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Appendix B

Analytical Data – 1 Diskette

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APPENDIX C
HYDROLOGIC AND HYDRAULIC ANALYSIS

Raymark - Ferry Creek
Operable Unit No. 3
Stratford, Connecticut

Hydrologic and Hydraulic Analysis
Remedial Investigation and Feasibility Study

March 1998

US Army Corps
of Engineers

New England District

STRATFORD SUPERFUND SITES
HYDROLOGIC EVALUATION OF AREAS OF CONCERN
STRATFORD, CONNECTICUT

1. DRAINAGE AREAS

1.1 General. Due to the widespread nature of the study area, drainage areas were delineated for each Area of Concern (AOC) identified during this investigation. These AOCs are depicted on figure 1, and the drainage areas are shown on figure 2.

1.2 Drainage Area A. Area A is the 1,330 acre watershed of Ferry Creek. It is a long narrow area extending from the tide gates and pump station at Broad Street in the south to Huntington Road and Connors Lane in the north, a distance of about 3 miles. The elevations in the watershed vary from 0 feet NGVD in the lower watershed near Broad Street to 150 feet NGVD in the northern upstream area. Elevations of potential fill areas within the Ferry Creek wetlands are generally below 10 feet NGVD.

The headwaters of Ferry Creek drain into Brewsters Pond via some intermittent streams and an extensive storm drain system. Brewsters Pond empties into Long Brook which flows southerly into Ferry Creek in the vicinity of Interstate 95 through a 6 by 10-foot box culvert. Ferry Creek flows into the Housatonic River at Broad Street. Three 72-inch diameter culverts with flap gates carry flow from upper Ferry Creek into the lower reaches of the waterway.

In the 1960s, the Corps completed feasibility level design of a hurricane barrier to protect this portion of Stratford against severe coastal storms. This barrier consisted of several dikes and pumping stations, one of which was proposed at Broad Street. During these past studies, a design flow of 800 cfs was adopted for Ferry Creek at Broad Street. This project was never constructed due to environmental concerns.

In the early 1980s, the Town of Stratford constructed a pump station at Broad Street very similar to earlier facility proposed by the Corps. The facility was designed to pump excess stormwater from Ferry Creek and downtown Stratford resulting from the town's adopted 100-year storm (design flow of 800 cfs) to the Housatonic side of Broad Street against a 25-year tide elevation (9.2 feet NGVD). Equipped with three 60-inch vertical axial flow pumps, the station is capable of pumping 360,000 gpm at a 13.7 foot head. The station is also equipped with three 168 by 84-inch hydraulic sluice gates, remote water level monitoring equipment, and an emergency generator. During tidal events above 9.2 feet NGVD, the Housatonic River overtops low areas surrounding the pump station and the pumps are incapable of pumping against the high head, making the station ineffective.

1.3 Drainage Area B. Area B consists of the extreme lower end of Ferry Creek, which is subject to tidal inflow and outflow, and Brown's Boat Yard. Of this 70 acre drainage area, about half flows into Selby Pond via overland flow, which drains to the Housatonic River through an open drainage ditch. The remainder flows in a storm drain system which drains into Ferry Creek.

The drainage area is primarily flat, residential land. Most of the flow from this area is carried to Selby Pond and Ferry Creek via the town storm drain system. Although tidally influenced, the average pond elevation of Selby Pond is about 3.6 feet NGVD. Wetlands in lower Ferry Creek and the boat yard are generally below about 5 feet NGVD.

1.4 <u>Drainage Area C</u>. Area C is a 45 acre watershed draining towards the Housatonic Boat Club. The area is mostly residential and drains through a stormdrain network to the wetlands and tidal inlet near the end of South Street. Fill areas within the boat club are generally above elevation 9 feet NGVD, however, wetland areas average between 2.5 and 3 feet NGVD.

