

ASSATEAGUE ISLAND, MARYLAND
EROSION CONTROL FEASIBILITY STUDY SUMMARY

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT CORPS OF ENGINEERS

FEBRUARY 1986

ASSATEAGUE ISLAND, MARYLAND EROSION CONTROL FEASIBILITY STUDY SUMMARY

INTRODUCTION

1. Continued erosion and migration of the northern section of the Assateague Island National Seashore towards the mainland area is of significant concern to the National Park Service of the United States Department of the Interior. The changes in the position of the northern section of the Island between 1931 and 1972 are illustrated in Figure 1. In order to analyze the erosion/migration processes, a study of the geomorphic changes and sediment transport along the northern section of Assateague Island was conducted. The following paragraphs discuss the major components of this study. The complete study is presented in the report entitled, "Assateague Island, Maryland - Erosion Control Feasibility Study - Phase I" prepared by the Baltimore District Corps of Engineers (November 1985).

SHORELINE POSITION

2. Changes in the shoreline position of Assateague Island from 1849 to 1980 were obtained from shoreline movement maps prepared as a result of a cooperative National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), and U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center (CERC), study of shoreline changes.

3. Changes in the shoreline position of Assateague Island were analyzed for the locations shown in Figure 2. The rate of change of the Assateague Island ocean shoreline for each of the periods covered by the NOS/CERC maps and the available profile surveys are shown in Table 1. Basically, the shoreline change rates can be divided into three time periods. The first period, 1849-1933, indicates the pre-inlet shoreline changes. During this period, the shoreline located at Profiles AI-8 to AI-32 experienced a significant increase in recession from the period 1849-1908 to 1908-1933. Figure 3 illustrates these changes. Since these periods precede the inlet formation (the inlet formed in August 1933; the 1933 NOS/CERC shoreline is from May 1933), this increase in shoreline recession is attributed to natural conditions.

4. The second time period, 1933-1962, indicates the post-inlet shoreline changes during the early history of the inlet. From Table 1, the most significant change is the increase in the recession rate of the shoreline between AI-T and AI-10 from 1908-1933 to 1933-1942. Figure 4 illustrates these changes. Between these two time periods, the recession rate for this shoreline area increased from an average of -9.8 feet per year to an average of -37.5 feet per year. The average recession rate for this shoreline area for the period 1849-1933 was also -9.8 feet per year. Analysis of Figure 4 indicates a net recession of the shoreline between Profile AI-12 and AI-32 during the 1908-1933 time period while during the 1933-1942 time period this shoreline area experienced a net accretion.

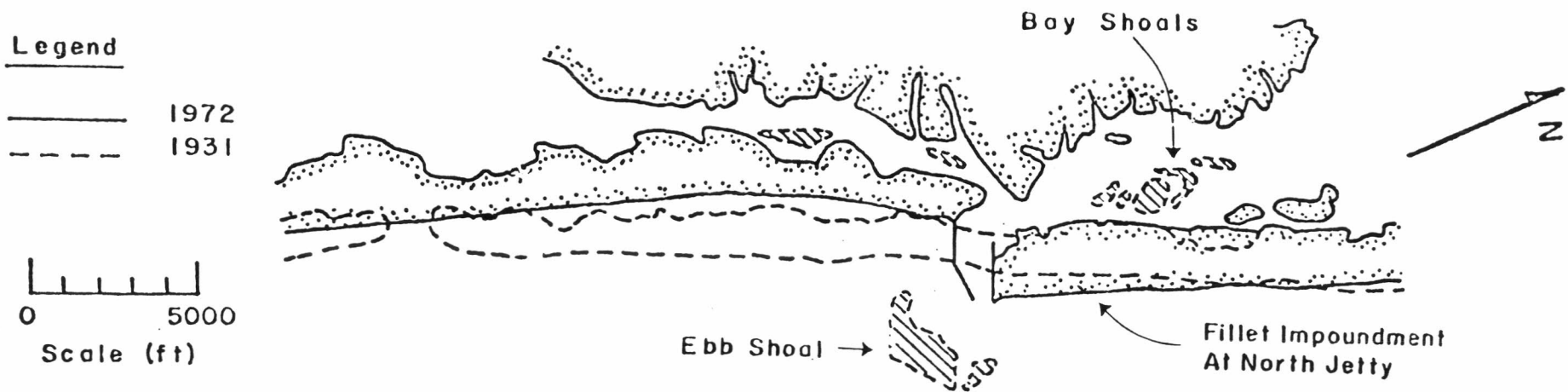


Figure 1: Shoreline Changes 1931-1972

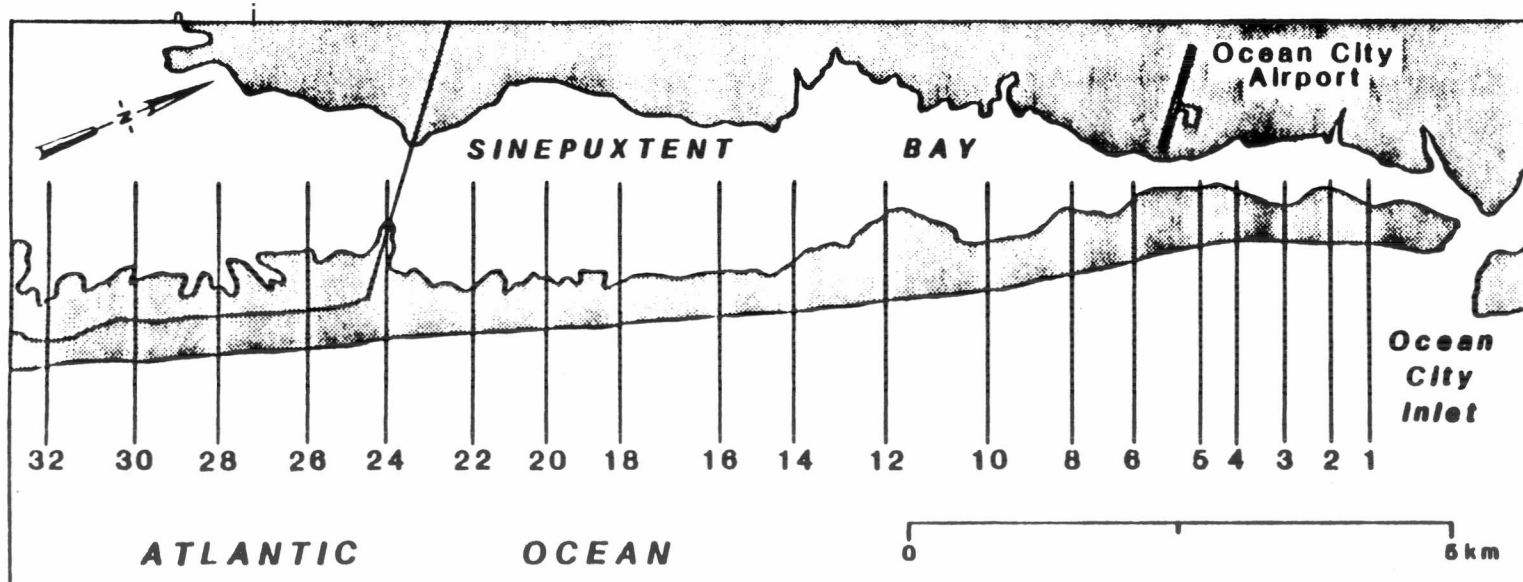


Figure 2: Profile Locations

TABLE 1
ASSATEAGUE ISLAND, MARYLAND
SHORELINE CHANGES 1849-1984

RATE OF CHANGE (FT./YR.)

	NOS/NOAA SHORELINE MAPS								PROFILE SURVEYS			
	1849 1908	1908 1929	1929 1933	1908 1933	1933 1942	1942 1962	1962 1976	1976 1980	1962 1980	1965 1979	1979 1984	1965 1984
PROFILE												
AI-T	-12.5	-5.4	0.0	-4.6	-43.1	-46.0	9.5	0.0	7.4	-1.4	7.5	1.1
AI-1	-13.5	-5.3	0.0	-4.5	-47.7	-43.0	-6.6	23.1	0.0	7.3	-0.1	5.2
AI-2	-13.2	-5.3	-15.2	-6.9	-45.6	-43.9	-13.9	23.1	-5.7	-0.5	29.5	7.8
AI-3	-12.7	-9.7	-4.9	-8.9	-43.1	-48.1	-13.2	4.9	-9.2	ND	ND	3.5
AI-4	-13.5	-7.7	-12.8	-8.5	-41.0	-65.4	14.4	-9.8	9.0	ND	-2.9	
AI-5	-12.8	-11.8	-1.9	-10.2	-37.7	ND	ND	-18.2	ND	ND		-1.7
AI-6	-11.1	-14.1	-23.1	-15.5	-29.6	-33.2	-24.1	-17.6	-22.7	ND		
AI-8	-8.8	ND	ND	-15.9	-29.6	-27.1	-26.2	-26.0	-26.2	-2.9	-4.7	-3.4
AI-10	-8.6	ND	ND	-13.1	-20.5	-23.5	ND	ND	-22.7	ND		-16.8
AI-12	-5.7	ND	ND	-11.8	-11.3	-18.9	ND	ND	-20.5	-21.6	-9.5	-18.2
AI-14	-1.6	ND	ND	-15.5	-11.3	-7.2	ND	ND	-12.0	ND		-11.0
AI-16	0.7	ND	ND	-14.3	6.8	-9.2	ND	ND	-11.3	-21.7	-13.0	-19.3
AI-18	1.7	ND	ND	-10.6	10.2	-7.8	ND	ND	-10.2	ND		-12.4
AI-20	0.3	ND	ND	-4.8	ND	ND	ND	ND	-2.8	-6.8	-14.8	-9.0
AI-22	1.2	ND	ND	-8.0	2.2	-3.0	ND	ND	-1.1	ND		-7.7
AI-24	1.7	ND	ND	-8.0	8.9	-6.5	ND	ND	-1.1	-3.4	-16.9	-7.1
AI-26	4.6	ND	ND	-7.2	2.2	-7.5	ND	ND	-2.2	ND		-6.7
AI-28	5.1	ND	ND	-5.0	1.0	-7.2	ND	ND	-3.3	ND		-5.4
AI-30	4.6	ND	ND	-4.4	6.7	-7.5	ND	ND	-1.1	ND		-7.0
AI-32	4.2	ND	ND	-3.2	3.3	-5.5	ND	ND	2.8	ND		-7.2

