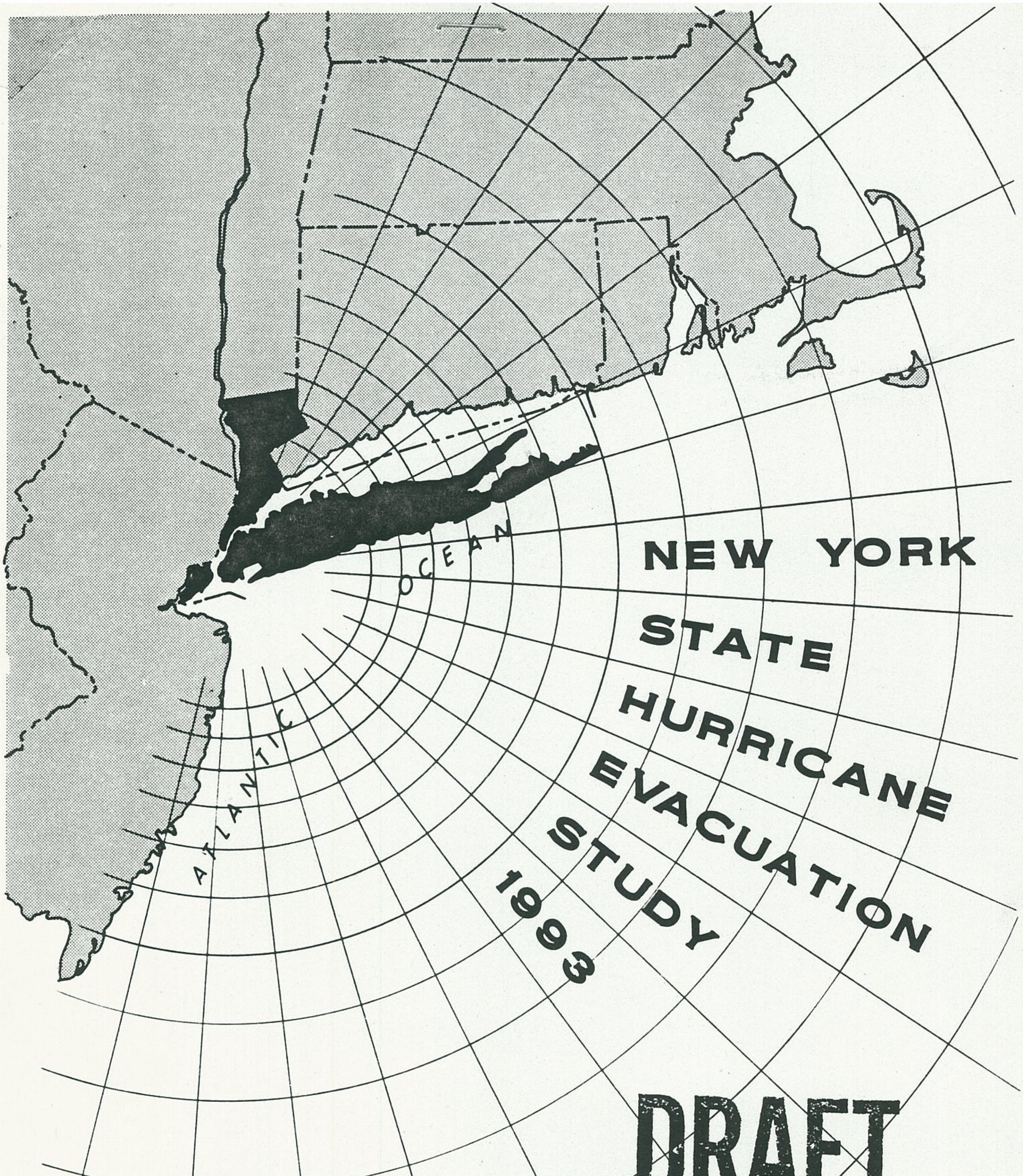
NEW YORK STATE HURRICANE EVACUATION STUDY 1993



DRAFT

Technical Data Report

New York State Emergency Management Office
Federal Emergency Management Agency
U.S. Army Corps of Engineers

TECHNICAL DATA REPORT
NEW YORK STATE HURRICANE EVACUATION STUDY

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INTRODUCTION

The Situation

The State of New York has the most densely populated coastline of any area in the United States. In some communities, a large percentage of that population does not have access to private automobiles, routinely relying on public transportation. The low frequency of occurrence of hurricanes in the region fosters a false sense of security for some public officials and for much of the citizenry. To further complicate hurricane preparedness, potential storm surges in this area are some of the highest that can be expected along the entire Atlantic coast of the United States. Many New York City metropolitan area transportation systems are vulnerable to flooding, some possibly with catastrophic consequences. All of these factors combine to present emergency management officials with the extremely difficult task of developing hurricane evacuation plans that will be reasonably safe and effective.

Purpose

Obtaining information critical to good hurricane evacuation planning requires comprehensive and specialized analyses. The fiscal and staffing limitations of state and local emergency management agencies usually preclude the development of this data. In order to provide the needed technical information, the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the National Weather Service have joined state and local emergency management agencies in New York in conducting the New York State Hurricane Evacuation Study.

The purpose of this Hurricane Evacuation Study is to furnish emergency management officials realistic data quantifying the major factors involved in hurricane preparedness. The technical data presented in this report is not intended to replace the detailed operations plans developed by New York City and each of the counties within the study area. Rather, this data is provided so that existing hurricane evacuation plans can be updated and operational procedures and decision guides can be developed to address future hurricane threats.

Funding

The New York State Hurricane Evacuation Study was funded by the Federal Emergency Management Agency and the U.S. Army Corps of Engineers. The State of New York Division of Military and Naval Affairs, State Emergency Management Office, and the National Oceanic and Atmospheric Administration, National Weather Service, generously contributed their time, coordinative skills, and expertise.

Authority

The study authority for the U.S. Army Corps of Engineers is Section 206 of the Flood Control Act of 1960 (Public Law 86-645) and for the Federal Emergency Management Agency, the Disaster Relief Act of 1974 (Public Law 93-288). These laws authorize the allocation of resources for planning activities related to hurricane preparedness.

This study was conducted by the Wilmington District, U.S. Army Corps of Engineers, which provided the project management and technical assistance in accordance with U.S. Army Corps of Engineers publication, Technical Guidelines For Hurricane Evacuation Studies, November 1984, and Federal Emergency Management Agency publication CPG 2-16, A Guide To Hurricane Preparedness Planning For State and Local Officials, December 1984.

Description of Study Area

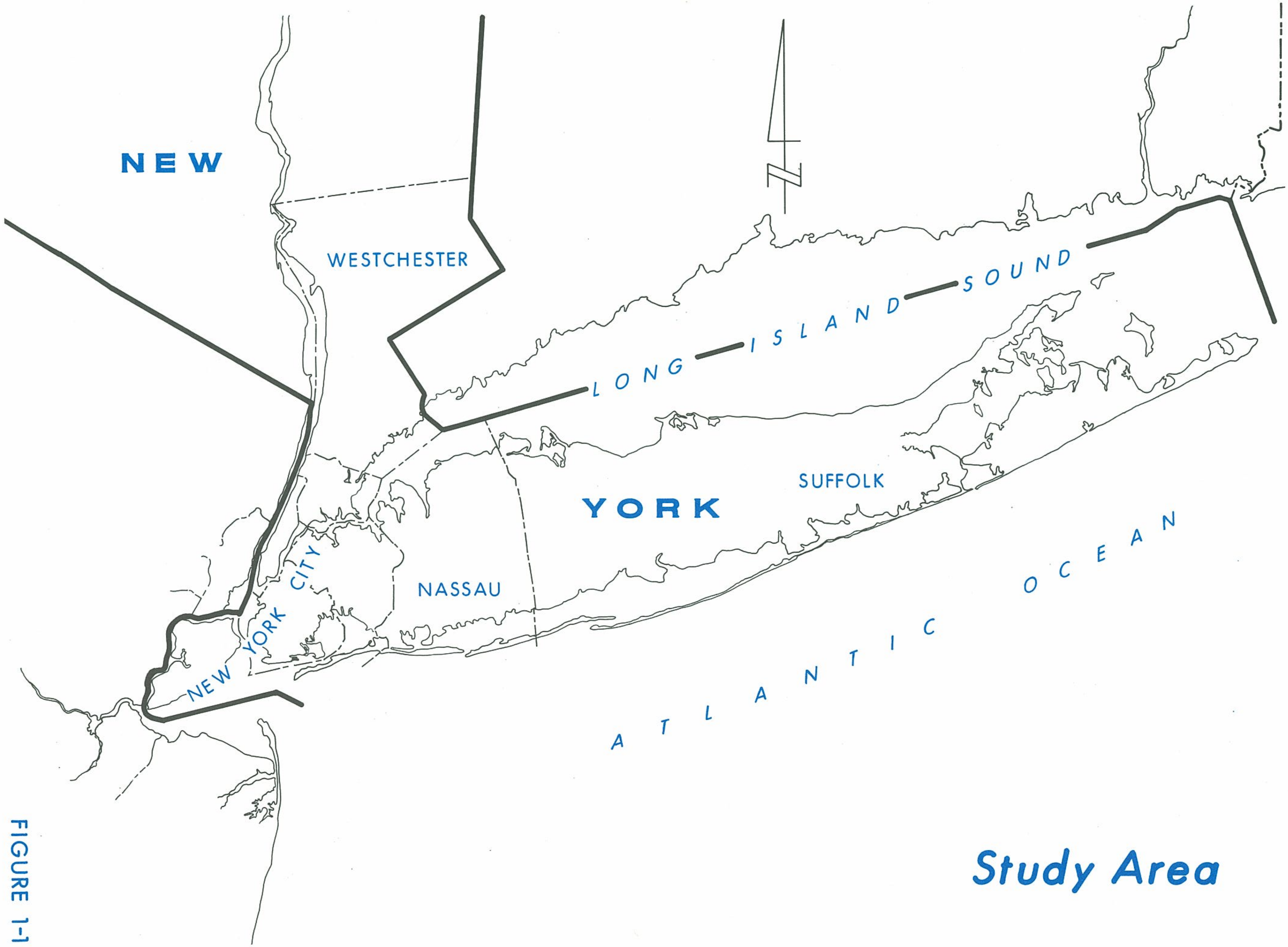
a. Geography. The New York State Hurricane Evacuation Study area includes approximately 135 miles of Atlantic coastline and 575 miles of sound/bay/riverine shoreline in New York City and Westchester, Nassau, and Suffolk Counties (figure 1-1).

The Atlantic coastline of New York State lies on two large islands: Long Island and Staten Island. Long Island, composed of the New York City boroughs of Brooklyn and Queens, Nassau County, and Suffolk County, is separated from the New England mainland by Long Island Sound and from the boroughs of Manhattan and the Bronx, to the west, by the East River. Long Island is about 120 miles long and has an area of approximately 800 square miles. Staten Island, a borough of New York City, is located in the extreme western portion of the study area. It covers 52 square miles; its maximum length and width are 14 miles and 8.5 miles, respectively. Staten Island is separated from New Jersey by Arthur Kill and Kill Van Kull and from the other New York City boroughs by The Narrows and the Upper Bay of New York Harbor.

The Harlem River divides the boroughs of Manhattan and the Bronx, and both boroughs are separated from New Jersey, to the west, by the Hudson River. Westchester County, immediately north of New York City, is bordered on the west by the Hudson River, and on the east by Long Island Sound.

There is an abrupt change in the orientation of the coastline from north-south along the New Jersey shore to east-west along the south shore of Long Island. This change in direction creates a geographic "funnel" with respect to the Atlantic Ocean; Raritan Bay and the Lower Bay of New York Harbor being located at its tip. Hurricanes with tracks that maximize the hydraulic effects of this funnel can create higher storm surges than similar storms affecting any other location along the eastern seaboard.

b. Geology and Topography. The topography of the study area is quite varied and unique, reflecting the geologic processes that have shaped the surface features. Long Island is the northeastern limit of the Atlantic coastal plain; the mainland to the north consists of bedrock of Lower Paleozoic and Precambrian ages that extends to the shore. The island is a



Study Area

FIGURE 1-1

relict of glaciation. It is composed of Mesozoic and Cenozoic sedimentary strata overlain by glacial deposits. Its surface was shaped by the Late Pleistocene Wisconsinian glaciers. West to east trending terminal and recessional moraines make up the center of the island. Outwash plains extend southward from the moraines toward the Atlantic Ocean.

Along the south shore of Long Island, a chain of barrier beaches stretches eastward for about 80 miles from Rockaway Point to Southampton, separated from the "mainland" of Long Island by bays in some areas over 3 miles wide. The width of these barriers varies from a few hundred feet to over a half-mile and, in some locations, their dunes afford considerable protection to Long Island from wave action in the Atlantic Ocean. However, most of these barriers are subject to overwash by surge accompanying hurricanes and extra-tropical storms (nor'easters). Much of the development on these islands is subject to storm surge inundation, wave action, and extreme winds.