1.5 <u>Drainage Area D</u>. This 75 acre watershed drains Area D, also referred to as Beacon Point and Birdseye Boat Launch, to the Housatonic River. Runoff from the mostly residential area drains through a storm drain system to the tidal inlet near the end of South Street. Runoff from the boat launch drains directly into the Housatonic River as overland flow. The fill and wetland areas within this AOC are generally below elevation 5 feet NGVD.

1.6 <u>Drainage Area E</u>. Area E is a 30 acre watershed located between Elm Street and the wastewater treatment plant. This area is flat and consists primarily of some limited residential development and wetlands. There are few drainage structures in this area and most of the overland flow collects in the wetland and infiltrates into the groundwater. The wetlands within area E are below elevation 5 feet NGVD.

2. TIDAL HYDRAULICS

2.1 <u>General</u>. In the study area, tides are semi-diurnal, with two high and low waters occurring during a lunar day (approximately 24 hours and 50 minutes). The resulting tide range is constantly varying in response to relative positions of the earth, moon, and sun, with the moon having the primary tide-producing effect. Maximum tide ranges occur when orbital cycles of these bodies are in phase. A complete sequence of astronomic tide ranges, approximately repeated over an interval of 19 years, is known as a tidal epoch. The total effect of astronomic tides (described above), combined with storm surge produced by wind, wave, and atmospheric pressure distributions, is reflected in actual tidal water surface elevations. Since the astronomical tide is so variable at the study area, time of occurrence of the storm surge greatly affects the magnitude of the resulting tide level.

Water levels within all of the AOCs can be impacted by stages on the tidally affected Housatonic River. Although detailed tidal information is not available at each of the sites, tidal profiles and frequency information have been developed at Stratford Point, Long Island Sound, at the mouth of the Housatonic. This information is presented in tidal profiles as developed by the Corps of Engineers in September 1988 and shown in figures 3 and 4. Table 1 lists pertinent tide frequencies and elevations from the profiles.

Table 1

Estimated
Tidal Datum Planes
Stratford, Connecticut

(Estimated from correlation with the Bridgeport, CT, National Ocean Service tide gage data and the Corps of Engineers Tidal Flood Profiles, New England Coastline, dated September 1988)

Tide Event	Tide Level (feet NGVD)
100-Year Frequency Flood Event	10.1
50-Year Frequency Flood Event	9.6
September 1938 Hurricane	9.3
Hurricane Carol, 1954	9.3
11 December 1992 Storm	9.3
31 October 1991 Storm	8.6
10-Year Frequency Flood Event	8.5
Maximum Astronomic High Water	6.3
1-Year Frequency Flood Event	5.7
Mean Spring High Water	4.5
Mean High Water	4.1
Mean Tide Level	0.7
National Geodetic Vertical Datum	0
Mean Low Water	-2.7
Mean Lower Low Water	-2.9
Mean Spring Low Water	-3.2

In addition to the detailed tide information presented in table 1, tidal datum information published by the National Ocean Survey for the Housatonic River at the I-95 bridge are presented in table 2.

Tidal datums for Long Island Sound are located 1 to 1.5 miles downstream of the AOCs. Tidal datums for the I-95 Bridge are located 1 to 1.5 miles upstream. These tide events compare well and are generally within two tenths of a foot, therefore, the tidal frequency curve for Long Island Sound was adopted for the AOCs. These adopted tidal frequencies are shown in figure 5.

Table 2

Estimated Tidal Datum Planes
I-95 Bridge, Housatonic River
Stratford, Connecticut

Tide Event	Tide Level (feet NGVD)
Mean Higher High Water	4.4
Mean High Water	4.1
Mean Tide Level	0.8
National Geodetic Vertical Datum	0
Mean Low Water	-2.5
Mean Lower Low Water	-2.8

3. RAINFALL RUNOFF ANALYSIS

3.1 Interior Rainfall Runoff. Peak rates and volumes of runoff were estimated for each AOC. Since the drainage area for AOC-A is relatively large 1,330 acres and somewhat complicated with an extensive stormdrain system and upstream storage in Brewsters Pond, detailed hydrologic modelling was performed to determine runoff rates (see section b).