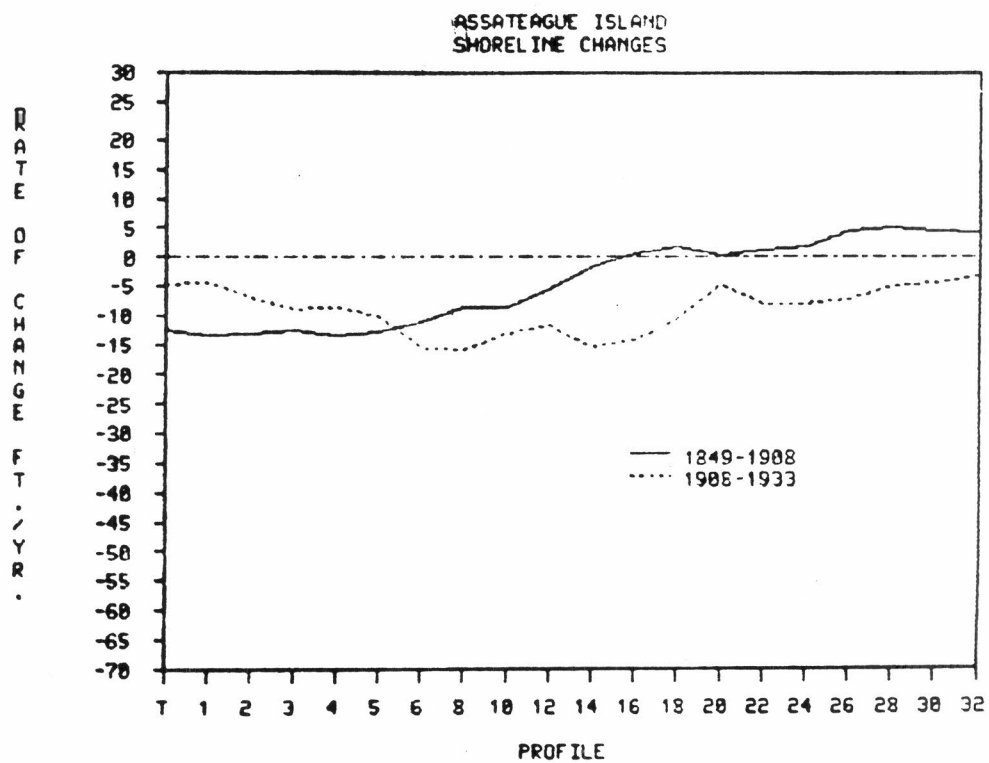


FIGURE 3

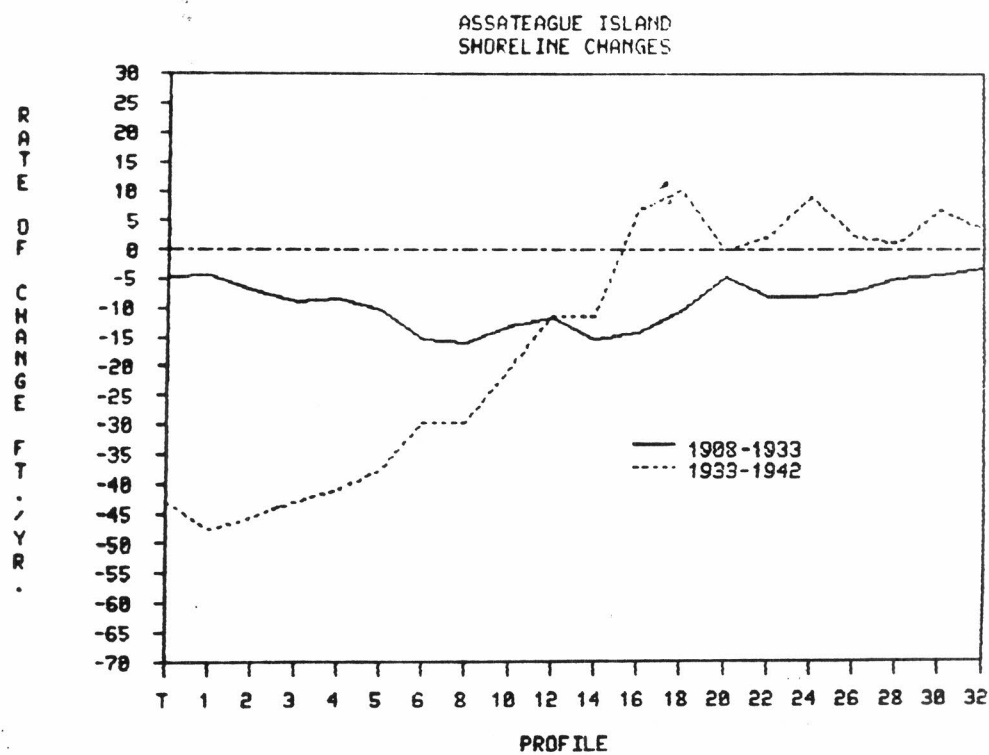


FIGURE 4

5. Figure 5 compares the shoreline changes between two post-inlet time periods, 1933-1942 and 1942-1962. For the shoreline area between Profiles AI-T and AI-10, the average recession rate increased from about -37.5 feet per year during 1933-1942 to about -41.3 feet per year during 1942-1962. The shoreline area between Profiles AI-12 and AI-32 experienced a net recession during the latter time period similar in magnitude to the rates experienced by this area during the 1908-1933 time period.

6. The third time period, 1962-1976, indicates the post-inlet shoreline changes during later stages of the inlet. Figure 6 compares the shoreline changes during the period 1942-1962 and 1962-1976. A significant decrease in the recession rate of the shoreline between AI-T and AI-8 (from an average of -41.3 feet per year during 1942-1962 to -8.6 feet per year during 1962-1976) occurred between these two periods. Figure 7 compares the shoreline changes between Profiles AI-T and AI-8 during the periods 1962-1976 and 1976-1980. During the latter period the average recession rate was -2.6 feet per year compared to -8.6 feet per year during the former period.

7. Figure 8 compares the shoreline changes between Profiles AI-T and AI-32 during the two periods, 1942-1962 and 1962-1980. Although a significant reduction in the recession rates was experienced between Profiles AI-T and AI-6 during the latter time period, little change occurred between Profile AI-8 and AI-32. From this comparison, it appears that the effects of the inlet/jetty system on recession rates extended from the inlet south to about Profile AI-6.

8. Figure 9 compares the shoreline changes during the period preceding the inlet formation, 1908-1933, to the more recent period, 1962-1980. From this comparison it appears that the shoreline changes occurring during the more recent time periods are similar in magnitude and location to the pre-inlet changes.

9. In summary, it appears that prior to the inlet formation, the ocean shoreline of Assateague Island was experiencing fluctuating periods of recession and accretion at various locations. Following the inlet formation, a definite increase in the recession rate of the northern section of the shoreline took place. From a comparison of the most recent shoreline changes, it appears that the shoreline changes are now approaching the pre-inlet condition.

ISLAND/SINEPUXENT BAY WIDTH

10. In addition to shoreline changes, the concurrent changes in the width of the island and the width of Sinepuxent Bay must be examined in order to understand the processes active in the area. Table 2 shows the width of the island at the profile locations for various years and also the average widths and standard deviations of the widths for the available data. These widths were obtained from the NOS/CERC shoreline change maps and a 1984 profile survey conducted as part of this study. Analysis of these data indicates that as the ocean shoreline of the island experienced significant recession in many locations, the width of the island experienced both increases and decreases during the same time period. It appears that the most significant changes in the island width occurred at the northern end of the island. This is also the area that has experienced the highest rate of shoreline recession.