Although elevations on Long Island exceed 300 feet above sea level, extensive areas along the south shore west of Southampton are vulnerable to surge inundation. Because of the gentle slope of the glacial outwash plain bordering the large bays, storm surge inundation accompanying an intense hurricane could extend over 2 miles inland. From Southampton eastward to Montauk Point, about 30 miles, the shoreline lies along the Ronkonkoma Moraine. Erosion of that moraine has resulted in cliffed headlands bordered by narrow beaches. In some places, cliffs rise abruptly to more than 100 feet above sea level. Small bays and barrier beaches occur at a few locations.

Staten Island's varied topography is a result of its location at the junction of three different geologic terranes. The western portion of the island lies along the eastern boundary of the Newark Triassic-Jurassic Basin. This rift basin formed as the North American and African continental plates diverged and opened the Atlantic Ocean in the latter part of the Mesozoic Era. Here the shoreline along Arthur Kill is bordered by wide areas of tidal marsh. The topography rises fairly rapidly from the edge of the marsh eastward toward the uplands.

The highlands in the central part of Staten Island are comprised of ancient Lower Paleozoic Era metamorphic rocks of oceanic origin overlain by Wisconsinian glacial deposits. The terminal moraine of the most recent glaciation runs from the northeast corner of the island, near The Narrows, southwestward along the east coast to Tottenville. Maximum elevations inland reach 400 feet above sea level.

The eastern shore of Staten Island borders The Narrows on the north, the Lower Bay of New York Harbor on the east, and Raritan Bay on the south. The gently sloping surface extending from the central highlands eastward to the shore is glacial outwash underlain by coastal plain deposits. This relatively low, flat, topography could allow storm surge inundation to reach over a mile inland at some locations. Because there is no protective barrier beach, the shoreline is subject to direct wave action.

c. Bathymetry. Since shallow water close to shore tends to increase the magnitude of hurricane-induced storm surge, the slope of the ocean bottom (bathymetry) offshore is extremely important. Along the south shore of Long Island, the bathymetry varies considerably. From Montauk Point to the western tip of Fire Island, the 10-fathom (60 feet below mean sea level) contour generally parallels the coastline about 1.5 miles offshore. However, just westward from Fire Island Inlet, the 10-fathom contour lies about 4 miles offshore, and at Rockaway Point, about 6 miles offshore. The 20-fathom contour lies about 8 miles offshore near Montauk Point but diverges with the coastline and reaches 30 miles offshore at Rockaway Point. From east to west, the 100-fathom contour varies from about 80 to 100 miles offshore. The configuration of the bathymetry tends to exacerbate the effects of the geographic "funnel" mentioned previously by increasing the magnitude of potential storm surge from Montauk Point westward to Staten Island.

d. Population. The 1990 census shows that, overall, the population of the study area has changed very little over the past 30 years. While the population of the United States has increased by over 40 percent since 1960, the population of the study area has increased by 2 percent and the population of New York City has decreased by about 6 percent. However, these figures could be misleading in that Bronx, Kings (Brooklyn) and New York (Manhattan) Counties have lost over 15 percent of their population, while Queens has gained 8 percent and Richmond (Staten Island) has gained 71 percent. The population of Nassau County has remained stable, while Westchester County has gained 8 percent and the population of Suffolk County has doubled.

Population density has a tremendous impact on the number of people who will be evacuating potential inundation areas and on public shelter demand. In much of the study area, the permanent resident population is extremely dense, but density also varies considerably. New York County has an average of over 67,000 people per square mile, Kings County nearly 33,000 per square mile and Queens County about 18,000 per square mile. The density of Nassau and Suffolk Counties is approximately 4,500 and 1,500 people per square mile, respectively.

Table 1-1 lists the total population for each of the study area counties for the years 1960, 1970, 1980, and 1990. The percentage of change is also shown.

Historical Hurricane Activity

a. General. Hurricanes are a classification of tropical cyclones which are defined by the National Weather Service as nonfrontal, low pressure synoptic scale (large scale) systems that develop over tropical or subtropical waters and have a definite organized circulation. The classification of tropical cyclones into tropical depressions, tropical storms, or hurricanes depends upon the speed of the sustained (1-minute average) surface winds near the center of the system and are $\leq$ 33 knots, 34 to 63 knots inclusive, or $\geq$ 64 knots, respectively.

TABLE 1-1

Total Population and Percent Change

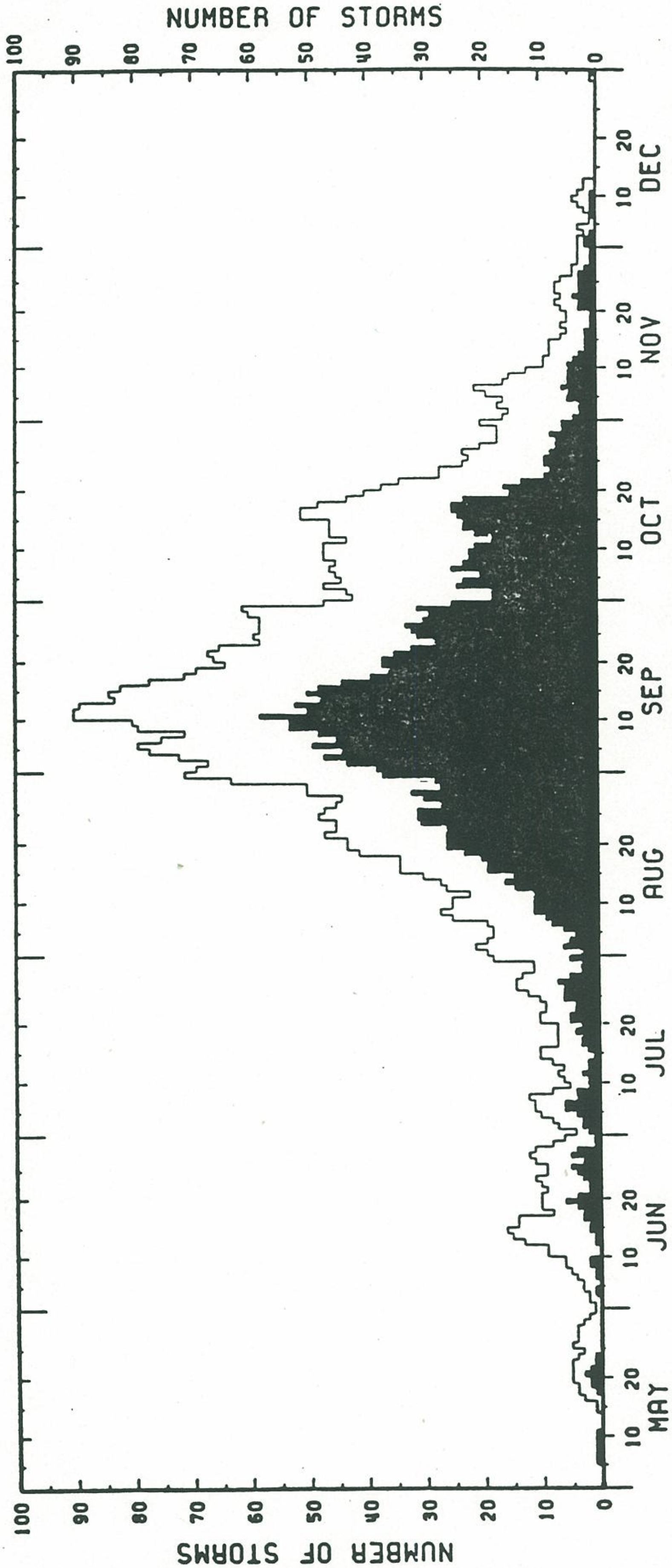
Governmental Unit	Population 1960 Census	Population 1970 Census	% Change 1960-1970	Population 1980 Census	% Change 1970-1980	Population 1990 Census	% Change 1980-1990
United States	179,300,000	203,304,863	13.4%	226,542,252	11.4%	249,632,692	10.2%
State of New York	16,782,304	18,241,584	8.7%	17,558,165	-3.7%	17,990,455	2.5%
Counties							
Suffolk	666,784	1,127,030	69.0%	1,284,231	13.9%	1,321,864	2.9%
Nassau	1,300,171	1,428,838	9.9%	1,321,582	-7.5%	1,287,348	-2.6%
Queens	1,809,578	1,987,174	9.8%	1,891,325	-4.8%	1,951,598	3.2%
Brooklyn	2,627,319	2,602,012	-1.0%	2,231,028	-14.3%	2,300,664	3.1%
Staten Island	221,991	295,443	33.1%	352,121	19.2%	378,977	7.6%
Manhattan	1,698,281	1,539,233	-9.4%	1,428,285	-7.2%	1,487,536	4.1%
Bronx	1,424,815	1,471,701	3.3%	1,168,972	-20.6%	1,203,789	3.0%
Westchester	808,891	894,406	10.6%	866,599	-3.1%	874,866	1.0%
Area Total	10,557,830	11,345,837	7.5%	10,544,143	-7.1%	10,806,642	2.5%

The geographical areas affected by tropical cyclones are referred to as tropical cyclone basins. The Atlantic tropical cyclone basin is one of six in the world and includes much of the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The official Atlantic hurricane season begins on June 1 and extends through November 30 of each year; however, occasional tropical cyclones occur outside of this period.

Early season tropical cyclones are almost exclusively confined to the western Caribbean and the Gulf of Mexico. However, by the end of June or early July, the area of formation gradually shifts eastward, with a slight decline in the overall frequency of storms. By late July, the frequency begins to slowly increase, and the area of formation shifts still farther eastward. By late August, tropical cyclones form over a broad area which extends eastward to near the Cape Verde Islands off the coast of Africa. The period from about August 20 through September 15 encompasses the maximum of the Cape Verde type storms, many of which travel across the entire Atlantic Ocean. After mid-September, the frequency begins to decline and the formative area retreats westward. By early October, the area is generally confined to longitudes west of 60^{o} West, and the area of maximum occurrence returns to the western Caribbean. In November, the frequency of tropical cyclone occurrence further declines.

b. Atlantic Tropical Cyclone Basin. Through the research efforts of the National Climate Center in cooperation with the National Hurricane Center, records of tropical cyclone occurrences within the Atlantic tropical cyclone basin have been compiled dating back to 1871. Although other researchers have compiled fragmentary data concerning tropical cyclones within this basin back to the late fifteenth century, the years from 1871 to the present represent the complete period of the development of meteorology and organized weather services in the United States. For the 120-year period 1871 through 1990, a total of 978 tropical cyclones have occurred within the Atlantic tropical cyclone basin; however, for the years 1871 through 1885, the existing data do not allow accurate determinations of the intensities of the storms occurring during those years. The National Hurricane Center maintains detailed computer files of the Atlantic tropical cyclone tracks back to 1886. Of the 889 known Atlantic tropical cyclones of at least tropical storm intensity occurring during the period 1886 through 1990, 519 are known to have reached hurricane intensity. Figure 1-2 illustrates the total number of tropical storms and hurricanes observed on each day, May 1 through December 31, 1886 through 1990.

c. Coastal New York. The frequency of occurrence for hurricanes affecting New York State is less than that of more southern latitudes. Since 1886, 11 hurricanes have directly affected the New York study area, for an average of one hurricane every 9.6 years. For the period 1871-1885, insufficient data exist to accurately determine which of the tropical cyclones that occurred might have reached hurricane intensity; therefore, for the period of record, 11 hurricane occurrences for the New York coast is probably a conservative estimate.



Number of tropical storms and hurricanes (open bar) and hurricanes (solid bar), observed on each day, May 1–December 31, 1886 through 1990

FIGURE 1-2

In recent history, hurricanes affecting the study area have either made landfall near astronomical low tide or passed to the east of Long Island, minimizing flood problems. This, combined with the low frequency of occurrence, has led to further complacency. Government officials and citizens alike must understand that New York will be struck by a catastrophic hurricane sometime in the future and that preparedness is of utmost importance.

The tracks of historical hurricanes passing within 100 statute miles of Coney Island, New York, from 1886 through 1990 are shown on figure 1-3.

Major Analyses

The New York State Hurricane Evacuation Study consists of several related analyses that develop technical data concerning hurricane hazards, vulnerability of the population, public response to evacuation advisories, timing of evacuations, and sheltering needs for various hurricane threat situations. The major analyses comprising the New York State Hurricane Evacuation Study and a description of the methodologies for each are as follows:

a. **Hazards Analysis.** The hazards analysis determines the timing, magnitude, and sequence of wind and storm surge hazards that can be expected from hurricanes of various categories, tracks, and forward speeds striking the study area. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) numerical model was used by the National Hurricane Center to develop the data. The potential for freshwater flooding was assessed from National Flood Insurance Program maps and by identifying areas within each of the counties that had a history of flooding from rainfall.

b. **Vulnerability Analysis.** Utilizing the results of the hazards analysis, the vulnerability analysis identifies those areas, populations, and facilities that are vulnerable to specific hazards under a variety of hurricane threats. Inundation maps were produced and evacuation scenarios were developed. Hurricane evacuation zones based primarily on census tracts were delineated for the entire area of New York City and each of the counties. Population data projected to 1992 were used to determine the vulnerable population within each evacuation zone. In areas of potential inundation, the first floor elevations of family care homes, nursing homes, and hospitals were determined by the U.S. Army Corps of Engineers using field surveys.

c. **Behavioral Analysis.** This analysis determines the expected response of the population threatened by various hurricane events in terms of the percentage expected to evacuate, probable destinations of evacuees, public shelter use, and utilization of available vehicles. The methodology employed to develop the behavioral data relied on telephone sample surveys and personal interviews within the study area, information from other Hurricane Evacuation Studies, and post-hurricane behavioral studies in other areas.