One and 6-hour rainfall values shown in table 3, were obtained from U.S. Weather Bureau Technical Paper No. 40. The 1-hour value was used in the rational formula to compute the peak runoff rates for AOCs B through E for the various frequencies.

Table 3

Rainfall Frequencies

Frequency (years)	1-Hour (inches)	6-Hour (inches)
2	1.3	2.4
5	1.7	3.1
10	2.1	3.6
25	2.4	4.1
50	2.6	4.3
100	3.0	5.1

The drainage areas of AOCs B through E are relatively small (less than 75 acres) and flat, therefore, the rational formula was adopted. Table 4 shows the adopted rational formula data for these drainage areas. Runoff coefficient "C" values are based on the highly permeable soils in the area with consideration given to the amount of urbanization within the watershed.

Table 4

Rational Formula Data
for AOCs B through E

Data Type	AOC-B	AOC-C	AOC-D	AOC-E
Drainage Area (acres)	70	45	75	30
Runoff Coefficient (C)	0.50	0.40	0.40	0.40

Table 5 lists the computed runoff from AOCs B through E for the selected return interval events.

Table 5

Peak Runoff Rates

Frequency (years)	Flow (cfs)			
	AOC-B	AOC-C	AOC-D	AOC-E
2	45	23	39	16
10	74	38	63	25
25	84	43	72	29
50	91	47	78	31
100	105	54	90	36

3.2 Drainage Area A (Ferry Creek). Runoff hydrographs were developed for this drainage area using the Corps of Engineers HEC-1 Flood Hydrograph Package. The area was divided into sub-basins, for which runoff was estimated using the kinematic wave modelling technique. This technique was adopted because it allows inclusion of the storm drain system into hydrograph development.

Rainfall values similar to those used for the rational formula were used in the model. Flows into Brewsters Pond were routed through reservoir storage using the modified Puls technique. As determined by the Maguire Group during development of FEMA's Flood Insurance Study, Brewsters Pond has a capacity of about 30 acre-feet at spillway crest. This pond appears to significantly attenuate flows from the upper 220 acres of the drainage area. The estimated peak 100-year inflow to the pond was 110 cfs, however, peak outflow was reduced by about 30 percent to 75 cfs and occurred 30 minutes after the peak inflow.

Flow in Tanners and Long Brook, and Ferry Creek, were routed through the channel reaches using the Muskingum-Cunge technique. This technique allows attenuation of the flow hydrograph based on channel characteristics. Table 6 presents the peak runoff for each event at the I-95 culvert and at the Broad Street tide gates.

Table 6

Peak Runoff Rates from AOC-A

Frequency (years)	Flow (cfs)	
	I-95 Culvert (1,120 acres)	Broad Street (1,330 acres)
2	60	70
10	280	315
25	440	460
50	530	590
100	690	770

Peak 100-year flows of about 360 cfs at Stratford Square (Long Brook at U.S. Route 1) and 770 cfs at the Broad Street tide gates were adopted for this study. These flows compare well with the reported Flood Insurance Study flows of 330 and 758 cfs at Stratford Square and Broad Street, respectively. In addition, the flows compare well with the 800 cfs adopted during earlier Corps hurricane barrier design.

FEMA's 10 and 50-year discharges at Broad Street of 518 and 691 cfs, respectively, are considerably higher than the flows of 315 and 590 cfs presented in this study. The computed flows at Stratford square compare well between the two studies, therefore, the difference in total discharge comes from differences in runoff rates from the lower watershed (Tanners Brook and the lower Ferry Creek watershed). Based on the relatively flat nature of the lower portion of this drainage area, we believe the lower flow rates are more representative and were adopted for this analysis.