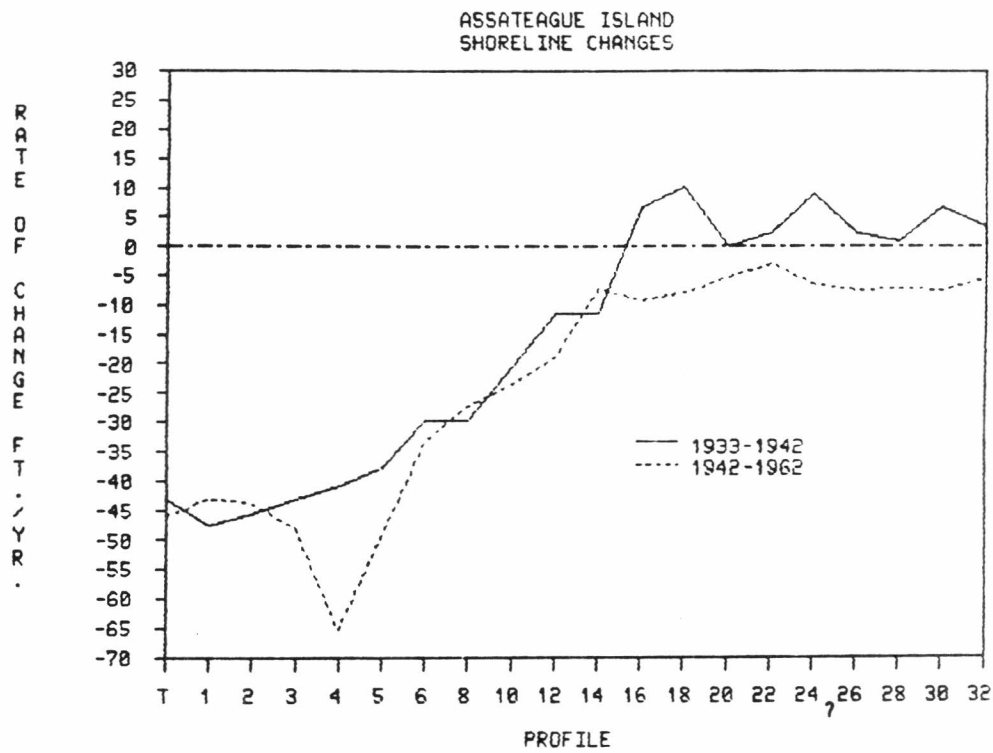


FIGURE 5

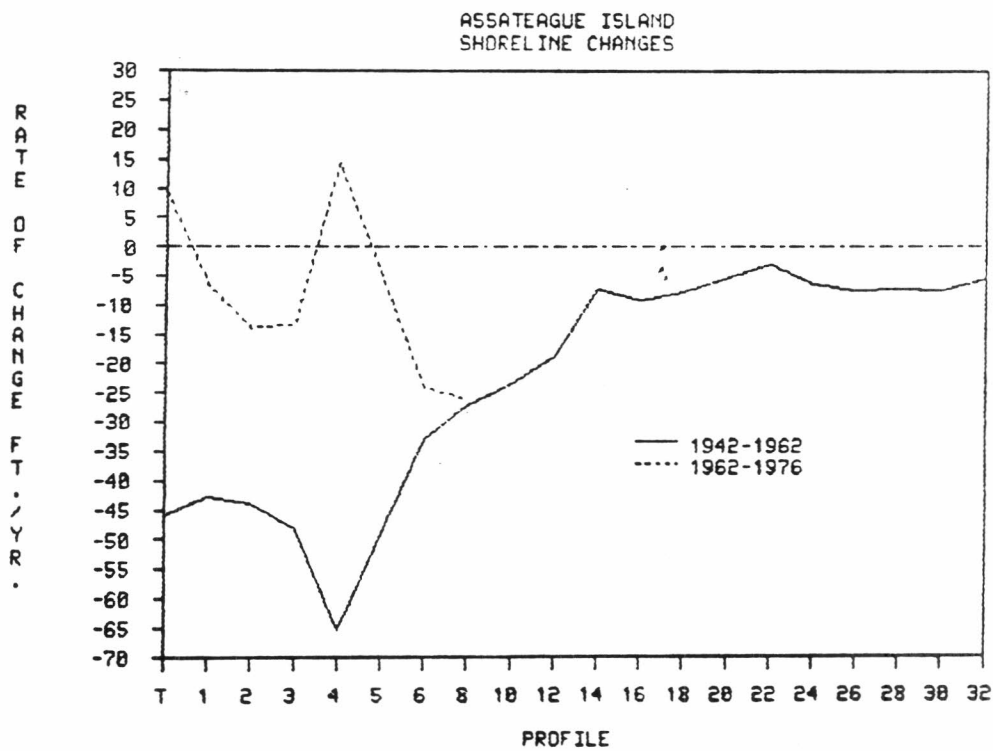


FIGURE 6

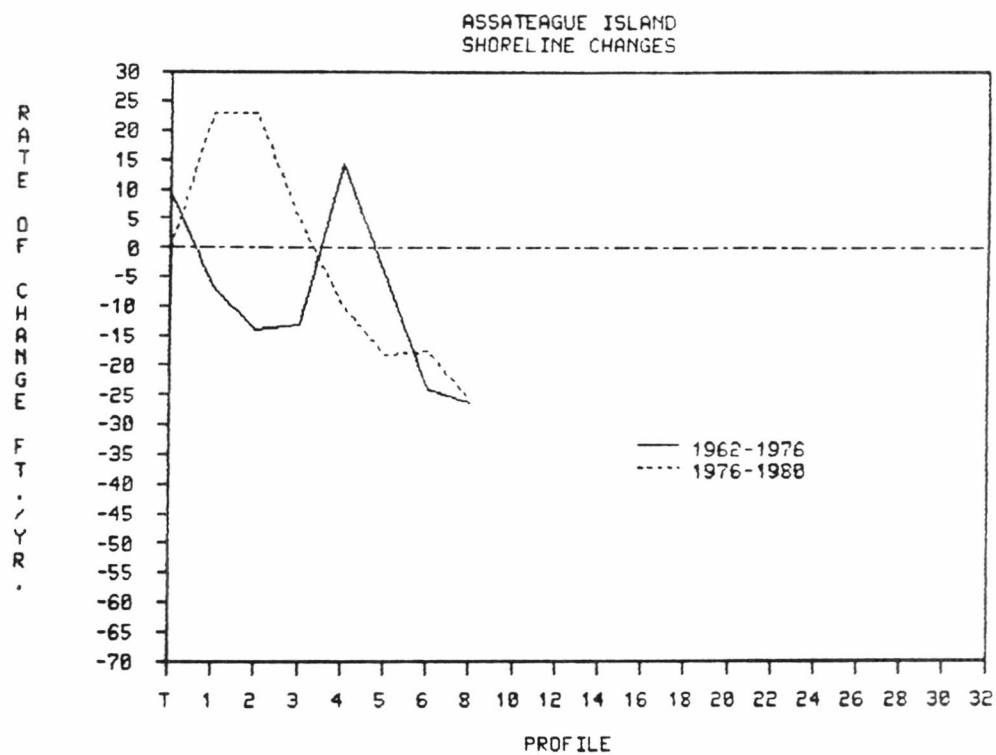


FIGURE 7

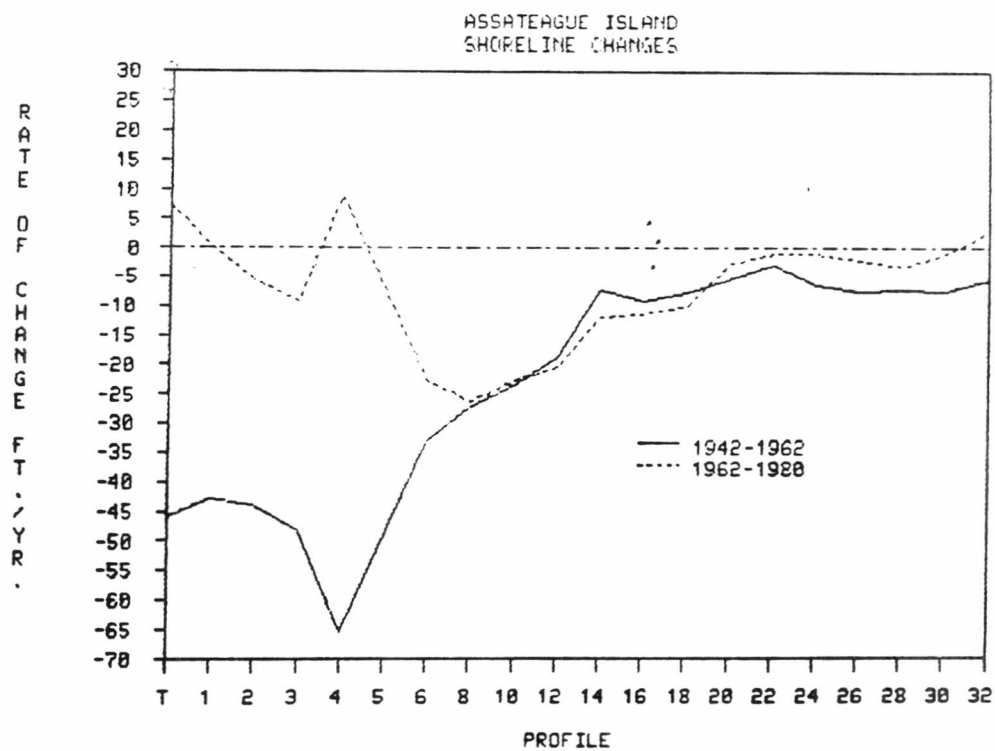


FIGURE 8

ASSATEAGUE ISLAND
SHORELINE CHANGES

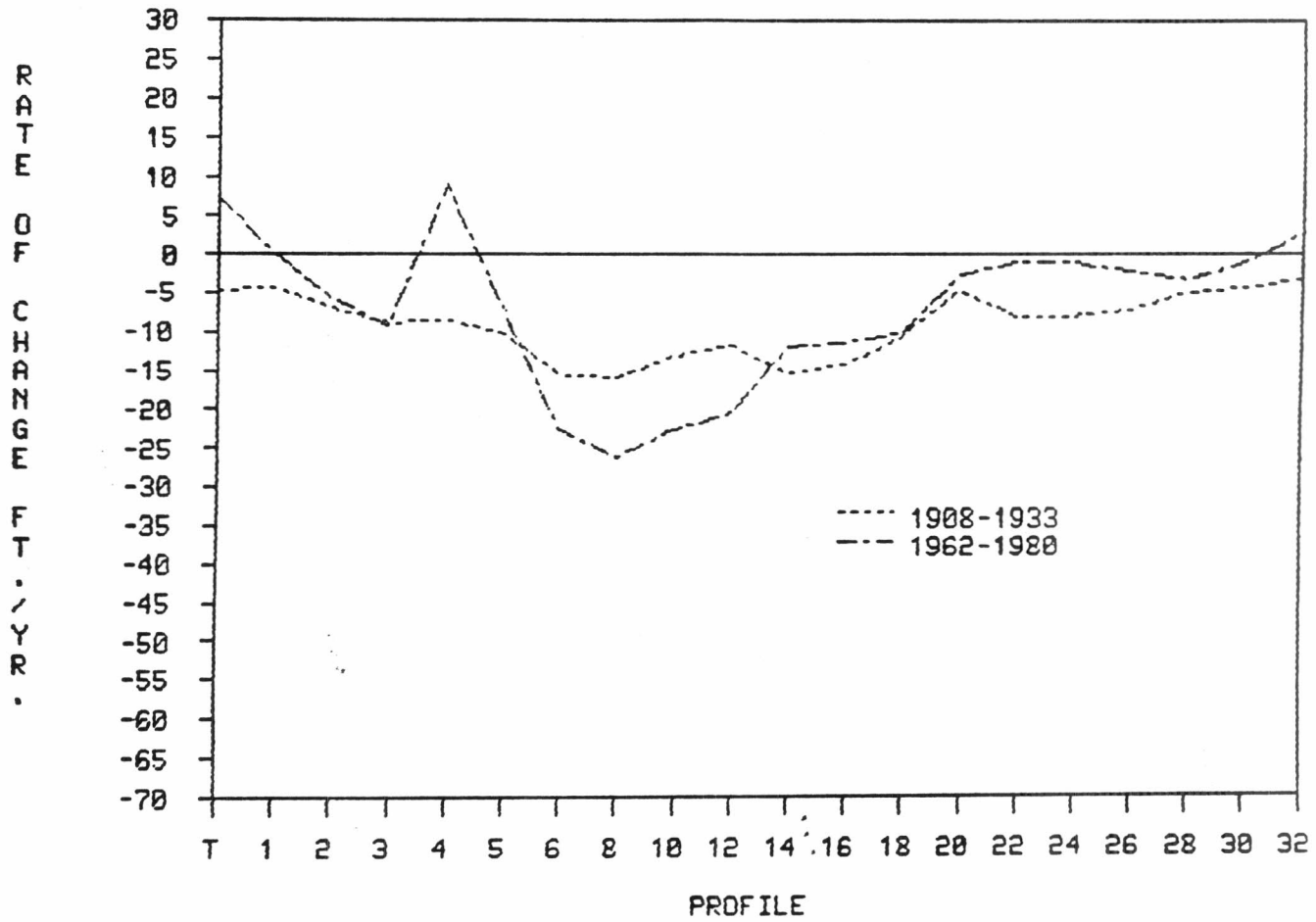


FIGURE 9

TABLE 2
ASSATEAGUE ISLAND, MARYLAND
ISLAND WIDTH 1849 - 1984

PROFILE	WIDTH (FT.)									STD.
	1849	1908	1929	1942	1962	1976	1980	1984	AVG.	
AI-T	1216	983	1124	920	1022	1155	1155	1468	1130	158
AI-1	1687	879	920	818	573	818	1002	1374	1009	332
AI-2	1891	1092	1094	736	563	1002	1769	1881	1254	491
AI-3	1073	1267	1400	961	655	869	939	1060	1028	217
AI-4	1228	1226	1422	888	532	1634	1604	1428	1245	350
AI-5	1034	1391	1226	898	ND	1412	1359	1381	1243	187
AI-6	1092	1114	1024	900	818	837	1381	1808	1122	310
AI-8	1667	1442	ND	1041	879	1657	1595	1618	1414	298
AI-10	1298	1034	ND	1063	879	ND	840	896	1002	156
AI-12	1748	1053	ND	3089	2752	ND	2398	2338	2230	667
AI-14	1320	1298	ND	1187	1196	ND	1053	1237	1215	87
AI-16	1983	1799	ND	1553	1318	ND	1165	1027	1474	339
AI-18	2097	1942	ND	ND	1646	ND	1400	1391	1695	284
AI-20	2012	1851	ND	ND	1641	ND	1561	1446	1702	204
AI-22	1301	1672	ND	1531	1371	ND	1411	1576	1477	127
AI-24	1901	3382	ND	3302	3202	ND	3182	2739	2951	512
AI-26	3007	3267	ND	3172	3022	ND	2992	3060	3087	100
AI-28	2272	2652	ND	2536	2392	ND	2332	1885	2345	241
AI-30	2352	3022	ND	3002	2832	ND	2832	2857	2816	222
AI-32	2391	2912	ND	2762	2962	ND	2745	2901	2779	190

11. Table 3 shows the distance between the Sinepuxent Bay shoreline of Assateague Island and the mainland to the west at the various profile locations for the same period of analysis. These data indicate that the most significant decrease in the distance between these shorelines occurred along the northern section of the island.

12. From the above analysis, it is apparent that the recession of the ocean shoreline of Assateague Island cannot be interpreted strictly as erosion. Although erosion of the shoreline is occurring to some degree, migration of the island towards the west is evident with the width of the island being maintained to a significant degree. As this process occurs, the width of Sinepuxent Bay to the west of the island is decreasing.

ISLAND ELEVATION

13. Since earlier profiles surveyed in 1965 and 1979 did not extend across the island to the Sinepuxent Bay shoreline, definitive data on changes in the elevation of the island are not available between those surveys. However, comparison of the data available from those surveys suggests that there was some decrease in island elevation at the northern end from 1965 to 1979. Comparison of the 1984 profiles with the available data from the 1965 and 1979 surveys also shows a slight decrease in elevation of the island at the northern end.

PROFILES

14. As discussed previously, profile surveys are available for three years, 1965, 1979, and 1984. Comparisons of all three surveys for various locations along the island are presented in Appendix A. The location of the ebb tide shoal is shown in Figures A1-A3. From Figures A1-A3, it is noted that the shoal appears to have migrated oceanward with time. A steepening of Profiles AI-2 to AI-20 and a significant change in submarine volume between the surveys is also noted.

EBB SHOAL

15. Following the formation of Ocean City Inlet in 1933, an extensive ebb shoal began to form about three-quarters of a mile offshore of the inlet as shown in Figure 10. The sediment composing this shoal is believed to be derived from the erosion and transport of sand from the beaches north of the inlet. Four bathymetric surveys of the area outlined in Figure 10 (May 1933, June 1976, November 1981 and May 1983) were analyzed to determine the volumetric growth of the shoal. The results of this analysis are shown in Table 4.

16. The data in Table 4 indicates that the growth rate of the shoal is not only decreasing, but that the shoal is actually decreasing in volume. However, this trend should be analyzed carefully. The surveys used for the first two comparisons provide adequate coverage of the shoal area and the decreasing growth rate indicated by these surveys is probably valid. However, there is some questions as to whether the last survey, May 1983, adequately covers the shoal area. It is possible that the shoal has migrated to the south beyond the limits of this survey.

