max. Intensity of Storm	Rel. Intensity at Coastal Location	Date of Influence On the Coast
1900 Aug 27-Sept 15		H	TS	Sept 8
1901 Aug 4-17		H	TD	Aug 14-15
1905 Sept 24-30		TS	TS	Sept 28-29
1909 Sept 10-21		H	TD	Sept 20
1912 June 7-16		TS	TD	June 12-13
1915 Aug 5-23		H	TS	Aug 16
1915 Sept 22-Oct 1		H	TD	Sept 29
1918 Aug 1-6		H	H	Aug 6
1920 Sept 16-23		H	TD	Sept 21
1932 Aug 11-14		H	TD	Aug 13
1934 June 4-21		H	TD	June 16
1934 Aug 26-Sept 1		H	TS	Aug 26-27
1937 Sept 29-Oct 3		TS	TD	Oct 2-3
1938 Aug 9-14		H	H	Aug 14
1939 June 12-16		TS	TD	June 14-16
1940 Aug 2-10		H	H	Aug 5-8
1940 Sept 19-24		TS	TS	Sept 23-24
1941 Sept 11-16		TS	TS	Sept 12-15
1942 Aug 17-22		H	TS	Aug 19-21
1943 July 25-29		H	TS	July 26-27
1943 Sept 15-19		TS	TD	Sept 19
1946 June 13-16		TS	TD	June 14-16
1947 Sept 4-21		H	TD	Sept 19-20
1949 Sept 27-Oct 6		H	TD	Sept 4
1954 July 27-30	Barbara	TS	TS	July 28-29
1956 June 12-14		TS	TD	June 13
1957 June 25-28	Audrey	H	H	June 27
1957 Aug 8-11	Bertha	TS	TS	Aug 9
1957 Sept 16-19	Esther	TS	TD	Sept 17-18
1961 Sept 3-15	Carla	H	TD	Sept 9-12
1963 Sept 16-19	Cindy	H	TD	Sept 17
1964 Sept 28-Oct 5	Hilda	H	TD	Oct 3-4
1965 Aug 26-Sept 12	Betsy	H	TD	Sept 9-10
1971 Sept 3-13	Edith	H	H	Sept 4-6
1974 Aug 29-Sept 10	Carmen	H	TD	Sept 7-8
1978 Aug 26-29	Debra	TS	TS	Aug 28
1982 Sept 9-12	Chris	TS	TS	Sept 11
1983 Aug 15-21	Alicia	H	TD	Aug 17-18
1985 Aug 12-20	Danny	H	TD	Aug 15-16
1985 Oct 26-Nov 1	Juan	H	TD	Oct 29-30
1986 June 23-28	Bonnie	H	TS	June 25-26

Appendix B

SUMMARY OF PORTS AND WATERWAYS USE BY OCS ACTIVITIES

by

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This appendix addresses the use of coastal waterways by vessels engaged in Outer Continental Shelf (OCS) drilling activities. An analysis of the most current data concerning vessel trips and cargo tonnage is presented. The analysis is accomplished by (1) a description of available data bases; (2) a review of the methodology of data collection, compilation, and verification; (3) the presentation of federal government data summaries; (4) a discussion of data weaknesses; (5) the presentation of alternative OCS-use estimates; and, (6) a conclusion.

Description of Available Data Bases

Several data sources are available concerning vessel movements. For example, Lloyd's Maritime Data Service provides on-line access to current (previous month) and historical vessel movements in foreign commerce but not domestics movements. Individual port authorities collect vessel and tonnage data but only for those ships that use public facilities and not those which use private facilities. The U.S. Department of Transportation collects waterborne transportation data through the U.S. Coast Guard and the Maritime Administration. The U.S. Department of Commerce collects information through U.S. Customs and the Bureau of the Census. However, none of these sources specify vessel data detailed by origin, destination, and milepost per waterway.

The Waterborne Commerce Statistical Center (WCSC) of the U.S. Army Corps of Engineers (COE) is the primary source of all waterborne commerce movements in the United States. The best source of data is from the log of ships engaged in OCS activities. The WCSC data base comes from the owners of those ships and vessel operators as reported on Form ER 335-2-1, "Vessel Operation Report, Statement of Freight and Passengers Carried." The data items included are number of trips, vessel name, vessel type, cargo tonnage, commodity type, and origin and destination information (e.g., port name, dock name, river mile, and date).

Since the WCSC data base contains the specific information needed to describe OCS-related waterway use, it was chosen for this study. However, because of some data deficiencies described in a later section, other sources were referenced to augment WCSC data or provide alternative estimates of activity.

The COE also records data on vessel movements through COE-maintained locks and dams. The data are stored at the Institute for Water Resources in Virginia and at the individual COE districts as part of the Performance Monitoring System (PMS). Only three of the 26 waterways in the study area have locks and participate in PMS. However, since PMS statistics are collected for all vessel types and WCSC data are collected for only 7 to 24 vessel types (described later), PMS data can be used to account for the vessel types not covered by WCSC data.

Methodology

The methodology for completing this study involves the collection, compilation, and verification of the data provided by WCSC. The initial step was to determine the extent of data available to address the requirements of this task. Discussions were held with WCSC officials and a request was made for historical data for the last ten years. There is often a one- to two-year delay between the time of the activity and the release of the data by WCSC. Therefore, the most recent data available are for the calendar year 1985. Hence, data were requested for the years 1975 to 1985. WCSC expressed severe concerns over the accuracy of the historical data. As is explained in the section "Data Reliability," WCSC has no estimate on the accuracy of any data except for the year 1985. Therefore, data from the calendar year 1985 is presented in the analysis.

Data were then requested for all waterborne commerce movements to the Gulf offshore destination. Once these data were compiled, it was necessary to ascertain whether or not the data could be published for the list of waterways pertinent to the study area. WCSC requires that before data can be released, precautions must be taken to assure that the data is aggregated sufficiently in order to disguise the publication of data for a specific company. To implement this requirement, WCSC employs the "rule of three," i.e., there must be at least three different operating companies for a specific waterway or region of a waterway before data can be published.

Table B-1 presents a list of 26 waterway categories considered in the study. Waterway categories are sometimes referred to as only the name of the principal or first WCSC waterway included in the category or abbreviations of waterways. For example, in category 11, Bayous La Loutre, St. Malo, and Yscloskey are sometimes referenced as Bayou La Loutre. WCSC waterway codes are provided for references to WCSC publications. A map of the study area is provided in Figure B-1 with abbreviated waterway names.

As shown in Table B-1, all waterways have at least three docks to satisfy the "rule of three" requirement. The minimum number of docks (7) is listed for the Gulf of Mexico via Baptiste Collette Bayou and Bayou Dupre waterways. Many of the above listed waterways have been aggregated with more than one river or bayou, and often a section of the Gulf Intracoastal Waterway (GIWW) is included.

Additional data aggregation was necessary to record vessels using coastal waterways not counted in coastal waterway statistics. Those uncounted had origins and/or destinations near but outside of the study area. If a vessel leaves a dock on the GIWW with a destination to an OCS oil rig, the vessel movement through the coastal waterway to the Gulf is not recorded as part of the coastal waterway's traffic. Since some of the docks on the GIWW serve companies involved in OCS activities, it was necessary to include these vessels with the closest coastal waterway. The closest reach was based on the most efficient route to the Gulf. Therefore, for example, data from GIWW mileposts 14 through 59 are included with the Bayou Terrebonne statistics.

Data were requested for all variables and all vessels with origins and destinations to OCS oil rigs by waterway. The data were then entered, verified, processed, and sorted to characterize the volume and type of traffic and tonnage using coastal waterways and those involved in OCS activity. Because data limitations were encountered in the process, alternative navigation activity estimates were derived based on available data.

Table B-1. Number of docks and WCSC waterway codes for OCS activities (from Waterborne Commerce Statistical Center).

	Name of Waterway	Number of Docks per Waterway	WCSC Waterway Codes			
			From	To	From	To
1.	Pascagoula Harbor, Mississippi	82		15555		
2.	Bayou Casotte, Mississippi	32		15556		
3.	Biloxi and Gulfport, Mississippi	48	15590	15899		
4.	Mississippi River Gulf Outlet	21		15951		
5.	Mississippi River and Passes, Harvey Canal and Gulf Intra Coastal Waterway (GIWW) Miles 0 to 5	646	20025	20449	66002	66010
6.	Gulf via Baptiste Collette Bayou	7	20460			
7.	Gulf via Grand Pass and Ostrica Canal		70	20451	20460	
8.	Empire, Louisiana Waterway to Gulf of Mexico	33	20479	20480		
9.	Inner Harbor Navigation Canal	87	20500			
10	Lake Pontchartrain, Louisiana	66	20503			
11	Bayous La Loutre, St. Malo, and Yscloskey, Louisiana	11	20537			
12	Bayou Dupre, Louisiana	7	20539			
13	Gulf via Barataria Bay	54	20656	20657		
14	Bayou Lafourche, Louisiana	81	20675			
15	Bayou Terrebonne and GIWW Miles 14-59	62	20710		66014	66058
16	Houma Navigation Canal; Big and Little Caillou and LeCarpe Bayous; and GIWW Miles 60-78	92	20715	20732	66060	66078
17	Atchafalaya River and GIWW Miles 79-95	398	20792	20799	66087	66095
18	Petit Anse, Tigre and Carlin Bayous		23	20848		
19	Bayou Teche	103	20860			
20	Vermilion Bay and GIWW Miles 159-160	73	20890			
21	Freshwater Bayou and GIWW Mile 161-193	30	20895			
22	Mermentau River	61	20925			
23	Mermentau River and Bayous Nezpique and Des Cannes	71	20933			
24	Calcasieu River and Passes and Port of Lake Charles	214	20955			
25	Sabine Pass Harbor, Texas	53	60020			
26	Beaumont, Texas	138	60056			
Subtotals						
	Outside of Study Area	1,989				
	Within Study Area	2,563				
TOTAL		4,552				

Presentation of Data

Coastal waterways navigation activity is presented in this section for the year 1985, by month, by cargo type moved, type of vessel use, and by waterway having OCS activity.

An explanation of the variable categories is presented to establish the variable definition used in the analysis. The primary variables are

(1) number of trips: all complete trips during a month by a vessel between the same two points, carrying the same commodity, and using the same alternate waterways are combined and included as one entry;
(2) vessel origin/destination (O/D) information: month and year that vessel was loaded/unloaded, river name, mile point, river bank, and port and dock names;
(3) commodity: Standard Industrial Classification (SIC) four-digit codes;
(4) tons: reported as short tons; and,
(5) vessel types: (a) self propelled, dry cargo and passenger; (b) self propelled, tanker; (c) towboat or tugboat; (d) non-self propelled, dry cargo; (e) non-self propelled, tanker; and, (f) other.

Therefore, vessel trips are presented as one-way trips and cargo is quantified in short tons. Origins and destinations, while compiled by specific river name and mile point, are presented by waterway to maintain the confidentiality of the data base. The commodity (SIC) codes are the four-digit level of industry aggregation as classified by the Bureau of the Census. The vessel types used by WCSC are recorded into six very general categories, as listed above, pertaining to dry, liquid or passenger cargo and self propelled, barge, and tug classifications. Table B-2 presents a listing of 24 functional categories of vessels that use coastal waterways. WCSC data base includes seven of the 24.

Table B-2. Vessel types included and not included in Waterborne Commerce Statistical Center data (source: Offshore Vessels Report Service).

Vessels Reported	Vessels Not Reported
Anchor-handling supply ships	Coring vessels
Crewboats	Container carriers
Crew/Supply Boats	Derrick vessels
Multiservice vessels	Fire-fighting vessels
Supply boats	Geochemical survey/analysis boats
Tug/Supply boats	Lift boats (self propelled/self elevating)
Utility boats	Line-handling boats
	Maintenance support boats
	Pipe carriers
	Production vessels
	Platform supply boats
	Recreational vessels
	Research vessels
	Stand-by boats
	Survey boats
	Well service boats

The 1985 data on OCS activity by month are presented in Table B-3. About 134,000 tons of cargo were not reported by month. Because some vessels contain more than one cargo type, only one vessel trip is assigned to one commodity type. If there are three types of cargoes, the vessel trip is not recorded for two cargo tonnages. This is done to assure that the total vessel counts do not include double counting.

Table B-3. Summary of monthly OCS activity.

Month	Trips	Tonnage	Tons/Trip
January	2,281	306,044	134.2
February	2,052	307,561	149.9
March	2,341	389,875	166.5
April	2,446	320,369	131.0
May	2,429	316,309	140.2
June	2,310	652,385	282.4
July	2,977	290,167	97.5
August	2,345	628,259	267.9
September	2,179	612,586	281.1
October	2,265	669,891	295.8
November	1,918	642,668	335.1
December	2,241	4,116,839	1,837.1
Not Specified	N/R	133,977	N/A
Monthly Average	2,315	782,244	
Standard Deviation	246	1,020,543	
Standard Deviation (Excluding December)	256	161,343	
Total	27,784	9,386,930	337.9

N/A - Not Available
N/R - Not Reported

The average number of trips per month to OCS rigs is 2,315. About 780,000 tons of cargo are moved to rigs monthly. The average trip count was within a standard deviation of 246 on a monthly basis. Thus, vessel traffic varied no more than about 10 percent from month to month. Tonnage variance is difficult to determine. About 4.3 million tons was either not specified or recorded with December data. Excluding these data, the standard deviation of monthly tonnage through November was about 161,000 tons or about 20%. Thus, OCS activity shows less variation in vessel trips than in vessel tonnage. Tonnage levels were twice the monthly average during the period August through November than the period January through April. Large variations in cargo tonnage (the 100% increase) can occur in a year.

Table B-4. Summary of commodity tonnage transported for OCS activities.

WCSC Commodity Code	Commodity Name	Tonnage Amount	Tonnage Percent of Total
3911	Misc. manufacturing	1,760,348	18.8
4111	Water	1,705,080	18.2
2914	Distillate fuel oil	1,242,931	13.2
3317	Iron & steel pipe	1,021,209	10.9
3241	Building cement	962,575	10.3
2819	Basic chemicals NEC	733,496	7.8
4112	Unidentifiable	482,902	5.1
1451	Clay, ceramic, etc.	435,987	4.6
2099	Misc. food products	169,345	1.8
2921	Liquefied hydrocarbons	162,384	1.7
4118	Waterway maintenance	158,232	1.7
2095	Ice	151,994	1.6
3511	Machinery (except elec.)	117,620	1.3
1499	Nonmetallic minerals	74,285	0.8
931	Marine shells, unmanuf.	70,800	0.8
1311	Crude petroleum	39,579	0.4
2094	Groceries	25,662	0.3
2915	Residual fuel oil	21,297	0.2
3411	Fabricated metal products	16,779	0.2
1411	Limestone et al	1,900	0.1
4029	Waste & scrap NEC	7,071	0.1
1442	Sand, gravel & rock	5,198	0.1
2491	Wood manufactures NEC	4,336	0.0
3315	Iron & steel bars	1,014	0.0
3291	Mis. nonmetallic minerals	838	0.0
4011	Iron & steel scrap	717	0.0
2911	Gasoline	650	0.0
3319	Iron & steel products NEC	594	0.0
2421	Lumber	480	0.0
4119	Empty containers	337	0.0
2916	Lubricating oils/greases	234	0.0
2414	Timber & wood in rough	197	0.0
3711	Motor vehicles	161	0.0
	Others (less than 5 tons)	698	0.0
TOTALS		9,386,930	100.0

NEC - Not otherwise specified.

OCS activity by vessel type is presented in Table B-5. Almost 89% of all vessels in the WCSC data base for OCS activity are self-propelled dry cargo and passenger vessels. There were almost three thousand vessel trips by non-self-propelled vessels and only 263 towboat/tugboat trips.

Table B-5. OCS activity by vessel type, 1985.

Vessel Type	Vessel Trips Amount	Vessel Trips Percent of Total	Tonnage Amount	Tonnage Percent of Total
Self Propelled, Dry Cargo and Passenger	24,714	88.95	8,288,808	88.30
Self Propelled, Tanker	1	0.00	13,665	0.15
Towboat or Tugboat	263	0.95	2,362	0.03
Non-Self Propelled, Dry Cargo	1,711	6.16	452,766	4.82
Non-Self Propelled, Tanker	1,095	3.94	629,329	6.70
Other	0	0.00	0	0.00
TOTAL	27,784	100.00	9,386,930	100.00

Vessel type could be viewed as a significant factor in determining the number of trips and environmental impact. An alternative vessel trip estimate could be based on the sum of self-propelled vessels plus towboat/tugboat convoys because non-self-propelled vessels must by definition be towed and part of a convoy. This would reduce the total trips by the amount of non-self-propelled vessels and account for about 10.5% of total trips. This would not affect the percentage of OCS use per waterway because both OCS trips and total waterway trips would be similarly adjusted.

In terms of environmental impact, the type of vessel and vessel speed are the most essential parameters to consider. Non-self-propelled vessels generate no speed on their own. Self-propelled vessels' engines are designed to provide sufficient speed to move the ship's maximum cargo capacity. Therefore, the horsepower is limited by the cargo carrying capacity.

Towboats and tugboats, however, must have excess towing power to handle multiple barge tows. Thus, with greater horsepower, tugs could then have the potential for a greater impact than self-propelled vessels. If the self-propelled vessel types used for OCS activities cause minimum degradation to waterway integrity, then perhaps the volume of towboats/tugboats would be a more critical environmental parameter.

Table B-6 presents OCS activity by vessel type for all waterways. Total self-propelled and towboat/tugboat vessel trips equalled 24,978. OCS activity for most waterways is carried by self-propelled vessels. However, five waterways have significant non-self-propelled vessel activity: Bayou Casotte, Bayou Dupre, Bayou Terrebonne, Biloxi/Gulfport, Baptiste Collette Waterway, Grand Pass/Ostrica Canal, and Freshwater Bayou have over 10% non-self-propelled vessel traffic.

OCS activity by waterway is summarized in Table B-7. A total of about 9.4 million tons of cargo were shipped in 27,784 vessel trips in 1985. The average tonnage carried per trip was 335 tons. Over 80% of all vessel trips are accounted for in the study area. About 93% of all cargo tonnage was handled within the study area. The waterway with the largest amount of OCS traffic is the Waterway Gulf via Grand Pass and Ostrica Canal (6,810 trips). The Mississippi River (3,149 trips), Bayou Lafourche (3,062 trips), the Atchafalaya River (2,602 trips), and the Houma Navigational Canal (2,189 trips) are the next most frequently used waterways.

Table B-6. OCS Activity by vessel type and waterway.

Vessel Code:	1		2		3		4		5	
Vessel Name:	SP-Dry Cargo/Passenger		SP-Tanker		Tow/Tugboat		NSP-Dry Cargo		NSP-Tanker	
Waterway Name	Trips	Tonnage	Trips	Tonnage	Trips	Tonnage	Trips	Tonnage	Trips	Tonnage
Pascagoula Harbor, MS	2	7,955								
Bayou Casotte, MS	22	608					2	1,802	116	112,067
Biloxi & Gulfport, MS	1	1,315					1	50	2	131
MRGO	47	23,755					1	40	1	487
Miss. River & Passes	2,910	96,113			4	65	138	66,098	97	99,138
Baptiste Collette Bayou	7	408							1	5
Grand Pass/Ostrica	5,879	503,605			218	722	519	45,455	194	33,236
Empire Waterway	1,287	9,195					2	85	4	341
Inner Harbor Nav. Canal							158	88,886	6	2,550
Lake Pontchartrain, LA	1	20					59	66,600	1	2,000
LaLoutre/St. Malo/ Yscloskey	138	104								
Bayou Dupre, LA									17	12,930
Barataria Bay	117	2,113					2	300	2	790
Bayou LaFourche, LA	3,039	344,549					23	2,036	0	251
Bayou Terrebonne, LA	110	2,802					229	35,980	178	153,429
Houma/Caillous/ Le Carpe	1,710	127,006					69	7,059	357	143,671
Atchafalaya River	2,564	6,278,589			10	530	37	5,076	44	8,841
Petit Anse/Tigre/Carlin	2	10,613								
Bayou Teche	73	7,775								
Vermilion Bay	294	68,373					5	500	19	1,949
Freshwater Bayou	159	19,425			31	1,045	76	5,718		
Mermentau River, LA	391	7,283					4	150		
Merm./Nezpique/ Des Carnnes	3	4								
Calcasieu River	626	129,594							19	17,455
Sabine Pass Harbor, TX	54	27,023								
Beaumont, TX	2	126								
Outside of Study Area	5,024	529,191	1	13,665			380	124,865	32	38,750
GIWW (Not Allocated[a])	252	91,264					6	2,066	5	1,308
TOTALS	24,714	8,288,808	1	13,665	263	2,362	1,711	452,766	1,095	629,329

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[a] Vessel type data was not available by GIWW milepost as of writing.

Table B-7. OCS activity by waterway.

Name of Waterways	Number of Trips	Tonnage	Tons per Trip
Pascagoula Harbor, MS	2	7,955	3,978
Bayou Casotte, MS	140	114,477	818
Biloxi & Gulfport, MS	4	1,496	374
Mississippi River, Gulf Outlet	49	24,282	496
Mississippi River, Harvey & GIWW 0-5	3,149	261,414	83
Gulf/Baptiste Collette Bayou	8	413	52
Gulf via Grand Pass/Ostrica	6,810	583,018	86
Empire, LA Waterway to Gulf	1,293	9,621	7
Inner Harbor Nav. Canal	164	91,436	558
Lake Pontchartrain, LA	61	68,620	1,125
La Loutre/St. Malo/Yscloskey, LA	138	104	1
Bayou Dupre, LA	17	12,930	761
Gulf via Bayou Barataria Bay	121	3,203	26
Bayou Lafourche, LA	3,062	346,836	113
Bayou Terrebonne & GIWW 14-59	617	125,979	204
Houma/LeCarpe/Caillou Bayous/ GIWW 60-78	2,189	277,984	127
Atchafalaya River & GIWW 79-95	2,602	6,292,788	2,418
Petit Anse/Tigre/Carlin Bayous	2	10,613	5,307
Bayou Teche, LA	73	7,775	107
Vermilion Bay & GIWW 159-160	580	165,360	285
Freshwater Bayou & GIWW 161-193	267	26,288	98
Mermentau River, LA	395	7,433	19
Merm/Bayous Nezpique/Des Cannes	3	4	1
Calcasieu Riv/Pass Lake Charles	645	147,049	228
Sabine Pass Harbor, TX	54	27,023	500
Beaumont, TX	2	126	63
Subtotal Outside of Study Area	5,337	772,703	132
Subtotal within Study Area	22,447	8,614,277	384
TOTALS	27,784	9,386,930	338

About 68% of total OCS tonnage was carried via the Atchafalaya River (6.2 million tons). The next largest amounts of tonnage were transported via the Waterway Gulf via Grand Pass and Ostrica Canal (585,000 tons), Bayou Lafourche (347,000 tons), and Houma Navigation Canal (278,000 tons). All but six waterways had at least 3,000 tons of OCS cargo.

Data Reliability

While WCSC data for vessels on inland waterways represent over 90% of all vessels, offshore vessel data are not as complete. This section begins with a description of the offshore vessel industry and some vessel types currently in use. Problems with the WCSC data are then presented, such as non-reporting companies, changes in vessel use caused by oil industry volatility, and limited vessel type reporting.

The vessels working for OCS can be divided mainly into three types: supply, crew, and utility vessels according to their function. *The Offshore Service Vessels Report* classifies vessels into 24 types. Only the seven most active types of vessels (those that carry workers and supplies and are included in WCSC statistics) were tabulated. Offshore vessels are listed as small (60-149 feet, usually 100-120 feet) or large (150 feet or more, usually 160-200 feet).

The data from the Offshore Reporting Service may also have deficiencies. Problems could affect the accuracy of the data, such as lack of data on foreign flag vessels, special purpose vessels, vessels located overseas, vessels located off California or in Alaskan waters, vessels on long-term contracts in specialized fields, vessels that have been repossessed or in the process of repossession, inactive vessels including newer vessels in poor condition, and older vessels laid up for disposal or scrapping. Therefore, this data source may not be completely accurate.

Table B-8 shows that most vessels are in the large category (68%). These vessels are generally about 180 feet long, have a 12-foot draft when loaded, and can carry 300 tons of materials, such as drill water, mud, cement, diesel fuel, drilling equipment, pipes, food, and water. A supply boat which can service from one to five rigs enters a port two or three times per week. Second, about 1,000 crewboats, 50 to 100 feet in length with 7 to 9 foot drafts frequently enter a port one to three times per day. Third, a smaller but unknown number of utility boats, about 100 feet in length with 10-to 12-foot drafts, generally perform a function at the rig and do not often enter ports.

Table B-8. Offshore vessel companies by size (Waterborne Commerce Statistical Center).

Company Size in Small Boat Equivalence		Number of Companies	Boats Number	Boats Percent	Average
Very Small	1 - 2	50	65	3	1.3
Small	3 - 5	47	175	9	3.7
Medium	6 - 14	49	397	20	7.9
Large	15+	39	1,317	68	33.8
TOTAL		185	1,944		

From Table B-8, total vessel count was almost 2,000. Yet, vessels tracked by WCSC in the Gulf of Mexico total only 731. Therefore, according to WCSC and vessels operators, at the present time only about 37% of offshore vessel traffic is reported:

731/1944 = 37% (vessels tracked by WCSC/estimated active offshore vessels) and,
76/185 = 42% (operators reporting to WCSC/estimated offshore operators).

It is unknown if the 37% represented by WCSC data uniformly reflects the Gulf area or if it is biased towards certain areas, such as Louisiana ports. WCSC conducted a survey in 1986 to determine which companies do not report data. A total of 829 vessels were identified. Table B-9 presents the number of vessels by waterway not reported in the 1985 WCSC waterborne traffic statistics. The waterway definitions are assumed based on the location of the companies. In some instances, a company may have vessels operating in other waterways not near the company office. When this was apparent from the data, these vessels were included with the "Outside of Study Area" category. Therefore, the waterway designations may not accurately reflect the distribution of vessel activity by waterway. Major OCS user waterways, such as the Atchafalaya River, Houma Navigation Canal, the Mississippi River, and Bayou Lafourche, are included in the listing with Vermilion Bay and the Calcasieu River. The inclusion of the latter two waterways could be the result of corporate offices located in Lafayette and Lake Charles.

Table B-9. Non-reporting vessels by area of vessel operation (in descending order).

Waterway	Number of Vessels Large	 Small	 Total
Outside of Study Area	69	142	211
Atchafalaya River	117	55	172
Vermilion Bay	40	103	143
Houma Nav. Canal	71	27	98
Mississippi River	56	39	95
Bayou Lafourche	34	35	69
Calcasieu River	0	41	41
TOTAL	387	442	829

All offshore vessels that operate principally out of about 14 ports on the Louisiana and Texas coasts are leased by oil companies. Leases vary considerably, from six months to several years. However, all leases allow termination of service given a short notice (24 to 72 hours). Vessel use can vary quickly with changes in active wellhead counts.

Another method often used to estimate vessel activity is the number of offshore vessels, i.e., the extent of offshore rig activity. Robert T. Lober, president and owner/operator of State Boat Corporation estimated in *The Work Boat,* March, 1985, that if there are 311 active rigs in the Gulf and 679 American-owned supply boats that are 15 years old or less with less than 4000 horsepower operating in the Gulf, a ration of 2.18 vessels per rig reflects an accurate estimate of OCS vessel activity. Mr. G. Allen Brooks writes in the same issue of *The Work Boat* that the ratio of vessels to drilling rigs averages 1.7 and the ratio of vessels to platforms is 0.25.

While it should be more accurate to separate vessels by rig activity because production rigs require far less activity than drilling rigs, the highest vessel per rig estimate was assumed for the analysis. According to Petroleum Information Corporation (*Sunday Advocate,* January 12, 1986), the average rotary rig count for 1985 was 1,969 compared with 2,341 in 1984. Therefore, applying a ratio of 2.18 vessels per rig, supply boat activity is estimated at 4,287. The total number of WCSC reporting vessels is 1,944 , 45% of the estimate based on rig counts.

Lockage data could be used to identify the total amount of vessels moving through a given waterway. However, only three coastal waterways record complete vessel counts for the COE Performance Monitoring System (PMS). Vessel trip data on those waterways are presented by PMS vessel categories in Table B-10.

Table B-10. Performance Monitoring System (PMS) lock vessel traffic data versus WCSC-based waterway estimates.

	Inner Harbor Navigational Canal		Calcasieu Lock		Freshwater Bayou	
	PMS	WCSC	PMS	WCSC	PMS	WCSC
Tonnage	24,008	91,436	40,219	147,049	4,027	26,288
Amount of WCSC Vessel Types	13,,146	12,409	14,083	57,275	5,590	3,355
Tows		12,905		14,079	440	
Cargo		241		4		5,150
Amount of Vessels Unreported to WCSC		9,516		2,375		27,351
Passenger Boats		25		4		0
Recreational		258		52		137
U.S. Government Tows		0		0		0
Other U.S. Government		260		10		15
Commercial Fishing		224		23		341
Other		1		2		3
Lightboats		2,082		158		10,553
Lightboats with others		5,962		1,833		13,19
Recreational with others		704		293		3,108
TOTAL		22,662		16,458		32,941

NOTE: The term "WCSC-based" data is used to distinguish the data totals referenced to WCSC from data published by WCSC. WCSC-based data are aggregated with additional data from sections of the GIWW.

Vessel trip data are also presented in Table B-10. Total vessel trips for PMS and WCSC comparable figures were different. Inner Harbor Navigation Canal figures were similar, PMS-13,146 and WCSC-12,409. The discrepancy could be attributed to activity from outside of the study area. WCSC Calcasieu Lock vessel trips were more than 43,000 trips greater than PMS statistics. This is because of the aggregation of data for the Calcasieu River and the amount of activity that does not use the lock. Freshwater Bayou PMS lock statistics are about 1,200 vessels greater than WCSC vessels trips. This discrepancy is most likely attributed to the lack of vessels reported to WCSC.

The volume of cargo carried by tows and cargo vessels (those covered by WCSC) represent varying degrees of significance with regard to total vessel traffic. Tow and cargo vessels represented almost 90% of total traffic through Calcasieu Lock in 1985. Only slightly more than 50% of total traffic through the Inner Harbor Navigation Lock are tow or cargo vessels. However, only 20% of these vessels used the Freshwater Bayou Lock.

Tonnage data based on WCSC data is at least 3.5 times greater than PMS data. The explanation for the discrepancies is primarily because of the methods WCSC employs in aggregating data to include entire waterways instead of one milepost, i.e., one section of a waterway such as a lock. A contributing explanation for the different estimates of tonnage could be the underestimation of tonnage carried through the locks.

Percentage OCS Use of Coastal Waterways

The percentage of OCS use of coastal waterways is presented in this section for WCSC data and extrapolations of that data based on the number of OCS vessels in the Gulf of Mexico and on Performance Monitoring System (PMS) data. Table B-11 presents estimates of OCS use by waterway. The first column of data presents OCS use by waterway based solely on data from WCSC. Waterway names are organized by waterway with highest WCSC-based OCS use. Based on these data, the Bayou Terrebonne category has the largest amount of OCS-use in the study area (46.7 %). The next highest OCS use waterways are Bayou Lafourche (21.3%), Empire Waterway (21.2%), Bayou La Loutre (19.3%), and Vermilion Bay (10.3%). The remaining waterways had less than 10% OCS use. Twelve of the remaining 19 waterways had less than 2% use.

Table B-11. Estimates of OCS percentage use of coastal waterways.

Name of Waterway (in order of WCSC-based % OCS Total)	WCSC-based Data %	Applied Only to Non-reporting Areas	Applied Equally %OCS/Total
Bayou Terrebonne & GIWW 14-59	46.7	N/C	70.3
Bayou Lafourche, LA	21.3	41.8	42.3
Empire, LA Waterway to Gulf	21.2	N/C	42.1
La Loutre/St. Malo/Yscloskey, LA	19.3	N/C	39.3
Vermilion Bay & GIWW 159-160	10.3	68.7	23.8
Houma/Le Carpe/Caillou Bayous/60-78	9.4	30.8	21.9
Bayou Dupre, LA	9.1	N/C	21.3
Freshwater Bayou & 161-193	8.0	N/C	18.9
Atchafalaya River & GIWW 79-95	7.7	32.8	18.4
Mermentau River, LA	6.1	N/C	14.9
Mississippi River & Passes	3.3	5.5	8.5
Bayou Teche, LA	2.1	N/C	5.5
Gulf via Bayou Barataria Bay	1.9	N/C	5.0
Bayou Casotte, MS	1.8	N/C	4.8
Innerharbor Navigation Canal	1.3	N/C	3.5
Lake Pontchartrain, LA	1.2	N/C	3.2
Calcasieu River	1.1	6.0	3.0
Mississippi River Gulf Outlet	0.9	N/C	2.3
Sabine Pass Harbor, TX	0.7	N/C	1.8
Beaumont, TX	0.3	N/C	0.8
Petit Anse/Tigre/Carlin Bayous	0.1	N/C	0.2
Merm/Nezpique/Des Cannes	0.1	N/C	0.2
Biloxi & Gulfport, MS	0.1	N/C	0.1
Pascagoula Harbor, MS	0.0	N/C	0.0
TOTALS	4.2	11.8	10.7

N/C - No change from WCSC-based numbers

The above OCS-use estimates are the most accurate available. However, because of the problems with WCSC data already discussed, alternative OCS use statistics were prepared.

Because WCSC has determined the 37% estimate for 1985 data, two alternative OCS-use estimates were prepared based on the amount of unreported vessels. One estimate is presented in which all WCSC data are extrapolated by the inverse of 37% for each waterway. These estimates are presented under the heading "Percent Reporting: Applied Equally," in Table B-11. This extrapolation resulted in an increase of OCS use by about 100% per waterway.

The other alternative use estimate was based on the location of non- reporting shipping companies. Table B-11 presents these data in the middle column. Those areas not listed in Table B-9 have "no change" in use estimates from the WCSC-based data. Using this procedure, Vermilion Bay and Calcasieu River estimates increased by a factor of five to six. Atchafalaya River, Houma Canal, and Bayou Lafourche estimates increased from 2 to 4.5 times.

PMS data were used to develop alternative total waterways estimates. Freshwater Bayou had the lowest percentage of vessels reported by WCSC to total lock traffic and Calcasieu Lock, the highest. This was done to provide the largest possible variation. Tables B-12 and B-13 present the results of this procedure with the new total traffic estimates and the percentage of OCS activity to total activity.

Table B-12. Total waterway estimates based on Freshwater Bayou data.

Name of Waterway (in order of WCSC-based % OCS/Total)	WCSC-based Data Total Traffic	% OCS/ Total (%)	Applied Equally Total Traffic	 OCS/ Total(%)	Applied Only to Non-reporting Areas Total Traffic	 OCS/ Total (%)
Bayou Terrebonne & GIWW 14-59	7,784	7.9	13,975	11.9	7,784	7.9
Bayou Lafourche, LA	84,633	3.6	115,356	7.2	114,392	7.1
Empire, LA Waterway to Gulf	35,899	3.6	48,873	7.2	35,899	3.6
La Loutre/St. Malo/Yscloskey, LA	4,213	3.3	5,598	6.7	4,213	3.3
Vermilion Bay & GIWW 159-160	33,047	1.8	38,867	4.0	94,716	11.7
Houma/Le Carpe/ Caillou Bayous/60-78	137,050	1.6	159,014	3.7	179,313	5.2
Bayou Dupre, LA	1,102	1.5	1,273	3.6	1,102	1.5
Freshwater Bayou & 161-193	19,770	1.4	22,450	3.2	19,770	1.4
Atchafalaya River & GIWW 79-95	198,701	1.3	224,809	3.1	272,874	5.6
Mermentau River, LA	38,380	1.0	42,343	2.5	38,380	1.0
Mississippi River & Passes	1,776,539	0.6	1,876,546	1.4	1,817,506	0.9
Bayou Teche, LA	20,265	0.4	20,998	0.9	20,265	0.4
Gulf via Bayou Barataria Bay	37,396	0.3	38,610	0.8	37,396	0.3
Bayou Casotte, MS	44,809	0.3	46,214	0.8	44,809	0.3
Innerharbor Navigation Canal	73,124	0.2	74,770	0.6	73,124	0.2
Lake Pontchartrain, LA	29,305	0.2	29,917	0.6	29,305	0.2
Calcasieu River	337,513	0.2	343,984	0.5	355,191	1.0
Mississippi River Gulf Outlet	33,931	0.1	34,423	0.4	33,931	0.1
Sabine Pass Harbor, TX	47,013	0.1	47,555	0.3	47,013	0.1
Beaumont, TX	3,931	0.1	3,951	0.1	3,931	0.1
Petit Anse/Tigre/Carlin Bayous	14,337	0.0	14,357	0.0	14,337	0.0
Merm/Nezpique/Des Cannes	31,173	0.0	31,203	0.0	31,173	0.0
Biloxi & Gulfport, MS	45,151	0.0	45,191	0.0	45,151	0.0
Pascagoula Harbor, MS	71,551	0.0	71,571	0.0	71,551	0.0
TOTALS	3,126,619		3,351,847		3,393,129	

Table B-13. Total waterway estimates based on Calcasieu Lock data.

Name of Waterway (in order of WCSC-based % OCS/Total)	WCSC-based Data	%	Applied	Equally	Applied Only to Non-reporting Areas	
	Total Traffic	OCS/ Total (%)	Total Traffic	OCS/ Total (%)	Total Traffic	OCS/ Total (%)
Bayou Terrebonne & GIWW 14-59	1,544	40.0	2,772	60.2	1,544	40.0
Bayou Lafourche, LA	16,784	18.2	22,877	36.2	22,686	35.8
Empire, LA Waterway to Gulf	7,119	18.2	9,692	36.1	7,119	18.2
La Loutre/St. Malo/Yscloskey, LA	836	16.5	1,110	33.6	836	16.5
Vermilion Bay & GIWW 159-160	6,554	8.8	7,708	20.3	18,784	58.8
Houma/Le Carpe/ Caillou Bayous/60-78	27,179	8.1	31,535	18.8	35,561	26.3
Bayou Dupre, LA	219	7.8	252	18.2	219	7.8
Freshwater Bayou & 161-193	3,921	6.8	4,452	16.2	3,921	6.8
Atchafalaya River & GIWW 79-95	39,405	6.6	44,583	15.8	54,115	28.1
Mermentau River, LA	7,611	5.2	8,397	12.7	7,611	5.2
Mississippi River & Passes	352,315	2.8	372,148	7.2	360,440	4.7
Bayou Teche, LA	4,019	1.8	4,164	4.7	4,019	1.8
Gulf via Bayou Barataria Bay	7,416	1.6	7,657	4.3	7,416	1.6
Bayou Casotte, MS	8,886	1.6	9,165	4.1	8,886	1.6
Innerharbor Navigation Canal	14,502	1.1	14,828	3.0	14,502	1.1
Lake Pontchartrain, LA	5,812	1.0	5,933	2.8	5,812	1.0
Calcasieu River	66,934	1.0	68,217	2.6	70,440	5.2
Mississippi River Gulf Outlet	6,729	0.7	6,827	1.9	6,729	0.7
Sabine Pass Harbor, TX	9,323	0.6	9,431	1.5	9,323	0.6
Beaumont, TX	779	0.3	783	0.7	779	0.3
Petit Anse/Tigre/Carlin Bayous	2,843	0.1	2,847	0.2	2,843	0.1
Merm/Nezpique/Des Cannes	6,182	0.0	6,188	0.1	6,182	0.0
Biloxi & Gulfport, MS	8,954	0.0	8,962	0.1	8,954	0.0
Pascagoula Harbor, MS	14,190	0.0	14,194	0.0	14,190	0.0
TOTALS	620,057		664,724		672,911	

Table B-12 presents total waterway estimates based on Freshwater Bayou Lock statistics. Resulting OCS use for the category WCSC-based data was about 10% of the unadjusted figure. Likewise, the alternative OCS use estimates were reduced significantly. Table B-13 indicates that the use of Calcasieu Lock WCSC-based data was about 90% of the unadjusted data. Using the alternative OCS use estimate category "Applied Equally" resulted in the highest OCS percentage use figures for all waterways except three. Those three, Vermilion Bay, Houma Canal, and Atchafalaya River were more influenced by the scenario under which only non-reporting areas were adjusted.

Arguments can be made to support the use of Freshwater Bayou or Calcasieu Lock data or neither. Some coastal waterways vessel traffic may resemble one over the other. Freshwater Bayou traffic represents less than 6% of the traffic volume on the Calcasieu River. Using traffic volume levels as the criteria for selecting one estimate over the other, four waterways (Calcasieu, Houma, Atchafalaya and the Mississippi River) would more resemble Calcasieu PMS data estimates. The other twenty waterways would more closely resemble Freshwater

Bayou PMS data. This would mean that the lower percentage use estimates would be more appropriate for most of the waterways considered in the study area.

Table B-14 summarizes the high/low range of estimates of OCS use as a percentage of total waterway use for each waterway. WCSC-based data percent use figures are presented again for reference. Use estimates vary considerably. WCSC-based data tend to represent the midpoint between the high/low estimates in most cases. The low percentage use estimates are all less than 8% for OCS use. Only two waterways have high estimates that are greater than 50%. No waterway has OCS use greater than 50% for the WCSC-based data.

Table B-14. Percentage use of coastal waterways for OCS Activities: alternative high/low estimates.

Name of Waterway (in order of WCSC-based % of OCS /total)	WCSC-Based Data	Alternative Estimates		Footnotes	
		High	Low	High	Low
Bayou Terrebonne & GIWW 14-59	46.7	60.2	7.9	a	c
Bayou Lafourche, LA	21.3	36.2	3.6	a	d
Empire, LA Waterway to Gulf	21.2	36.[a]	3.6	a	c
La Loutre/St. Malo/Yscloskey, LA	19.3	33.6	3.3	a	c
Vermilion Bay & GIWW 159-160	10.3	58.8	1.8	b	d
Houma/Le Carpe/Caillou Bayous/60-78	9.4	26.3	1.6	b	d
Bayou Dupre, LA	9.1	18.2	1.5	a	c
Freshwater Bayou & 161-193	8.0	16.2	1.4	a	c
Atchafalaya River & GIWW 79-95	7.7	28.1	1.3	b	d
Mermentau River, LA	6.1	12.7	1.0	a	c
Mississippi River & Passes	3.3	7.2	0.6	a	d
Bayou Teche, LA	2.1	4.7	0.4	a	c
Gulf via Bayou Barataria Bay	1.9	4.3	0.3	a	c
Bayou Casotte, MS	1.8	4.1	0.3	a	c
Innerharbor Navigation Canal	1.3	3.0	0.2	a	c
Lake Pontchartrain, LA	1.2	2.8	0.2	a	c
Calcasieu River	1.1	5.2	0.2	b	d
Mississippi River Gulf Outlet	0.9	1.9	0.1	a	c
Sabine Pass Harbor, TX	0.7	1.5	0.1	a	c
Beaumont, TX	0.3	0.7	0.1	a	c
Petit Anse/Tigre/Carlin Bayous	0.1	0.2	0.0	a	c
Merm/Nezpique/Des Cannes	0.1	0.1	0.0	a	c
Biloxi & Gulfport, MS	0.1	0.1	0.0	a	c
Pascagoula Harbor, MS	0.0	0.0	0.0	a	c

[a] High estimates attributed to adjusting OCS data equally by the inverse of 37% and for the category where total is adjusted by Calcasieu Lock PMS distribution with the same OCS data adjustments.

[b] High estimates attributed to adjusting OCS data for waterways with non-reporting companies alone and for the category where total waterway traffic is adjusted by Calcasieu Lock PMS distribution with the same OCS data adjustments.

[c] Low estimates attributed to the adjustment of total waterway traffic by the Freshwater Bayou PMS distribution using unadjusted WCSC-based OCS data and the adjustments to OCS data by non-reporting area.

[d] Low estimates attributed to the adjustment of total waterway traffic by the Freshwater Bayou PMS distribution using unadjusted WCSC-based OCS data.

Conclusion

While this report has demonstrated several problems with the presentation of navigation data for the study area, percentage OCS use estimates have been derived. However, after accounting for problem areas by applying other sources, such as number of reporting vessels and lock statistics, it appears that WCSC-based data present a mid-range estimate of OCS use of coastal waterways. However, with the potential for the extent of variation as was presented in Table B-14, a clear incontestable estimate cannot be presented from available secondary sources. Only additional study of this very complex subject can more precisely identify the degree of use of coastal waterways for OCS activities.

Additional Study Needs

The degree and extent of OCS use can be determined by conducting primary research and using field surveys. However, this method cannot identify tonnage nor origin/destination information without direct access to information in the ship's logs. Only WCSC data can be used for those purposes. In this regard, this chapter makes a contribution to that body of knowledge. Nonetheless, field surveys could be used for total vessel traffic data per waterway or as the basis for extrapolations to estimate total vessel traffic.

Of critical importance, however, are the purposes for which OCS percentage use estimates will be utilized. As an indicator for the environmental impact of navigation traffic on coastal waterways, percentage-use estimates could incorrectly estimate environmental consequences. As was discussed in the presentation of vessel type data, it is possible that self-propelled vessels could have less effect on channel and bank integrity than tugboats and towboats. Also, the number of vessels may not be as important a factor as the speed at which the vessel travels. For example, the self-propelled passenger boat may travel faster than tugboats. Therefore, such estimates must be determined to assess the environmental effect of navigation on coastal waterway.

The application of state-of-the-art techniques to determine vessel speed and consequent rate of environmental degradation should be performed. Dr. Anatoly Hochstein of LSU has developed such a methodology and tested it in several recent studies. The methodology has been verified by field measurements and calibrated for the Ohio River (Gallipolis Lock and Dam Replacement Study, 1977), Kanawah River (Winnfield Lock and Dam Replacement Study, 1985), Tennessee-Tombigbee (Litigation, 1981-83), the Upper Mississippi and Illinois Rivers (Upper Mississippi System Master Plan, 1972-73), and St. Mary River (Extension of Navigation Season for the Great Lakes Connecting Study, 1986). The methodology has been successfully applied and calibrated for these five waterway studies and should be performed for the Gulf Coast.

Appendix C

SALTWATER INTRUSION MODEL FOUNDATION

by

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Governing Equations of Saltwater Intrusion

The governing equations of the two-dimensional flow systems describing the salt water intrusion problems (Figure C-1) are the laterally integrated equations of motion, the equation of continuity, the salinity conservation equation, and the equation of state as follows.

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{1}{\rho}\frac{\partial}{\partial x}\left(\rho N_x \frac{\partial u}{\partial x}\right) + \frac{1}{\rho}\frac{\partial}{\partial y}\left(\rho N_y \frac{\partial u}{\partial y}\right) \tag{Eqn. C. 1}$$

$$\frac{1}{\rho}\frac{\partial p}{\partial y} + g = 0 \tag{Eqn. C. 2}$$

$$\frac{\partial u}{\partial x} + \frac{\partial w}{\partial y} = 0 \tag{Eqn. C. 3}$$

$$\frac{\partial C}{\partial t} + \frac{\partial (uC)}{\partial x} + \frac{\partial (wC)}{\partial y} = \frac{\partial}{\partial x}\left(K_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial C}{\partial y}\right) \tag{Eqn. C. 4}$$

$$\rho = \rho_f\,(\alpha + \beta\, C) \tag{Eqn. C. 5}$$

in which

x = longitudinal axis (positive upstream)
y = vertical axis (positive upward)
t = time
u = horizontal velocity (width-averaged)
w = vertical velocity (width-averaged)
p = dynamic pressure
C = salinity concentration
g = gravitational acceleration
ρ = local water density
ρ_f = freshwater density
N_x = horizontal eddy viscosity coefficient
N_y = vertical eddy viscosity coefficient
K_x = horizontal diffusion coefficient
K_y = vertical diffusion coefficient, and
α, β = coefficients related to temperature
$\alpha = 1.\ \beta = 0.001\ \mathrm{ppt}^{-1}$

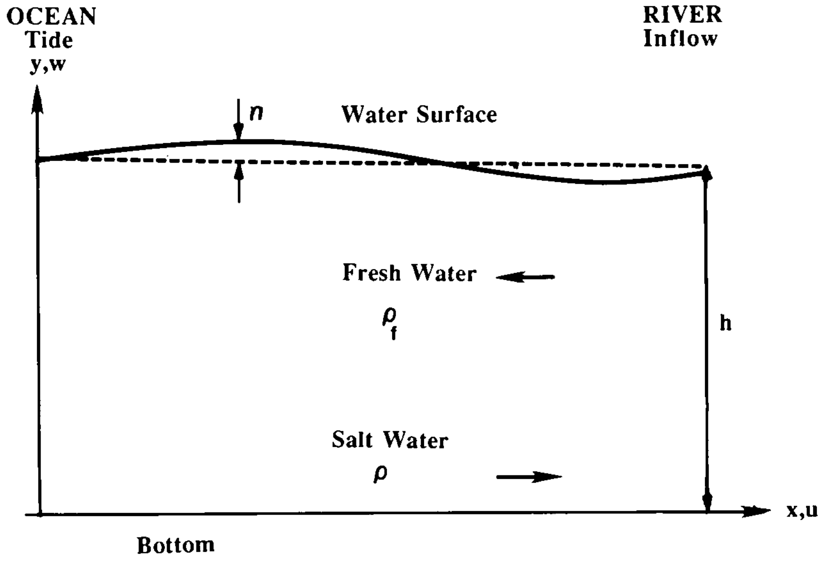


Figure C-1. Definition sketch of a two-dimensional flow system.

Boundary Conditions for Velocity Field

The boundary conditions for the velocity field are prescribed in the following:

(1) The bottom boundary condition is the no-slip condition

$u = w = 0$ at $y = 0$ (Eqn. C. 6)

(2) The surface boundary condition is imposed by the wind shear stress, τ_W, computed as

$$\tau_w = \rho N_y \frac{\partial u}{\partial y} = \rho_a c_d |W| W \cos\theta \qquad \text{(Eqn. C. 7)}$$

where ρ_a is the air density = 1.266 x 10-3 g/cm3, W is the wind speed, θ is the angle between the channel axis and the direction of wind, and C_d is the drag coefficient (Wu, 1982). For no-wind condition, Eqn. C.7. implies a zero velocity gradient at the free surface, that is, $\partial u/\partial y = 0$ at $y = \eta$.

(3) A single harmonic tide is imposed at the ocean side

$\eta(x, t) = a \sin \sigma t$ at $x = 0$ (Eqn. C. 8)

where a is the tidal amplitude at the ocean side, and σ is the tidal frequency = 2II/T, and T is the tidal period.

(4) The freshwater discharge, q in cms/m, is given at the upstream end of the channel. The initial velocity in the channel at the beginning of time period is assumed zero

$u = w = 0$ at $t = 0$ (Eqn. C. 9)

Boundry Conditions for Salinity Concentration

The boundary conditions for the salinity consevation equation, Eqn. C.4, are stated in the following:

(1) There is no salt flux through the channel bottom

$$\frac{\partial C}{\partial y} = 0 \qquad \text{at } y = 0 \qquad \text{(Eqn. C. 10)}$$

2) There is no salt flux across the channel water surface

$$\frac{\partial C}{\partial y} = 0 \qquad \text{at } y = h+\eta \qquad \text{(Eqn. C. 11)}$$

where h is the channel water depth, and η is the free surface elevation

(3) The salinity at the ocean side is specified as

$$C(x,y) = C(y) \qquad \text{at } x = 0 \qquad \text{(Eqn. C. 12)}$$

(4) The salinity at the upstream end of the channel is given or known. The initial values of salinity in the channel is either zero or specified.

Simplified Solution for Velocity Field

It has not been possible to obtain the exact solution of the hydrodynamic equations and the salt mass transport equation as presented in previous section (Eqns. C.1 to C.12). Investigators have to make assumptions regarding various processes governing the dynamic structure of velocity field problems being studied.