From the published flood profiles, it appears that during significant storm events, depth of flow in Ferry Creek between I-95 and Broad Street is quite deep. During FEMA's 10-year flood, a depth of about 11.5 feet is expected. This depth increases rather uniformly to 13 feet during a 100-year flood. Although we believe that the 10 and 50-year flood flows reported by FEMA are conservatively high, the impact of lower flows on the water surface elevation is minimal. The flat nature of Ferry Creek and the influence of the tide gates of Broad Street contribute to the backwater effects, resulting in profiles that would probably only be about 0.5 feet lower than those presented by FEMA.

The tide gates at Broad Street were originally designed to prevent backwater from high tides from passing upstream in Ferry Creek. Due to piping and erosion of the road embankment and conduit embedment, these gates are now ineffective. During daily high tides, flow has been observed moving upstream of the gates. As a result, average depth in Ferry Creek during normal flows appears to be 3 to 4 feet deep. These gates and the embankment may have to be repaired prior to performing any work in the river to minimize the risk of sediments moving downstream during construction activities.

4. REFERENCES

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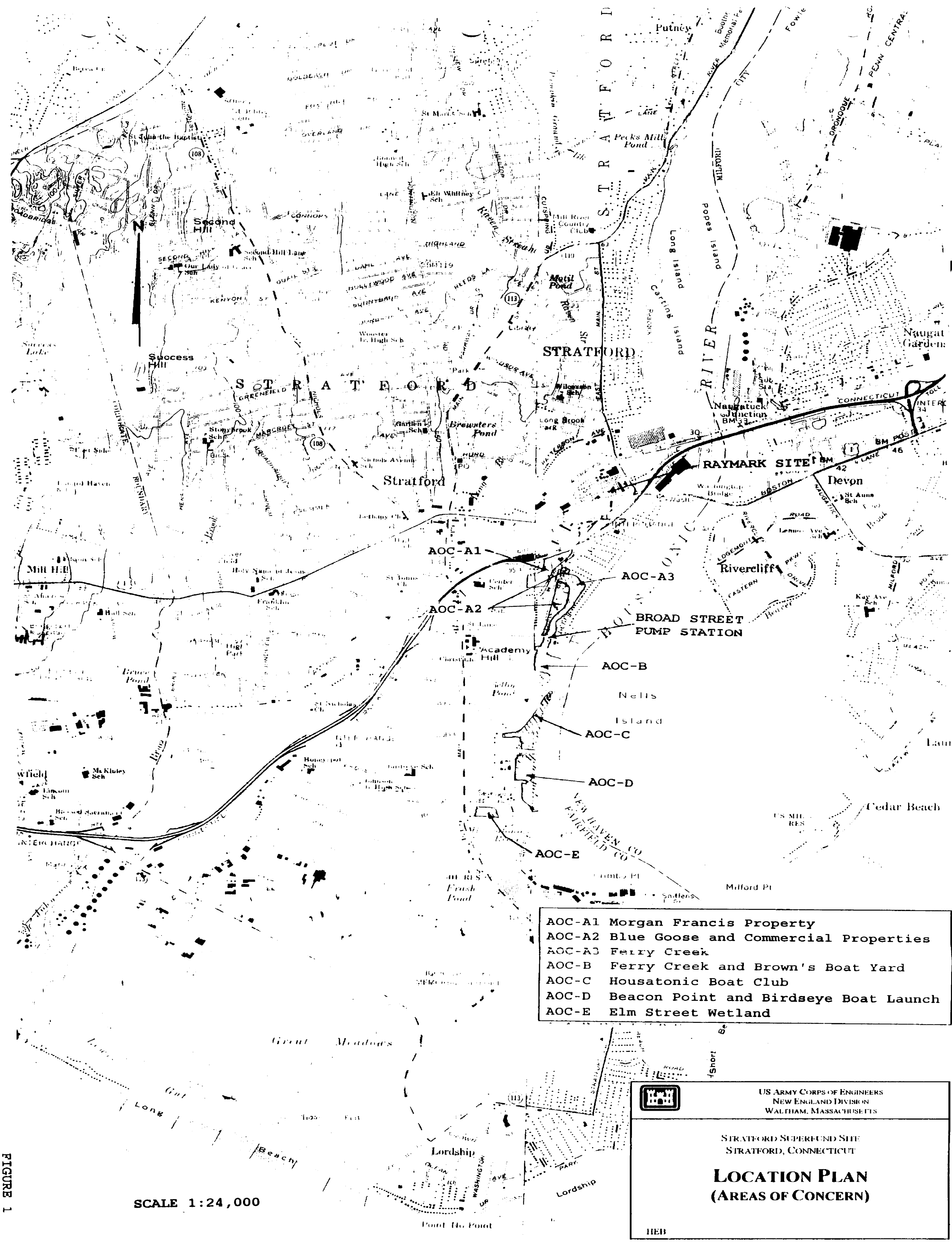
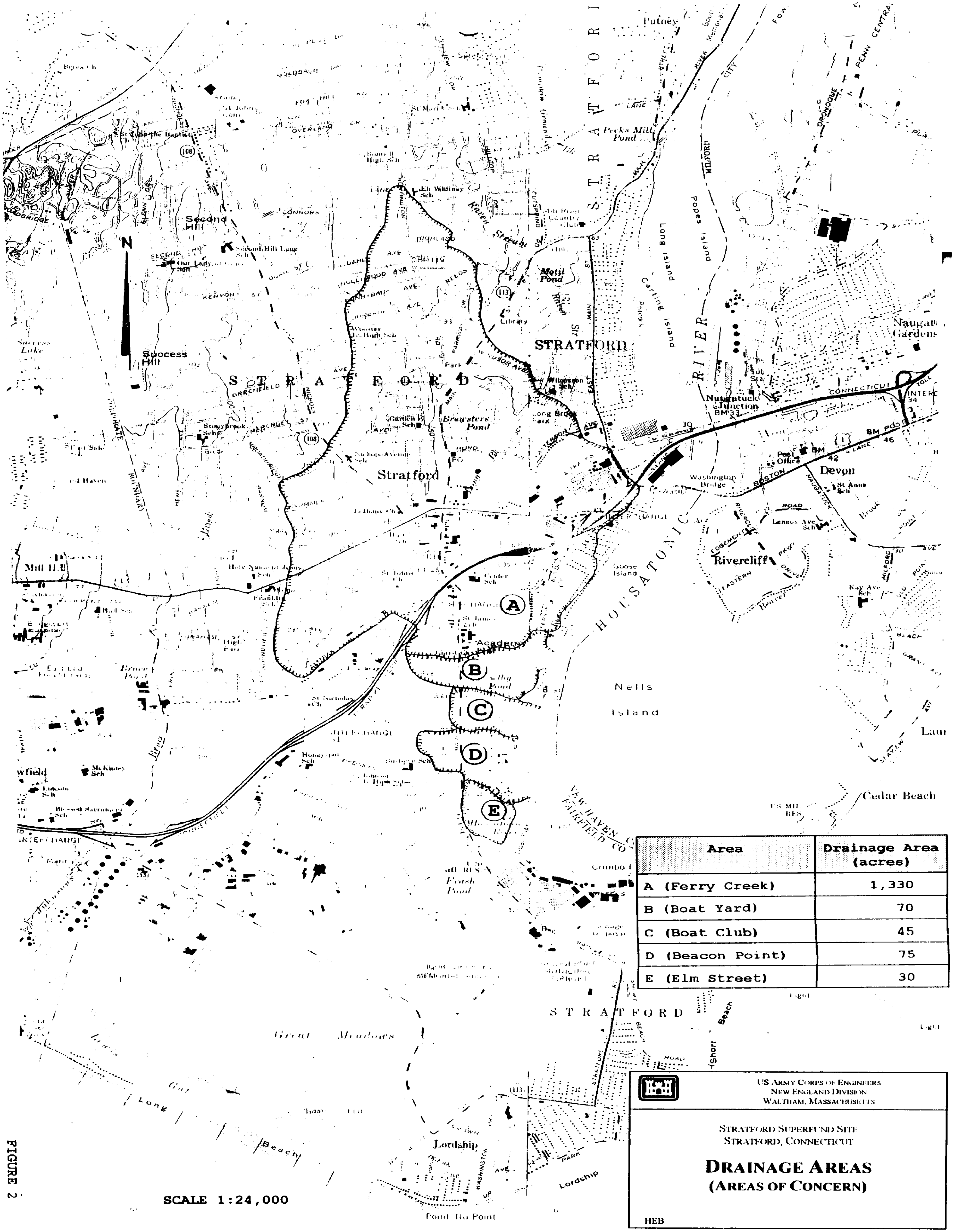