TABLE 3

DISTANCE BETWEEN THE SINEPUXENT BAY SHORELINE
OF ASSATEAGUE ISLAND AND THE MAINLAND

PROFILE	YEAR						
	1849	1908	1929	1942	1962	1976	1980
AI-T	2891	2389	2134	1950	928	928	928
AI-1	3003	3012	2859	2532	1918	1581	1488
AI-2	3290	3312	3198	3086	2380	1747	1072
AI-3	4215	3274	2937	2968	2313	1915	1864
AI-4	4102	3306	2947	3061	2110	1210	1200
AI-5	3946	2832	2749	2730	ND	1123	1104
AI-6	4192	3517	3311	3075	2493	2136	1522
AI-8	4277	3981	ND	3716	3338	2193	2151
AI-10	5245	5000	ND	4459	4172	ND	3804
AI-12	6030	6389	ND	3955	3914	ND	3899
AI-14	5430	5359	ND	4981	4828	ND	4755
AI-16	4459	4685	ND	4634	4685	ND	4634
AI-18	4514	4771	ND	ND	4739	ND	4800
AI-20	5683	5863	ND	ND	5823	ND	5853
AI-22	5360	5059	ND	5019	5120	ND	5059
AI-24	5255	3874	ND	3834	3804	ND	3804
AI-26	4832	4842	ND	4777	4777	ND	4767
AI-28	6294	6214	ND	6214	6214	ND	6214
AI-30	10045	9644	ND	9614	9634	ND	9614
AI-32	10619	10349	ND	10449	10139	ND	10406

TABLE 4
EBB SHOAL

	1933-1976	1976-1981	1981-1983
Total (CY.)	+6,970,700	+522,700	-272,400
Annual (CY./YR.)	+162,100	+95,000	-172,000

FLOOD SHOAL

17. In addition to the ebb shoal, a series of flood shoals, shown in Figure 10, have been developing in the Isle of Wight Bay area since the formation of the inlet. These shoals have been formed from sediment transported into the bay area through the inlet by the flood currents. Prior to the inlet formation, this area was not affected by tidal fluctuations and currents. As a result, a relatively uniform depth of about 3-4 feet of water existed in this area. Following the inlet formation, significant changes in the bay took place as the sediment transported through the inlet began to deposit in shoals in the bay. Based on an analysis of aerial photographs of the area, it is estimated that about 25,000 cubic yards of sediment per year deposited in the shoal area during the early history of the inlet. As these shoals formed, the ebb and flood tidal currents began to scour channels in several locations.

18. In July 1984, thirteen survey transects were obtained across Isle of Wight and Assawoman Bays. These transects were compared to transects in the same locations from 1933. The results of this comparison indicate that between 1933 and 1984 the bay area encompassed by these transects has experienced a net erosion of about -50,100 per year. This is an interesting result since the formation of the shoals gives the impression that the bay areas have been filling in with sand since the inlet formed. It appears that the scouring effects of the ebb and flood currents, which have been induced by the formation of the shoals, have eventually resulted in the bay area becoming a source of sediment rather than a sink.

OCEAN CITY, MARYLAND

SHORELINE POSITION

19. For the Ocean City area the average shoreline erosion rate has been on the order of 2-3 feet per year during the same period of analysis. The one exception to this erosion rate has been the shoreline immediately to the north of the north jetty. This area has experienced a net accretion as a result of the sand trapping effect of the north jetty. As discussed in the report entitled, "A Coastal Engineering Study of Ocean City Inlet", Dean et al (1978), a comparison of surveys conducted prior to the jetty construction and two years after construction indicated that 148,000 cubic yards of sand per year were impounded within 1,800 feet north of the jetty. Subsequent surveys indicated that between 1934-1947 about 36,000 cubic yards of sand per year were impounded in this area. As part of the current study a comparison of surveys of this area in 1934 and 1937 was made. This comparison indicates that about 52,000 cubic yards of sand per year are impounded in this area. Based on the existing location of the shoreline north of the jetty, it appears that this area is impounded to capacity and that any net transport arriving there is bypassing the jetty.

LONGSHORE SEDIMENT TRANSPORT

20. The Delmarva Peninsula from Cape Henlopen south to Fishing Point is shown in Figure 11. Longshore sediment transport along this area is a major component of the sediment budget analysis of the Assateague Island area. Wave data from the U.S. Army Corps of Engineers' Wave Information Study (WIS) were used to compute the longshore sediment transport rates along the various reaches of the Delmarva Peninsula shoreline. These reaches coincide with the shoreline reaches associated with the WIS Phase III wave data stations as shown in Figure 11.

21. Analysis of the data in Table 5 indicates the relatively large degree of variability of the transport rate magnitudes and also direction in some cases during the twenty year period for each station. The sign convention for this data is that negative transport is to the left or south to north in this area; positive transport is to the right or north to south.

22. For Station 67, the Ocean City, Maryland area, the computed average net transport is about 356,200 cubic yards per year to the south. Previous studies have estimated the net longshore transport rate to be in the range of about 150,000-200,000 cubic yards per year to the south. The rate of sand-trapping at the north jetty of about 148,000 cubic yards per year in addition to transport of sand overtop of the jetty during the same time period gives some support for an average net transport rate on the order of 200,000 cubic yards per year. However, analysis of the data in Table 5 shows that for 4 out of the 20 years, the computed net transport is about 1,000,000 cubic yards per year or more. These rates appear to be high for the area based on the rates of impoundment at the north jetty and the shoaling rates in the area. Elimination of these 4 years results in an average longshore transport rate of about 174,500 cubic yards per year. In the report entitled, "Longshore Sand Transport Statistics", Douglas (1985) conducted an independent analysis of the data. The results of this analysis indicated that the average net longshore transport rate (1956-1975) was about 280,000 cubic yards per year to the south. Thus, based on the available data, it appears that the net longshore transport rate at Ocean City is on the order of 150,000 to 300,000 cubic yards per year to the south.

EXISTING CONDITIONS SEDIMENT BUDGET

23. Under existing conditions, the north jetty is assumed to have reached its impoundment capacity and any longshore transport arriving there is bypassing the jetty. The bay area behind Ocean City is no longer acting as a sediment sink, but is now functioning as a sediment source as a result of the scouring effect of the tidal currents in the area. A comparison of surveys prior to the inlet formation and July 1984 indicates that this area has experienced a net volume change of -50,100 cubic yards per year. The rate of deposition of sediment in the ebb shoal has decreased to 95,000 cubic yards per year (from 162,100 cubic yards per year during 1933-1976) during 1976-1981. From 1981 to 1983, the shoal has experienced a loss of -172,000 cubic yards per year. During this period, the northerly longshore transport along the Assateague Island shoreline is assumed to have passed through and over the south jetty (as a result of deterioration of the jetty) and into the navigation channel in the inlet.

PHASE III WIS
WAVE AND SEDIMENT TRANSPORT
LOCATIONS

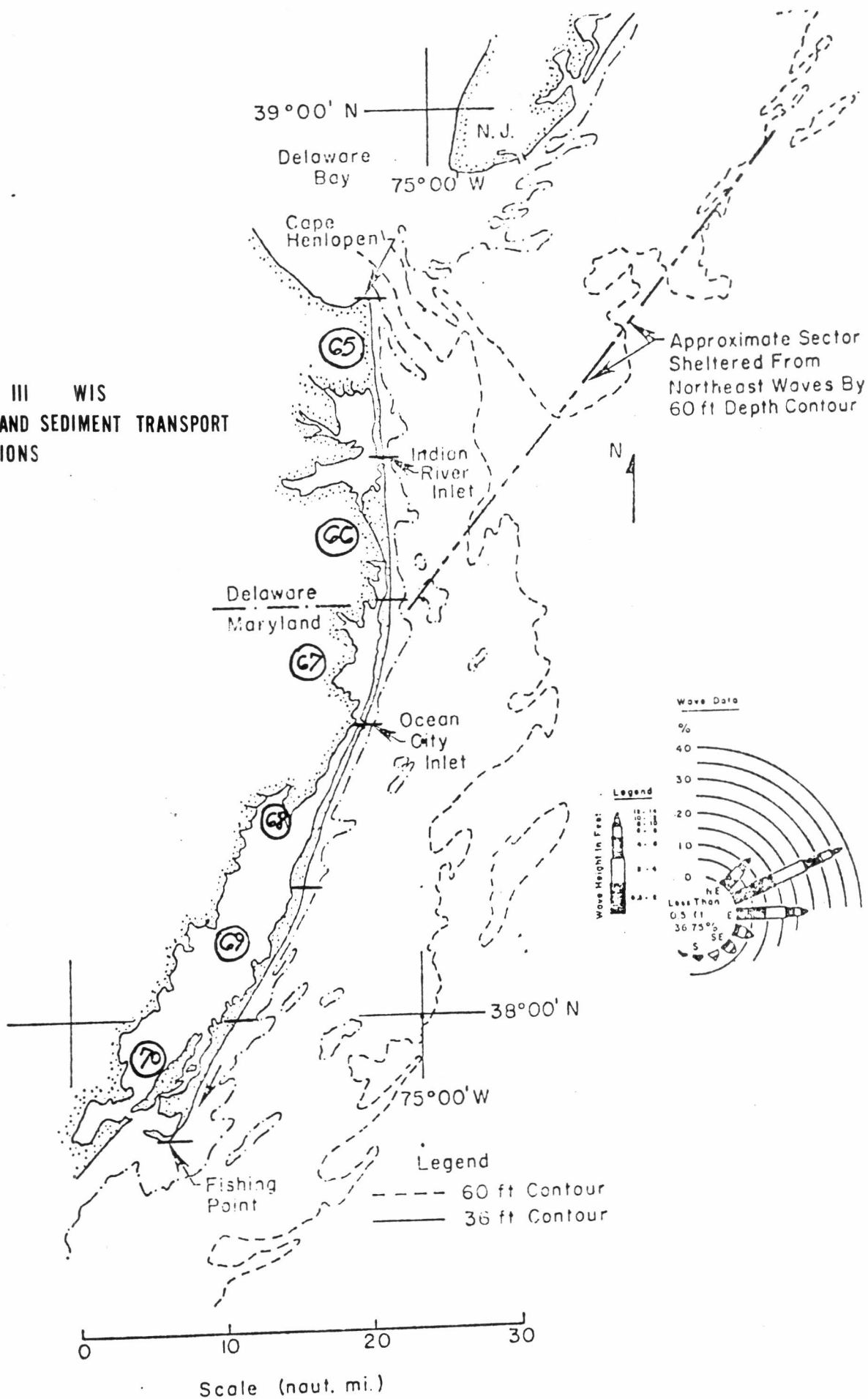


FIGURE 11

TABLE 5
DEL MARVA PENINSULA
LONGSHORE SEDIMENT TRANSPORT DATA
WIS PHASE 3 STATION

YEAR	65	66	67	68	69	70
	QNET (CY./YR.)					
1956	-68900	392600	1420000	1353000	1307000	1120000
1957	-141060	-37200	160900	-29700	-4900	-137000
1958	-228000	-509600	248300	388400	380600	493500
1959	-216870	-184400	-46900	-297100	-288000	-419000
1960	-143200	94000	429000	282100	288400	99590
1961	-128300	134000	315400	118110	140000	-50700
1962	-61740	755400	1116000	944200	986400	613100
1963	-165600	45200	213400	6000	22000	-154600
1964	-84900	310000	312400	-115000	-96770	-413000
1965	-116970	111700	230500	41800	50600	-103300
1966	-241700	-24300	113000	27200	29000	-94890
1967	-54145	111400	197300	-150000	-139900	-371200
1968	-242300	62100	111250	-69000	-72200	-211300
1969	-127000	524000	10020000	786300	813500	546000
1970	-191112	-71900	265000	76100	61400	-93400
1971	-289700	-87300	192300	78800	97160	-57640
1972	-254300	170900	359100	69000	89000	-186000
1973	-534100	-191200	-259300	-656200	-626600	-930020
1974	-225210	-38300	-49700	-314200	-309500	-503400
1975	-294900	193300	794800	565000	586300	373800
QNET AVG.	-190500	88020	356238	155241	165675	-23973
STD. DEV.	107518	265624	406136	452783	448106	451031
MAX.	-54145	755400	1420000	1353000	1307000	1120000
MIN.	-534100	-509600	-259300	-656200	-626600	-930020

24. For the 1976-1981 period, a decrease in the recession rate of the northern end of the island occurred. In general, it appears that the width of the island increased between Profiles AI-T to AI-4. South of Profile AI-4, the island width remained relatively constant. The width of Sinepuxent Bay to the west of the northern end of the island remained relatively constant during this period. These data indicate that the erosion/migration process has slowed down and that the volumetric change should have also decreased. Comparison of the 1979 and 1984 profiles indicates a net volume change of -27,300 cubic yards per year during that period, which is a significant reduction over previous periods. One possible explanation to account for these changes is that some longshore transport from the Ocean City area and/or material from the ebb shoal is being bypassed to the northern end of the island.

