FLORIDA
SEA GRANT PROGRAM

MATANZAS INLET
GLOSSARY OF INLETS REPORT #5

by A. J. Mehta and C. P. Jones

Report Number 21

May 1977

Marine research · Education · Advisory Services

A Sea Grant Program for Florida

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FOREWORD

The numerous inlets connecting Florida's inner waters to the Atlantic Ocean and the Gulf of Mexico are important from consideration of recreational and commercial vessel traffic and also because they provide small boats access to safe refuge during unexpected severe weather and waves. In addition, inlets act as flushing agents, providing renewal of bay waters by exchange with outer continental shelf waters. Unfortunately, inlets also contribute significantly to the serious beach erosion problem prevalent along most of Florida's shoreline. The complexities of the hydraulic and sediment transport mechanics in the vicinity of inlets present a formidable challenge to engineers and scientists. These factors, along with the interesting historical role that inlets have played in the early development of Florida have resulted in considerable documentation pertaining to the major inlets of the State.

This report on Matanzas Inlet is one in a "Glossary of Inlets" series to be prepared under the State University System Sea Grant project, "Nearshore Circulation, Littoral Drift and the Sand Budget of Florida." The purpose of this series is to provide for each inlet a summary of the more significant available information and to list known documentation. It is hoped that this series will yield an improved understanding of the overall effect of each inlet on the economics, recreation, water quality and shoreline stability of the surrounding area. The proper future management, use and control of Florida's inlets will require an appreciation of the evolution and past response of the inlets as well as considerable future study.

ACKNOWLEDGEMENT

We would like to sincerely thank Andy Hobbs, Eldon Russell, Keith Hamilton and Barbara Lancaster of the Corps of Engineers, Jacksonville District, for their assistance in obtaining surveys, dredging records, current measurements and other pertinent information necessary for the completion of this report. Comments by Dr. T.Y. Chiu of the Coastal and Oceanographic Engineering Laboratory on the hydraulics and flushing characteristics of Matanzas Inlet and the surrounding waterways have been appreciated. Our thanks are extended to J.A. Crookshank and Tom Alberdi, Jr. of the Florida Department of Transportation for the valuable information they have provided about the Matanzas Inlet bridges. We are indebted to Larry Nash, Park Ranger at the Fort Matanzas National Monument and to Luis Arana, National Park Historian at St. Augustine for their assistance in obtaining historical information and National Park Service reference materials.

I. INTRODUCTION

Matanzas Inlet, shown in Fig. 1.3 and Fig. 1.4, is a natural inlet connecting the Atlantic Ocean to the Matanzas River on the east coast of Florida in southern St. Johns County. The inlet is located approximately 13 miles south of St. Augustine and 40 miles north of Daytona Beach. Its coordinates are as follows:

Latitude	Longitude
29° 42' 54" N	81° 13' 42" W

If referenced to the Florida State plane coordinate system, east zone, transverse mercator projection, its coordinates are:

North	East
1,953,000'	427,500'

Matanzas River extends northward to St. Augustine Inlet and southward from Matanzas Inlet for approximately 8 miles, being connected ultimately with Ponce de Leon Inlet, 52 miles south, through the Intracoastal Waterway, Smith Creek, and the Halifax River (see Fig. 1.2).

In this report, that portion of the Matanzas River north of the inlet will be referred to as the north arm and the portion to the south of the inlet as the south arm of the Matanzas River.

Matanzas Inlet is bordered on the north by Anastasia Island, on the south by Summer Haven and on the west by Rattlesnake Island, the site of the Fort Matanzas National Monument.

The inlet is the last unimproved inlet on the east coast of Florida. It is characterized by a significant offshore bar that is very transitory in nature, and the presence of appreciable inner shoals, and as such is not suitable for navigation purposes except by small craft. Records indicate that the Spanish ships of the sixteenth and seventeenth centuries were able to navigate the inlet at high tide (Bruun, 1966).

Due to the fact that relatively little use is made of the inlet by private or commercial interests, very little work has been done studying the inlet and its morphological changes, hydraulics and sedimentary processes. There has been, however, some work done in connection with the construction and maintenance of the Intracoastal Waterway in the vicinity. The U.S. Army Corps of Engineers is responsible for maintaining the Intracoastal Waterway and derives its authority to do so from the 1945 River and Harbor Act. This federally maintained waterway has project dimensions everywhere between the cities of Jacksonville and Fort Pierce of 125 ft. width and 12 ft. mean depth. The economic importance of this waterway has increased in recent years as the yearly amount of cargo transported along it has increased. During the year 1973, 1,182,000 tons of cargo were transported via this route (U.S. Army Corps of Engineers, 1975a). With the relatively rapid expected development

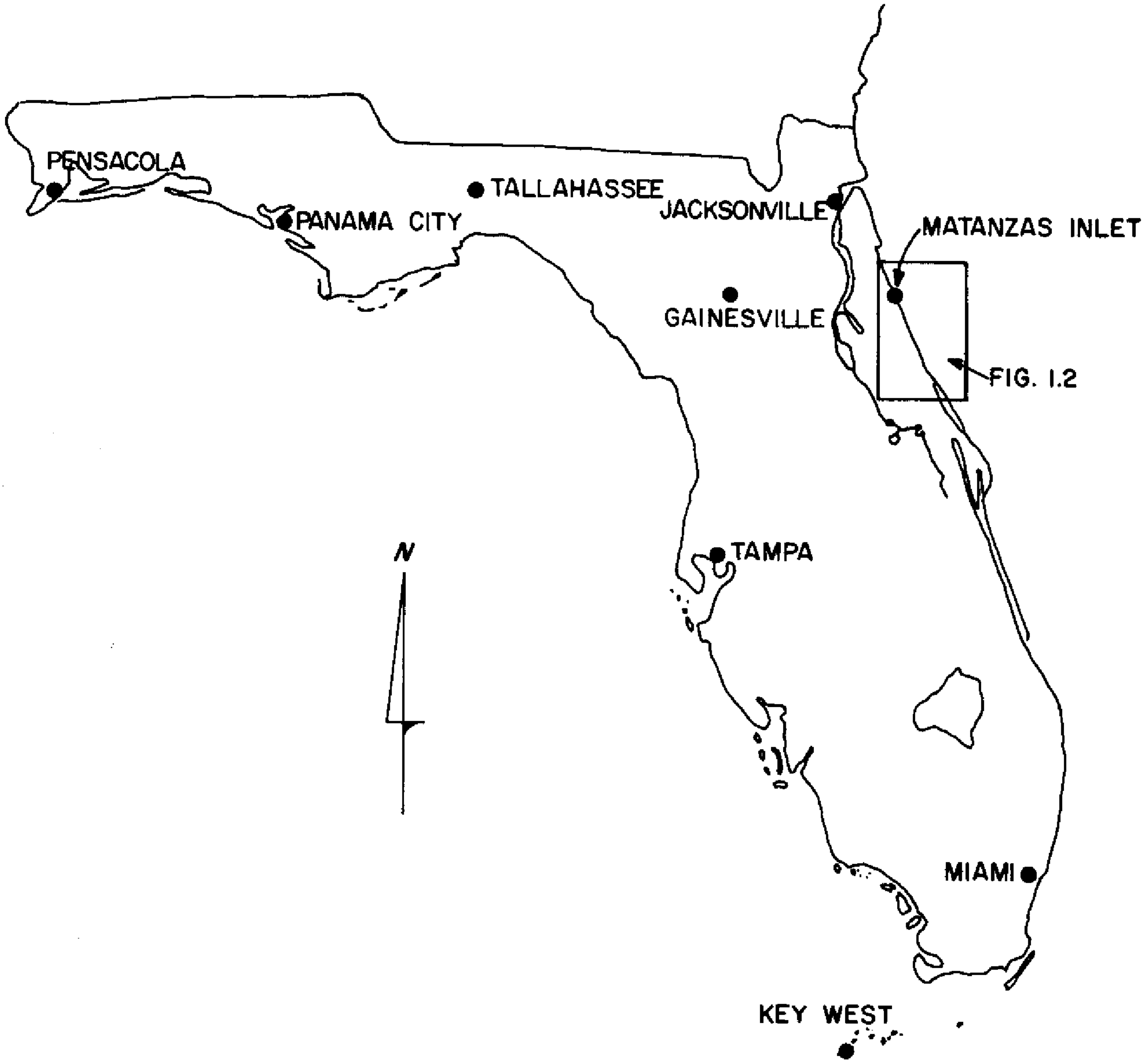


Fig. 1.1 Location Map.

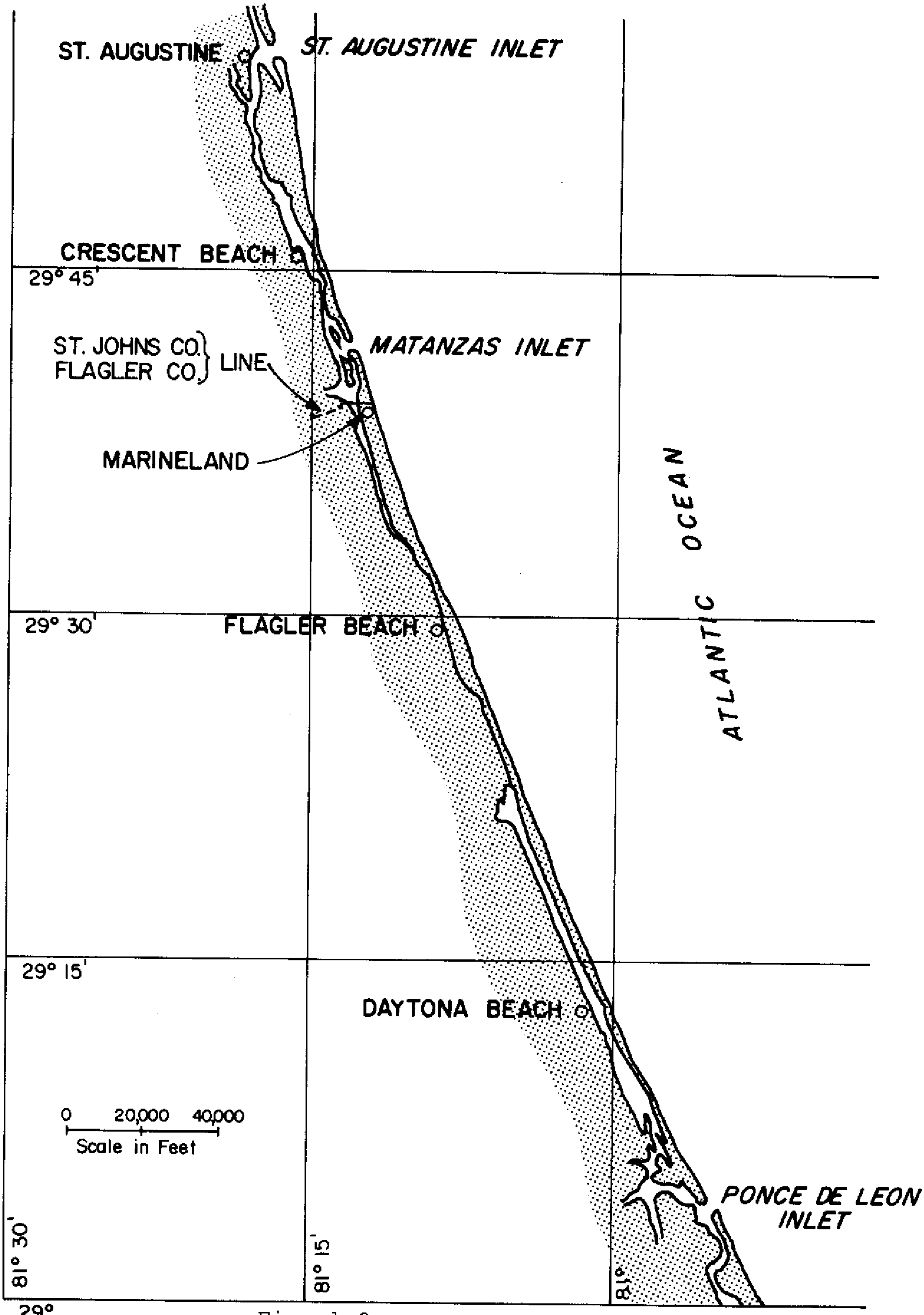

ST. AUGUSTINE
ST. AUGUSTINE INLET
CRESCENT BEACH
29° 45'
ST. JOHNS CO.
FLAGLER CO.
LINE
MATANZAS INLET
MARINELAND
ATLANTIC OCEAN
29° 30'
FLAGLER BEACH
29° 15'
DAYTONA BEACH
0
20,000
40,000
Scale in Feet
PONCE DE LEON INLET
81° 30'
81° 15'
81°
29°

Fig. 1.2

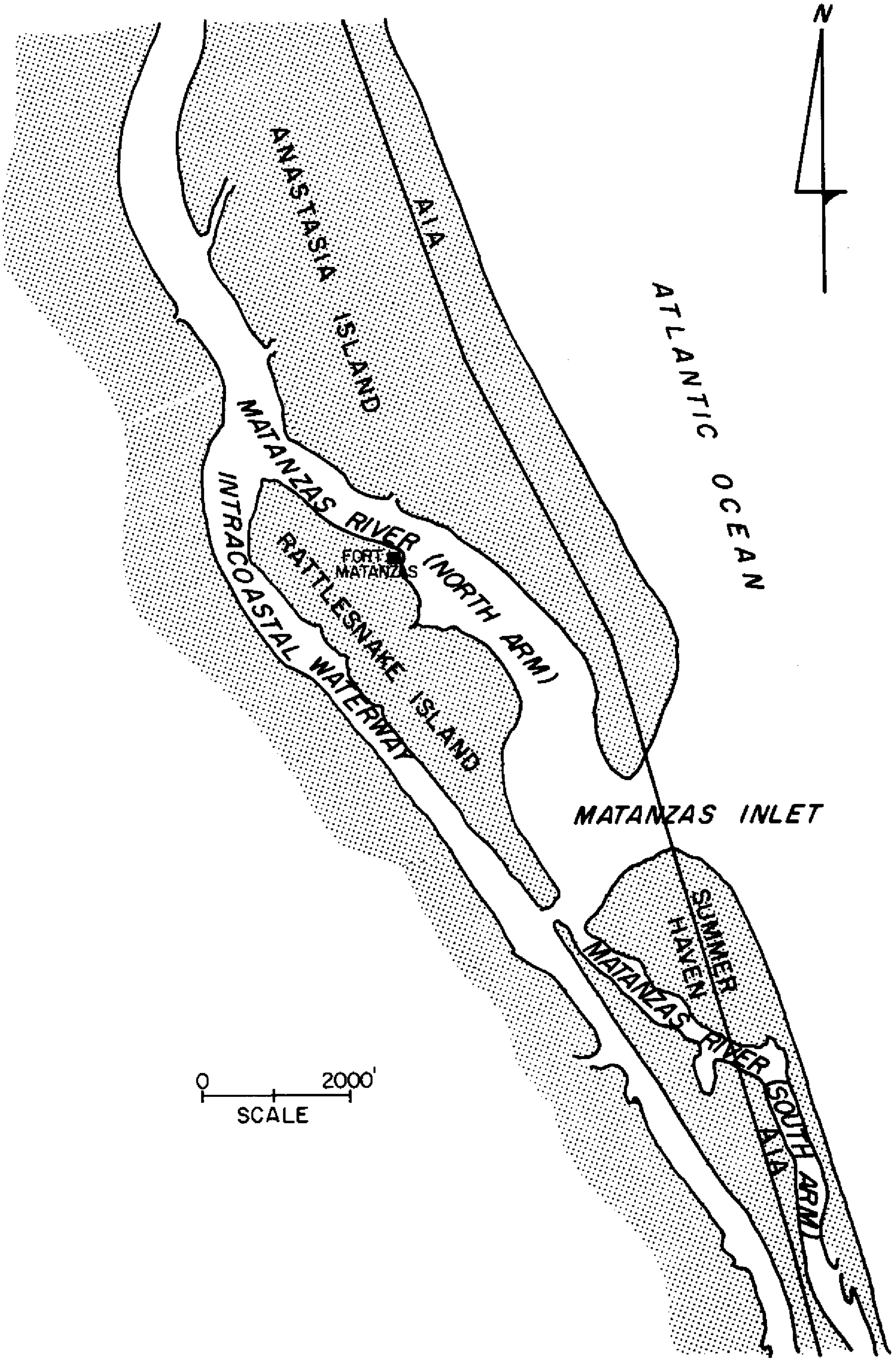

N
ANASTASIA ISLAND
A1A
ATLANTIC OCEAN
MATANZAS RIVER (NORTH ARM)
FORT MATANZAS
RATTLESNAKE ISLAND
INTRACOASTAL WATERWAY
MATANZAS INLET
SUMMER HAVEN
MATANZAS RIVER (SOUTH ARM)
A1A
0
2000'
SCALE

Fig. 1.3

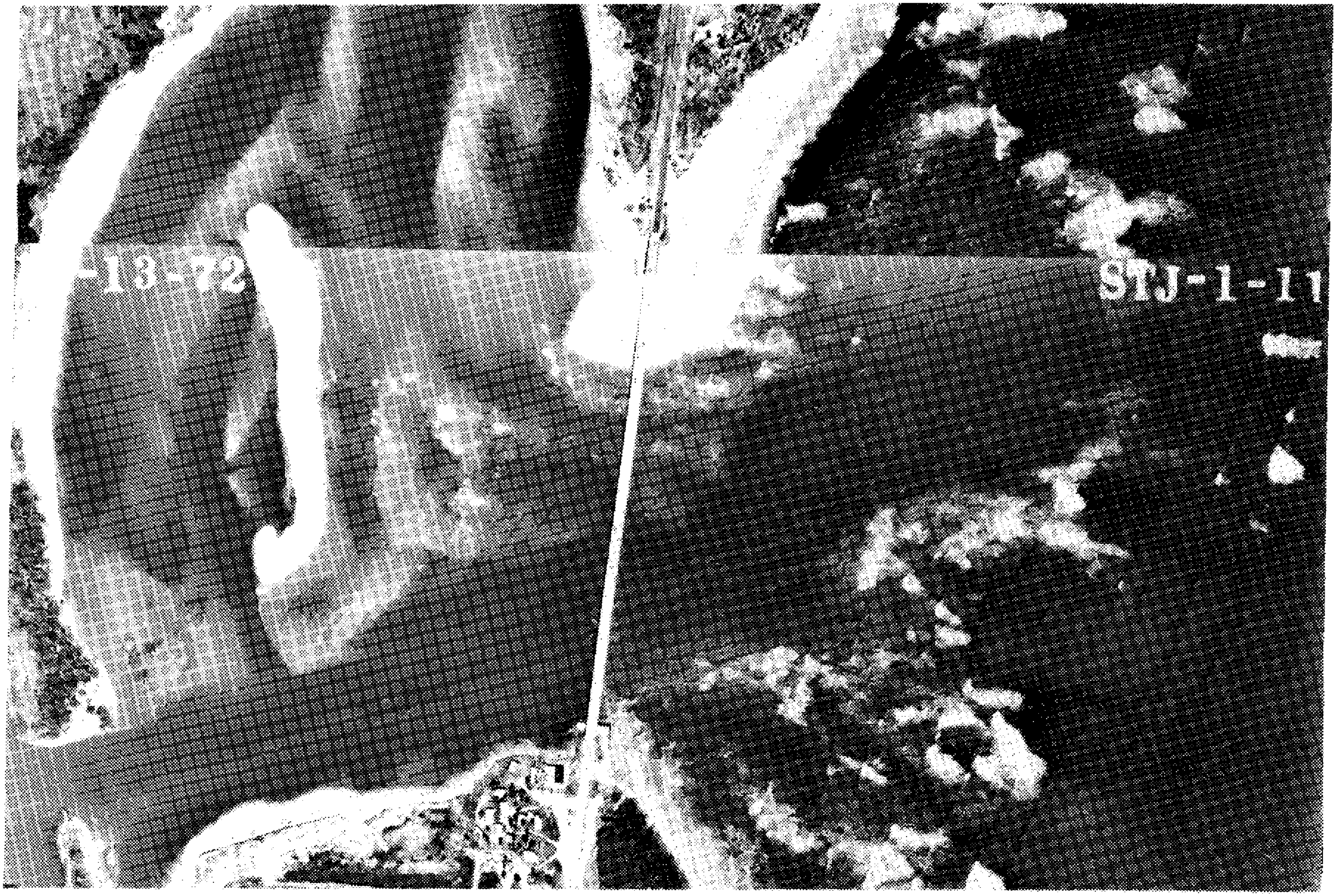


Fig. 1.4 Matanzas Inlet in 1972.

of the coastal region between St. Augustine and Daytona Beach, Matanzas Inlet will correspondingly assume greater importance and its improvement for the purposes of navigation is likely to occur.

Development in the vicinity of the inlet has thus far been limited to the small community of Summer Haven immediately south of the inlet, while development in the Crescent Beach area has increased considerably in recent years. It is expected that this development trend will move southward toward Matanzas Inlet in the not too distant future. For more information on development in the area the reader is referred to two National Park Service reports: "Environmental Threats in St. Johns County to Fort Matanzas," (1972a) and "Anastasia Island Development and Effects on Fort Matanzas National Monument," (1972b).

Recreational facilities around the inlet include the waters and beaches of the area, the site of fishing, surfing and swimming; the Fort Matanzas National Monument, Anastasia State Park 11 miles to the north and Marineland, located 2.5 miles to the south. Fort Matanzas, built by the Spanish in 1742, was declared a National Monument in 1924 and the original 1 acre site has since been enlarged to 298 acres on both Rattlesnake Island and on adjacent Anastasia Island. The monument is under the jurisdiction of the National Park Service, U.S. Department of the Interior. A superintendent for Fort Matanzas and the Castillo de San Marcos in St. Augustine, as well as a national park historian, may be reached at 1 Castillo Drive, St. Augustine, Florida 32084. The facilities at Anastasia State Park include camping areas and access to the nearby beaches. This park is administered by the Florida Department of Natural Resources, Division of Recreation and Parks, Tallahassee, Florida. The Marineland complex is the site of marine aquariums and shows; nearby motel and marina facilities are available. The University of Florida's C.V. Whitney Laboratory is also located at Marineland and is the site of ongoing coastal and marine research.

II. GEOLOGIC SETTING

Underlying the east coast of Florida from Anastasia Island southward to the Palm Beach/Broward County line is the rock formation known as the Anastasia. This formation is composed of different segments formed during several events in the Pleistocene, not just one period as was previously believed (Brooks, 1972). Outcrops of this formation appear along the continental shelf and are often found in locations where canals have been dug or inlets cut along the east coast of Florida. There are several exposed, consolidated outcrops on the beaches in the Matanzas Inlet area, as well as exposed segments of the Anastasia along various parts of the Intracoastal Waterway. One outcrop occurs on the southeast point of Matanzas Inlet and a larger outcrop, striking in a northwesterly direction from the beach, occurs near Marineland.

The lithology of the Anastasia formation varies from coarse rock composed of whole coquina shells and minor amounts of quartz sand to a sandstone composed of carbonate and quartz sand particles. The cementing agent can be calcium carbonate or iron oxide (Cooke, 1945).

The surficial geologic structure in the Matanzas Inlet vicinity consists of perched barrier islands, which are Pleistocene features, overlain by mixed Holocene sands; a lagoon and tidal marsh area west of the barrier island, and low elevation, low relief coastal terraces further to the west. Such a shoreline has been termed a young shoreline of emergence (Johnson, 1919), although this description may not be correct. According to Brooks (personal communication), the development and landward migration of these barrier islands is likely to occur where there is: a sufficient supply of relic sediments offshore, adequate wave energy to transport these sediments, and a period of rising sea level.

Core borings in the area indicate that the surficial sediments are composed primarily of a fine quartz sand with varying amounts of silt, clay and shell intermixed (U.S. Army Corps of Engineers, 1965). The reader is referred to section 8.3 for a detailed discussion of the sedimentary characteristics of the area.

In addition, offshore sedimentary characteristics were investigated between August 1966 and February 1967 by the U.S. Army Corps of Engineers. They used seismic reflection profiling and sediment cores to determine the availability of inner continental shelf sediments suitable for beach nourishment purposes. Results indicate that such material may be found offshore of Matanzas Inlet and Marineland. Detailed findings are available in the report by Meisburger and Field (1975).

III. VEGETATION

The area surrounding Matanzas Inlet can be divided into four different localized environments, each supporting its own specific types of vegetation. Regardless of the differences though, each species must be able to adapt to a dry environment that is exposed to high temperatures, saline sands, high winds and salt spray. The four divisions are indicated on Fig. 3.1 which was adapted from a National Park Service diagram. The taxonomic descriptions are taken from Burnson (1972) and Davis (1975).

The first of the four localized environments is that consisting of the older, more stabilized regions of the area. This environment supports the growth of live oak, palmetto and some southern red cedar. These older areas are found on the inner portions of Anastasia Island, in Summer Haven east of AlA and to some extent on the inner reaches of Rattlesnake Island.

Surrounding the first environmental division will most likely be the second, consisting of palmetto scrub and some grasses. These plants usually serve as a transition region between the older, more stabilized areas and either the salt marshes or the beach areas.

The third environmental division, the salt marsh, comprises a large portion of the area, occurring north and west of the National Park Service property on Anastasia Island and throughout most of the area west of the Intracoastal Waterway, excepting locations of dredge spoil along that waterway. The most abundant of the marsh grasses is the Spartina alterniflora. This species stands usually from a few inches to a few feet in height, but has been known to reach seven feet in other areas (Ursin, 1972). There are also some stands of the black mangrove Avicennia nitida in the area, most occurring in the foremarsh along the Intracoastal Waterway. Some isolated individuals grow to the west of the Intracoastal Waterway along the marshy sloughs and channels.

The last division is that of the sand beach and dune areas. The most noticeable plants in the inner, sandy reaches are the yucca, optunia and other small shrubs. On the dunes there are three predominant species: the sea oat Uniola paniculata, the sea purslane Sesuvium portulacastrum and a small shrub called the marsh elder, Iva imbricata. All of these plants are necessary for the growth and stabilization of the dune areas. The roots of the sea oat often extend down several feet, anchoring the dunes in place, and for this reason the sea oat is protected by Florida law.