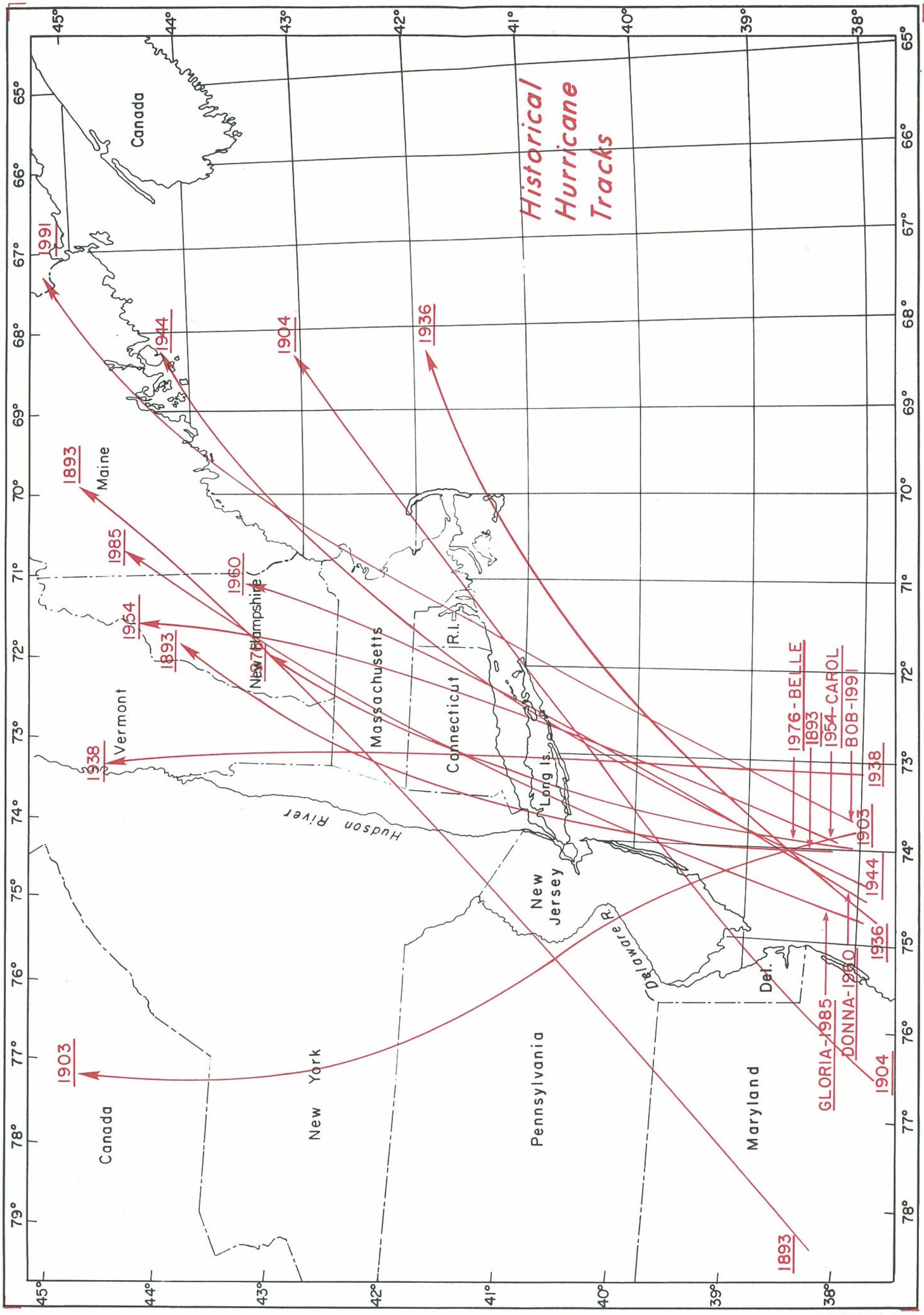

Historical Hurricane Tracks
Canada
Maine
New Hampshire
Vermont
Massachusetts
Connecticut
R.I.
Long Is.
New York
Hudson River
New Jersey
Delaware R.
Del.
Pennsylvania
Maryland
1991
1944
1904
1936
1893
1985
1960
1954
1938
1903
1976-BELLE
1954-CAROL
BOB-1991
GLORIA-1985
DONNA-1960

FIGURE 1-3

d. Shelter Analysis. The shelter analysis presents an inventory of predesignated public shelter facilities, capacities of the shelters, vulnerability of shelters to storm surge flooding, and identifies the range of potential shelter demand for each county. Inventories of predesignated shelters were furnished by the American Red Cross and the various emergency management offices. All predesignated shelters within the study area are located above expected surge inundation elevations. Potential shelter demands for ranges of hurricane threats were developed using data from the behavioral analysis.

e. Transportation Analysis. The results of all previous analyses were utilized in the transportation analysis. The principal purpose of this analysis is to determine the time required to evacuate the threatened population (clearance times) under a variety of hurricane situations and to evaluate traffic control measures that could improve the flow of evacuating traffic. Transportation computer modeling techniques developed to simulate hurricane evacuation traffic patterns were used to conduct this analysis.

Coordination

A comprehensive coordination program was established for the New York State Hurricane Evacuation Study that included state and local emergency management officials and representatives from other organizations having direct responsibilities in hurricane emergencies. A bi-level coordinative mechanism was implemented to assure proper and thorough data gathering and coordination of the study and to provide maximum flexibility in the effort. A description of the coordinative structure of the New York State Hurricane Evacuation Study follows:

a. Interagency. The New York State Emergency Management Office has an established channel of communication and coordination from the central State offices through Regional Directors to the city and county Directors of Emergency Management. From the outset, the U.S. Army Corps of Engineers and Federal Emergency Management Agency relied on this established system to coordinate the study effort. All meetings with the counties and New York City were arranged by the State Regional Director, who also served as a clearinghouse for reviews and comments by others on the products of the study. The Wilmington District, U.S. Army Corps of Engineers, provided quarterly status reports to the U.S. Army Corps of Engineers' North Atlantic Division office; FEMA, Region II; the New York State Emergency Management Office; New York City; and Westchester, Nassau, and Suffolk Counties.

b. Disaster Preparedness Committees. The Disaster Preparedness Committees consisted of New York State Emergency Management Office officials, city and county Directors of Emergency Management, and officials of other agencies and organizations, primarily at the county level, who have direct responsibility and authority in some aspect of hurricane emergency operations or planning. These officials represented agencies and organizations that included state and county law enforcement, fire departments, school boards, departments of social services, American Red Cross, and the National Weather Service. The primary purpose of the Disaster Preparedness Committees was to provide important data for the study and to review study products. Since the committee members will be the "users" of the information generated by the evacuation study, committee meetings provided the forum needed to explain the methodologies and products of the various study analyses and the opportunity to receive comments on the study process. Meetings were held at major milestones in the study to gather essential information, to present the results of analyses accomplished to date, to describe the relationships of the major analyses, and to review the progress of the study.

Metropolitan New York Hurricane Transportation Study

Concurrent with the New York Study, Hurricane Evacuation Studies have also been conducted for New Jersey and Connecticut. In the course of conducting the Transportation Analyses for the three studies, U.S. Army Corps of Engineers' study managers identified several locations where the metropolitan transportation infrastructure is disturbingly vulnerability to hurricane winds or surge. In some areas, there could be life-threatening danger to users of the systems. State emergency management officials expressed concern that the general treatment of transportation-related issues that is normal to the hurricane evacuation study process would be insufficient to support comprehensive regional emergency transportation plans. These officials requested an expansion of the evacuation studies to provide a broader base for metropolitan area commuter network hurricane emergency operation plans. When completed, the Metro New York Hurricane Transportation Study will complement the Evacuation Study by providing vital data for planning coordinated bridge and tunnel closings and alternative routings in hurricane emergencies.

CHAPTER TWO

HAZARDS ANALYSIS

Purpose

The purpose of the hazards analysis is to quantify the wind speeds and still-water surge heights for various intensities, approach speeds, approach directions, and tracks of hurricanes considered to have a reasonable meteorological probability of occurrence within a particular coastal basin. Due to the wide variation in amounts and times of occurrence from one storm event to another, potential freshwater flooding from rainfall accompanying hurricanes is addressed only in general terms.

The primary objective of the hazards analysis is to determine the probable worst-case effects from hurricanes of various intensities that could strike the region. For the purposes of this study, the term worst-case is used to describe the peak surges and wind speeds that can be expected at all locations within the study area without regard to hurricane track.

Forecasting Inaccuracies

The hazards analysis is used to determine worst-case effects because of inaccuracies in forecasting the precise tracks and other parameters of approaching hurricanes. An analysis of hurricane forecasts made by the National Hurricane Center indicates the normal magnitude of error. From 1976 to 1990, the average error in the official 24-hour hurricane track forecast was 140 statute miles left or right of the forecast track. The average error in the 12-hour official forecast was 70 miles. During the same time period, the average error in the official 24-hour wind speed forecast was 15 miles per hour (m.p.h.), and the average error in the 12-hour official forecast was 10 m.p.h. Hurricane evacuation decision-makers should note that an increase of 10 to 15 m.p.h. can easily raise the intensity value of the approaching hurricane one category on the Saffir/Simpson Hurricane Scale (see table 2-1). Also, other factors may work to increase apparent hurricane surge heights above the potential heights calculated by the SLOSH model (see Potential Storm Surge, paragraph e, Adjustments To SLOSH Model Values). Because of these forecast and modeling inaccuracies, public officials who are faced with an imminent evacuation should consider preparing for a hurricane one category on the Saffir/Simpson Hurricane Scale above the strength forecast for landfall.

Potential Storm Surge

a. General. A hurricane moving over the continental shelf produces a buildup of water at the coastline that is commonly referred to as storm (hurricane) surge. Storm surge is the increase in height of the surface of the sea due to the forces of an approaching hurricane. It normally occurs over coastline distances of 100 miles or more. The winds associated with a hurricane are the primary cause of storm surge. Wind blowing over the surface of the water exerts a horizontal force that induces a surface current in the general direction of the wind. The surface current, in turn, forms currents in subsurface water. The depth affected by this process of current creation depends upon the intensity and forward motion of the hurricane. For example, a fast-moving hurricane of moderate intensity may only induce currents to a depth of a hundred feet, whereas a slow moving hurricane of the same intensity might induce currents to several hundred feet. As the hurricane approaches the coastline, these horizontal currents are impeded by a sloping continental shelf, thereby causing the water level to rise. The amount of rise increases shoreward to a maximum level that is often inland from the usual coastline.

The elevation reached by the storm surge within a coastal basin depends upon the meteorological parameters of the hurricane and the physical characteristics existing within the basin. The meteorological parameters affecting the height of the storm surge include the intensity of the hurricane, measured by the storm-center sea-level pressure, track (path) of the storm, forward speed, and radius of maximum winds. Generally, the highest surges from a hurricane occur in the region of the radius of maximum winds. This radius is measured from the center of the hurricane eye to the location of the highest wind speeds within the storm. The radius of maximum winds can vary from as little as 4 miles to as much as 50 miles. The physical characteristics of a basin that influence the surge heights include the basin bathymetry (water depths), roughness of the continental shelf, configuration of the coastline, and natural or man-made barriers.

Another factor that contributes to the total water height is the initial water level within the basin at the time the hurricane strikes. This is determined by the astronomical tide and any anomalous sea surface height.

b. Saffir/Simpson Hurricane Scale. One of the earlier guides developed to describe the potential storm surge generated by hurricanes is the Saffir/Simpson Hurricane Scale. It was developed by Herbert Saffir, Dade County, Florida, Consulting Engineer, and Dr. Robert H. Simpson, former Director of the National Hurricane Center. The Saffir/Simpson Hurricane Scale, shown in tables 2-1 and 2-2, categorizes hurricanes based on wind speed and related damage potential.

TABLE 2-1

SAFFIR/SIMPSON HURRICANE SCALE

CATEGORY 1. Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real wind damage to other structures. Some damage to poorly constructed signs. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.

CATEGORY 2. Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major wind damage to buildings. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying island areas required.

CATEGORY 3. Winds of 111 to 130 miles per hour. Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris.

CATEGORY 4. Winds of 131 to 155 miles per hour. Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows, and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Major erosion of beaches.

CATEGORY 5. Winds greater than 155 miles per hour. Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes.