STRATFORD
S T R A T F O R D
Stratford
RAYMARK SITE
AOC-A1
AOC-A2
AOC-A3
BROAD STREET
PUMP STATION
AOC-B
AOC-C
AOC-D
AOC-E
Nells
Island
Second Hill
Success Hill
Mill Hill
Academy Hill
Rivercliff
Devon
Naugatuck Junction
Naugat Garden
Lordship
Cedar Beach
Milford Pt
Long Island
Carting Island
Popes Island
RIVER
Peck Mill Pond
Putney
Brewsters Pond
Great Meadows
Long Beach
NEW HAVEN CO
FAIRFIELD CO
N
AOC-A1 Morgan Francis Property
AOC-A2 Blue Goose and Commercial Properties
AOC-A3 Ferry Creek
AOC-B Ferry Creek and Brown's Boat Yard
AOC-C Housatonic Boat Club
AOC-D Beacon Point and Birdseye Boat Launch
AOC-E Elm Street Wetland
SCALE 1:24,000
US ARMY CORPS OF ENGINEERS
NEW ENGLAND DIVISION
WALTHAM, MASSACHUSETTS
STRATFORD SUPERFUND SITE
STRATFORD, CONNECTICUT
LOCATION PLAN
(AREAS OF CONCERN)
HEB

FIGURE 1



Area	Drainage Area (acres)
A (Ferry Creek)	1,330
B (Boat Yard)	70
C (Boat Club)	45
D (Beacon Point)	75
E (Elm Street)	30

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DIVISION
WALTHAM, MASSACHUSETTS

STRATFORD SUPERFUND SITE
STRATFORD, CONNECTICUT

DRAINAGE AREAS
(AREAS OF CONCERN)