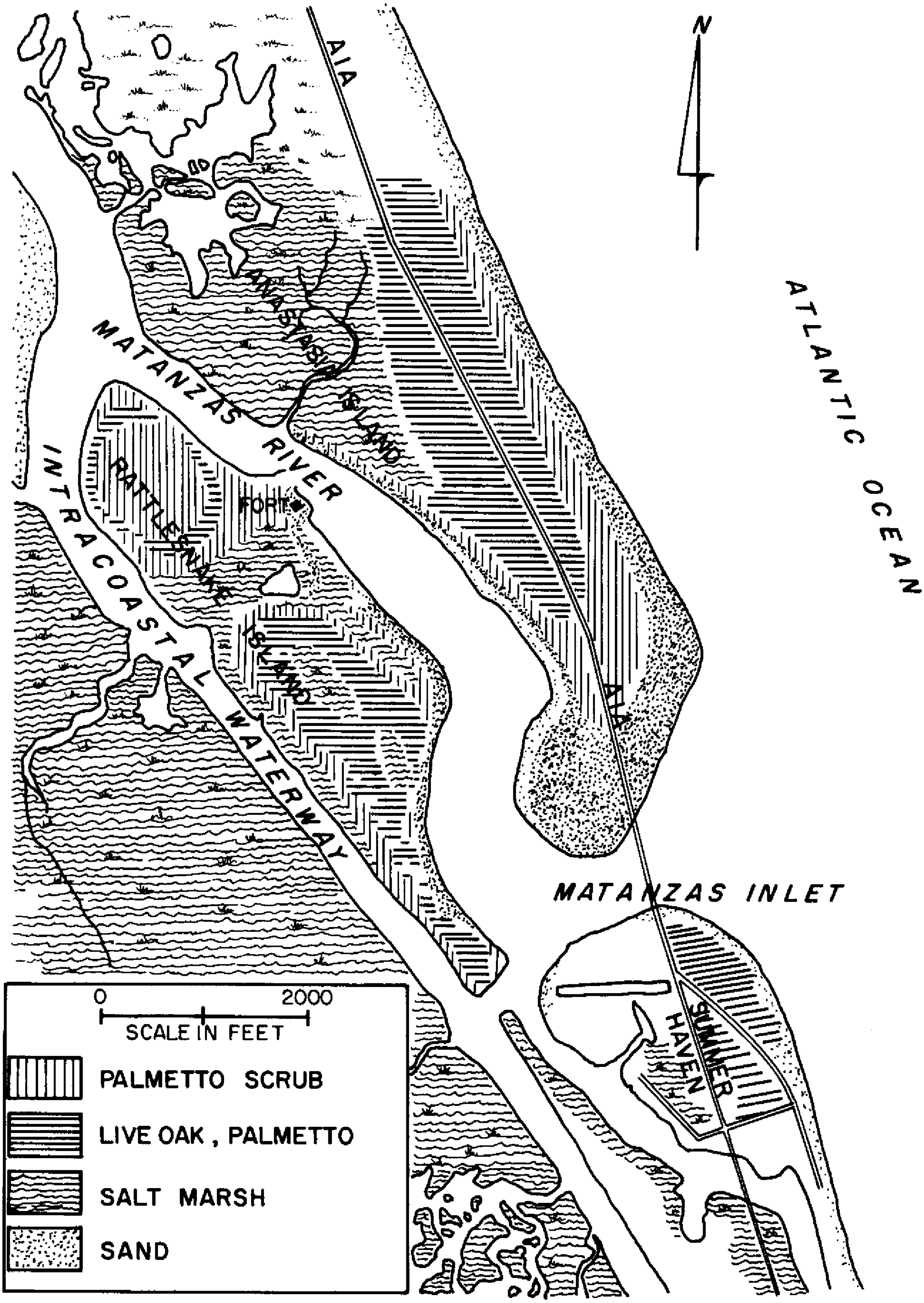


Fig. 3.1 Vegetative Base Map Adapted from NPS (1971).

IV. CLIMATE AND STORM HISTORY

The climate characterizing the Matanzas Inlet area can best be described as humid subtropical. Precipitation occurs chiefly during the months of June through October with from one-half to two-thirds of the total yearly precipitation falling during this period. The majority of this rainfall is due to convection, that is to say, the condensation resulting from the adiabatic expansion of rising air currents over the land areas, which heat up faster than the adjacent waters during the daytime. During the winter months the remaining rainfall is usually due to the frontal lifting of warm, moist air over a wedge of cool, dry air (Burnson, 1972).

The average yearly precipitation at the St. Augustine weather station (Sta. No. 08-7812-2) for the period 1940-1970 was 47.39 in. The mean daily temperature at that same location is given as 69.6°F, but the National Park Service records show the St. Augustine reading to be typically higher than the temperature at Fort Matanzas by the following amounts: 1°F higher during the winter months and 2.5°F higher during the summer months (National Park Service, 1971). The prevailing winds are from the NE during the winter months and E to SE during the spring, summer and fall. Table 4.1 gives wind velocity and direction frequencies for the area offshore at Matanzas Inlet. These data are the results of 86,716 observations during the years 1856 through 1968 and may be found in the "Summary of Synoptic Meteorological Observations," Volume 4 (U.S. Naval Weather Service Command, 1970). These SSMO data were collected in the area offshore and centered at 29° 32' N, 78° W.

Storms that strike the St. Johns County coastline can be subdivided into two categories: hurricanes (and tropical storms) and northeast storms. The N.E. storms are, with few exceptions, the more damaging of the two. This is generally due to the fact that the hurricane generated winds and waves are usually of a short duration and occur in a localized area, whereas a N.E. storm may cause high winds and waves over a larger area for a longer duration. The typical N.E. storm affecting St. Johns County is caused by a stationary high pressure area off of the coast of the S.E. United States with a low pressure area held directly south of the stationary high. The N.E. storm, because of its duration, can have a much more detrimental effect on an area's beaches and coastal structures. A good storm history for the area can be obtained from appendix D of the "Northern St. Johns County Coastal management Plan" (Florida Coastal Engineers, 1974) and from appendix C of the 1965 Corps of Engineers report, "Beach Erosion Control Study on St. Johns County, Florida."

Between the years 1830 and 1968 there were 20 storms of hurricane intensity that passed within 50 miles of Matanzas Inlet - an average of 1 storm of hurricane intensity of every 7 years. Between those same years 46 storms of hurricane intensity passed within 150 miles of St. Augustine - an average of 1 every 3 years. Fig. 4.1 shows the paths of some of these storms. A description of some of the more damaging storms follows:

Oct. 13 - 21, 1944	This hurricane caused extreme high tides along the N.E. coast of Florida. Twenty foot waves were reported offshore from Fernandina Beach to St. Augustine.

Table 4.1

OFFSHORE WIND VELOCITY AND DIRECTION FREQUENCIES

Wind Direction	Speed (knots) 0-6	7-16	17-27	28-40	>41	Percent Frequency	Mean Speed
N	2.0	6.1	3.7	0.6	0.1	12.6	14.5
NE	2.4	8.8	4.8	0.7	*	16.8	14.4
E	2.6	8.8	2.6	0.3	*	14.3	12.3
SE	1.7	6.2	1.6	0.2	*	9.7	12.2
S	1.8	7.1	2.7	0.3	*	11.8	13.2
SW	1.5	6.7	2.7	0.3	*	11.2	13.7
W	1.4	5.7	3.2	0.8	*	11.1	15.2
NW	1.1	5.0	3.6	0.8	*	10.6	16.0
Calm	1.9					1.9	
Percent Frequency	16.4	54.4	24.9	4.0	0.2	100.0	

* Indicates percent frequency less than 0.05. From the S.S.M.O., Vol. 4, 1970.

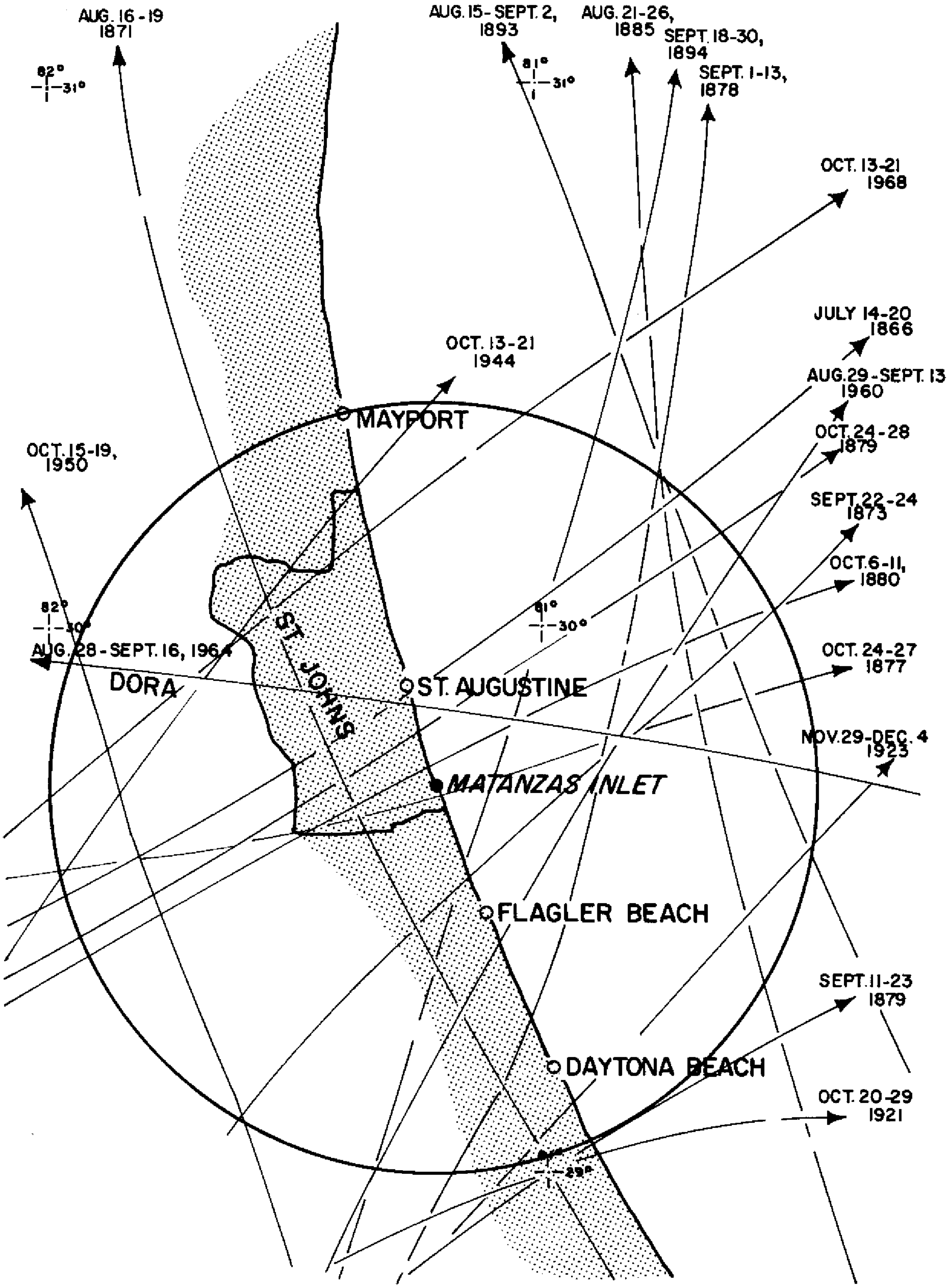


Fig. 4.1 Storm Tracks Within 50 Miles of Matanzas Inlet Adapted from Fl. Coastal Engineers (1974).

	Beach erosion at Summer Haven ranged from 50 ft. to 150 ft. horizontally and 3 ft. to 4 ft. vertically.
Sept. 24 - Oct. 7, 1947	This N.E. storm was characterized by an extremely long duration and was accompanied by high winds, high tides and large waves. Beach erosion was widespread in N.E. Florida.
Oct. 15 - 19, 1950	This hurricane traveled northward along virtually the entire east coast of Florida and passed into central Georgia. Tides were 3 ft. to 4 ft. above normal and some flooding occurred in St. Johns County.
Oct. 14 - 17, 1956	This N.E. storm sustained winds out of the N.E. at 20 to 30 m.p.h. for four days. Tides were 4 ft. above normal and highway A1A was damaged in parts of St. Johns County. Beach erosion was severe and in some places the beach profile dropped 3 ft. in the vertical direction.
Oct. 30 - Nov. 7, 1956	Hurricane Greta caused high tides along the St. Johns County coastline that carried sand and water across highway A1A between Summer Haven and Marineland. Some stretches of A1A in this area were protected along the east side with sand bags to prevent undermining. This storm damaged seawalls in the Jacksonville area and caused some flooding in southern Florida (St. Augustine News Record, Nov. 5, 1956).
March 8 - 9, 1962	The winds from this N.E. storm, known as the Great Middle Atlantic Coastal Storm, caused extensive damage along the entire east coast of the United States. This storm was exceptionally destructive due to the long fetch (1,200 miles) and the occurrence during a perigee spring tide. Damage estimates for the U.S. exceeded $200 million and over 350 people were killed by the flooding (Ludlum, 1963), (Stewart, 1962).
Nov. 26 - Dec. 3, 1962	This N.E. storm remained 300 to 500 miles east of St. Johns County for several days. Waves with 20 ft. heights and 11 second periods were generated by the storm and battered the N.E. coast of Florida. Water levels rose 7.5 ft. and beach erosion was

	extensive, as was damage to the coastal highway, seawalls and private homes. Damage in St. Johns County was estimated at $555,000. The remnant of the former course of the old, natural St. Augustine Inlet, known as Salt Run, was opened to the ocean at its southerly end by this storm. Since that time this opening has occluded and been reinforced with sand dikes(Corps of Engineers, 1971).
Sept. 9 - 11, 1964	Hurricane Dora was probably the most severe tropical storm to enter St. Johns County in modern times. Sustained winds of 125 m.p.h. were recorded at St. Augustine and at the same location the lowest recorded barometric pressure was 966 m.b. (28.52 in Hg). Tides were estimated at 12 ft. above MSL along Anastasia Island and waves of 20 ft. to 30 ft. in height were also reported along the island. Damage due to both wind and wave action was extensive; roads and structures were undermined in many places along the coast. The high water level and waves breached the north end of the dike along Rattlesnake Island and this breakthrough has since been the cause of significant changes in the inlet morphology and hydraulics (this dike was breached by storms in 1963, but was closed again before Hurricane Dora struck). Damages to structures were estimated at $1.8 million in St. Johns County. Beach erosion at St. Augustine Beach was heavy, with the shoreline receding approximately 100 ft. At Crescent Beach severe dune scarps up to 15 ft. had occurred (COEL, 1964). Total storm damage estimates for Florida were put at $200 to $300 million.
Feb. 10 - 11, 1973	This N.E. storm caused extensive beach erosion in St. Johns County. Over 60 - 70 ft. of beach were washed away along parts of St. Augustine Beach and at Crescent Beach the beach profile dropped about 3 ft. (St. Augustine News Record, Feb. 14, 1973).

V. HISTORY OF THE INLET

The area surrounding Matanzas Inlet is important historically with respect to two time periods. The first is the Late Orange period (distinguished by the use of fiber tempered pottery), ending about 1000 B.C., and the second period extends from the Spanish occupation, beginning in 1565, through the present.

Only in the past few years have anthropologists begun to recognize the importance of those Indians living at the Summer Haven site in the development of Indian culture in Florida. The original site is south of Matanzas Inlet and west of highway A1A. By 1959 only 750 square feet, less than 1 percent of the original site, lay undisturbed (Bullen, 1961). This particular site differs from most Late Orange sites in the St. Johns River valley since it lies east of the Intracoastal Waterway. Digs at this site indicate that tools and pottery characteristic of the Late Orange are present and also that those Indians present engaged in fishing and made use of water transportation, most likely using dugout canoes in both cases.

During the mid-sixteenth century Spain became concerned about increasing French encroachment into Spanish America, for both political and religious reasons. As a result, in 1565, Phillip II dispatched Pedro Menendez de Aviles to the Americas to halt the French. As the French forces, led by Jean Ribault, sought to gain the advantage over the Spanish forces, a hurricane struck, wrecked and scattered the French ships. The French forces, reduced in number and scattered, surrendered to the Spanish at the inlet. On September 29, 111 Frenchmen were taken across the inlet to Anastasia Island and put to death. On October 12, another 134 were similarly killed. With these acts the inlet received its name - Matanzas, which translated means "Slaughters."

Matanzas Inlet soon thereafter became important to the Spanish in the defense of St. Augustine, a growing settlement. It provided the entrance to a navigable waterway to St. Augustine, it provided a position from which to detect approaching enemies and it provided an additional route for supply and communication in the event that St. Augustine Inlet was blockaded. The first of several wooden watch towers, built to accomodate 6 soldiers, was completed on the south end of Anastasia Island in 1569. The British seige on St. Augustine in 1740 convinced the Spanish Governor that more permanent defense measures than wooden towers were needed. A stone fort constructed of coquina rock quarried on Anastasia Island was completed in 1742.

The history of the inlet from this point in time through the present is summarized in the following chronology of events:

1834/35 - The area surrounding the inlet was surveyed by the Clements brothers for the United States Land Office.

1857 - Field notes by Gabriel W. Perpall indicate that the present day Summer Haven area was, at high tide, separated from the adjacent land to the south by a small amount of water. This is probably the inlet referred to by the Spanish as Peñon Inlet, which probably occluded in the early 1800's.

1872 - The inlet and waters of the Matanzas River were surveyed by Harrison (see Fig. 6.2). According to Burnson (1972), Harrison states in his report that the inlet had widened from 220 meters to 520 meters between 1869 and 1872. It can be seen from the survey drawing that the shoal in the inlet is approximately 500 yards wide and that a channel immediately north of Summer Haven varies from 10 to 18 ft. in depth.

1883 - The Florida East Coast Canal Company received 1 million acres of state owned lands in exchange for the construction of an intracoastal canal which began in this same year.

1885 - Construction of the canal in the vicinity of Matanzas Inlet began. Second Lieutenant Scriven, who surveyed the fort property at this time, made mention of the canal construction and also said that the fort stood one-half mile distant from the inlet.

1912 - The Florida East Coast Canal was completed. The project depth was 5 ft. at low water and the project width varied from 40 to 50 ft. Indications are that the controlling depth was less than 3.5 ft. in many places. In subsequent years the canal deteriorated and the project dimensions were not maintained.

1916 - Protective measures were taken by the War Department to stabilize the Fort Matanzas property. A concrete retaining wall was built around the north, east and south sides of the fort.

1923 - The area offshore of Matanzas Inlet was surveyed by the U.S. Coast and Geodetic Survey. This survey details the waters between 12 and 30 ft. deep.

1924 - Fort Matanzas was declared a National Monument (NPS, 1975).

1925/26 - The first bridge to be built across Matanzas Inlet was completed. This bridge was built with private funds and connected the area north of the inlet to Ocean Shore Boulevard in Summer Haven. This road later became State Road 140 and later yet, highway A1A.

1927 - The Florida Inland Navigation District was created by the Florida legislature to maintain the inland waterways (FIND, 1967).

1928 - Eleven east coast counties, including St. Johns, voted a bond issue in order to purchase the canal and right of way for surrender to the federal government (FIND, 1935).

1929 - The controlling depth of the canal was increased to 8 ft.

1930 - In April and June the dredges Northwood and Ideal removed shoal material on the south and north sides of the inlet. The Northwood removed 31,644 cu. yds. over a distance of 2,277 ft. and the Ideal removed 27,000 cu. yds. over a distance of 1,387 ft. (Corps of Engineers, 1930).

1932 - On January 19th a project dimension by-pass channel 9,450 ft. long through the marsh west of the inlet was completed, removing 523,555 cu. yds. of material at a cost of $50,252.57. It was the construction of this channel, known as the Matanzas Relocation Cut, that changed the configuration of the land on which the fort lay and that to the south to what is known today as Rattlesnake Island. With the construction of this channel, the Intracoastal Waterway was rerouted to the west of this island, away from the river adjacent to the inlet (Corps, 1932).

1934/35 - A seawall and three short groins were constructed about Fort Matanzas. At the same time a series of eleven rock groins were constructed on the west side of Anastasia Island to stabilize that property, which had been reportedly eroding badly.

1935 - A 2,100 ft. steel sheet pile dike with bank revetment separating the Matanzas River west of Summer Haven from the Intracoastal Waterway at Rattlesnake Island was completed by the Corps of Engineers in May. The elevation of the top of the dike was 10 ft. above MLW. A total of 193,428 cu. yds. of fill were dredged and deposited along the dike at a cost of $24,554.86. In addition, 10,729 cu. yds. of riprap were placed along the dike (Corps, 1935).

1938 - A Corps of Engineers survey of the Matanzas River south of the inlet shows typical depths of 4 to 5 ft. below MLW. The channel at the inlet is shown as being 10 to 20 ft. deep and located immediately north of Summer Haven.

1939 - Corps of Engineers records show the controlling depth in the Matanzas Relocation Cut was 4.7 ft. (Corps, 1939).

1943 - Another Corps of Engineers survey indicates both depths and current measurements from the inlet north to the junction of the Intracoastal Waterway and Matanzas River, just north of Rattlesnake Island. The channel north through the Matanzas River is 15 to 20 ft. deep in places. Current measurements near the junction show maximum currents of 2.17 ft./sec. during flood and 2.50 ft./sec. during ebb.

1945 - The River and Harbor Act authorized the improvement of the Intracoastal Waterway to a 12 ft. depth and 125 ft. width between Jacksonville and Fort Pierce. An obstructive shoal in the Intracoastal Waterway opposite Pellicer Creek, approximately one mile south of Marineland, was removed (Corps, 1945). Over 4,470 cu. yds. of material were removed at a cost of $2,374.39.

1947 - Emergency dredging by the Colonel G.P. Howell removed critical shoals in the Matanzas Relocation Cut (Corps, 1947).

1951 - The improvement of the Intracoastal Waterway to a 12 ft. controlling depth was completed. (See Table 5.1 for the dredging record subsequent to this data.)

Table 5.1

INTRACOASTAL WATERWAY
DREDGING RECORD SINCE 1958

Date	Location (measured in statute miles from Fernandina Beach. See Fig. 5.1 for location).	Amount Dredged (cubic yards)
1958	75.3	149,911
1960	75.3	118,078
1960	76.5	16,313
1962	75.3	126,189
1962	76.5	13,224
1963	75.3, 76.3	117,869
1964	75.3	66,900
1966	75.3	89,992
1966	76.3	7,112
1967	75.3	20,420
1968	75.3	53,413
1973	75.3	112,447

From records on file, U.S. Army Corps of Engineers, Jacksonville District.

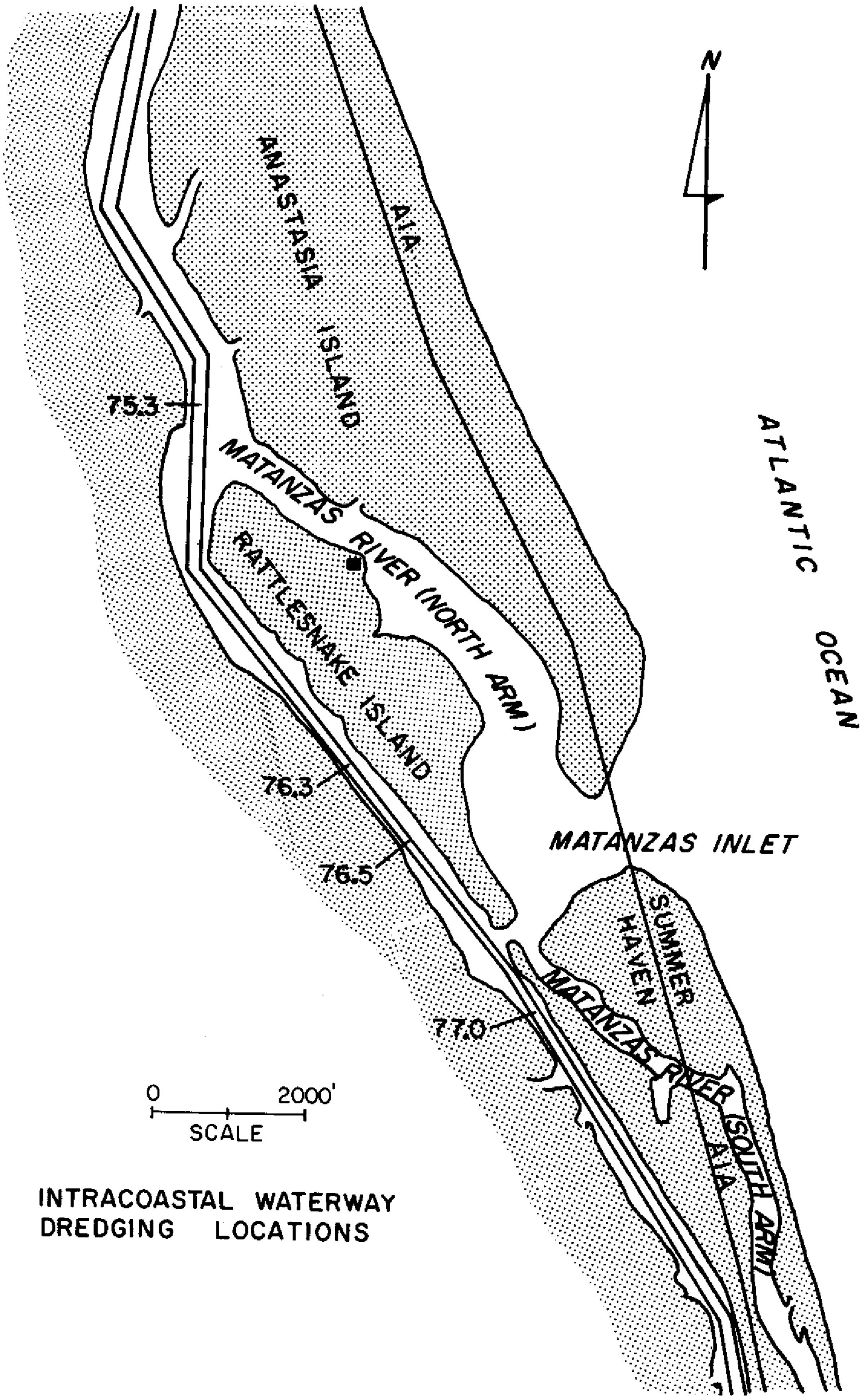

N
ANASTASIA ISLAND
A1A
ATLANTIC OCEAN
75.3
MATANZAS RIVER (NORTH ARM)
RATTLESNAKE ISLAND
76.3
76.5
MATANZAS INLET
SUMMER HAVEN
77.0
MATANZAS RIVER (SOUTH ARM)
A1A
0
2000'
SCALE
INTRACOASTAL WATERWAY
DREDGING LOCATIONS

Fig. 5.1

1956 - The bridge built across the inlet in 1925/26 was replaced with a new bridge (Project No. 7804-203) by the Florida Department of Transportation. The new bridge, a 1,704 ft. structure, cost $379,885.35.