25. For the 1981-1983 period, the same basic data is available to detect the changes in the erosion/migration of the island. However, comparison of an additional survey (1983) of the ebb shoal during this period with the 1981 survey indicates that the shoal has decreased in size at a rate of about -172,000 cubic yards per year. Loss of material from the shoal and the decrease in the erosion/migration of the island may indicate that material is now being bypassed to the northern end of the island. As discussed previously, another survey of the ebb shoal area is needed to evaluate this bypassing process and the overall migration of the shoal.

26. During 1984-1985 rehabilitation of the south jetty at the northern end of the island was accomplished. The purpose of this rehabilitation was to render the jetty sand-tight to prevent northerly moving longshore transport from passing through and over the jetty and into the inlet. The anticipated result of this work is a reduction in the erosion/migration of a segment of the northern end of the island as the longshore transport (estimated to be about 82,000 cubic yards per year) is trapped on the south side of the rehabilitated jetty. No data is available yet to determine the effects of this project. However, an intensive monitoring program is scheduled to be initiated in Fiscal Year 1986 under the Monitoring of Completed Coastal Projects work unit of the U.S. Army Coastal Engineering Research Center. Data obtained as part of this monitoring effort will be used to evaluate the effects of the project on the northern end of the island.

CONCLUSIONS

27. From the above analysis and the data presented in this report, the following conclusions are reached:

a. Prior to the formation of the inlet, the ocean shoreline of Assateague Island experienced fluctuating periods of recession and accretion at various locations. After the inlet was formed and stabilized, a definite increase in the recession rate of the northern end of the island occurred.

b. During the pre-inlet and post-inlet time periods, the width of the island at specific locations has varied. The most significant changes occurred at the northern end of the island. In this area, a general decrease in the island width occurred after the inlet formed.

c. For the same time periods, the distance between the Sinepuxent Bay shoreline of Assateague Island and the mainland shoreline to the west has decreased along the northern end of the island. This decrease in combination with the recession of the ocean shoreline and the changes in width of the island indicates that the northern section of the island is migrating towards the mainland.

d. Recent data indicates that the rate of erosion/migration of the northern end of the island is decreasing. The data indicate that some natural bypassing of material from the Ocean City shoreline and/or the ebb shoal may be occurring.

e. Rehabilitation of the south jetty to render it sand-tight will result in a reduction in the erosion/migration of some segments of northern Assateague Island. }

APPENDIX A

PROFILE SURVEYS

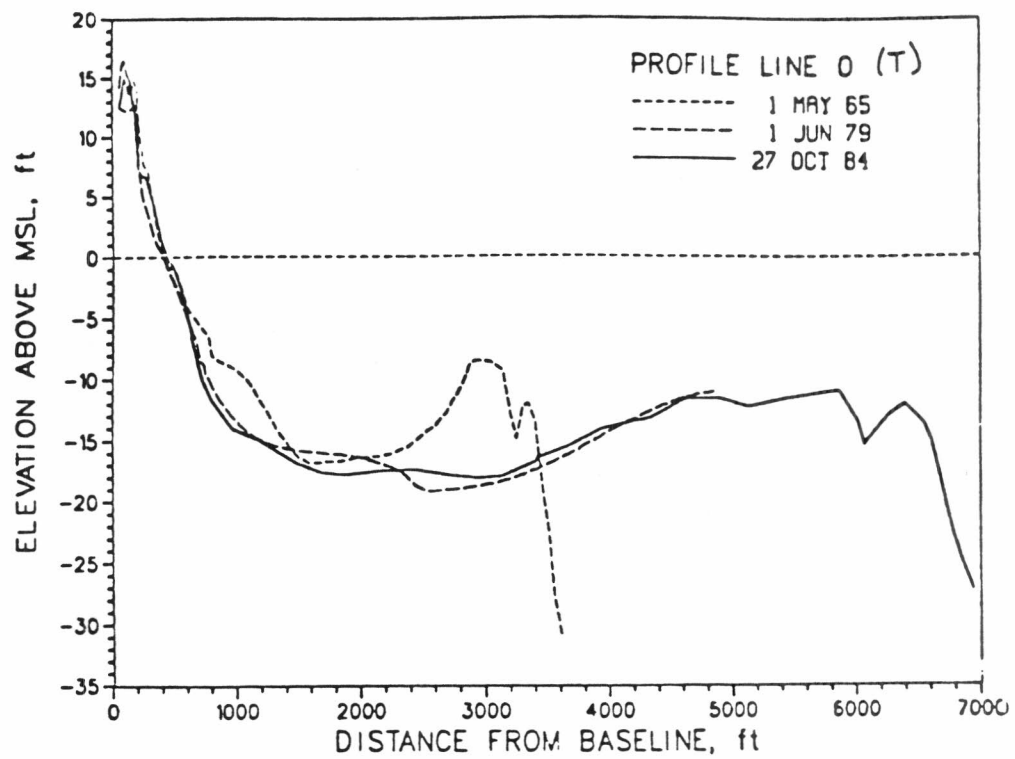


Figure A1.

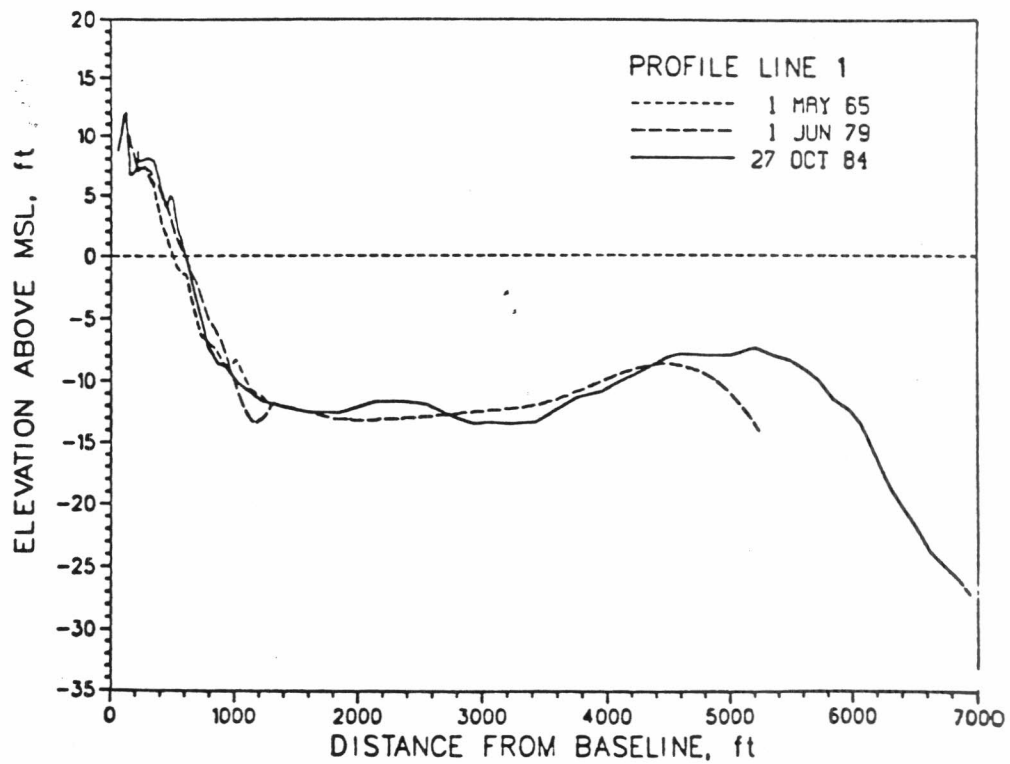


Figure A2.

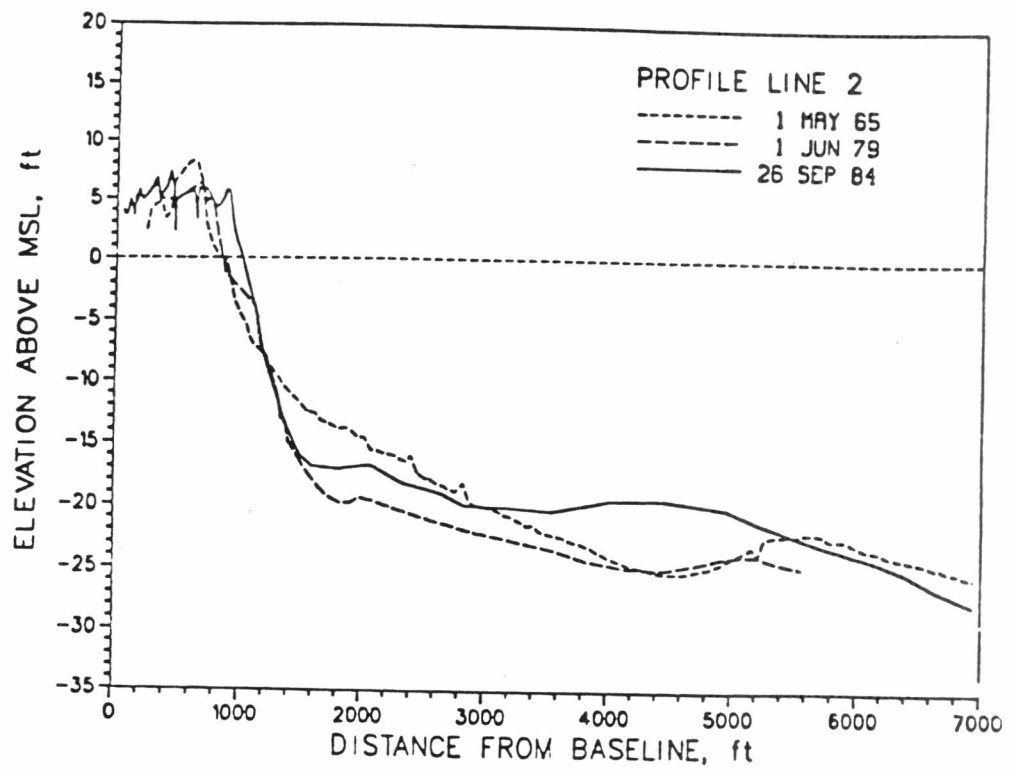


Figure A3.

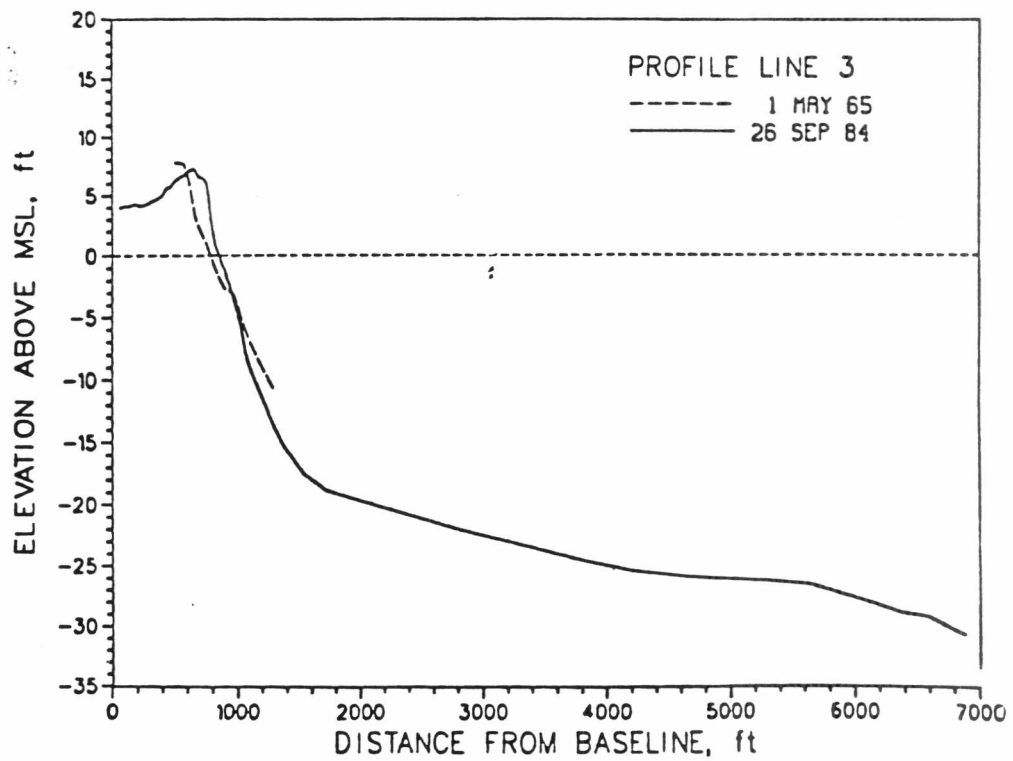


Figure A4.