HEB

SCALE 1:24,000

FIGURE 2

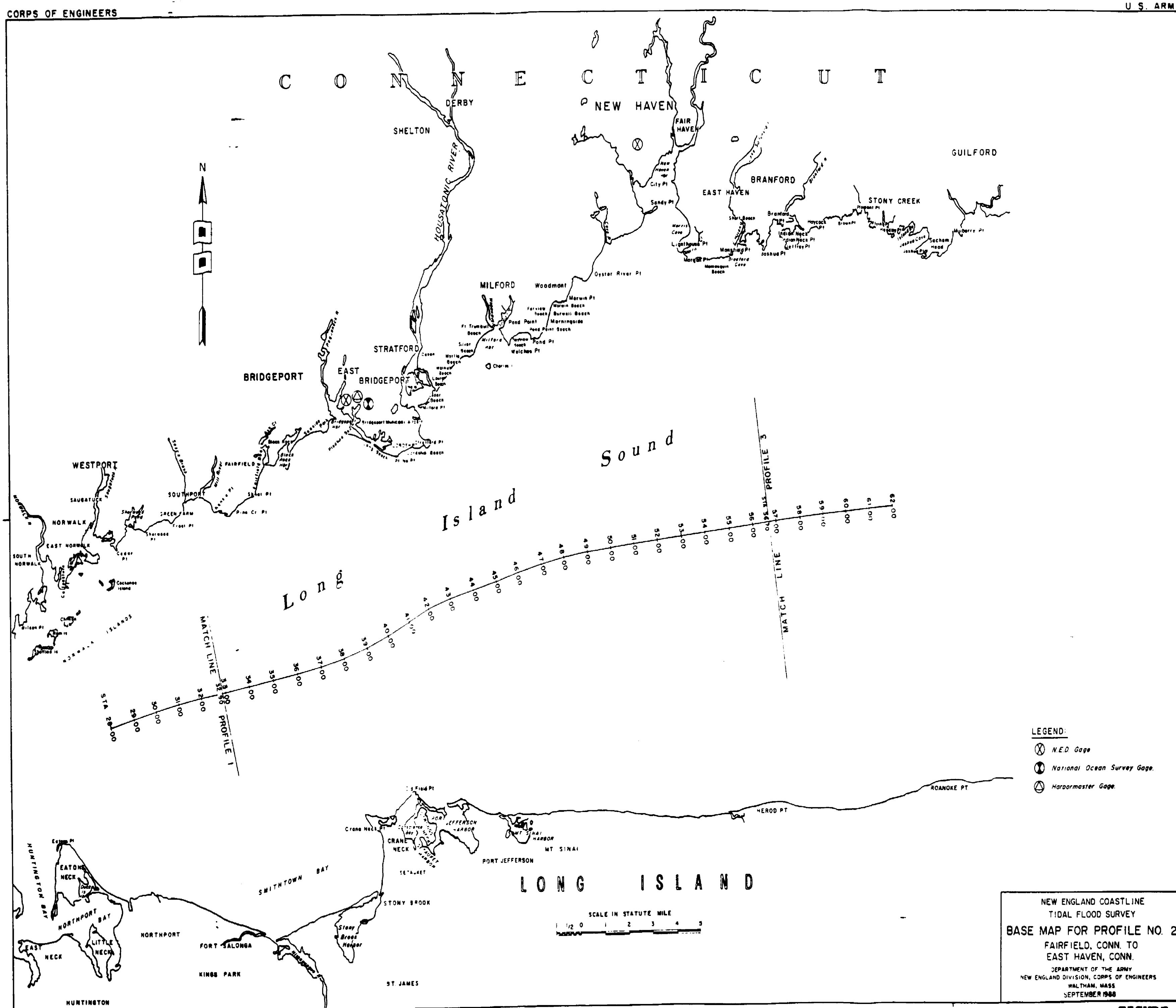
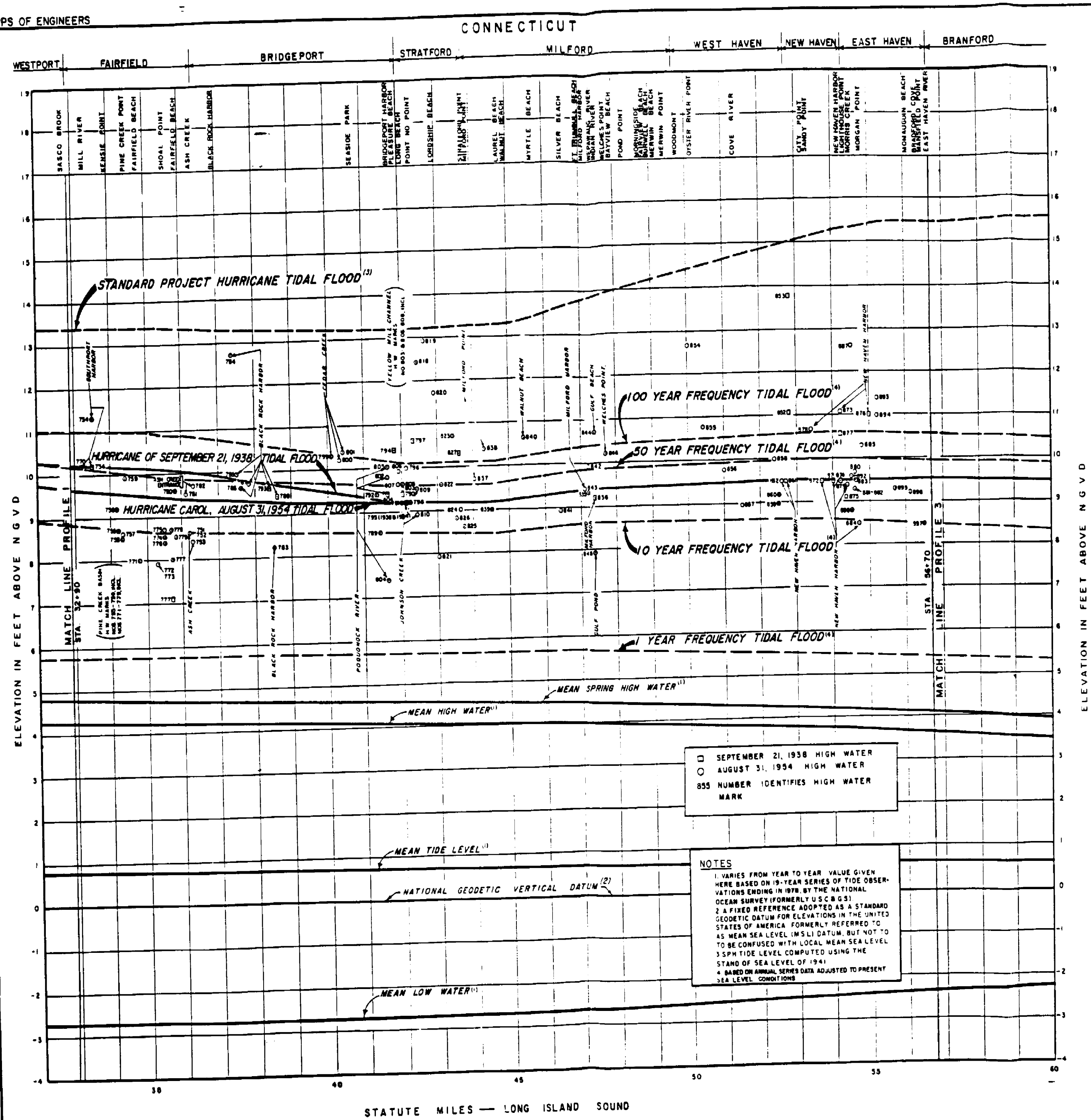