Lung and O'Connor (1984) presented an analytical approach to obtain an approximate solution of the general equations of velocity field (Eqn. C.1 to Eqn. C.3), after simplifications were made to keep the problem tractable. Under the steady-state and tidally averaged conditions for a partially stratified flow, the longitudinal momentum equation, Eqn. C.1, can be simplified as

$$Uo\frac{\partial Uo}{\partial x} + \frac{1}{\rho}\frac{\partial p}{\partial x} = N\frac{\partial^2 u}{\partial y^2} \qquad \text{(Eqn. C. 13)}$$

where U_0 is the amplitude of tidal current, and N is the vertical eddy viscosity assuming constant with depth. Other equations, Eqns. C.2 to C.3, are remained the same. They further used a linear function of salinity variation in the vertical direction

$$C(x,y) = C_s(x)\,\Phi(y) \qquad \text{(Eqn.C. 14)}$$

and

$$\Phi(y) = 1 + ay \qquad \text{(Eqn.C. 15)}$$

in which C_s is the surface salinity at a given station, ϕ (y) is a linear function of salinity, and a is a coefficient expressing the linear relationship in salinity with depth. Both $C_s(x)$ and $\phi(y)$ have to be determined from available data or measured.

Integrating the momentum equation, Eqn. C.13, twice, incorporating the surface and bottom boundary conditions, and utilizing the assumed linear function of salinity variation, the analytical solution for the horizontal velocity at a given station under the no-wind condition is obtained by Lung and O'Connor (1984) and expressed as

$$u(y) = \frac{1}{2N}(gs + U_o\frac{\partial U_0}{\partial x})(y^2 - h^2) - \frac{g\alpha\, dC_s}{Ndx}\int_y^h \{\int_{-\eta}^y [\int_{-\eta}^y \phi(y)dy]dy\}dy -$$
$$g\alpha C_s \int_y^h \{\int_{-\eta}^y \frac{\partial}{\partial x}[\int_{-\eta}^y \phi(y)dy]dy\}dy \qquad \text{(Eqn. C. 16)}$$

In this study, Lung and O'Connor approach are extended to include the effect of wind stress on velocity distribution. Similarly, integrating Eqn. C.13 twice and utilizing the wind shear stress boundary condition, Eqn. C.7, at the surface instead, the analytical solution of horizontal velocity *with* wind is derived

$$u(y) = \frac{1}{N}C_w U_w^2(y-h) + \frac{1}{2N}(gs + U_o\frac{\partial U_0}{\partial x})(y^2 - h^2) - \frac{g\alpha\, dC_s}{Ndx}\int_y^h \{\int_{-\eta}^y [\int_{-\eta}^y \phi(y)dy]dy\}dy -$$
$$g\alpha Cs \int_y^h \{\int_{-\eta}^y \frac{\partial}{\partial x}[\int_{-\eta}^y \phi(y)dy]dy\}dy \qquad \text{(Eqn. C. 17)}$$

By comparing Eqn. C.16 with Eqn. C.17, the effect of wind on velocity distribution is obvious. The wind stress changes the shape of velocity profile depending on the magnitude and the direction of the wind. Figure C-2 displays the analytical results of horizontal velocity profiles without and with wind, respectively.

The Lung and O'Connor (1984) procedure of velocity calculations indicates that local conditions control the magnitude of horizontal velocity at a give station. They further suggest that the salinity intrusion problem can be solved by decoupling the equations of motion and salt transport.

Analytical Solutions for Saline Wedge

An analytical approach to estimate the shape and the length of salt wedge has been given by Schijf and Schonfeld (1953). Their approach was based on assumptions of two-layered homogeneous flow with no salt exchange across the interface, a constant interfacial stress coeffiecient, negligible velocity in the lower layer, and neglible bottom stress.

The two-layered homogenous flow system represents a special case of stratified flows. The governing equations for such a flow system are greatly simplified and can be written for the separate layers (Figure C-3). The momentum equations for the upper and lowers layers become:

$$\frac{dh_1}{dx} + \frac{dh_2}{dx} + \frac{u_1}{g}\frac{du_1}{dx} + S_{1E} - S_b = 0 \qquad \text{(Eqn. C. 18)}$$

$$(1 - \frac{\Delta\rho}{\rho})\frac{dh_1}{dx} + \frac{dh_2}{dx} + \frac{u_2}{g}\frac{du_2}{dx} + S_{2E} - S_b = 0 \qquad \text{(Eqn.C. 19)}$$

and the continuity equations for the upper and lower layers are:

$$u_1\frac{dh_1}{dx} + h_1\frac{du_1}{dx} = 0 \qquad \text{(Eqn. C. 20)}$$

$$u_2\frac{dh_2}{dx} + h_2\frac{du_2}{dx} = 0 \qquad \text{(Eqn. C. 21)}$$

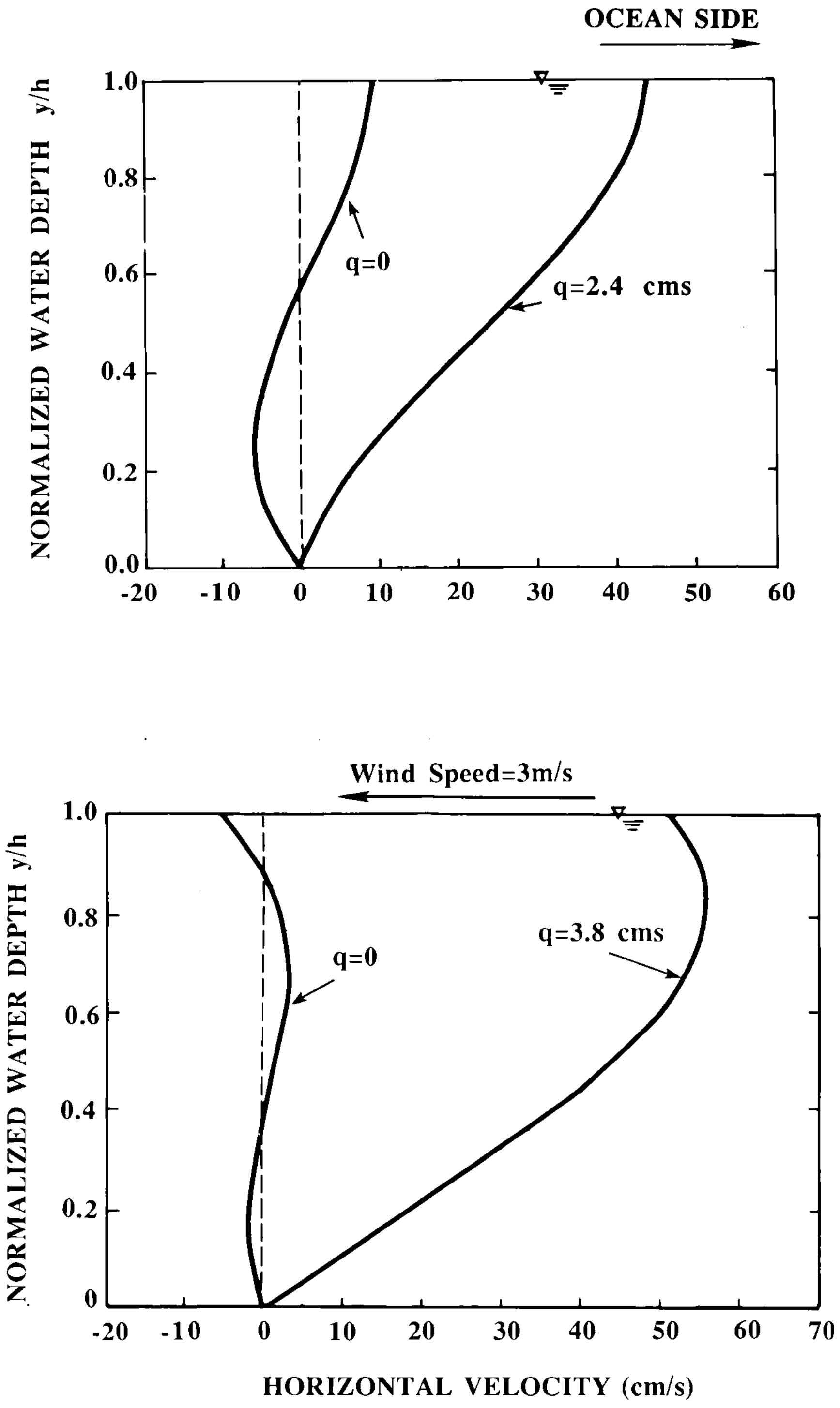


Figure C-2. Simplified analytical solution of velocity profiles; (a) without wind (Lung and O'Conner, 1984; (b) with wind (this study).

where

h_1, h_2 = water depth of the upper and lower layers
u_1, u_2 = average velocity in the upper and lower layers
ρ_1, ρ_2 = water density in the upper and lower layers
S_b = slope of the channel botttom
S_{1E}, S_{2E} = energy gradient of the upper and lower layers.

The energy gradients are defined by:

$$S_{1E} = \frac{\tau_i}{\rho g h_1} \qquad \text{(Eqn. C. 22)}$$

$$S_{2E} = -\frac{\tau_i}{\rho g h_2} \qquad \text{(Eqn. C. 23)}$$

where

τ_i = shear stress at the interface and is given by

$$\tau_i = \frac{f_i}{8} \rho \, |u_1| \, u_1 \qquad \text{(Eqn. C. 24)}$$

in which

fi = interfacial friction coefficient

The simplified one-dimensional momentum and continuity equations, Eqns. C.18 to C.24, have been used to solve the problem of the stationary or arrested salt wedge in an idealized estuary Harmeman (1961). Under the steady-state condition, the shape and the position of the wedge relative to the ocean entrance can be determined by noting that the salt wedge will intrude inland till the freshwater flow of the upper layer becomes critical at the ocean entrance, and the saline wedge becomes arrested (Fig. C.3)

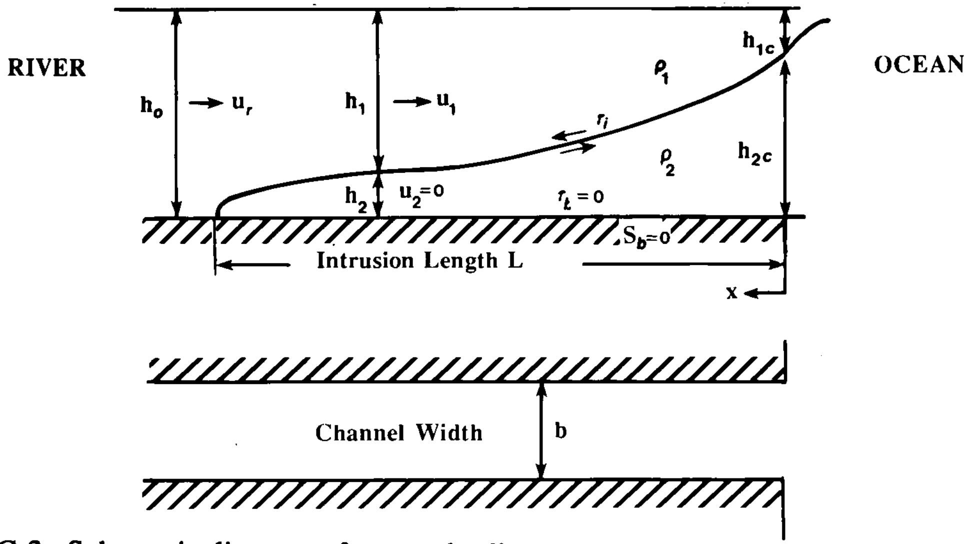


Figure C-3. Schematic diagram of arrested saline wedge (after Dermiss and Parthenides, 1985).

The analytical solutions for the shape, x/h_0 versus h_1/h_0, and the length, L, of the arrested wedge obtained by Schijf and Schonfeld (1953), Harleman (1961), and Dermisis and Parthenides (1985) are expressed as:

$$\frac{x}{h_0} = \frac{8}{f_1}\frac{h_1}{h_0}\left[\frac{1}{5\,(F_0')^2}\left(\frac{h_1}{h_0}\right)^4 - \frac{1}{4(F_0')^2}\left(\frac{h_1}{h_0}\right)^3 - \frac{1}{2}\left(\frac{h_1}{h_2}\right) + 1\right] + 3\,(F_0')^{2/3}\left[\frac{1}{10}(F_0')^{2/3} - \frac{1}{4}\right] \qquad \text{(Eqn. C. 25)}$$

$$L = \frac{2}{f_1}h_0\left[\frac{1}{5(F_0')^2} - 2 + 3\,(F_0')^{2/3} - \frac{6}{5}(F_0')^{4/3}\right] \qquad \text{(Eqn. C. 26)}$$

in which

h_0 = total water depth
F_0' = densimetric Froude Number for the water column h_0, and is given by

$$(F_0')^2 = \frac{u_r^{\,2}}{\frac{\Delta\rho}{\rho}gh_0} \qquad \text{(Eqn. C. 27)}$$

u_r = velocity of river inflow, and
$\Delta\rho$ = density difference of two layers.

Officer (1976) further simplified the above analytical solution and presented the following equation to calculate the shape and the length of the saline wedge.

$$\frac{x}{h_0} = \frac{2}{f_i\,\gamma}\left[\frac{1}{4}n_2^{\,4} + \frac{3}{2}n_2^{\,2} + (8 + \gamma)(n_2 + 3\ln\frac{3-n_2}{3})\right. \qquad \text{(Eqn. C. 28)}$$

in which

$$n_2 = \frac{h_2}{h_0} \qquad \text{(Eqn. C. 29)}$$

$$\gamma = \frac{\rho_1 q^2}{(\rho_2 - \rho_1)gh_0^{\,3}} \qquad \text{(Eqn. C. 30)}$$

q = freshwater discharge per unit width

From Eqns. C.25, C.26, and C.28, they reveal that, in the absence of wind and tide, the shape and the length of saline wedge are highly depend on the freshwater discharge, q, the water depth h_0, and the density of fresh and saline water, ρ_1 and ρ_2.

These variables are grouped into a single dimensionless parameter, γ, as defined in Eqn. C.30. Figures C-4a and C-4b depict relationship of salt wedge length as functions of freshwater discharge and water depth respectively.

Momentum Equation in Finite Difference Form

From Eqn. C.2, the dynamic pressure p(x,y) can be expressed as

$$p(x,y) = g\int_y^{\eta}\rho dy = g\rho_f\int_y^{\eta}[\alpha + \beta C(x,y)]dy \qquad \text{(Eqn. C. 31)}$$

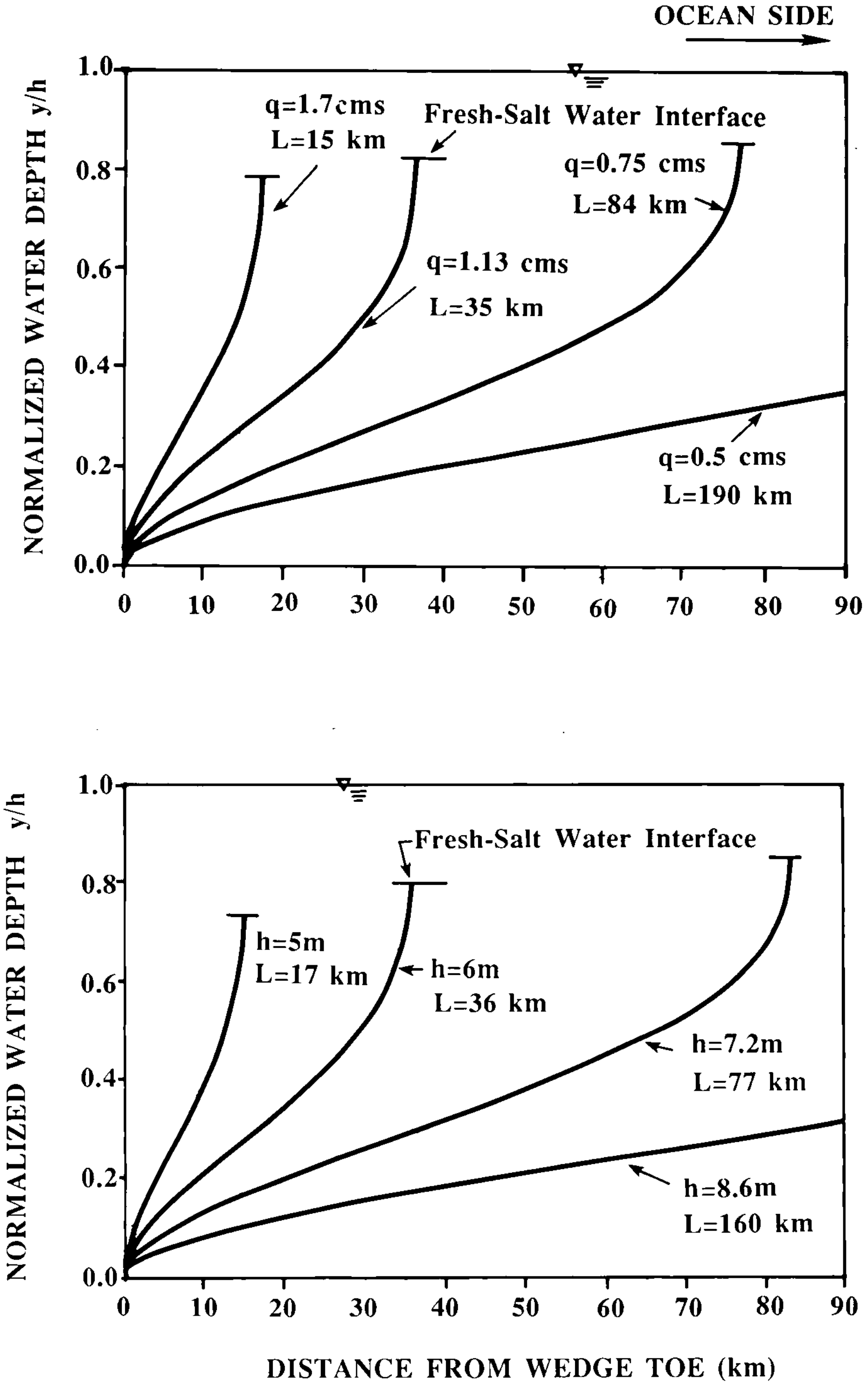


Figure C-4. Analytical results showing the relationsip of salt wedge length L as a function of (a) freshwater discharge q; (b) channel water depth h.

where η is the free surface elevation (Figure C-1).

The pressure gradient in x-direciton is then obtained by using the Leibnitz's rule (Wylie, 1966), it gives

$$\frac{1}{\rho}\frac{\partial p}{\partial x} = \frac{g}{\alpha + \beta C(x,y)} \{\frac{\partial \eta}{\partial x}(\alpha + \beta C_s) + \beta \int_y^\eta \frac{\partial C(x,y)}{\partial x} dy\} \qquad \text{(Eqn. C.32)}$$

Substitution of Eqn. C.32 into Eqn. C.31 yields

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} + \frac{1}{\rho}\frac{\partial}{\partial x}(\rho N_x \frac{\partial u}{\partial x}) + \frac{1}{\rho}\frac{\partial}{\partial y}(\rho N_y \frac{\partial u}{\partial y}) - \frac{g}{\alpha + \beta C(x,y)} \{\frac{\partial \eta}{\partial x}(\alpha + \beta C_s) + \beta \int_y^\eta \frac{\partial C(x,y)}{\partial x} dy\} \qquad \text{(Eqn. C.33)}$$

The Double Sweep Method (Abbott, 1980), a semi-implicit numerical approach is selected to solve Eqn. C.33. The time level considered for each term in Eqn. C.33 is given below:

n & n+1, n, n, n & n+1, n & n+1/2

With this arrangement, implicit in the y-direction only, the stability of numerical computation is greatly improved, and the constraint imposed on small vertical grid size is relaxed.

The finite difference form for the momentum equation, Eqn. C.33, is then formulated into the following format:

$$\frac{u_{i,j}^{n+1} - u_{i,j}^{n}}{\Delta t} = \frac{(u^n_{i+\frac{1}{2},j})^2 - (u^n_{i-\frac{1}{2},j})^2}{0.5(\Delta x_i + \Delta x_{i-1})} + \frac{(\rho N_x \frac{\partial u}{\partial x})^n_{i+\frac{1}{2},j} - (\rho N_x \frac{\partial u}{\partial x})^n_{i-\frac{1}{2},j}}{\rho_{i-\frac{1}{2},j} 0.5(\Delta x_i + \Delta x_{i-1})} +$$

$$\frac{(\rho N_y \frac{\partial u}{\partial y})^n_{i,j+1/2} - (\rho N_y \frac{\partial u}{\partial y})^n_{i,j-1/2}}{2\rho_{i,j}\Delta y_j} - \frac{(\rho N_y)^n_{i,j+1/2}(\frac{\partial u}{\partial y})^{n+1}_{i,j+1/2} - (\rho N_y)^n_{i,j-1/2}(\frac{\partial u}{\partial y})^{n+1}_{i,j-1/2}}{2\rho_{i,j}\Delta y_j} +$$

$$\frac{g}{\alpha + \beta C^n_{i,j}} [\frac{\eta^{n+1/2}_{i+1} - \eta^{n+1/2}_{i}}{0.5(\Delta x_i + \Delta x_{i-1})}(\alpha + \beta C^n_{i,J}) + \sum_{k=j}^{J} \frac{\beta C^n_{i,j} - \beta C^n_{i-1,j}}{0.5(\Delta x_i + \Delta x_{i-1})} \Delta y_k \qquad \text{(Eqn.C. 34)}$$

where the subscripts i+1/2 and j+1/2 stand for the average value of u and w between i and i+1 and j and j+1, respectively. The superscript n+1/2 implies the center of each time step.

For convenience, Eqn. C.34 can be written in term of horizontal velocity, u, at time level n+1 as

$$Au^{n+1}_{i,j+1} + Bu^{n+1}_{i,j} + Cu^{n+1}_{i,j-1} = D \qquad \text{(Eqn. C. 35)}$$

where, A, B, and C are coefficients associated with $u_{i,j+1}$, $u_{i,j}$ and $u_{i,j-1}$ at time level n; and the coefficient D is associated with those u terms at time level n and n+1/2.

Salinity Concentration in Finite Difference Form

Similarly, the finite difference form for the salinity conservation, Eqn. C.4, is formulated into a semi-implicit numerical scheme as follows:

$$\frac{C_{i,j}^{n+1} - C_{i,j}^{n}}{\Delta t} = \frac{u_{i+1,j}^{n} C_{i+1/2,j}^{n} - u_{i,j}^{n} C_{i-1/2,j}^{n}}{\Delta x_i} - \frac{w_{i,j+1}^{n} C_{i,j+1/2}^{n} - w_{i,j}^{n} C_{i,j-1/2}^{n}}{2\Delta y_j} -$$

$$\frac{w_{i,j+1}^{n} C_{i,j+1/2}^{n+1} - w_{i,j}^{n} C_{i,j-1/2}^{n+1}}{2\Delta y_j} + \frac{(K_x \frac{\partial C}{\partial x})_{i+1,j}^{n} - (K_x \frac{\partial C}{\partial x})_{i,j}^{n}}{\Delta x_i} +$$

$$\frac{(k_y)_{i,j+1/2}^{n} (\frac{\partial C}{\partial y})_{i,j+1/2}^{n+1} - (k_y)_{i,j-1/2}^{n} (\frac{\partial C}{\partial y})_{i,j-1/2}^{n+1}}{2\Delta y_j} +$$

$$\frac{(K_y \frac{\partial C}{\partial y})_{i,j+1/2}^{n} - (K_y \frac{\partial C}{\partial y})_{i,j-1/2}^{n}}{2\Delta y_j}$$

(Eqn. C. 36)

Equation C.36 can be rearranged in terms of the concentration of salinity at time level n+1 and rewritten as

$$G\, C_{i,j+1}^{n+1} + H C_{i,j}^{n+1} + X C_{i,j-1}^{n+1} = S$$

(Eqn.C. 37)

where G, H, K, and S are coefficients associated with $C_{i,\,j+1}$, $C_{i,j}$, and $C_{i,\,j-1}$ at time level n.

Eddy Viscosity and Difference Coefficients

A functional form to estimate the vertical eddy viscosity coefficient is given by Bowden and Hamilton (1977) expressed as:

$$N_y = k^2 y^2 (1 - \frac{y}{h})^2 \left|\frac{\partial u}{\partial y}\right| \phi_1(RI)$$

(Eqn. C. 38)

where h is the total water depth, K is the Von-Karman constant, and ϕ is a function of the Richardson Number RI defined as

$$RI = \frac{g\, \partial\rho/\partial y}{\rho(\partial u/\partial y)^2}$$

(Eqn. C. 39)

$$\phi_1(RI) = (1 + \alpha_1 RI)^{q_1}$$

(Eqn. C. 40)

and the two constants, α_1 and q_1 need to be calibrated with field data.

The functional form of N_y as expressed in Eqn. C.38 arises from the necessity to express the Reynold stress components in terms of flow properties. The equations is derived based on the Prandtl's mixing length theory (Schlichting, 1968), and is taken into consideration of the effect of buoyancy as a damping factor on N_y (Munk and Anderson, 1948). The horizontal eddy viscosity, N_x, is selected as 10,000 m2/sec as discussed by Lin (1986).

Similarly, the vertical diffusion coefficient is also expressed in the functional form of

$$K_y = k^2 y^2 (1 - \frac{y}{h})^2 \left|\frac{\partial u}{\partial y}\right| \phi_2(RI) \qquad \text{(Eqn. C. 41)}$$

with

$$\phi_2(RI) = (1 + \alpha_2 RI)^{q_2} \qquad \text{(Eqn. C. 42)}$$

in which, α_2 and q_2 constants have to be field calibrated. The horizontal diffusion coefficient, K_x, is determined form calibration, a value of 105 to 106 times the vertical eddy coefficient was found to be satisfactory by Kuo et al. (1978).

Stability Criteria in Numerical Scheme

In a study of the Potomac River estuarine circulation, Blumberg (1977) performed a detailed stability analysis for his numerical model and found that two numerical stability conditions must be met:

(1) The Courant-Friedrichs-Lewy stability criterion (CFL condition)

$$\Delta t \leq \frac{\Delta x}{\sqrt{gh}} \qquad \text{(Eqn. C. 43)}$$

(2) The viscosity-disffusion criteria

$$\Delta t \leq \frac{(\Delta x)^2}{4N_y} \qquad \text{(Eqn. C. 44)}$$

$$\Delta t \leq \frac{(\Delta x)^2}{4K_y} \qquad \text{(Eqn. C. 45)}$$

in which

Δx = grid size in s derection,
Δy = grid size in y direction, and
Δt = interval of time step.
Ny = vertical eddy viscosity coefficient, and
Ky = vertical diffusion coefficient.

Equations C.43, C.44, and C.45 are used as the stability criteria in our numerical model. However, the time step, Δt, as computed from above equations, is adjusted slightly for the calculation of net salinity-induced current in this study.

Saltwater Intrusion Computer Model

A comprehensive computer model, PROGRAM SALT, is developed for this study. The model is designed for the computation of the approximate solutions of the velocity field and salinity distribution in coastal channels. PROGRAM SALT is written in PASCAL Language based on the numerical approach for solving the momentum, continuity, and salt

APPENDIX D

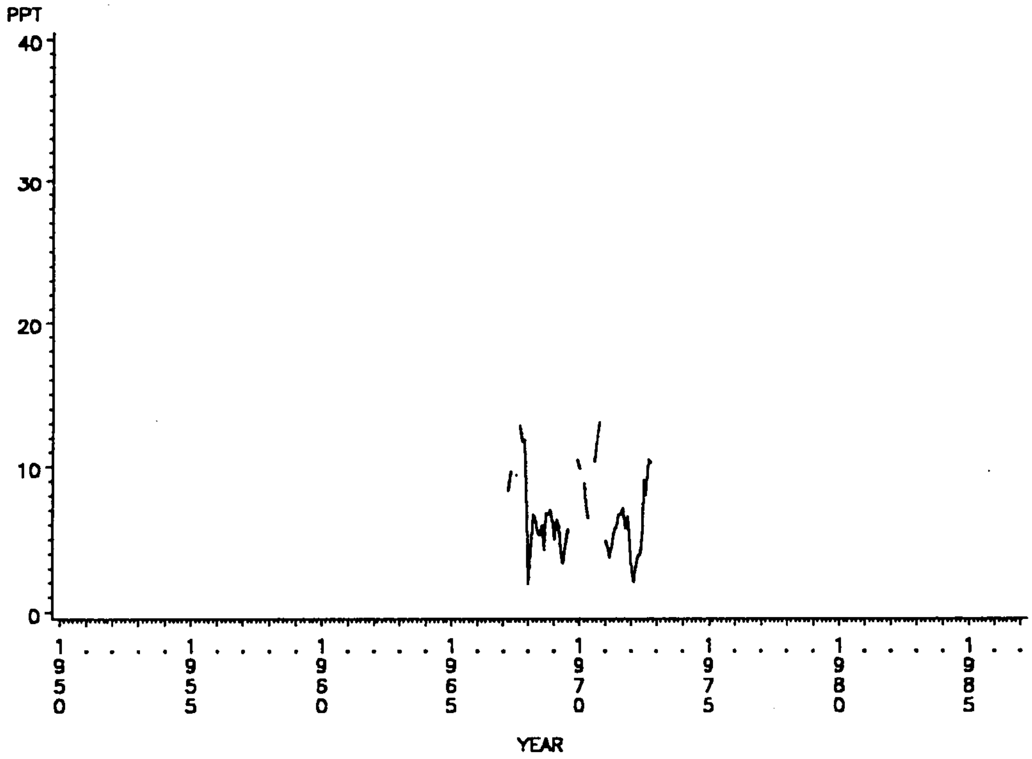
The following appendix contains two sets of data. The first set is a series of time series plots for the stations analyzed in Chapter 6. These are monthly mean salinities and the variance about the monthly mean salinity. The data comes from both the U. S Army Corps of Engineers (COE) and the Louisiana Department of Wildlife and Fisheries (LDWF). Before the time series plots we also present a list of station names and locations, as well as a map showing the locations. A number of points about the records should be noted. There are breaks in the records which make standard spectrum analysis difficult to interpret in a physically meaningful manner. The records are of varying lengths, which also contributes to the difficulty in applying standard spectrum comparisons. In addition, the records are of different character. The monthly mean salinities near the coast are dominated by the seasonal signal while those furthur up the estuaries are dominated by events. These events show up as spikes, which do not occur at a periodic interval.

The second data set is a series of table with estimates of persistance. The persistances were estimated from the daily salinity values. The daily values for the COE data are comprised of 8 A.M. readings, where as the dailly values for the LDWF data are daily averages from hourly readings. Both sets of values contain several gaps. These gaps are often so large, that a meaningful interpolation could not be made across the gaps. Thus, two estimates of the persistance were made. In one case, all the missing values were assumed to be zero salinity. This maximizes the number of high salinity events estimated, but minimizes their duration. In the other case, all missing values were assumed to be unrealistically high. This maximizes the the duration of the high salinity events.

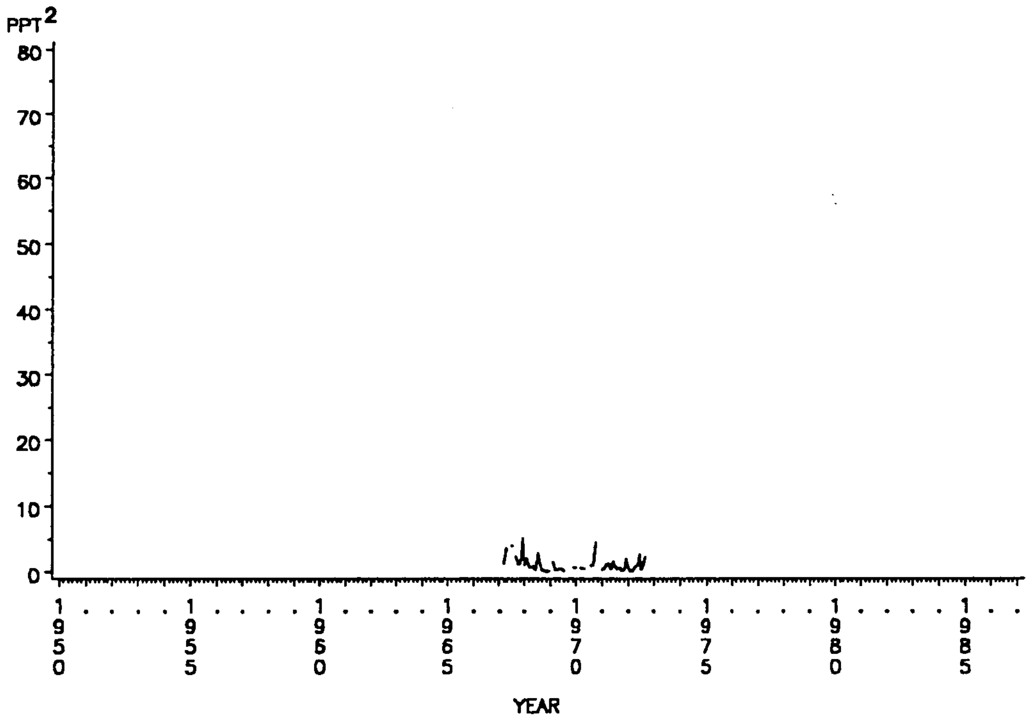
The results therefore give an upper and lower bound on the persistance estimate. The number of times that salinity exceeded and remained above a given level were counted. The levels used were 5, 10, 15, 20, and 25 ppt. The duration (in days) for each event was also counted. These data were used to produce the tables that follow. It is hoped that these data may be of use in estimating the probability of occurance of detrementally high salinities in the bayous and canals adjacent to the marsh.

Table D-1. List of stations used in the analysis. Indicated is the major water body, the station number and location description (5 digit numbers refer to USACOE data stations, 3 digit numbers refer to LDWF data stations). Summary statistics (mean, strandard deviation and number of observations) for the period of record are also presented. Asterisks refer to stations with weekly instead of daily samples.

		STATISTICS FOR PERIOD OF RECORD			
MAJOR WATER BODY	SALINITY STATIONS	MEAN PPT	SD PPT	N DAYS	
LAKE PONTCHARTRAIN	102 - CHEF MENTEUR	3.89	2.73	2157	
	118 - THE RIGOLETS	6.32	2.80	954	
	85683 - NORTH SHORE	4.01	2.41	976	
	85650 - LITTLE WOODS	3.95	2.35	10830	
	85700 - THE RIGOLETS	4.84	3.57	6378	
	85750 - CHEF MENTEUR	5.38	2.98	8189	
LAKE BORGNE	117 - GRAND PASS	16.25	5.85	856	
BRETON SOUND	221 - BAY GARDENE	13.61	5.07	2023	
	251 - LONG BAY	11.29	5.72	991	
	252 - CALIFORNIA BAY	17.14	5.85	806	
	253 - SABLE ISLAND	19.29	6.35	788	
	76042 - GIWW PARIS RD.	9.90	4.66	242	*
	85820 - MRGO @ NAVIG. LIGHT 101	15.28	6.97	275	*
BIRDS' FOOT DELTA	01500 - THE JUMP	0.42	1.25	1408	
	01420 - PORT SULPHUR	0.17	0.38	14862	
BARATARIA BAY	315 - MARINE LAB @ GRAND TERRE	20.90	5.71	7664	
	317 - ST. MARY'S POINT	12.90	6.36	2984	
	82203 - LAROSE	0.56	1.19	7951	
	82750 - BARATARIA	1.93	1.58	168	*
	82300 - GALLIANO	1.72	3.17	6527	
	82350 - LEEVILLE	15.50	5.45	7621	
TERREBONNE BAY	416 - COCODRIE	9.44	5.49	3370	
	76403 - B. TERR. @ BOURG	0.62	1.60	5854	
	76320 - GIWW @ HOUMA	0.34	1.04	10426	
	76323 - GR. CAILLOU @ DULAC	1.20	2.79	11117	
	76343 - HOUMA NAV. C. @ CROZIER	0.55	1.76	5883	
TERREBONNE MARSHES	518 - CAILLOU LAKE CAMP	10.76	5.14	2763	
	03780 - ATC. R. @ MORGAN CITY	0.07	0.05	6134	
	52800 - B. BOEUF @ AMELIA	0.14	0.11	1135	*
	64800 - B. TECHE @ PATTERSON	0.11	0.09	1467	*
ATCHAFALAYA-VERMILION BAYS	619 - CYPREMORT PT.	3.83	2.41	2046	
	620 - SOUTHWEST PASS	6.07	4.07	701	
	03720 - WAX LAKE OUTLET	0.06	0.04	5561	
	64450 - CHAR. DRAIN. C. @ BALDWIN	0.24	0.56	9772	
	64380 - B. TECHE @ CHARENTON	0.17	0.25	7970	
	88600 - ATC. R @ EUGENE ISLAND	4.93	7.16	3119	
	88850 - CYPREMORT PT.	4.90	3.46	7027	
CALCASIEU, SABINE, WHITE LAKES	701 - ROCKEFELLER S.	13.55	6.83	1490	
	702 - ROCKEFELLER N.	11.74	6.79	1283	
	719 - CAMERON	15.89	5.86	2939	
	76720 - GIWW VERM. LOCK EAST	1.73	2.28	3288	
	76800 - GIWW VERM. LOCK WEST	1.32	1.96	5874	
	76690 - SCHOONER BAYOU	1.33	1.04	647	*
	70675 - MERMENTAU RIVER	1.35	2.86	9367	

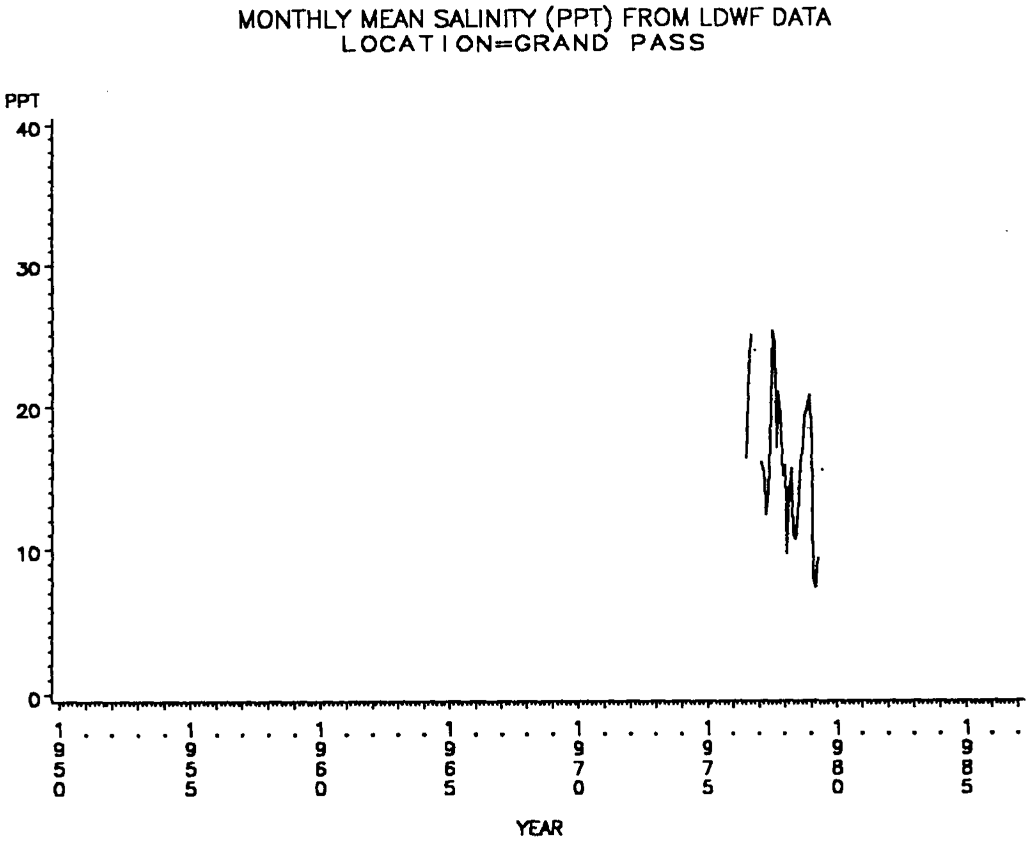


MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=THE RIGOLETS (L. PONT.)



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=THE RIGOLETS (L. PONT.)

Figure D-2. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from The Rigolets (LDWF station 102).



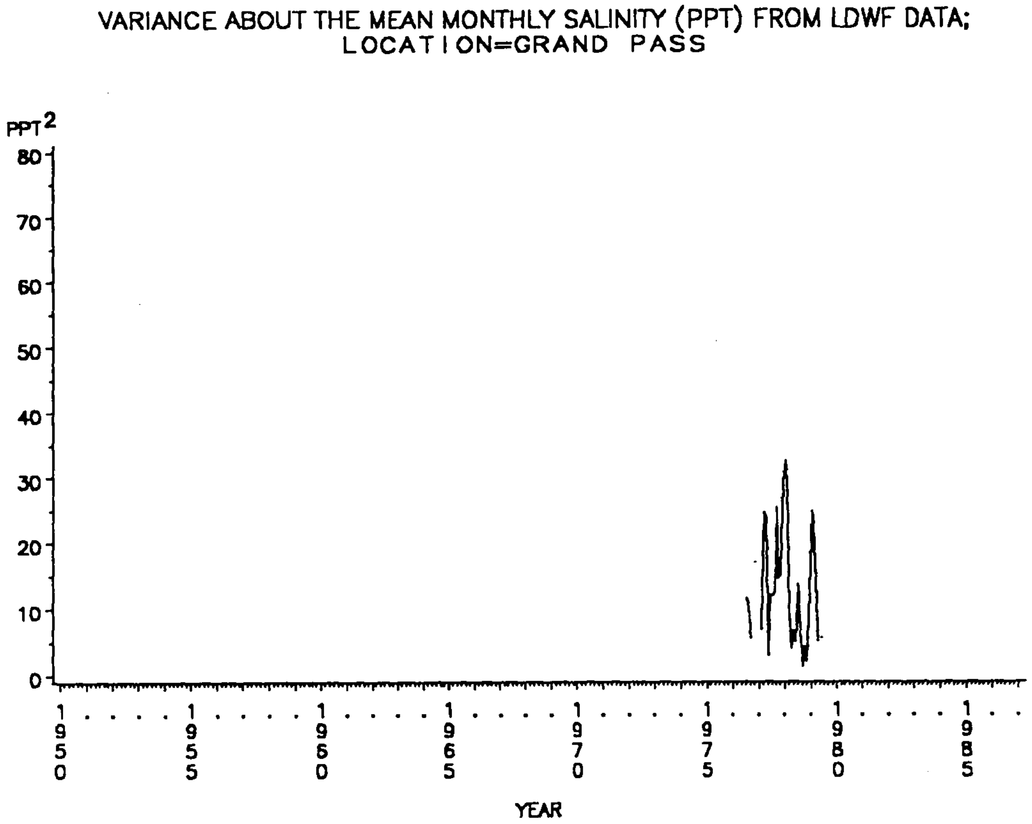
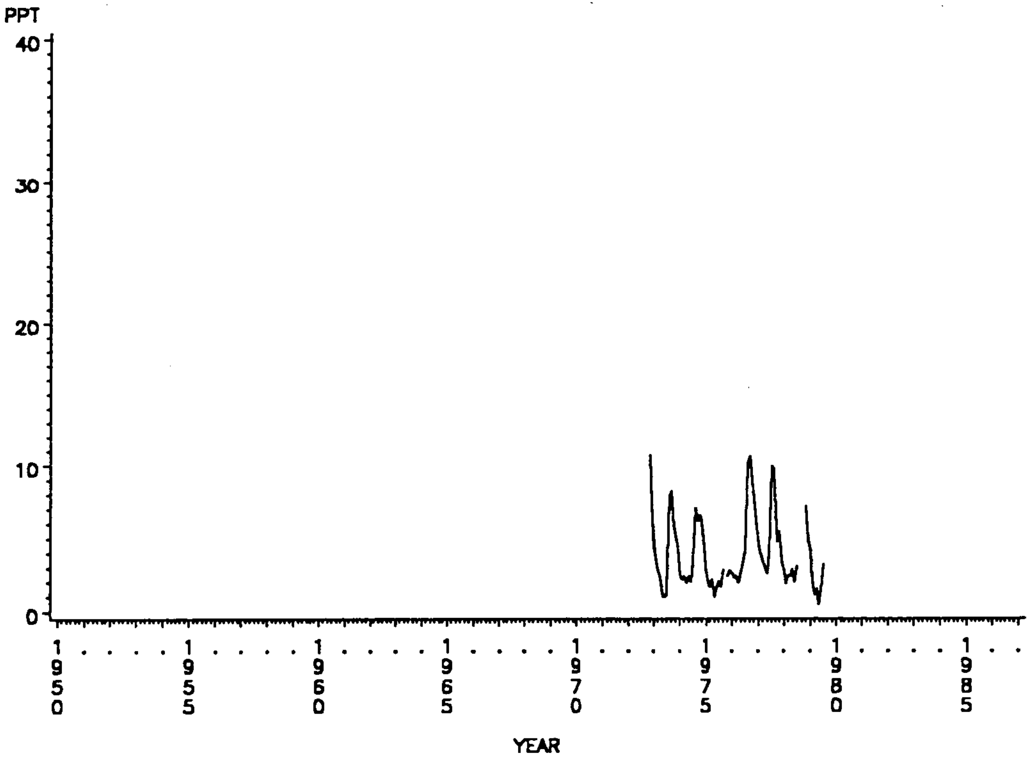


Figure D-3. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Grand Pass (LDWF station 117).

MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=CHEF MENTEUR (L. PONT.)



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=CHEF MENTEUR (L. PONT.)

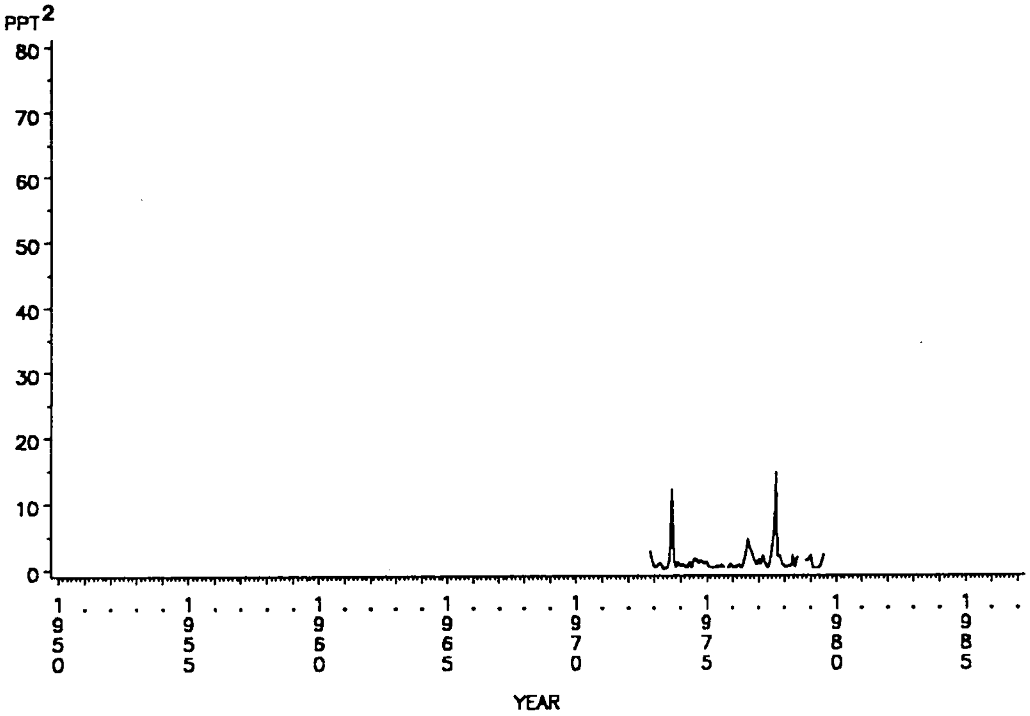
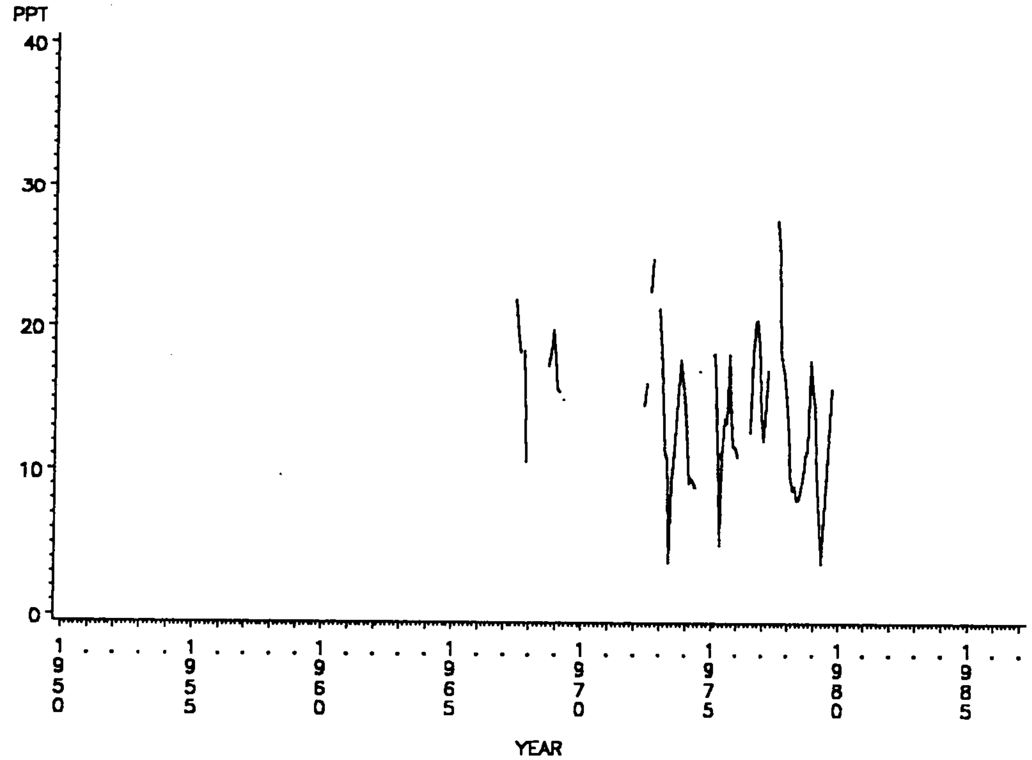
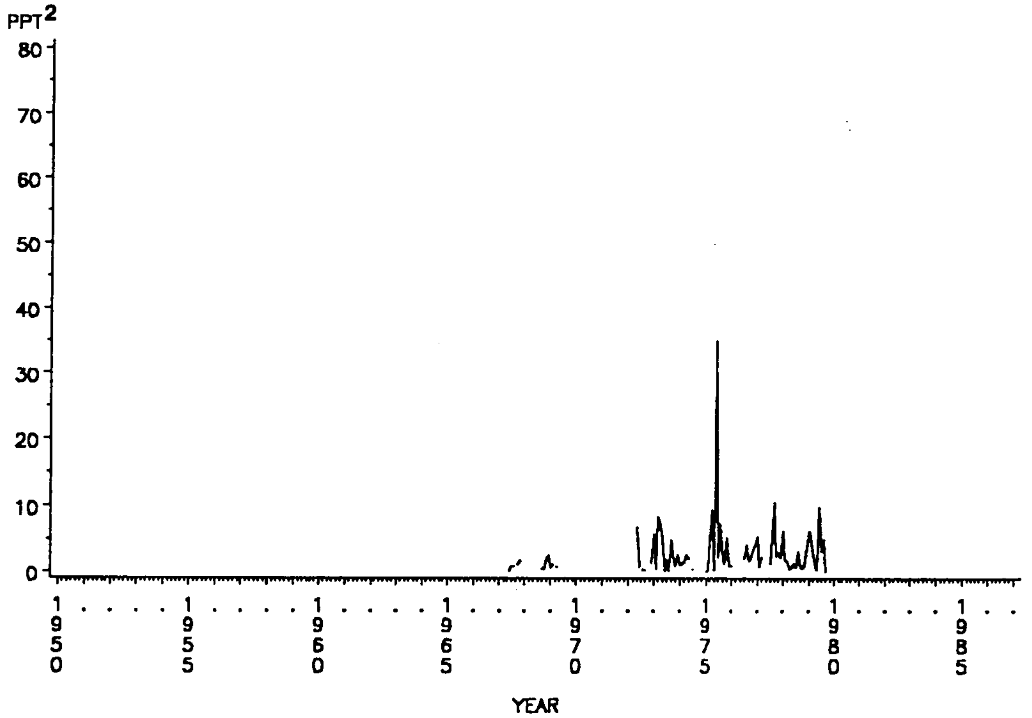


Figure D-4. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Chef Menteur Pass (LDWF station 118).