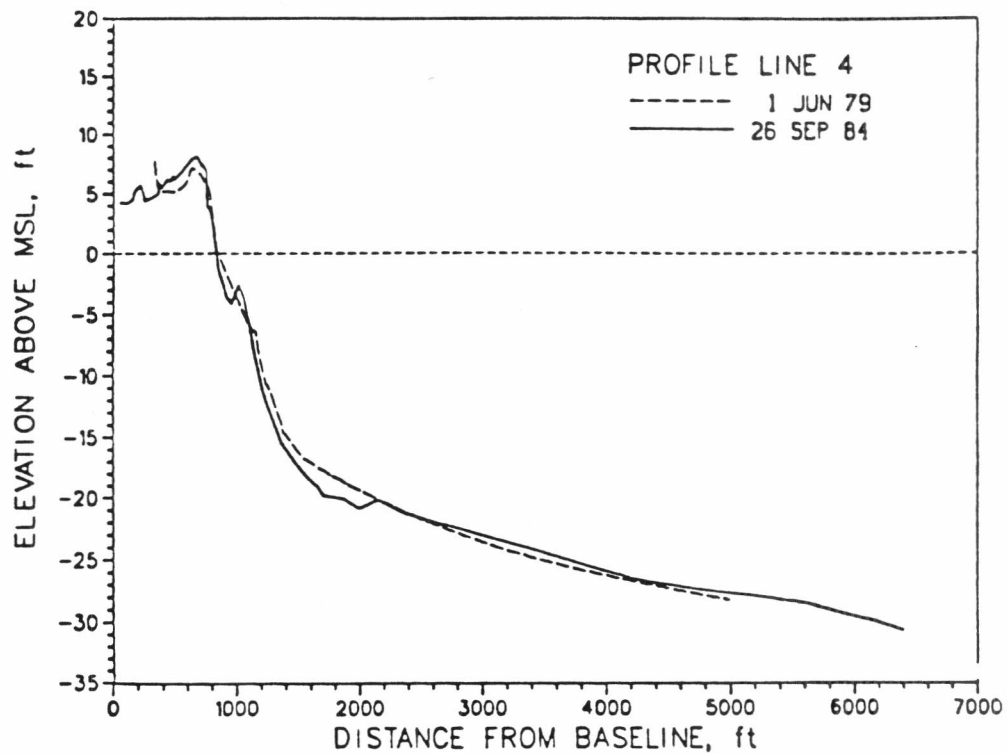


Figure A5.

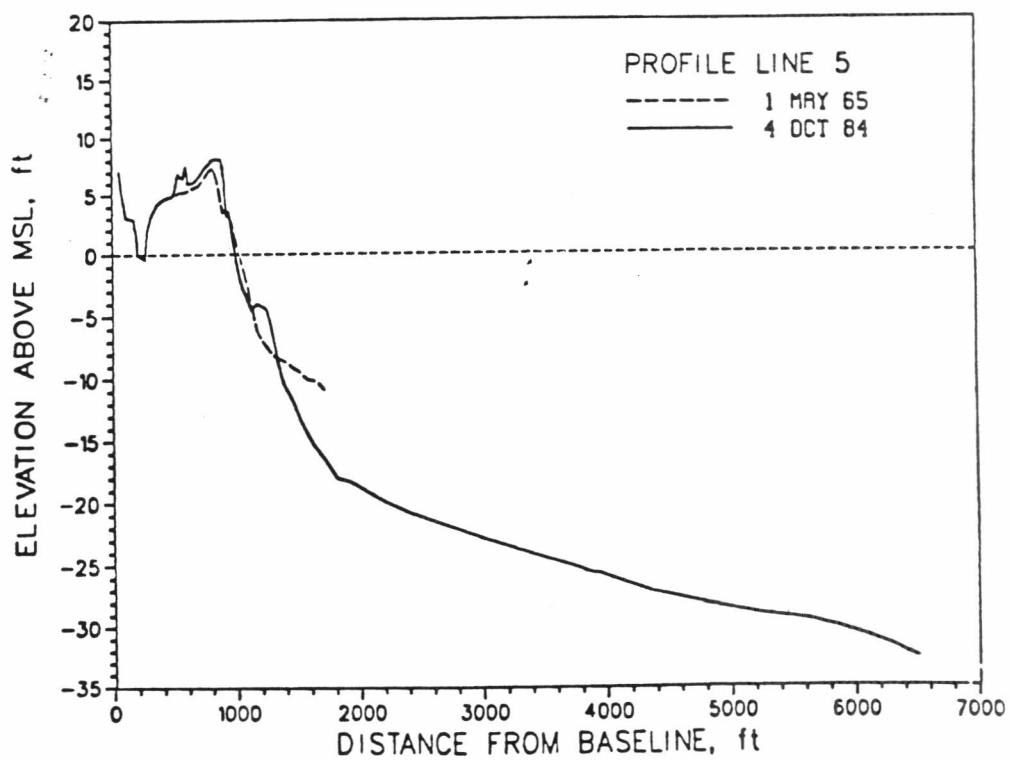


Figure A6.

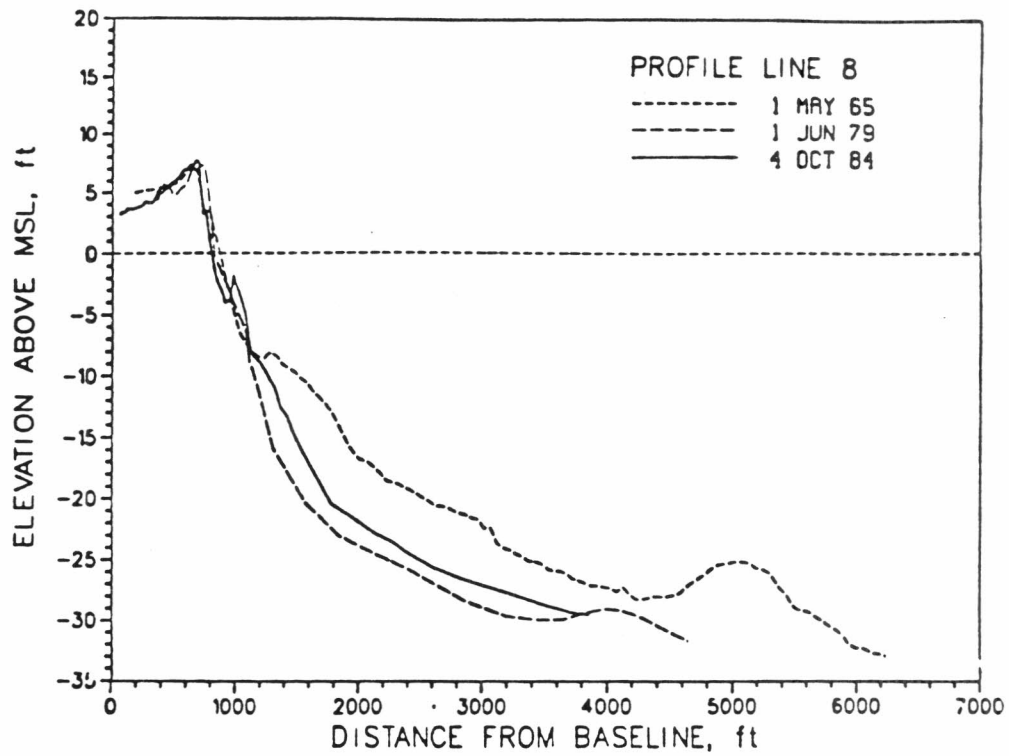


Figure A7.

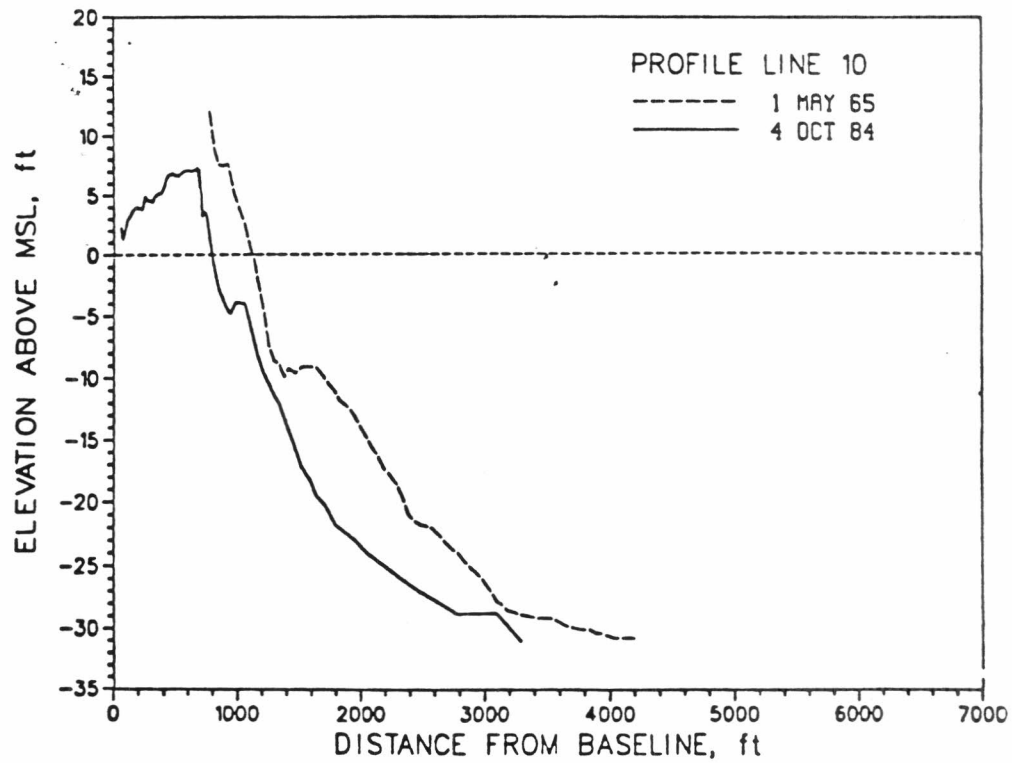


Figure A8.