1957/58 - A 415 ft. concrete sheet pile seawall was built in Summer Haven to protect highway A1A. This seawall was damaged extensively by both the November 1962 N.E. storm and by Hurricane Dora in 1964.

1960 - A bridge across the Matanzas River south of Summer Haven was completed, thus rerouting the path of highway A1A away from the location immediately adjacent to the beach.

1962 - Extensive damage by the N.E. storm during November 26 - December 3 necessitated $82,400 in repairs along highway A1A in Summer Haven. Repairs were made to 1,130 ft. of roadway pavement and embankment and 1,800 ft. of granite revetment were placed east of the highway.

1964 - Hurricane Dora struck the St. Johns County coastline on September 9th and caused widespread erosion, as well as the undermining of roads and structures. Repairs at Summer Haven included the addition of 430 ft. of rubble splash apron landward of the existing revetment, and the addition of 1,070 linear ft. of granite revetment and rubble splash apron south of the existing revetment. Road repairs were made along a 925 ft. stretch of highway A1A. These repair costs totaled $112,000. This hurricane was also responsible for the breakthrough at Rattlesnake Island which has caused significant changes in the area over the past 12 years.

1970 - The University of Florida Coastal and Oceanographic Engineering Laboratory (UF/COEL), in studying the Intracoastal Waterway in Flagler County, measured tides and currents at the inlet and southward along the Matanzas River and Intracoastal Waterway.

1971 - Hopkins (1971) estimated that both the general and local scour around the bridge piers at the Matanzas Inlet Bridge were about 5 ft.

1972 - The breakthrough at Rattlesnake Island had widened to 250 ft. Erosion along both sides of the inlet had taken place, although it was more significant at Summer Haven. In May, the National Park Service recommended closure of the breakthrough on the grounds that swift currents through the breakthrough were causing extensive erosion of government owned property (Burnson, 1972).

1973 - The coastal construction set-back line for St. Johns County was completed.

1973/74 - A Corps of Engineers survey of the breakthrough shows depth measurements and core boring locations from the inlet bridge west through the breakthrough and north along the Matanzas River to the intersection of the river and the Intracoastal Waterway. The survey indicates a channel approximately 12 ft. deep at the bridge which deepens to 30 ft. at the breakthrough. Depths of 40 to 45 ft. are indicated west of the Intracoastal Waterway at the breakthrough and an indentation in the marsh at this location is visible on aerial photographs. Significant shoaling is indicated in the north arm of the Matanzas River.

1974 - The UF/COEL again measured tides and currents at the inlet and along the Intracoastal Waterway for the calibration of a numerical model used to evaluate flushing characteristics at the Palm Coast development, 7.5 miles south (UF/COEL, 1974). The Corps of Engineers, in conjunction with the U.S. Geological Survey, measured current velocities and computed discharges at the inlet, the breakthrough, and the Matanzas River north of the inlet during July 18 and 19.

1975 - On June 16 a public notice concerning a proposed project to close the breakthrough was released by the Corps of Engineers. The proposed work included:

1) Construction of a steel sheet pile dike at the breakthrough.

2) Dredging a relief channel through the shoal in the Matanzas River north of the inlet.

3) Nourishment of 3,200 ft. of beach south of the inlet.

1976 - The dike breakthrough width was 310 ft. in September (as measured by the UF/COEL). Work was begun on the project to close the breakthrough in October and is expected to be completed by March 1977. The contract cost of the dike closure is $873,419. The cost of the entire project is approximately $1,980,000 (Corps of Engineers, 1976).

VI. MORPHOLOGICAL CHANGES

6.1 Maps, Surveys and Photographs

Matanzas Inlet appears on the following charts and maps: NOS Coast Chart No. 11486 (replacing No. 1244), NOS Small Craft Chart No. 11485 (replacing No. 843-SC), and USGS topographic map of the Matanzas Inlet Quadrangle, photorevised in 1970.

Surveys of the inlet and offshore areas have been infrequent and even though the Corps of Engineers and the USC & GS have made numerous surveys of the St. Augustine Inlet vicinity between 1854 and 1964, most of these surveys terminated about 2 miles north of Matanzas Inlet. The only offshore data taken near the inlet appear to be those surveys taken in 1923/24 (USC & GS), 1963/64 (Corps of Engineers) and in 1972 (COEL) in conjunction with the coastal construction setback line for St. Johns County. Surveys detailing the inlet and/or the adjacent inland waters have been made in 1872 (U.S. Coast Survey), 1943 (Corps of Engineers) and 1973/74/76 (Corps of Engineers), the latter being made in conjunction with the closure of the dike breakthrough. Positions of the high water shoreline are available from the following maps and charts: 1765 (Moncrief), 1872 (U.S. Coast Survey), 1882 (USC & GS), 1923/24 (USC & GS), 1956 (USGS), 1963/64 (Corps of Engineers) and 1970 (USGS).

The 1923/24 survey details the offshore bathymetry only beyond the 12 ft. depth contour. The 1963/64 survey details the 6, 12, 18 and 30 ft. contours, as well as a series of offshore profile lines along the St. Johns County coastline. These profile lines are shown on Fig. 6.9. In conjunction with the coastal construction setback line study of the area, a series of Department of Natural Resources permanent reference monuments were placed along the coastline at approximately 1,000 ft. intervals. Beach profiles were taken to a depth of 30 to 35 ft. at every third monument and at all other monuments beach profiles were taken to wading depth. Since Florida law requires the review of the setback line every 5 years, this project could provide a valuable monitoring of accretional or erosional trends in the Matanzas Inlet area, if these profile lines are surveyed in the future. These profile lines are also shown in Fig. 6.9.

Fifteen aerial photographs showing Matanzas Inlet are on file in either the COEL Archives (433 Weil Hall, University of Florida) or from the COEL/DNR setback line project records. These photographs span the years 1951 to 1972. Additional photographs for the years 1942 and 1960 are on file at the map library (Library East) at the University of Florida. Fig. 6.4, 6.5, 6.6 and 6.7 show photographs of Matanzas Inlet in 1942, 1962, 1967, and 1968, respectively. Several photographs not included above may be obtained from other sources (Barwis, 1975).

6.2 Outercoast Shoreline Changes

The major changes in the inlet and adjacent coastline are shown in Fig. 6.8. It is apparent that the southern tip of Anastasia Island has migrated southward while erosion has taken place along the north and east sides

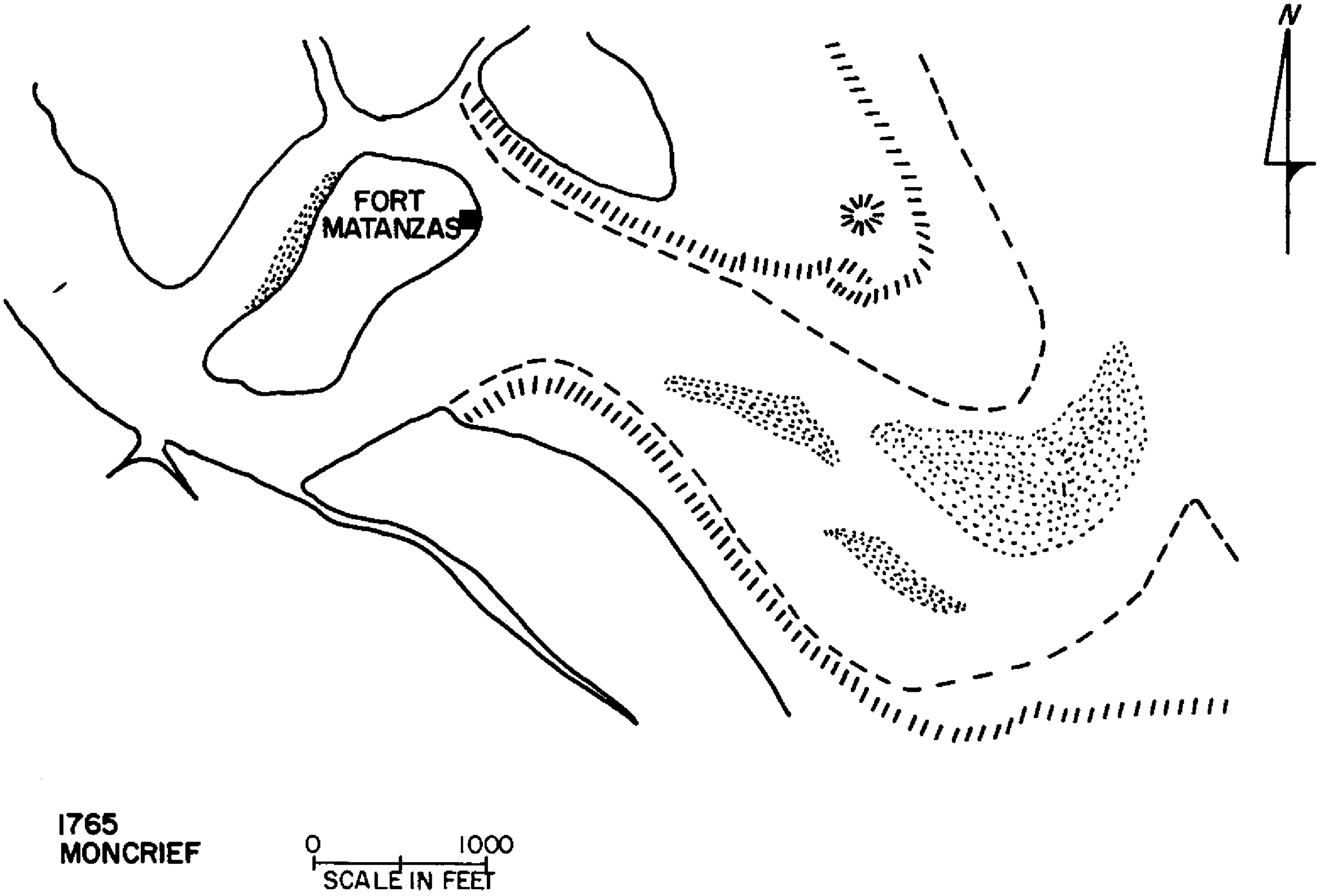
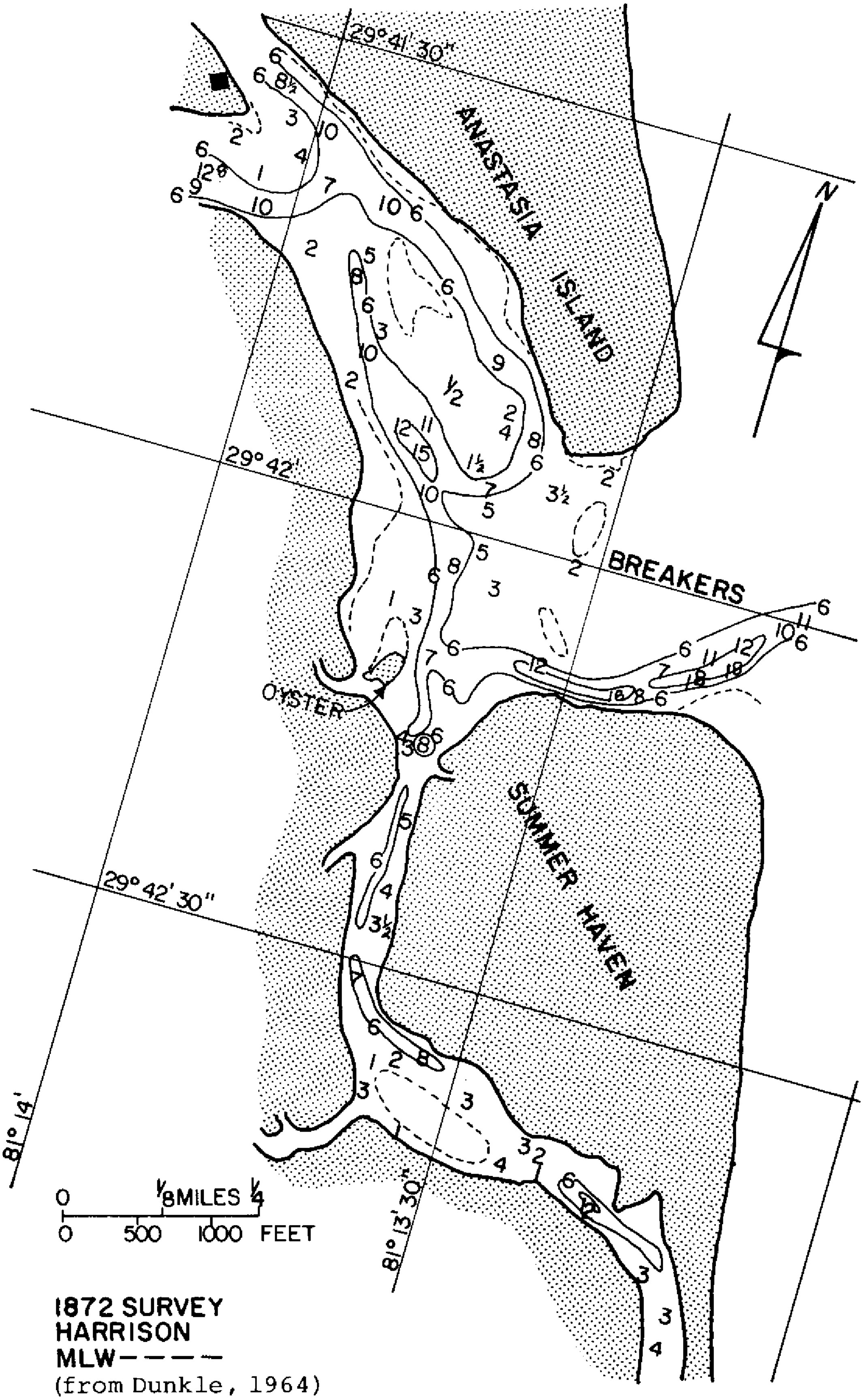


Fig. 6.1



1872 SURVEY
HARRISON
MLW— — — —
(from Dunkle, 1964)

Fig. 6.2

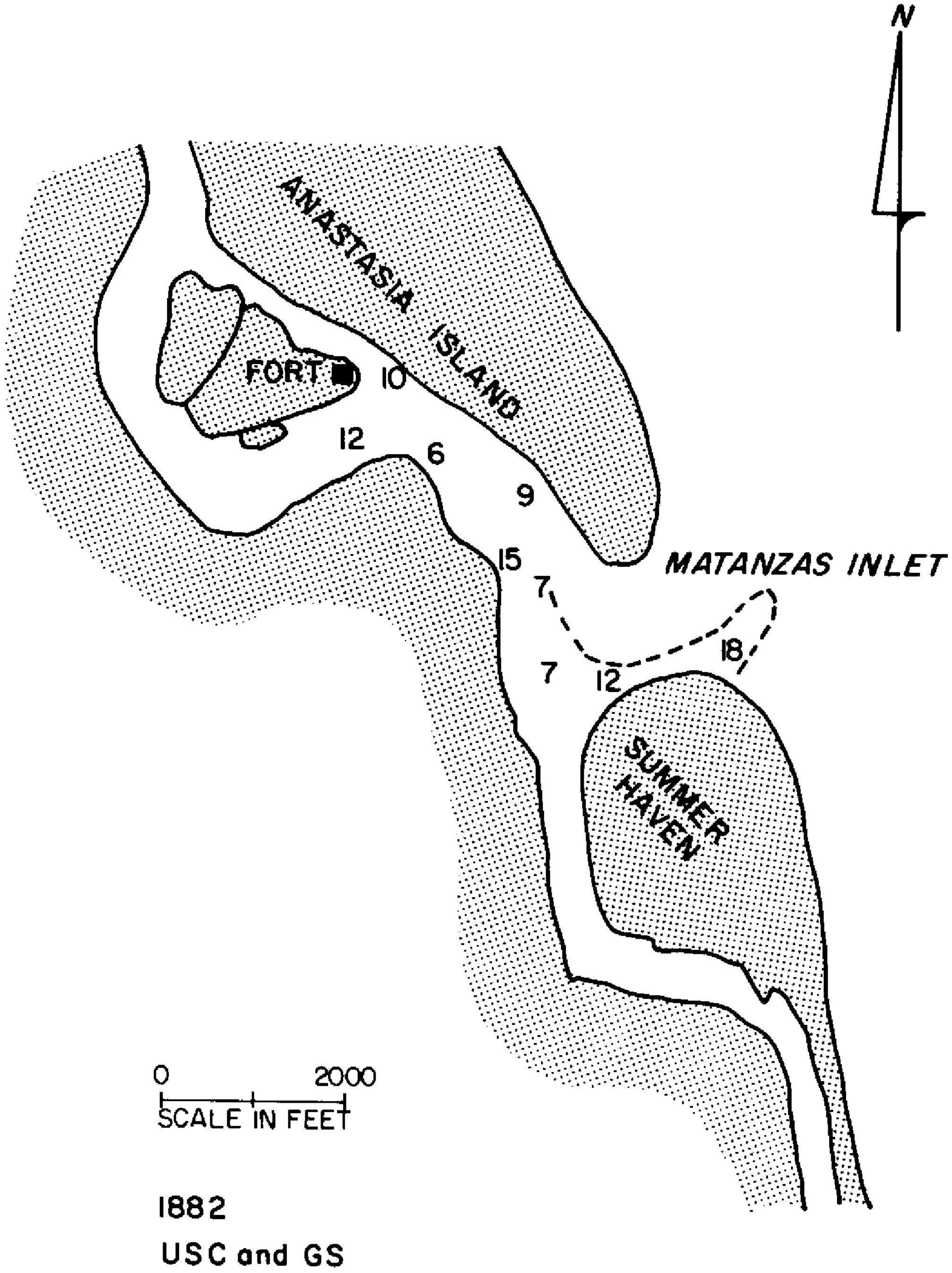

N
ANASTASIA ISLAND
FORT
10
12
6
9
15
7
MATANZAS INLET
7
12
18
SUMMER HAVEN
0
2000
SCALE IN FEET
1882
USC and GS

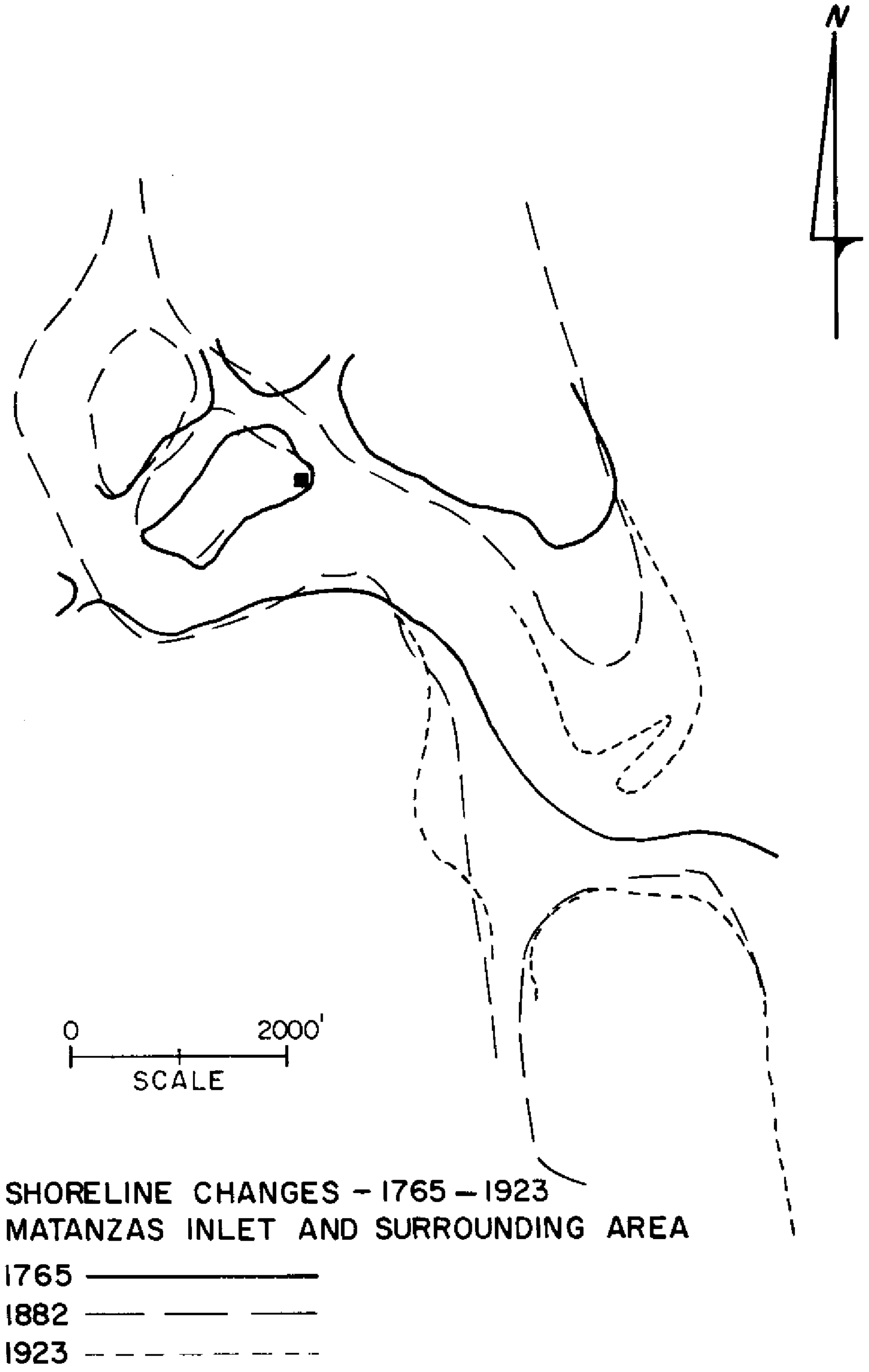
Fig. 6.3

Fig. 6.4 Matanzas Inlet in 1942.

Fig. 6.5 Matanzas Inlet in 1962.

Fig. 6.6 Matanzas Inlet in 1967.

Fig. 6.7 Matanzas Inlet in 1968.


N
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SHORELINE CHANGES – 1765 – 1923
MATANZAS INLET AND SURROUNDING AREA
1765
1882
1923

Fig. 6.8

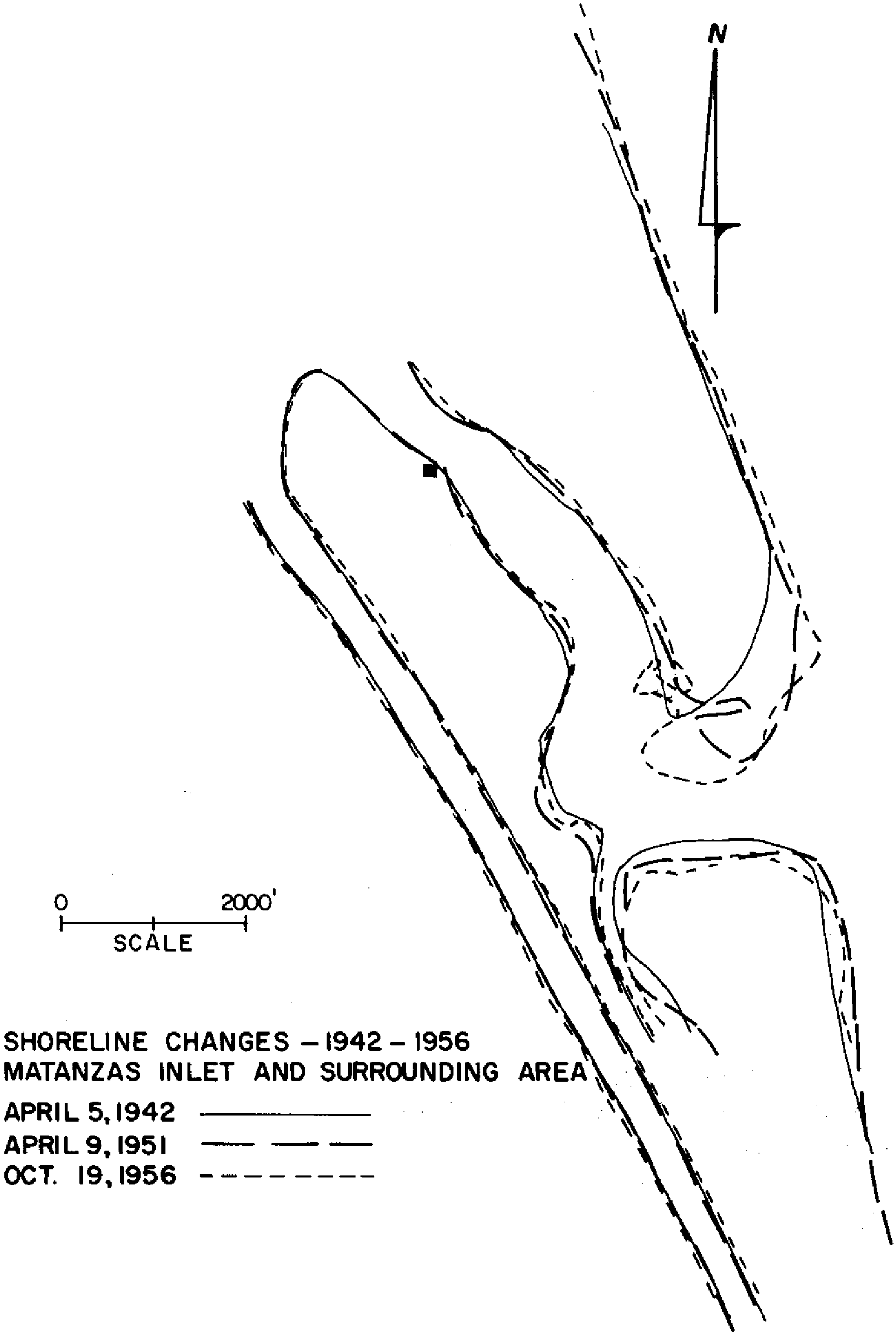


Fig. 6.8 Continued.