The National Hurricane Center has added a range of central barometric pressures associated with each category of hurricane described by the Saffir/Simpson Hurricane Scale. A condensed version of the Saffir/Simpson Hurricane Scale with the barometric pressure ranges by category is shown in table 2-2.

TABLE 2-2

SAFFIR/SIMPSON HURRICANE SCALE
WITH
CENTRAL BAROMETRIC PRESSURE RANGES

CATEGORY	CENTRAL PRESSURE MILLIBARS	CENTRAL PRESSURE INCHES	WINDS (MPH)	WINDS (KTS)	DAMAGE
1	> 980	> 28.94	74-95	64-83	Minimal
2	965-979	28.50-28.91	96-110	84-96	Moderate
3	945-964	27.91-28.47	111-130	97-113	Extensive
4	920-944	27.17-27.88	131-155	114-135	Extreme
5	< 920	< 27.17	> 155	> 135	Catastrophic

c. The SLOSH Model.

(1) General. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is the latest and most sophisticated mathematical model yet developed by the National Weather Service to calculate potential surge heights from hurricanes. The SLOSH model was developed for real-time forecasting of surges from approaching hurricanes within selected Gulf and Atlantic coastal basins. In addition to furnishing surge heights for the open coast, the SLOSH model has the added capability to simulate the routing of storm surge into sounds, bays, estuaries, and coastal river basins, as well as calculating surge heights for overland locations. Significant natural and manmade barriers are represented in the model, and their effects simulated in the calculations of surge heights within a basin.

The SLOSH model is designed for use in an operational mode; that is, for forecast/hindcast runs without controlled, local calibration, or observed winds. This design was selected so that the user would not be forced to estimate unavailable input data. The SLOSH model contains a storm model into which simple, time-dependent meteorological data are input and from which the driving forces of a simulated storm are calculated. These data are as follows:

(a) Central barometric pressure at 6-hour intervals.

(b) Latitude and longitude of storm positions at 6-hour intervals for a 72-hour tract.

(c) The storm size measured from the center (eye) to the region of maximum winds, commonly referred to as the radius of maximum winds. Wind speed is not an input parameter since the model calculates a windfield for the modeled storm by balancing forces according to meteorological input parameters.

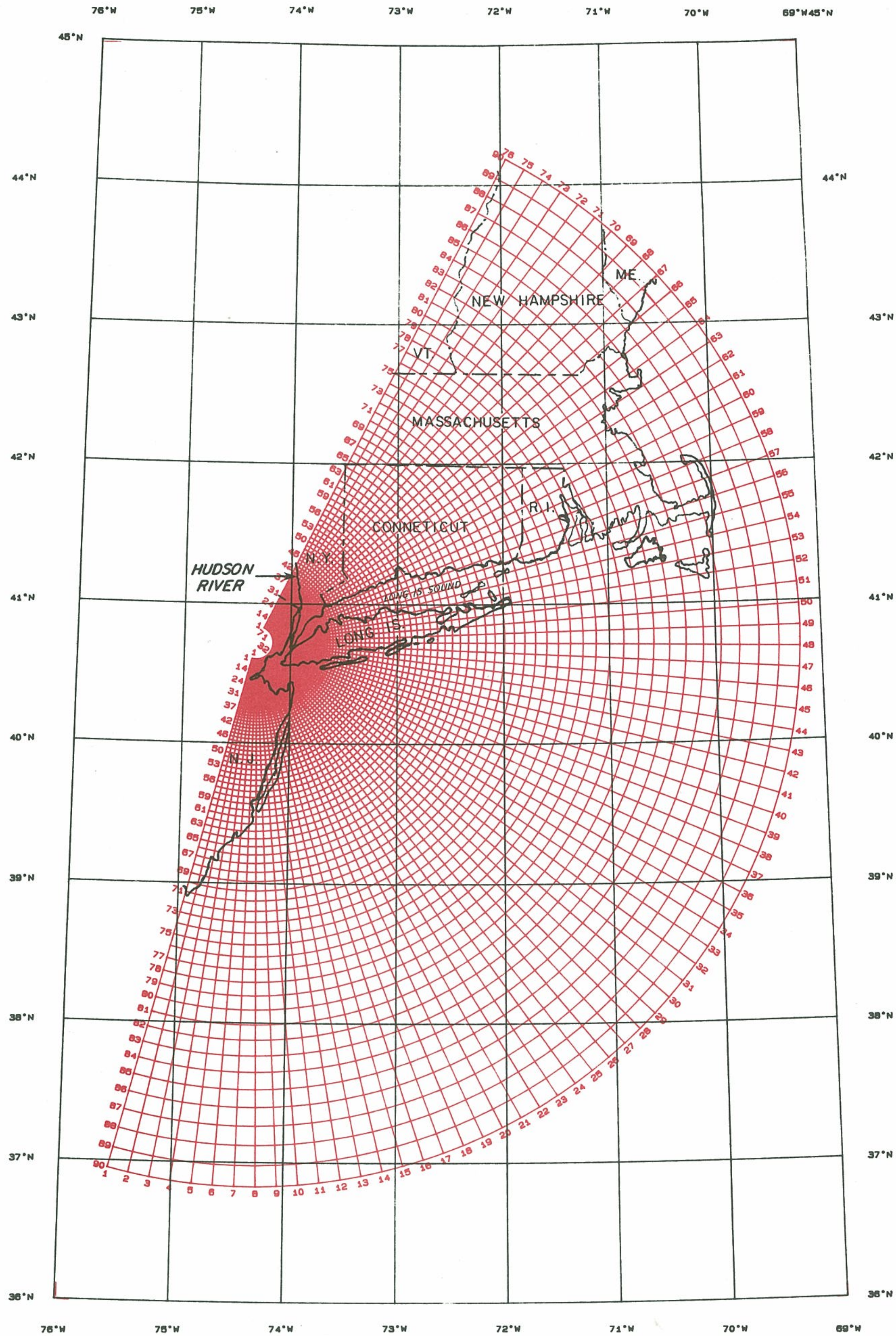
Also required is the height of the water surface well before the storm directly affects the area of interest. This initial height is the observed, quiescent, water surface height occurring about 2 days before storm arrival, including any existing anomalous rise in the water surface. Astronomical high tide was not set in the model.

The values or functions for the coefficients within the SLOSH model are generalized to serve for modeling all storms within all basins and are set empirically through comparisons of computed and observed meteorological and surge height data from numerous historical hurricanes. The coefficients are a function of differing storm parameters and basin characteristics. Calibration of the model based on a single storm event within a basin is avoided since there is no guarantee that the same coefficient values will serve as well for other storms.

(2) SLOSH Grid Configuration. The SLOSH model utilizes a telescoping polar coordinate (fan-shaped) grid system within which a particular coastal basin is represented. The grid configuration of a SLOSH model is illustrated in figure 2-1. The resolution of the model for inland locations near the focus is approximately 1 square mile per grid square and increases to approximately 106 square miles at the outer fringe. As shown in figure 2-1, the grid squares constantly expand in size and become progressively larger farther from the coastline. Storm surge heights in the ocean remote to the coastline are of secondary interest in evacuation planning. The advantage of this grid system is that it offers good resolution in areas of primary interest, while conserving computer resources by minimizing the number of calculations.

The characteristics of a particular basin are constructed as input data within the model. These characteristics include the topography of inland areas; river basins and waterways; bathymetry of nearshore areas, sounds, bays, and large inland water bodies; significant natural and manmade barriers such as barrier islands, dunes, roads, levees, etc.; and a segment of the continental shelf. The SLOSH model simulates inland flooding from storm surge and permits the overtopping of barriers and flow through barrier gaps.

(3) Verification of the Model. After a SLOSH model has been constructed for a coastal basin, verification experiments are conducted. These experiments are performed as real-time operational runs in which available meteorological data from historical storms are input in the model. These input data consist solely of observed or hindcast storm parameters and an initial observed sea surface height occurring approximately 48 hours before the storm makes landfall or affects the basin.



LONG ISLAND SOUND SLOSH GRID

FIGURE 2-1

The computed surge heights are compared with those measured from historical storms and, if necessary, adjustments are made to the input or basin data. These adjustments are not made to force agreements between computed and measured surge heights from historical storms but to more accurately represent the basin characteristics or historical storm parameters. In instances where the model has given realistic results in one area of a basin, but not in another, closer examination has often revealed inaccuracies in the representation of barrier heights or missing values in bathymetric or topographic charts. In the case of historical storms, much of the data are often coarse, with parameters prescribed invariant with time and with an unrealistically smoothed storm track. When necessary, further analysis and subjective decisions are employed to amend the track or other parameters of the historical storms used in the verification process. The hurricanes used to verify the Long Island Sound Basin SLOSH model were the hurricane of 1821 and Hurricane Gloria, 1985.

(4) Model Output. The SLOSH model output for a modeled storm consists of a tabulated storm history containing hourly values of storm position, speed, direction of motion, pressure drop, and radius of maximum winds; a surface envelope of highest surges; and for preselected grid points, time-history tabulations of values for surge heights, wind speeds and wind directions. Values in the time-history tabulations are 10-minute averages, given every 30 minutes.

The printed envelope of highest surges from the SLOSH model shows the computed surge heights above mean sea level (m.s.l.) in the center of each grid square, symbols for natural or manmade geographic features, Latitude and Longitude lines, and the storm track through the basin. In order to output computed surges on a line printer, the polar grid is transformed onto an image plane having grid squares of equal size. This results in the polar grid being represented by equally spaced parallel lines, while Latitude and Longitude lines and all other geographic features within the basin are distorted.

The highest water level reached at each location along the coastline during the passage of a hurricane is called the maximum surge. Maximum surges along the coastline do not necessarily occur at the same time. The time of the maximum surge for one location may differ by several hours from the maximum surge that occurs at another location. The SLOSH model printout of the envelope of highest surges contains the maximum surge height values calculated for each grid point in the model irrespective of the time during the simulation that the maximum surge height occurs. The datum used in the model is m.s.l.

The time-history data of surge heights, wind speeds, and wind directions are tabulated for each of 120 preselected grid points in the model. These data are listed for each grid point at 30-minute intervals for a 72-hour segment of a simulated storm track, starting 48 hours prior to landfall and continuing for 24 hours after landfall or closest approach. The surge heights are in feet above m.s.l.; the wind speeds in statute miles per hour; and the wind directions in azimuths from which the wind is blowing. Table 2-3 shows maximum surge heights by Saffir/Simpson hurricane categories. Surge heights at arrival of sustained tropical storm winds are presented in table 3-10. Information is provided for each of the 100 critical grid points that were selected for New York State (20 additional grid points were selected in Connecticut) in consultation with the city and county Directors of Emergency Management at the outset of the study (see figure 2-2).

d. New York State Modeling Process.

(1) General. The Long Island Sound Basin SLOSH model was used for the New York State Hurricane Evacuation Study. The Long Island Sound Basin covers the Atlantic coastline from Cape May, New Jersey, to Cape Cod, Massachusetts.

(2) Simulated Hurricanes. A total of 533 hypothetical hurricanes were modeled for the New York State Hurricane Evacuation Study. The characteristics of the simulated hurricanes were determined from an analysis of historical hurricanes that have occurred within the study area. The parameters selected for the modeled storms were the intensities, forward speeds, approach directions, and radii of maximum winds that are considered to have the highest meteorological probability of occurrence within the Long Island Sound Basin.

Sixty-five storm tracks were modeled for the New York Evacuation Study. They are shown on figures 2-3 through 2-8. The simulated hurricanes moving along these tracks had combinations of parameters representing categories 1 through 4 of hurricane intensity, as described by the Saffir/Simpson Hurricane Scale; six approach directions for hurricanes making landfall or paralleling the coast (west-northwestward, northwestward, north-northwestward, northward, north-northeastward, and northeastward); and numerous landfall or closest approach locations, usually spaced about 20 miles apart along the coastline. A forward speed of 20 miles per hour was used for west-northwestward and northwestward moving hurricanes; 20, 40, and 60 miles per hour for north-northwestward, northward, and north-northeastward; and 20 and 40 miles per hour for northeastward moving hurricanes. The radius of maximum winds specified for all the simulated hurricanes at landfall was 30 miles.

Because of their extremely low chance of occurrence, category 5 hurricanes were not modeled. However, when the velocity of translation (forward speed) of a fast-moving category 3 or 4 hurricane is added to the rotational winds within those storms, total wind velocities to the right of the eye can exceed 155 miles per hour, the category 5 threshold.