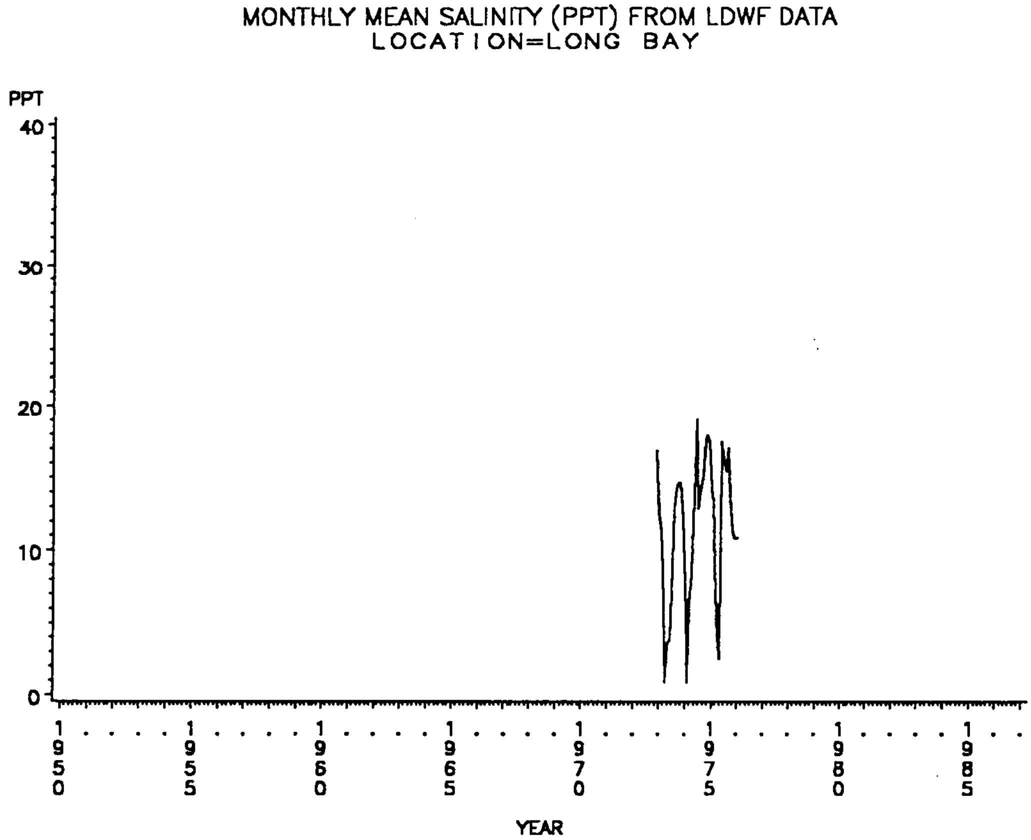


MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=BAY GARDENE



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=BAY GARDENE

Figure D-5. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bay Gardene (LDWF station 221).



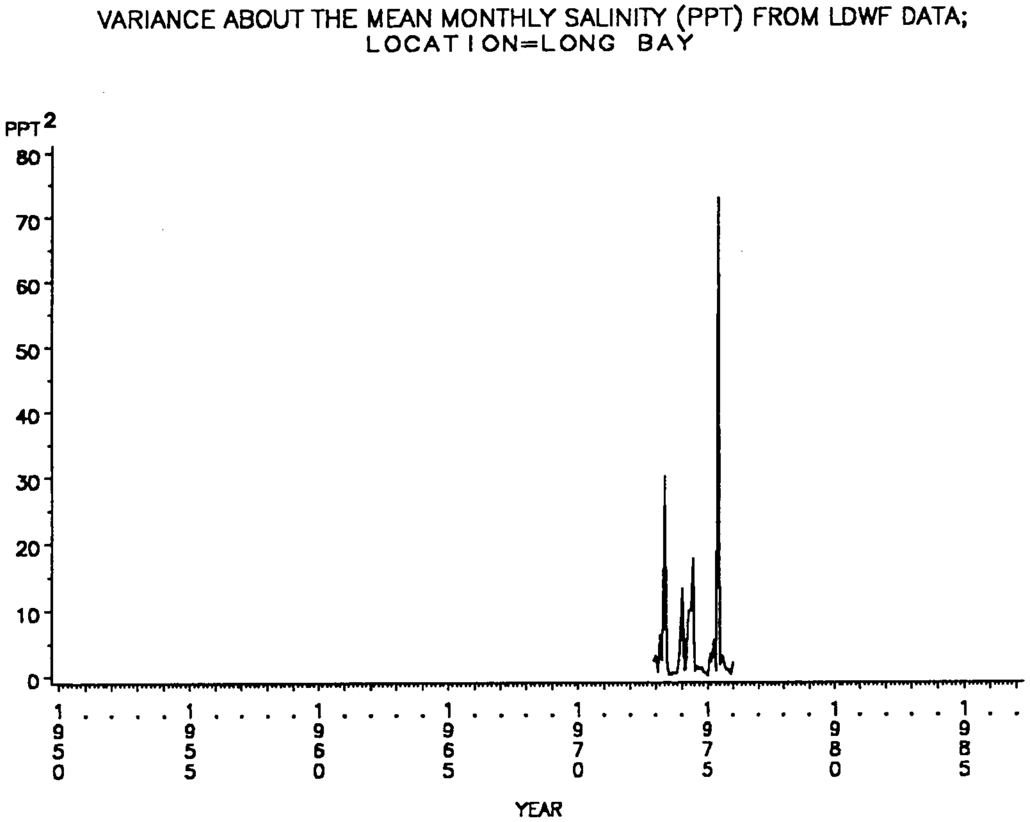
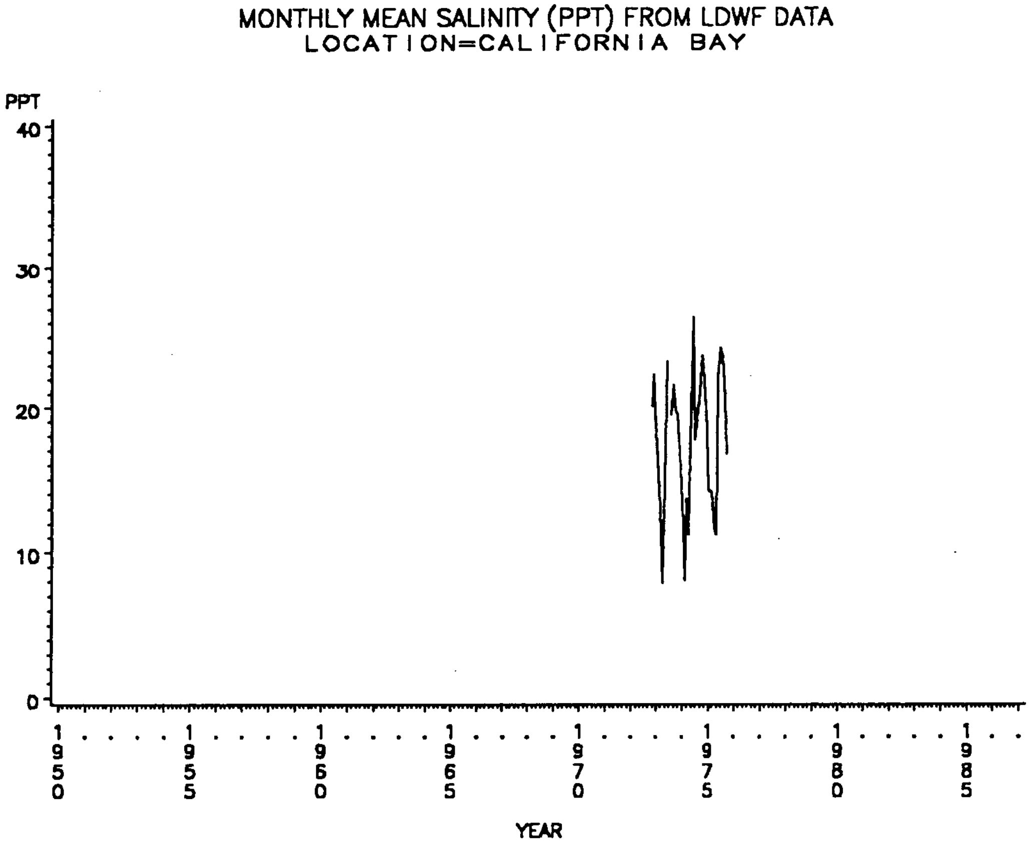


Figure D-6. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Long Bay (LDWF station 251).



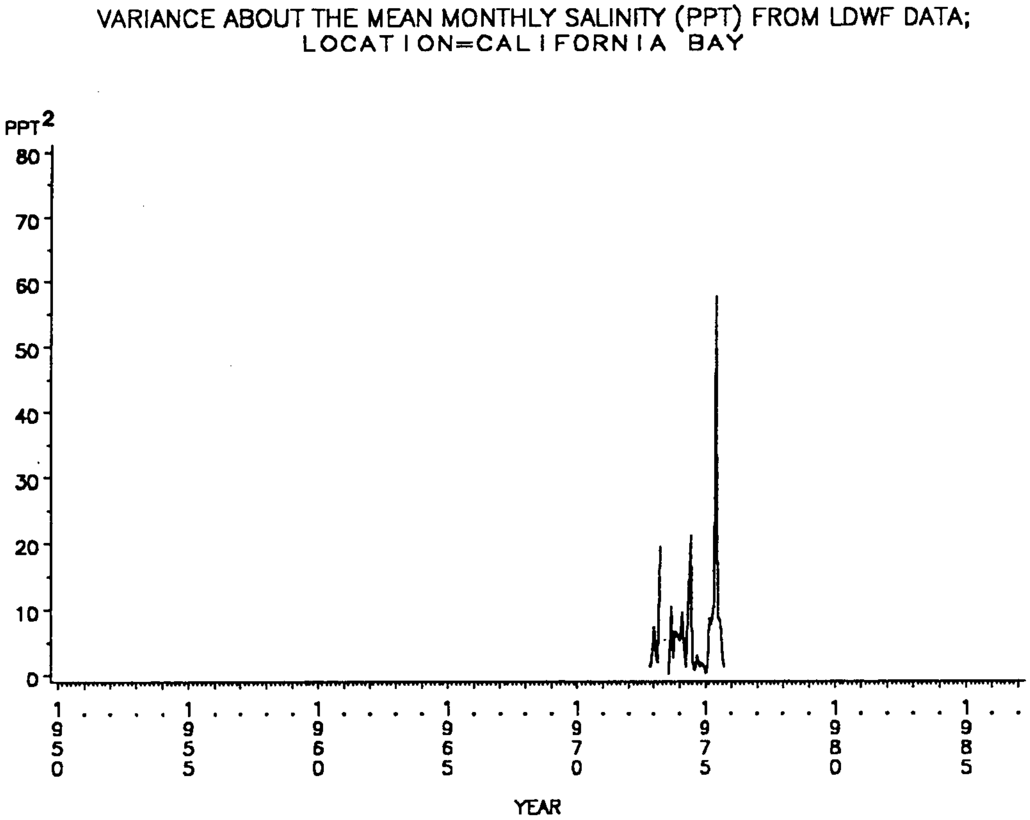
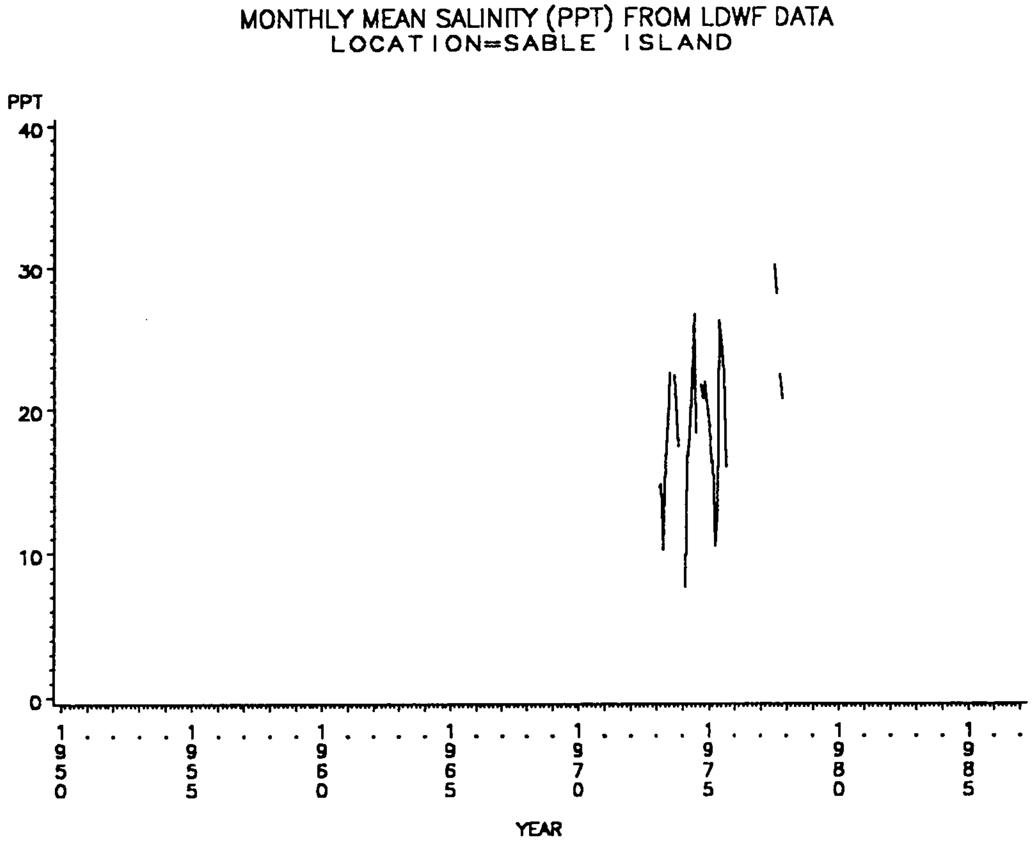


Figure D-7. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from California Bay (LDWF station 252).



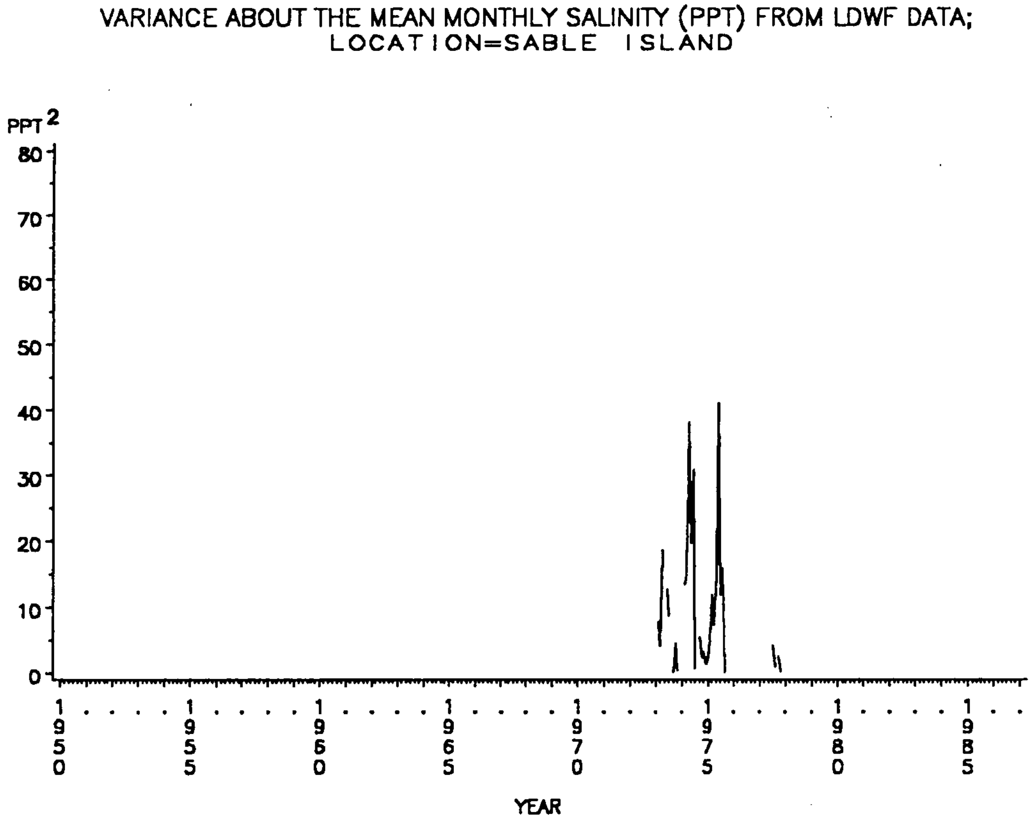
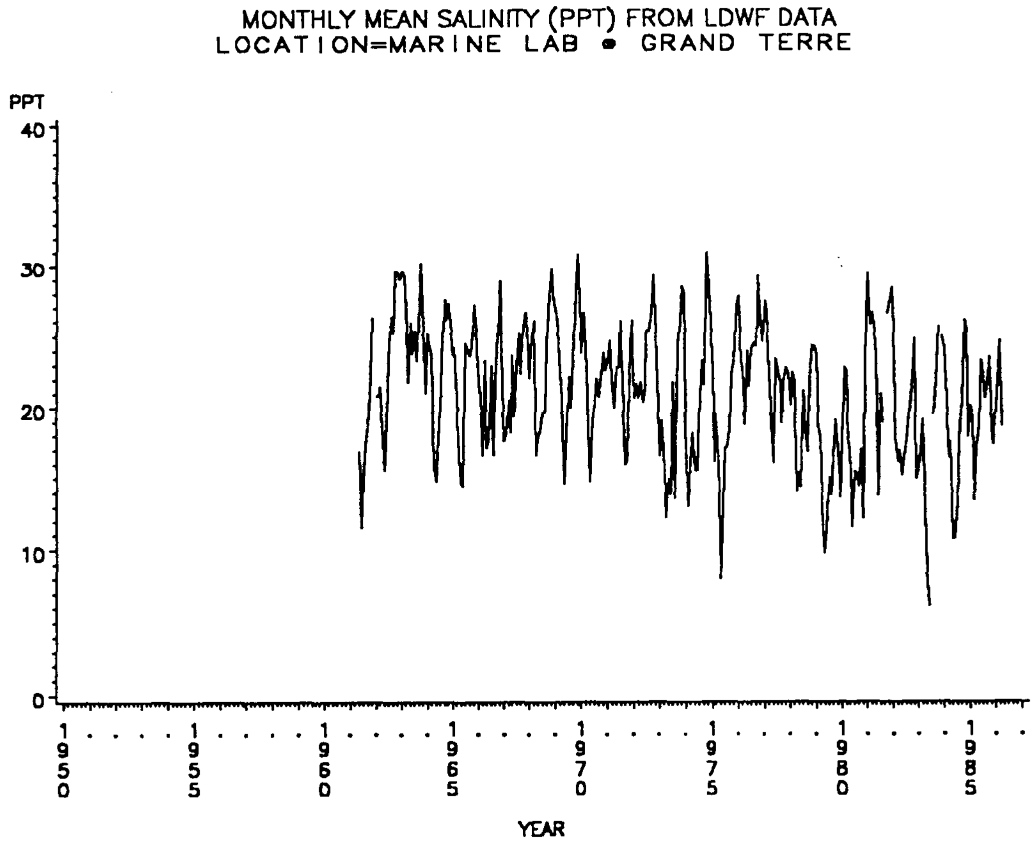


Figure D-8. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Sable Island (LDWF station 253).



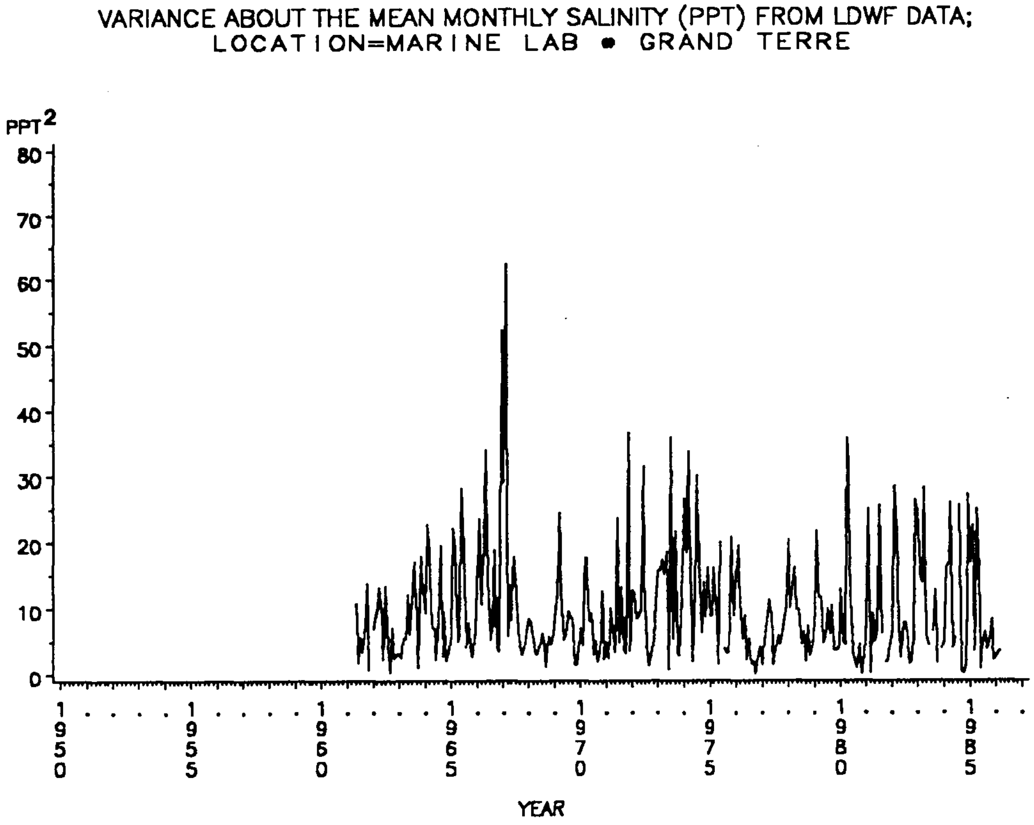
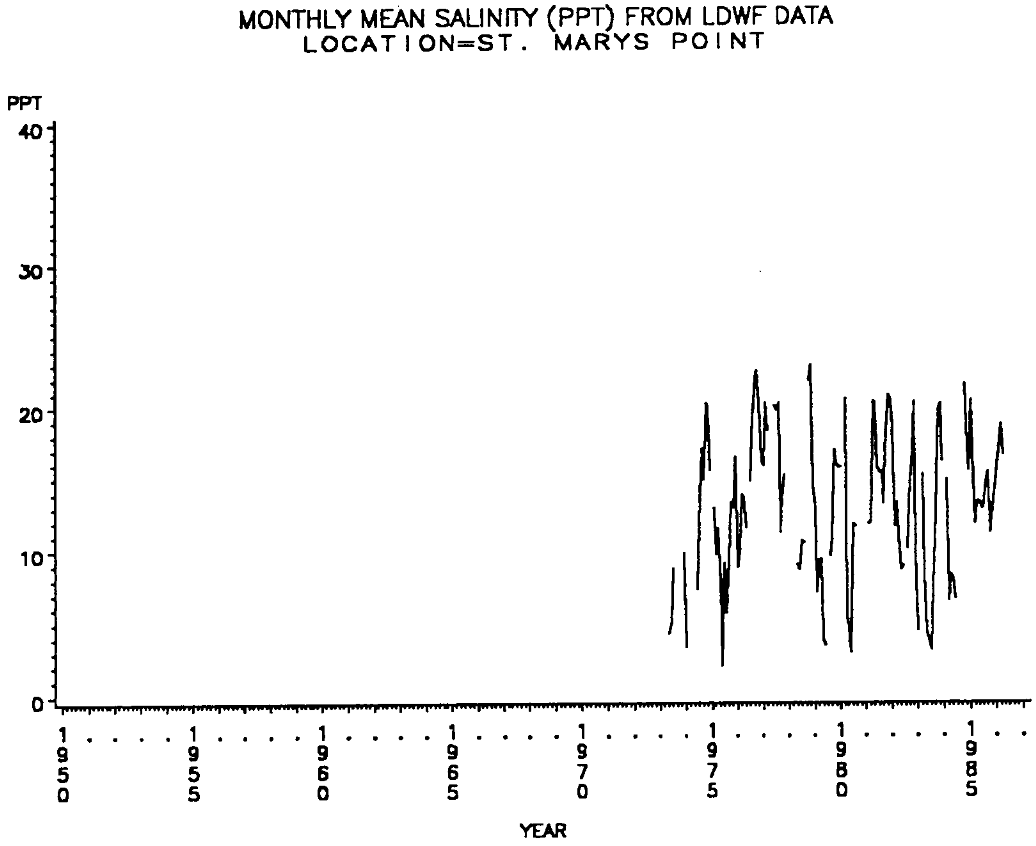


Figure D-9. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from The Marine lab at grand Terre (LDWF station 315).


MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=ST. MARYS POINT

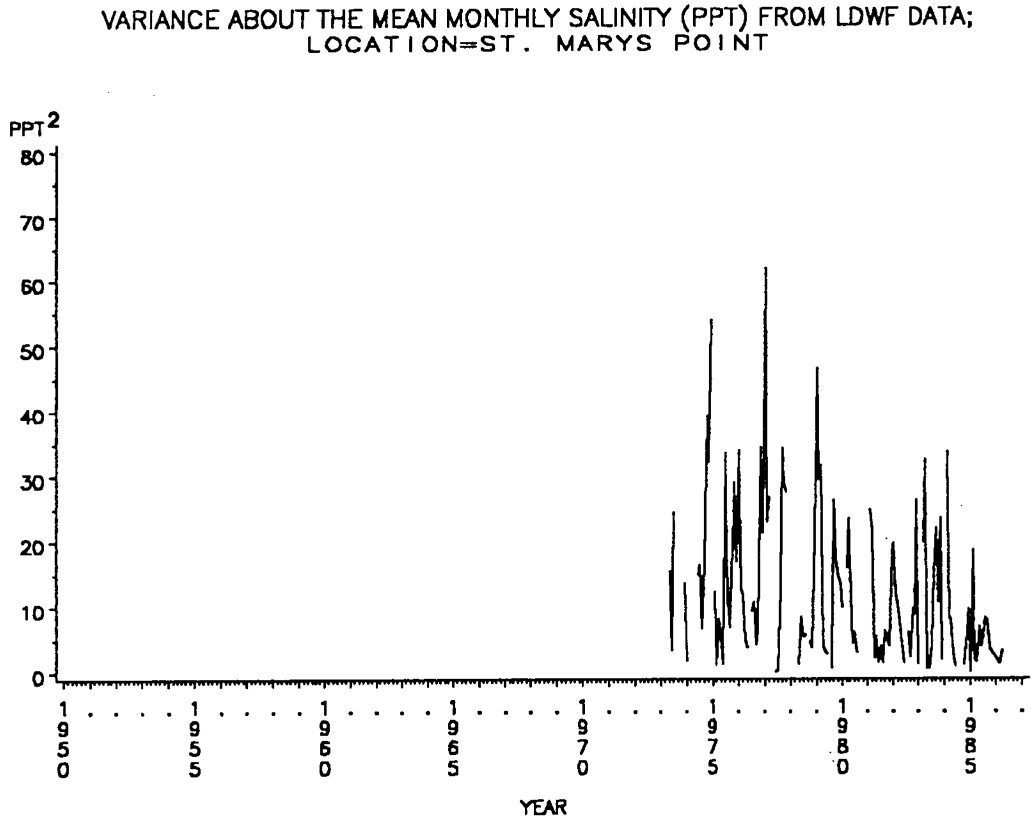
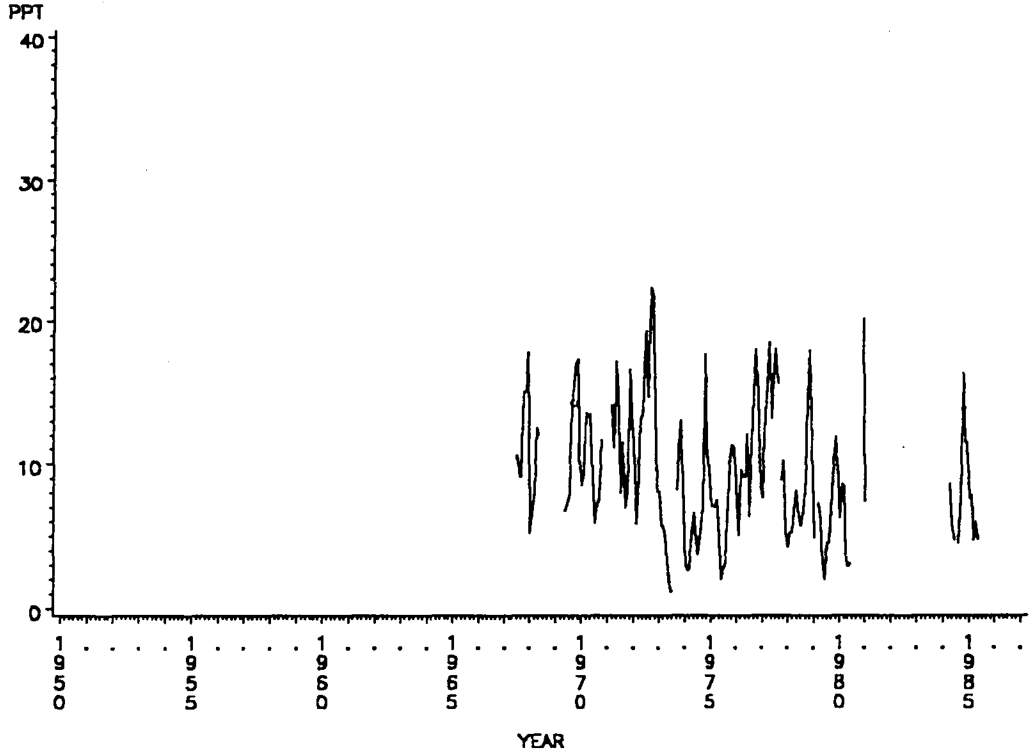

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=ST. MARYS POINT

Figure D-10. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from St. Mary's Point (LDWF station 317).

MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=COCODRIE



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=COCODRIE

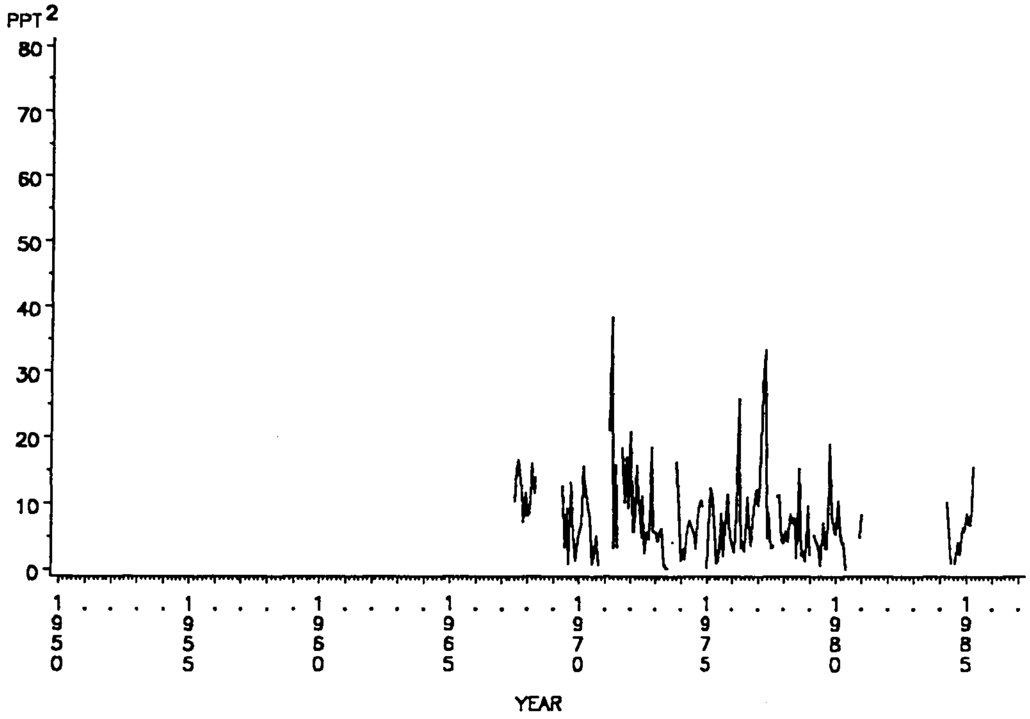
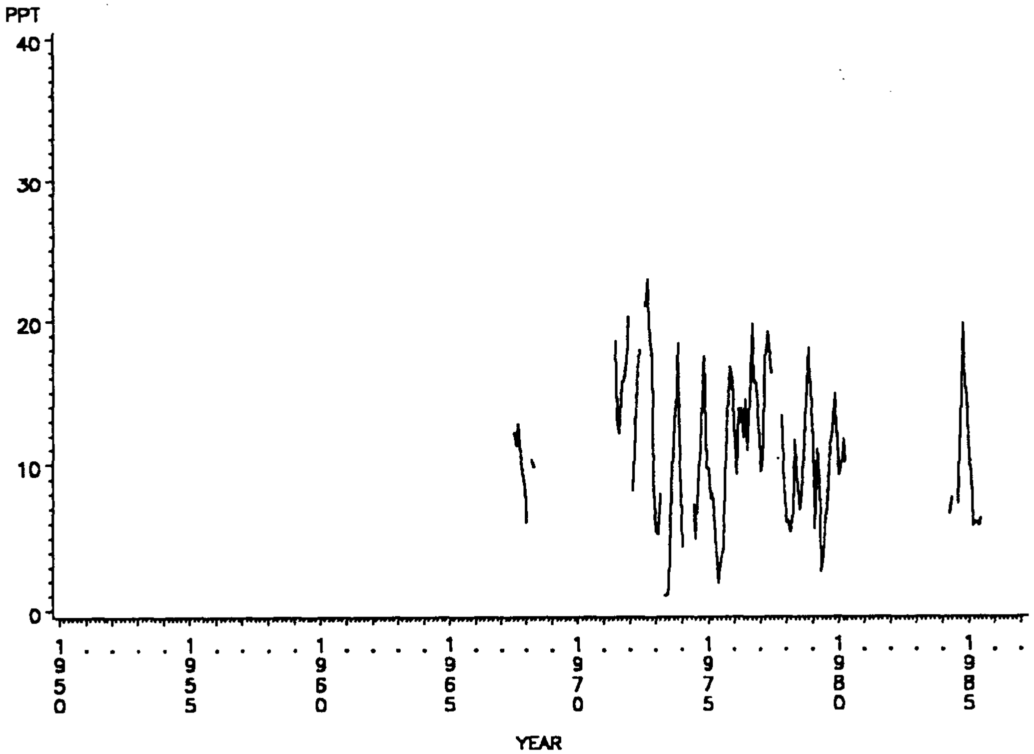


Figure D-11. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Cocodrie (LDWF station 416).


MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=CAILLOU LAKE CAMP

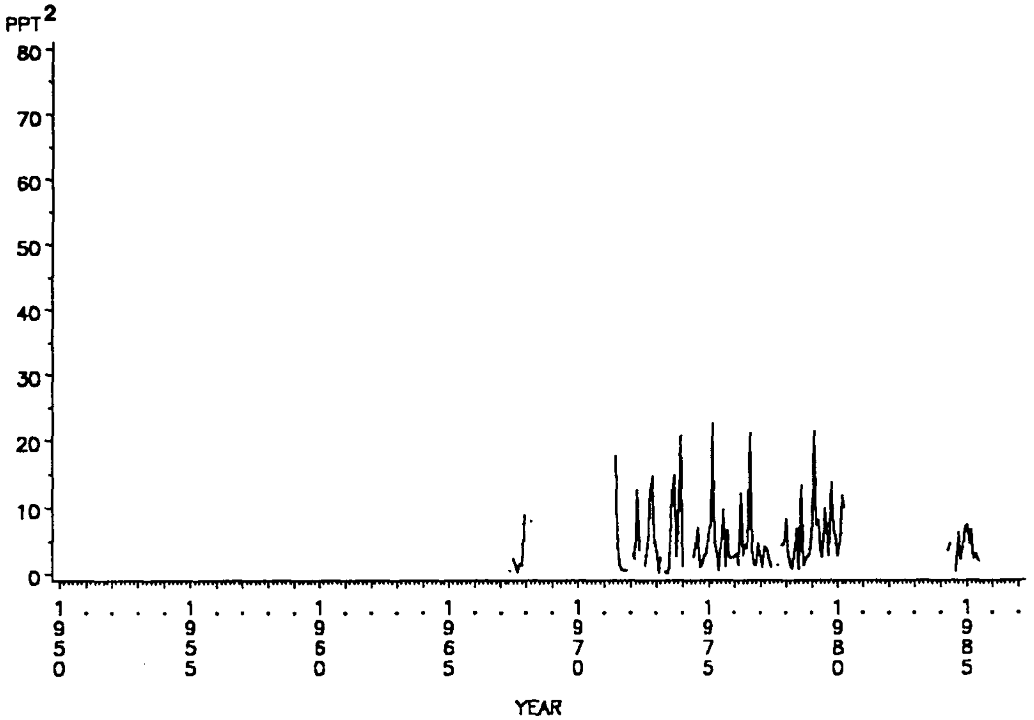
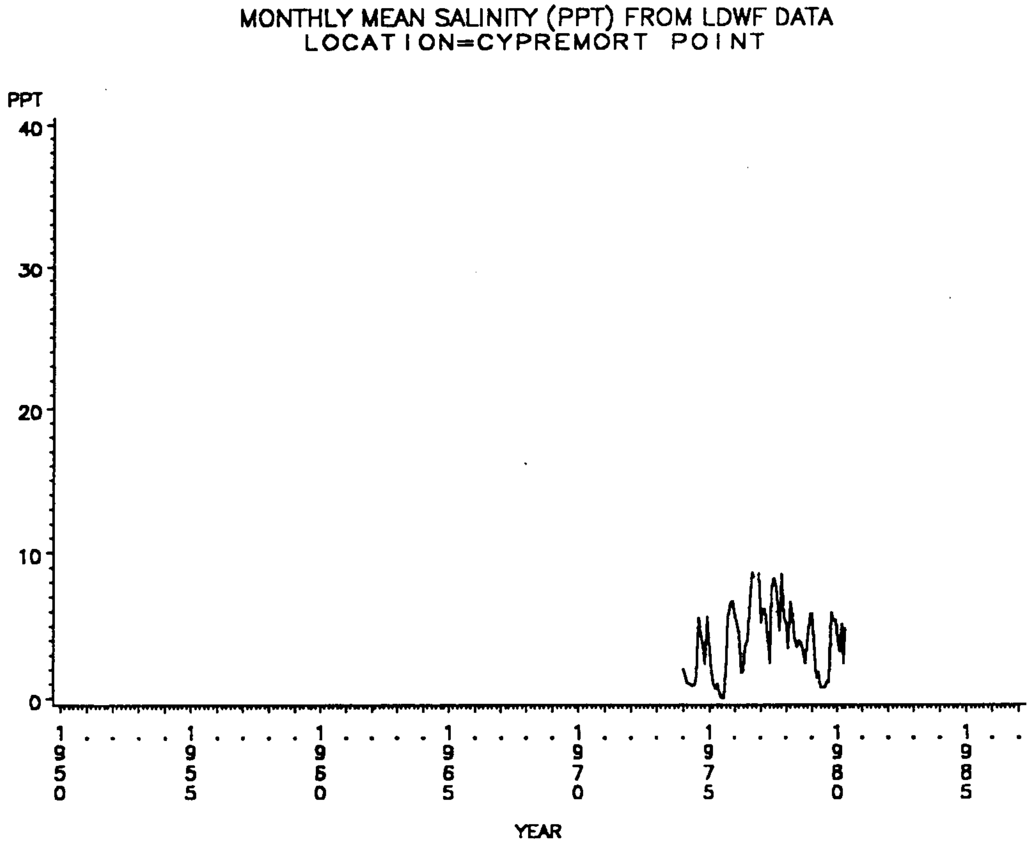

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=CAILLOU LAKE CAMP

Figure D-12. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Caillou Lake Camp (LDWF station 518).



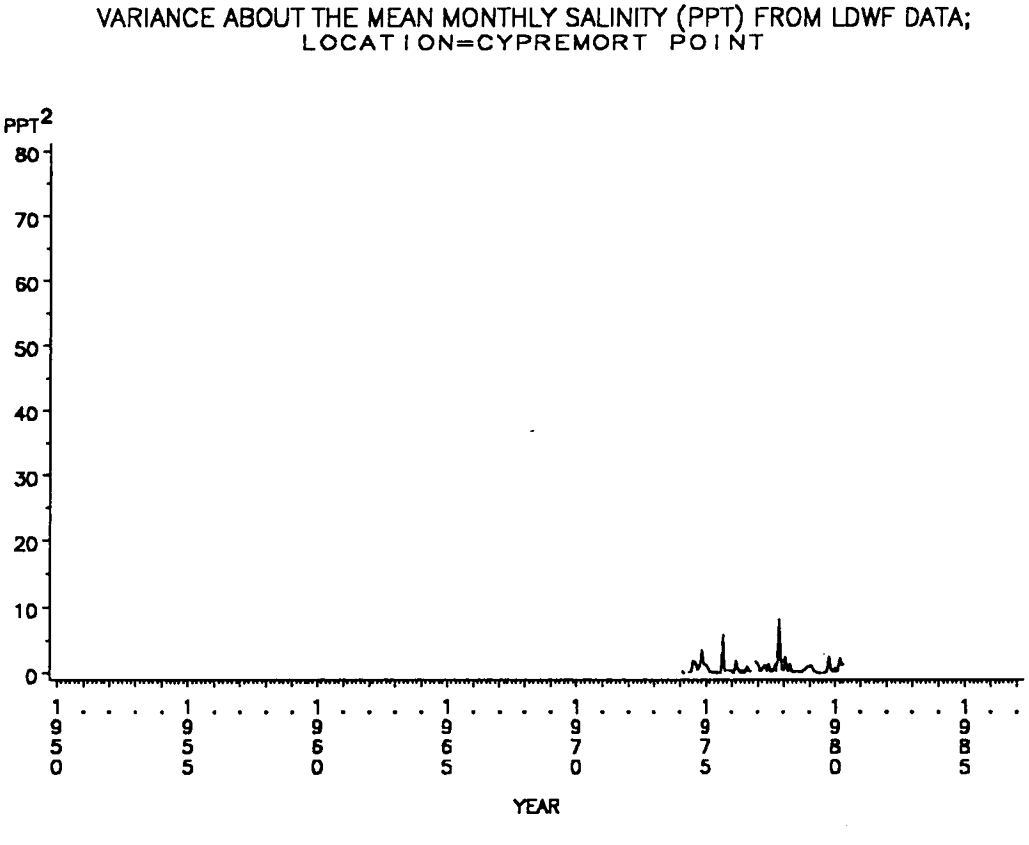
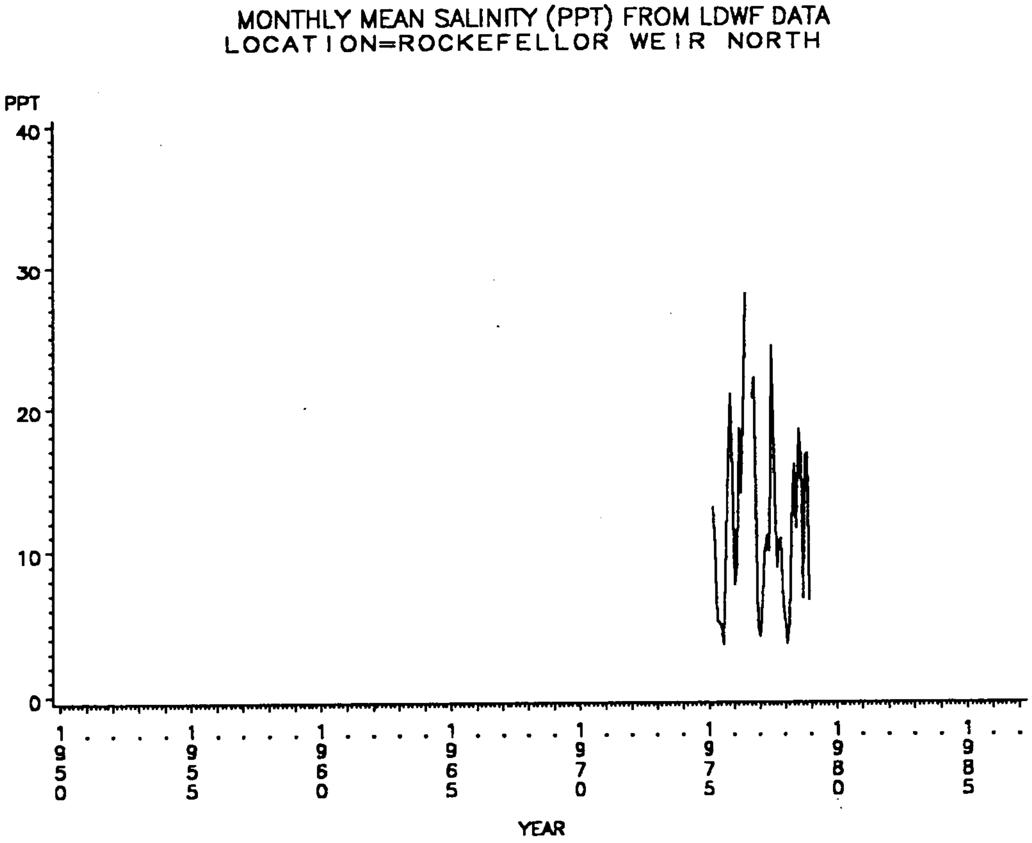


Figure D-13. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Cypremort Point (LDWF station 619).



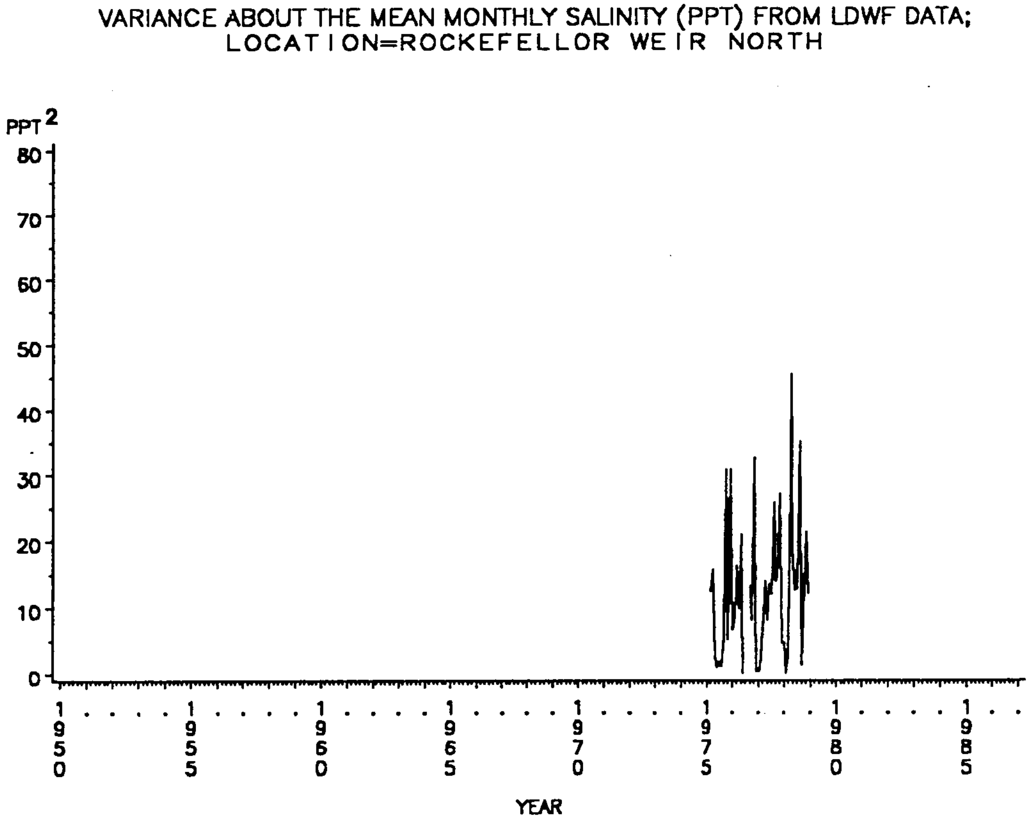
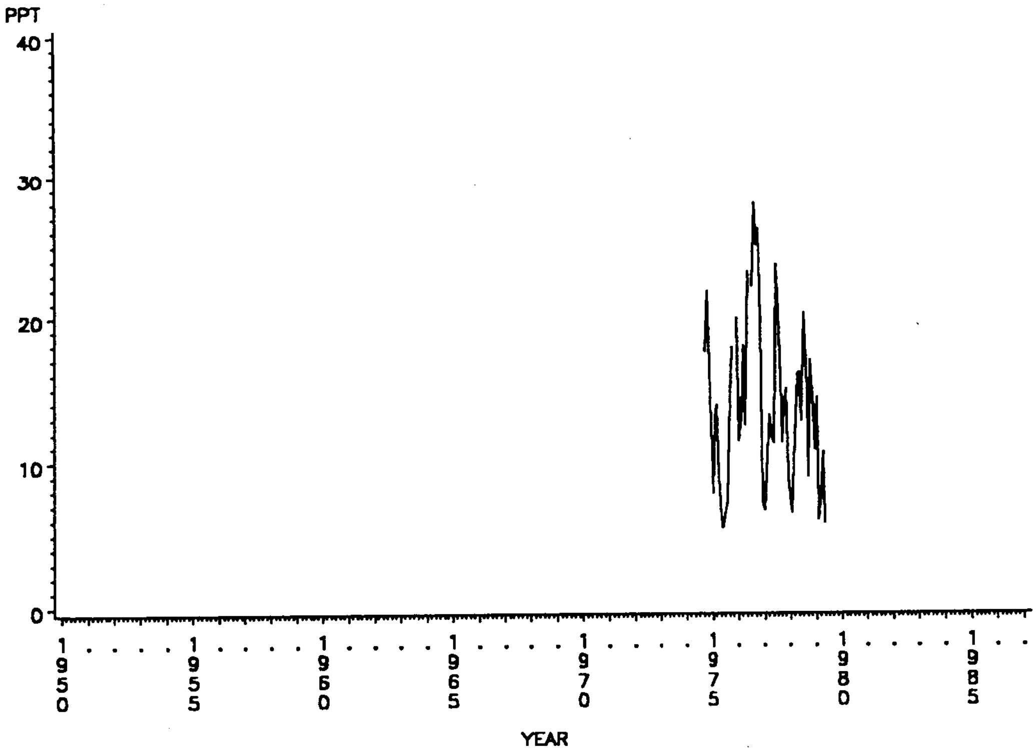


Figure D-14. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Rockefeller, North of weir (LDWF station 701).