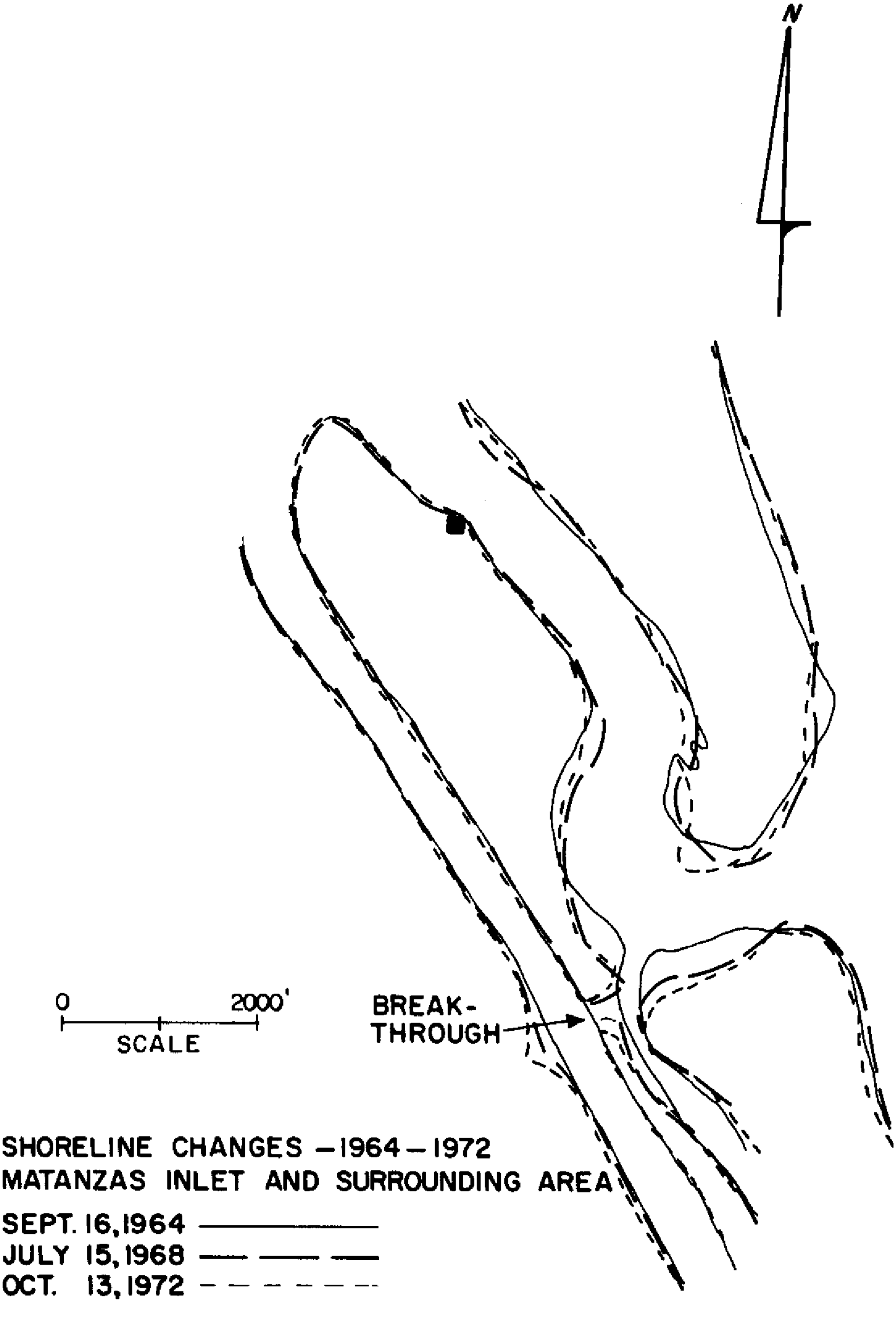


Fig. 6.8 Continued.

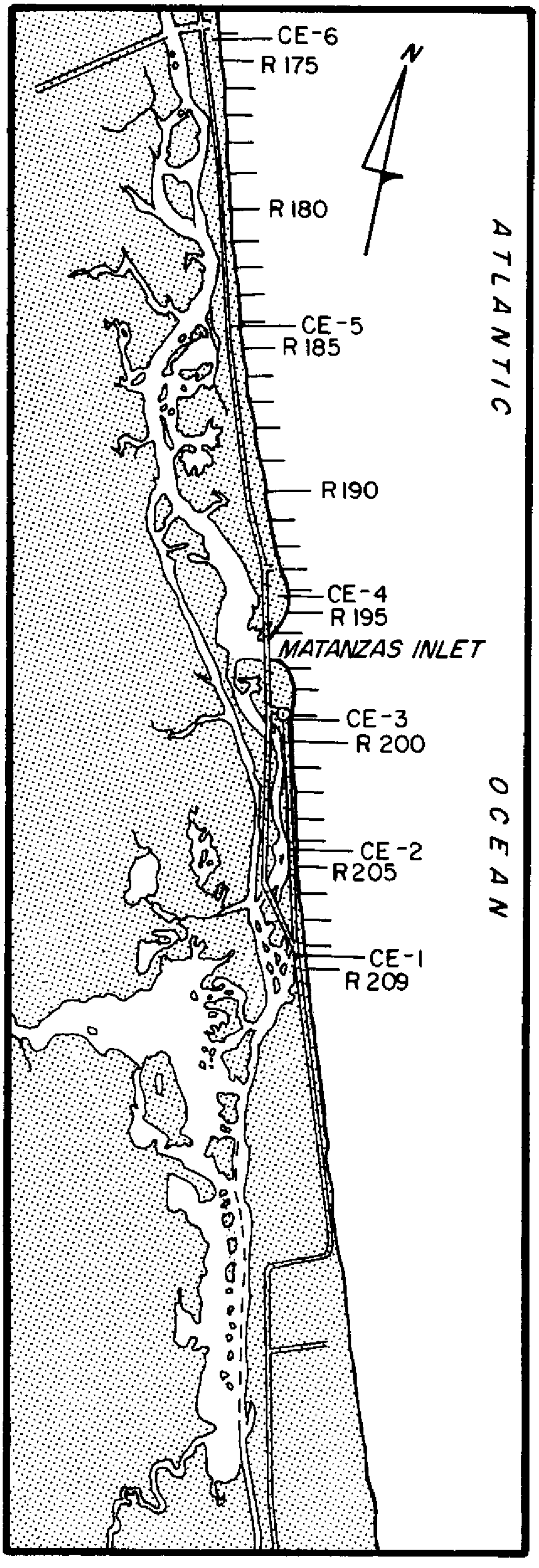


Fig. 6.9 Corps of Engineers (1965) profile lines are designated, "CE-1" through "CE-6." UF/COEL (1973) Setback line profile lines are designated "R175," etc. Unmarked lines are setback line profiles.

Fig. 6.9 Profile Line Locations.

of Summer Haven. The configuration of the island on which Fort Matanzas is situated has changed significantly. This change in the shape of the original island and the land to the south to what is known today as Rattlesnake Island is due almost entirely to the dredging of the Matanzas Relocation Cut in 1932 and subsequent dredging in the Intracoastal Waterway. Fig. 6.3 shows an 1882 USC & GS chart with the position of Fort Matanzas shown on the original island configuration. One interesting feature not shown on any of the aforementioned figures in this report is the Peñon Inlet, which was said to have been just south of Summer Haven and is said to have occluded in the early 1800's (Burnson, 1972).

The Corps of Engineers (1965) calculated total and annual rates of accretion and erosion at those six profile lines indicated on Fig. 6.9, as well as six more profile lines to the north along Anastasia Island. The report indicated that over the period 1860/61 to 1963/64 there was an average annual high water shoreline accretion of 0.81 ft./year along profile lines 4 through 6. The report also indicated an average annual high water shoreline erosion of 1.39 ft./year along profile lines 1 through 3. Fig. 6.10 and Table 6.1 give a more detailed look at the shoreline changes at the inlet between profile lines 3 and 4 from 1860/61 to 1972. The data for the years 1963/64 to 1972 were obtained by plotting the 1972 shoreline from aerial photographs onto the Corps of Engineers survey map covering the years 1860/61 to 1963/64 (see Fig. 6.10). It is evident that the erosion rate immediately south of the inlet is much greater than the average rate from the inlet to the St. Johns/Flagler County line and the average accretion rate north of the inlet is less than that for all of Anastasia Island. These results indicate that the inlet has affected the shoreline both to the north and south of it and that the general trend is one of erosion (see also Bruun, 1962). The fact that accretion is taking place north of the inlet and erosion is taking place south of the inlet points to the predominance of littoral drift in the southerly direction (see section 8.2).

6.3 Changes In the Inlet Cross Section

Measurements of the inlet cross section have been made at the following times: August 1954 (State Road Department survey, obtained from the Department of Transportation); November 1963 (Corps of Engineers); April 1972 (Krishnamurthy and Coleman, COEL); October 1973 (determined from Corps of Engineers' dike breakthrough survey data); June 1974 (COEL); September 1976 (COEL). All but the April 1972 cross sections are shown in Fig. 6.11. Although an exact profile shape is not given in the report by Krishnamurthy and Coleman (1972), sufficient detail is given to know that the cross section is similar in shape and size to the 1973 cross section. The locations of these cross sections are shown on Fig. 6.12; the characteristics of these cross sections are indicated in Table 6.2.

Apparently the inlet throat section (location of minimum cross sectional area) is near the inlet bridge. Note that the 1963 cross section was taken 100 to 125 ft. east of the bridge and is evidently influenced by the inlet channel, which at that time turned northward after passing under the bridge. This may account for the large cross sectional area of 12,500 sq. ft., as compared to the others, which average about 7,900 sq. ft. (Even today the main channel turns northward.)

Table 6.1

SHORELINE CHANGES IN THE VICINITY OF MATANZAS INLET 1860/61 TO 1972 (FIG. 6.10)

Station	1860/61 1923/24 (ft.)	1923/24- 1963/64 (ft.)	1963-1972 (ft.)	Total Change (ft.)	Annual Change (ft.)
C.E. 4	-100	+130	+ 30	+ 60	+ 0.54
4000' N	- 90	+130	+ 30	+ 70	+ 0.63
3500' N	- 70	+110	+ 20	+ 60	+ 0.54
3000' N	- 20	+ 60	+ 20	+ 60	+ 0.54
2500' N	+110	- 50	0	+ 60	+ 0.54
2000' N	+220	- 70	- 40	+110	+ 0.98
1500' N	*	-150	-140	-290	- 5.91[a]
1000' N	*	**	-150	-150	-16.67[b]
1000' S	-330	-270	-150	-750	- 6.70
1500' S	-230	-250	- 80	-560	- 5.00
2000' S	-180	-170	- 30	-380	- 3.39
2500' S	-180	-140	- 20	-350	- 3.13
C.E. 3	-210	- 90	- 20	-320	- 2.86

\+ denotes accretion, - denotes erosion

* the southern limit of Anastasia Island was north of the profile line

** the prograding spit precluded accurate measurements

a average for a 49 year period, 1923 to 1972

b average for a 9 year period, 1963 to 1972

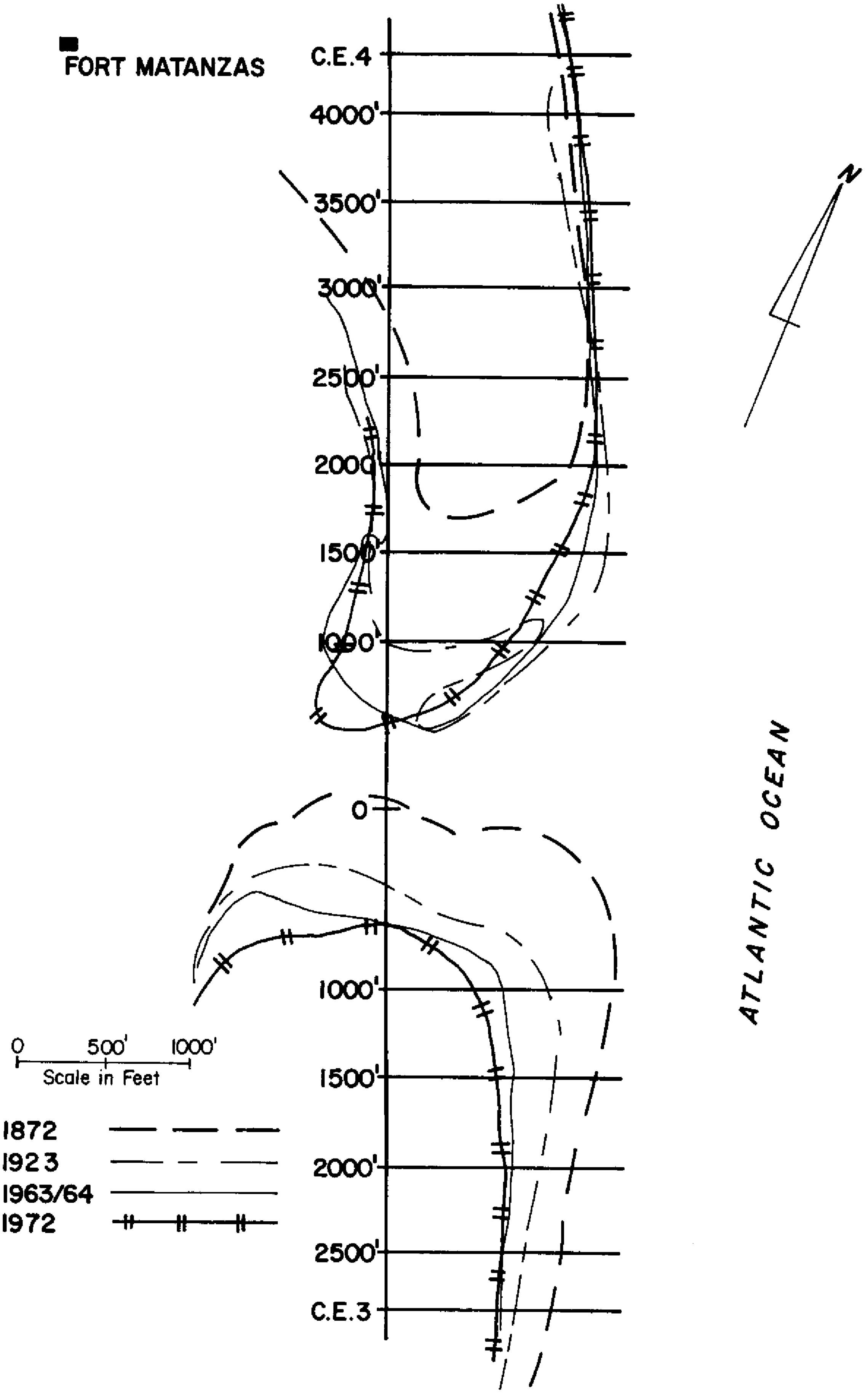


Fig. 6.10 Inlet Shoreline Changes.

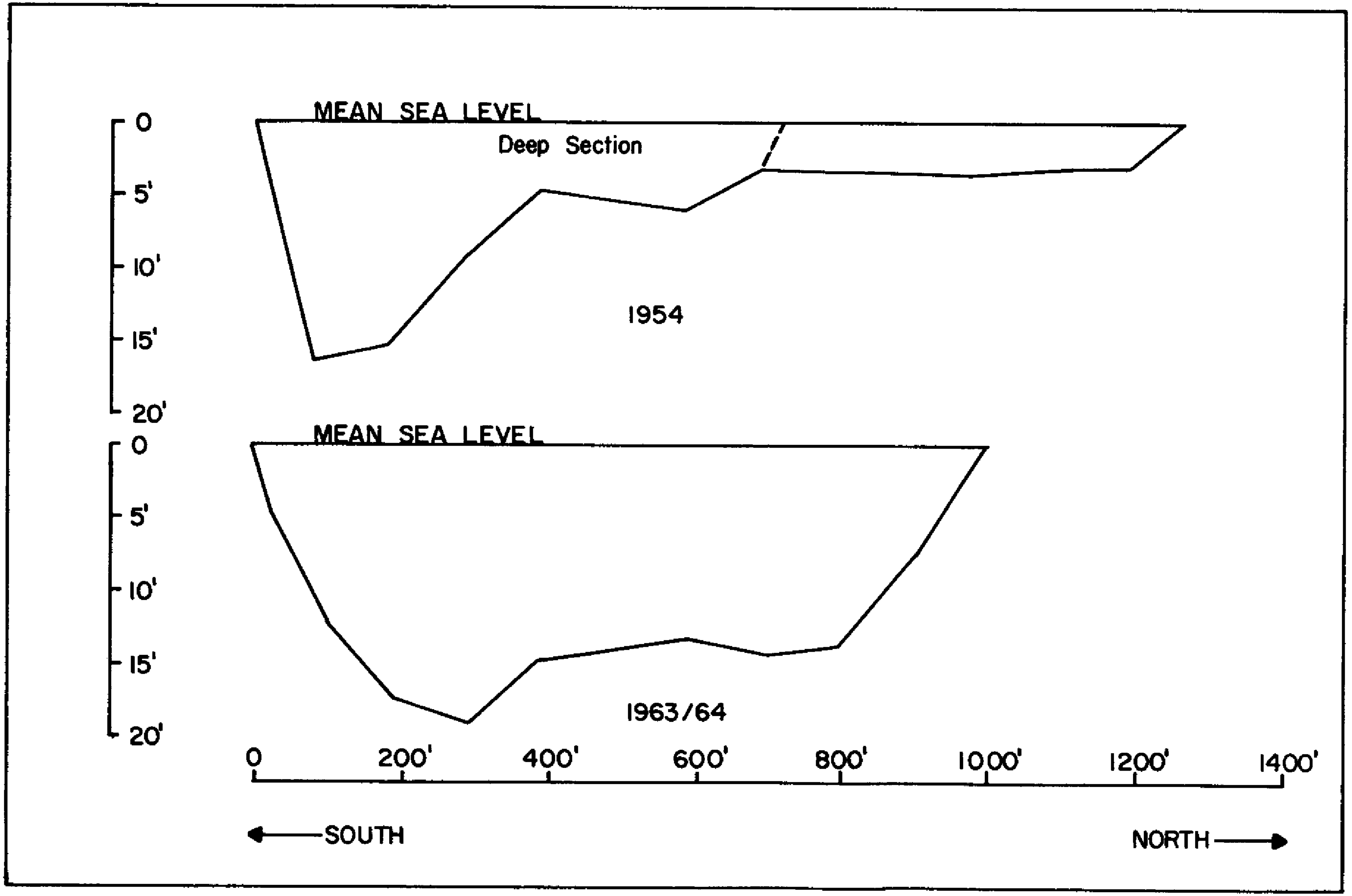


Fig. 6.11 Inlet Cross Sections.

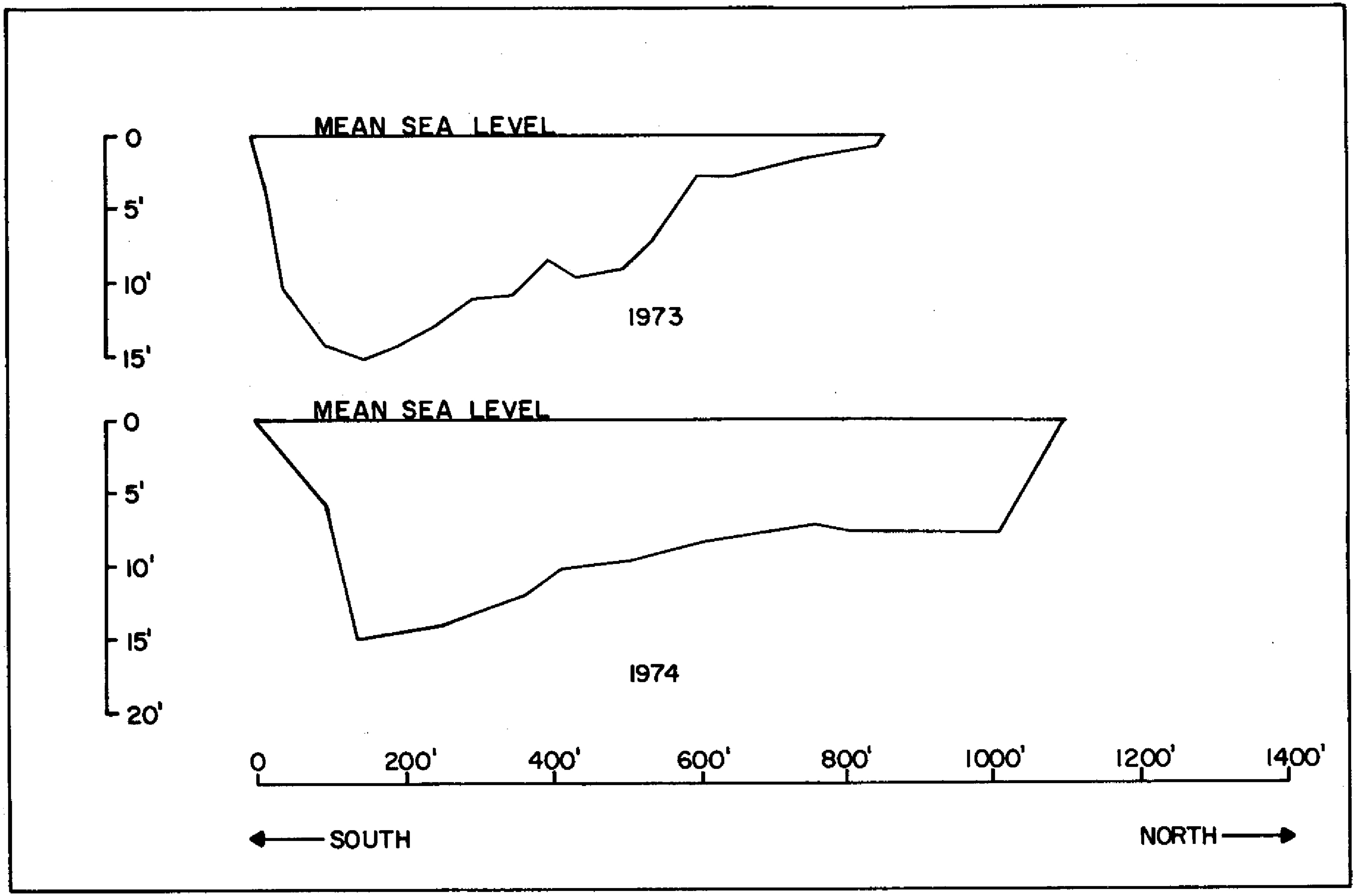


Fig. 6.11 Inlet Cross Sections (continued).

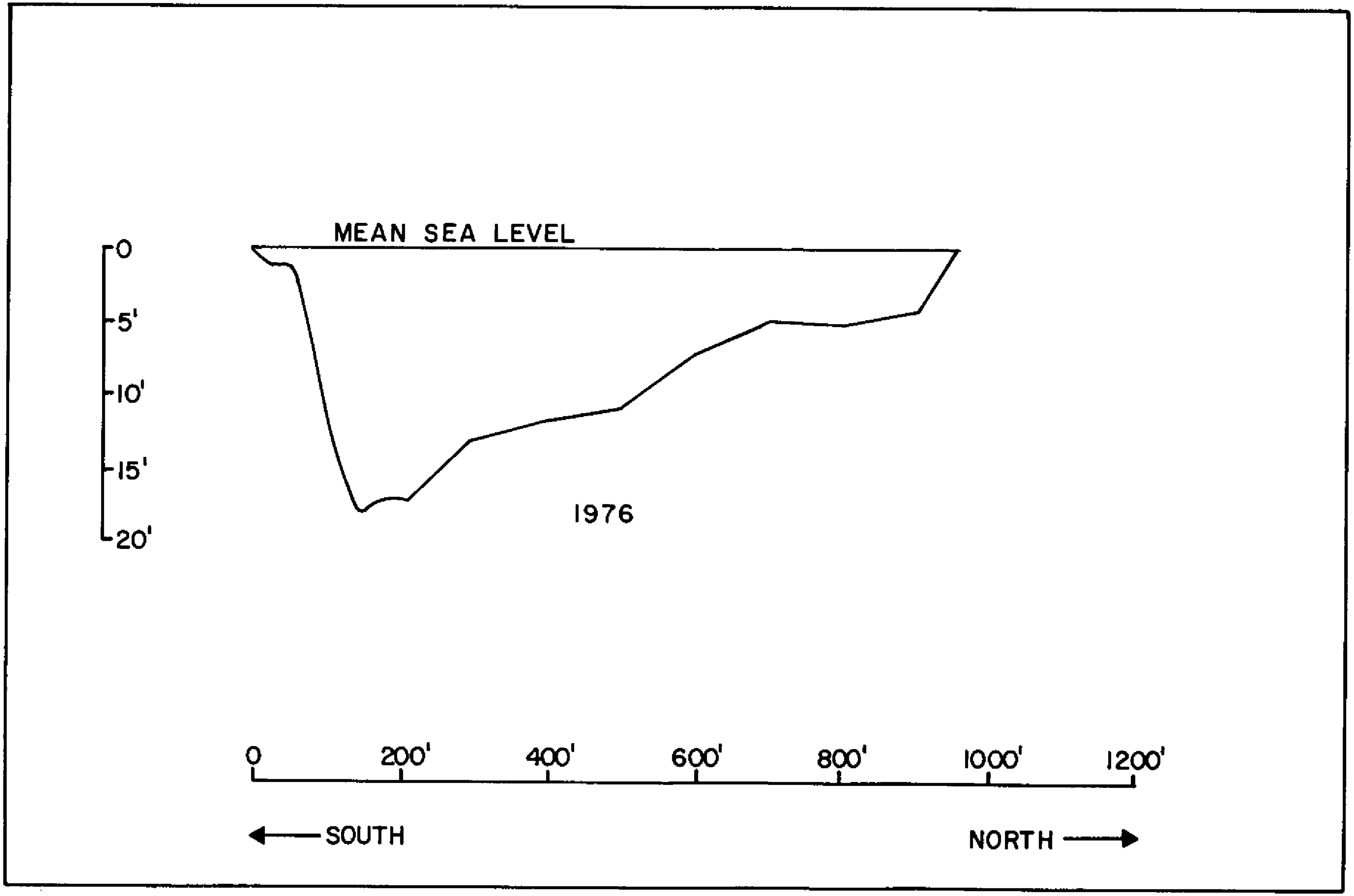


Fig. 6.11 Inlet Cross Sections (continued).