TABLE 2-3
SLOSH SURGE ELEVATIONS

LOCATION		MAXIMUM SURGE HEIGHT (msl)* STILL-WATER ELEVATION			
		Cat 1	Cat 2	Cat 3	Cat 4
1.	MONMOUTH BEACH	6.2	10.2	13.8	17.4
2.	SANDY HOOK	7.7	12.3	16.5	21.7
3.	KEANSBURG	9.7	15.6	20.8	26.2
4.	KEYPORT HARBOR	10.3	16.6	22.4	27.4
5.	SAYREVILLE	8.2	11.6	17.1	27.8
6.	AMBOY	10.8	18.7	23.8	26.9
7.	VICTORY BRIDGE	10.7	18.0	19.7	24.9
8.	TOTTENVILLE	10.4	20.0	23.2	26.9
9.	WOODBRIDGE	10.0	12.5	19.3	21.9
10.	FRESH KILLS LANDFILL	8.6	10.5	12.8	17.3
11.	TRAVIS	9.0	10.5	14.3	17.7
12.	LINDEN	9.0	10.6	14.3	18.0
13.	GOETHALS BRIDGE	8.9	10.7	14.4	17.8
14.	ELIZABETH	8.4	10.3	13.6	17.2
15.	NEWARK BAY BRIDGE	7.1	9.1	11.8	15.0
16.	US 1 @ PASSAIC RIVER	7.4	9.2	11.9	14.0
17.	PASSAIC RIVER	8.5	10.0	13.4	15.9
18.	PULASKI SKYWAY	6.8	9.0	11.8	14.4
19.	N.J. TURNPIKE	6.9	7.4	8.5	12.2
20.	ROUTE 3	5.2	6.3	7.7	11.4
21.	RIDGEFIELD PARK	Dry	Dry	Dry	9.9
22.	PALISADES PARK	Dry	Dry	Dry	9.2
23.	STAPLETON	9.9	15.4	21.1	26.0
24.	ST. GEORGE	10.0	16.0	22.0	26.7
25.	BAYONNE	9.2	12.5	19.3	27.9
26.	BUSH TERMINAL	10.4	15.7	22.3	27.6
27.	LIBERTY ISLAND	10.3	15.7	22.8	28.0
28.	BATTERY	10.5	16.6	23.9	28.7
29.	LINCOLN TUNNEL	7.5	17.2	20.5	30.8
30.	W 96TH STREET	8.2	15.0	17.7	28.1
31.	GEORGE WASHINGTON BRIDGE	6.9	14.1	16.8	26.7
32.	SPUYTEN DUYVIL	6.1	13.0	14.8	24.6
33.	CITY LINE	5.5	11.6	13.4	22.5
34.	TAPPAN	4.6	9.5	10.5	17.5
35.	OSSINING	2.9	7.6	8.7	14.6
36.	PEEKSKILL/INDIAN POINT	2.0	6.6	7.8	13.7
37.	MANHATTAN BRIDGE	10.1	15.8	22.4	25.6
38.	NEWTOWN CREEK	9.6	14.4	21.0	23.6
39.	HELLGATE	7.9	11.7	14.9	18.1
40.	LA GUARDIA	6.4	11.2	15.7	20.8
41.	FLUSHING BAY	6.6	11.6	16.3	20.9
42.	WHITESTONE (BRONX)	6.5	11.3	16.6	22.2
43.	PELHAM BAY	6.4	11.6	17.5	22.4
44.	WILLETS POINT	6.3	11.4	18.3	23.0
45.	CITY ISLAND	6.3	11.5	17.3	22.2
46.	MANORHAVEN	6.5	11.7	17.8	22.7
47.	SANDS POINT	6.1	11.1	16.3	21.5
48.	ROSLYN	6.2	11.3	16.5	21.8
49.	GLEN COVE	6.0	10.9	16.0	21.0
50.	MILL NECK	5.7	10.3	15.2	19.8

TABLE 2-3 (Cont.)
SLOSH SURGE ELEVATIONS

LOCATION	MAXIMUM SURGE HEIGHT (msl)* STILL-WATER ELEVATION			
	Cat 1	Cat 2	Cat 3	Cat 4
51. CENTRE ISLAND	5.7	10.3	15.2	19.8
52. COLD SPRING HARBOR	5.7	10.3	15.1	19.8
53. NORTHPORT BAY	5.4	9.8	13.7	18.1
54. ASHAROKEN	5.2	9.3	13.6	18.0
55. PORT JEFFERSON	5.0	9.0	13.1	17.3
56. SHOREHAM	4.6	8.1	11.8	15.5
57. MATTITUCK	4.3	7.6	11.0	14.6
58. ORIENT	4.5	7.4	10.4	13.4
59. SHELTER ISLAND	5.1	8.5	12.0	15.5
60. JAMESPORT	3.8	6.8	10.2	13.8
61. WARD POINT	10.7	17.5	23.2	27.6
62. HUGUENOT	10.2	16.6	22.1	27.4
63. GREAT KILL	10.1	15.9	21.2	27.1
64. OAKWOOD BEACH	9.7	15.7	21.0	27.0
65. MIDLAND BEACH	9.4	15.3	20.7	26.8
66. SOUTH BEACH	9.1	15.0	20.4	26.4
67. FORT HAMILTON	9.3	15.2	20.9	27.0
68. GRAVESEND BAY	9.2	15.2	20.8	27.2
69. SEAGATE	9.1	15.0	20.5	26.4
70. SHEEPSHEAD BAY	7.8	15.1	21.0	27.4
71. FLOYD BENNETT	6.7	14.0	21.7	28.5
72. PENNSYLVANIA AVE.	6.2	15.7	25.0	31.3
73. KENNEDY	6.6	15.6	24.5	31.2
74. BREEZY POINT	9.1	14.3	20.0	25.9
75. ROCKAWAY BEACH	9.1	14.0	20.4	26.6
76. EAST ROCKAWAY INLET	9.0	14.8	20.0	25.2
77. LAWRENCE	6.7	15.7	20.4	25.4
78. LONG BEACH	8.7	15.5	20.1	24.8
79. ISLAND PARK	8.3	16.0	21.0	25.7
80. EAST ROCKAWAY	6.1	17.0	22.1	26.9
81. OCEANSIDE	6.1	16.7	23.0	28.3
82. FREEPORT	7.7	14.9	23.2	29.4
83. LOOP PARKWAY	7.7	14.9	21.0	26.3
84. JONES BEACH	8.4	13.8	19.1	24.1
85. WANTAGH PARKWAY	2.3	13.3	20.5	27.0
86. GILGO BEACH	8.0	13.6	17.3	23.5
87. AMITYVILLE	2.5	8.7	19.7	26.8
88. WEST ISLIP	3.2	8.4	15.9	22.6
89. ATLANTIQUE	6.8	11.4	15.4	19.8
90. DAVIS PARK	6.5	11.3	15.9	19.6
91. PATCHOGUE	2.4	4.8	9.2	15.1
92. SMITH PT./MORICHES	6.2	10.6	14.8	18.2
93. CENTER MORICHES	5.5	9.7	13.2	19.7
94. WEST HAMPTON	6.0	10.4	14.1	18.1
95. MECOX	5.7	9.9	14.0	17.9
96. NAPEAGUE	5.2	8.9	12.6	16.2
97. MONTAUK POINT	4.9	7.9	10.7	13.5
98. NEW ROCHELLE	6.1	11.2	16.4	21.5
99. MAMARONECK HARBOR	6.0	11.0	15.9	21.0
100. PORT CHESTER	5.8	10.6	15.6	20.5

*** For high tide see table 2-5**

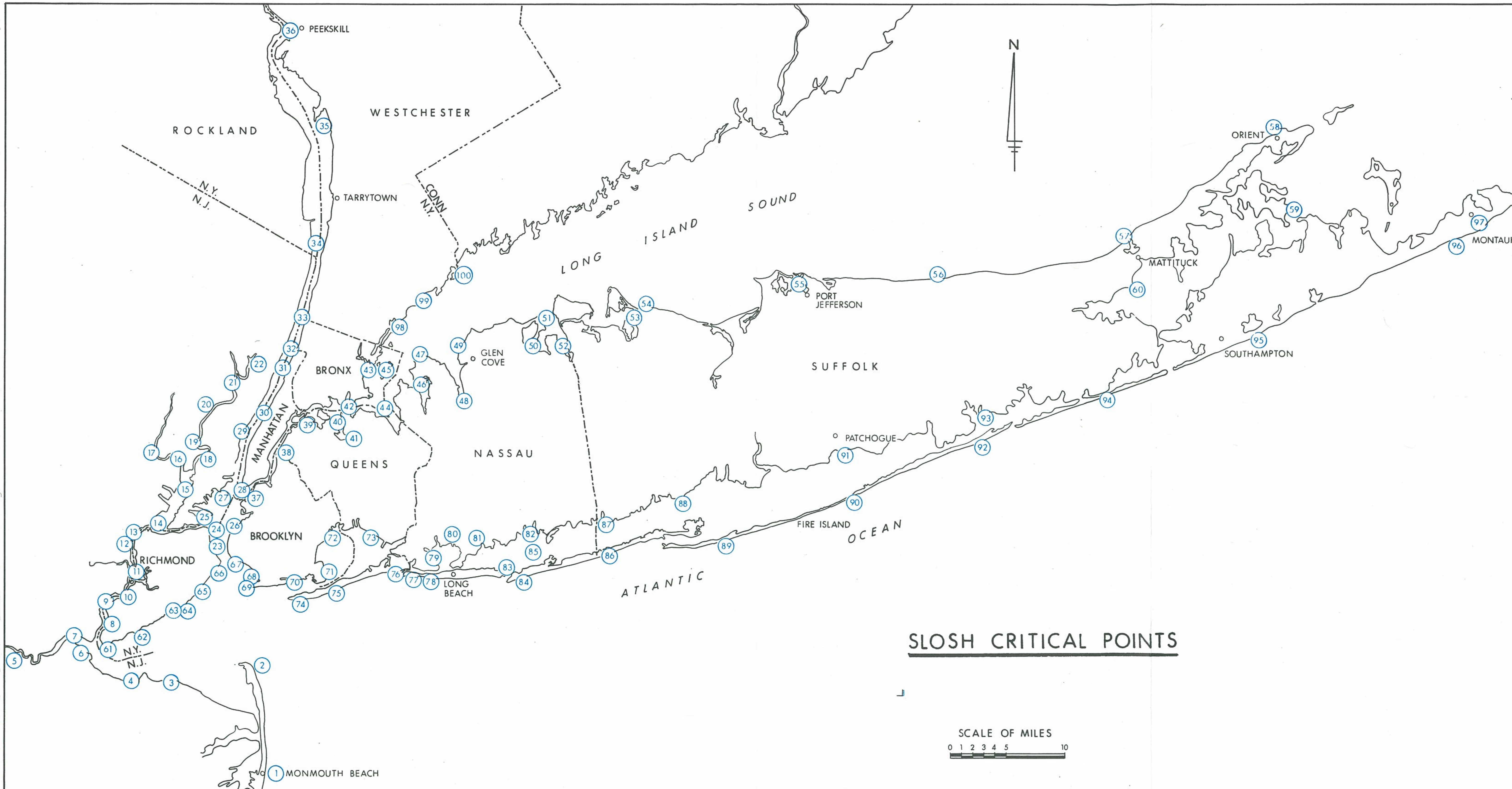
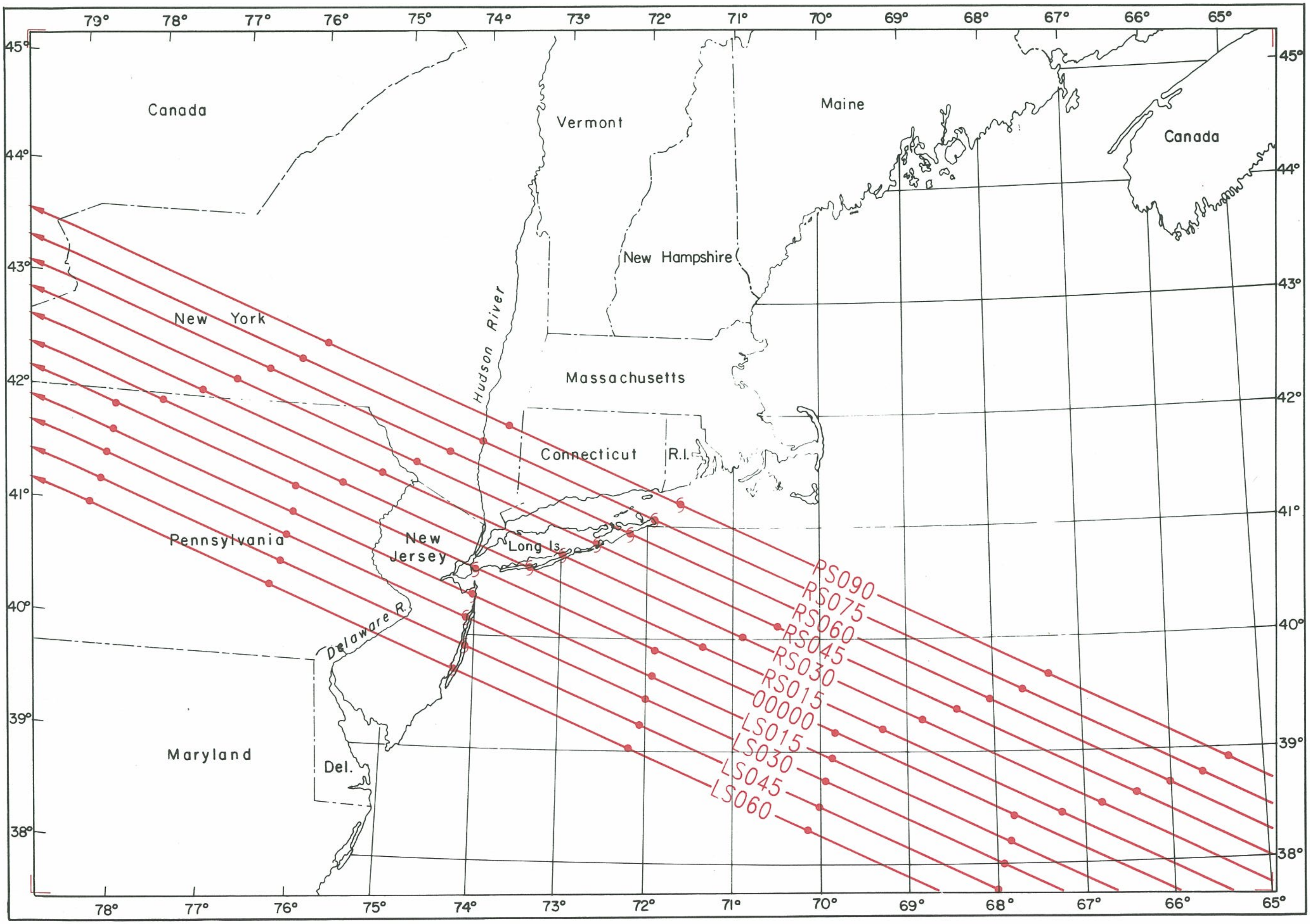
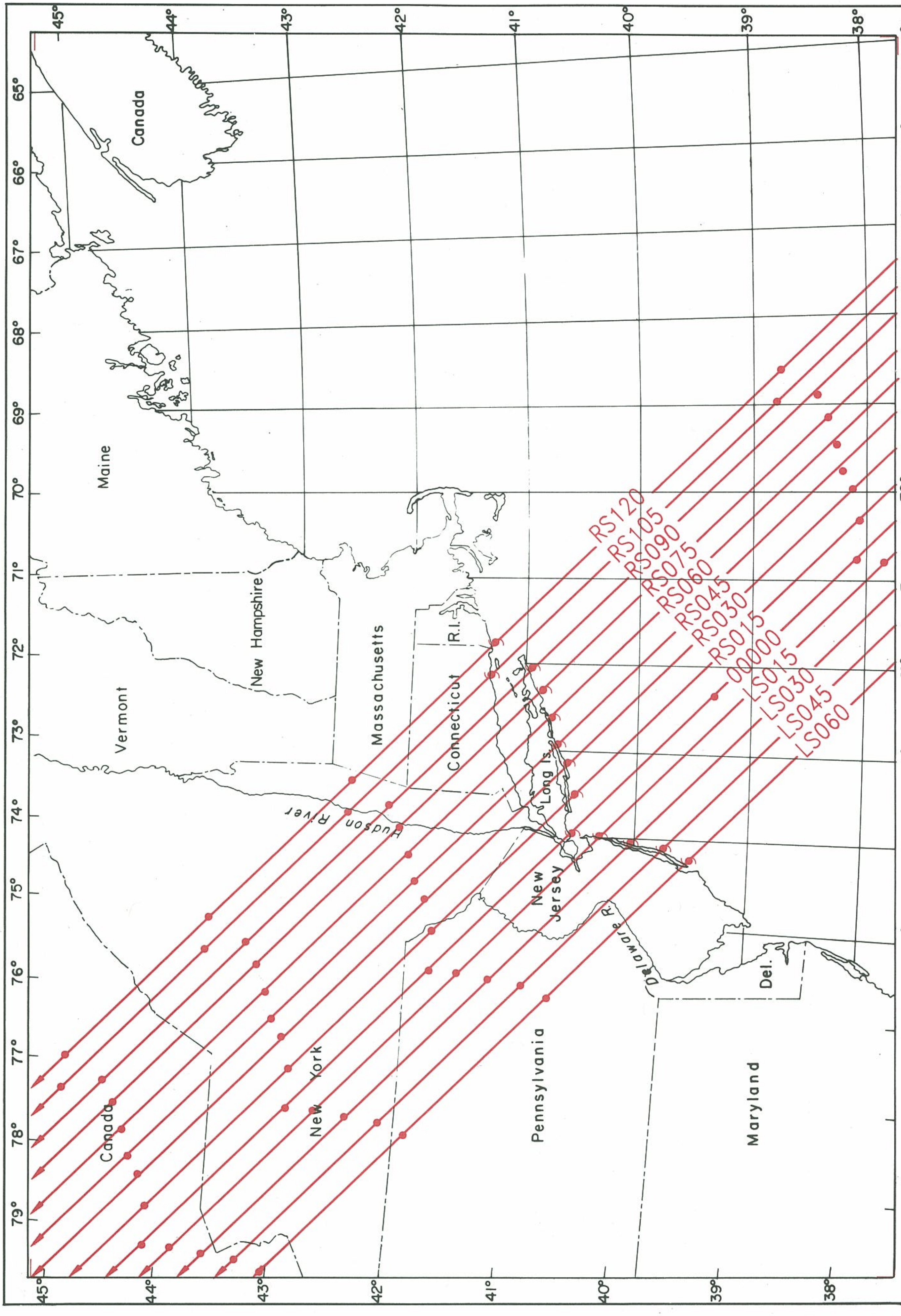