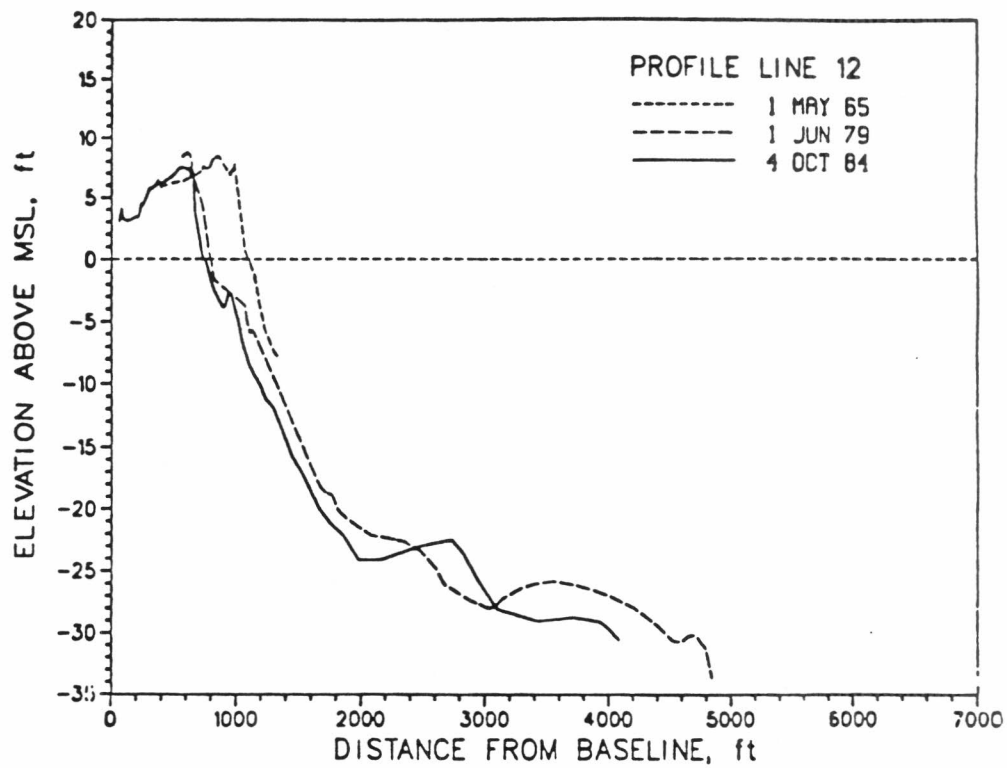


Figure A9.

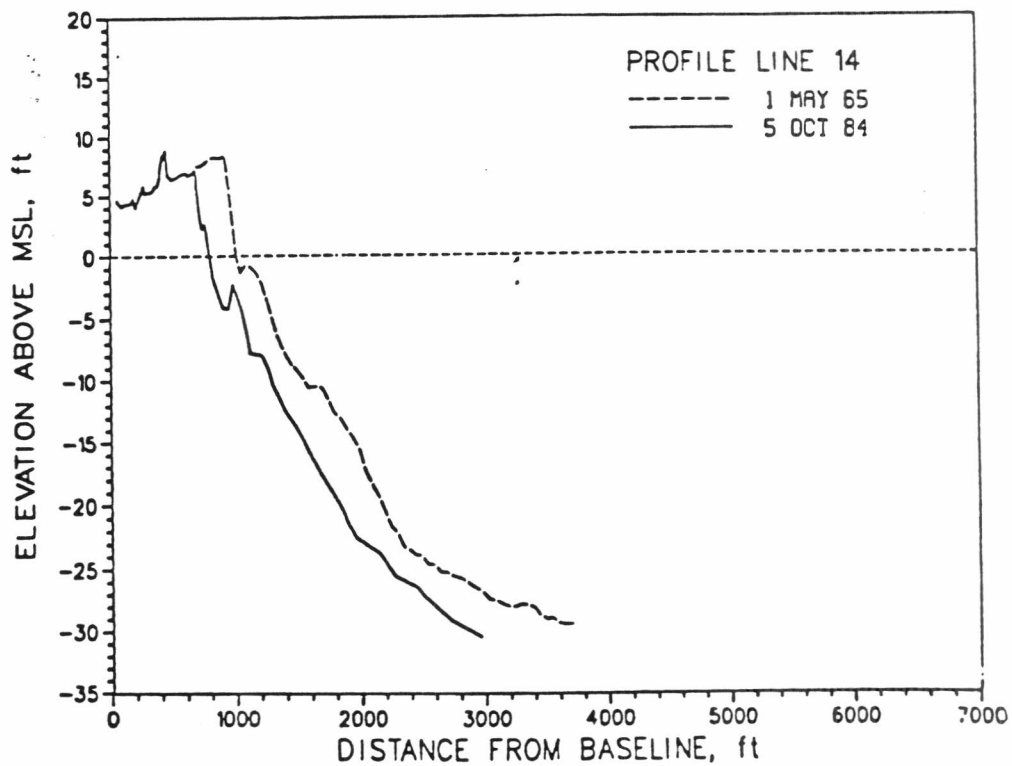


Figure A10.

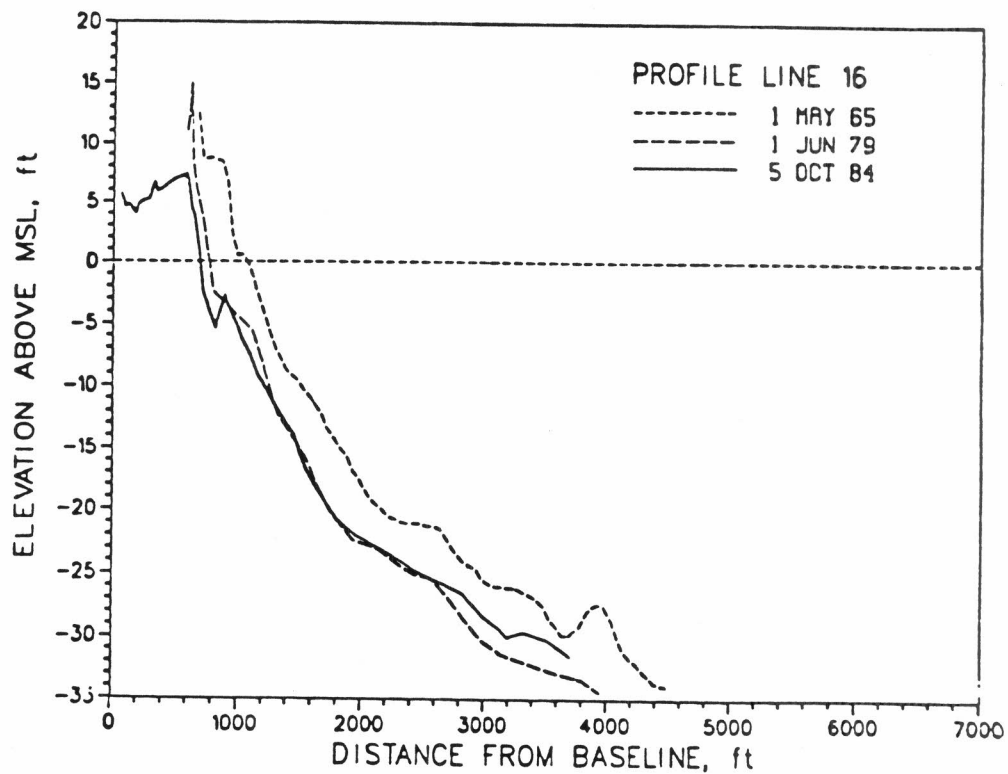


Figure A11.

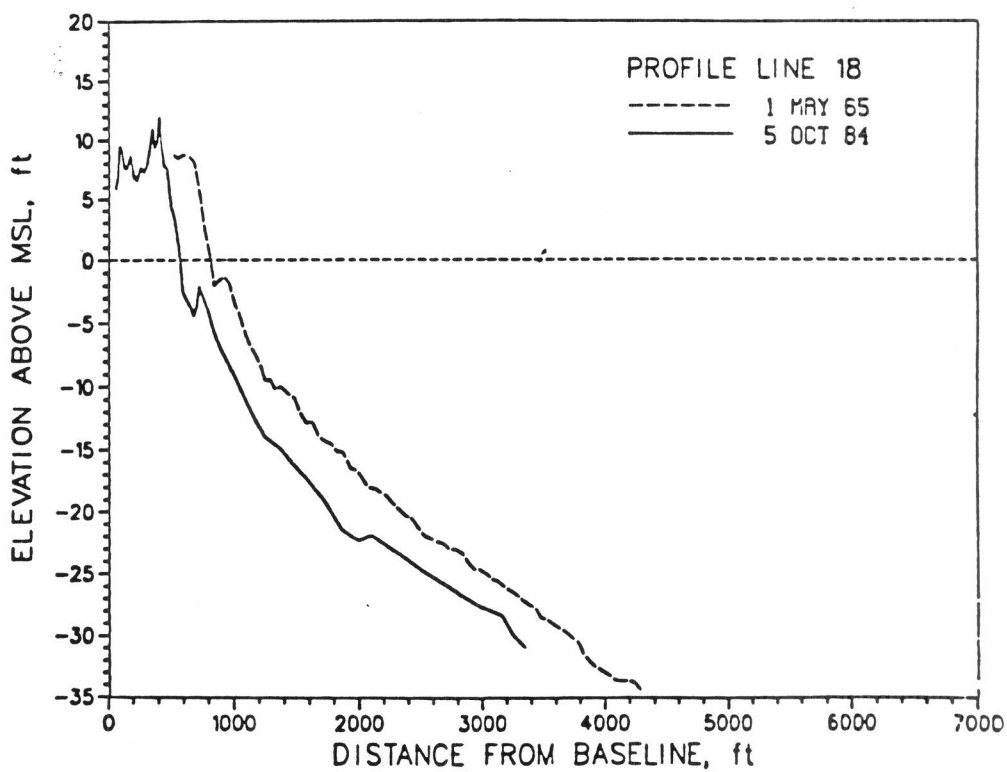


Figure A12.

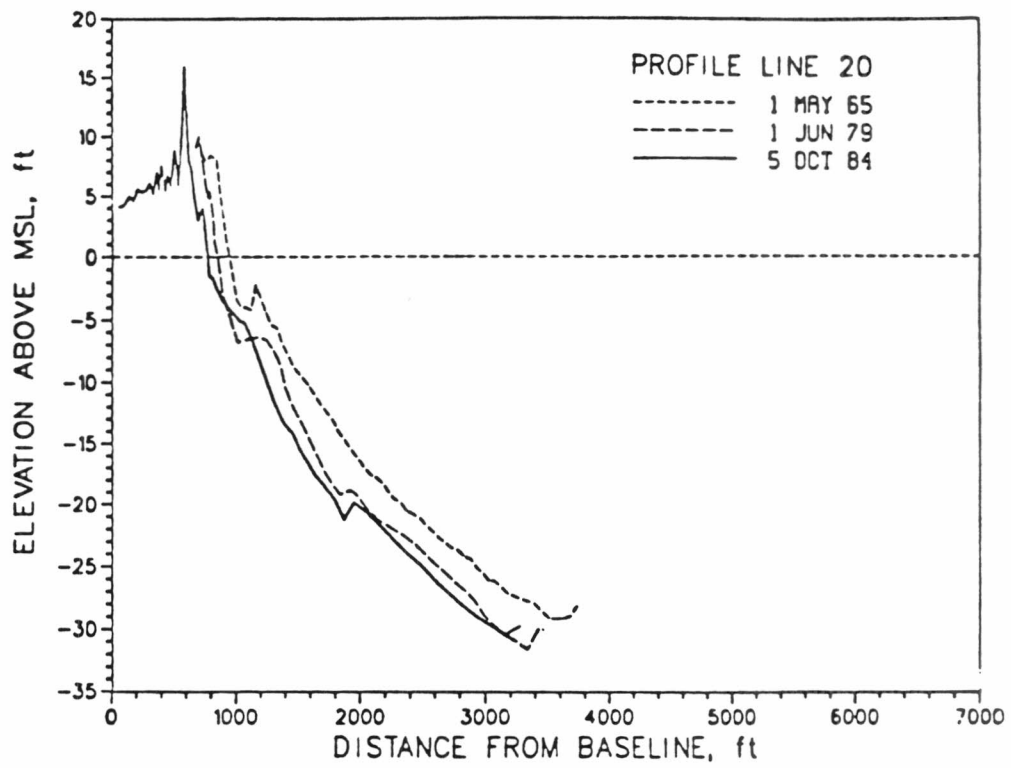


Figure A13.