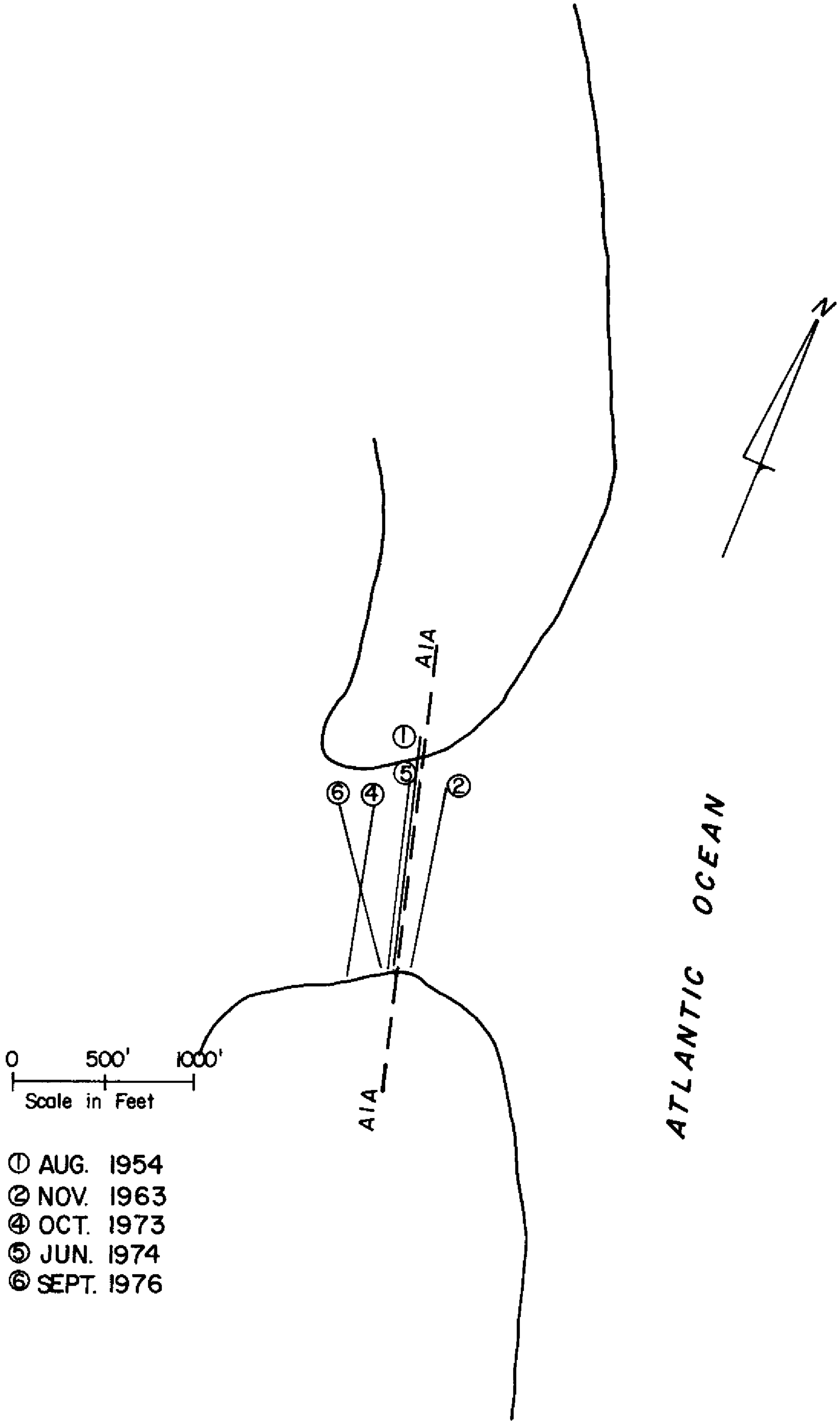


Fig. 6.12 Inlet Cross Section Locations. Exact Location of 1972 Cross Section is not Known.

Appearing in Fig. 6.13 is the location of a longitudinal profile taken on April 1, 1976 (COEL) extending from the Intracoastal Waterway, through the breakthrough, under the inlet bridge and turning N-NE for a distance of approximately 1,800 ft. The total length of the section is approximately 4,000 ft.

Table 6.2

COMPARISON OF INLET CROSS SECTIONS

	1954	1963	1972	1973	1974	Sept. 1976
Maximum Depth below MWL (ft.)	16	19	16	15	15	17
Area below MWL (sq. ft.)	6,895 (5,400)	12,500	7,136 (5,436)	6,720	9,766	8,800
Width at MWL (ft.)	1,260 (690)	1,010	1,692 (720)	860	1,092	950
Average Depth below MWL (ft.)	5.5 (7.8)	12.4	(7.6)	7.8	8.9	9.3
Width/Depth ratio at MWL	(88.2)	81.5	(95.4)	110.1	122.1	102.6

Numbers in parentheses indicate results for the deep section only.

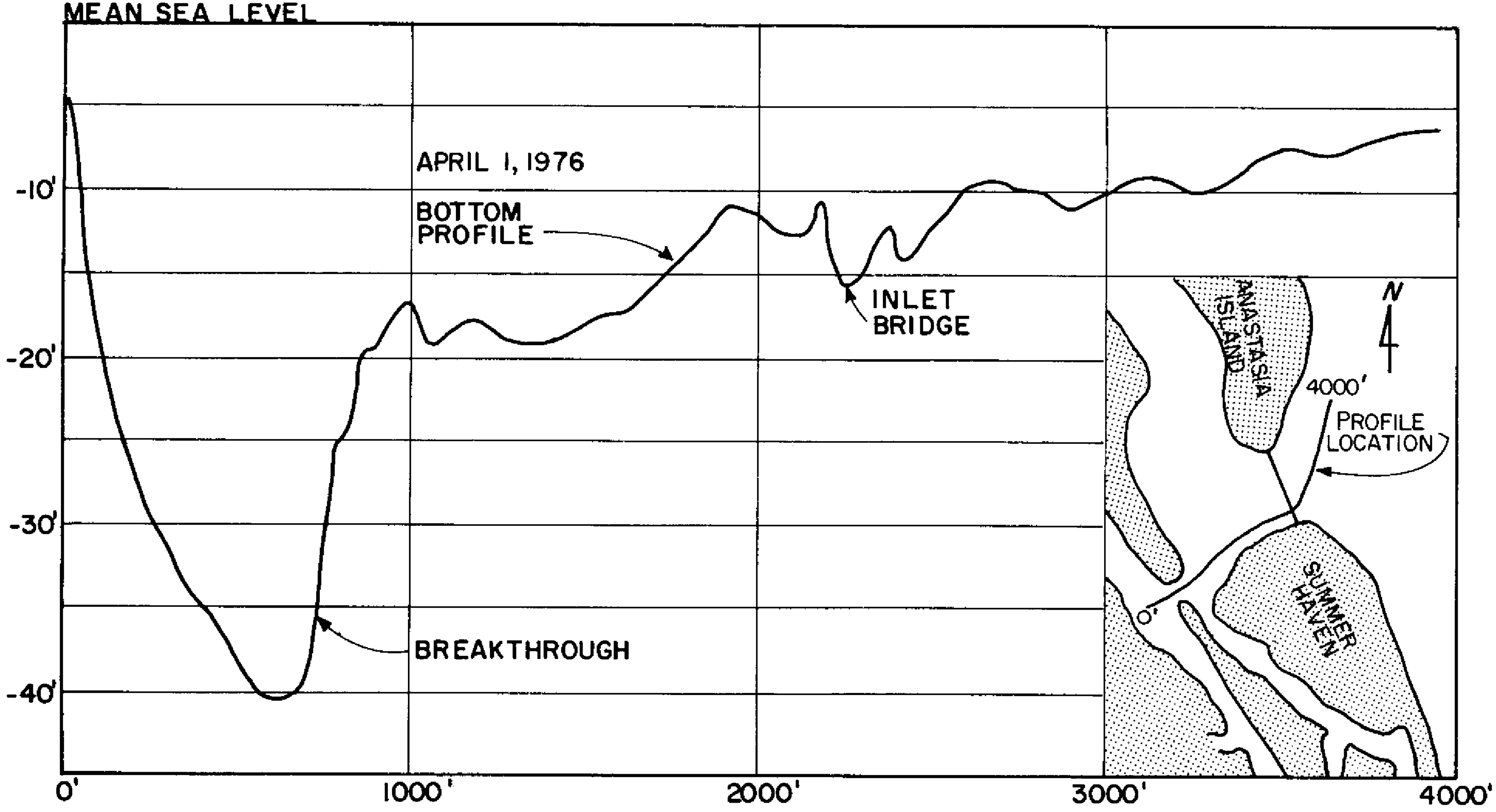


Fig. 6.13 Longitudinal Profile.

VII. HYDRAULICS

7.1 Freshwater Discharge, Runoff and Salinity Measurements

Very little information on freshwater discharge and runoff is available for the Matanzas Inlet vicinity. Table 7.1 shows data available for Pellicer Creek, four miles south of the inlet, and Table 7.2 shows data for Moses Creek, five miles north of the inlet (Kenner, 1963). The measurements at Pellicer Creek were taken at the Florida East Coast Railroad Bridge, about 5.7 miles southwest of Summer Haven, while those at Moses Creek were taken from a bridge on highway U.S. 1, three miles south of Moultrie, Florida. The only available surface runoff is given for a 100 year frequency in Flagler County as 0.6 cfs per acre (COEL, 1970).

Salinity measurements taken on March 18 and 19, 1970 in conjunction with a study in Flagler County (COEL, 1970) show a decrease in salinity as one travels south from Matanzas Inlet along the Intracoastal Waterway. These data are summarized in Table 7.3.

7.2 Tides

The National Ocean Survey (NOS) presently maintains a tide gage at the National Park Service dock near Fort Matanzas, but tidal predictions for this region have not yet been included in the NOS Tide Tables. Nearest locations for which predictions are available are St. Augustine Inlet (15 miles north of Matanzas) and Daytona Beach (35 miles south of Matanzas). The tidal ranges for these stations are as follows:

TABLE 7.4

RANGES FROM NOS TIDE TABLES

Station	Mean Range (ft)	Spring Range (ft)
St. Augustine Inlet	4.5	5.3
Daytona Beach	4.1	4.9

The line of mean water level (MWL) along the open coast in the vicinity of Matanzas is estimated (Flood Control Section, Corps of Engineers, Jacksonville District) to be 0.35 ft above the 1929 mean sea level datum, which is the reference datum for many USC & GS and SRD bench marks in the area. The line of mean low water is estimated to be 2.2 ft below MWL.

The Coastal and Oceanographic Engineering Laboratory (COEL) obtained tidal records at the Flagler Beach pier in July 1974 (COEL, 1974). Since this pier (16 miles south of the inlet) is the nearest open coast location to the inlet, the tidal records there will be considered, for the purposes

TABLE 7.1

PELLICER CREEK FRESHWATER DISCHARGE

Date	Discharge (cfs)
April 11, 1956	66.8
May 24, 1956	2.19
June 24, 1958	6.71
May 27, 1965	3.07
April 21, 1967	3.92

TABLE 7.2

MOSES CREEK FRESHWATER DISCHARGE

Date	Discharge (cfs)
April 11, 1956	16.6
June 23, 1958	0.6

From USGS, Ocala, Florida; Kenner (1963).

TABLE 7.3

SALINITY DISTRIBUTION IN THE INTRACOASTAL WATERWAY SOUTH OF MATANZAS INLET

Location	Salinity (p.p.t.) High Tide 3/18/70	Salinity (p.p.t.) Low Tide 3/19/70
Inlet Bridge	31.6	31.0
5 miles S	26.4	26.1
10 miles S	19.8	19.6
15 miles S	19.0	18.7
20 miles S	14.8	14.5
25 miles S	10.8	

From COEL (1970)

of hydraulic computation in Section 7.4, the effective ocean tide for Matanzas Inlet. The records at the pier yield the following ranges:

July 11, 1974	Neap Tide	3.33 ft.
July 18, 1974	Spring Tide	5.69 ft.

7.3 Currents

A 1943 Corps of Engineers survey map shows the results of current measurements at the junction of Matanzas River and Matanzas Relocation Cut, just north of Rattlesnake Island. These measurements indicate a maximum flood of 2.17 fps and a maximum ebb of 2.50 fps. The range of tide at the time of the measurements is not given but a mean range of 3.5 ft. is reported.

COEL obtained current data at the inlet bridge on July 11, 1974 (COEL, 1974) under neap tide conditions (range at Flagler Beach was 3.33 ft as noted previously). The current meter was approximately 2/3 of the total depth below the surface and therefore probably recorded a velocity which was close to the depth-averaged velocity at that point. The data show a maximum flood of 3.30 fps and an ebb of 4.00 fps. Since the cross sectional distribution of the velocity was not determined at that time, it is difficult to evaluate the flow discharge through the inlet based on these data.

On July 18, 1974, USGS, in cooperation with the Corps of Engineers, Jacksonville District, obtained cross sectional velocity profiles at the inlet bridge, in the breakthrough and in Matanzas River near the fort. These profiles were converted to the corresponding discharge curves which are reproduced in Fig. 7.1 (Correspondence on file, Corps of Engineers, Jacksonville District, 1974; Corps of Engineers, 1976).

7.4 Hydraulic Parameters

a. Tidal Prism

Mainly as a consequence of the circulation of the tidal waters between St. Augustine, Matanzas and Ponce de Leon Inlets, the flood and the ebb tidal prisms at Matanzas Inlet are not equal. The discharge data of Fig. 7.1 yield the following prisms, all of which are under a spring range of tide in the ocean.

TABLE 7.5

TIDAL PRISMS ON JULY 18, 1974

Location	PRISM		
	Ebb (ft^3)	Flood (ft^3)	Average (ft^3)
Inlet	$4.15\text{x}10^{8}$	$5.84\text{x}10^{8}$	$5.00\text{x}10^{8}$
Breakthrough	$3.22\text{x}10^{8}$	$4.74\text{x}10^{8}$	$3.98\text{x}10^{8}$
River (north arm)	$0.83\text{x}10^{8}$	$1.07\text{x}10^{8}$	$0.95\text{x}10^{8}$
River (south arm)	$0.10\text{x}10^{8}$	$0.03\text{x}10^{8}$	$0.07\text{x}10^{8}$

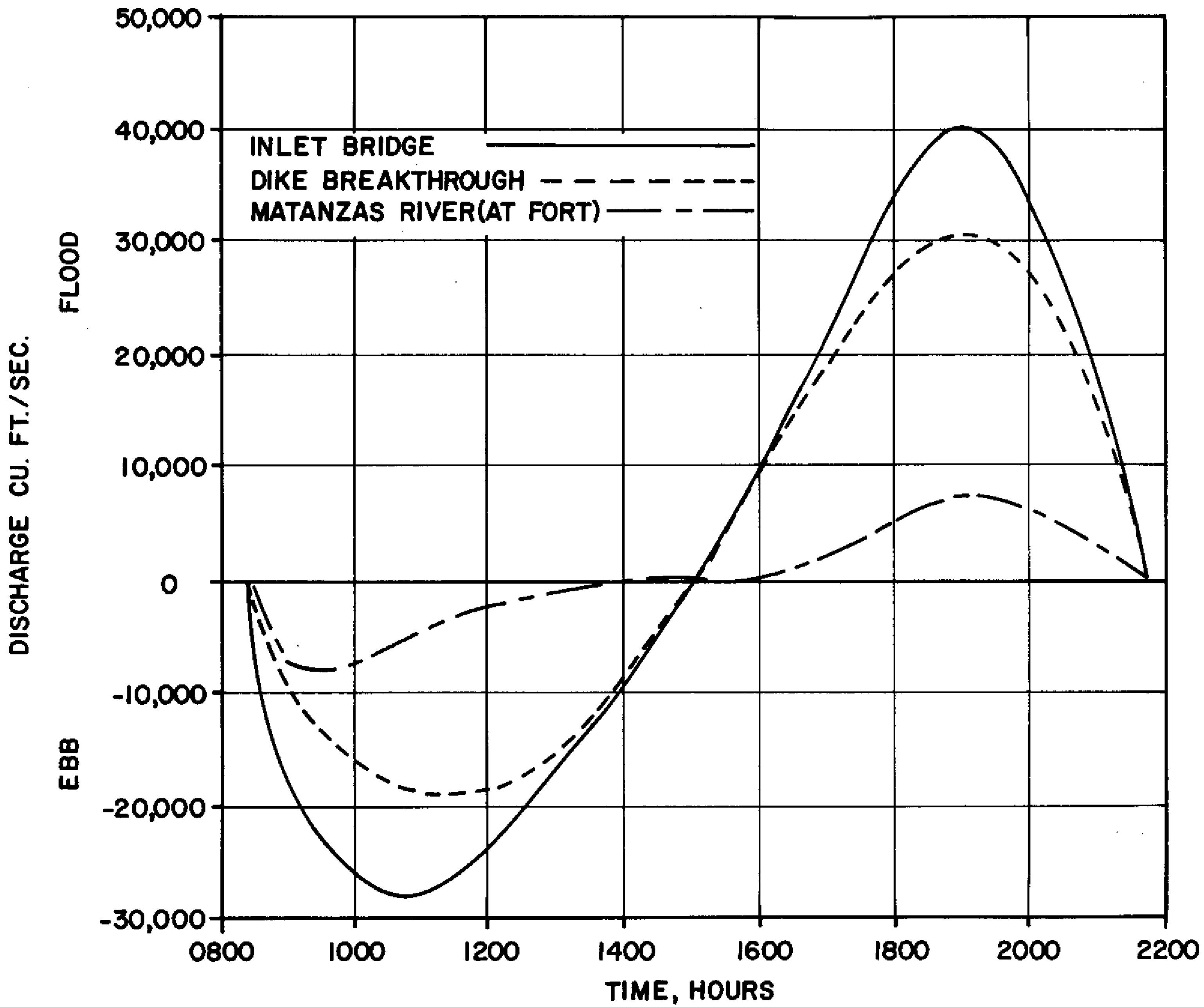
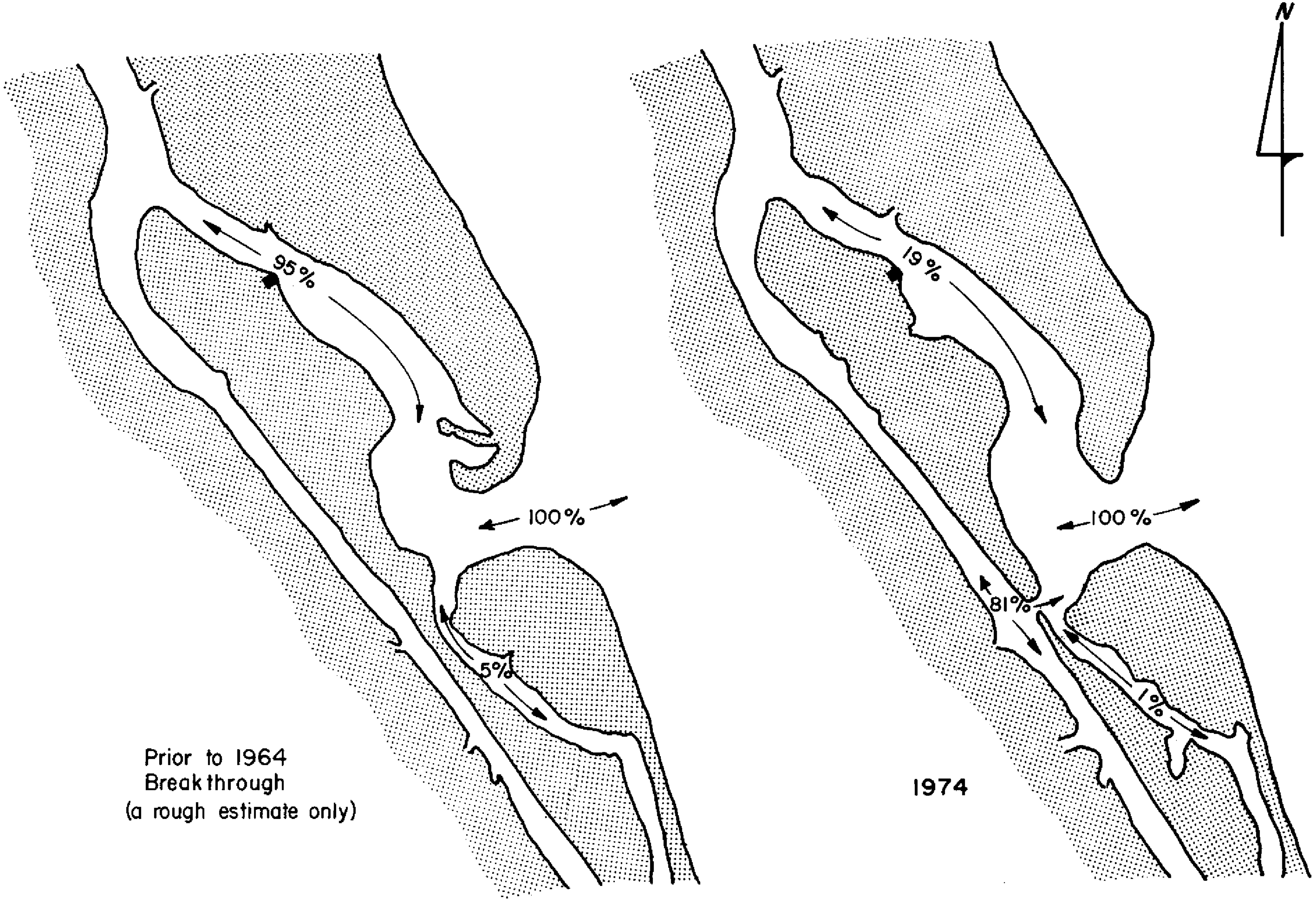


Fig. 7.1 Discharge Hydrographs (Corps of Engineers, 1976).



(a) (b)

Fig. 7.2 Percent Distribution of Tidal Prism Through Matanzas Inlet.

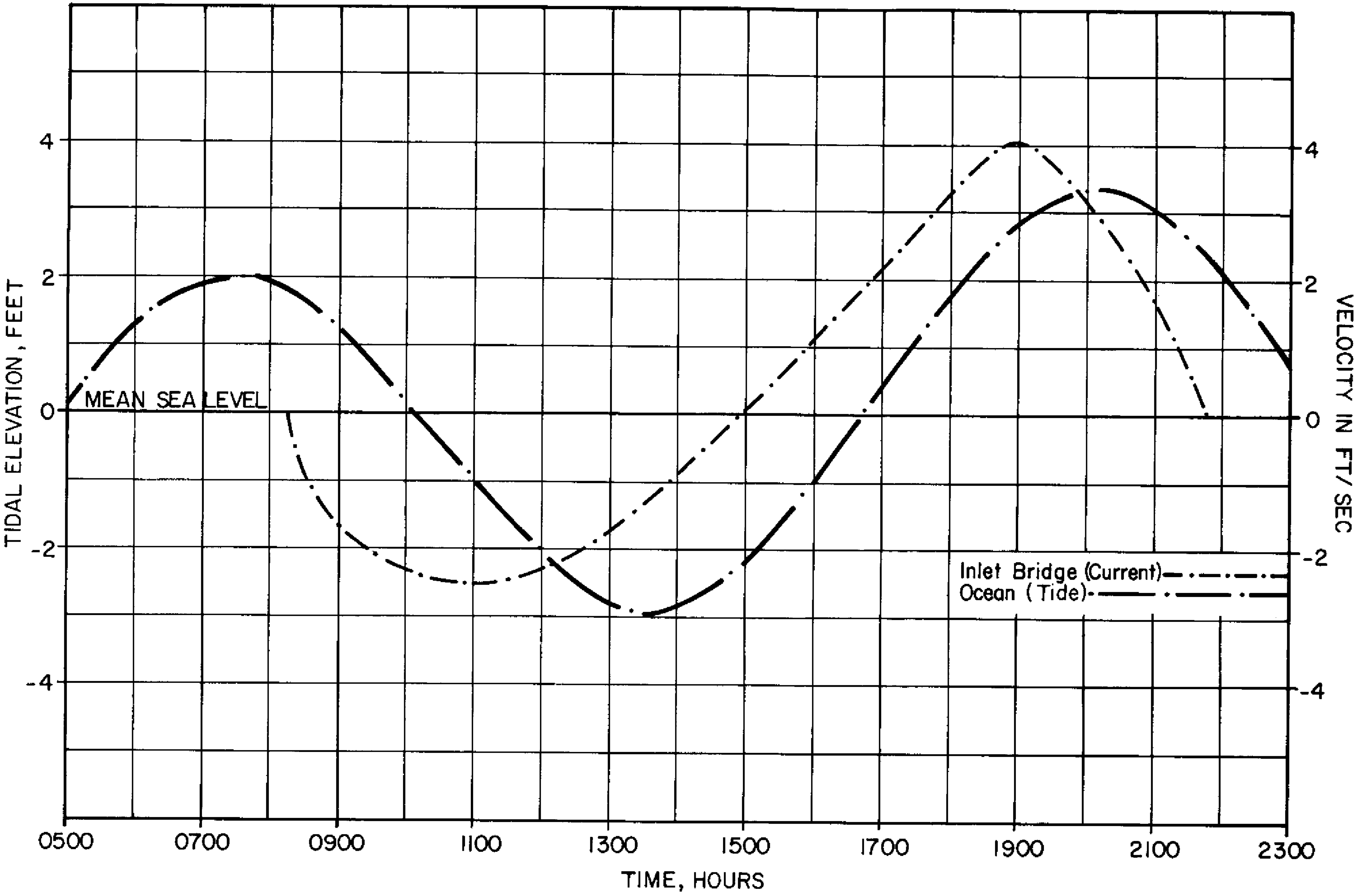


Fig. 7.3 Ocean Tide and Inlet Current (July 18, 1974).