SLOSH CRITICAL POINTS
PEEKSKILL
ROCKLAND
WESTCHESTER
N.Y.
N.J.
TARRYTOWN
CONN
N.Y.
LONG ISLAND SOUND
ORIENT
MATTITUCK
MONTAUK
PORT JEFFERSON
GLEN COVE
BRONX
SUFFOLK
MANHATTAN
QUEENS
NASSAU
PATCHOGUE
SOUTHAMPTON
BROOKLYN
RICHMOND
FIRE ISLAND
OCEAN
ATLANTIC
LONG BEACH
MONMOUTH BEACH
SCALE OF MILES
0 1 2 3 4 5 10

FIGURE 2-2



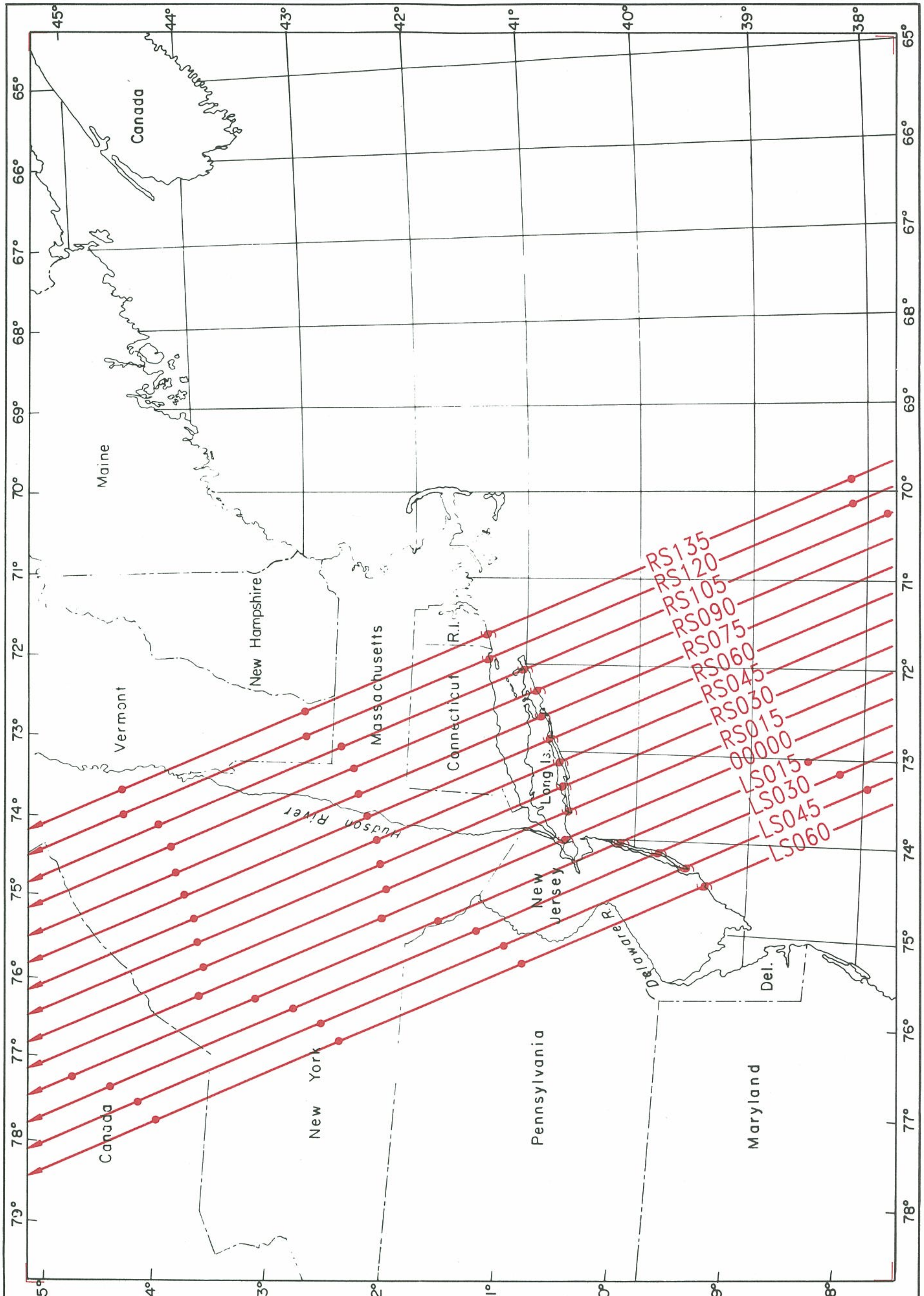
WEST-NORTHWESTWARD MOVING HURRICANES

FIGURE 2-3



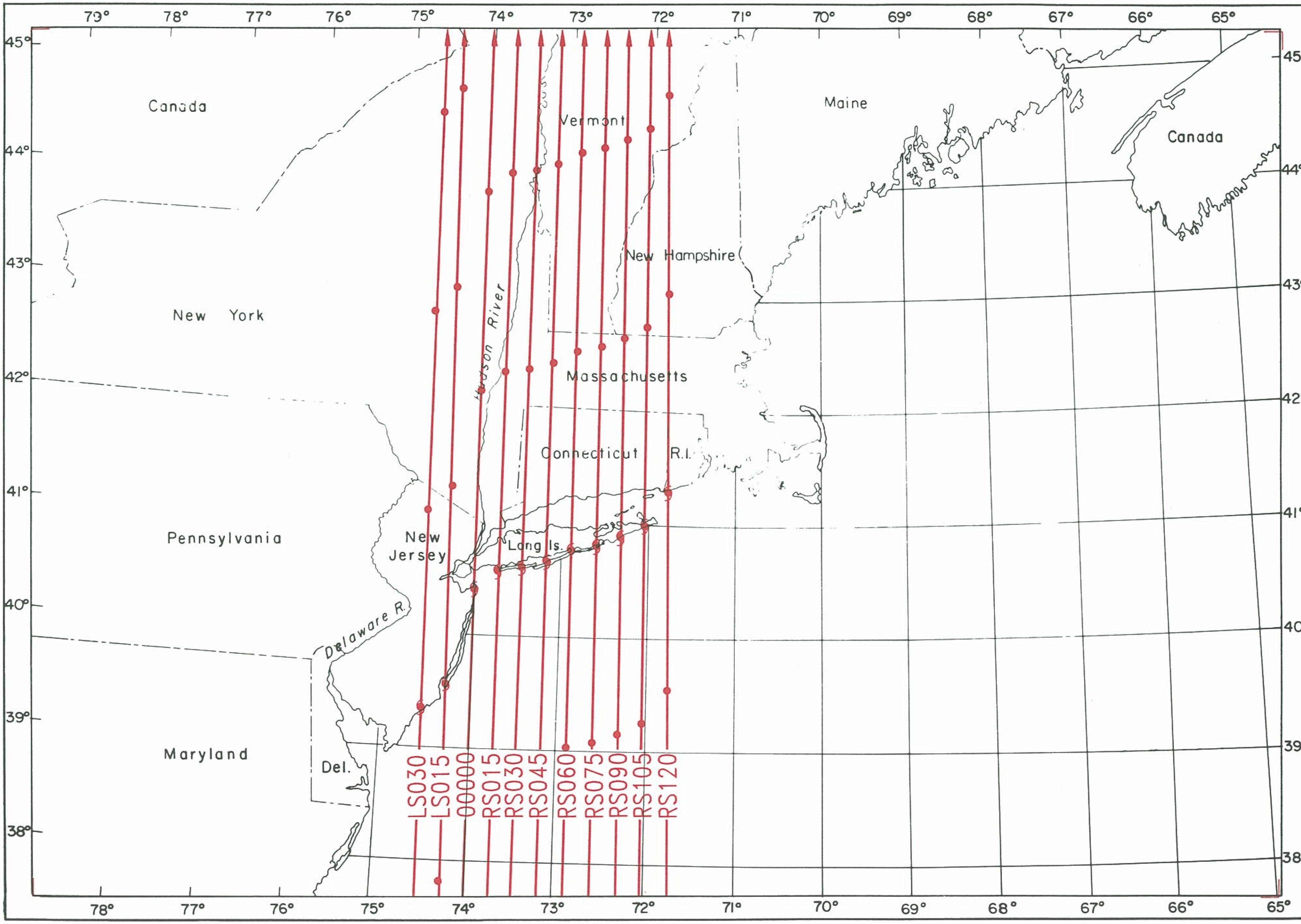
NORTHWESTWARD MOVING HURRICANES

FIGURE 2-4



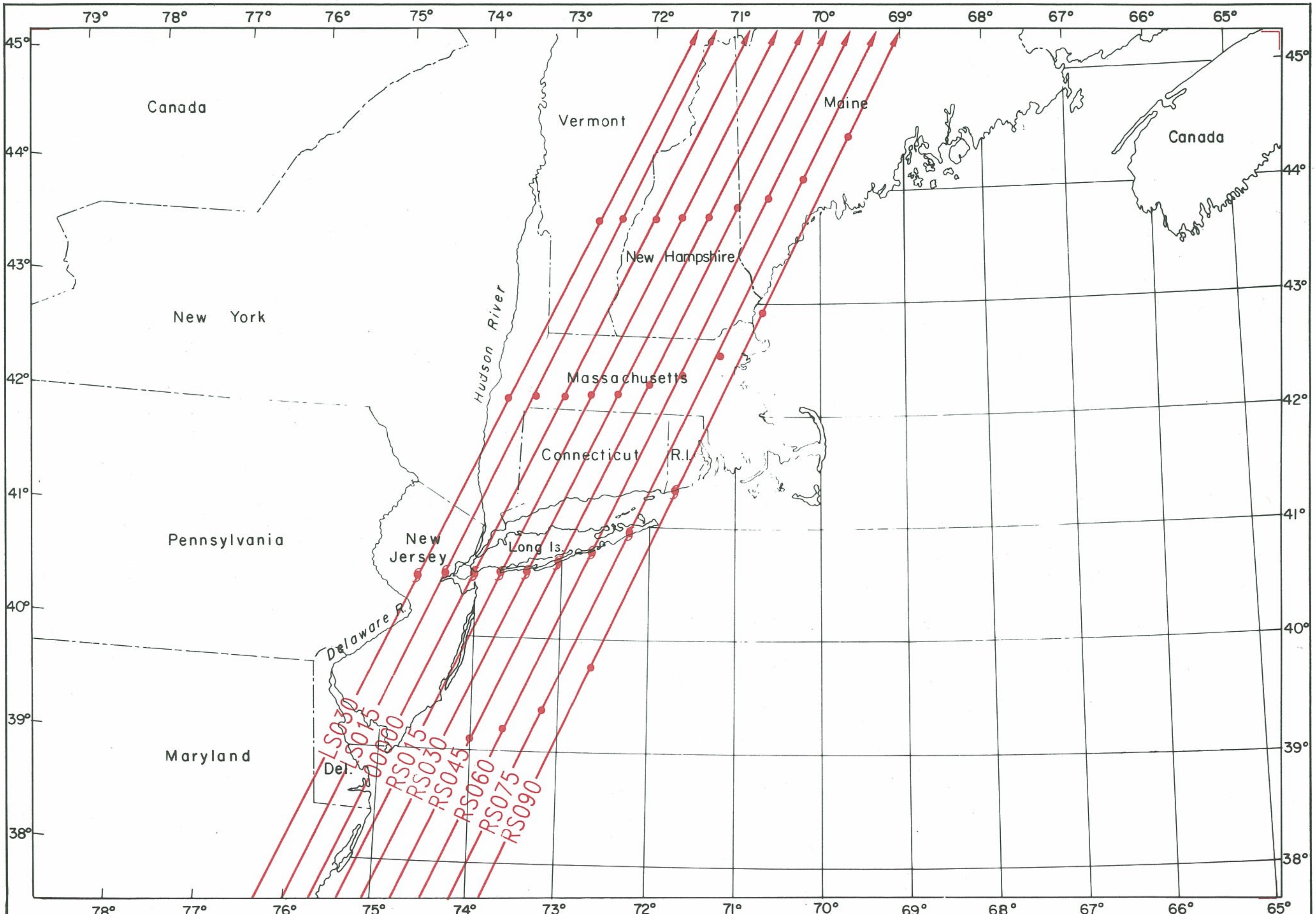
NORTH-NORTHWESTWARD MOVING HURRICANES

FIGURE 2-5



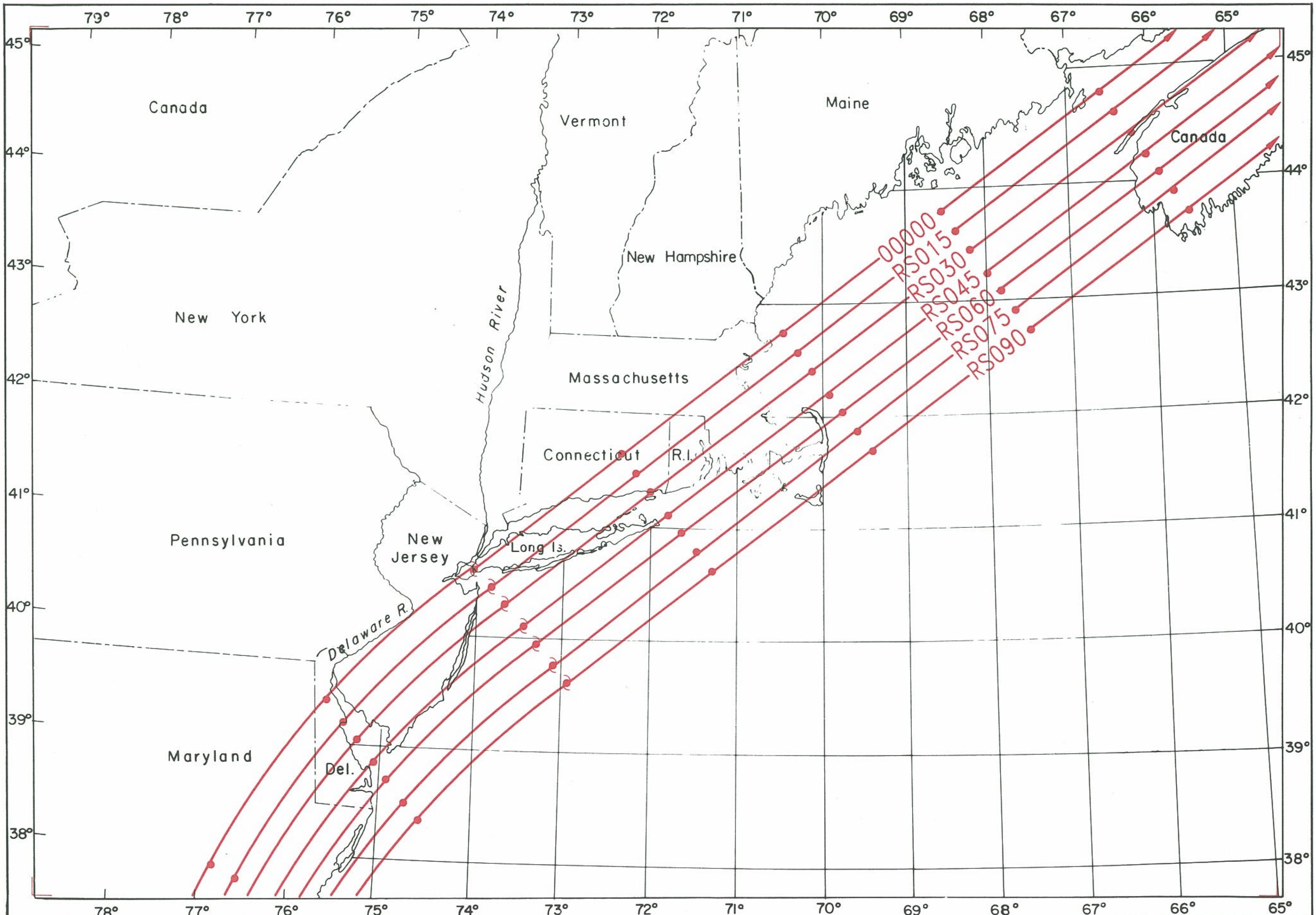
NORTHWARD MOVING HURRICANES

FIGURE 2-6



NORTH-NORTHEASTWARD MOVING HURRICANES

FIGURE 2-7



NORTHEASTWARD MOVING HURRICANES

FIGURE 2-8

The primary factor that determines the intensity or category of a hurricane is the difference between the central barometric pressure within the center of the storm and the ambient barometric pressure surrounding the system. The term for the difference in internal and external pressures of a tropical cyclone is delta-p (Δp). Table 2-4 lists the categories of hurricanes modeled for the New York State Hurricane Evacuation Study, the ranges of pressures constituting each category, the central barometric pressures for the simulated storms modeled for the study and the resulting Δp, assuming an ambient standard barometric pressure of 1,010 millibars (mb).

TABLE 2-4

CENTRAL BAROMETRIC PRESSURES AND Δp
FOR SIMULATED HURRICANES, LONG ISLAND SOUND BASIN

CATEGORY	CENTRAL BAROMETRIC PRESSURE		PRESSURE DIFFERENCE
	ACTUAL HURRICANE	MODELED HURRICANE	
1	1,000mb - 980mb	990mb	Δp = 20mb
2	979mb - 965mb	970mb	Δp = 40mb
3	964mb - 945mb	950mb	Δp = 60mb
4	944mb - 920mb	930mb	Δp = 80mb

After making landfall, most hurricanes weaken because the central pressure and radius of maximum winds increase. This expected weakening due to the landmass was taken into account in modeling each of the storm tracks.

The initial sea surface height set in the Long Island Sound SLOSH model was 1.0 foot. This initial height, known as tide anomaly, represents the height of the water surface above m.s.l. existing several days in advance of approaching hurricanes. The value for the tide anomaly used in the SLOSH model represents the average sea surface height recorded at tide gauges for historical hurricanes prior to landfall.

(3) Maximum Envelopes of Water. The highest surges reached at all locations within the affected area of the coastline during the passage of a hurricane are called the maximum surges for those locations; the highest maximum surge in the affected area is called the peak surge. The location of the peak surge depends on where the eye of a hurricane crosses the coastline, hurricane intensity, the bathymetry of the basin, configuration of the coastline, the approach direction, and the radius of maximum winds of the hurricane. In most instances, the peak surge from a hurricane occurs to the right of the storm path and within a few miles of the radius of maximum winds. Due to the inability to precisely forecast the ultimate landfall location, forward speed, approach direction, and other characteristics of a threatening hurricane, the objective of the hazards analysis is to determine the potential peak surges for all locations within the study area. For that purpose, Maximum Envelopes of Water (MEOWs) are utilized.