MONTHLY MEAN SALINITY (PPT) FROM LDWF DATA
LOCATION=ROCKEFELLOR WEIR SOUTH



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM LDWF DATA;
LOCATION=ROCKEFELLOR WEIR SOUTH

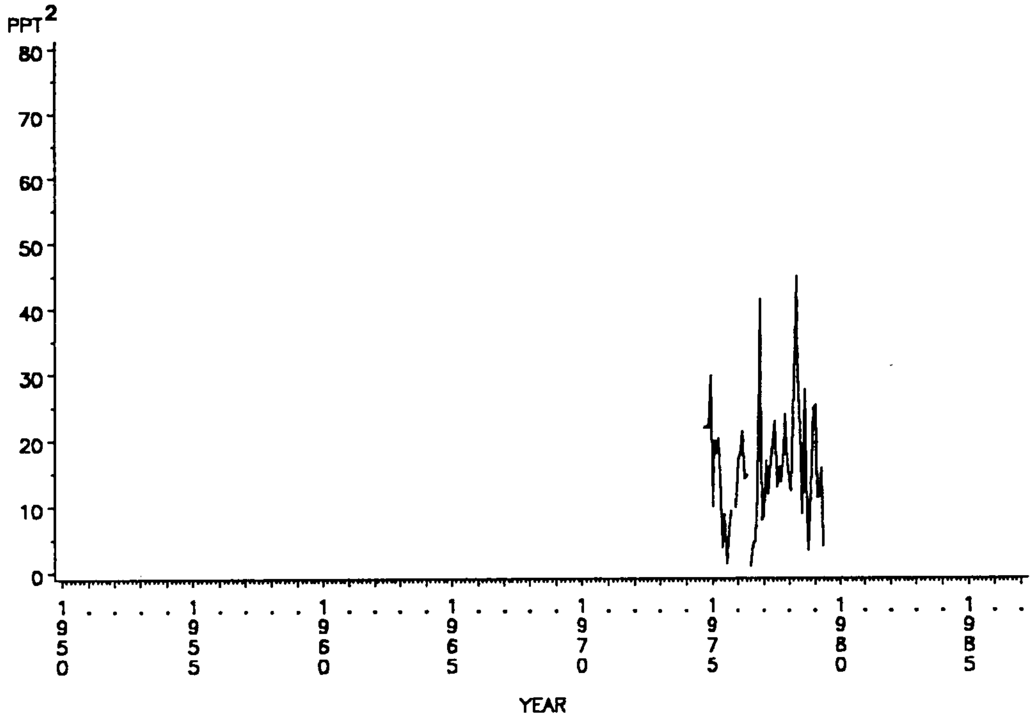


Figure D-15. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Rockefeller, South of weir (LDWF station 702).

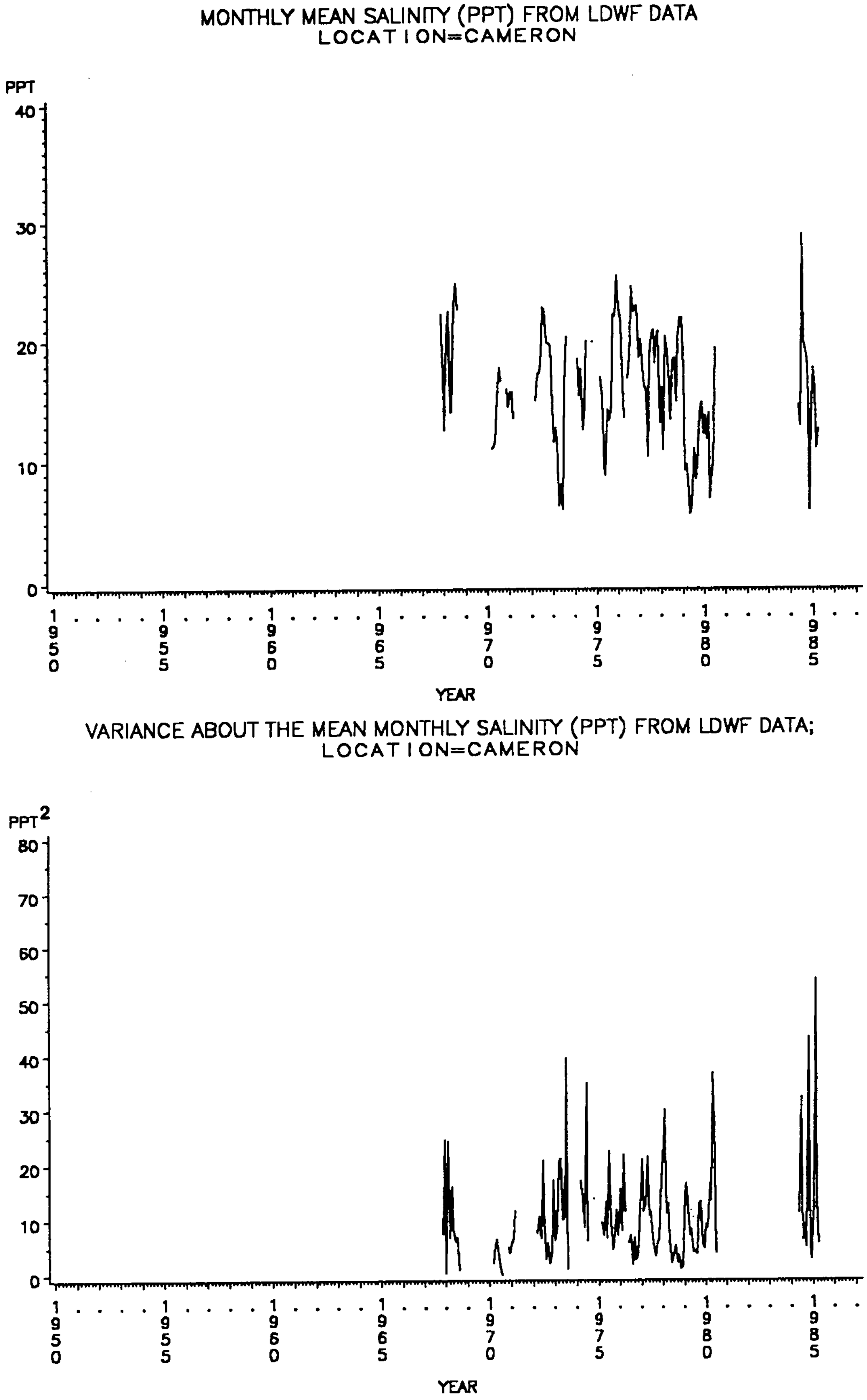
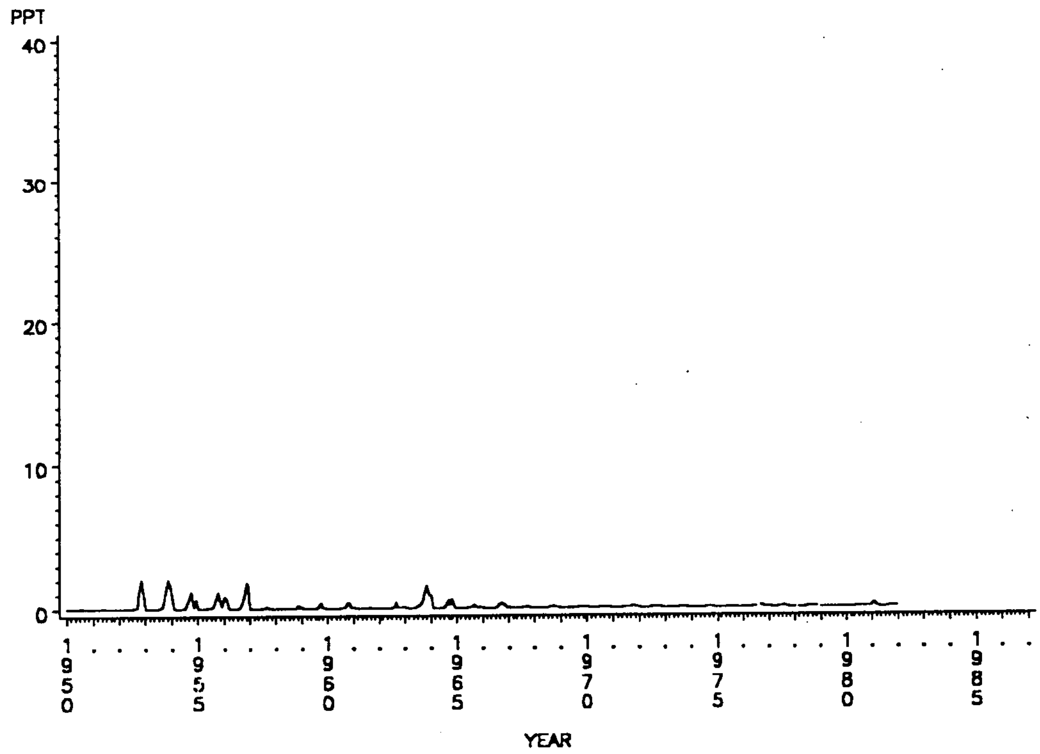
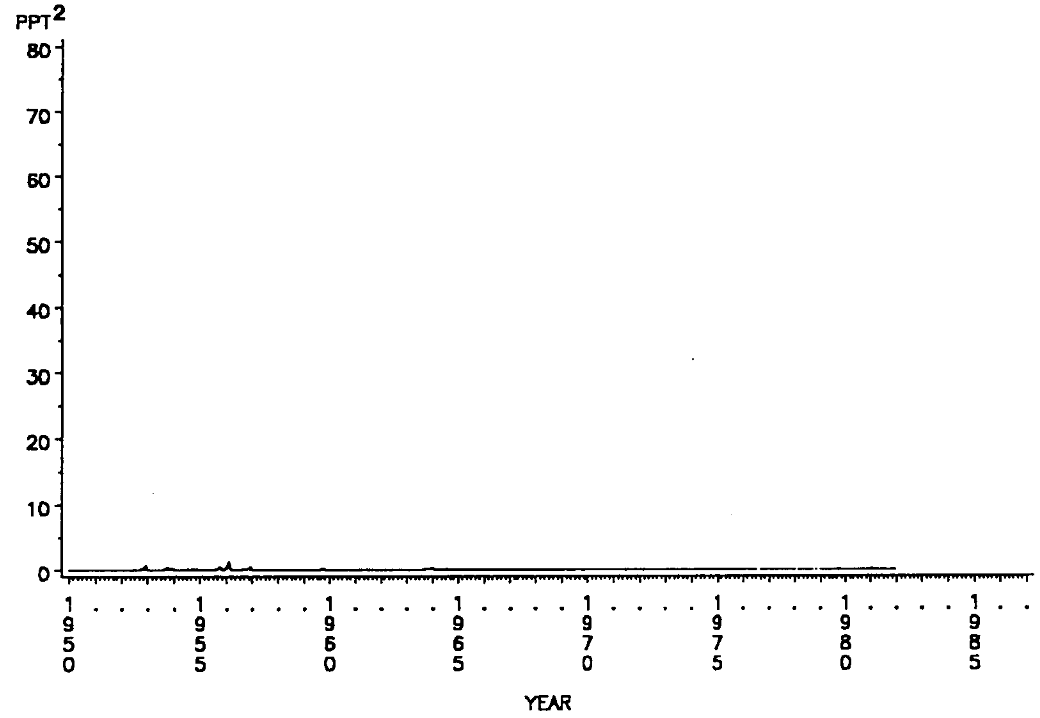


Figure D-16. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Cameron (LDWF station 719).

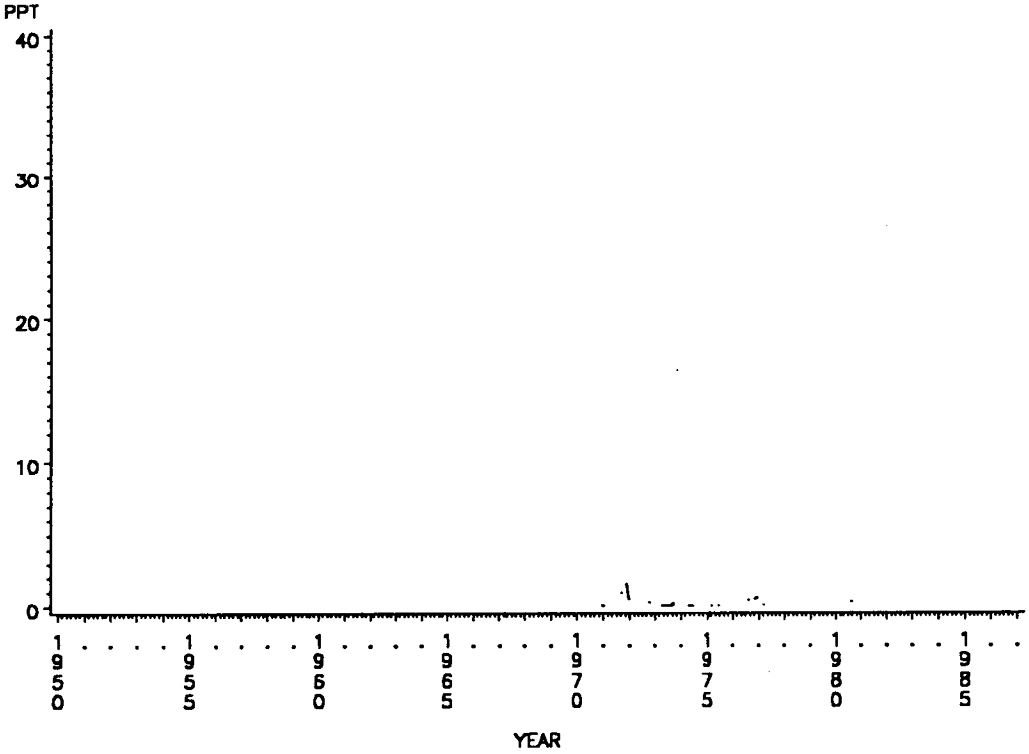


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=PORT SULPHUR



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=PORT SULPHUR

Figure D-17. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Port Sulphur (COE station 01420).


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=MISSISSIPPI R. • VENICE

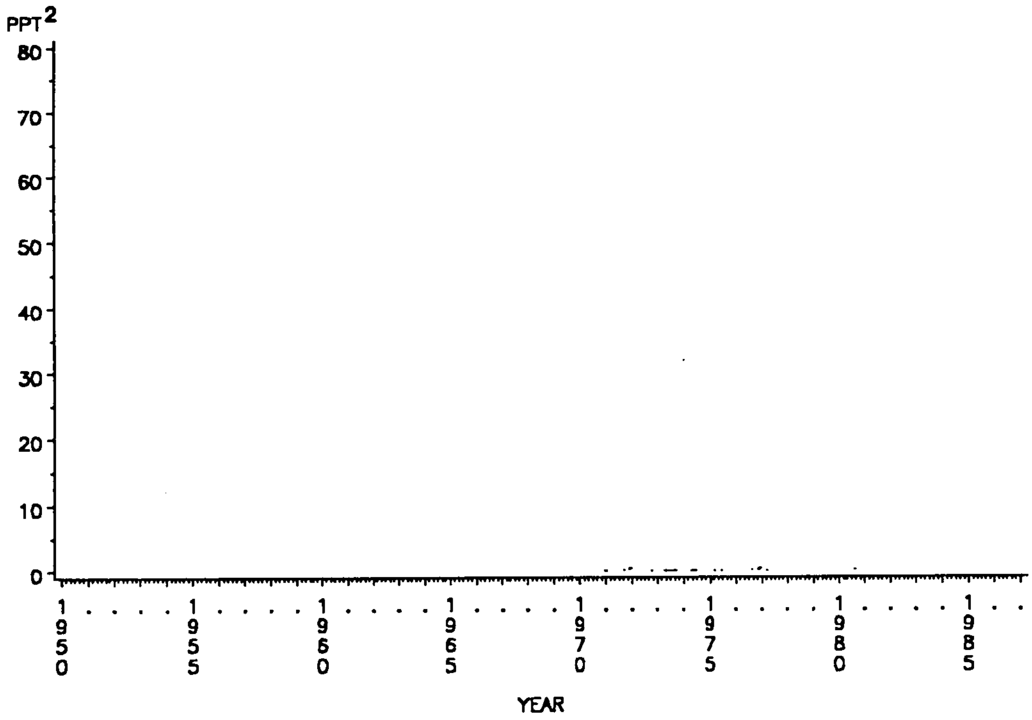
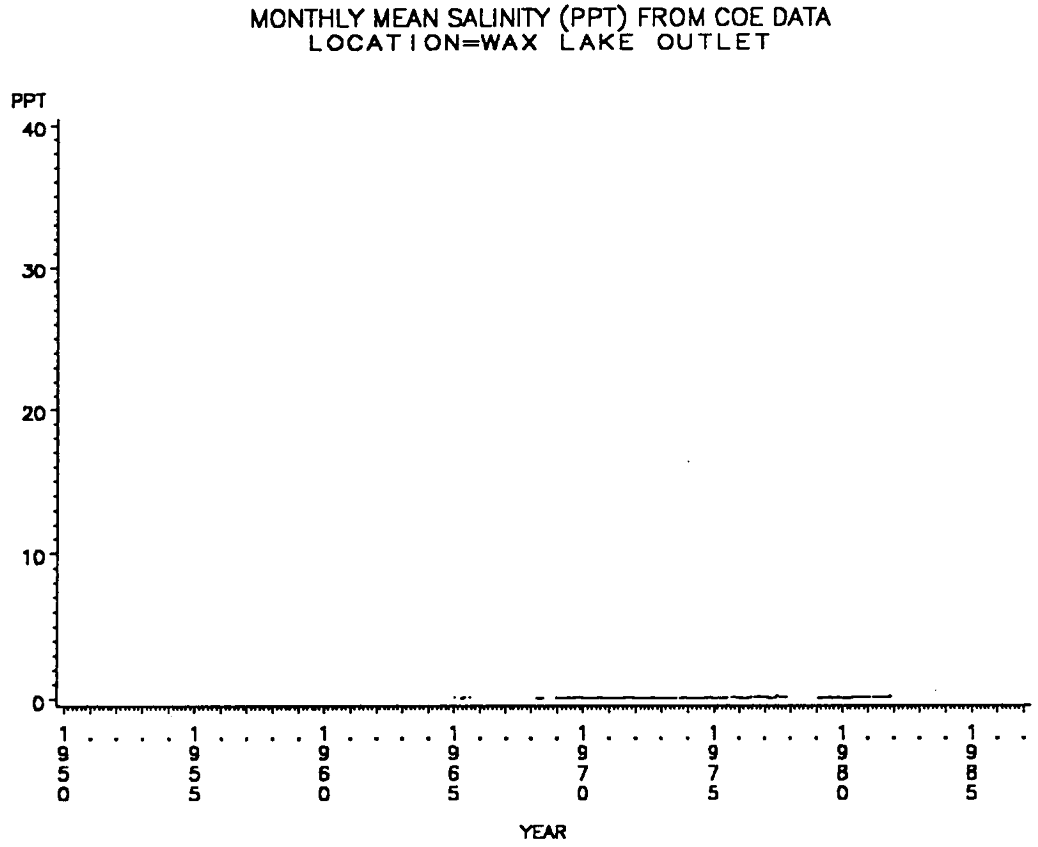

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=MISSISSIPPI R. • VENICE

Figure D-18. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Venice (COE station 01500).


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=WAX LAKE OUTLET

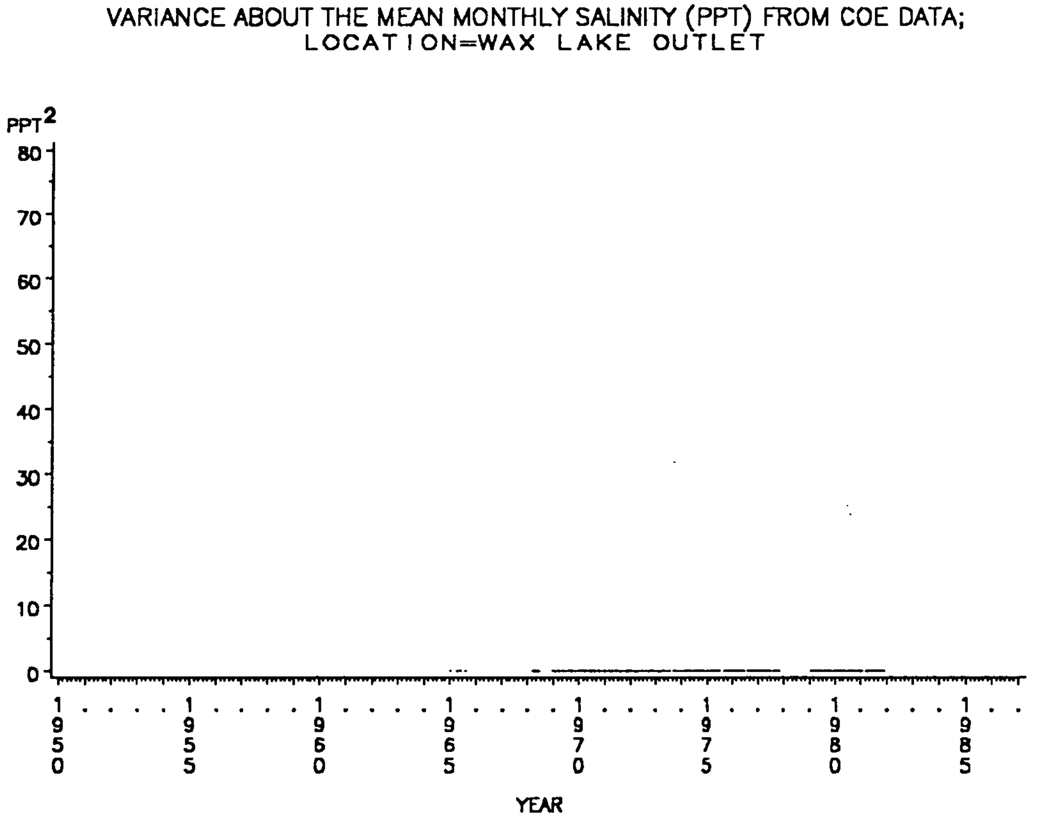
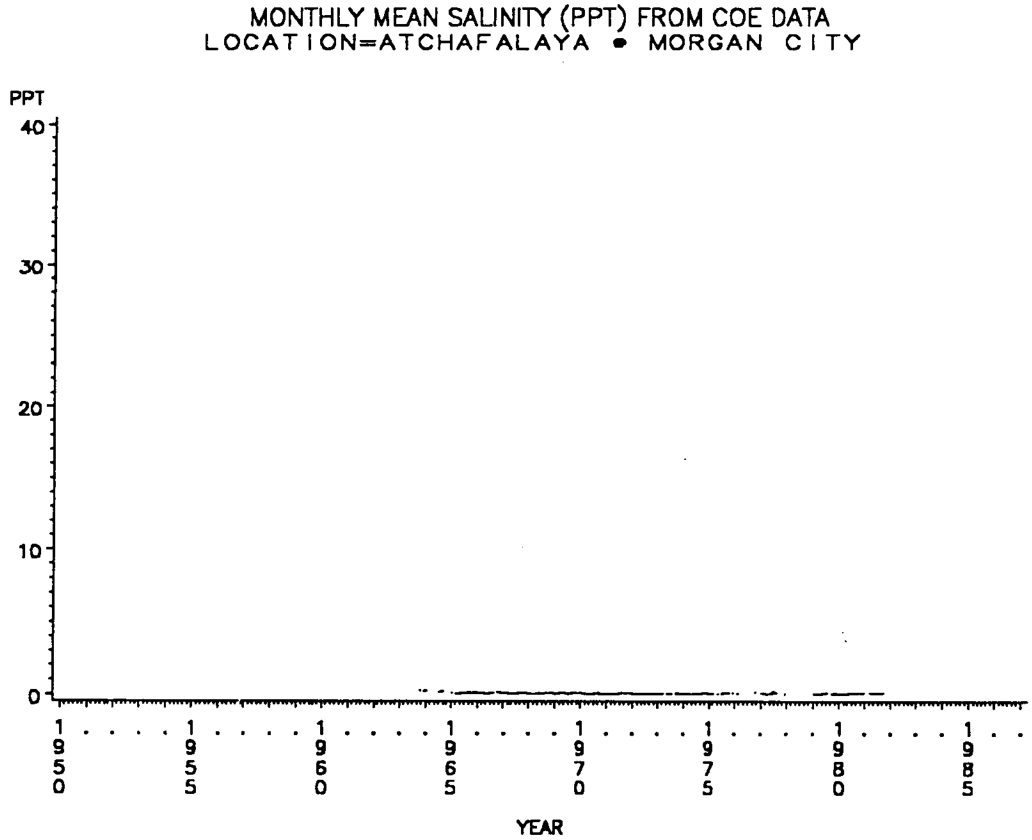

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=WAX LAKE OUTLET

Figure D-19. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Wax Lake Outlet (COE station 03720).



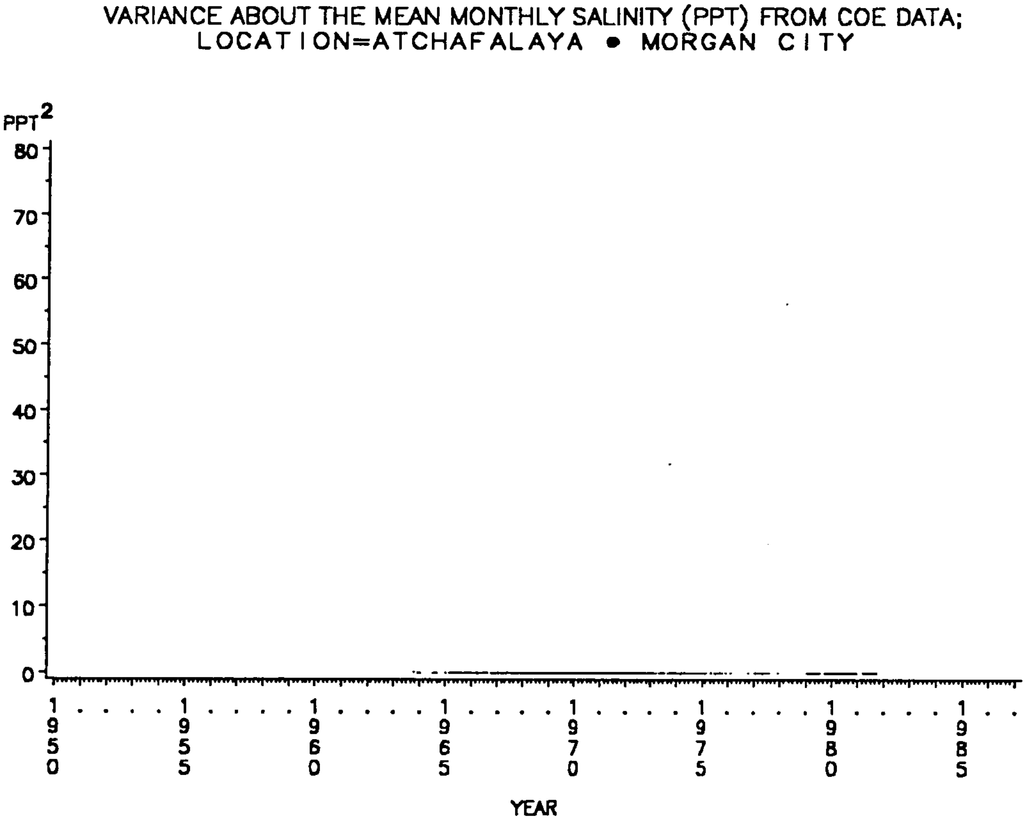
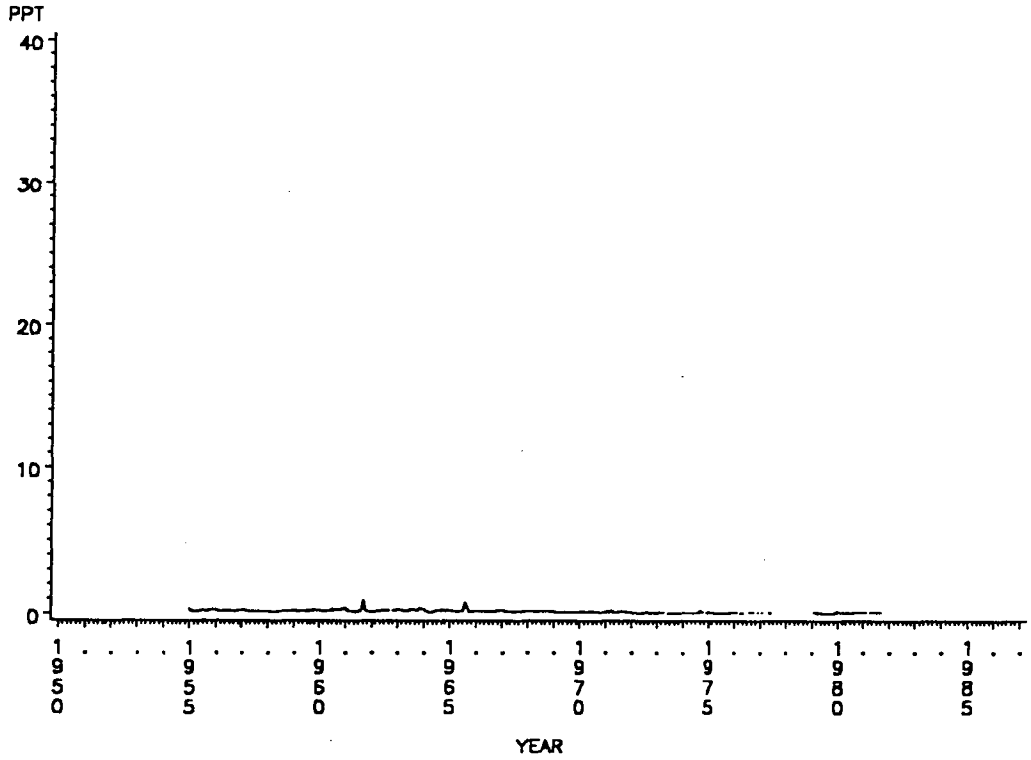


Figure D-20. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Atchafalaya River @ Morgan City (COE station 03780).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=B. BOEUF • AMELIA



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=B. BOEUF • AMELIA

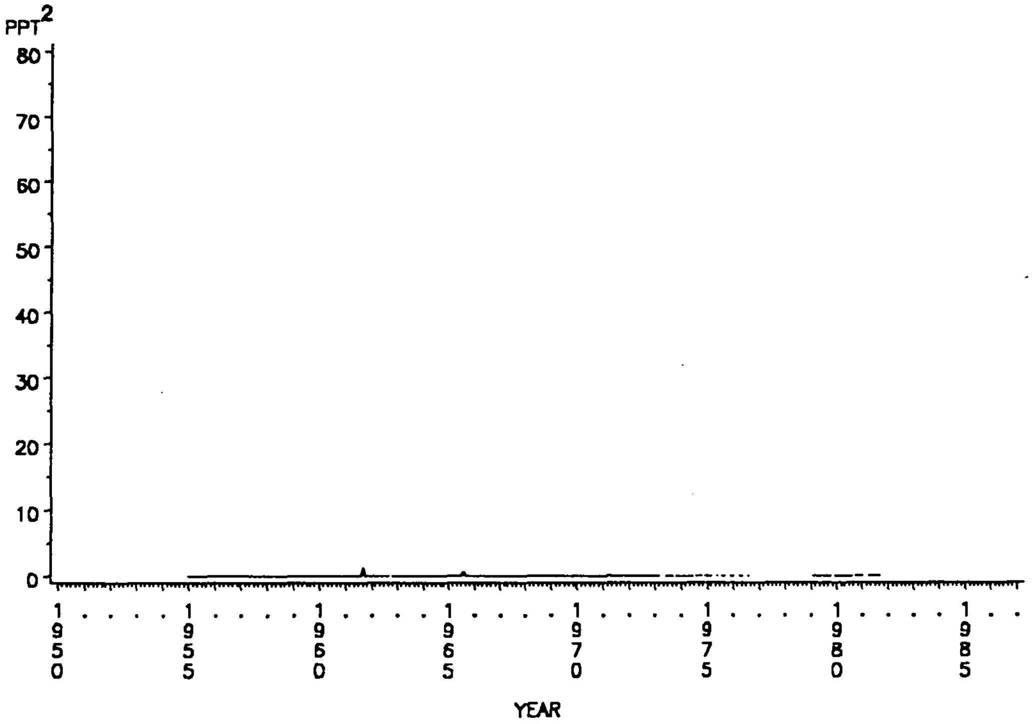
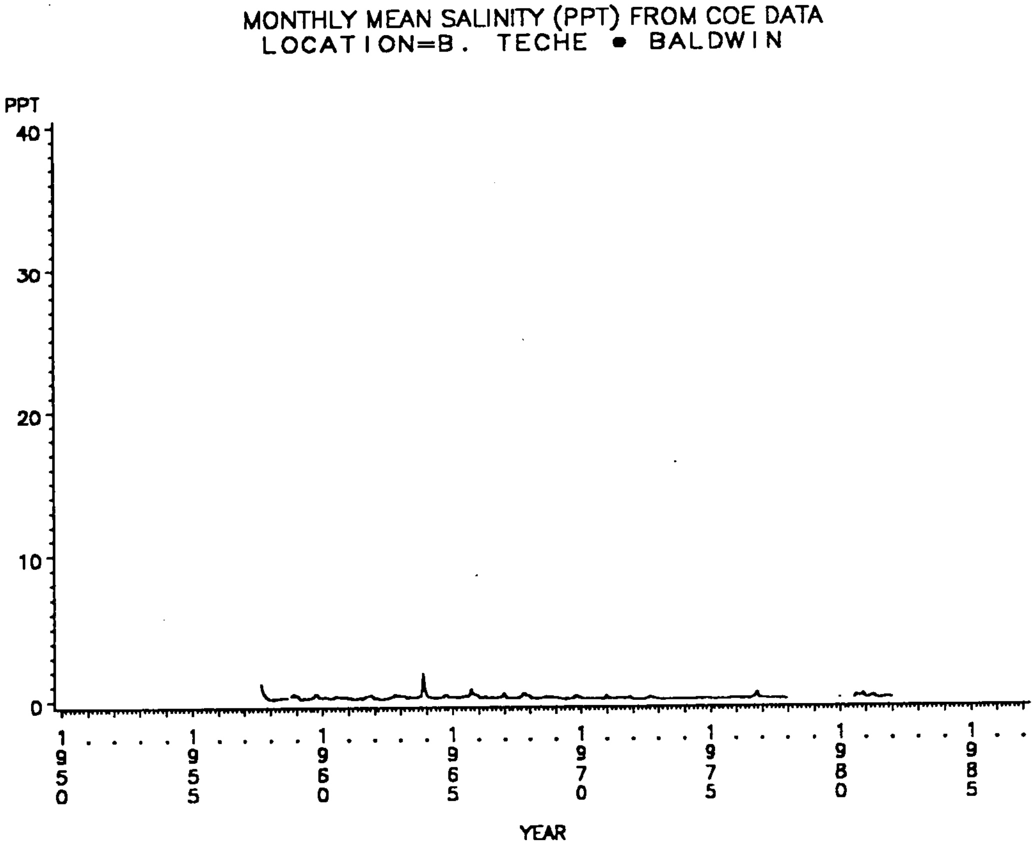


Figure D-21. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Boeuf (COE station 52800).



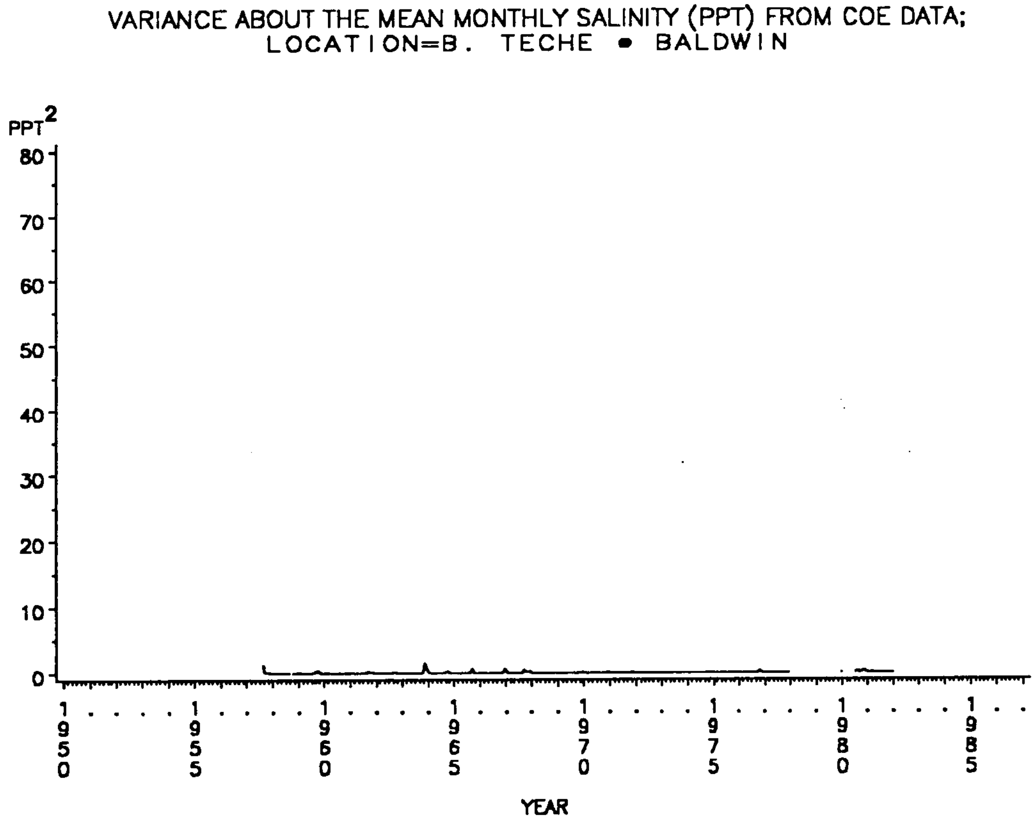
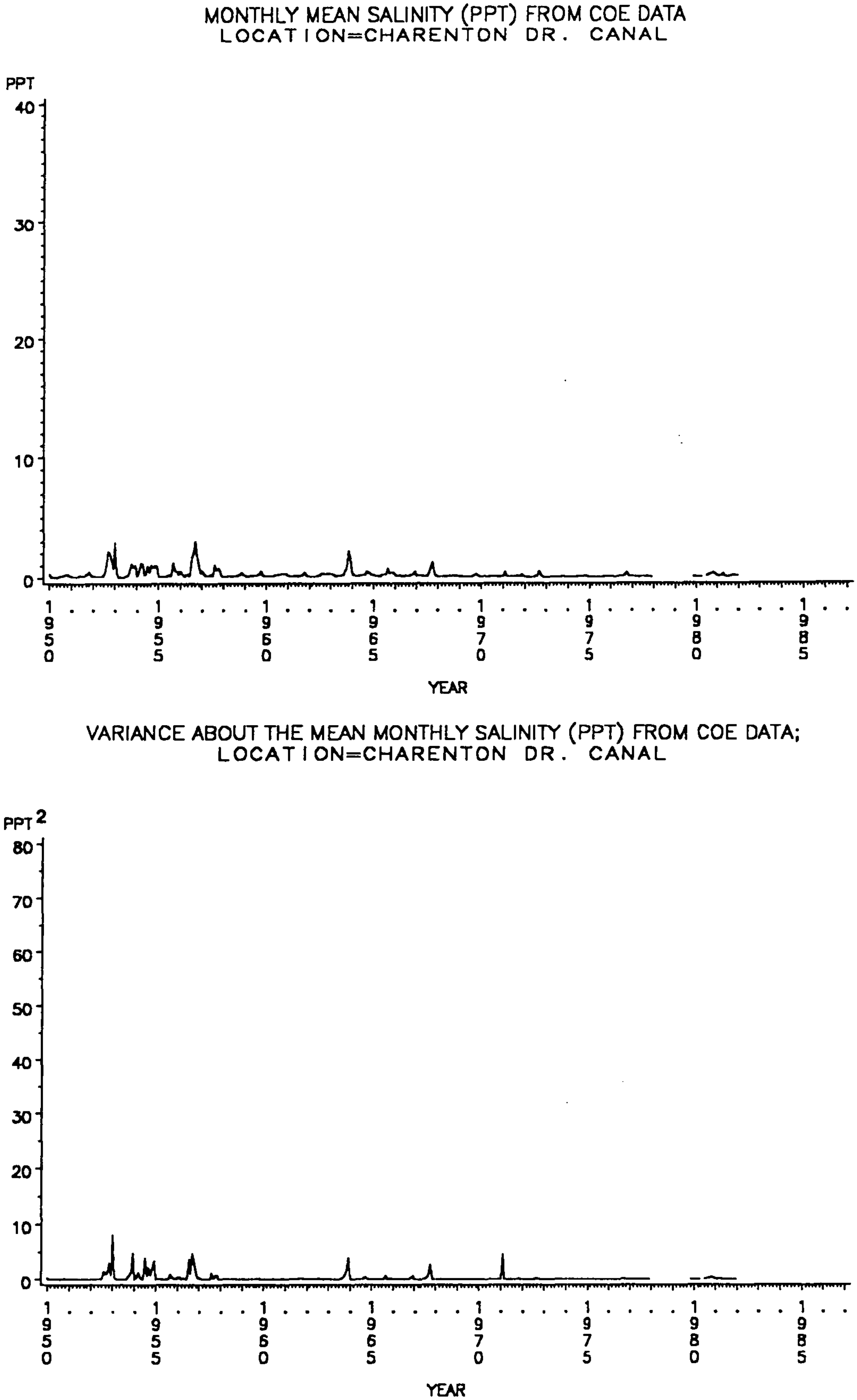
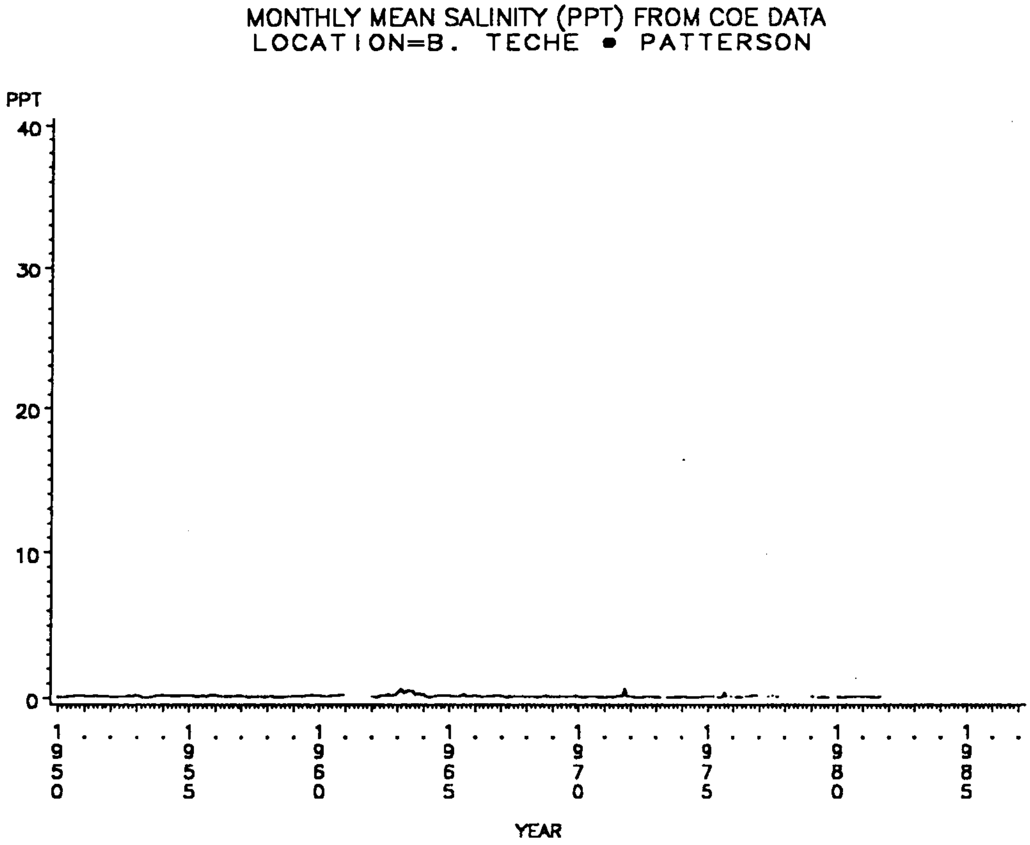


Figure D-22. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Teche @ Baldwin (COE station 64380).


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=CHARENTON DR. CANAL

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=CHARENTON DR. CANAL

Figure D-23. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Charenton Drainage Canal (COE station 64450).



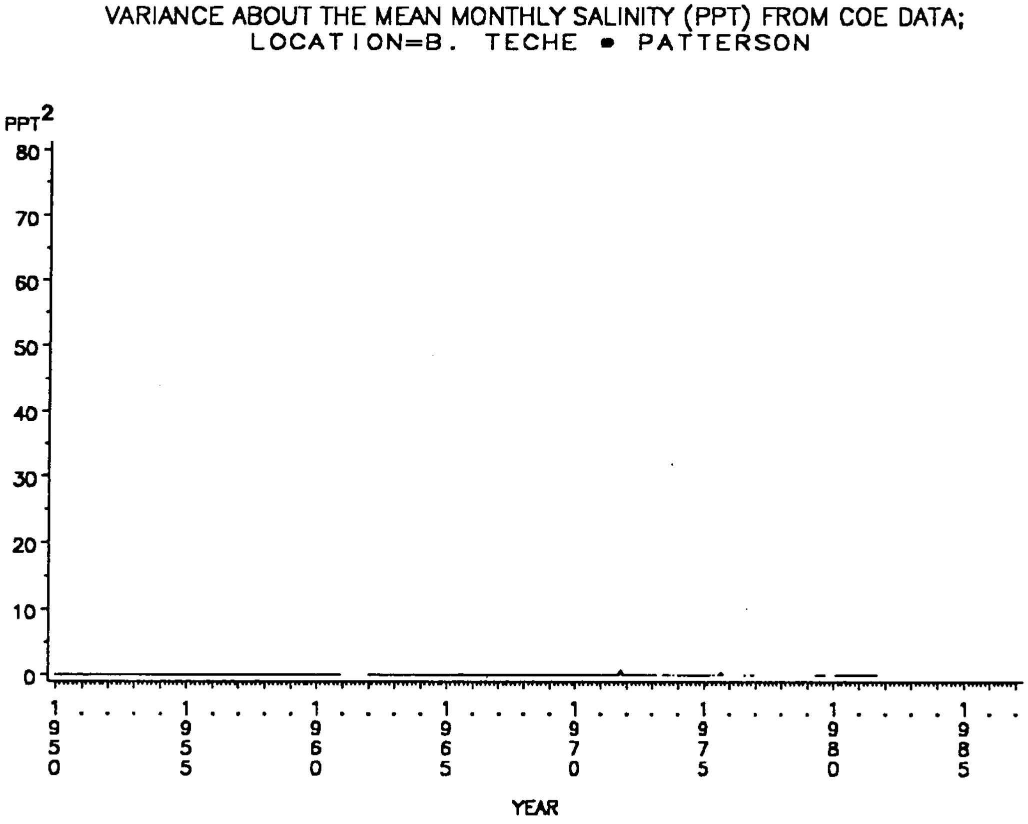
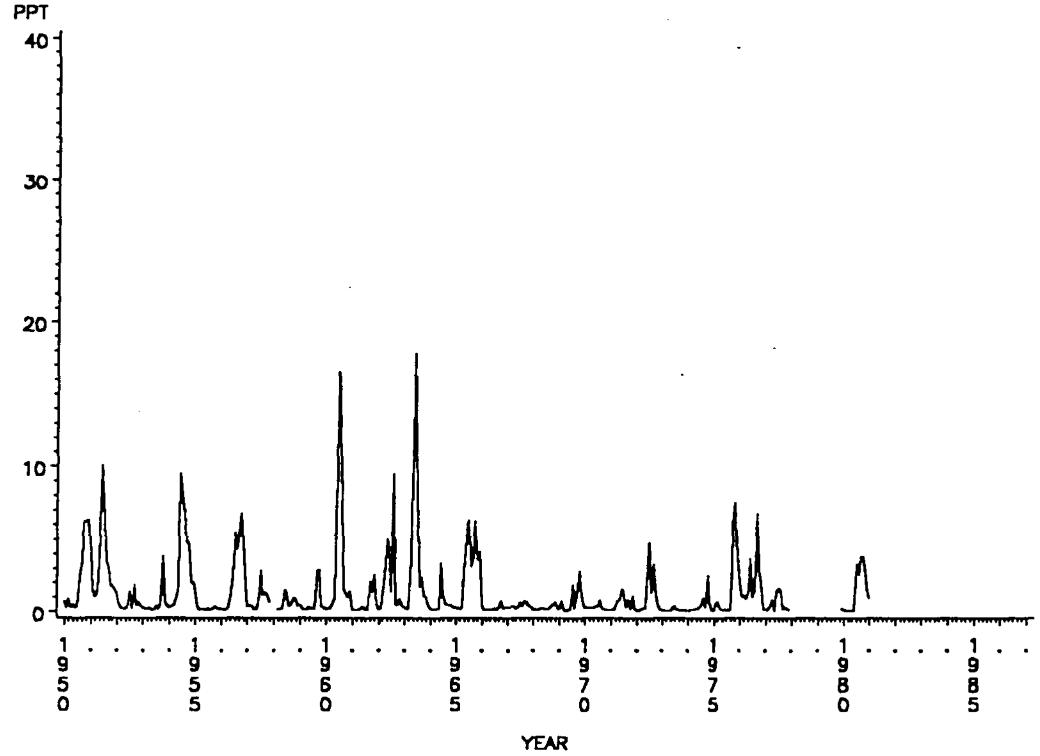


Figure D-24. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Teche @ Patterson (COE station 64800).


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=MERMENTAU RIVER

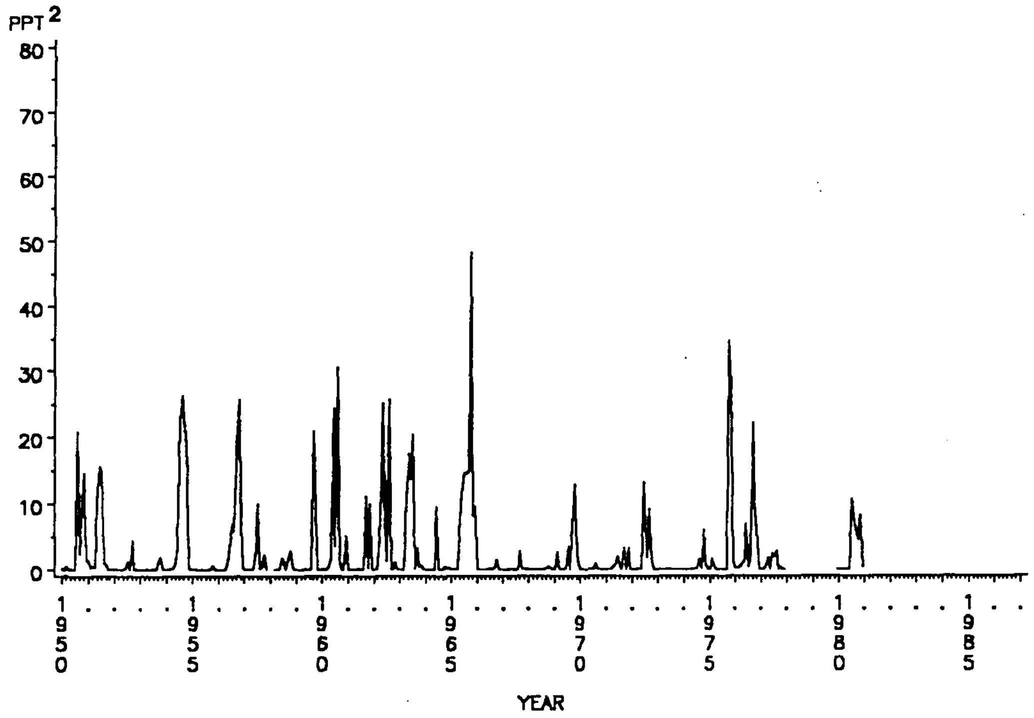
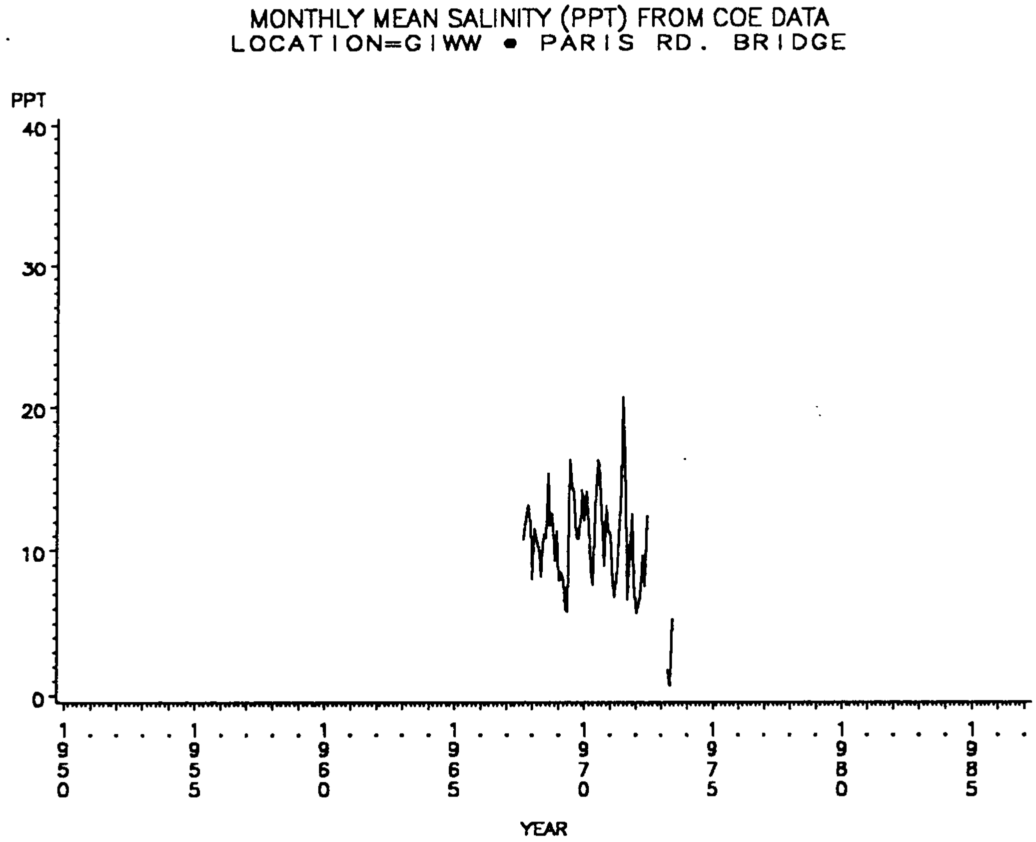

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=MERMENTAU RIVER

Figure D-25. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Mermentau River (COE station 70675).