The prism through the south arm of the river is the difference between the prism through the inlet and the sum of the prisms through the breakthrough and the north arm of the river. In Fig. 7.2(a) a rough estimate (Chiu, COEL, personal communication) is given of the percent distribution of the prism through the inlet, prior to the occurence of the breakthrough in 1964. This may be compared with the 1974 distribution shown in Fig. 7.2(b) based on the data in Table 7.5. An important observation here is that the percent of prism passing through the north arm of the river dropped from 95 to 19 as a result of the breakthrough. Since the maximum flow rate is proportional to the prism, the maximum flow rate was reduced to 20% of its pre-breakthrough value. This, at least qualitatively, accounts for the rather significant sand deposition that has occurred in the north arm of the river. A similar argument can be made concerning the shoaling in the south arm of the river, particularly in the section adjacent to the breakthrough.

b. Maximum Current

The discharge curve for the inlet bridge in Fig. 7.1 may be divided by the 1974 cross section (From Table 6.2) to yield the corresponding velocity curve. This is plotted in Fig. 7.3 along with the ocean (Flagler Beach) tide record on July 18, 1974. It is observed that the maximum cross sectional average ebb velocity is 4.12 fps and the corresponding flood velocity is 2.39 fps. Note that the spring range of ocean tide is 5.69 ft.

c. Lag of Slack Water

It is observed from Fig. 7.3 that the time lag of slack water (zero current) after high water (HW) in the ocean is 45 minutes and the lag after low water (LW) is 110 minutes.

d. Bay Range

The bay tide range on July 18, 1974 has been obtained by averaging the tide ranges at three gages, located 2.7 miles north of the inlet, at the inlet and 2.6 miles south of the inlet (COEL, 1974). The range on that day was 4.47 ft.

e. Bay Area

The bay area may be obtained by dividing the spring tidal prism by the bay tide range, i.e.

$$5.00 \times 10^{8}/4.47 = 1.11 \times 10^{8}\ \text{ft}^{2}.$$

The following hydraulic parameters have thus been obtained (based on July 18, 1974 data):

Spring ocean tide range = 5.69 ft

Spring bay tide range = 4.47 ft.

Spring max. cross sectional avg. velocity (flood) = 2.39 fps

Spring max. cross sectional avg. velocity (ebb) = 4.12 fps

Spring max. cross sectional avg. velocity (avg. of flood & ebb) = 3.26 fps

Spring flood tidal prism = 5.84×10^{8} ft^{3}

Spring ebb tidal prism = 4.15×10^8 ft^3

Spring tidal prism (avg. of flood and ebb) = 5.00×10^8 ft^3

Bay area = 1.11×10^8 ft^2

Tidal period (for spring tide) = 12.5 hours

Inlet throat cross sectional area (below MLW) = 9,766 ft^2

Inlet throat surface width = 1,092 ft

Inlet throat hydraulic radius (mean depth) = 8.9 ft

Lag of slack water after MW = 45 min

Lag of slack water after LW = 110 min

Avg. lag of slack water = 78 min

7.5 Wave Climate

There are currently no data on the wave climate specific to the outer coast vicinity at Matanzas Inlet. The COEL is, however, installing a series of four pressure transducers at a distance of 2500 ft. offshore at Marineland (water depth approximately 30 ft.) from which the directional spectra of the waves, as well as wave heights will be determined. The wave data available at this time include the offshore data from Volume 4 of the SSMO (Summary of Synoptic Meteorological Observations) published by the U.S. Naval Weather Service Command, and some data from the Corps of Engineers Coastal Engineering Research Center (CERC) wave gage at Daytona Beach. Figs. 7.4 and 7.5 show the offshore wave heights and wave period roses for the area, derived from the SSMO data by Walton (1973). Fig. 7.6, also from Walton (1973), shows a comparison of the offshore SSMO data, the CERC wave gage data and the SSMO data after being extrapolated to the coastline, taking into account refraction and shoaling. Note the reduction in wave heights upon reaching the shoreline and the strong correlation between the wave directions (Figs. 7.4 and 7.5) and the offshore wind directions from Table 4.1.

Another related factor of importance is the water level elevation along the coastline due to storm surge and wave setup. These data were necessary to compute the wave uprush elevations along the coastline for the coastal construction setback line project. Fig. 7.7 (COEL, 1973) shows a comparison between storm surge elevation frequencies, as calculated by both the National Oceanic and Atmospheric Administration (NOAA) and the COEL. In the establishment of the setback line for St. Johns County a storm surge elevation of 8 ft (100 year return frequency according to NOAA) was superimposed upon a wave setup of 2 ft., resulting in a 10 ft. water level elevation above normal (COEL, 1973; Purpura and Sensabaugh, 1974).

7.6 Inlet Stability

The stability of the inlet is examined in terms of the relationship between Keulegan's repletion coefficient, K, and a dimensionless velocity, ν (Keulegan, 1967). The definitions are:

$$K = \frac{Tg^{\frac{1}{2}}}{(2a_o)^{\frac{1}{2}}\pi} \; \frac{A_c}{A_b} \; \frac{1}{\left(k_{en} + k_{ex} + \frac{fL_cW_c}{4A_c}\right)^{\frac{1}{2}}} \qquad (7\text{-}1)$$

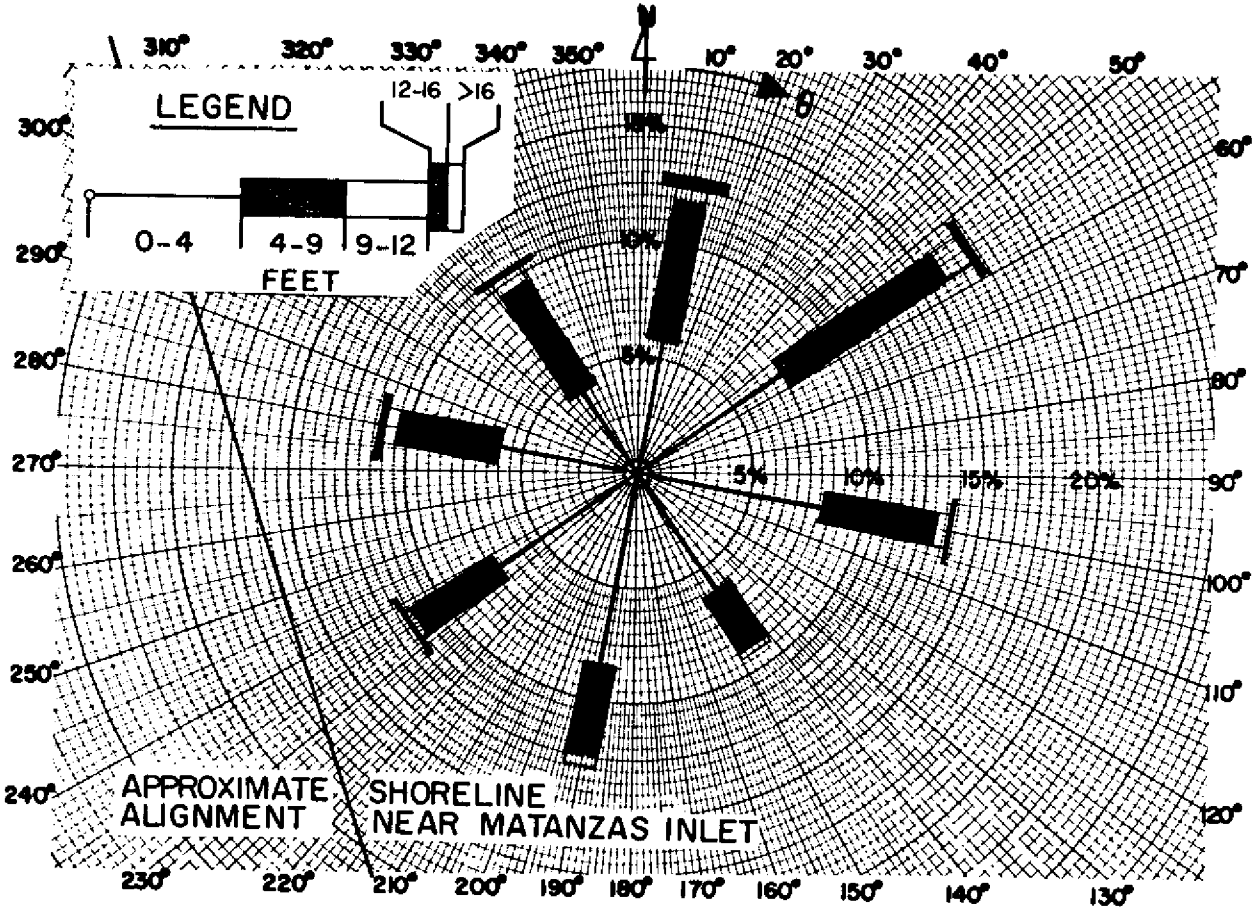


Fig. 7.4 Wave Height Rose For Offshore Wave Climate SSMO Data Square No. 11 - Annual

From Walton (1973).

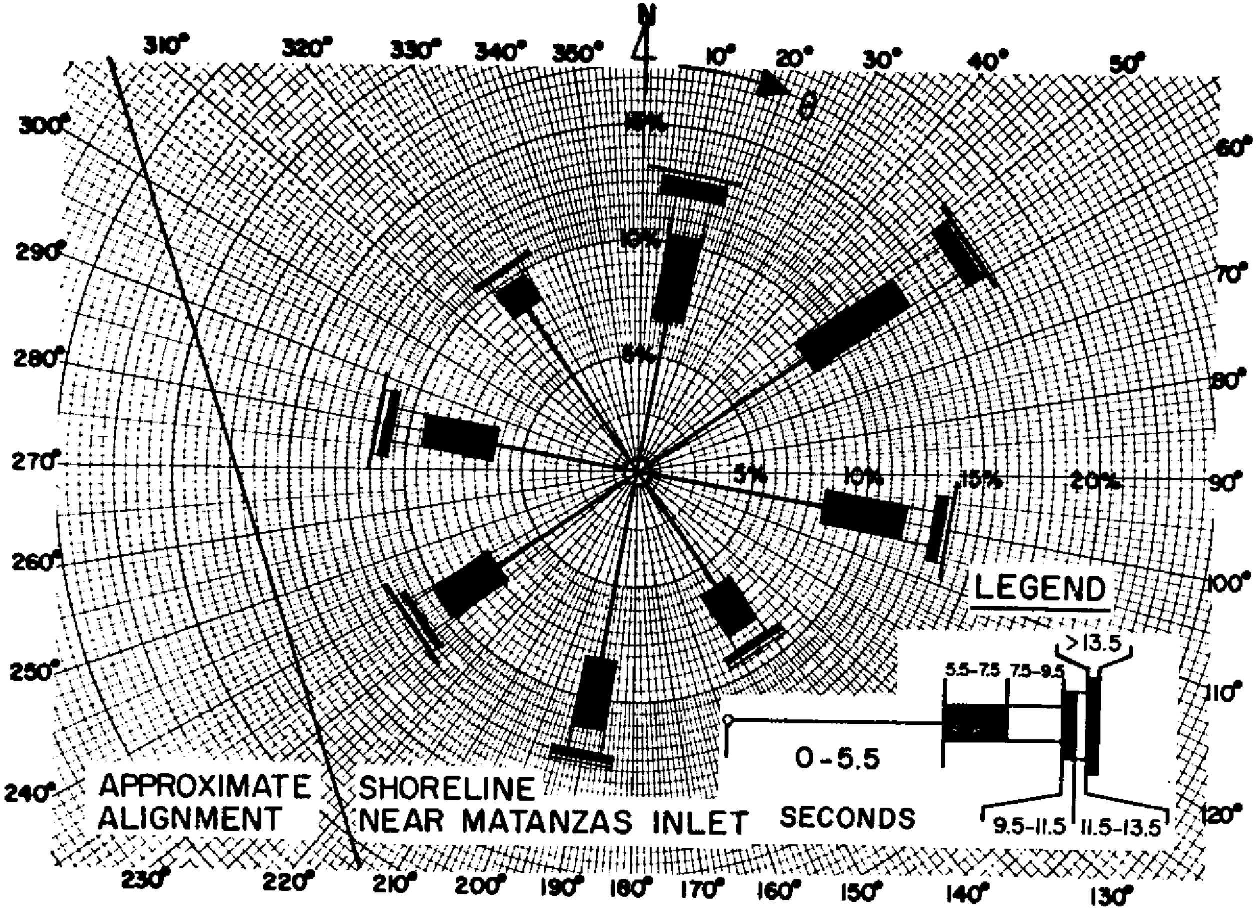


Fig. 7.5 Wave Period Rose For Offshore Wave Climate SSMO Data Square No. 11 - Annual

From Walton (1973).

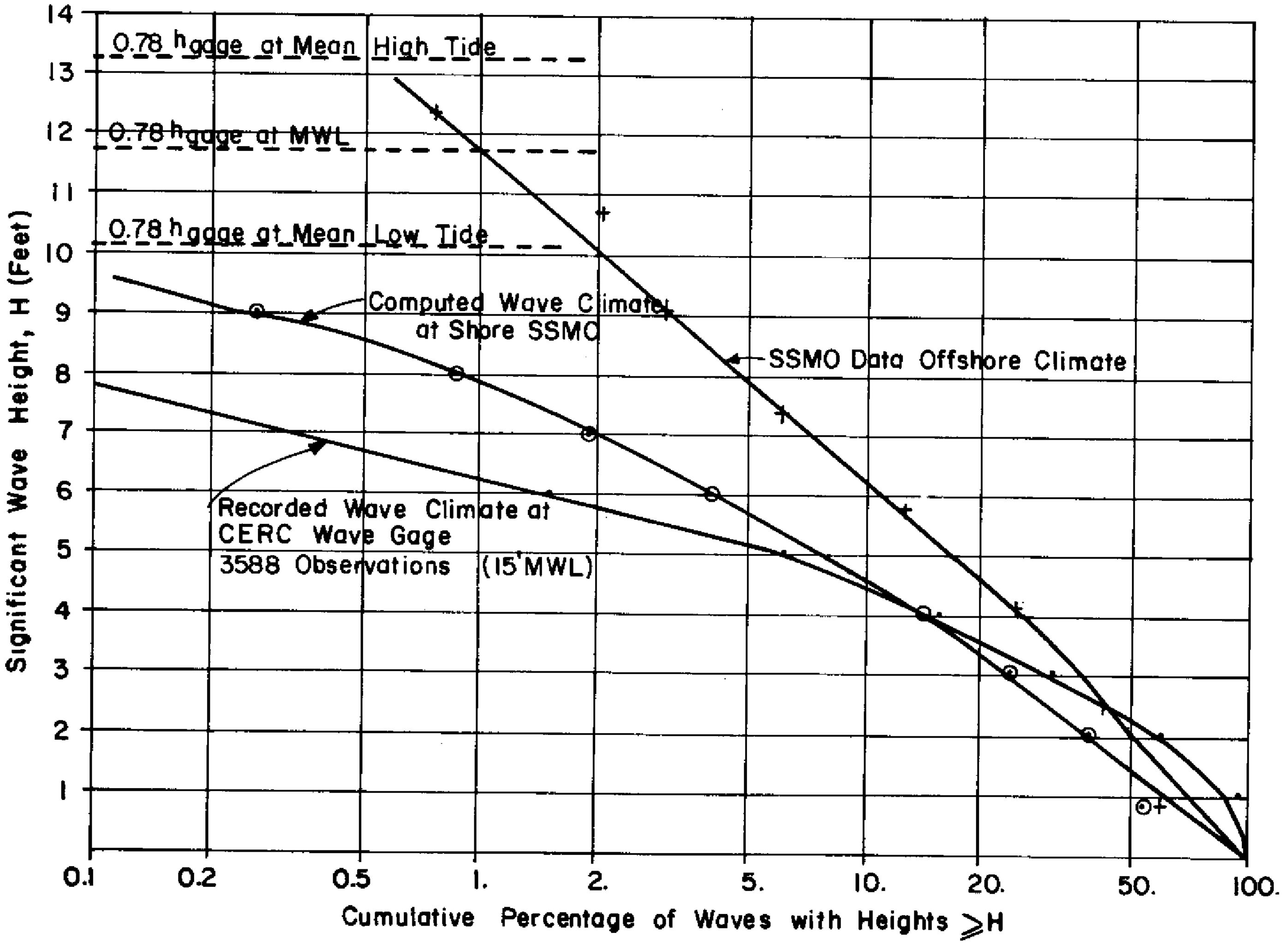


Fig. 7.6 Wave Height Comparison - Daytona Beach
From Walton (1973).

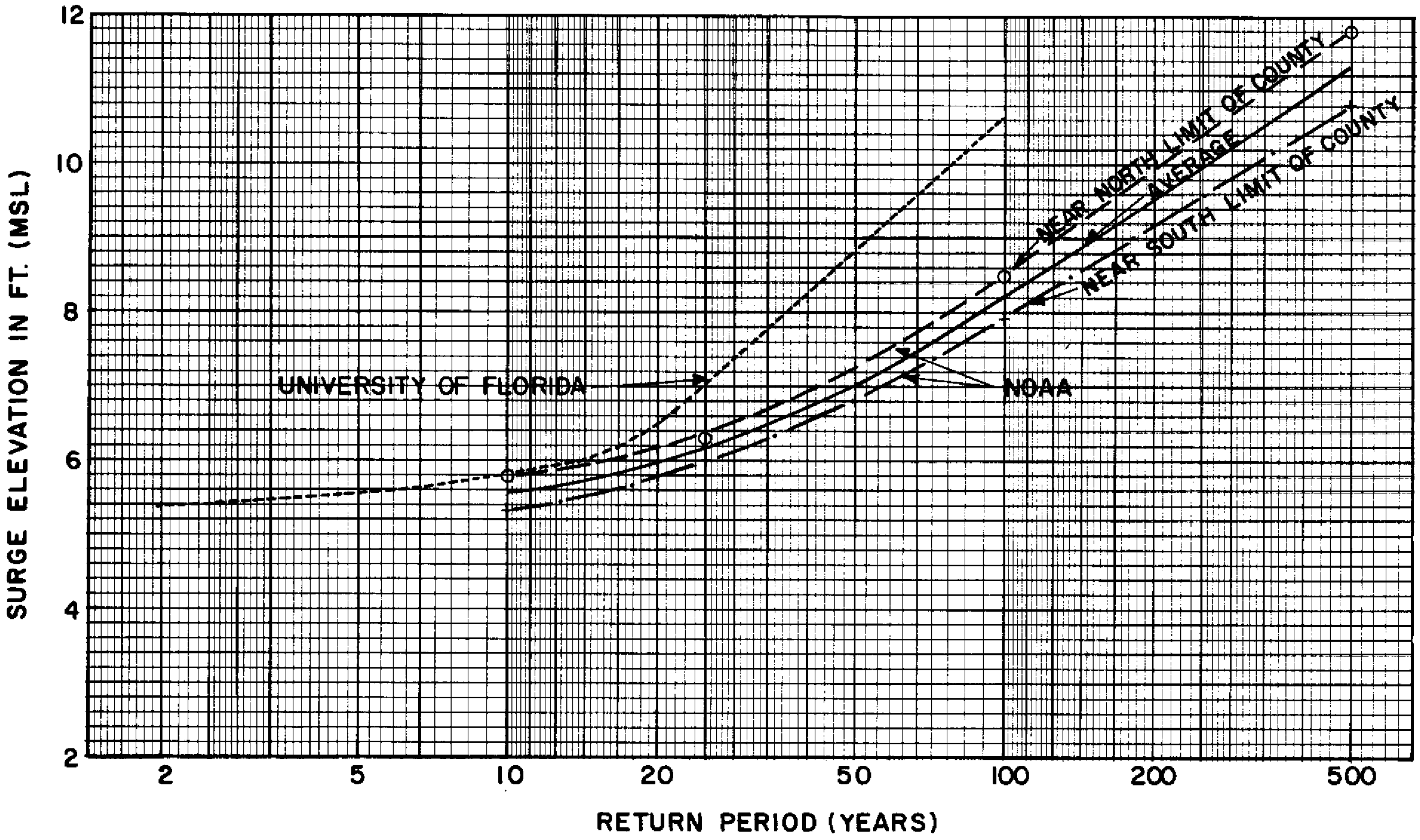


Fig. 7.7 Storm Surge Frequencies - St. Johns County
From UF/COEL (1973).

$$\nu = \frac{V_{max}}{\sqrt{2a_0 g}} \tag{7-2}$$

Where T = tidal period

$2a_0$ = ocean tide range

A_c = inlet throat cross section

A_b = bay surface area

f = Darcy-Weisbach friction factor

W_c = surface width at the throat

L_c = length of an equivalent inlet with a cross section equal to the throat section of the real inlet and a head loss due to friction as in the real inlet (O'Brien and Clark, 1973, 1974).

K_{en}, K_{ex} = entrance and exit loss coefficients for the inlet

V_{max} = maximum cross sectional average current through the inlet

g = acceleration due to gravity

a. Evaluation of L_c

Prior to deriving the relationship between K and ν it is necessary to determine L_c in Eq. (7-1). Section 7.5 yields the following values:

T = 12.5 hours

$2a_0$ = 5.69 ft

A_c = 9,766 ft^2

A_b = 1.11 x 10^8 ft^2

W_c = 1,092 ft

g = 32.2 ft/sec^2

Note that the bay surface area A_b was obtained in Section 7.4 by dividing the spring tidal prism by the spring range of tide in the bay. The A_b thus obtained is an effective value over which the bay tide rises and falls in phase, i.e., the water surface is horizontal at all times. The existance of such a bay is assumed in Keulegan's computations. The following values will be assumed:

$K_{en} + K_{ex}$ = 1 (O'Brien and Clark, 1973, 1974)

f = 0.025 (a reasonable value)

These values are sufficient to evaluate L_c from Eq. (7-1) provided a value of K is determined independently. Note that the average lag ε = 78 min from Section 7.5. Thus:

$$\varepsilon = 78 \times \frac{360°}{T} = 37.2°$$

From Keulegan's (1967) report, $\varepsilon = 37.2°$ corresponds to $K = 0.86$. Substitution of this value of K and the other parameters specified above in Eq. (7-1) gives $L_c = 16{,}020$ ft. This value of L_c is considerably larger than the real length (on the order of 3,000 ft) of the inlet as may be deduced from an aerial photograph of the inlet.

b. Evaluation of the relationship between K and ν.

In Eq. (7-1), substitution of the values of all the parameters except A_c yields

$$K = 3.07 \times 10^{-4} A_c \left\{ \frac{1}{1 + \frac{100 W_c}{A_c}} \right\}^{\frac{1}{2}} \tag{7-3}$$

and Eq. (7-2) without substituting the value of V_{max} is:

$$\nu = 0.074 V_{max} \tag{7-4}$$

Two additional relationships are needed to relate ν to K, namely:

1. A relationship between A_c and W_c. Fig. 7.8 shows the variation of W_c with A_c. The curve is the mean of many data points from unimproved tidal inlets, both real and model (Mehta, 1976).

2. The relationship between V_{max} and K. This can be obtained from Keulegan's (1967) report in which a dimensionless velocity V'_{max}, which is related to V_{max} according to

$$V_{max} = \frac{2a_0\pi}{T} \frac{A_b}{A_c} V'_{max} \tag{7-5}$$

   is given as a function of K.

The procedure is to select an A_c, obtain W_c from Fig. 7.8, substitute these in Eq. (7-1) and obtain a K; go to Keulegan's relationship in his report and obtain V'_{max}. Then Eq. (7-5) gives V_{max} which is then converted to ν according to Eq. (7-4). In Fig. 7.9 a relationship is thus obtained by selecting a range of A_c values from 1,500 ft^2 to 12,500 ft^2.

From Fig. 7.9 it is observed that the value of K, i.e. K_{max} at the peak value of ν is is 0.53. It can be shown (Escoffier, 1940; O'Brien and Dean, 1972) that the case in which the actual value of K for the inlet, $K_{act} > K_{max}$ implies a hydraulically stable inlet and $K_{act} < K_{max}$ means that the inlet is unstable. From Section 7.4, $V_{max} = 3.6$ fps which yields $\nu = 0.24$. Also, the same V_{max} after converting to V'_{max} with $A_c = 9{,}766$ ft^2 corresponds to $K = 0.95$, which is K_{act}. Thus $K_{act} > K_{max}$, which implies that Matanzas is a stable inlet, which confirms the known long-term stability of Matanzas Inlet.

It should be noted that the magnitude of K_{act} embodies within it the aspect concerning the sedimentary equilibrium of the inlet inasmuch as the actual throat cross-sectional area of the inlet is determined by the nature of sediment transport through the inlet. When an inlet is under a nonsilting, non-scouring sedimentary equilibrium, the throat cross section is uniquely determined by the spring tidal prism (O'Brien, 1969). Indeed, utilizing the O'Brien relationship between the prism and the throat area is tantamount to using the measured cross-sectional average maximum velocity in the computation of K_{act}. This was accomplished in the above computations.