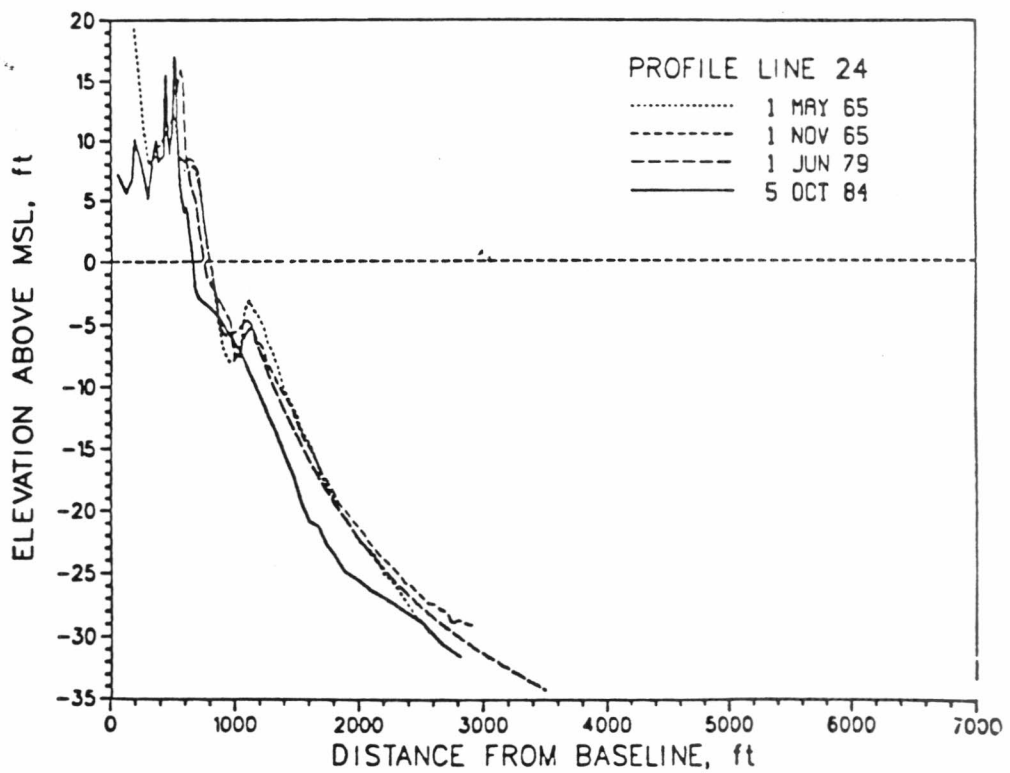


Figure A14.

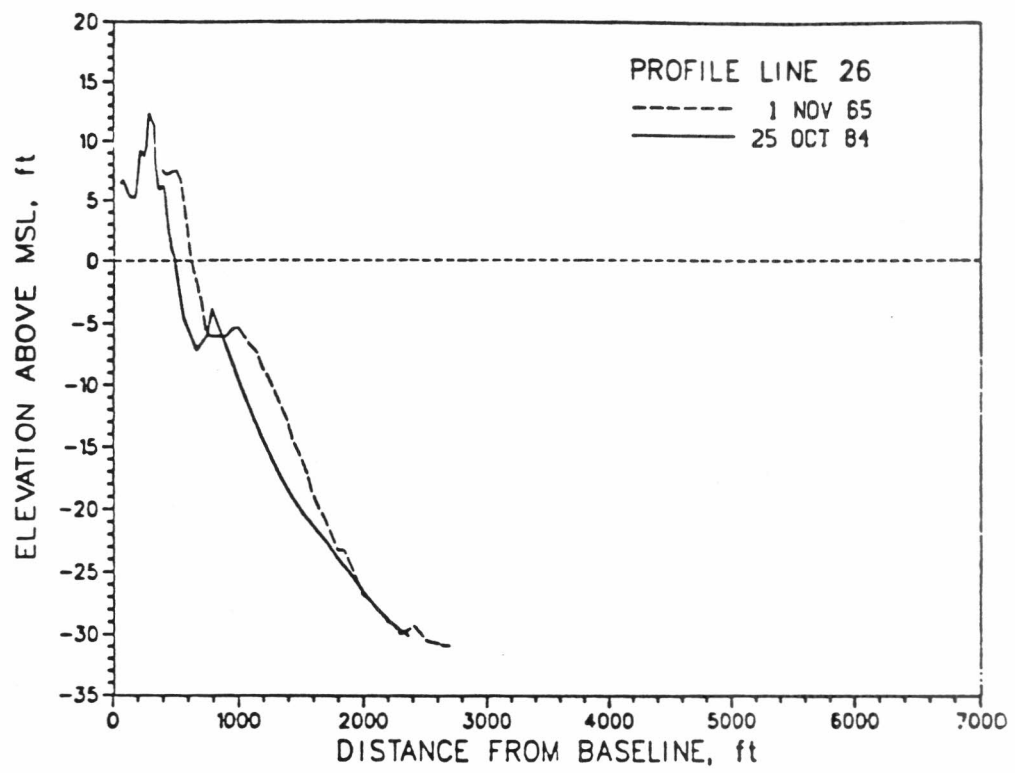


Figure A15.

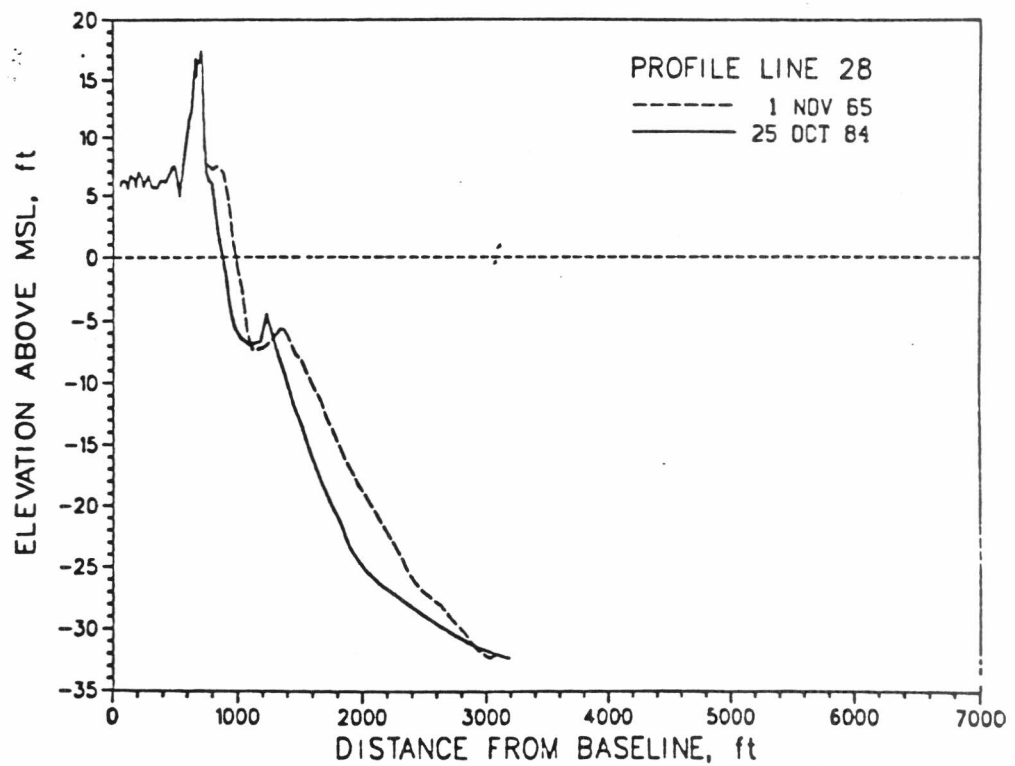


Figure A16.

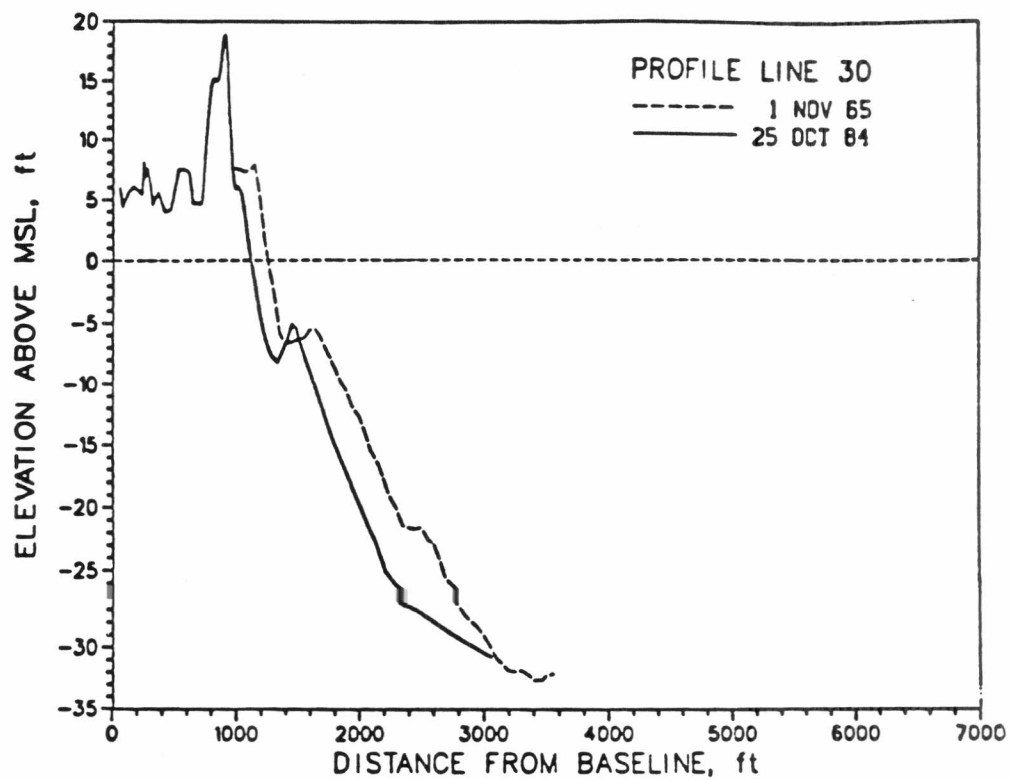


Figure A17.

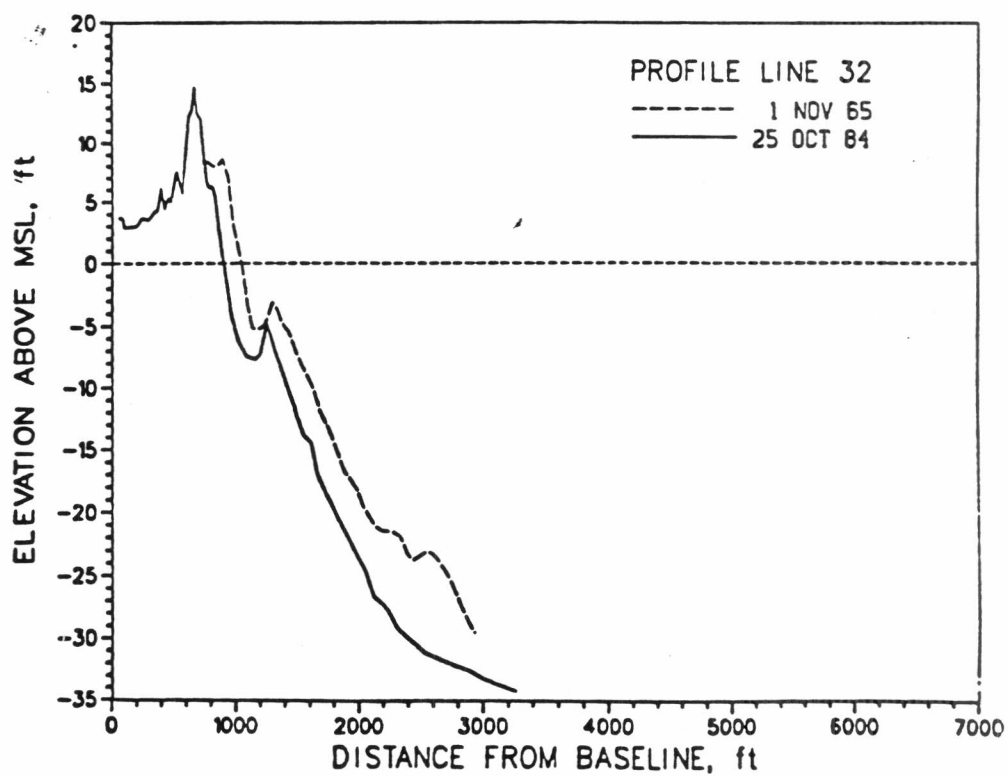


Figure A18.