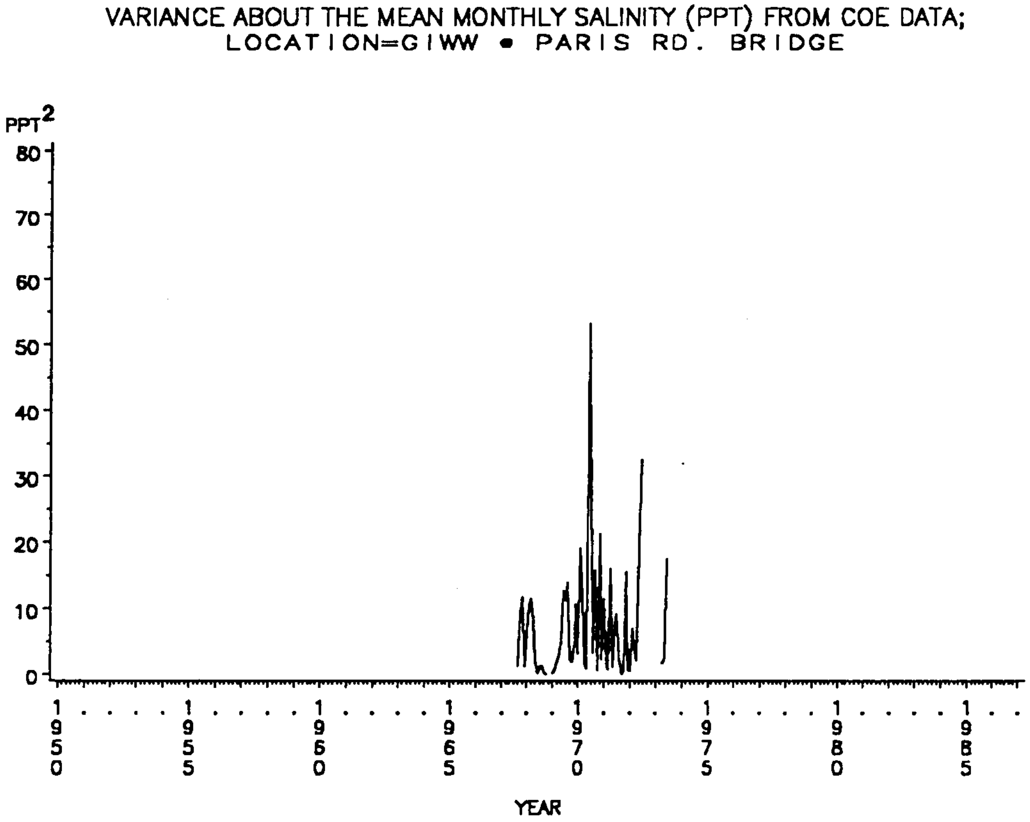
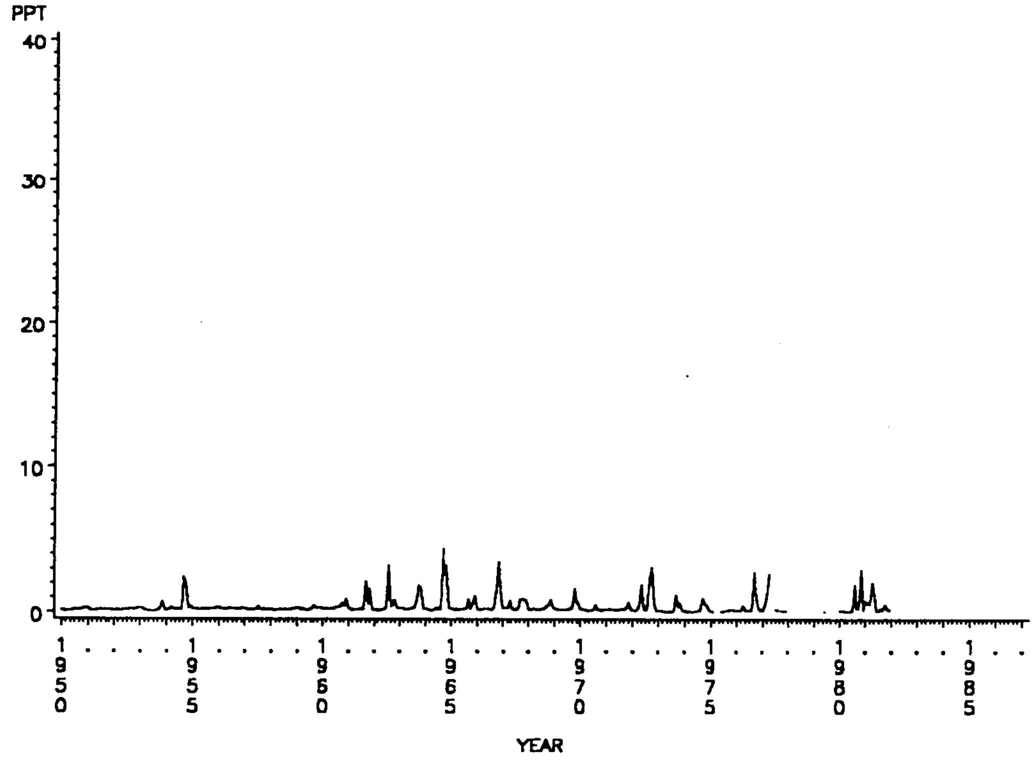


Figure D-26. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from GIWW @ Paris Rd. Bridge (COE station 76042).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=GIWW • HOUMA



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=GIWW • HOUMA

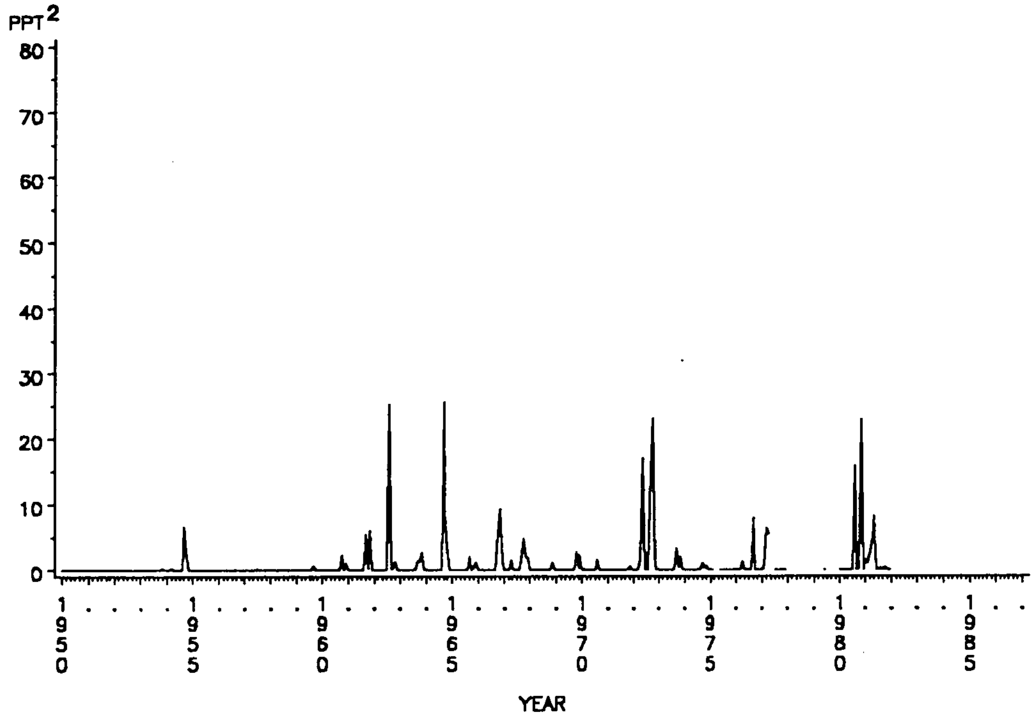
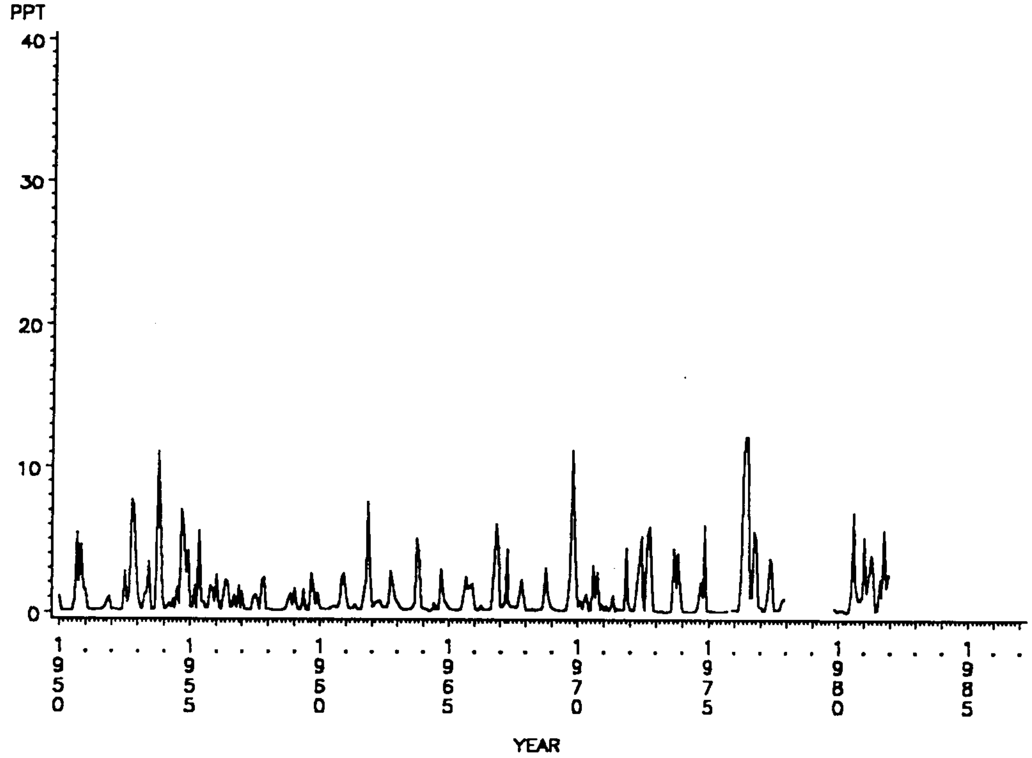


Figure D-27. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from GIWW @ Houma (COE station 76320).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=B. GRAND CAILLOU • DULAC



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=B. GRAND CAILLOU • DULAC

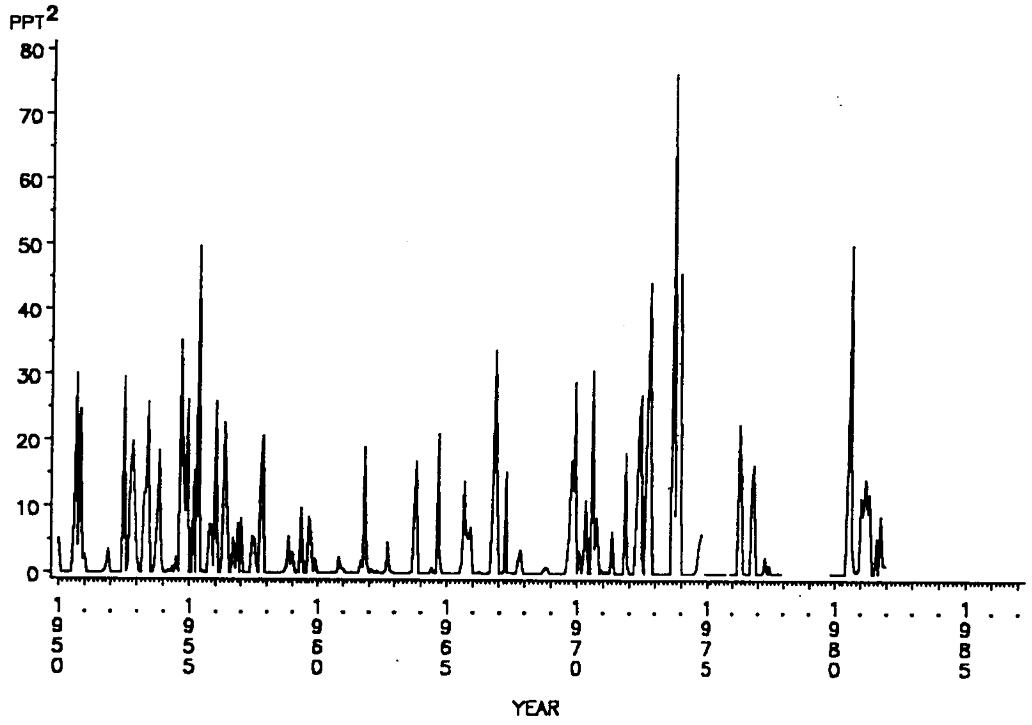
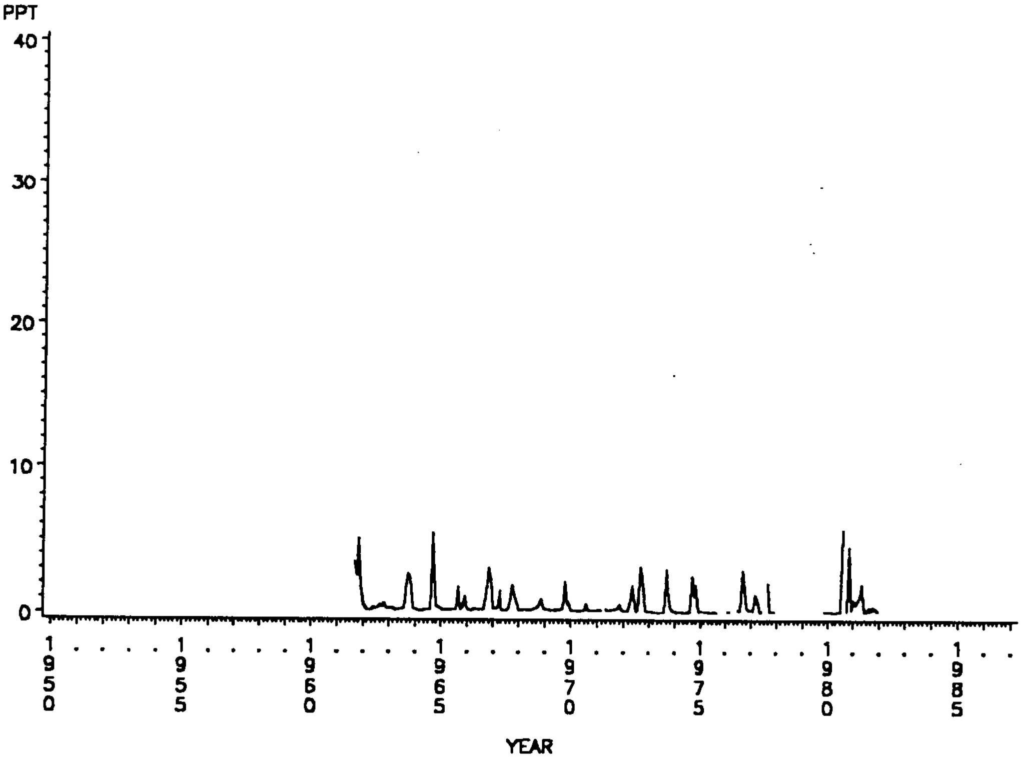
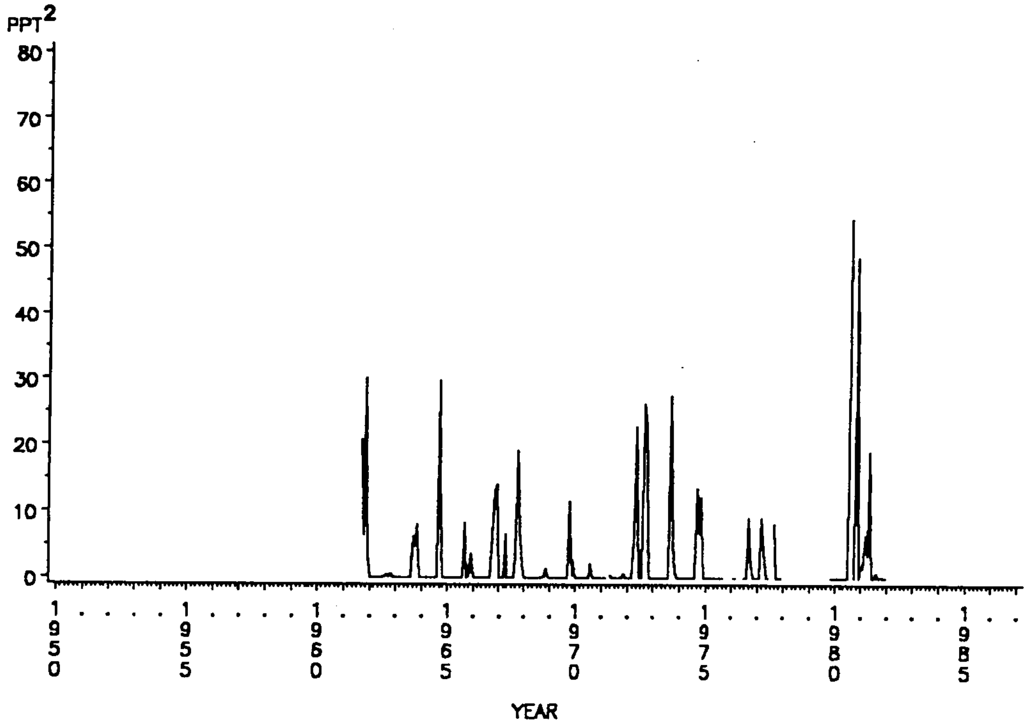


Figure D-28. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Grand Caillou near Dulac (COE station 76323).

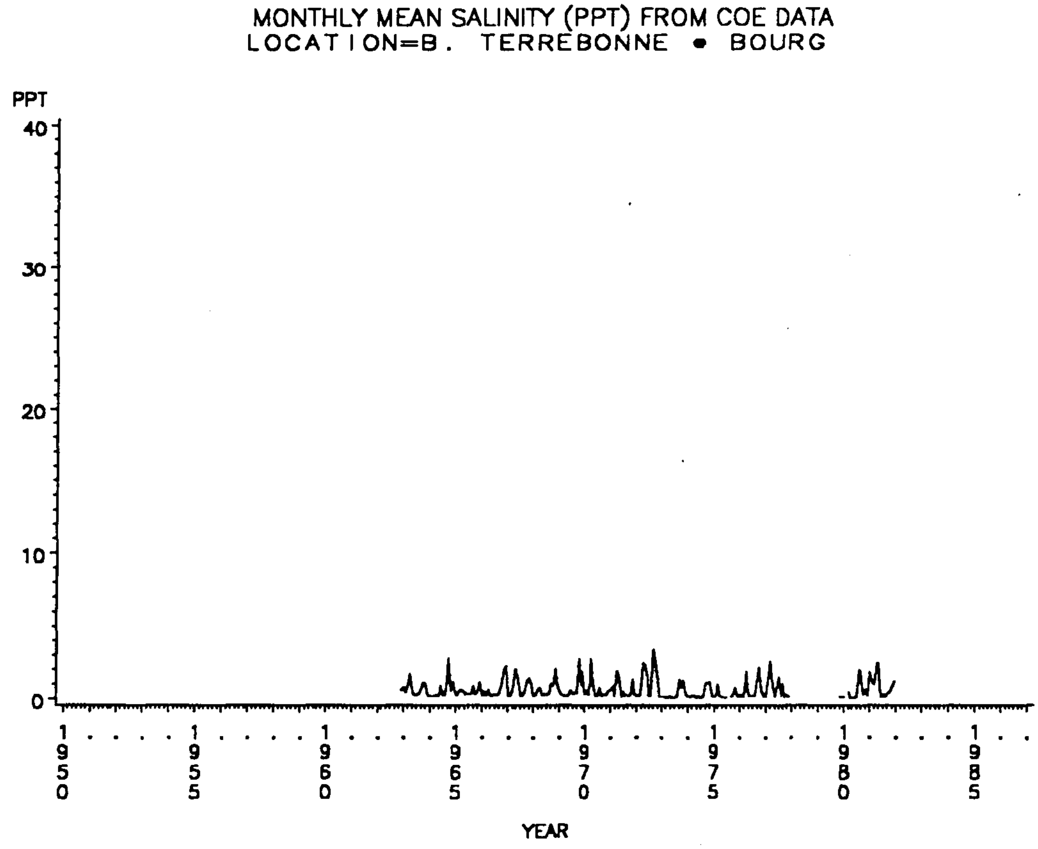


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=HOUMA NAV. CAN. • CROZIER



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=HOUMA NAV. CAN. • CROZIER

Figure D-29. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Houma Navigation Canal @ Crozier (COE station 76343).



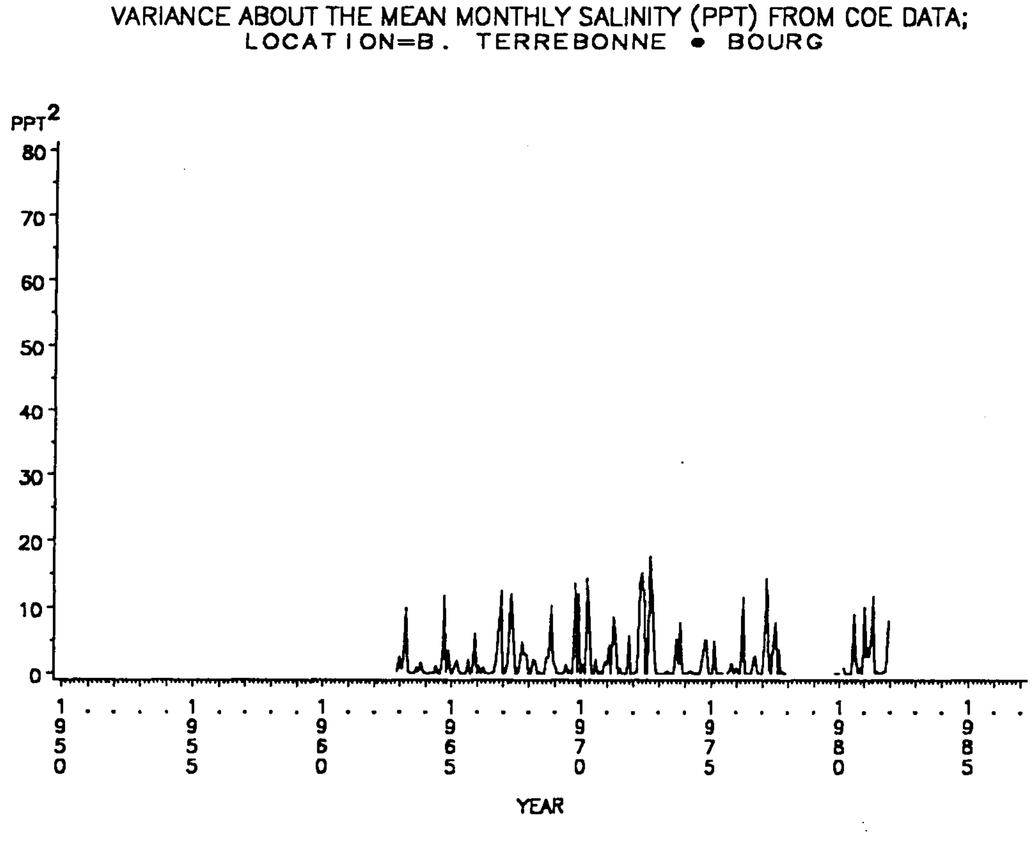
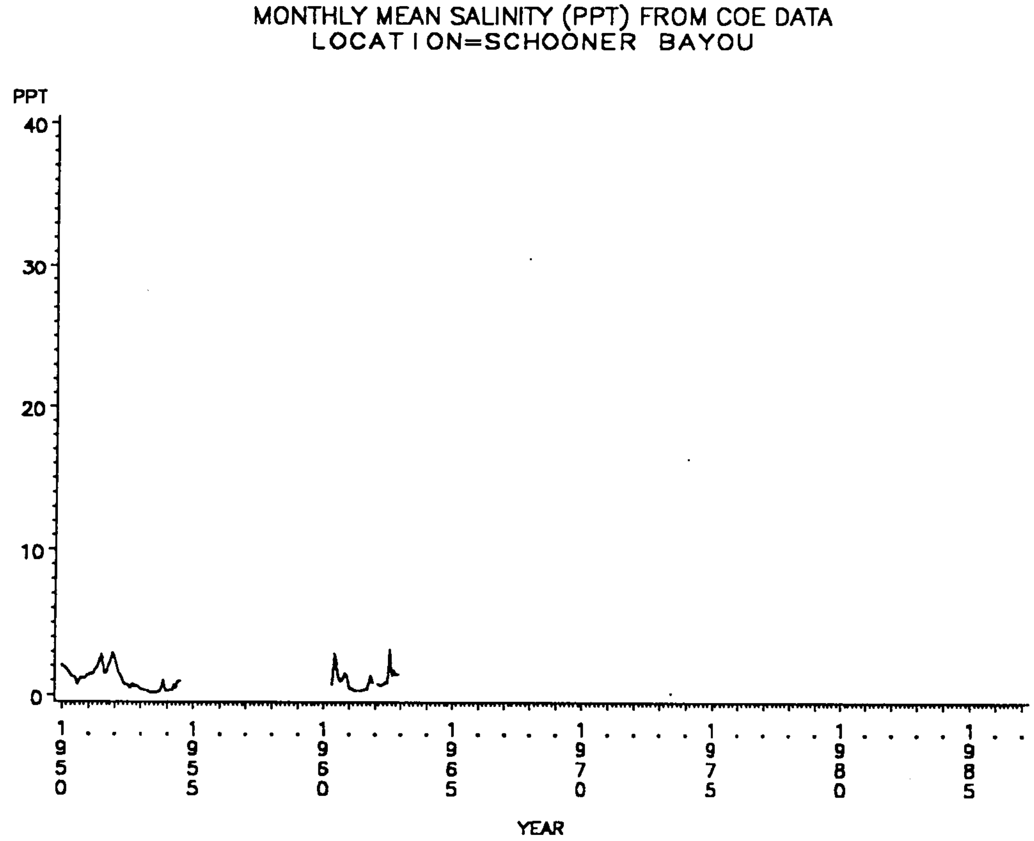


Figure D-30. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Terrebonne @ Bourg (COE station 76403).



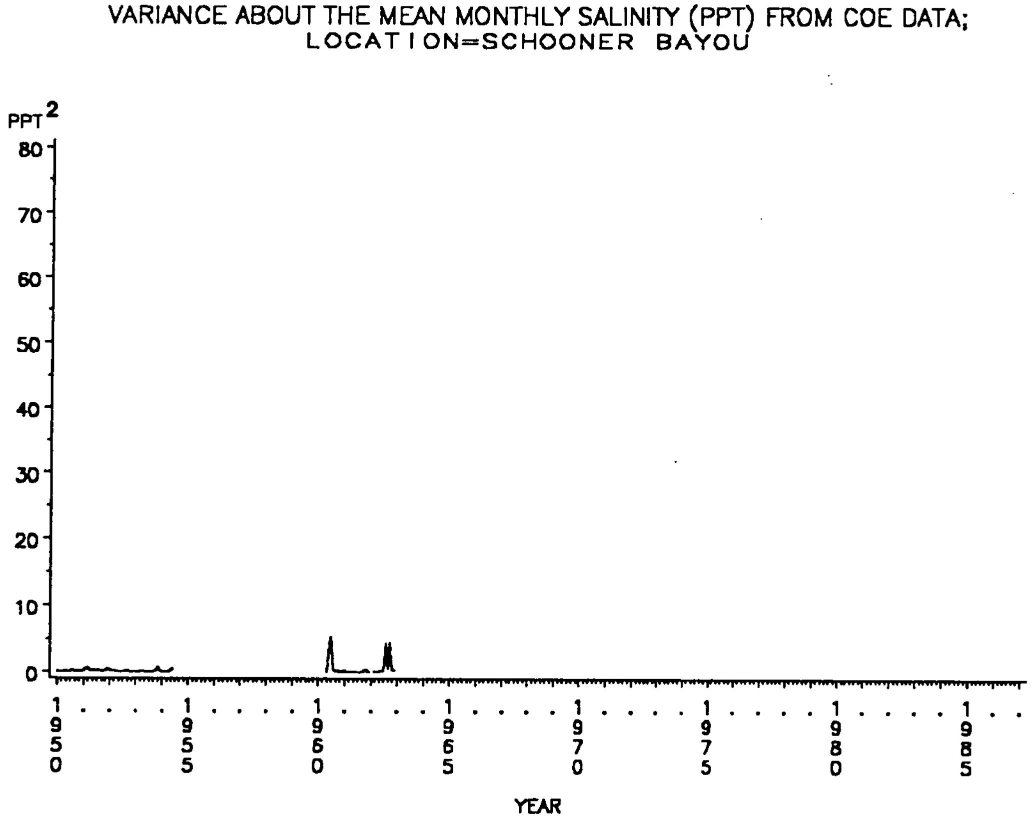
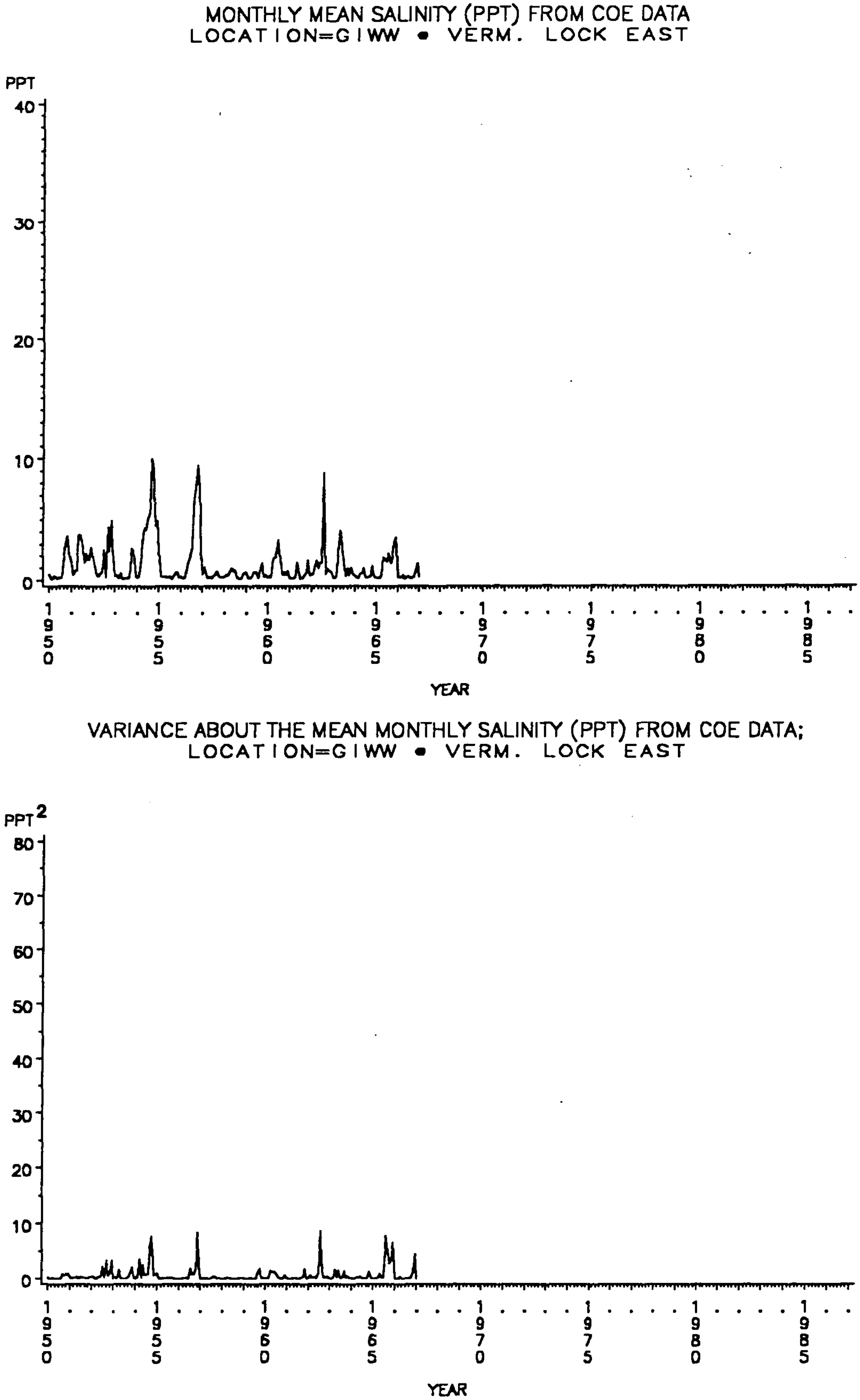


Figure D-31. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Schooner Bayou (COE station 76690).

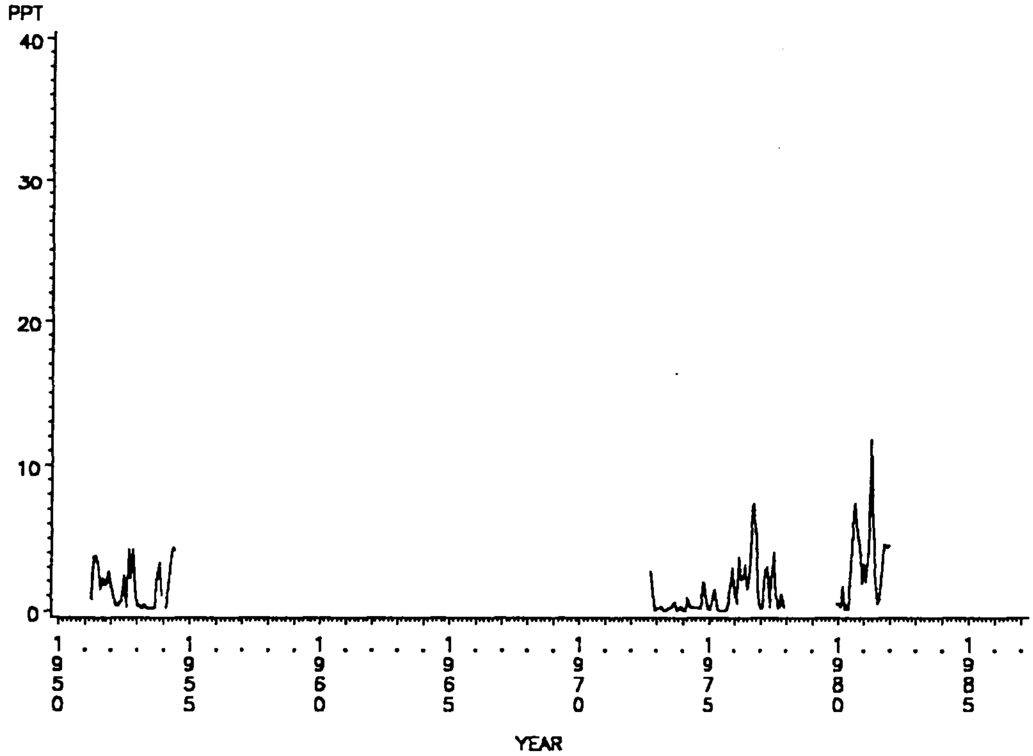


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=GIWW • VERM. LOCK EAST

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=GIWW • VERM. LOCK EAST

Figure D-32. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Vermillion Lock, East (COE station 76720).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=GIWW • VERM. LOCK WEST



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=GIWW • VERM. LOCK WEST

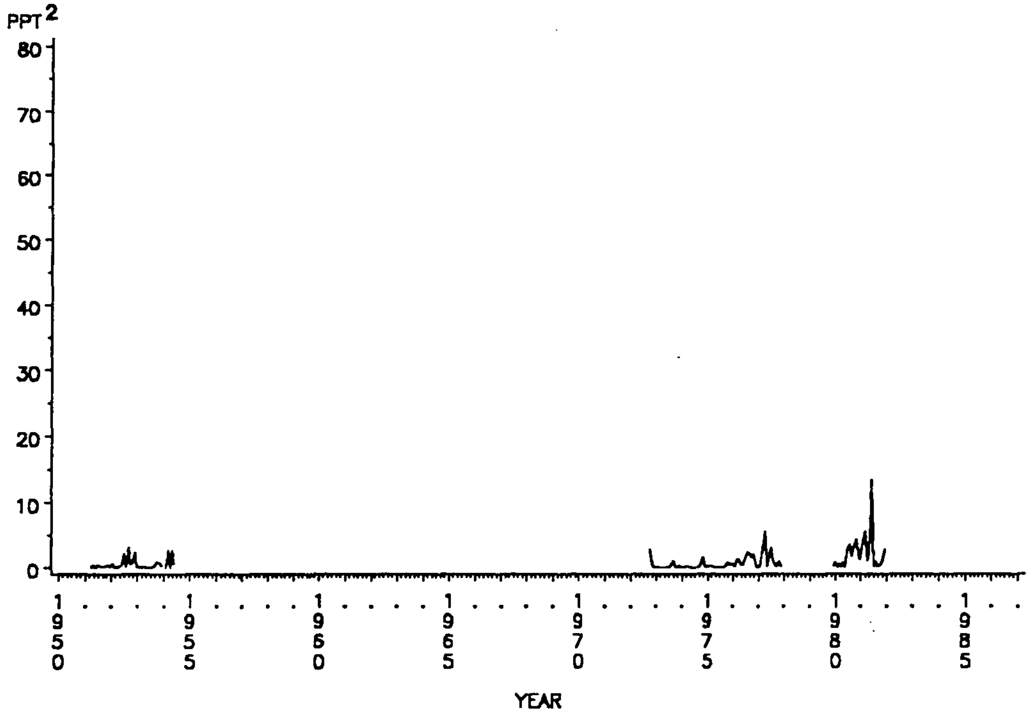
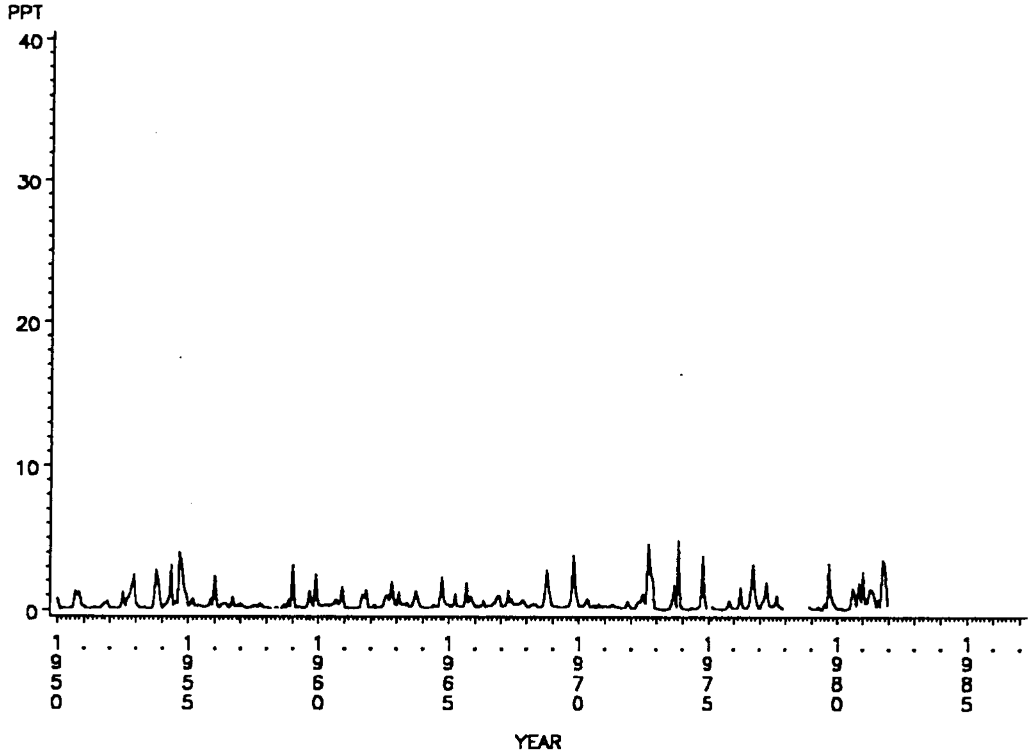
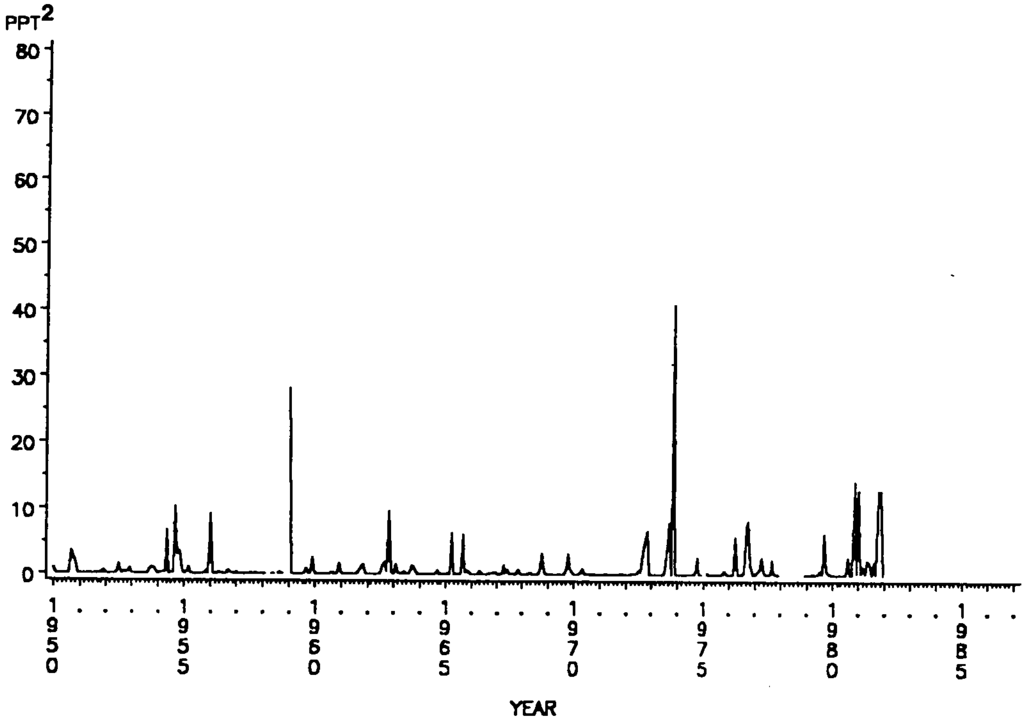


Figure D-33. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Vermillion Lock, West (COE station 76800).

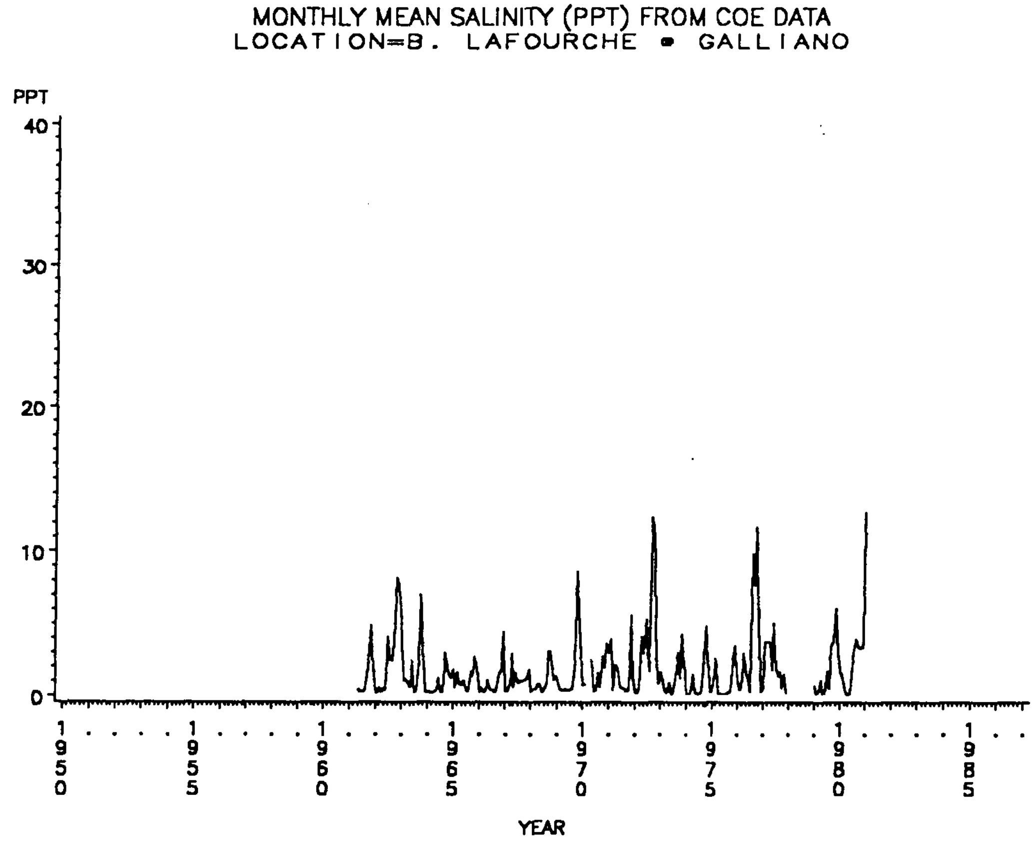


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=B. LAFOURCHE • LAROSE



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=B. LAFOURCHE • LAROSE

Figure D-34. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Lafourche @ Larose (COE station 82203).



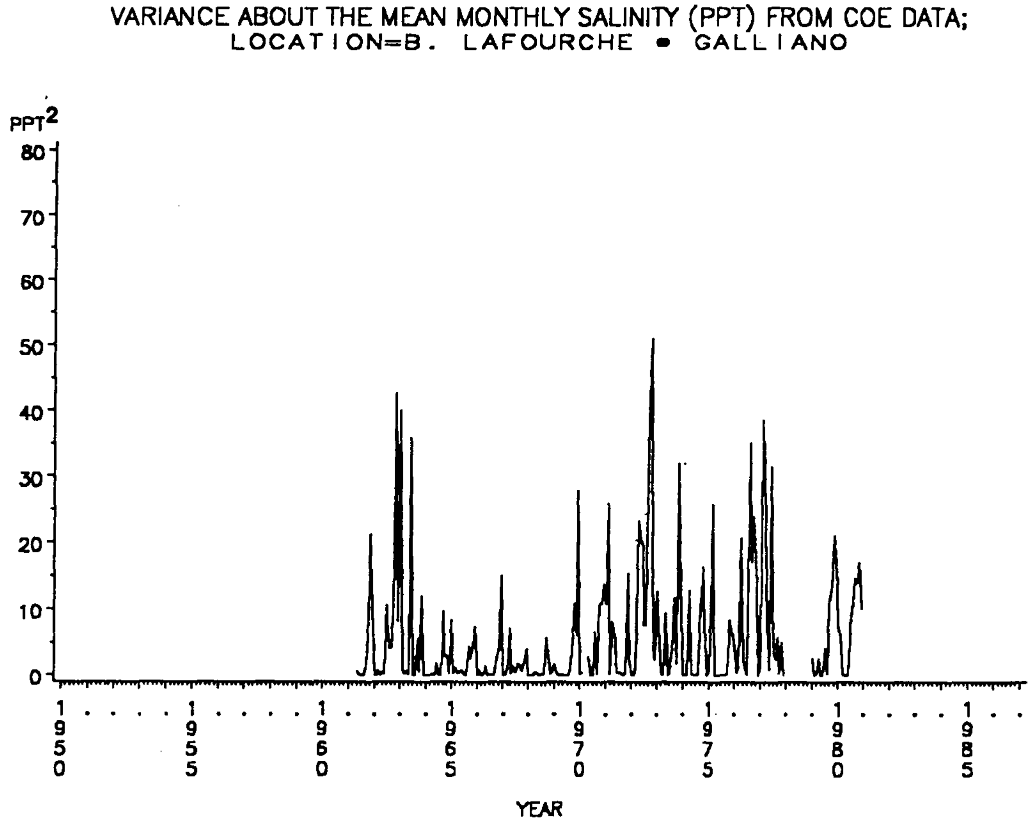
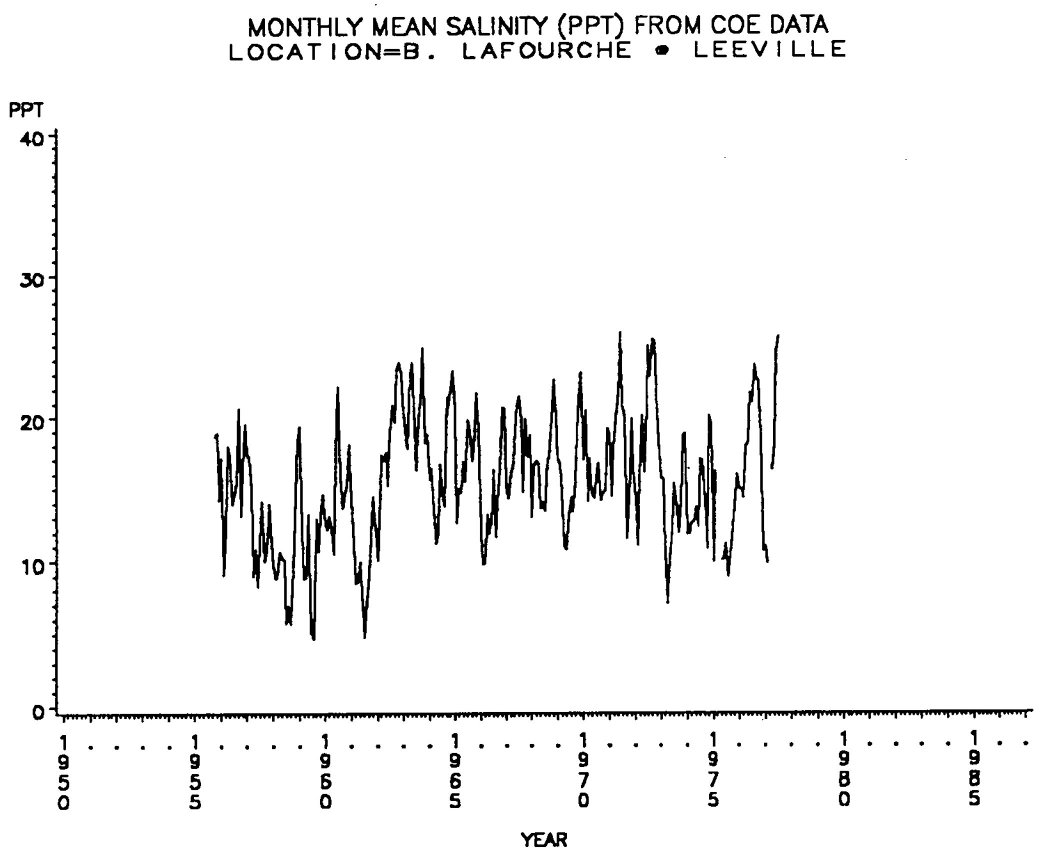


Figure D-35. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Lafourche @ Galliano (COE station 82300).