CORPS OF ENGINEERS
U.S. ARMY
CONNECTICUT
NEW HAVEN
FAIR HAVEN
DERBY
SHELTON
HOUSATONIC RIVER
GUILFORD
BRANFORD
EAST HAVEN
STONY CREEK
MILFORD
Woodmont
Oyster River Pt
STRATFORD
EAST BRIDGEPORT
BRIDGEPORT
FAIRFIELD
SOUTHPORT
WESTPORT
SAUGATUCK
NORWALK
EAST NORWALK
SOUTH NORWALK
N
Long Island Sound
MATCH LINE PROFILE 3
MATCH LINE PROFILE 1
STA 28+00
LEGEND:
N.E.D. Gage
National Ocean Survey Gage.
Harbormaster Gage.
ROANOKE PT
HEROD PT
MT SINAI
PORT JEFFERSON
CRANE NECK
Crane Neck Pt
SMITHTOWN BAY
STONY BROOK
LONG ISLAND
SCALE IN STATUTE MILE
NORTHPORT
FORT SALONGA
KINGS PARK
ST JAMES
HUNTINGTON BAY
EATONS NECK
NORTHPORT BAY
LITTLE NECK
EAST NECK
HUNTINGTON
NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY
BASE MAP FOR PROFILE NO. 2
FAIRFIELD, CONN. TO
EAST HAVEN, CONN.
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS
SEPTEMBER 1988

FIGURE 3

U. S. ARMY

CORPS OF ENGINEERS



NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY

TIDAL FLOOD PROFILE NO. 2
FAIRFIELD, CONN., TO
EAST HAVEN, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
SEPTEMBER 1988

FIGURE 4