MEOWs were developed by the National Hurricane Center from an array of peak surges calculated for the individual hurricanes modeled for the Long Island Sound Basin. MEOWs that disregard storm track can be created for any specified storm parameter or sets of parameters desired.

Initially, 52 MEOWs were developed for the Long Island Sound SLOSH Basin. These MEOWs consisted of computer printouts showing peak surge values developed for each combination of category, approach speed, and approach direction modeled for the study, without regard to storm track. Therefore, the values contained on these original MEOWs were the peak surge height values for each of the models' grid points regardless of where landfall may have occurred.

The results of the 52 original MEOWs were analyzed to determine which changes in storm parameters (i.e., intensity, approach speed, and approach direction) resulted in the greatest differences in the values of the peak surges for all locations and which could reasonably be combined to facilitate evacuation decision-making. In most instances, a change in storm category accounted for the greatest change in peak surge heights calculated for the SLOSH grid points. Another consideration was that along the Atlantic coast, approach speed and direction are more difficult to predict than intensity. In 1984, after an evacuation advisory had been issued, Hurricane Diana stalled, then made a 270° loop before making landfall on the North Carolina coast. If an evacuation plan is based on specific actions that are contingent upon hurricane approach speed or direction, such erratic behavior could easily play havoc with the evacuation decision-making process. With these facts in mind, careful consideration was given to the impacts of the various combinations of approach speeds, approach directions, and Saffir/Simpson categories on hurricane evacuation decision-making. To simplify the planning process, the National Hurricane Center was asked to compile additional MEOWs eliminating consideration of hurricane approach speed and direction, while maintaining data separation by hurricane intensity.

The National Hurricane Center subsequently developed additional MEOWs (MEOWs of the MEOWs, or MOMs) combining all hurricane approach speeds and directions but maintaining the separation of categories 1, 2, 3, and 4. It was from those MOMs that the inundation maps shown in Appendixes A through D of this report were developed. Those inundation maps depict the limits of inundation from peak storm surge heights that could be generated by the four categories of storm intensity, without regard to approach speed, direction, or track.

e. Adjustments to SLOSH Model Values. The surge height values contained in the MOMs represent the water surface elevations produced by the driving forces of the modeled hurricanes in combination with the 1.0-foot tide anomaly. The datum for the SLOSH model values and tide anomaly is m.s.l.