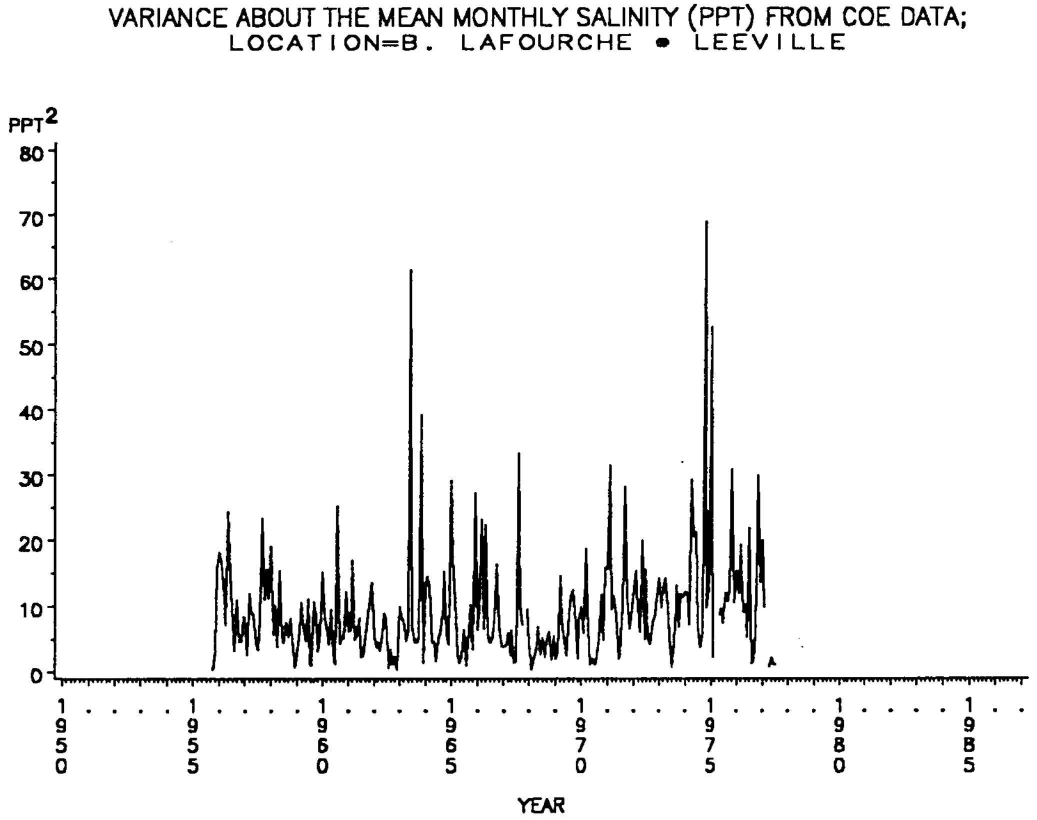
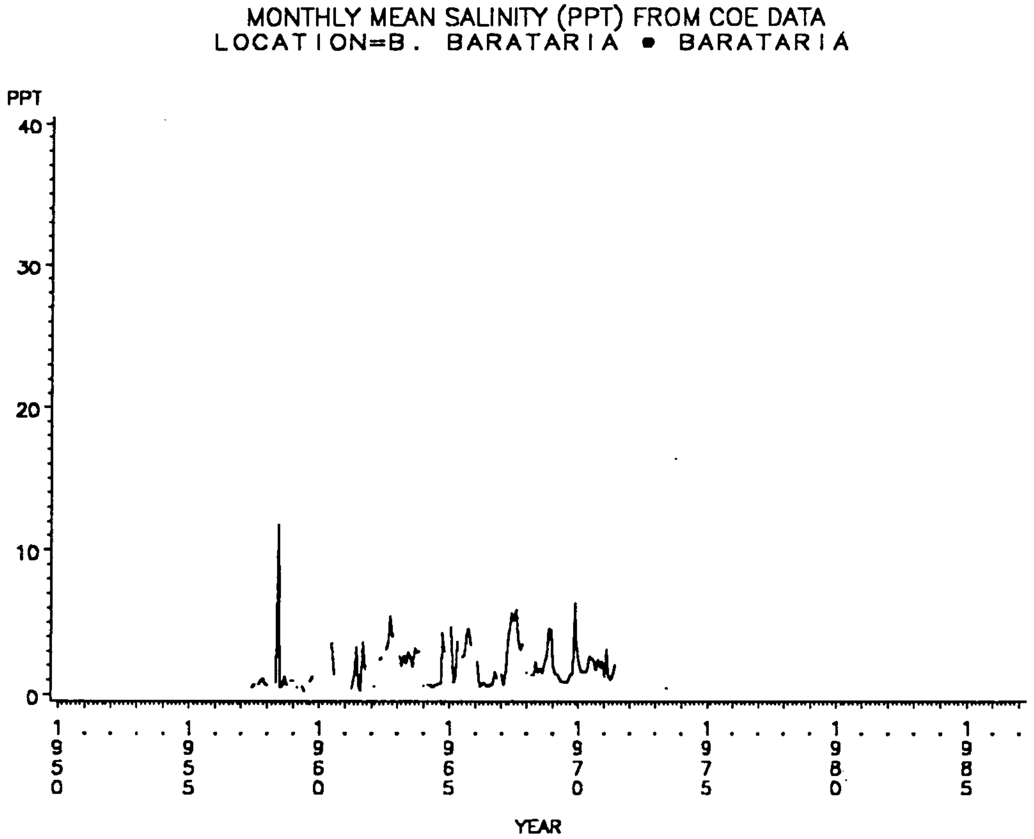


Figure D-36. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Lafourche @ Leeville (COE station 82350).



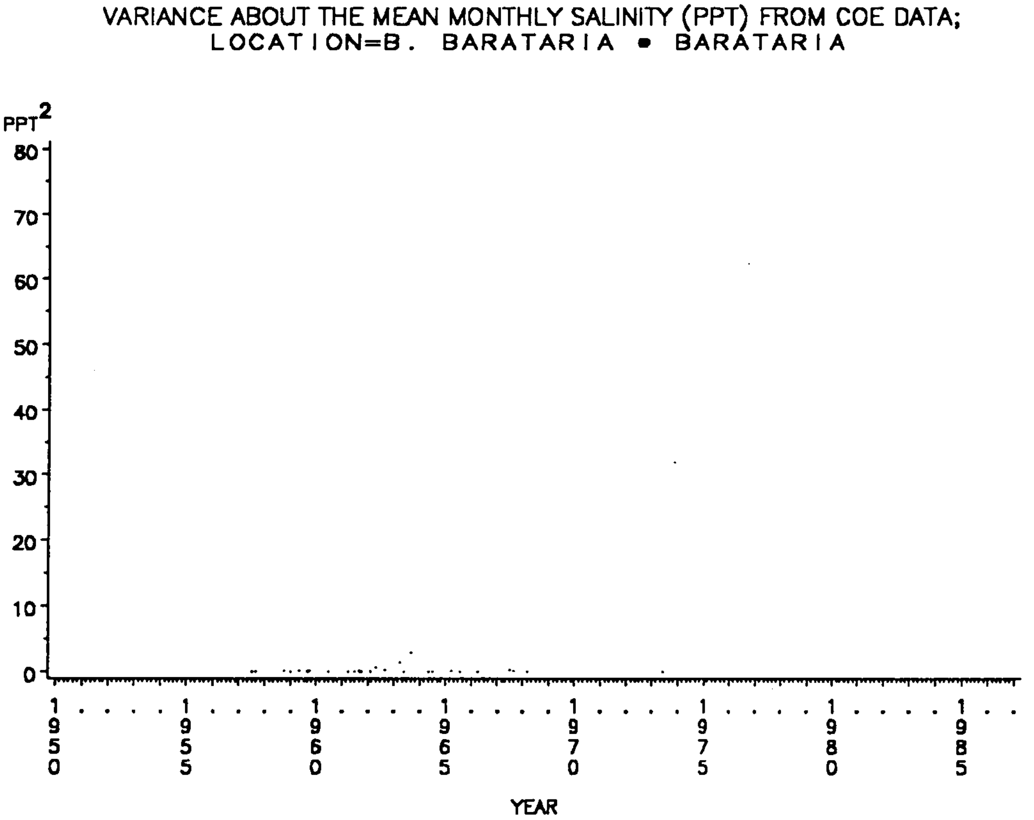
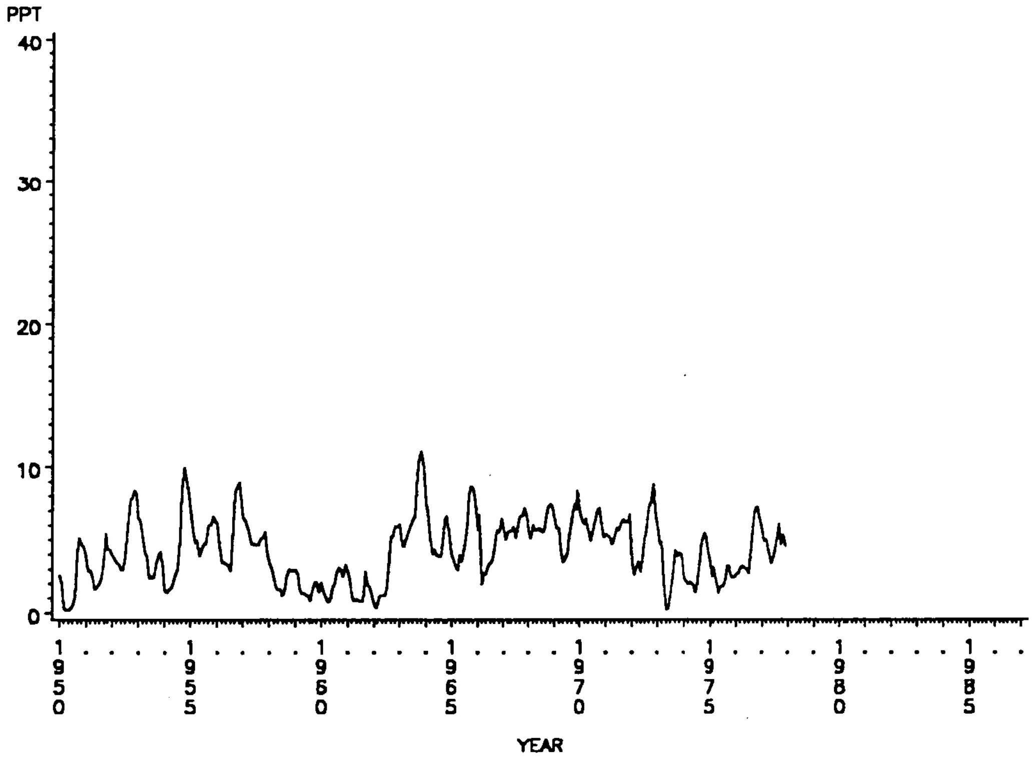


Figure D-37. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Bayou Barataria @ Barataria (COE station 82750).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=LITTLE WOODS (L. PONT.)



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=LITTLE WOODS (L. PONT.)

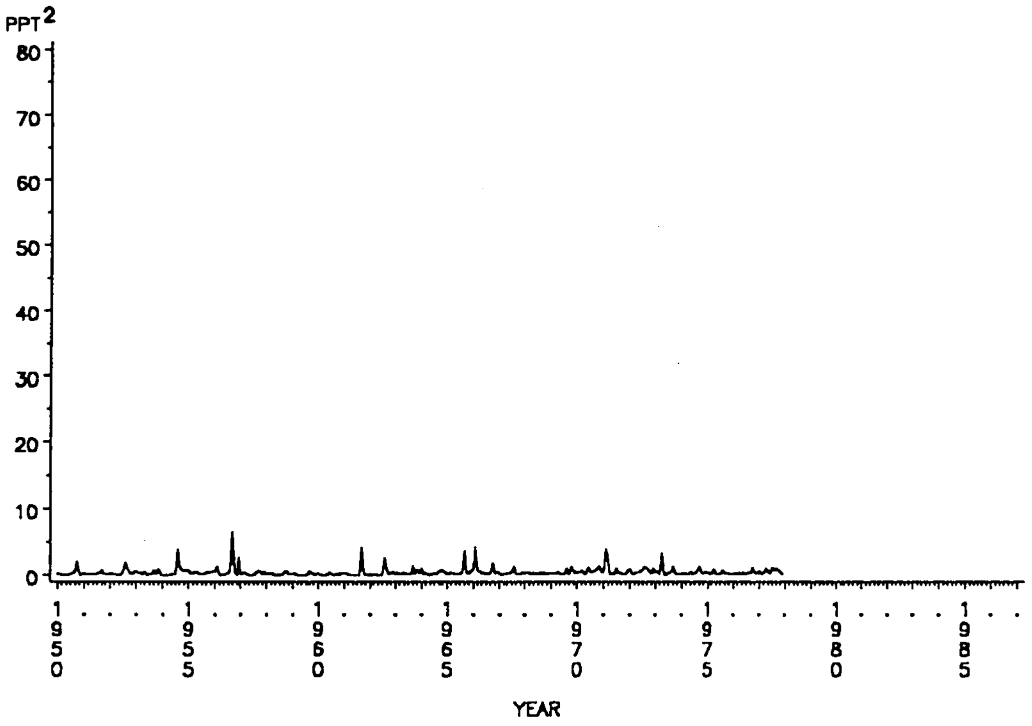
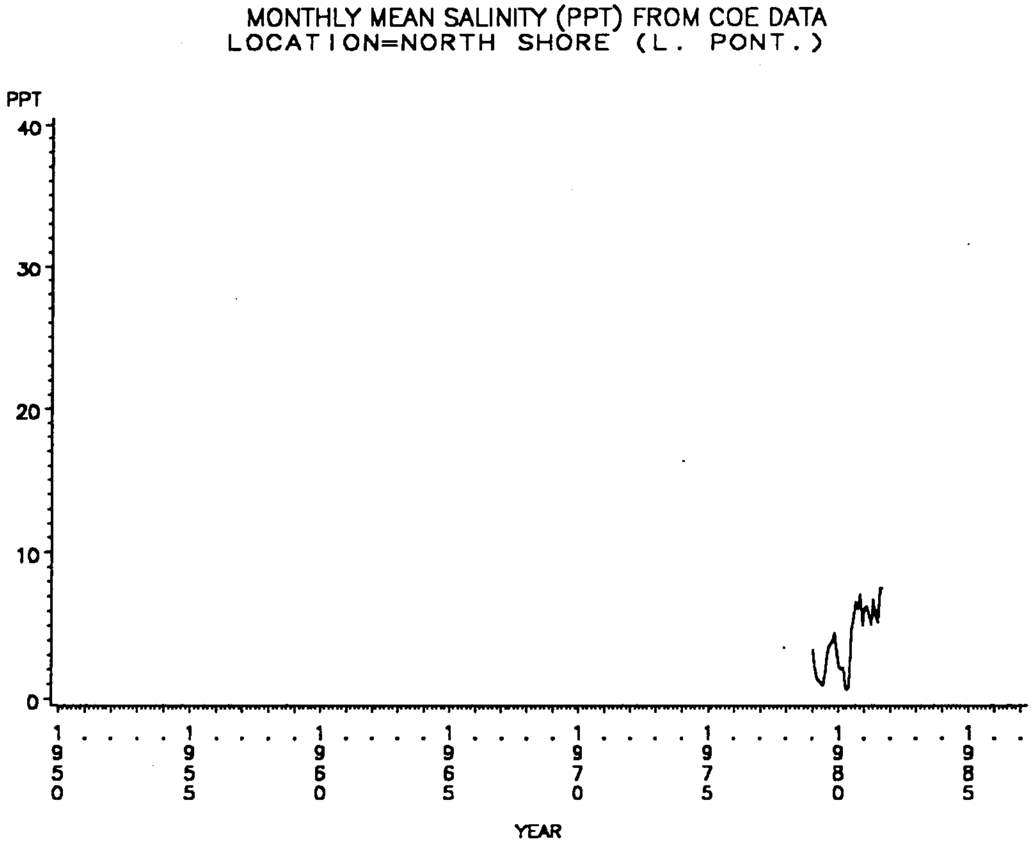


Figure D-38. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Lake Pontchartrain @ Little Woods (COE station 85650).



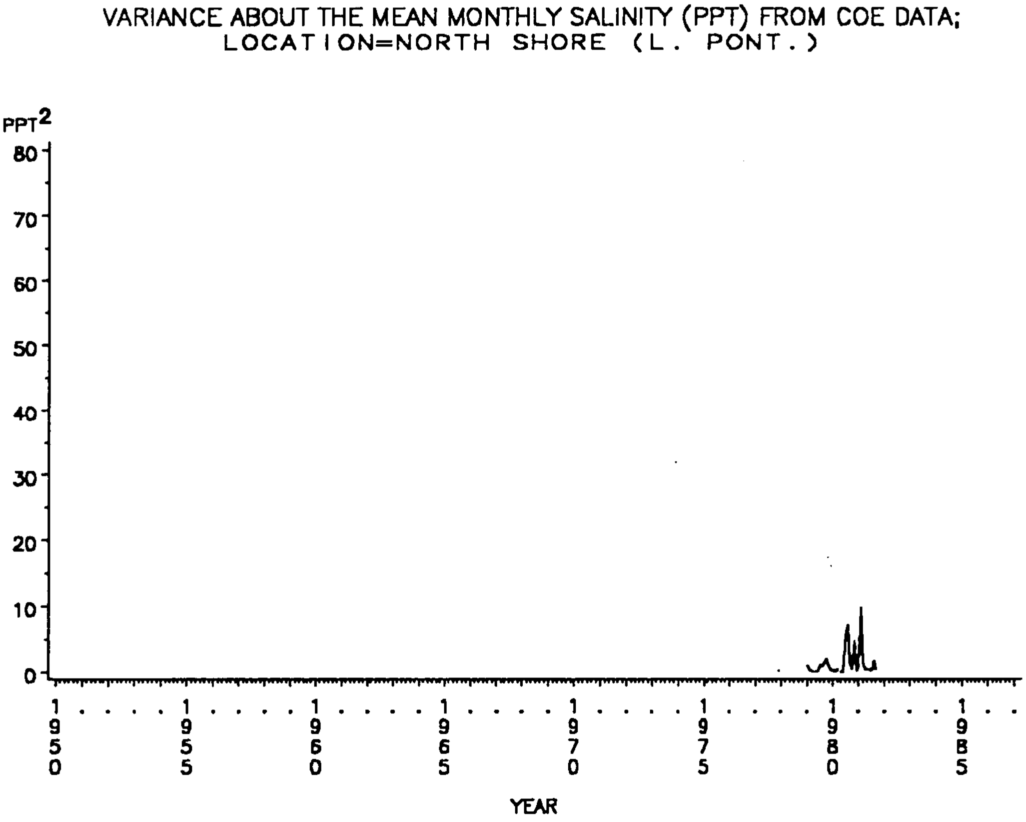
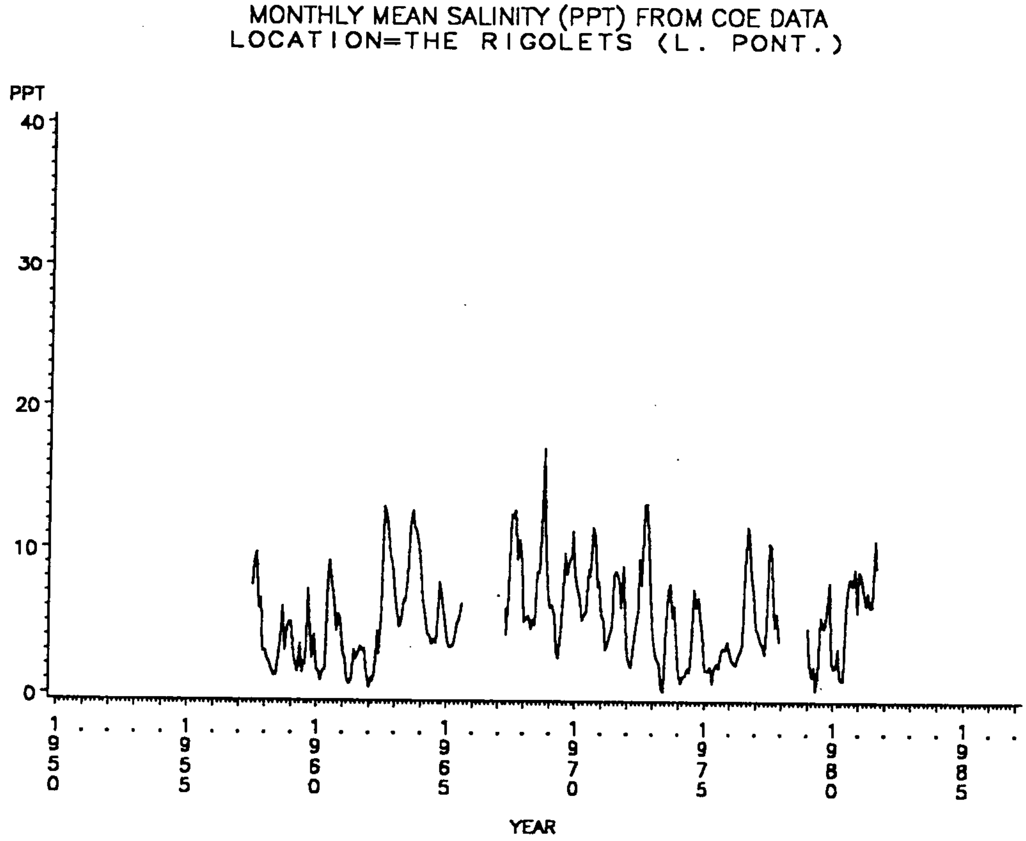


Figure D-39. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Lake Pontchartrain @ North Shore (COE station 85683).



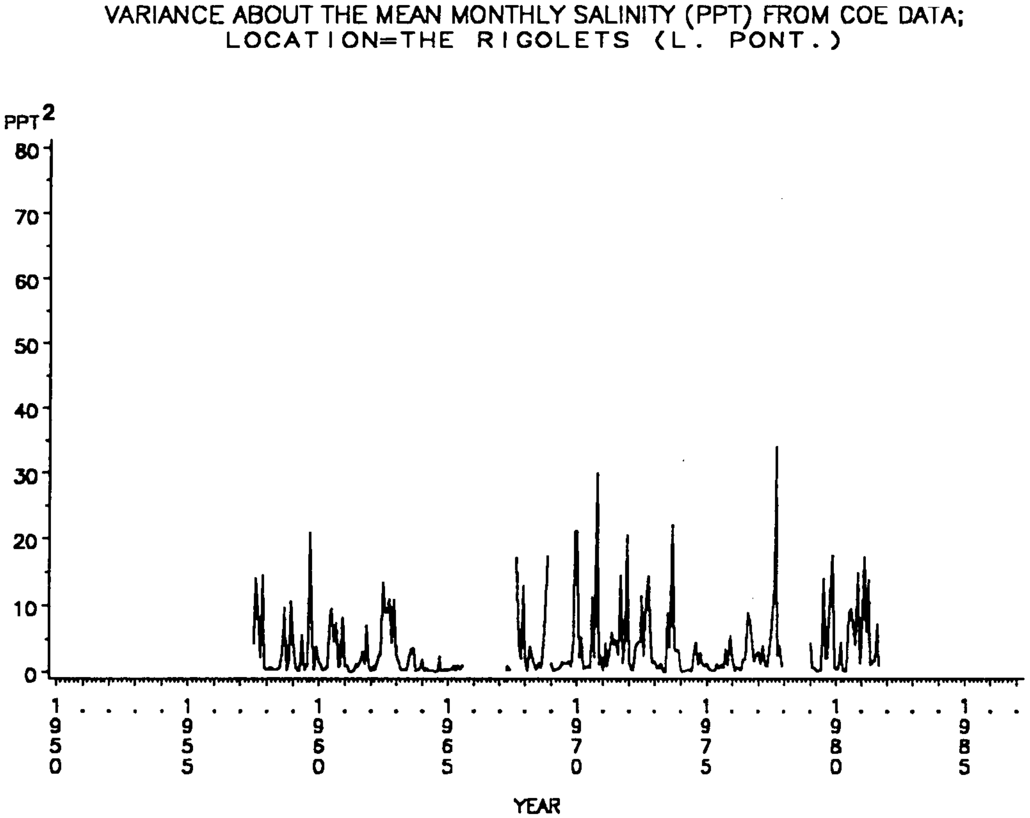
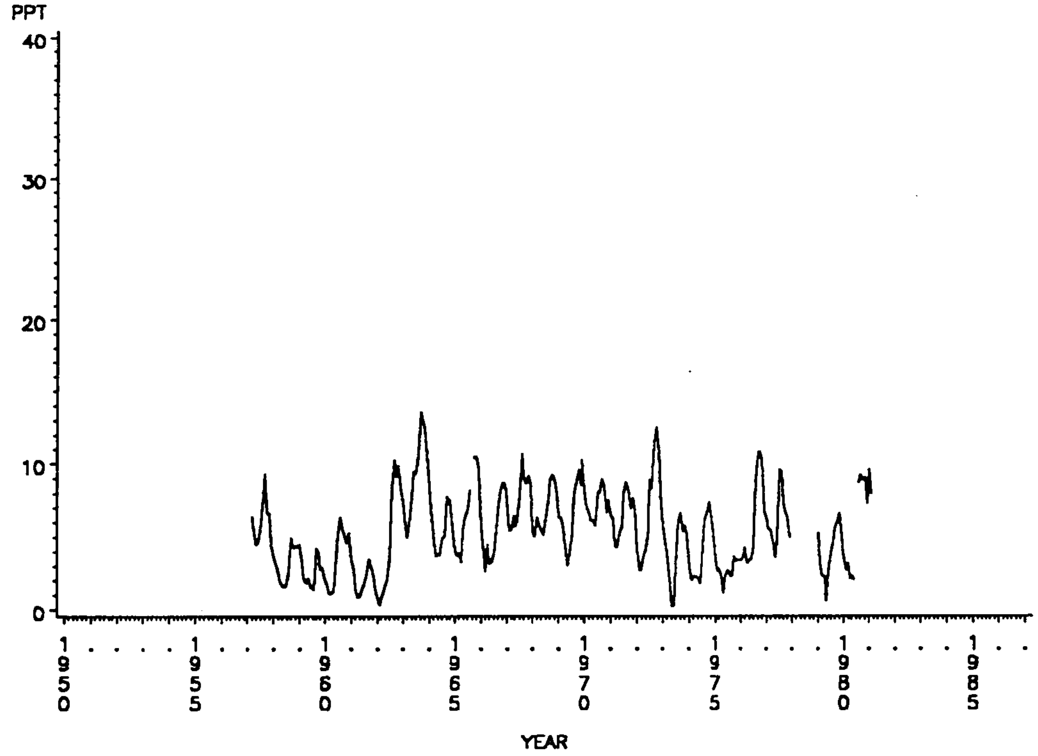


Figure D-40. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from The Rigolets (COE station 85700).


MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=CHEF MENTEUR (L. PONT.)

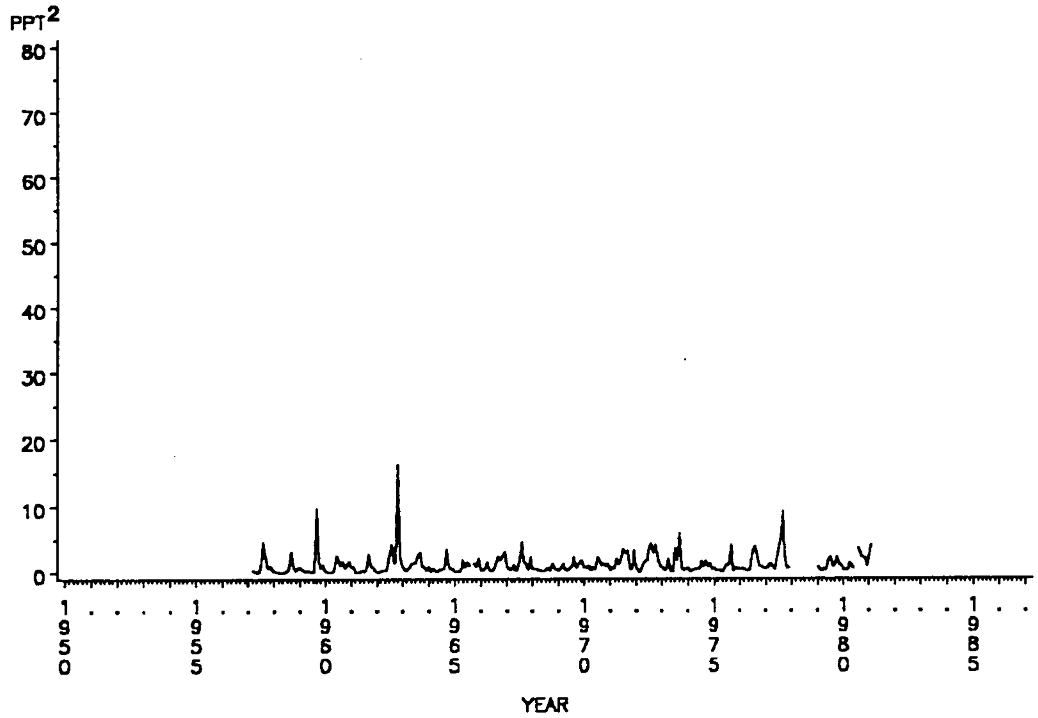
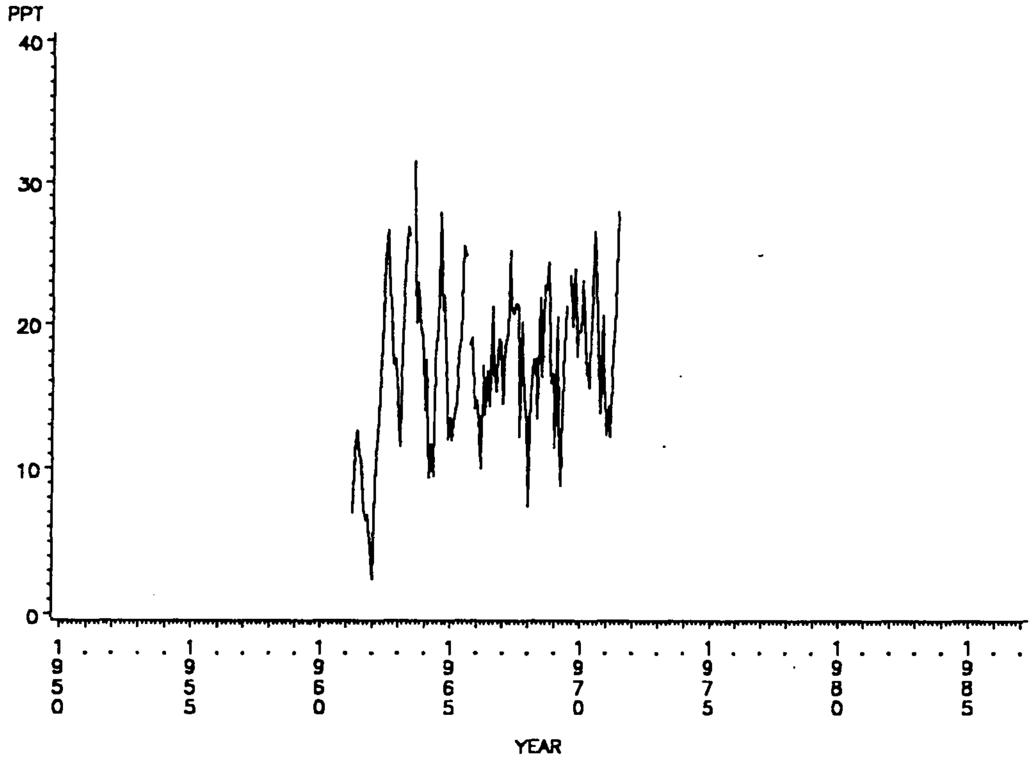

VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=CHEF MENTEUR (L. PONT.)

Figure D-41. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Chef Menteur Pass (COE station 85750).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=MRGO • NAV. LIGHT 101



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=MRGO • NAV. LIGHT 101

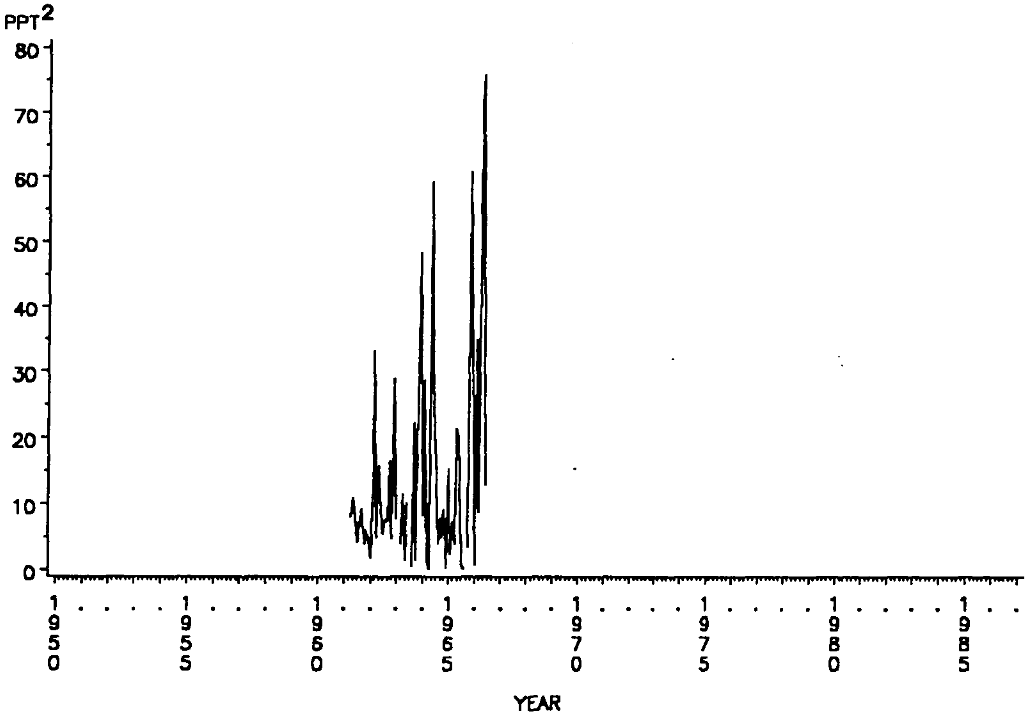
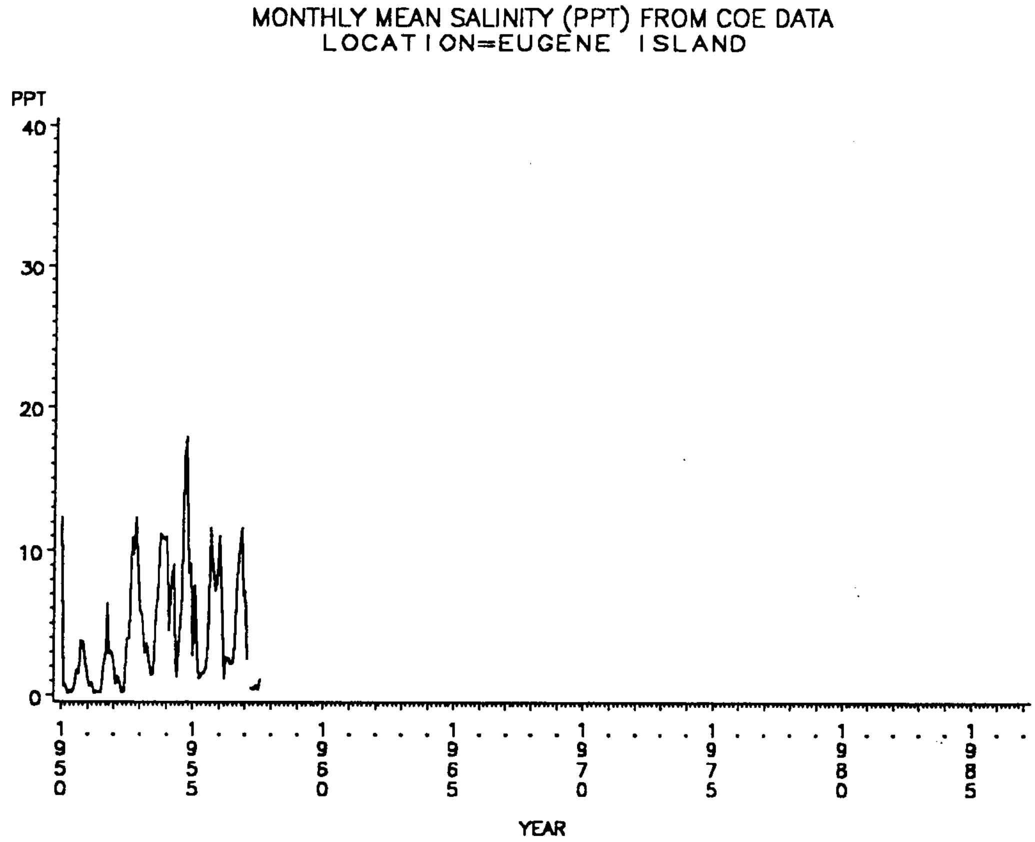


Figure D-42. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from MRGO @ Light 101 (COE station 85820).



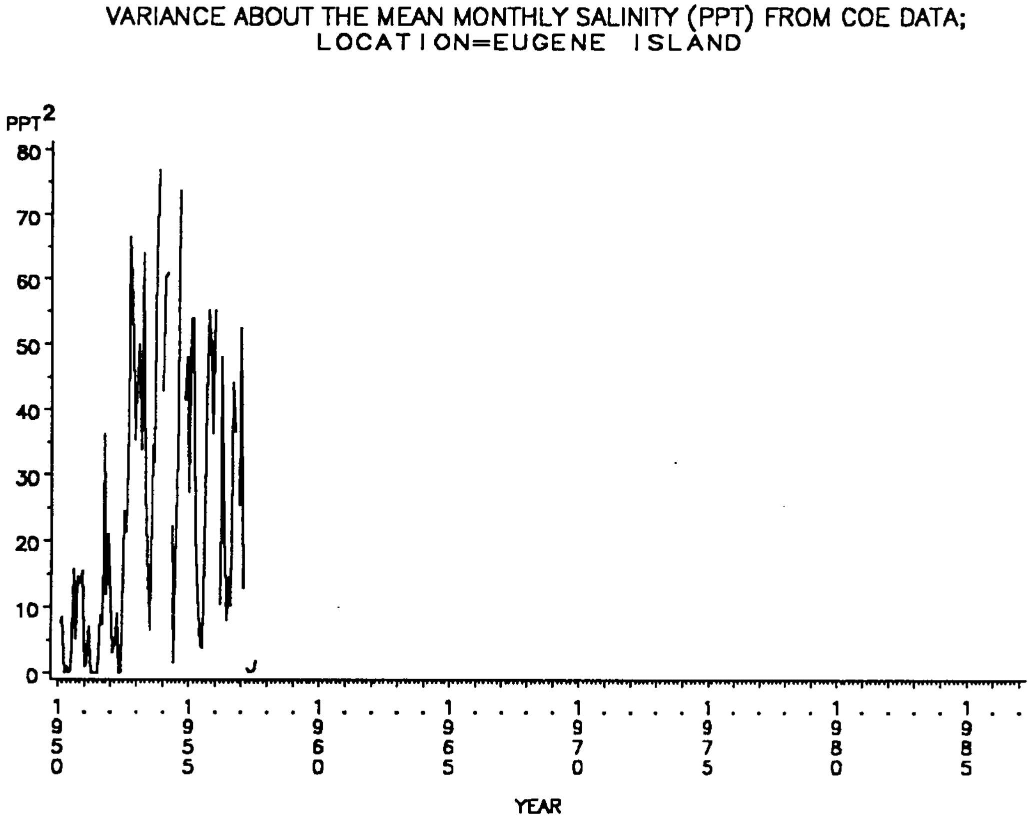
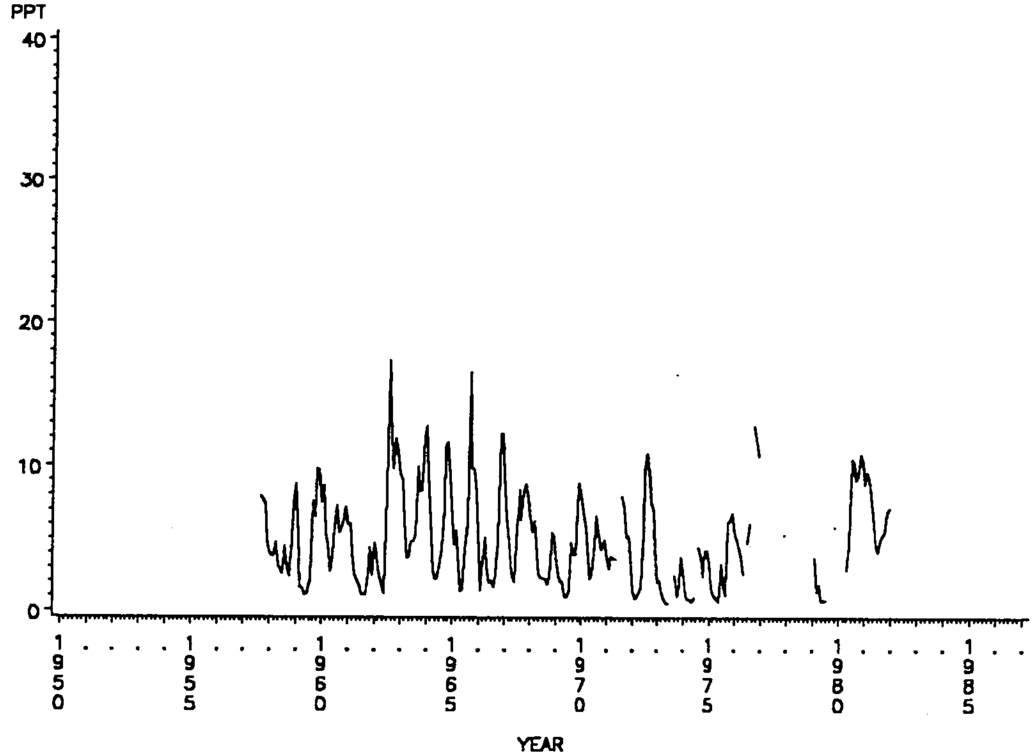


Figure D-43. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Eugene Island (COE station 88600).

MONTHLY MEAN SALINITY (PPT) FROM COE DATA
LOCATION=CYPREMORT POINT



VARIANCE ABOUT THE MEAN MONTHLY SALINITY (PPT) FROM COE DATA;
LOCATION=CYPREMORT POINT

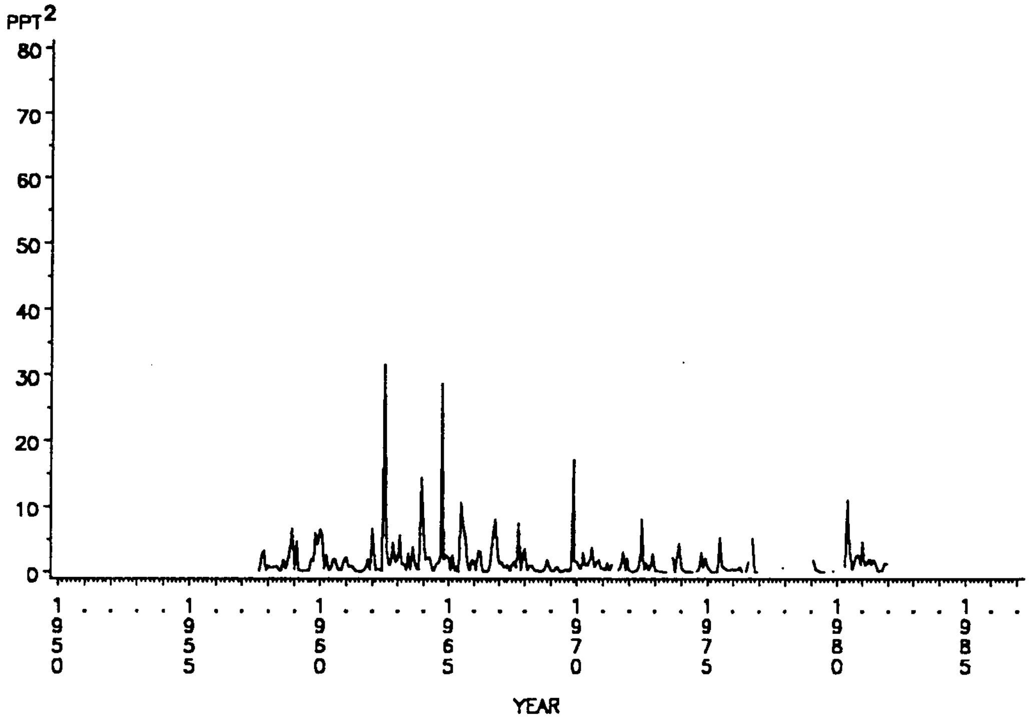


Figure D-44. Time series plots of monthly mean salinity (top) and the variance of the monthly mean salinity (bottom) from Cypremort Point (COE station 88850).