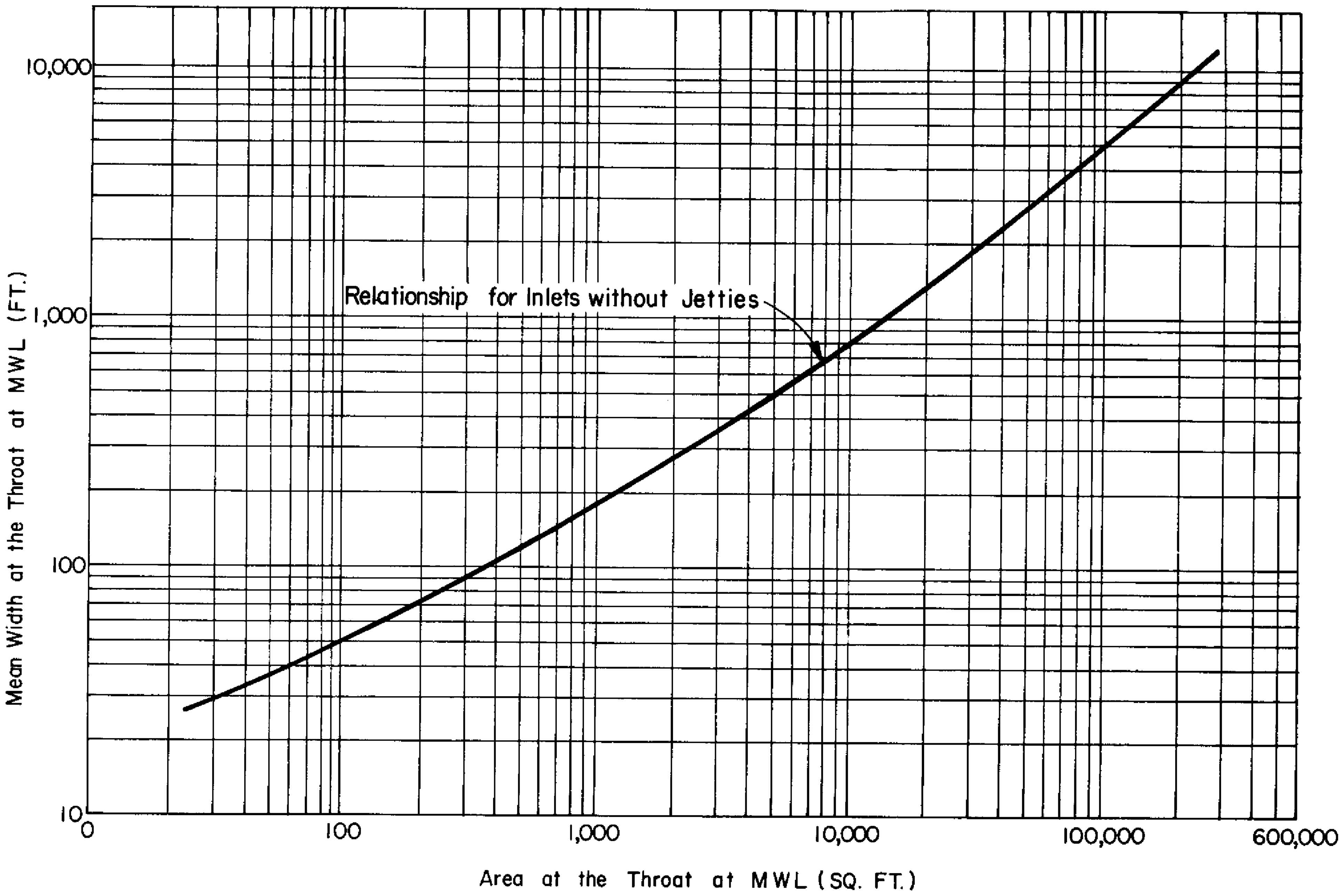


Fig. 7.8 Throat Width-Area Relationship for Unimproved Inlets.

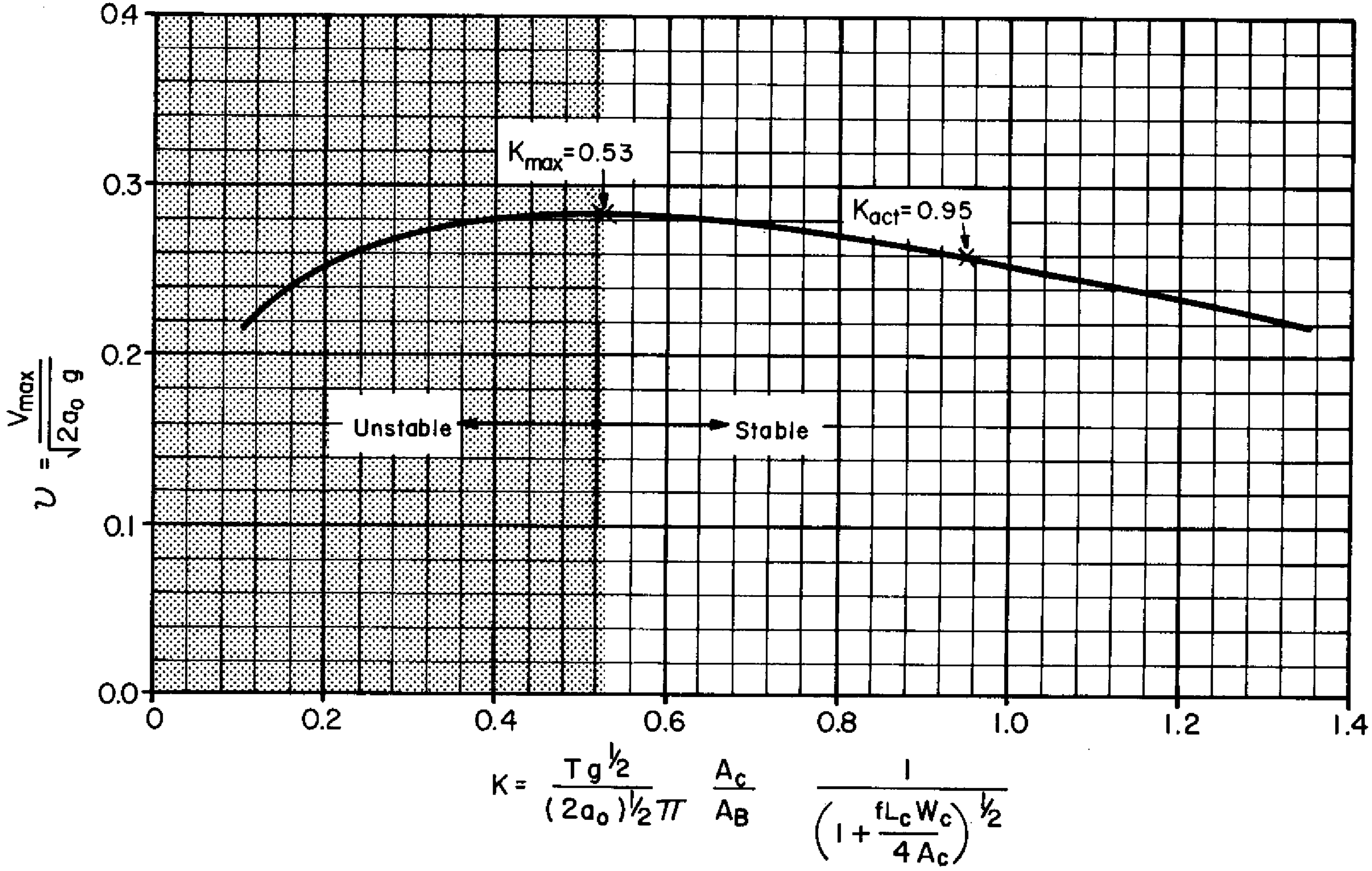


Fig. 7.9 Stability Curve for Matanzas Inlet.

VIII. SEDIMENTARY CHARACTERISTICS

8.1 Volumetric Changes

a. Outer Coast

Material presented in section 6.2 indicates that the predominant trend along the coastline, both to the north and south of Matanzas Inlet, is one of erosion. As Bruun (1962) has postulated, one reason for this trend, a statewide phenomenon, has been the eustatic rise in the sea level over the past century. Since 1870 the elevation of the mean sea level has risen approximately 0.01 ft/year. This rise tends to cause an erosion of the beach face and a landward migration of the shoreline (see also Mehta and Brooks, 1973).

Computations by the Corps of Engineers point to the movement of offshore contours toward the shoreline (i.e. a steepening of the entire profile) during the period 1923/24 to 1963/64 and a general volumetric decrease in offshore sediment within the 30 ft. contour during the same period, over a 7.5 mile stretch of the coastal region examined, as shown in Fig. 8.1. The length of the beach has been divided into six sections numbered 1 through 6. Table 8.1 gives the average recession of the indicated contours within each section. Table 8.2 shows, for the same sections, total accretion, total erosion, net volumetric change and average annual change of sand volumes. As observed from Table 8.1, the period 1923/24 to 1963/64 exhibits a net erosion for the region within the 30 ft. contour. Furthermore, comparing the recession of the 6, 12, 18 and 30 ft. contours with the recession of the shoreline over the same period from Table 8.1 shows that the contours have receded more than the shoreline, indicating a steepening of the beach. Three possible causes of such a phenomenon could be: 1) that the Anastasia formation or the presence of dune vegetation prevents the shoreline from receding as fast as the offshore profile, 2) the average wave climate has changed so that the wave steepness has increased or 3) the size of the sedimentary material on the profile has increased. One other cause could be that the ebb and particularly the flood flow patterns near the inlet have altered, causing the flow to hug the shore more closely than before. This phenomenon however, would probably not extend as far up beach and down beach from the inlet as the region selected for computations.

Fig. 8.1 shows the annual average volumetric erosion per foot of beach at each of the six sections. The additive effect of the inlet on the rate of erosion is apparent.

b. Bar Volume

The offshore bar volume at Matanzas Inlet was calculated from the 1963/64 Corps of Engineers survey map of the outer coast vicinity. Although the bathymetry was not indicated in the form of individual depth measurements, the contour lines enabled an approximate calculation to be made following the method developed by Dean and Walton (1975). The volume of sand estimated to lie in the outer bar for the 1963/64 survey was 4.4 x 10^6 cu. yds. This offshore bar volume calculation was made for that region shown in Fig. 8.2.

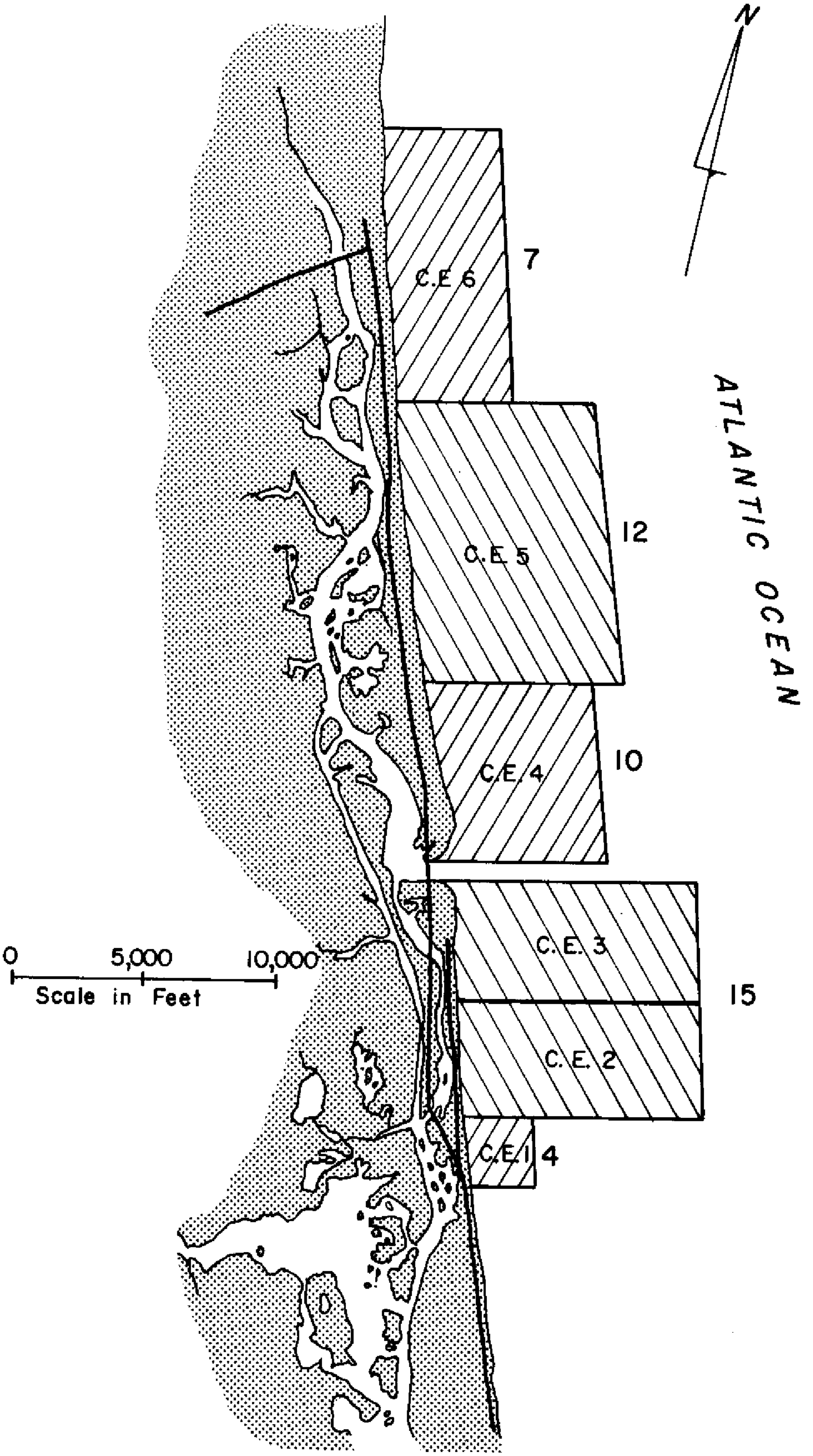


Fig. 8.1 Annual Average Volumetric Erosion along the Beach (figures are in cu. yds. per ft. of beach per year).

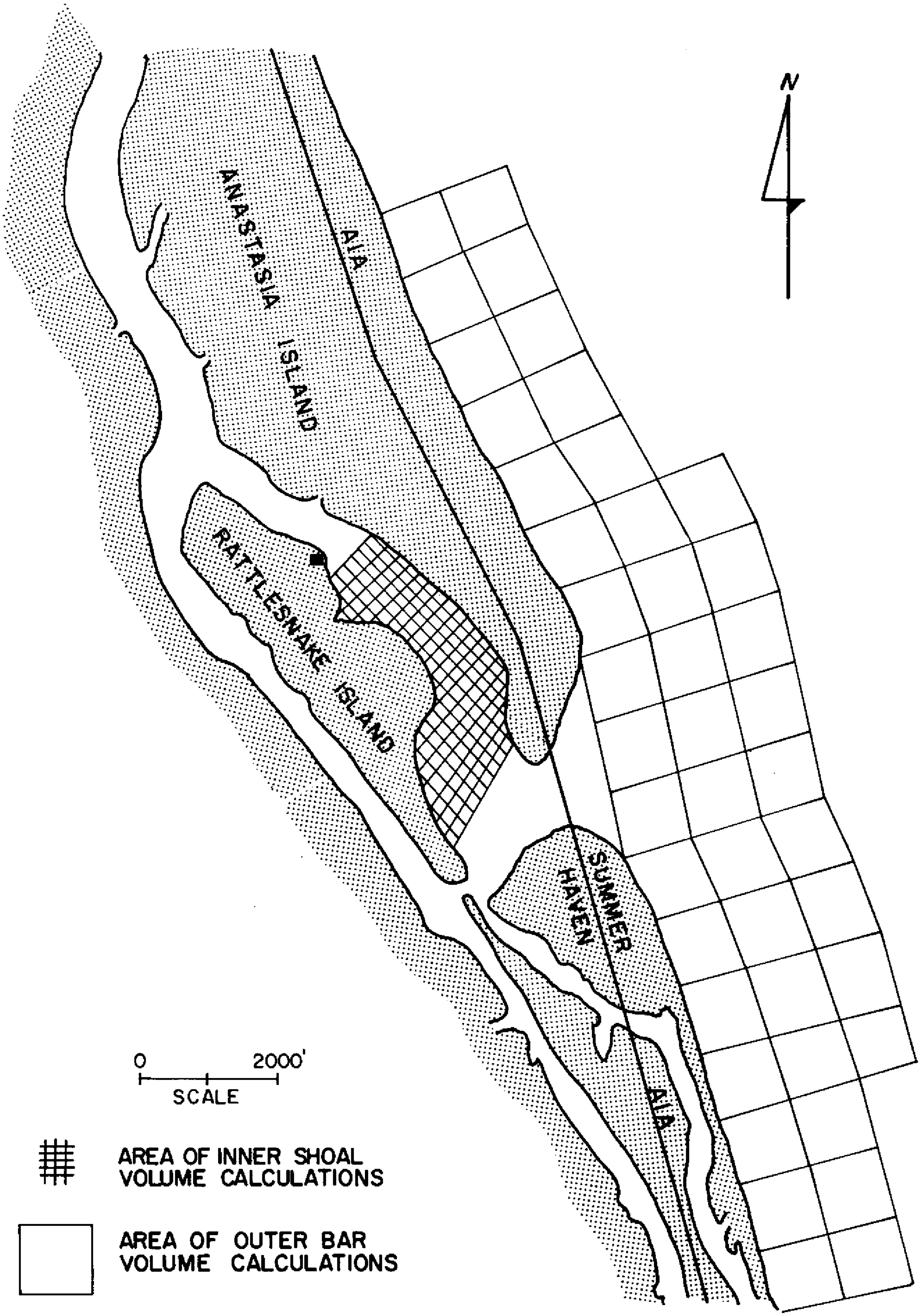


Fig. 8.2 Regions of Sand Volume Calculations.

Table 8.1

OFFSHORE DEPTH CHANGES 1923/24 TO 1963/64

Section	6 ft. Contour	12 ft. Contour	18 ft. Contour	30 ft. Contour
1	*	- 420	- 100	- 280
2	*	- 600	- 630	- 750
3	*	- 700	- 760	- 200
4	*	- 550	- 300	- 350
5	- 600	- 900	- 450	- 280
6	- 350	- 900	- 320	- 320

* No data

+ indicates progradation (east); distance measured in feet

- indicates recession (west); distance measured in feet

Above data are from Table D-3 of the "Beach Erosion Control Study on St. Johns County, Fla.," 1965.

Table 8.2

VOLUMETRIC ACCRETION AND EROSION 1923/24 TO 1963/64

Section	Total Accretion	Total Erosion	Net Change	Average Annual Net Change
1	146	631	- 485	- 12
2	0	3,338	-2,672	- 83
3	0	3,005	-3,005	- 75
4	435	2,981	-2,546	- 64
5	99	4,727	-4,628	-116
6	1,158	3,830	-2,672	- 66

+ indicates accretion, measured in 1,000 cubic yards

- indicates erosion, measured in 1,000 cubic yards

Above data are from Table D-4 of the "Beach Erosion Control Study on St. Johns County, Fla.," 1965.

Walton and Adams (1976) have shown that a relationship exists between the outer bar volume and the spring tidal prism for sandy inlets along highly exposed, moderately exposed and mildly exposed coastlines. Inlets on Florida's Atlantic coast fall into the second category and the relationship determined was

$$\rlap{\,-}V = 10.5 \times 10^{-5} P_s^{1.23} \qquad (8\text{-}1)$$

where $\rlap{\,-}V$ = outer bar volume in cubic yards

P_s = spring tidal prism in cubic feet.

The spring tidal prism for Matanzas Inlet was determined to be 5.00×10^8 ft.^{3} (see section 7.4a). For this value of P_s, the above relationship predicts $\rlap{\,-}V = 5.2 \times 10^6$ cu. yds., which is close to the measured value.

c. Inner Shoals

Dean and Walton (1975) have also proposed a method by which changes in the inner shoal volumes within an inlet can be determined if hydrographic surveys of an area have been made over a period of time. The change in accumulated shoal sediments was calculated for the region in the north arm of Matanzas River indicated in Fig. 8.2 over the period 1943 to 1973 using Corps of Engineers surveys. The calculations show that approximately 3.54 x 10^5 cu. yds. of material had accumulated during that 30 year period. It is not known if the majority of this accumulation occurred before or after the breakthrough at Rattlesnake Island in 1964, but as noted in section 7.4 (a), the rather significant reduction in the flow velocity through the north arm of the river since 1964 must have greatly increased the rate of shoaling in the north arm.

An examination of the data in Table 5.1 indicates the following rates of shoaling

Table 8.3

RATES OF SHOALING

Location	Period	Rate (cu. yds./yr)
Intracoastal Waterway	1953-64	99,000
Intracoastal Waterway	1964-73	40,000
Matanzas River (north arm)	1964-73	59,000

The rate of shoaling in the north arm is computed as the difference between the rate of shoaling in the waterway during 1958-64 and that during 1964-73. Because of the somewhat limiting assumptions involved in making such a computation, the numbers should be considered as first approximations only. The actual yearly rate in the north arm probably varied as the shoals steadily developed since 1964.

The impact of the flow reduction on the transport capacity of the flow through the north arm of Matanzas River may be viewed quantitatively in terms of the comparison between the maximum bed shear stress before and after the breakthrough and the critical bed shear stress for incipient motion of the sand. The shear stresses computed in Table 8.4 are based on the following data:

Spring maximum current velocity at fort, 1974 = 1.13 fps (USGS)

Friction factor f = 0.025 (assumed)

Median sand grain size = 0.45 mm (Table 8.6)

Percent reduction in prism due to breakthrough = 80 (section 7.4(a)).

Table 8.4

ESTIMATED BED SHEAR STRESSES IN THE RIVER NEAR THE FORT

Bed Shear Stress	(psf)
Critical value for sand motion	0.0086
Maximum before breakthrough	0.20
Maximum after breakthrough (in 1974)	0.0080

It is observed from Table 8.5 that prior to the breakthrough the maximum bed shear stress was greater than the critical value and therefore the flow was capable of transporting the sand through the north arm. However, the maximum bed shear stress dropped below the critical value as a result of the breakthrough, thus prohibiting the flow from transporting the sand even when the currents were maximum. This clearly seems to account for the sand accumulation in the north arm.

8.2 Littoral Material Balance

Fig. 8.3 shows a control volume encompassing the offshore region surrounding the inlet. The boundaries of the region have been selected as follows. The western boundary passes through the throat section of the inlet. The eastern boundary is in the offshore region parallel to the shoreline. The north and the south boundaries are normal to the beach at points 6.5 miles north and 6.5 miles south of the inlet. These boundaries are at sufficient distances from the inlet such that the influence of the latter on the beach configuration may be considered to be negligible. The stretch of the beach between the north boundary and the inlet is relatively straight and the normal to the beach subtends a 75° angle relative to the north, as observed in Fig. 8.4. The normal to the relatively straight beach south of the inlet subtends an angle of 69°.

With reference to the subscripted rate of littoral drift, Q, in Fig. 8.3, the following material balance may be expressed for the control volume.

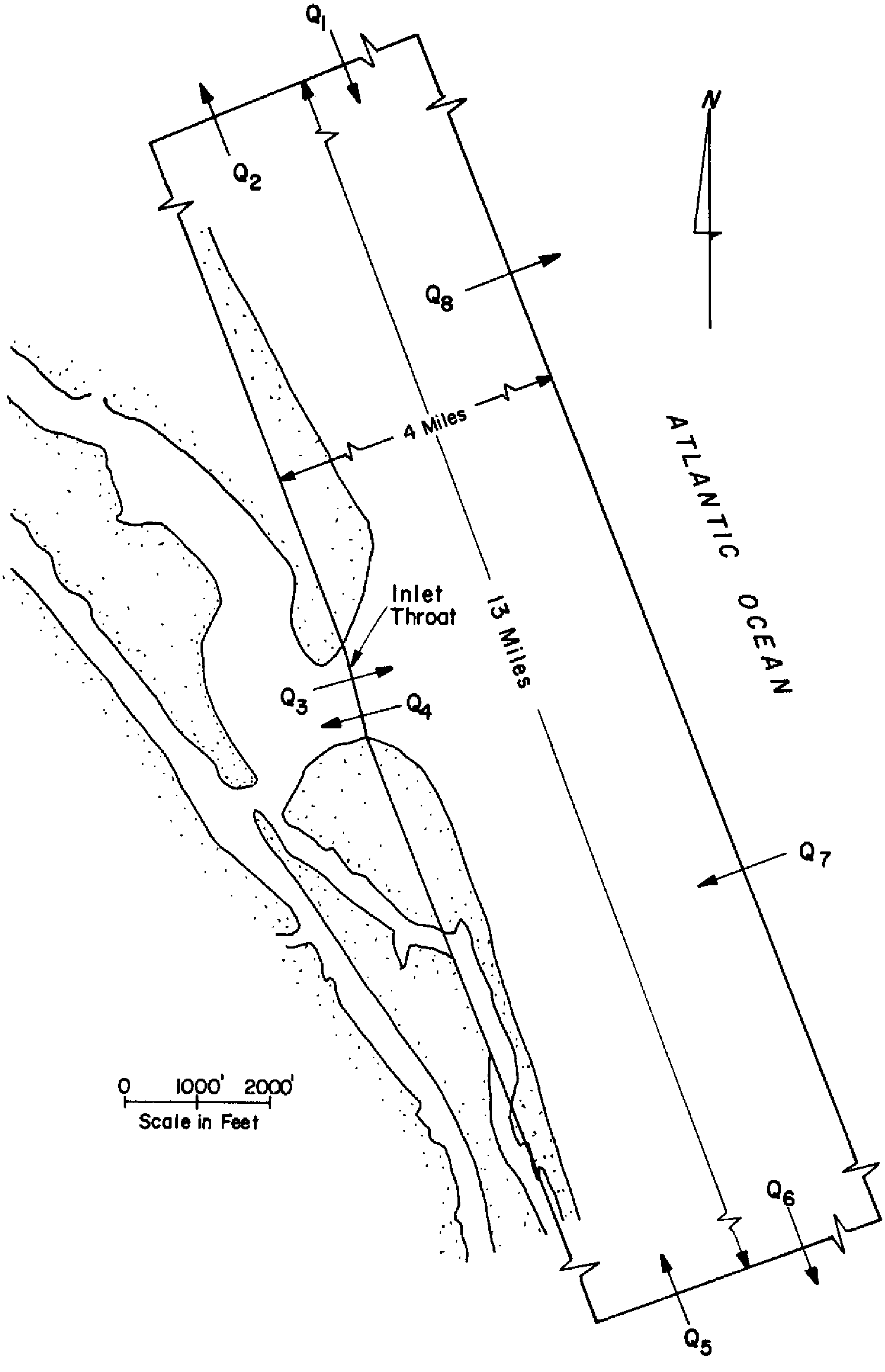


Fig. 8.3 Control Volume for Material Balance Calculations.