Table D-2. Salinity persistance summary for LDWF stations 102 and 117. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 102 RECORD LENGTH: 1,866 DAYS = 5.11 YEARS MEAN SALINITY = 3.89 PPT

A. MISSING VALUES ASSUMED HIGH												
	25	4	2	0	0	0	1	0	0	0	0	1
	20	4	2	0	0	0	1	0	0	0	0	1
PPT	15	7	2	0	0	0	1	0	0	0	0	1
	10	17	1	1	0	0	1	0	0	0	0	1
	5	26	0	0	0	0	1	0	1	0	0	3
B. MISSING VALUES ASSUMED LOW												
	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	3	0	0	0	0	0	0	0	0	0	0
	10	15	0	0	0	0	0	0	0	0	0	0
	5	25	0	2	1	0	0	1	1	0	0	1

STATION: 117 RECORD LENGTH: 1,096 DAYS = 3.00 YEARS MEAN SALINITY = 16.25 PPT

A. MISSING VALUES ASSUMED HIGH												
	25	16	1	2	0	1	0	1	1	0	0	0
	20	38	2	1	0	2	0	0	1	0	0	1
PPT	15	31	10	3	1	1	1	0	1	0	0	1
	10	15	5	1	1	0	1	0	0	0	0	2
	5	3	1	1	0	0	0	0	0	0	0	1
B. MISSING VALUES ASSUMED LOW												
	25	19	1	0	0	0	0	0	0	0	0	0
	20	39	4	0	0	1	0	0	0	0	0	0
PPT	15	35	11	2	2	1	0	0	1	0	0	0
	10	17	6	0	2	1	1	0	0	0	0	2
	5	7	2	0	1	0	0	0	0	0	1	2
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-3. Salinity persistance summary for LDWF stations 221 and 251. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 221 RECORD LENGTH: 3,046 DAYS = 8.34 YEARS MEAN SALINITY = 13.61 PPT

A. MISSING VALUES ASSUMED HIGH

	25	17	6	2	1	1	0	1	0	0	1	3
	20	30	7	3	0	0	0	1	0	0	0	4
PPT	15	45	7	3	1	1	1	0	0	0	0	5
	10	29	3	2	1	1	1	0	0	0	1	5
	5	11	0	0	0	0	0	0	0	0	0	2

B. MISSING VALUES ASSUMED LOW

	25	2	0	0	1	0	0	0	0	0	0	0
	20	19	3	0	0	0	0	1	0	0	0	0
PPT	15	37	10	2	1	2	0	0	0	0	0	2
	10	33	7	3	2	1	3	2	2	0	1	2
	5	17	6	1	1	0	2	1	0	2	1	4

STATION: 251 RECORD LENGTH: 1,158 DAYS = 3.17 YEARS MEAN SALINITY = 11.29 PPT

A. MISSING VALUES ASSUMED HIGH

	25	3	2	1	0	0	2	0	0	0	0	0
	20	2	4	1	0	0	2	0	0	0	0	0
PPT	15	22	2	3	0	2	1	0	0	0	0	1
	10	18	1	1	1	0	0	0	0	0	0	3
	5	6	0	0	0	1	0	0	0	0	0	2

B. MISSING VALUES ASSUMED LOW

	25	2	0	0	0	0	0	0	0	0	0	0
	20	1	2	0	0	0	0	0	0	0	0	0
PPT	15	25	1	1	2	2	0	0	0	0	0	0
	10	20	4	2	1	1	0	0	0	0	0	3
	5	6	3	1	1	2	0	1	0	0	0	3
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-4. Salinity persistance summary for LDWF stations 252 and 253. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 252 RECORD LENGTH: 1,096 DAYS = 3.00 YEARS MEAN SALINITY = 17.14 PPT

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	8	3	3	1	1	0	0	0	1	0	0
	20	25	5	3	2	0	1	0	0	1	0	1
PPT	15	25	0	1	0	1	0	0	1	0	0	3
	10	10	1	1	0	0	1	0	0	0	0	2
	5	2	2	0	0	0	0	0	0	0	0	1

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	8	2	0	0	0	0	0	0	0	0	0
	20	26	8	2	1	0	0	0	0	0	0	0
PPT	15	26	2	1	0	4	0	2	1	0	0	0
	10	12	5	1	1	2	0	1	0	0	0	3
	5	2	5	0	1	1	0	1	0	0	0	4

STATION: 253 RECORD LENGTH: 1,765 DAYS = 4.83 YEARS MEAN SALINITY = 19.29 PPT

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	9	6	0	0	1	1	0	0	0	0	2
	20	21	4	3	1	1	1	0	0	0	0	2
PPT	15	10	2	0	0	0	0	0	0	0	0	2
	10	10	2	0	0	0	0	0	0	0	0	2
	5	0	2	0	0	0	0	0	0	0	0	1

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	10	5	0	1	0	0	0	0	0	0	0
	20	22	5	5	2	1	0	0	0	0	0	0
PPT	15	17	4	2	2	1	1	0	0	1	0	1
	10	12	3	1	1	1	1	1	0	1	0	2
	5	2	3	1	1	1	1	1	0	0	0	2

PERSISTANCE (DAYS)

Table D-5. Salinity persistance summary for LDWF stations 315 and 317. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 315 RECORD LENGTH: 3,435 DAYS = 9.41 YEARS MEAN SALINITY = 20.90 PPT

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	63	5	0	0	0	1	0	0	1	0	0
	20	59	16	5	1	0	0	2	1	0	0	1
PPT	15	34	6	1	0	0	1	1	1	0	1	4
	10	11	2	1	1	0	0	1	1	0	0	2
	5	1	0	0	0	0	0	0	0	0	0	0

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	65	7	0	0	0	0	0	0	0	0	0
	20	60	17	7	1	1	0	2	1	0	0	0
PPT	15	35	7	2	0	0	1	2	1	0	1	4
	10	13	3	2	1	0	0	1	1	0	0	5
	5	1	1	1	0	0	0	0	0	0	0	3

STATION: 317 RECORD LENGTH: 4,257 DAYS = 11.66 YEARS MEAN SALINITY = 12.90

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	25	3	4	0	2	3	1	0	0	1	3
	20	63	5	6	0	1	3	1	1	0	1	3
PPT	15	86	8	6	0	2	2	0	1	0	0	6
	10	60	13	6	2	2	2	3	0	0	0	7
	5	22	3	3	2	1	0	1	2	0	0	9

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	19	1	0	0	0	0	0	0	0	0	0
	20	66	3	1	0	0	0	0	0	0	0	0
PPT	15	86	8	2	1	1	0	0	0	0	1	0
	10	69	17	5	3	2	1	1	0	0	0	1
	5	32	6	7	7	2	1	4	0	0	0	3

PERSISTANCE (DAYS)

Table D-6. Salinity persistance summary for LDWF stations 416 and 518. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 416 RECORD LENGTH: 3,739 DAYS = 10.24 YEARS MEAN SALINITY = 9.44 PPT

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	9	2	1	2	1	2	0	0	0	0	0
	20	16	4	1	2	1	2	0	0	0	0	0
PPT	15	29	9	3	2	2	1	1	0	0	0	0
	10	58	10	1	2	2	1	0	1	0	0	2
	5	51	13	2	3	0	3	0	0	1	0	4

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	4	0	0	0	0	0	0	0	0	0	0
	20	14	1	0	0	0	0	0	0	0	0	0
PPT	15	29	6	2	0	1	0	0	0	0	0	0
	10	62	6	1	1	0	0	0	1	0	0	2
	5	54	16	3	4	0	1	0	1	1	0	3

STATION: 518 RECORD LENGTH: 4,043 DAYS = 11.08 YEARS MEAN SALINITY = 10.76 PPT

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	7	2	3	3	0	0	1	0	0	0	1
	20	15	3	2	4	0	0	1	0	0	0	1
PPT	15	52	7	2	3	2	1	0	1	0	1	1
	10	67	5	5	2	5	0	0	0	0	1	5
	5	32	7	1	0	0	1	0	2	0	0	5

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	1	0	0	0	0	0	0	0	0	0	0
	20	9	1	0	0	0	0	0	0	0	0	0
PPT	15	49	7	0	0	1	1	0	1	0	0	0
	10	70	9	4	1	3	0	0	0	0	2	2
	5	34	10	2	4	1	1	0	0	0	2	3

PERSISTANCE (DAYS)

Table D-7. Salinity persistance summary for LDWF stations 620 and 701. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 620 RECORD LENGTH: 793 DAYS = 2.17 YEARS MEAN SALINITY = 6.07

A. MISSING VALUES ASSUMED HIGH

	25	1	0	0	0	0	0	1	0	0	0	0
	20	2	0	0	0	0	0	1	0	0	0	0
PPT	15	8	0	0	0	0	0	1	0	0	0	0
	10	36	1	0	0	0	0	1	0	0	0	0
	5	24	1	4	0	0	0	0	0	0	0	1

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	7	0	0	0	0	0	0	0	0	0	0
	10	35	2	0	0	0	0	0	0	0	0	0
	5	25	1	4	0	0	0	0	0	0	1	1

STATION: 701 RECORD LENGTH: 1,403 DAYS = 3.84 YEARS MEAN SALINITY = 13.55 PPT

A. MISSING VALUES ASSUMED HIGH

	25	10	1	0	0	0	0	0	0	0	0	1
	20	38	4	1	0	0	0	0	0	0	0	1
PPT	15	43	4	1	1	1	2	0	0	0	0	1
	10	37	3	1	1	1	1	2	1	0	0	1
	5	18	2	0	1	0	0	0	0	0	1	3

B. MISSING VALUES ASSUMED LOW

	25	10	2	0	0	0	0	0	0	0	0	0
	20	39	5	1	0	0	0	0	0	0	0	0
PPT	15	43	5	2	1	1	2	0	0	0	0	0
	10	38	3	1	1	2	1	3	1	0	0	0
	5	18	2	0	1	0	1	1	0	0	1	3
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-8. Salinity persistance summary for LDWF stations 702 and 719. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 702 RECORD LENGTH: 1,735 DAYS = 4.75 YEARS MEAN SALINITY = 11.74 PPT

A. MISSING VALUES ASSUMED HIGH

	25	28	4	2	1	0	2	0	0	0	0	0
	20	63	6	2	1	0	0	1	0	0	0	1
PPT	15	86	6	5	1	0	1	0	0	1	0	1
	10	78	10	4	1	1	0	2	0	0	1	2
	5	42	5	1	1	1	0	0	0	1	0	3

B. MISSING VALUES ASSUMED LOW

	25	21	2	1	0	0	0	0	0	0	0	0
	20	61	6	1	0	0	0	1	0	0	0	0
PPT	15	89	8	3	2	0	1	1	0	0	0	0
	10	88	11	4	2	1	0	3	2	0	0	0
	5	51	6	2	2	1	1	1	1	1	0	4

STATION: 719 RECORD LENGTH: 3,953 DAYS = 10.83 YEARS MEAN SALINITY = 15.87 PPT

A. MISSING VALUES ASSUMED HIGH

	25	39	2	3	0	2	0	0	0	1	0	1
	20	91	10	6	0	1	1	1	0	0	1	1
PPT	15	100	10	2	2	1	2	1	1	1	0	3
	10	53	5	3	2	1	0	0	1	0	0	5
	5	13	2	1	0	2	1	0	0	0	0	2

B. MISSING VALUES ASSUMED LOW

	25	34	0	0	0	0	0	0	0	0	0	0
	20	97	9	5	0	0	0	0	0	0	0	0
PPT	15	104	13	3	4	1	2	1	1	0	0	1
	10	58	8	5	3	3	0	0	1	0	0	4
	5	15	4	6	1	3	2	1	0	0	0	4
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-9. Salinity persistance summary for USACOE stations 01420 and 01500. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 01420 RECORD LENGTH: 17,718 DAYS = 48.52 YEARS MEAN SALINITY = 0.17

A. MISSING VALUES ASSUMED HIGH

	25	955	7	1	2	0	5	0	0	0	0	2
	20	955	7	1	2	0	5	0	0	0	0	2
PPT	15	055	7	1	2	0	5	0	0	0	0	2
	10	955	7	1	2	0	5	0	0	0	0	2
	5	955	7	1	2	0	5	0	0	0	0	2

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	1	0	0	0	0	0	0	0	0	0	0
	5	1	0	0	0	0	0	0	0	0	0	0

STATION: 01500 RECORD LENGTH: 3,988 DAYS = 10.93 YEARS MEAN SALINITY = 0.42

A. MISSING VALUES ASSUMED HIGH

	25	408	16	2	5	0	0	0	0	0	0	5
	20	408	16	2	5	0	0	0	0	0	0	5
PPT	15	408	16	2	5	0	0	0	0	0	0	5
	10	408	16	2	5	0	0	0	0	0	0	5
	5	408	16	2	5	0	0	0	0	0	0	5

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	4	0	0	0	0	0	0	0	0	0	0
	5	7	0	0	0	0	0	0	0	0	0	0
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-10. Salinity persistance summary for USACOE stations 03720 and 03780. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 03720 RECORD LENGTH: 11,720 DAYS = 32.11 DAYS MEAN SALINITY = 0.06

A. MISSING VALUES ASSUMED HIGH

	25	1259	14	2	1	0	0	0	0	0	0	1
	20	1259	14	2	1	0	0	0	0	0	0	1
PPT	15	1259	14	2	1	0	0	0	0	0	0	1
	10	1259	14	2	1	0	0	0	0	0	0	1
	5	1259	14	2	1	0	0	0	0	0	0	1

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	1	0	0	0	0	0	0	0	0	0	0
	5	1	0	0	0	0	0	0	0	0	0	0

STATION: 03780 RECORD LENGTH: 18,246 DAYS = 49.98 YEARS MEAN SALINITY = 0.07

A. MISSING VALUES ASSUMED HIGH

	25	1141	15	3	3	2	0	1	0	1	0	1
	20	1141	15	3	3	2	0	1	0	1	0	1
PPT	15	1141	15	3	3	2	0	1	0	1	0	1
	10	1141	15	3	3	2	0	1	0	1	0	1
	5	1141	15	3	3	2	0	1	0	1	0	1

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	1	0	0	0	0	0	0	0	0	0	0
	5	1	0	0	0	0	0	0	0	0	0	0
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-11. Salinity persistance summary for USACOE stations 64380 and 64450. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 64380 RECORD LENGTH: 8,920 = 24.44 YEARS MEAN SALINITY = 0.17

A. MISSING VALUES ASSUMED HIGH

	25	25	0	0	0	0	0	0	0	0	0	2
	20	25	0	0	0	0	0	0	0	0	0	2
PPT	15	25	0	0	0	0	0	0	0	0	0	2
	10	25	0	0	0	0	0	0	0	0	0	2
	5	25	0	0	0	0	0	0	0	0	0	2

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	1	0	0	0	0	0	0	0	0	0	0
	5	1	0	0	0	0	0	0	0	0	0	0

STATION: 64450 RECORD LENGTH: 12,938 DAYS = 35.45 YEARS MEAN SALINITY = 0.24

A. MISSING VALUES ASSUMED HIGH

	25	612	11	1	0	0	0	1	0	0	0	1
	20	612	11	1	0	0	0	1	0	0	0	1
PPT	15	612	11	1	0	0	0	1	0	0	0	1
	10	612	11	1	0	0	0	1	0	0	0	1
	5	612	11	1	0	0	0	1	0	0	0	1

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	1	0	0	0	0	0	0	0	0	0	0
	5	12	0	0	0	0	0	0	0	0	0	0
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-12. Salinity persistance summary for USACOE stations 70675 and 76320. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 70675 RECORD LENGTH: 11,539 DAYS = 31.61 YEARS MEAN SALINITY = 1.35

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	653	3	0	0	0	0	0	0	0	0	2
	20	658	3	0	0	0	0	0	0	0	0	2
PPT	15	686	4	0	0	0	0	0	0	0	0	2
	10	710	6	0	1	0	1	0	0	0	0	2
	5	752	8	3	2	1	0	2	0	0	0	2

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	2	0	0	0	0	0	0	0	0	0	0
	20	8	0	0	0	0	0	0	0	0	0	0
PPT	15	45	1	0	0	0	0	0	0	0	0	0
	10	102	1	2	1	0	0	0	0	0	0	0
	5	215	4	2	2	1	0	0	0	0	0	0

STATION: 76320 RECORD LENGTH: 12,906 DAYS = 35.36 YEARS MEAN SALINITY = 0.34

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	643	6	1	0	2	0	0	0	0	1	3
	20	643	6	1	0	2	0	0	0	0	1	3
PPT	15	646	6	1	0	2	0	0	0	0	1	3
	10	653	6	1	0	2	0	0	0	0	1	3
	5	678	8	1	0	2	0	0	0	0	1	3

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	3	0	0	0	0	0	0	0	0	0	0
	10	11	0	0	0	0	0	0	0	0	0	0
	5	41	1	0	0	0	0	0	0	0	0	0

PERSISTANCE (DAYS)

Table D-13. Salinity persistance summary for USACOE stations 76323 and 76343. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 76323 RECORD LENGTH: 12,238 DAYS = 33.53 YEARS MEAN SALINITY = 1.21

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	96	6	0	0	2	1	0	0	0	0	1
	20	96	6	0	0	2	1	0	0	0	0	1
PPT	15	118	6	0	0	2	1	0	0	0	0	1
	10	135	12	2	0	1	1	0	0	0	1	1
	5	183	24	5	2	1	1	0	0	0	1	1

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	4	0	0	0	0	0	0	0	0	0	0
	20	4	0	0	0	0	0	0	0	0	0	0
PPT	15	28	0	0	0	0	0	0	0	0	0	0
	10	55	7	2	0	0	0	0	0	0	0	0
	5	110	19	4	2	0	0	0	0	0	0	0

STATION: 76343 RECORD LENGTH: 7,428 DAYS = 20.35 YEARS MEAN SALINITY = 0.55

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	127	3	1	0	1	0	1	1	0	0	3
	20	127	3	1	0	1	0	1	1	0	0	3
PPT	15	135	3	1	0	1	0	1	1	0	0	3
	10	149	3	1	0	1	0	1	1	0	0	3
	5	166	3	2	0	1	0	1	0	1	0	3

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	11	0	0	0	0	0	0	0	0	0	0
	10	30	0	0	0	0	0	0	0	0	0	0
	5	54	0	1	0	0	0	0	0	0	0	0

PERSISTANCE (DAYS)

Table D-14. Salinity persistance summary for USACOE stations 76403 and 76720. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 76403 RECORD LENGTH: 6,972 DAYS = 19.10 YEARS MEAN SALINITY = 0.62

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	33	11	2	2	0	0	0	0	0	0	1
	20	33	11	2	2	0	0	0	0	0	0	1
PPT	15	35	11	2	2	0	0	0	0	0	0	1
	10	62	12	2	2	0	0	0	0	0	0	1
	5	113	13	2	2	0	0	0	0	0	0	1

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	2	0	0	0	0	0	0	0	0	0	0
	10	34	0	0	0	0	0	0	0	0	0	0
	5	88	0	0	0	0	0	0	0	0	0	0

STATION: 76720 RECORD LENGTH: 11,903 DAYS = 32.61 YEARS MEAN SALINITY = 1.73

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	213	4	1	0	0	0	1	0	0	0	3
	20	213	4	1	0	0	0	1	0	0	0	3
PPT	15	213	4	1	0	0	0	1	0	0	0	3
	10	215	4	1	1	0	0	1	0	0	0	3
	5	226	10	2	0	1	0	1	2	0	0	3

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	5	0	1	0	0	0	0	0	0	0	0
	5	34	4	2	0	2	1	0	0	0	0	0

PERSISTANCE (DAYS)

Table D-15. Salinity persistance summary for USACOE stations 76800 and 82203. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 76800 RECORD LENGTH: 7,156 DAYS = 19.61 YEARS MEAN SALINITY = 1.32

A. MISSING VALUES ASSUMED HIGH

	25	639	2	0	0	0	0	0	0	0	0	0
	20	639	2	0	0	0	0	0	0	0	0	0
PPT	15	639	2	0	0	0	0	0	0	0	0	0
	10	637	5	0	0	0	0	0	0	0	0	0
	5	600	8	2	1	0	0	2	0	0	0	1

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	12	1	0	0	0	0	0	0	0	0	0
	5	85	0	1	0	0	0	0	0	0	0	0

STATION: 82203 RECORD LENGTH: 11,720 DAYS = 32.11 YEARS MEAN SALINITY = 0.56

A. MISSING VALUES ASSUMED HIGH

	25	521	32	5	1	3	0	0	1	0	0	1
	20	521	32	5	1	3	0	0	1	0	0	1
PPT	15	522	31	5	0	4	0	0	1	0	0	1
	10	525	32	5	0	4	0	0	1	0	0	1
	5	542	38	6	0	3	1	0	1	0	0	1

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	2	0	0	0	0	0	0	0	0	0	0
	10	5	1	0	0	0	0	0	0	0	0	0
	5	42	4	0	0	0	0	0	0	0	0	0
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-16. Salinity persistance summary for USACOE stations 82300 and 82350. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 82300 RECORD LENGTH: 7,186 DAYS = 19.69 YEARS MEAN SALINITY = 1.72

A. MISSING VALUES ASSUMED HIGH

	25	53	1	4	1	0	0	1	0	0	0	1
	20	59	1	4	1	0	0	1	0	0	0	1
PPT	15	79	1	4	1	0	0	1	0	0	0	1
	10	118	5	4	1	0	0	1	0	0	0	1
	5	176	16	8	1	1	0	1	0	0	0	1

B. MISSING VALUES ASSUMED LOW

	25	2	0	0	0	0	0	0	0	0	0	0
	20	8	0	0	0	0	0	0	0	0	0	0
PPT	15	31	0	0	0	0	0	0	0	0	0	0
	10	71	4	0	0	0	0	0	0	0	0	0
	5	139	14	4	0	1	0	0	0	0	0	0

STATION: 82350 RECORD LENGTH: 7,976 DAYS = 21.85 YEARS MEAN SALINITY = 15.47

A. MISSING VALUES ASSUMED HIGH

	25	108	12	0	0	0	1	0	0	1	0	0
	20	243	20	13	5	2	3	1	0	1	0	1
PPT	15	369	47	14	8	6	3	3	1	3	4	6
	10	220	33	15	10	6	7	4	3	2	2	17
	5	38	11	7	1	3	6	2	2	0	1	20

B. MISSING VALUES ASSUMED LOW

	25	79	6	0	0	0	0	0	0	0	0	0
	20	231	20	10	3	3	2	1	0	0	0	1
PPT	15	385	53	14	9	5	4	3	1	2	3	4
	10	239	38	18	12	8	10	6	2	2	2	12
	5	59	14	10	2	7	10	6	3	0	1	17
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-17. Salinity persistance summary for USACOE stations 85650 and 85700. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 85650 RECORD LENGTH: 11,658 DAYS = 31.94 YEARS MEAN SALINITY = 3.95

A. MISSING VALUES ASSUMED HIGH

	25	272	4	3	0	0	0	1	0	0	0	0
	20	272	4	3	0	0	0	1	0	0	0	0
PPT	15	273	4	3	0	0	0	1	0	0	0	0
	10	294	5	3	1	0	0	1	0	0	0	0
	5	320	26	15	11	6	4	5	1	2	0	9

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	1	0	0	0	0	0	0	0	0	0	0
	10	24	1	0	1	0	0	0	0	0	0	0
	5	240	38	17	9	4	6	1	2	1	1	6

STATION: 85700 RECORD LENGTH: 8,859 DAYS = 24.27 YEARS MEAN SALINITY = 4.84

A. MISSING VALUES ASSUMED HIGH

	25	215	32	2	0	1	0	0	0	0	1	2
	20	219	32	2	0	1	0	0	0	0	1	2
PPT	15	240	28	6	0	1	0	0	0	0	1	2
	10	281	38	10	0	1	0	1	0	0	2	3
	5	204	32	14	5	6	2	2	1	0	0	11

B. MISSING VALUES ASSUMED LOW

	25	1	0	0	0	0	0	0	0	0	0	0
	20	5	0	0	0	0	0	0	0	0	0	0
PPT	15	38	0	0	0	0	0	0	0	0	0	0
	10	142	9	2	0	0	0	0	0	0	0	1
	5	288	24	11	6	7	1	1	0	0	0	4
		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+

PERSISTANCE (DAYS)

Table D-18. Salinity persistance summary for USACOE stations 85750 and 88600. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 85750 RECORD LENGTH: 8,767 DAYS = 240.02 YEARS MEAN SALINITY = 5.38

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	28	1	1	2	0	1	0	0	0	0	1
	20	29	1	1	2	0	1	0	0	0	0	1
PPT	15	33	1	1	2	0	1	0	0	0	0	1
	10	151	9	4	1	1	1	0	0	0	1	1
	5	197	30	7	5	4	0	0	2	0	0	16

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	1	0	0	0	0	0	0	0	0	0	0
	20	1	0	0	0	0	0	0	0	0	0	0
PPT	15	5	0	0	0	0	0	0	0	0	0	0
	10	130	9	3	0	0	0	0	0	0	1	0
	5	188	36	9	7	5	1	0	1	1	0	14

STATION: 88600 RECORD LENGTH: 3,380 DAYS = 9.26 YEARS MEAN SALINITY = 4.93

A. MISSING VALUES ASSUMED HIGH

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	177	0	0	2	0	0	0	0	0	0	0
	20	218	0	0	2	0	0	0	0	0	0	0
PPT	15	254	3	0	2	0	0	0	0	0	0	0
	10	306	6	0	2	0	0	0	0	0	0	0
	5	297	15	4	4	0	0	0	0	0	0	0

B. MISSING VALUES ASSUMED LOW

		<10	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+
	25	68	0	0	0	0	0	0	0	0	0	0
	20	119	0	0	0	0	0	0	0	0	0	0
PPT	15	163	2	0	0	0	0	0	0	0	0	0
	10	229	5	0	0	0	0	0	0	0	0	0
	5	248	12	3	1	0	0	0	0	0	0	0

PERSISTANCE (DAYS)

Table D-19. Salinity persistance summary for USACOE station 88850. Data show the number of events during which the salinity stayed above the indicated level for the indicated length of time. The analysis was run twice, with missing values assumed high (99.99) in one case and low (zero) in the other case. Also indicated is the record length and the mean salinity of the record.

STATION: 88850 RECORD LENGTH: MEAN SALINITY =

A. MISSING VALUES ASSUMED HIGH

25

20

PPT 15

10

5

B. MISSING VALUES ASSUMED LOW

25

20

PPT 15

10

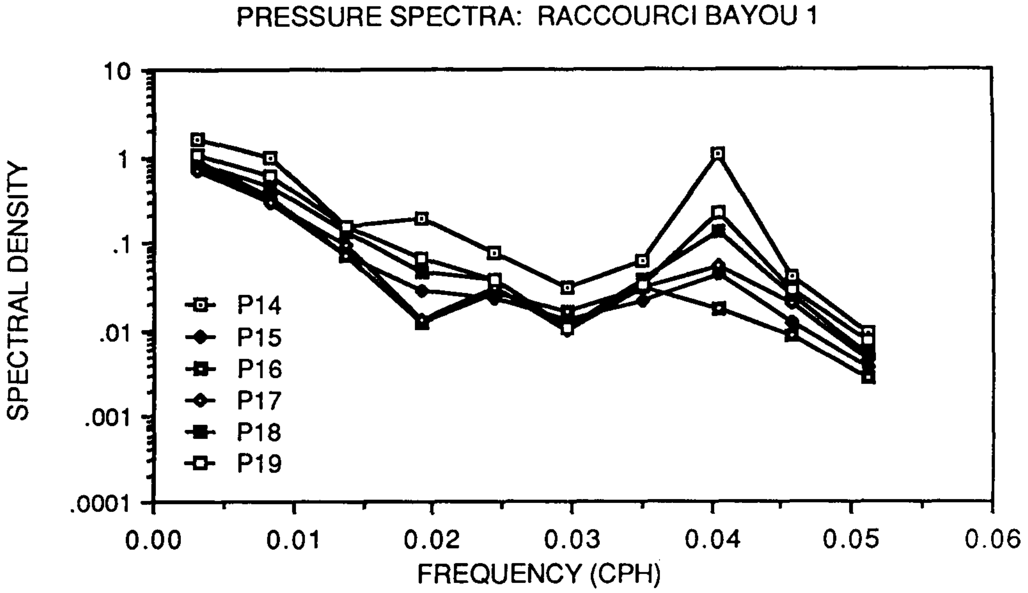
5

<10 10-19 20-29 30-39 40-49 50-59 60-69 70-79 80-89 90-99 100+

PERSISTANCE (DAYS)

APPENDIX E

The following appendix presents a series of plots of spectrum and coherence estimates for the time series collected during the field program discussed in chapter III-7. The data were measured in canals and bayous near Lake Decade (Terrebonne Parish) and in the adjacent marsh. All gages (serial numbers 14 thru 19) were deployed in the same numerical order. Gage 14 was always in the canal or bayou and gages 15 thru 19 were deployed progressively furthur into the marsh beginning on the natural levee or the spoil bank. The data were sampled at half-hourly intervals. Spectrum and coherence estimates from this data were calculated using a standard fast Fourier transform routine. All estimates have 12 degrees of freedom and no windowing was applied, so neighboring estimates are independent. Because the initial time series are of different lengths, the frequency bandwith of the estimates associated with each deployment of the instruments is different.


PRESSURE SPECTRA: RACCOURCI BAYOU 1

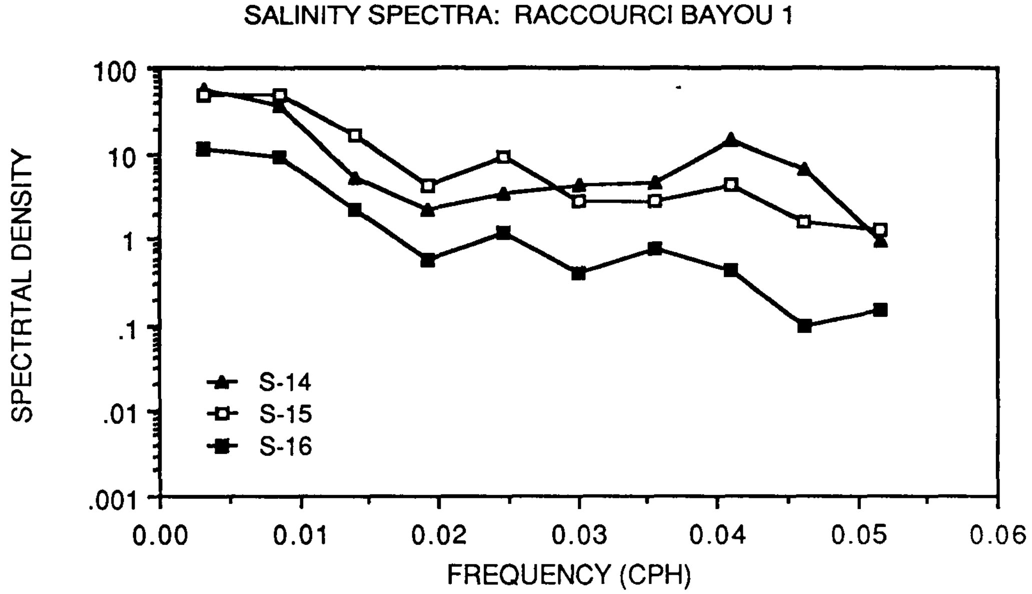

SALINITY SPECTRA: RACCOURCI BAYOU 1

Figure E-1. Spectral density estimates for pressure (top) and salinity (bottom) for the deployment at Raccourci Bayou 1 (RB1). The deployment covered the time period from January 23, 1987 through March 11, 1987.

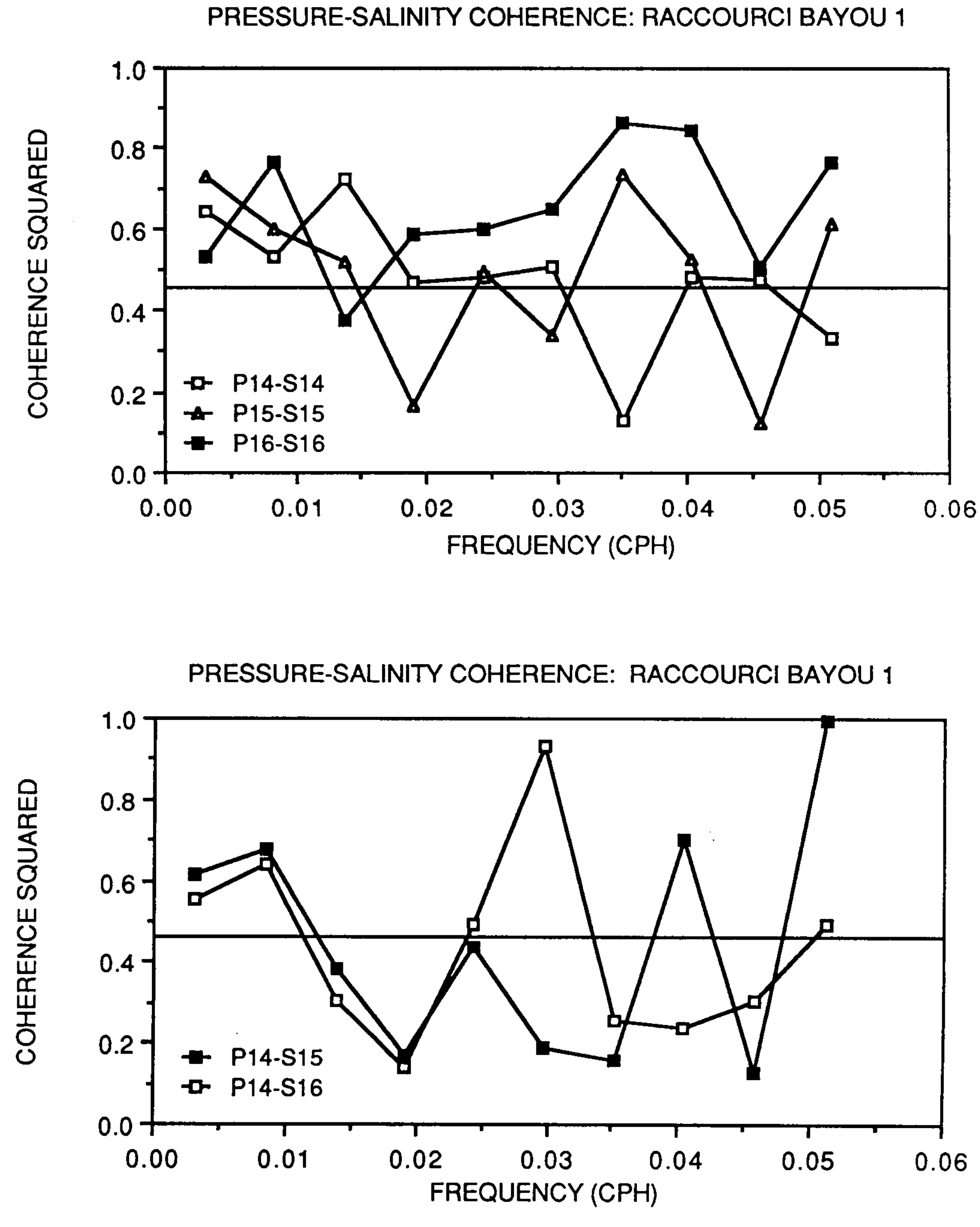
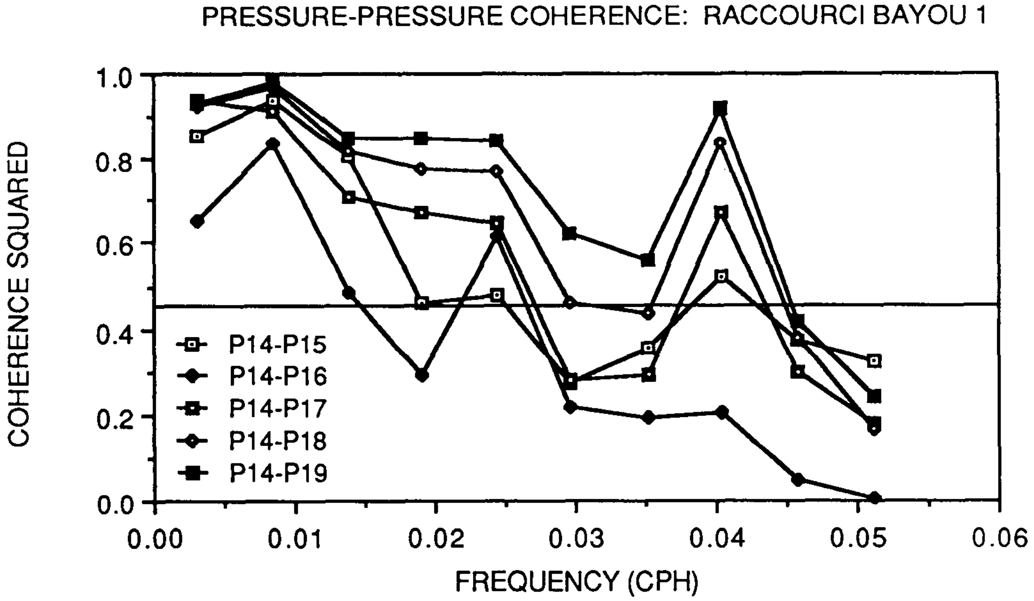


Figure E-2. Pressure-salinity coherence estimates for the deployment at Raccourci Bayou 1 (RB1). The top plot presents the coherence between pressure and salinity at each gage location, and the bottom plot presents the coherence between pressure in the bayou and salinity at the gages in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from January 23, 1987 through March 11, 1987.



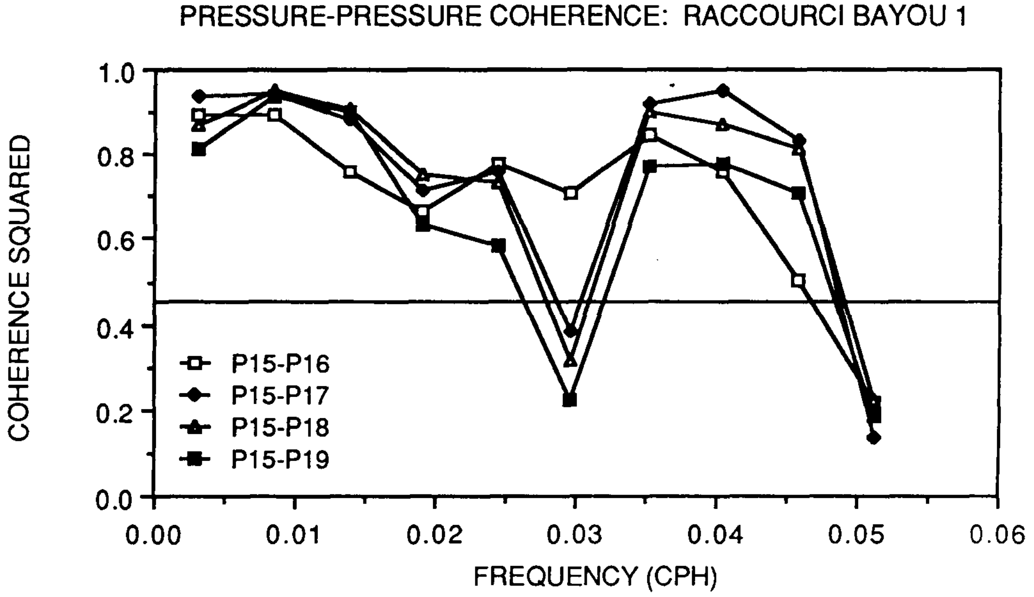


Figure E-3. Pressure-pressure coherence estimates for the deployment at Raccourci Bayou 1 (RB1). The top plot presents the coherence between pressure in the bayou and pressure at each gage in the marsh. The bottom plot presents the coherence between pressure on the natural levee and pressure at each gage in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from January 23, 1987 through March 11, 1987.

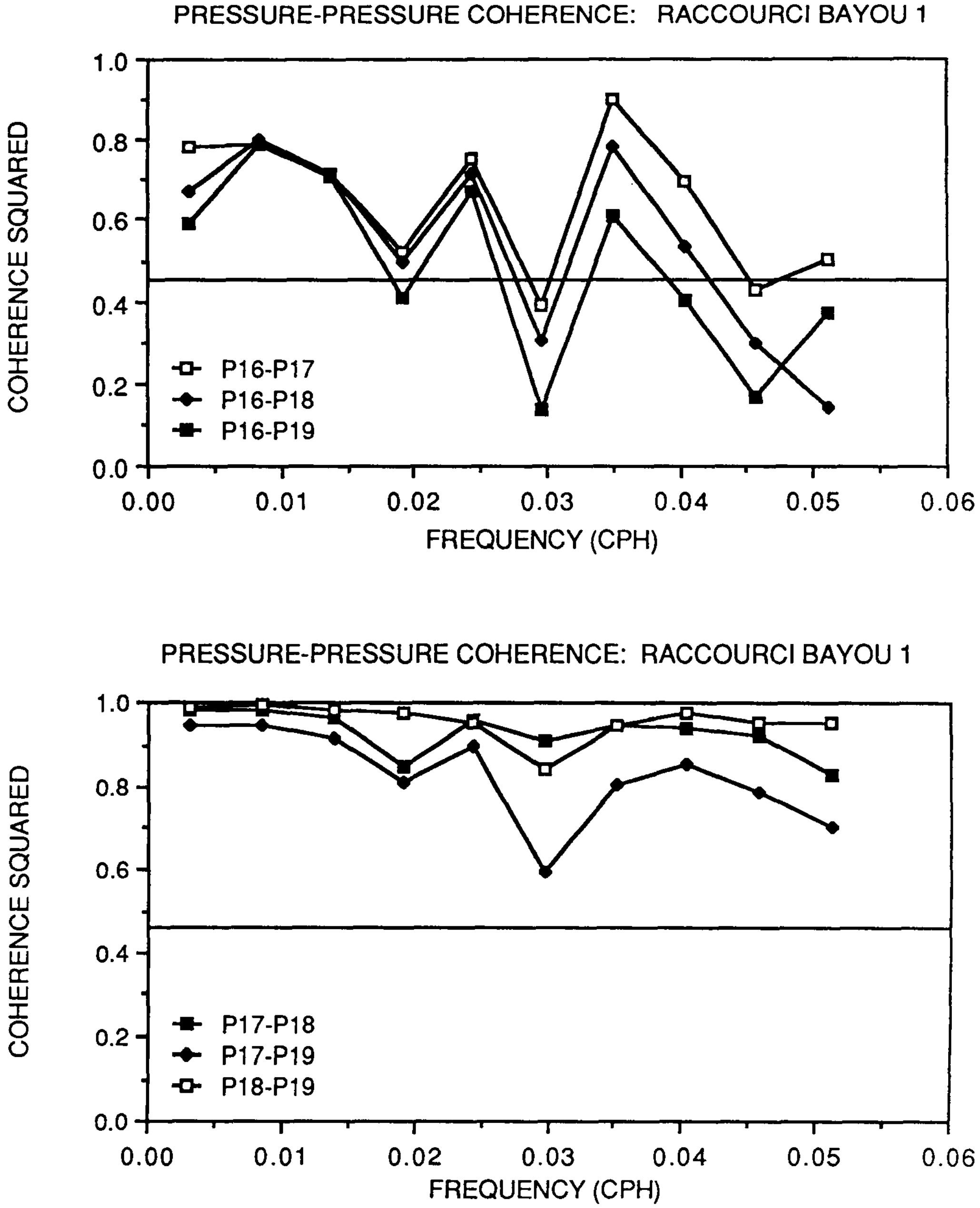


Figure E-4. Pressure-pressure coherence estimates for the deployment at Raccourci Bayou 1 (RB1). The plots present the coherence between pressure at the various gages in the inland marsh sites. The solid horizontal line indicates the 95% level. The deployment covered the time period from January 23, 1987 through March 11, 1987.

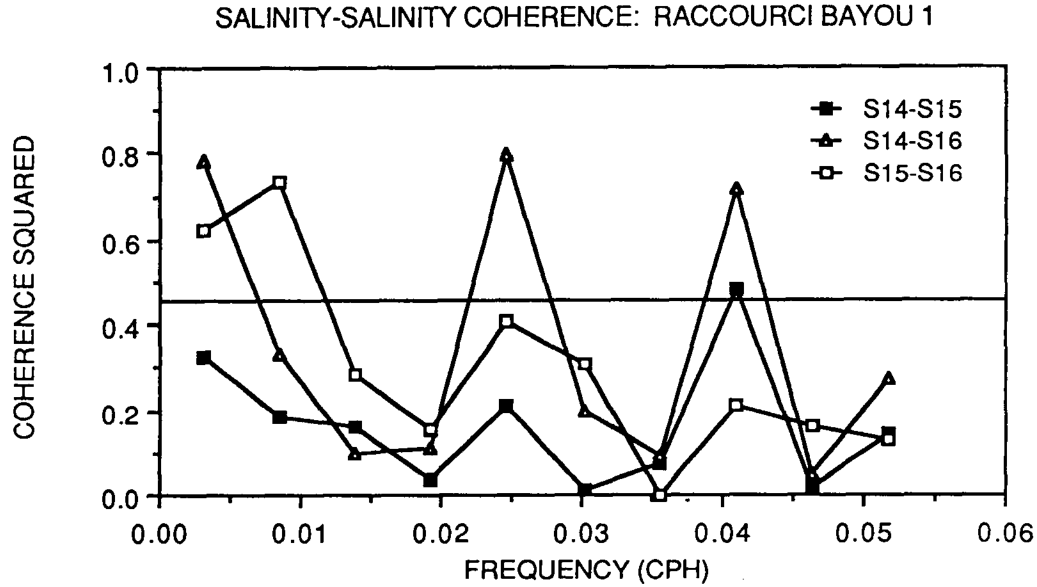
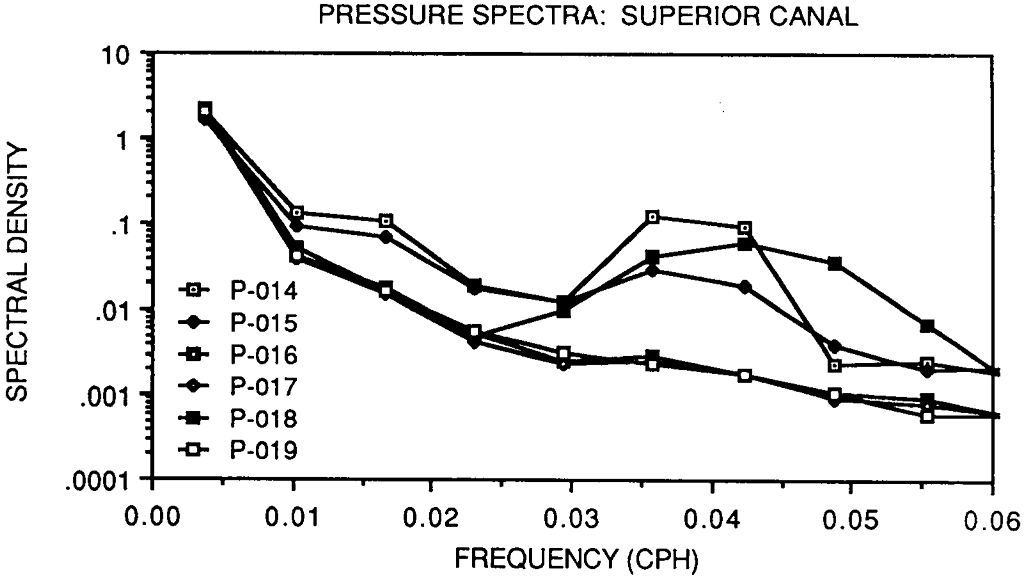


Figure E-5. Salinity-salinity coherence estimates for the deployment at Raccourci Bayou 1 (RB1). The plot presents the coherence between salinities measured at the three gages from which reliable data was obtained. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from January 23, 1987 through March 11, 1987.



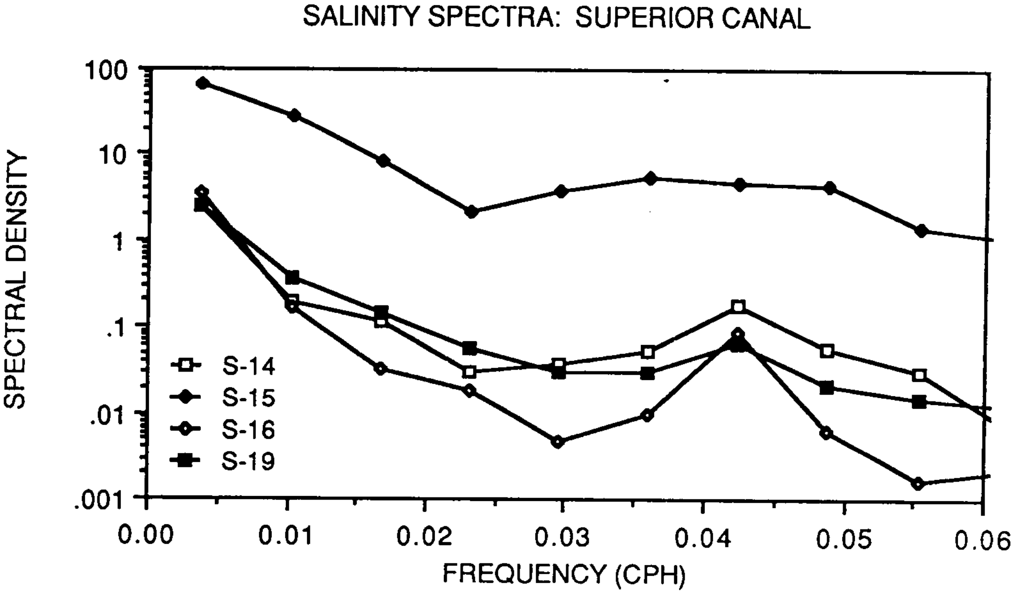
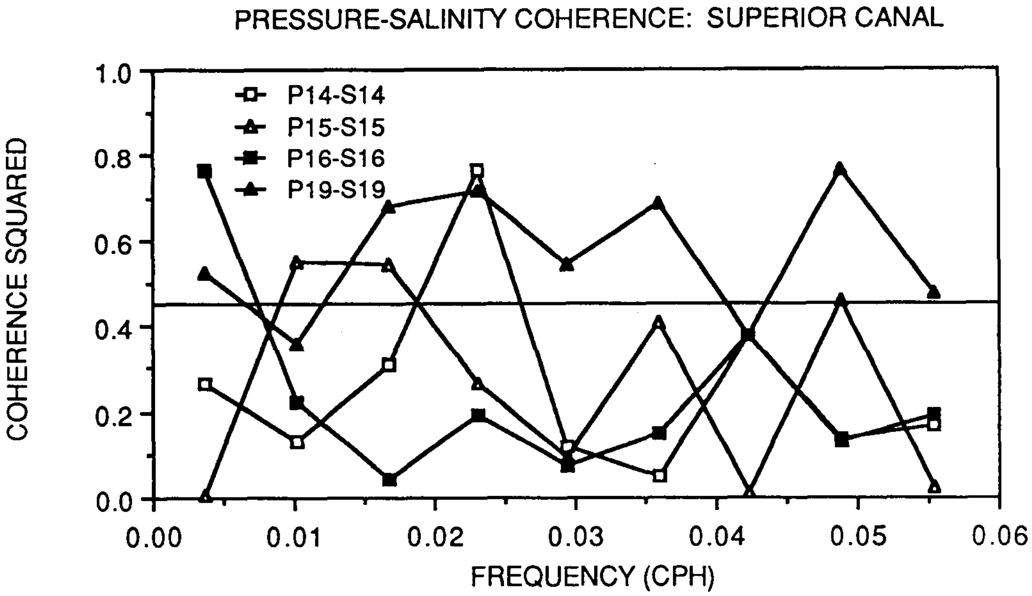


Figure E-6. Spectral density estimates for pressure (top) and salinity (bottom) for the deployment at Superior Canal (SC). The deployment covered the time period from March 13, 1987 through April 21, 1987.



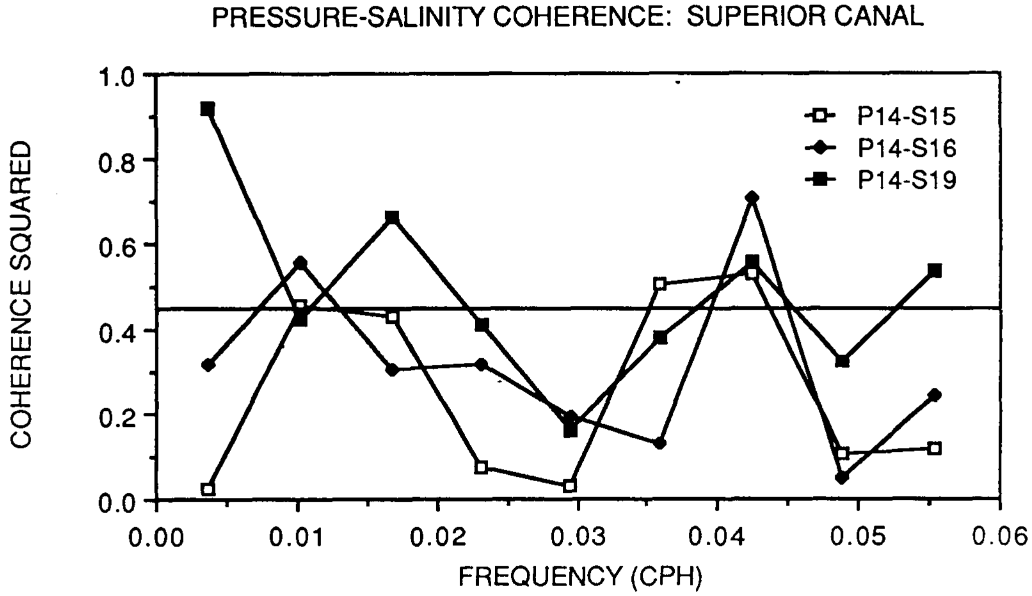
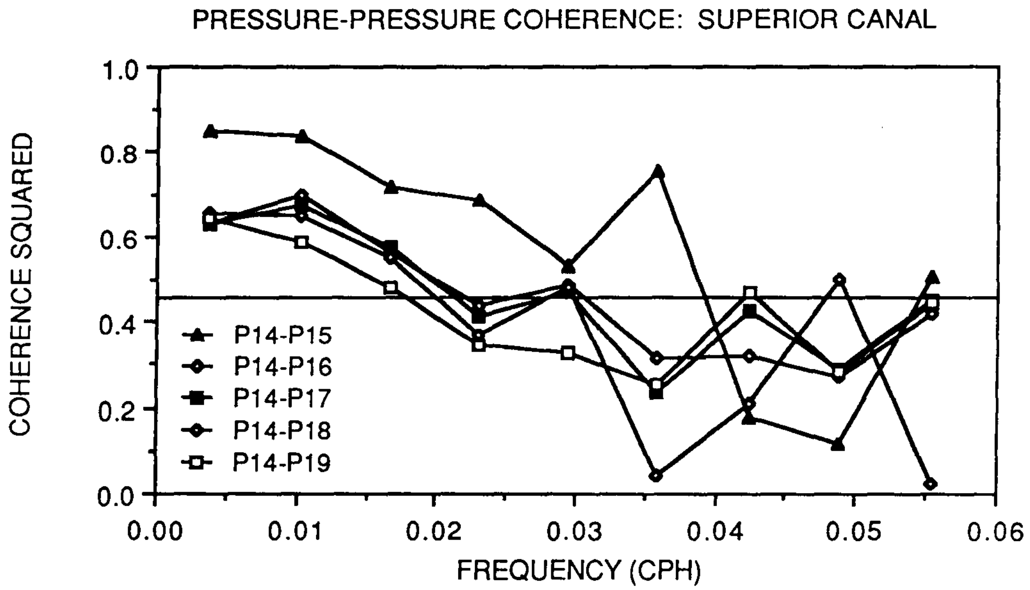


Figure E-7. Pressure-salinity coherence estimates for the deployment at Superior Canal (SC). The top curve presents the coherence between pressure and salinity at each gage location, and the bottom plot presents the coherence between pressure in the bayou and salinity at the gages in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from March 13, 1987 through April 21, 1987.



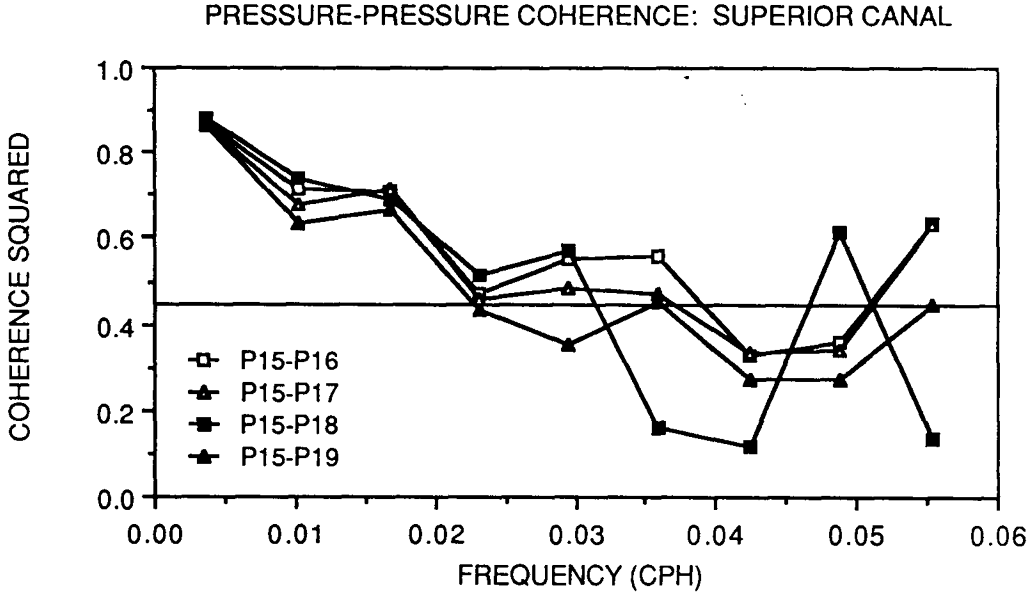
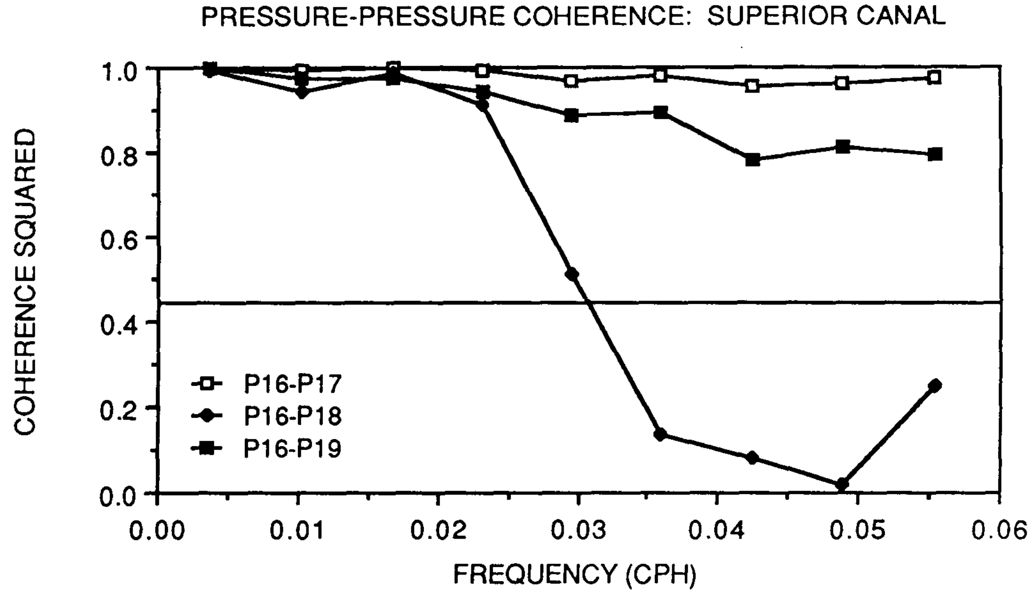


Figure E-8. Pressure-salinity coherence estimates for the deployment at Superior Canal (SC). The top curve presents the coherence between pressure in the bayou and pressure at each gage in the marsh. The bottom plot presents the coherence between pressure on the spoil bank and salinity at each gage in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from March 13, 1987 through April 21, 1987.



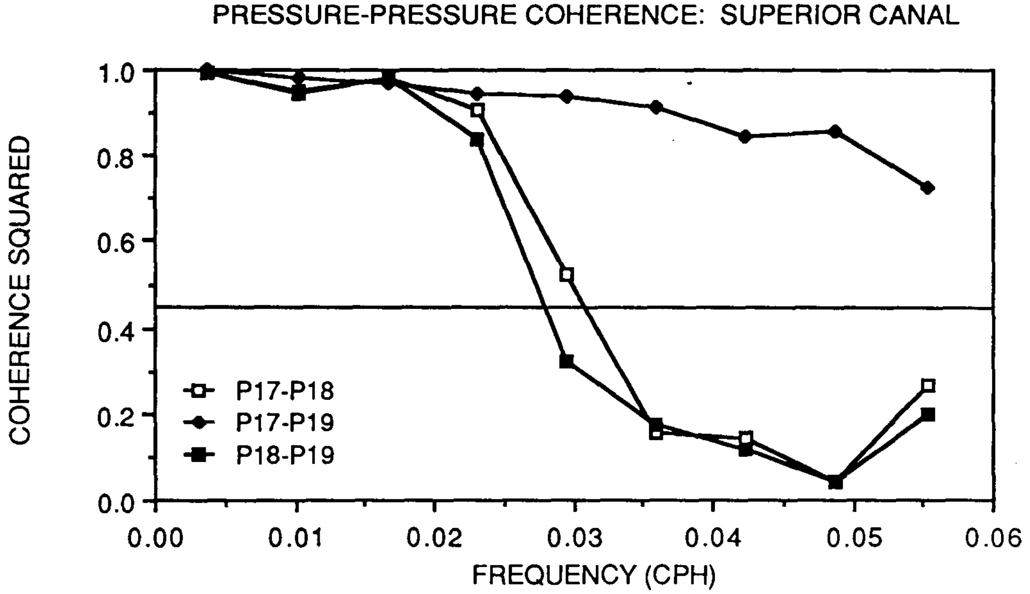
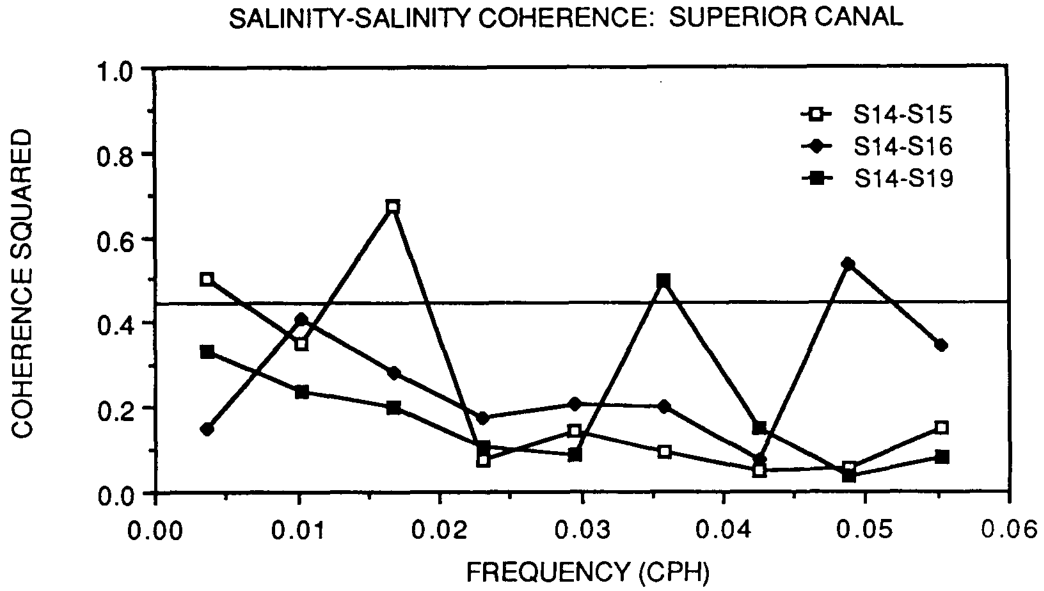


Figure E-9. Pressure-pressure coherence estimates for the deployment at Superior Canal (SC). The plots present the coherence between pressure at the various gages in the inland marsh sites. The solid horizontal line indicates the 95% level. The deployment covered the time period from March 13, 1987 through April 21, 1987.



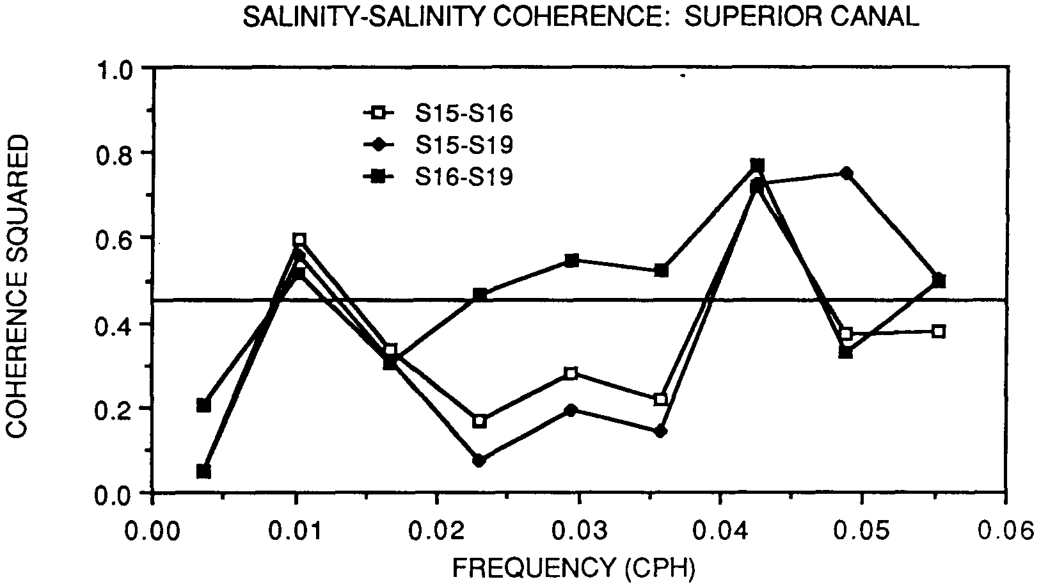
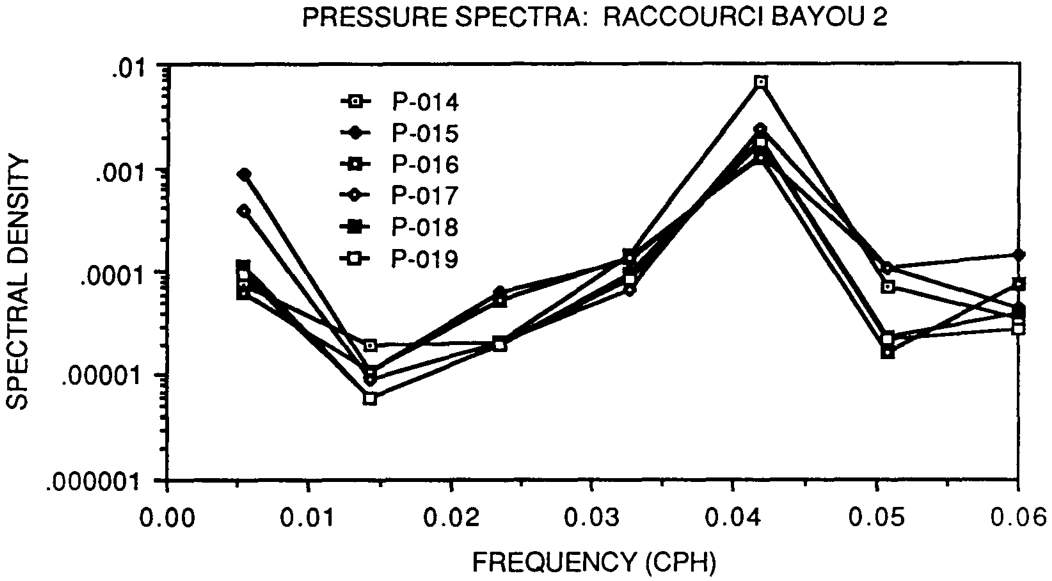


Figure E-10. Salinity-salinity coherence estimates for the deployment at Superior Canal (SC). The plot presents the coherence between salinities measured at the four gages from which reliable data was obtained. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from March 13, 1987 through April 21, 1987.



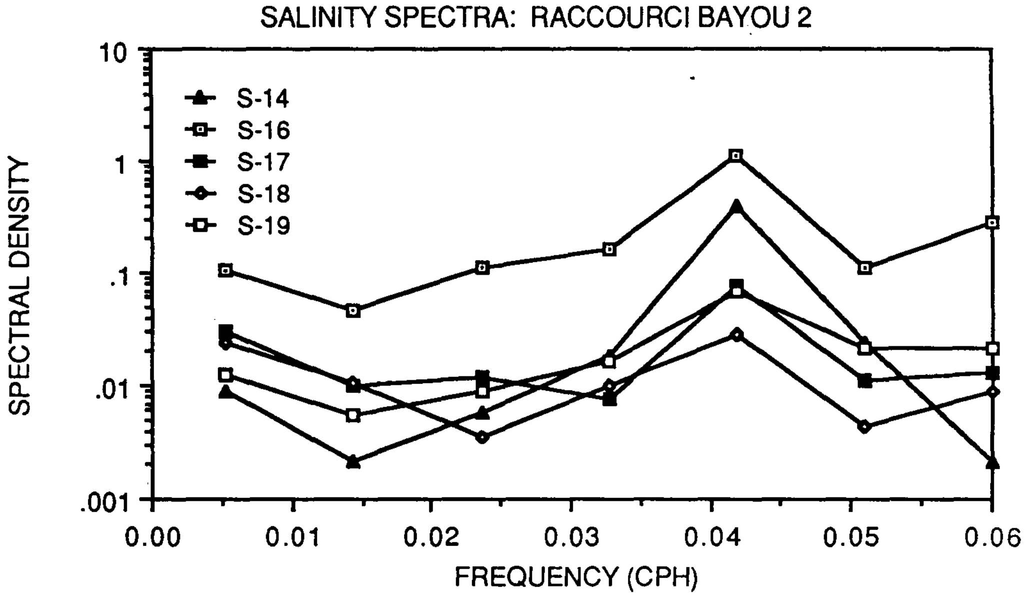
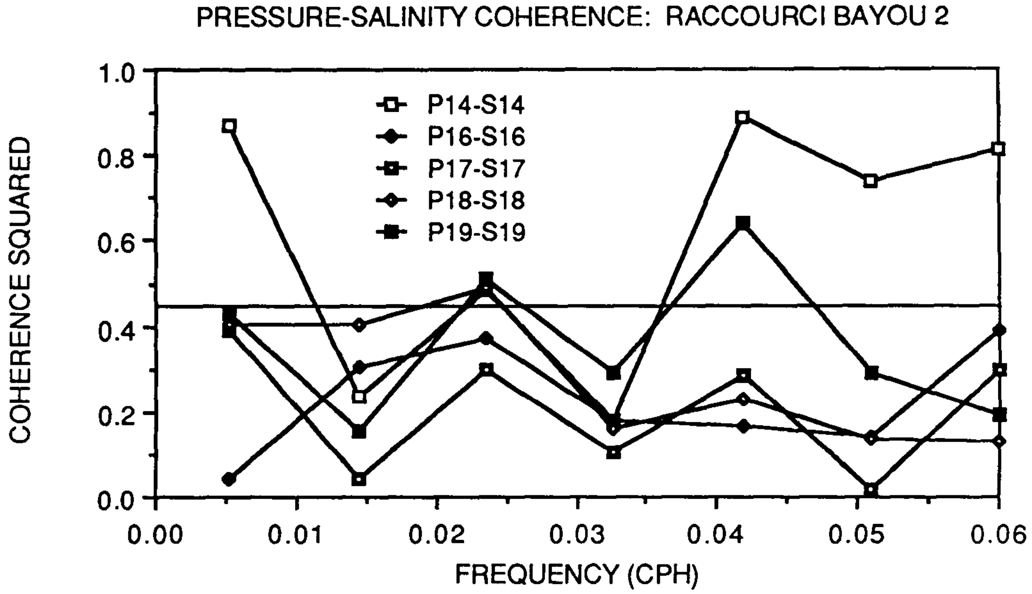


Figure E-11. Spectral density estimates for pressure (top) and salinity (bottom) for the deployment at Raccourci Bayou 2 (RB2). The deployment covered the time period from May 8, 1987 through June 4, 1987.



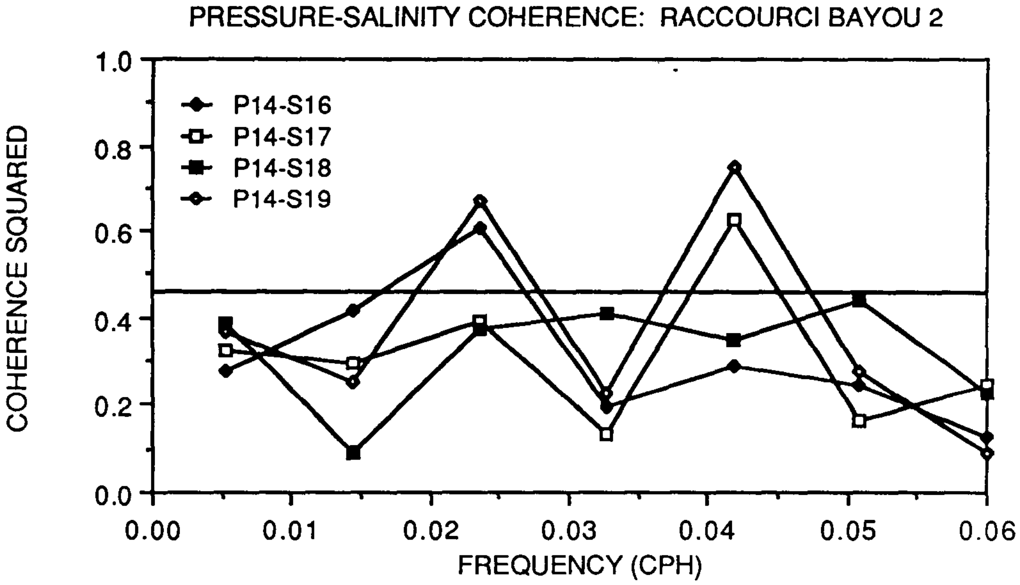
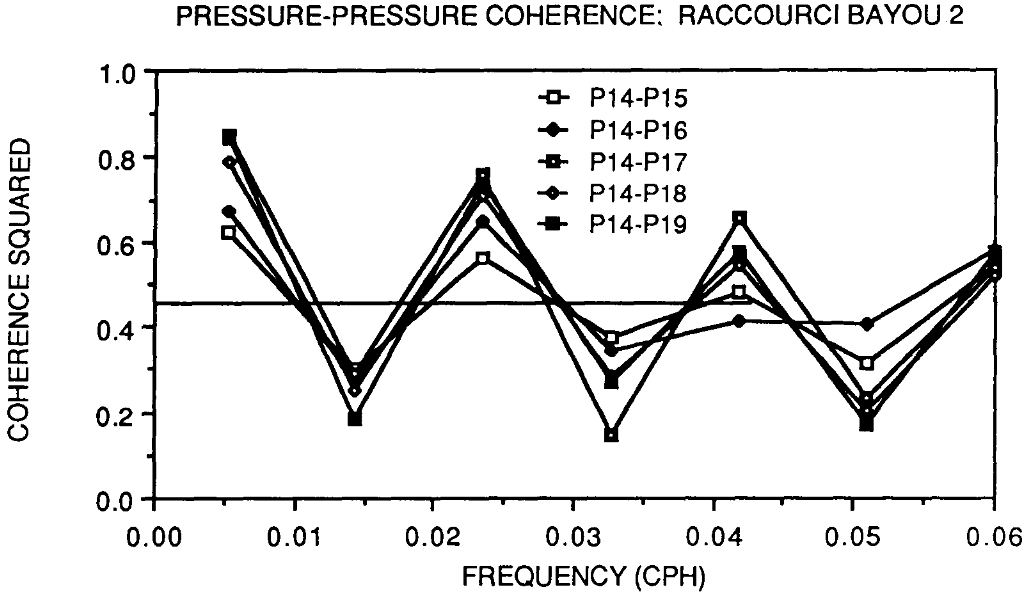


Figure E-12. Pressure-salinity coherence estimates for the deployment at Raccourci Bayou 2 (RB2). The top curve presents the coherence between pressure and salinity at each gage location and the bottom plot presents the coherence between pressure in the bayou and salinity at the gages in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from May 8, 1987 through June 4, 1987.



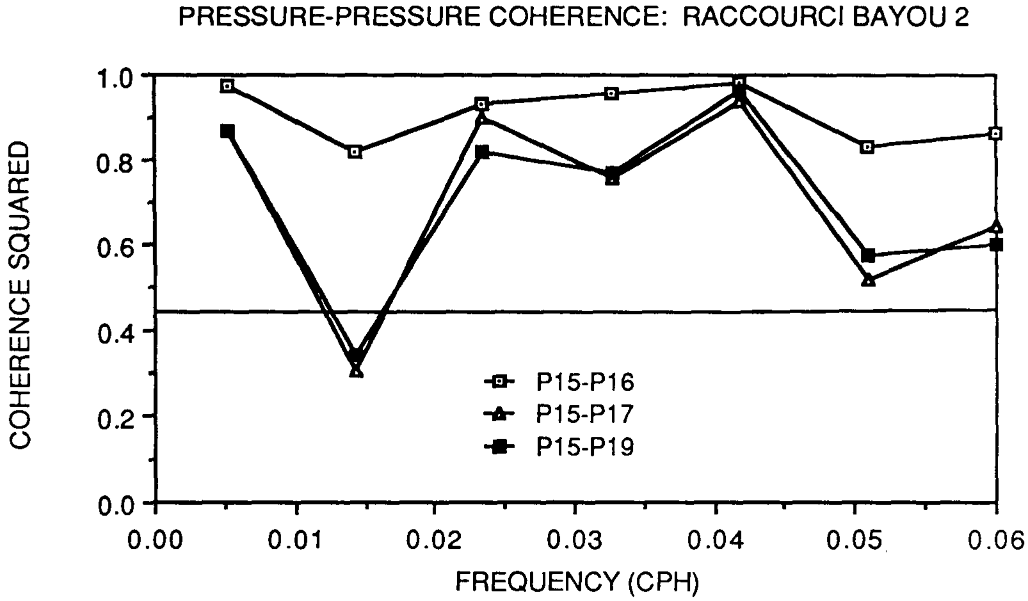
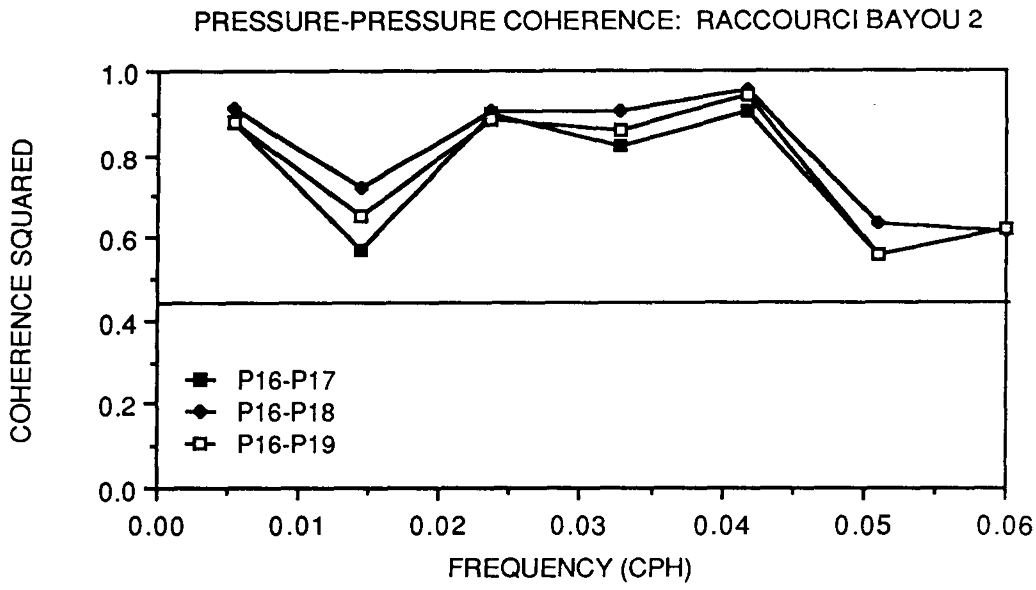


Figure E-13. Pressure-pressure coherence estimates for the deployment at Raccourci Bayou 2 (RB2). The top plot presents the coherence between pressure in the bayou and pressure at each gage in the marsh. The bottom plot presents the coherence between pressure on the natural levee and pressure at each gage in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from May 8, 1987 through June 4, 1987.



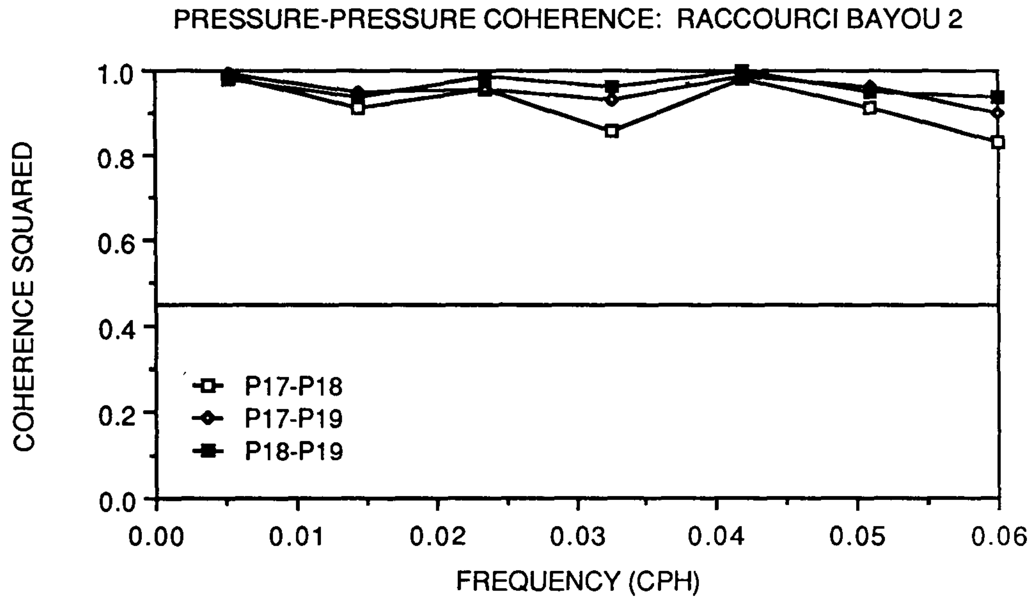


Figure E-14. Pressure-pressure coherence estimates for the deployment at Raccourci Bayou 2 (RB2). The plots present the coherence between pressure at the various gages in the inland marsh sites. The solid horizontal line indicates the 95% level. The deployment covered the time period from May 8, 1987 through June 4, 1987.

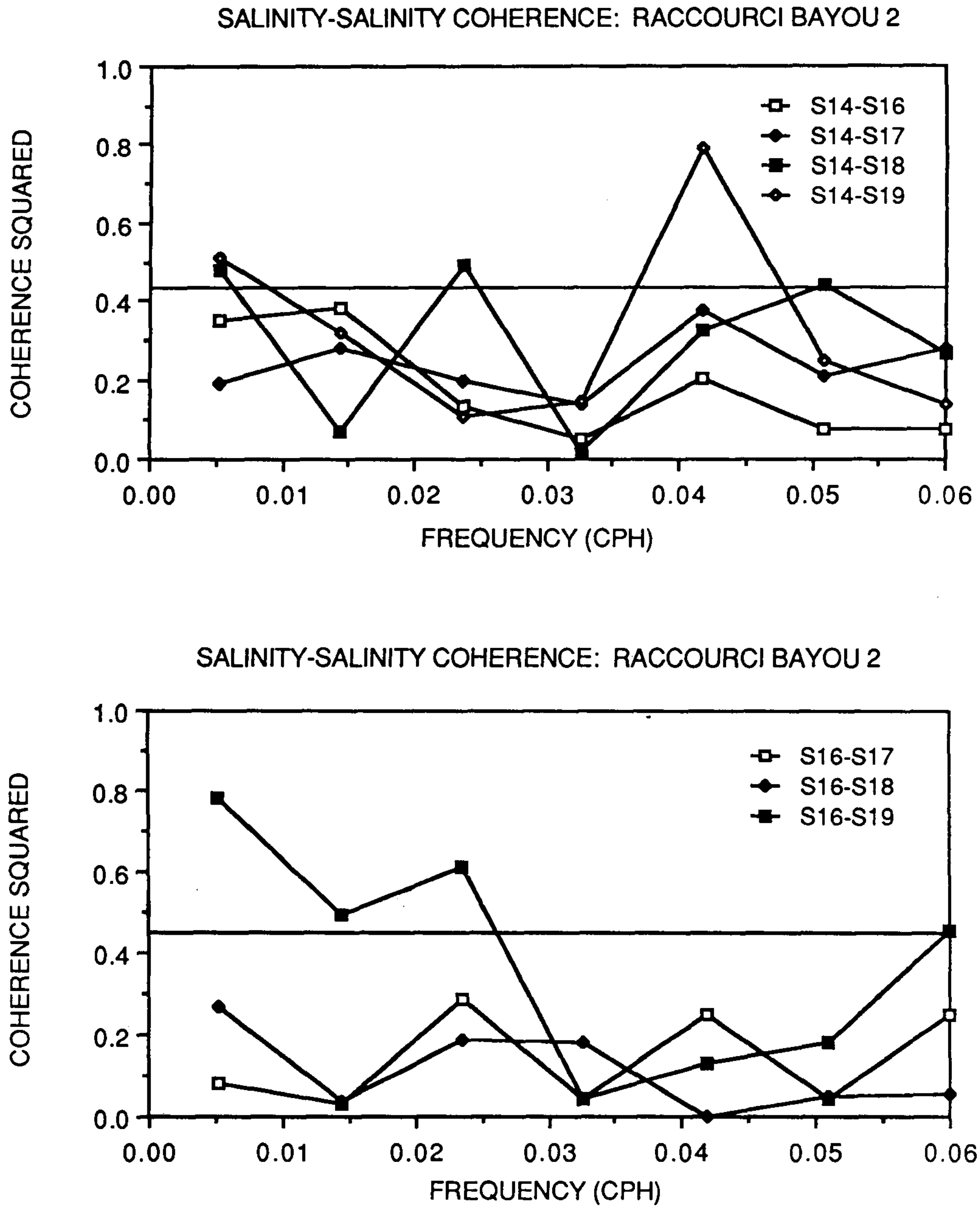


Figure E-15. Salinity-salinity coherence estimates for the deployment at Raccourci Bayou 2 (RB2). The top plot presents the coherence between salinities in the bayou and salinity at each gage in the marsh. The bottom plot presents the coherence between salinities measured in the marsh. The data from the natural levee was unreliable. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from May 8, 1987 through June 4, 1987.

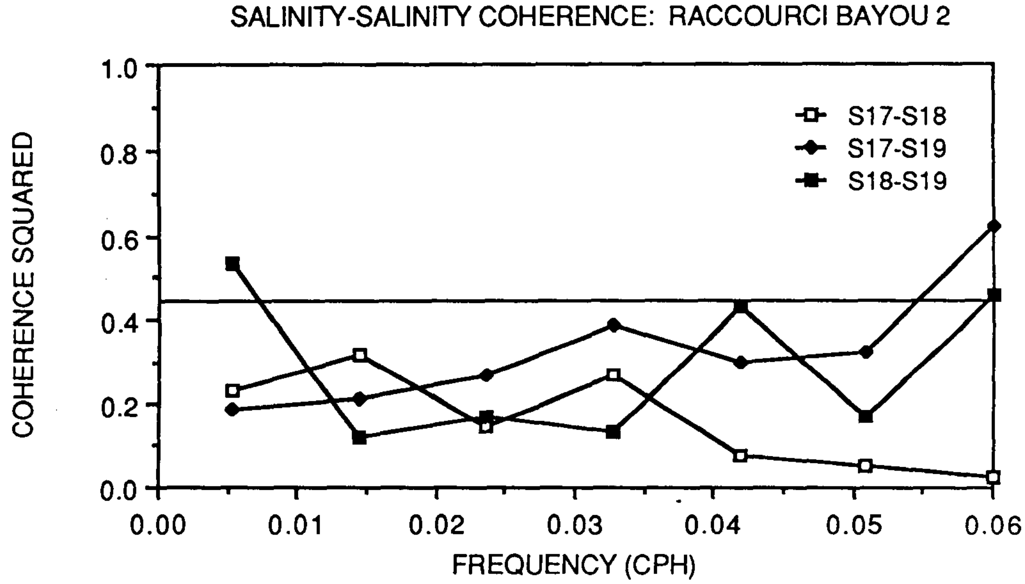
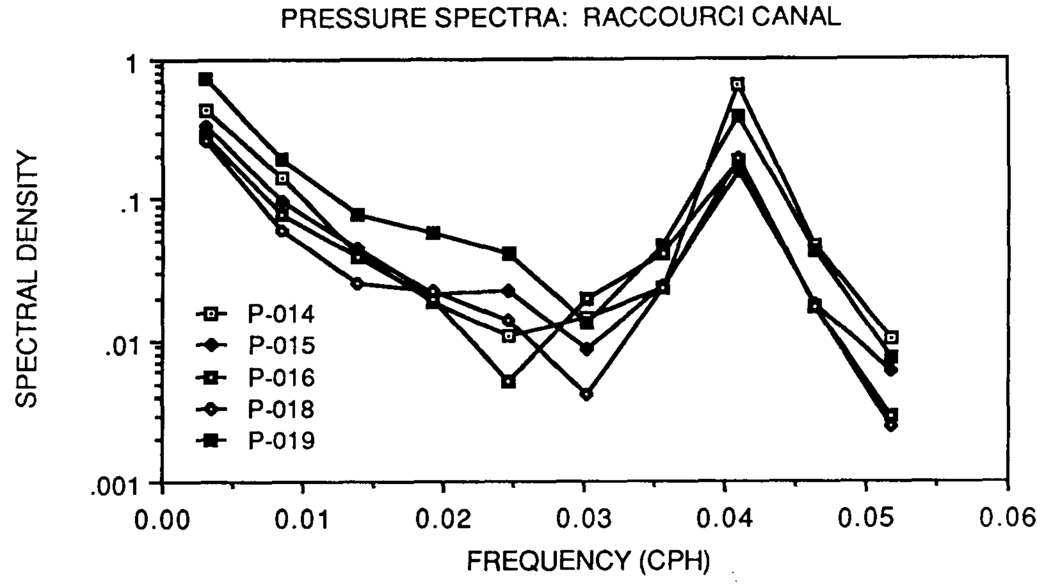


Figure E-16. Salinity-salinity coherence estimates for the deployment at Raccourci Bayou 2 (RB2). The plot presents the coherence between salinities measured in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from May 8, 1987 through June 4, 1987.



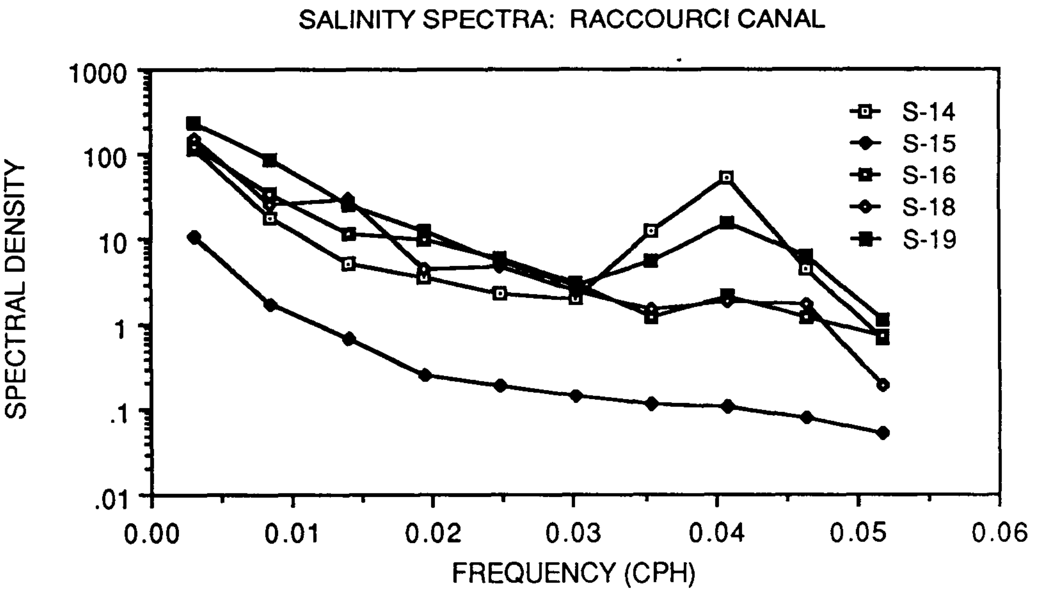
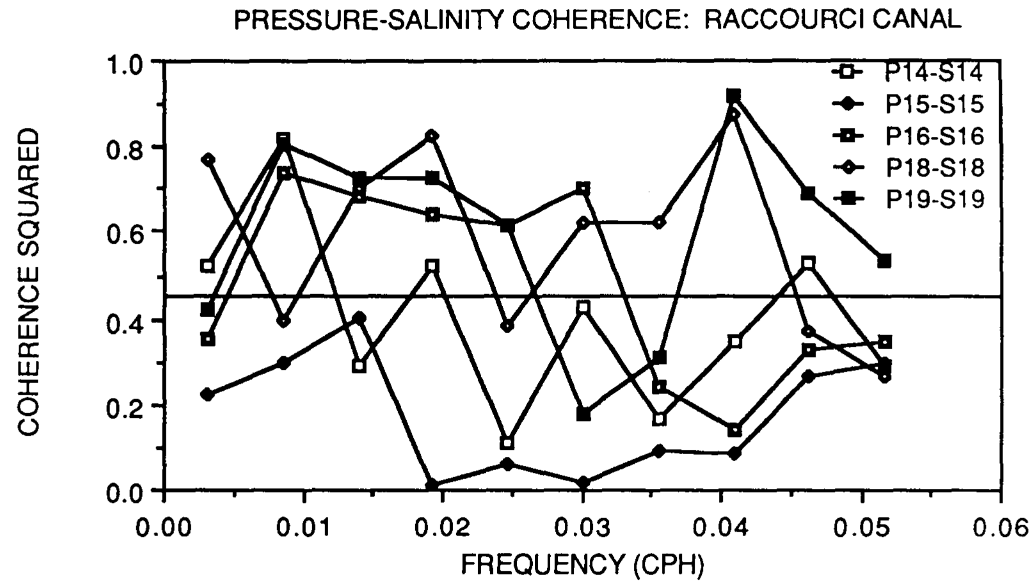


Figure E-17. Spectral density estimates for pressure (top) and salinity (bottom) for the deployment at Raccourci Canal (RC). The deployment covered the time period from June 5, 1987 through July 21, 1987.



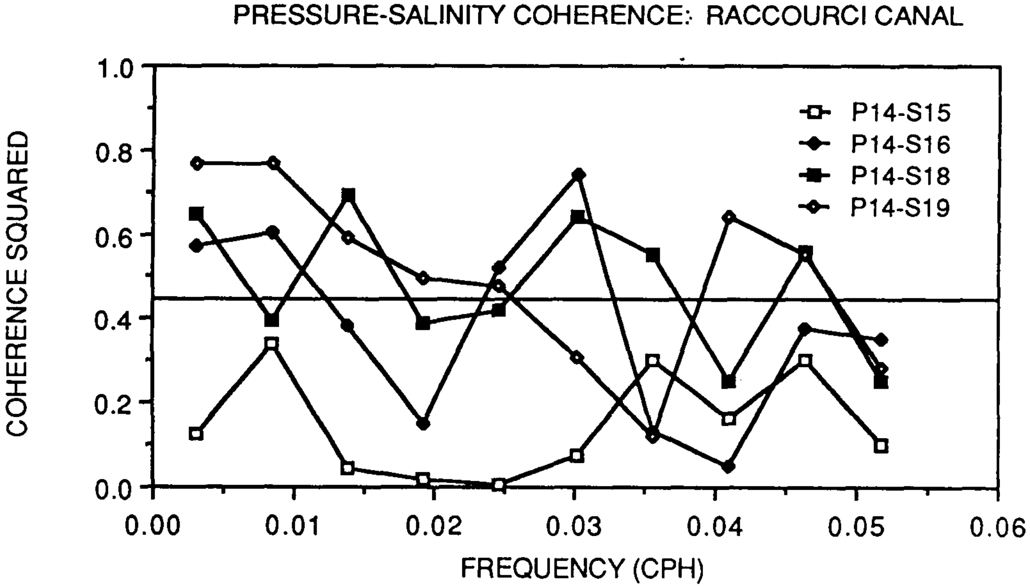
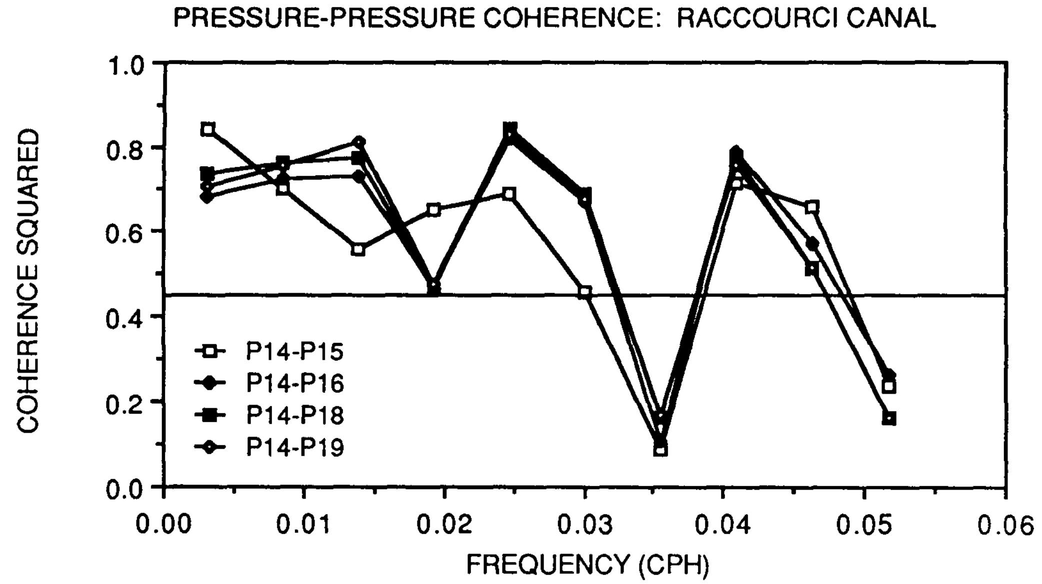


Figure E-18. Pressure-salinity coherence estimates for the deployment at Raccourci Canal (RC). The top curve presents the coherence between pressure and salinity at each gage location and the bottom plot presents the coherence between pressure in the bayou and salinity at the gages in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from June 5, 1987 through July 21, 1987.



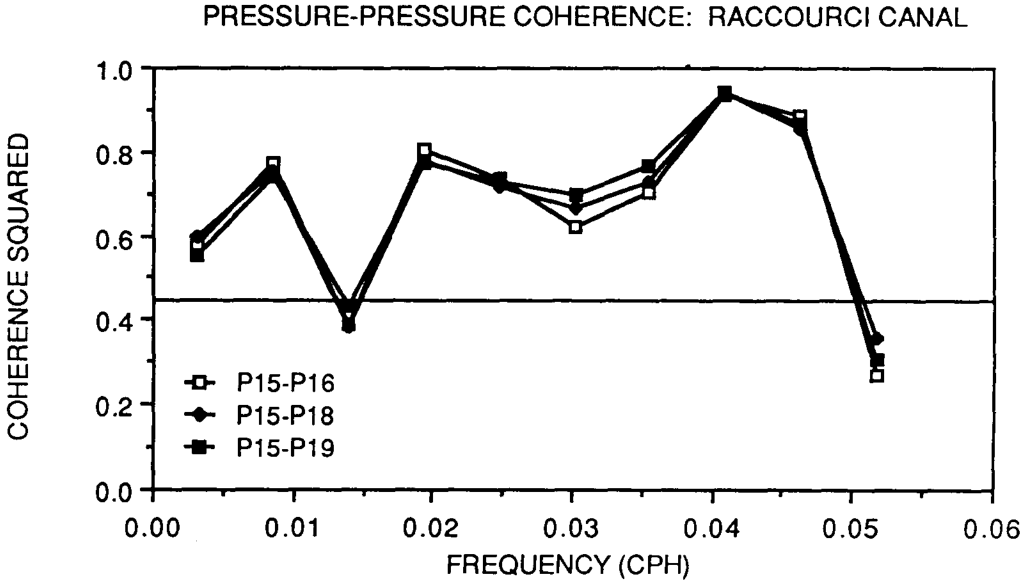


Figure E-19. Pressure-pressure coherence estimates for the deployment at Raccourci Canal (RC). The top plot presents the coherence between pressure in the bayou and pressure at each gage in the marsh. The bottom plot presents the coherence between pressure on the spoil bank and pressure at each gage in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from June 5, 1987 through July 21, 1987.

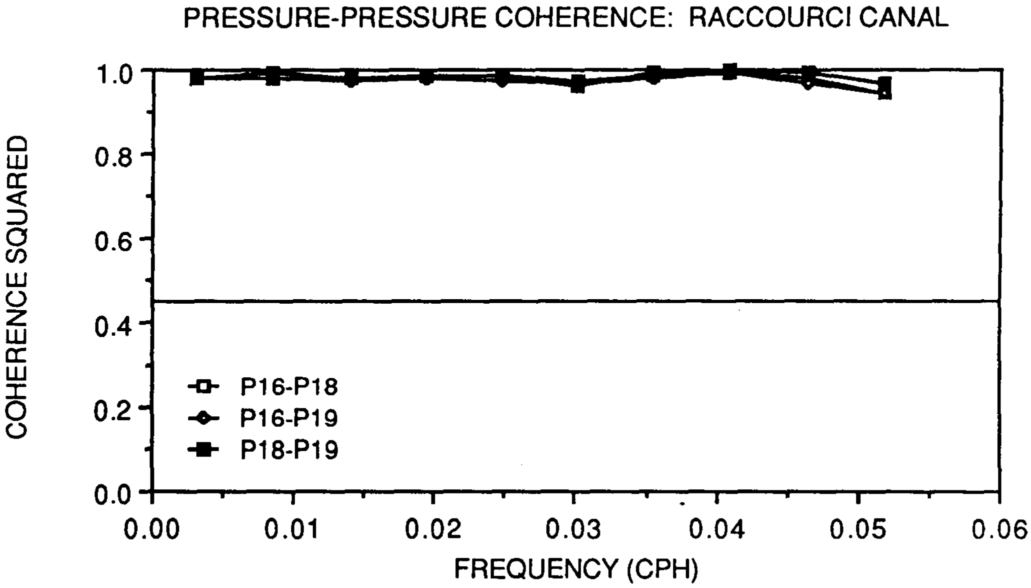
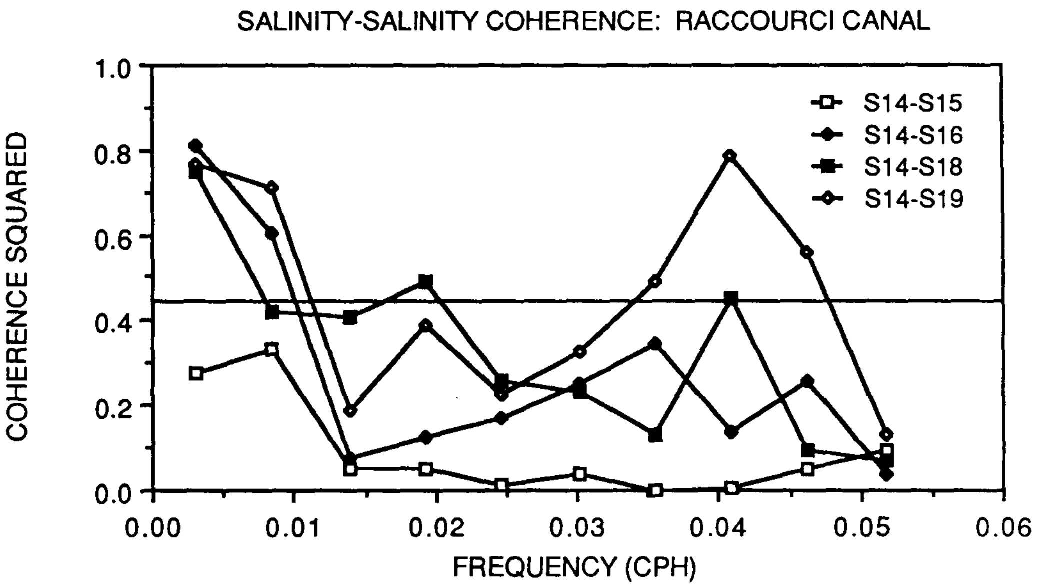


Figure E-20. Pressure-pressure coherence estimates for the deployment at Raccourci Canal (RC). The plots present the coherence between pressure at the various gages in the inland marsh sites. The solid horizontal line indicates the 95% level. The deployment covered the time period from June 5, 1987 through July 21, 1987.



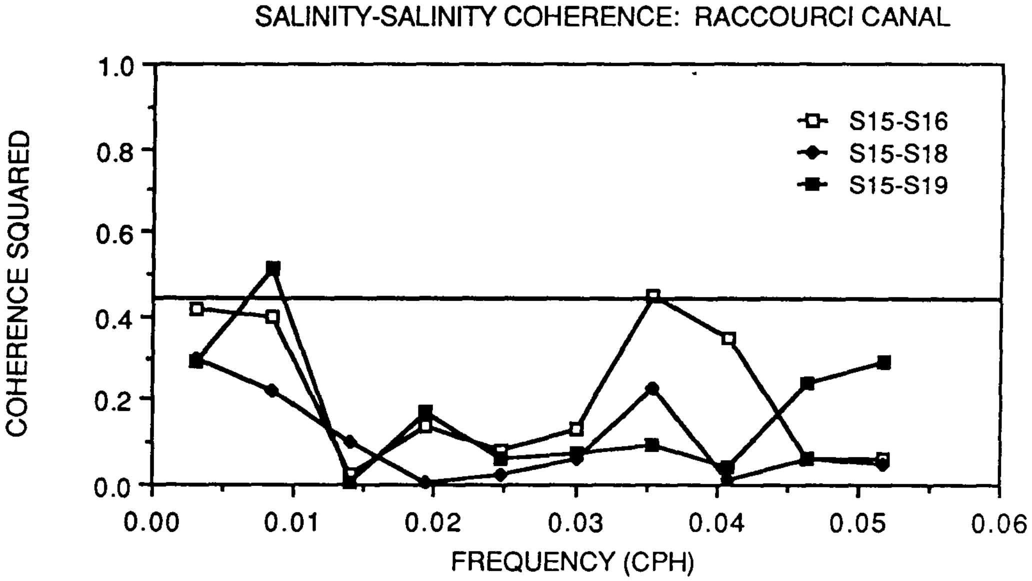


Figure E-21. Salinity-salinity coherence estimates for the deployment at Raccourci Canal (RC). The top plot presents the coherence between salinities in the bayou and salinity at each gage in the marsh. The bottom plot presents the coherence between salinities measured in the marsh. The data from the spoil bank was unreliable. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from June 5, 1987 through July 21, 1987.

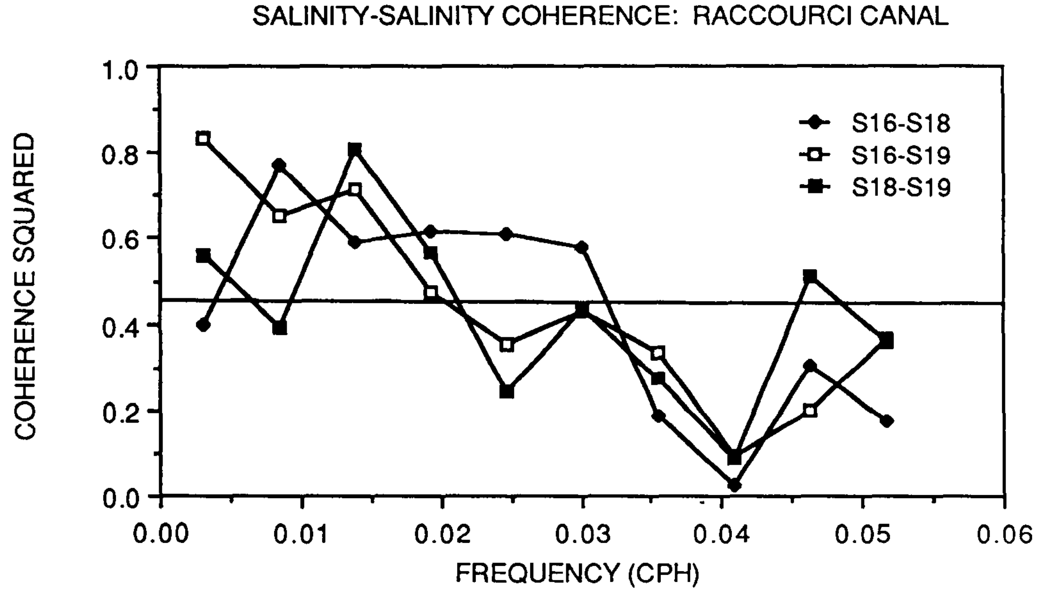


Figure E-22. Salinity-salinity coherence estimates for the deployment at Raccourci Canal (RC). The plot presents the coherence between salinities measured in the marsh. The solid horizontal line indicates the 95% confidence level. The deployment covered the time period from June 5, 1987 through July 21, 1987.

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March 3, 1849

MINERALS MANAGEMENT SERVICE