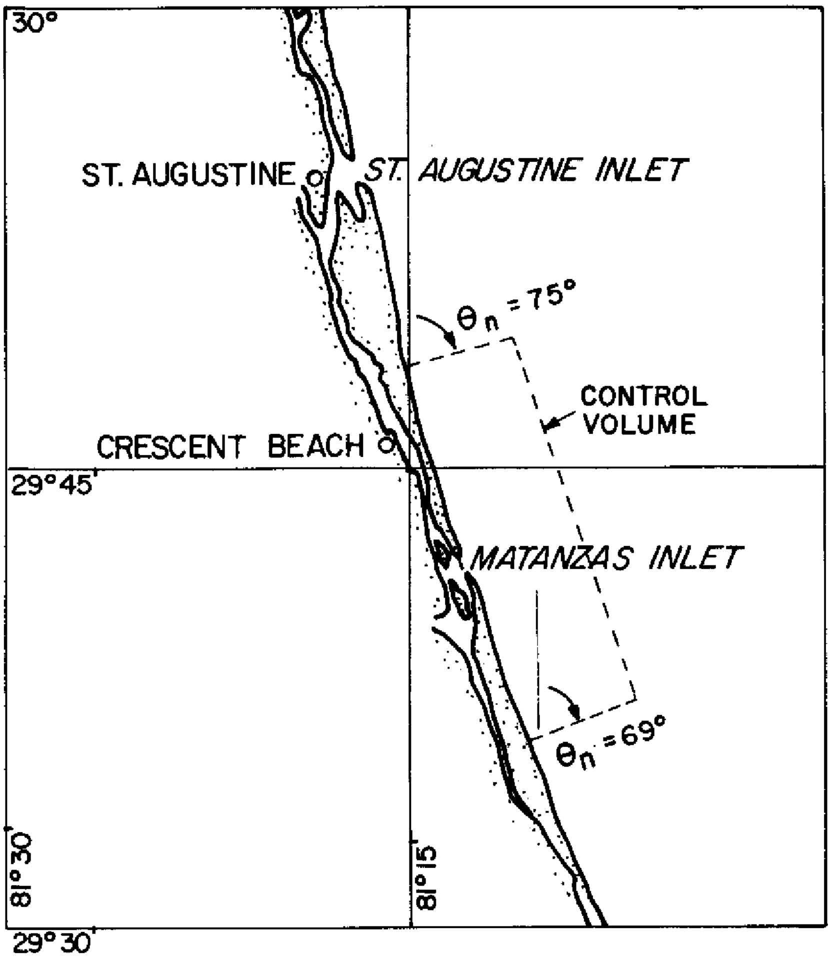


Fig. 8.4 Control Volume and Average Shoreline Orientations.

$$\frac{\Delta \forall}{\Delta t} = Q_1 + Q_3 + Q_5 + Q_7 - (Q_2 + Q_4 + Q_6 + Q_8) \qquad (8\text{-}2)$$

Where $\Delta \forall$ is the change of sediment volume within the control volume over a time period Δt. In the following, it will be assumed that the volume change $\Delta \forall$ over the 13 mile long section is not significant. This implies that even though there may be local changes in the bathymetry, the sediment is redistributed (e.g. some may have moved from the beach to the offshore region) in such a manner that the total volume of sediment in the control volume has not changed significantly over a period Δt which may be considered to be on the order of two or three decades. If the 60 ft. depth contour is chosen as the eastern boundary, the transport of sediment across this boundary, which would be approximately 3 to 4 miles offshore, is probably negligible. Therefore Q_7 and Q_8 may be assumed to be equal to zero. The rates Q_1, Q_2, Q_5 and Q_6 may be estimated from the littoral drift rose computations by Walton (1973), based on the indicated shoreline orientations shown in Fig. 8.4. The difference $Q_4 - Q_3$ may be estimated as follows. Calculations in section 8.1 show an average yearly increase in the inner shoals of the inlet to be 11,800 cu. yds. over the period 1943 to 1973. The figures from Table 5.1 indicate an average dredging rate 59,458 cu. yds. per year along the Intracoastal Waterway in the Matanzas Inlet vicinity between 1958 and 1973. If it is assumed, as a first approximation, that all of this dredged material was introduced through Matanzas Inlet and that the majority of the inner shoal volume increase occurred in the region shown in Fig. 8.2, then the total yearly amount of material captured by the inlet (equal to the yearly volume of inner shoal growth plus the yearly dredged material) is 71,258 cu. yds. This is $Q_4 - Q_3$. (Note that some sand accumulation has also occurred at the junction of the south arm of Matanzas River with the bay-like region of the inlet, near the location of the breakthrough. However, the accumulated volume in this region is probably not significant compared to that in the indicated region). Estimates of the various volumetric rates Q are given in the following table.

Table 8.5

VOLUMETRIC TRANSPORT RATE ESTIMATES FOR MATERIAL BALANCE

Quantity	Amount (cu. yds./year)	Source of Data
Q_1	557,000	Walton (1973)
Q_2	308,000	Walton (1973)
$Q_4 - Q_3$	71,258	See computation above
Q_5	306,000	Walton (1973)
Q_6	498,000	Walton (1973)
Q_7	0	Assumption
Q_8	0	Assumption

With $\Delta \forall = 0$, Eq. (8-2) may be expressed as

$$Q_4 - Q_3 = Q_1 + Q_5 + Q_7 - Q_6 - Q_8 \tag{8-3}$$

Let I be the left hand side of Eq. (8 - 3) and II be the right hand side, then with numbers from Table 8.5,

I = 71,258

II = 57,000.

I and II are observed to be comparable and account for the material balance (Eq. (8-3)) for the control volume.

A point of interest is to compare the littoral drift rates calculated from the figures in Table 8.5 with those cited by the Corps of Engineers. If Q_1 and Q_6 are averaged (resulting in an average southerly drift in the inlet vicinity) and if Q_2 and Q_5 are averaged (resulting in an average northerly drift in the inlet vicinity), both net and gross littoral drift rates are obtained. The net and gross drift rates obtained from Table 8.5 are 220,500 cu. yds./year south and 834,500 cu. yds./year. The Corps of Engineers (1965) cites a net drift rate in the vicinity of the southern St. Johns County coastline of 400,000 to 500,000 cu. yds./year south, which does not compare well with the above figure of 220,500 cu. yds./year. However, the gross rate of drift is estimated to be on the order of 700,000 cu. yds./year, which compares well with the figure calculated above-834,500 cu. yds./year.

8.3 Sedimentary Characteristics

a. Grain size

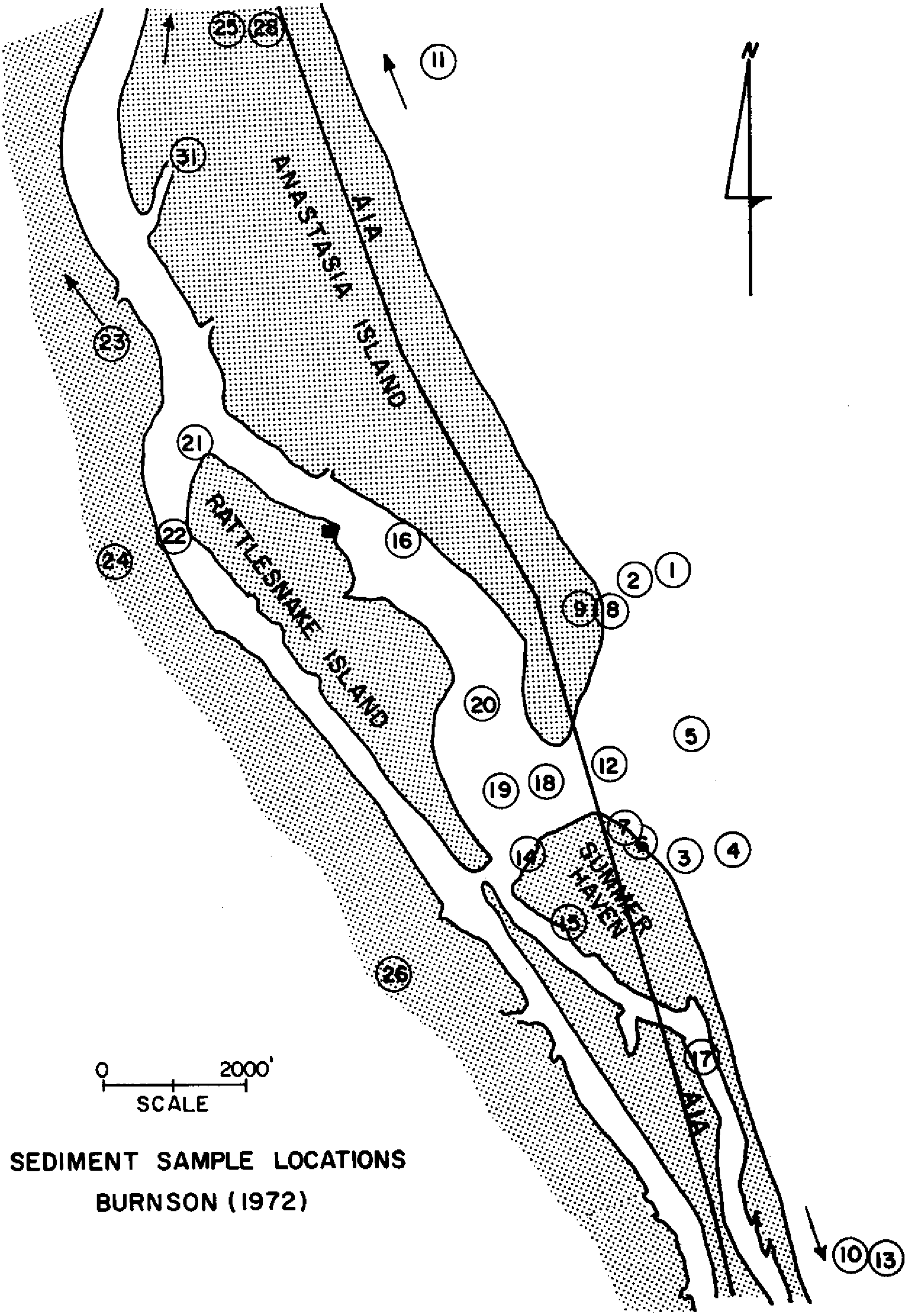
Between August 1971 and February 1972, Burnson (1972) collected sediment samples throughout the Matanzas Inlet area. Those sample points near the inlet are shown in Fig. 8.5 and combined results of his investigation are shown in Table 8.6. The average of the median diameters of the sediment samples was computed for those sample locations offshore, on the beaches, within the lagoon, and in the tidal marsh areas and is presented in Table 8.6 as average D_{50}. A sorting coefficient $S_0 = \sqrt{D_{75}/D_{25}}$ is also presented, as is the percent shell for selected samples. Several important results obtained from these data are discussed below:

Table 8.6

SEDIMENT GRAIN CHARACTERISTICS IN THE INLET VICINITY

Sample Points	Location	Ave. D_{50} (mm)	S_0	% Shell
1- 5	Offshore	0.18	1.13-1.21	
6-13	Beaches	0.36*	1.09-1.41*	32-33
14-22	Lagoon	0.45	1.10-1.77	22-87
22-28	Marsh	0.19	1.10-1.23	3-5

* 3 samples yielding anomalous results have been omitted.



SEDIMENT SAMPLE LOCATIONS
BURNSON (1972)

Fig. 8.5.

1) The average sediment grain size tends to be the largest inside the lagoon and on the beaches - the areas of highest energy.

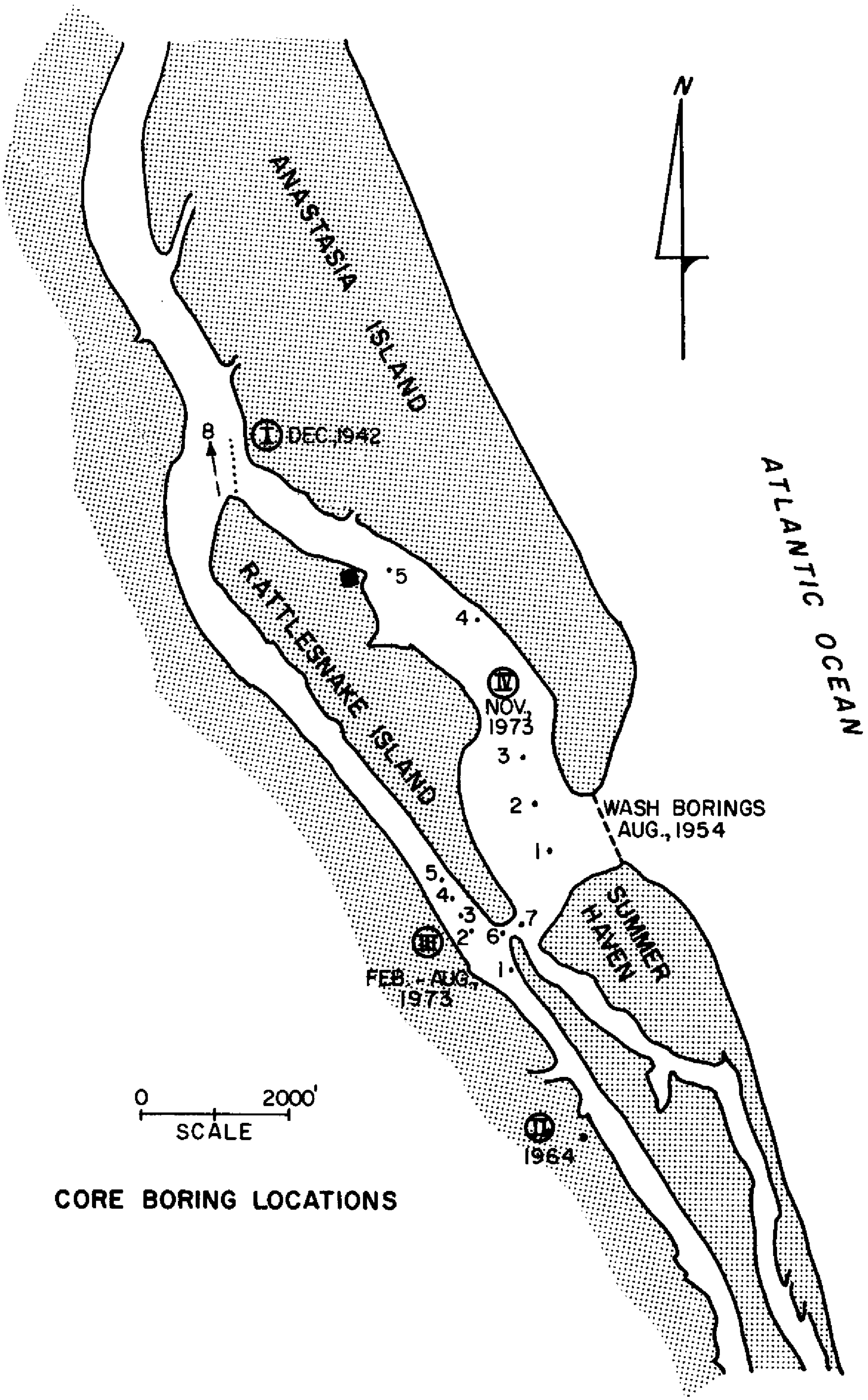
2) The samples tend to be more sorted in the offshore area and within the tidal marshes. The beach samples are moderately well sorted while the samples in the lagoon are relatively poorly sorted.

3) The percentage of shell in the samples tended to correlate well with the median sediment grain size and the degree of sorting. The marsh samples contain the lowest percentage of shell - 3 to 5 percent, while the lagoon samples contain 22 to 87 percent shell, the latter occurring on the seaward face of the lagoonal bar. Those samples obtained on the beaches to either side of the inlet contain 32 to 33 percent shell. The shell present was found to consist mainly of reworked shell fragments from the Anastasia formation and mollusk shells. The other main constituent of the sediment samples was a medium to fine quartz sand.

b. Boring

Core borings in the area include those taken in 1942, 1965 and 1973. The first group, taken by the Corps of Engineers in December 1942, is designated "I" on Fig. 8.6. These borings were taken in conjunction with the current measurements mentioned in section 7.3. Along with other field work done by the Corps of Engineers in 1964, core borings were taken in the St. Johns County area to determine the availability of suitable material for beach renourishment purposes. One such boring was made in the Matanzas Inlet vicinity and is designated "II" on Fig. 8.6. Those borings designated as "III" on the figure were made by the Corps of Engineers in conjunction with the surveys of the breakthrough on Rattlesnake Island. Some borings were also taken at this time in the north arm of the Matanzas River, the proposed site for the dredging of a relief channel upon the planned closure of the breakthrough (Corps of Engineers, 1976). This group is designated "IV" on Fig. 8.6.

The borings at I indicate the presence of 4 to 14 ft. of sand mixed with some clay. Only boring 6 indicated the presence of shell (underlain by sand and clay). None of these borings penetrated beyond a depth of 20 ft. below MLW. The boring at II showed predominantly sand of median diameter 0.15 mm with some clay present. The Corps of Engineers study (1965) went on to conclude, "The materials penetrated by the one boring in the area contained a high percentage of unsuitable material. A dredged fill obtained from that area would probably contain at least 30 percent clay and silt." Boring 1 through 5 of group III indicate the predominance of fine sand mixed with some silt and shell to depths of 20 ft. below MLW. Borings 6 and 7, whose depths of penetration were 29.5 ft. below MLW and 41.5 ft. below MLW, indicate the presence of clay from 19.2 to 22 ft. and below 41 ft., respectively. The results of wash borings taken in 1954 prior to the construction of the new inlet bridge are presented in Fig. 8.7.



CORE BORING LOCATIONS

Fig. 8.6

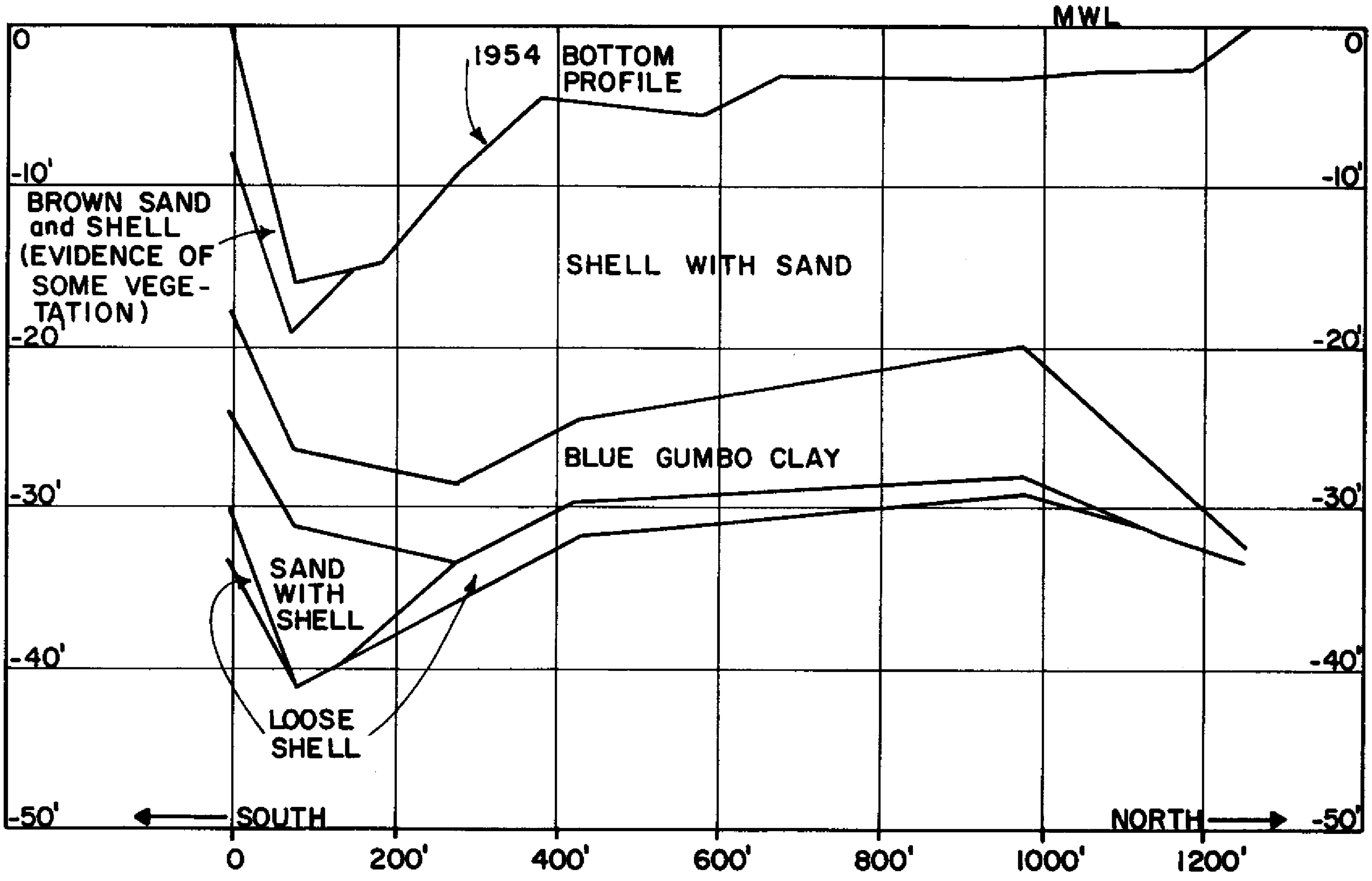


Fig. 8.7 1954 Wash Boring Results (SRD).

IX. SUMMARY

It has been the purpose of this report to compile historical, geological, climatological, morphological, hydraulic and sedimentary information about Matanzas Inlet. It must be noted here that many of these characteristics, especially hydraulic and sedimentary, are subject to changes, both long-term and short-term, the latter arising with such events as the occurrence of the breakthrough at Rattlesnake Island and its current closure, among others. The information contained herein is intended to summarize past conditions, not to predict those that might occur in the future. Some of the more important information contained in this report is summarized below:

1) Matanzas Inlet is a natural inlet approximately 13 miles south of St. Augustine, Florida and has remained open and remarkably stable at least for the past four centuries and probably for a much longer period.

2) Fort Matanzas, on Rattlesnake Island, north of the inlet, was built by the Spanish in 1742 and declared a national monument in 1924.

3) The rock formation underlying the inlet is the Anastasia formation, a Pleistocene feature, and it is overlain by mixed Holocene sands.

4) The inlet vicinity experiences relatively mild winters and long, relatively humid summers. The mean daily temperature at St. Augustine (between 1940 and 1970) was 69.6° F., but the temperature at the inlet may be 1° to 2.5° F cooler. The average yearly rainfall at St Augustine (between 1940 and 1970) was 47.39 in.

5) The storm data on record predict that a hurricane will pass within 50 miles of the inlet approximately once every 7 years; a hurricane will pass within 150 miles of the inlet approximately once every 3 years. Dora, in 1964, was the last hurricane to cause major changes in the area.

6) The portion of the Florida East Coast Canal in the vicinity of Matanzas Inlet was constructed around 1885. This canal later came under the jurisdiction of the Florida Inland Navigation District and the U.S. Army Corps of Engineers.

7) The construction of the Matanzas Relocation Cut west of Rattlesnake Island in 1932 changed the island's configuration and altered the course of the Intracoastal Waterway.

8) Rattlesnake Island was breached west of the inlet in 1932 and was closed in 1935 with a steel sheet-pile dike. This dike was breached by Hurricane Dora in 1964 and is presently being closed.

9) There has been a general trend of shoreline accretion north of the inlet and shoreline recession south of the inlet. However, there has been volumetric erosion along the offshore profiles, both to the north and south of the inlet. The combined result is a steepening of the offshore profile in the inlet vicinity.

10) Measurements in September 1976 indicate that the throat section is approximately 950 ft. wide at MLW and that the cross sectional area below MWL at the throat is approximately 8,800 sq. ft. The throat section apparently lies west of the Matanzas Inlet Bridge.

11) Hydraulic and tidal measurements during July 1974 indicate the following:

Spring ocean tide range = 5.69 ft.
Spring bay tide range = 4.47 ft.
Average spring max. cross sectional velocity = 3.26 fps.
Average spring tidal prism = 5.00×10^8 cu. ft.
Bay area = 1.11×10^8 sq. ft.
Average lag of slack water = 78 min.

12) Stability calculations indicate that the inlet is hydraulically stable.

13) The average annual dredging rate along the Intracoastal Water way in the inlet vicinity decreased from 99,000 cu. yds./year (1958-1964) to 40,000 cu. yds./year (1964-1973).

14) The outer bar volume is estimated to be 4.4×10^6 cu. yds. (1963).

15) Material balance calculations show that the inlet "captures" only a minor portion of the littoral drift moving past the inlet. Estimates of the gross drift rate at the inlet range from 700,000 to 834,500 cu. yds./year. Estimates of the net drift rate range from 220,500 to 400,000-500,000 cu. yds./year in the southerly direction.

16) The average median sediment grain diameter at four locations are as follows:

offshore - 0.18 mm., marsh - 0.19 mm.,
beaches - 0.36 mm., lagoon - 0.45 mm.

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The Florida Sea Grant Program is supported by award of the Office of Sea Grant, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, contract number 04-6-158-44055, under provisions of the National Sea Grant College and Programs Act of 1966. The Florida Sea Grant Program was initiated in 1972 with three major components: applied marine research, education, and advisory services.

This public document was promulgated at a cost of $1980.90 or 99 cents per copy, to provide current information to persons interested in the management, use, and control of Florida's coastal inlets.

State University System of Florida Sea Grant Reports are published by the Marine Advisory Program which functions as a component of the Florida Cooperative Extension Service, John T. Woeste, dean, in conducting Cooperative Extension work in Agriculture, Home Economics, and Marine Sciences, State of Florida, U.S. Department of Agriculture, U.S. Department of Commerce, and Boards of County Commissioners, cooperating. Printed and distributed in furtherance of the Acts of Congress of May 8 and June 14, 1914.

5/2M/77

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