(1) Statistical Analysis. Hurricane evacuation decision-makers should keep in mind that the SLOSH model is a mathematical model and does not always give perfect results. To determine the accuracy of the SLOSH model, computations were made by the National Weather Service for 13 historical landfalling hurricanes in 8 separate coastal basins. A total of 523 observations of storm surge heights were made and compared to the SLOSH model values for the same locations (i.e., SLOSH model height minus observed height). A negative difference meant the SLOSH model underestimated the storm surge. Tide gage readings accounted for 14 percent of the observations, while the remainder were high-water mark readings. The range of error was from -7.1 feet to +8.8 feet. The arithmetic mean was -0.3 feet, which indicates a slight negative bias. The standard deviation was 2.0 feet. Most of the errors, 79 percent, fell within one standard deviation, compared to 68 percent for a normal distribution.

Based on the results of the statistical analysis conducted by the National Weather Service, a +20 percent adjustment to the SLOSH values would eliminate most of the potential negative errors occurring from the model. However, such an adjustment would also add additional surge height to those values that already contain positive errors, possibly endangering the credibility of the SLOSH results. Therefore, a general adjustment was not made to the computed surge heights. Evacuation planners should remain cognizant of the potential 20 percent underestimate of some SLOSH surge values.

(2) Astronomical Tide. No permanent adjustment has been made to the SLOSH surge values for astronomical tide. However, since the datum used in the SLOSH model is m.s.l., an astronomical tide level above m.s.l. would add an additional height to the values computed by the SLOSH model. If such is the case in an actual hurricane emergency, public officials should base their evacuation decisions on the potentially higher flood heights. If astronomical high tide occurs coincidentally with the peak storm surge, the combination could be considerably higher than the SLOSH surge values shown on the inundation maps, Appendices A through D. Table 2-5 gives the height of the normal high tide above mean tide level for sample locations within the study area. Spring tide situations would add less than 1 foot to these values.

Appendix E to this Technical Data Report furnishes additional information on the SLOSH model in general, and the New York State modeling process in particular. Descriptions of SLOSH modeling procedures and related meteorological information contained in this chapter and Appendix E were provided by the Storm Surge Group, National Hurricane Center.

TABLE 2-5

NORMAL ASTRONOMICAL HIGH TIDES

Location	Height Above Mean Tide Level (ft)
New York City	
Coney Island	2.0
Timbale	2.5
St. George	2.0
The Battery	2.0
Spuyten Duyvil	2.0
East 41st Street	2.0
Wards Island	2.5
Bronx River	3.0
Whitestone Bridge	3.5
Westchester County	
Yonkers	2.0
Ossining	1.5
Peekskill	1.0
New Rochelle	3.5
Port Chester	3.5
Nassau County	
Manhasset Bay	3.5
Oyster Bay	3.5
Massapequa	0.5
Freeport	1.5
Long Beach	2.0
Woodmere	2.0
Suffolk County	
Lloyd Harbor	3.5
Port Jefferson	3.0
Mattituck	2.5
Plum Island	1.0
Riverhead	1.0
Threemile Harbor	1.0
Montauk Point	1.0
Shinnecock Inlet	1.5
Moriches Inlet	1.5
Mastic Beach	0.5
Fire Island	2.0
Bellport	0.5
Sayville	0.5
Babylon	0.5
Amityville	0.5

Time-History Data

One hundred grid points were selected in New York for the time-history tabulation of surge height, wind speed, and wind direction. These grid points were chosen to coincide with critical locations identified by the city and county Emergency Management Directors for their respective jurisdictions. They are located at low-lying roads and bridges that would be critical to an evacuation, at potentially vulnerable population centers, or at significant natural or manmade barriers. The time-history information produced by the SLOSH model for the 100 critical points lists values for still-water surge heights, wind speeds, and wind direction at 30-minute intervals for 72 hours.

The purpose of the time-history data is to determine the prelandfall hazards distances for New York City and each of the counties within the study area. Prelandfall hazards distance is the distance from the eye of an approaching hurricane to each jurisdiction at the time an evacuation would be curtailed by hazardous weather conditions. This distance must be accounted for in timing evacuation decision-making. For the New York State Hurricane Evacuation Study, two specific conditions were evaluated: the arrival of sustained gale-force winds (34-knot sustained wind speed, 1-minute average) and the onset of storm surge inundation of low-lying roads, bridges, or other critical areas. The first of these two conditions to occur determines the prelandfall hazard distance.

The arrival of sustained tropical storm winds, which are accompanied by much higher wind gusts, is selected as a threshold because high-profile vehicles and vehicles pulling campers or boats could easily be overturned, especially on high-rise bridges. Such an accident would most certainly cripple or halt traffic flow on that evacuation route. That threshold is also the time, under the majority of hurricane threats, when heavy rainfall begins. Generally, one-half of the total amount of rainfall received from a hurricane occurs from the arrival of sustained tropical storm winds until the eye reaches the coastline.

The other condition limiting evacuation, the onset of storm surge inundation, should not be a significant factor in most of the study area prior to the arrival of sustained tropical storm winds. At all 100 SLOSH time-history critical points, the wind threshold is expected to be reached before the onset of storm surge inundation and therefore will determine the prelandfall hazards distance. As discussed in the section above, however, evacuation decision-making officials should be aware that the coincidental occurrence of astronomical high tide and rising storm surge could cause moderate flooding in low-lying areas, particularly on causeways, prior to the arrival of sustained tropical storm winds. Table 3-10 lists the still-water surge heights at the time of arrival of sustained tropical storm winds computed by the SLOSH model. In order to determine the total potential water level at the time tropical storm winds are forecast to arrive, anticipated astronomical tide height above m.s.l. level should be added to the surge heights shown in table 3-10.

Since the limiting factor for hurricane evacuation in the study area is expected to be winds, not surge, the prelandfall hazards distance can be defined as the distance to the eye of the approaching hurricane from the leading edge of sustained tropical storm winds, or, said a little simpler, it is the radius of sustained tropical storm winds of the threatening hurricane. Thus, for the New York Evacuation Study area, the prelandfall hazards distance and the radius of sustained tropical storm winds are equal.

Marine advisories, produced by the National Hurricane Center every 6 hours, give the measured distance in nautical miles of the 34-knot (approximately 40 miles per hour), 1-minute sustained wind speed (tropical storm) from the eye of an approaching hurricane. These distances are given for the four quadrants of the storm (i.e., northwest, northeast, southeast, southwest). Forecasts of these distances for 12, 24, 36, 48, and 72 hours into the future are also given. The largest radius listed for the forecast time of landfall should be used for the prelandfall hazards distance in evacuation decision-making.

Further discussion of the application of the radius of tropical storm winds to hurricane evacuation decision making is contained in chapter 8, Decision Arcs.

Wave Effect

The SLOSH model does not provide data concerning the additional heights of waves generated on top of the still-water storm surge. Generally, waves do not add significantly to the area flooded and have little effect on the numbers of people that will be required to evacuate. Since near-shore wave phenomena under hurricane conditions are not well understood, it is assumed that for the open coast, maximum theoretical wave heights based upon relationships of fetch length to water depth occur near the time of landfall. Immediately along the coastline or the shorelines of very large sounds and estuaries, wave crests can increase the expected still-water depth above the terrain by one-third, thus greatly increasing the hazard. Due to the presence of barriers such as structures, dunes, or vegetation, the waves break and dissipate a tremendous amount of energy within a few hundred yards of the coastline. Buildings within that zone that are not specifically designed to withstand the forces of wave action are often heavily damaged or destroyed.

For evacuation planning purposes, it is perhaps more important to consider potential wave effects for less than sustained tropical storm winds. If wave heights above theoretical still-water levels exceed the elevations of roads, bridges, or other critical areas near the coastline, evacuation could be curtailed sooner than expected, increasing the prelandfall hazards distance.

A review of the SLOSH time-histories shows that maximum surges at the time of arrival of tropical storm winds should be on the order of 3.5 feet m.s.l., or less. Since tides of this level are experienced fairly routinely without major traffic problems, calculations of wave height and runup were not made. However, evacuation planners should be aware that low-lying sections of highway could be subject to some wave action and overwash prior to the arrival of sustained tropical storm winds. This would be especially true with the coincidental occurrence of astronomical high tide.

Freshwater Flooding

Amounts and arrival times of rainfall associated with hurricanes are highly unpredictable. For most hurricanes, the heaviest rainfall begins near the time of arrival of sustained tropical storm winds; however, heavy rains in amounts exceeding 20 inches can precede an approaching hurricane by as much as 24 hours. Unrelated weather systems can also contribute significant rainfall amounts within a basin in advance of a hurricane.

Due to the unpredictability of rainfall from hurricanes, no attempt was made to employ sophisticated modeling or analysis in quantifying those effects for the study area. Locations and facilities which have historically flooded during periods of heavy rainfall were identified throughout the study area and assumed to be vulnerable to freshwater flooding from hurricane conditions.

CHAPTER THREE

VULNERABILITY ANALYSIS

Purpose

The primary purpose of the vulnerability analysis is to identify the areas, populations, and facilities that are subject to storm surge inundation and to establish levels of vulnerability. Storm surge data from the hazards analysis were used to map inundation areas; to develop evacuation scenarios and evacuation zones; to quantify the vulnerable population; to identify major medical, institutional, and other facilities that are potentially vulnerable to storm surge.

Since mobile homes have proven to be particularly susceptible to wind damage, they have been given special attention in the vulnerability analysis. No attempt has been made to identify other types of construction that may have a high risk of wind damage.

Storm Surge Inundation

Because of unavoidable inaccuracies in hurricane forecasting, the MEOW approach is used for preparedness planning. The inundation maps (Appendixes A through D) depict peak surge values from the MOMs computed by the SLOSH model [See chapter 2, Potential Storm Surge, paragraph d (3)]. These maps show the maximum extent of storm surge flooding that is expected to be produced by any category 1, 2, 3, or 4 hurricane, regardless of its track. However, they are based on still-water surge heights at mean tide and do not include possible increased flood levels due to astronomical high tide or wave height. Since the extent of flooding will actually depend a great deal on the hurricane track, the overall flooded area shown on the inundation maps for each hurricane category will never be exactly duplicated by a single storm. To produce the inundation maps, areas vulnerable to storm surge were delineated on U.S. Geological Survey 7.5-minute series topographic maps at scale 1 inch equals 2,000 feet, and then printed for distribution at scale 1 inch equals 0.5 mile. Potential flooding shown on these maps covers large areas of nearly every major jurisdiction, involving over 2.5 million inhabitants.

In order to determine the potential depth of storm surge flooding at a particular location, the elevation of the ground must be known. The depth of flooding above the ground can be calculated by subtracting the known ground elevation (using local field survey data referenced to the National Geodetic Vertical Datum) from the pertinent surge elevation.

Hurricane Evacuation Scenarios

Hurricanes with quite different parameters can have virtually the same flooding impacts on the population of a community. When this occurs, the MOMs (see chapter 2) are combined into evacuation scenarios that depict the similar effects of unlike hurricanes. Evacuation scenarios are developed by comparing the potential flood areas shown on each inundation map to those on all the other maps and to the census tract or other data base boundaries. Scenarios are designated for each of the study area counties and New York City boroughs. Table 6-2 contains the hurricane evacuation scenarios developed for each jurisdiction and lists the associated evacuation zones. These scenarios are illustrated on the Traffic Evacuation Zone Maps (figures 6-2 through 6-9).

Hurricane Evacuation Zones

The potential inundation areas associated with each of the hurricane evacuation scenarios have been divided into evacuation zones. These zones were delineated as much as possible using major natural or manmade geographic features and conform to existing political or demographic boundaries (i.e., counties, townships, census tracts, or traffic analysis zones). The purpose of evacuation zones is to aid in geographically locating and quantifying the vulnerable population and other socioeconomic data, provide a base to model traffic movements, determine sheltering requirements, and facilitate future updating. County and borough evacuation zone delineations are shown on the Traffic Evacuation Zone Maps (figures 6-2 through 6-9).

Vulnerable Population

The vulnerable population, or population at risk, for each of the major study area jurisdictions comprises all of those persons residing within the evacuation zones subject to storm surge and the residents of mobile homes located in zones not expected to flood.

It is important to emphasize that there are special provisions for mobile home residents. Because of their proven vulnerability to the strong winds, all mobile home residents are advised to evacuate regardless of their location in the event of a hurricane.

The potential tourist population, based on the number of occupied tourist units, is also included in the population of each evacuation zone. Table 3-1 shows the vulnerable population for each scenario based on projected 1990 population data.

Institutions/Medical Facilities

A complete inventory of institutions/medical facilities has been compiled for each of the major study area jurisdictions. The purpose of this analysis is to determine which of these institutions may require evacuation due to potential flooding under various hurricane threats. The first floor elevations of all medical facilities found to be in or near vulnerable areas have been established by field surveys. The inventories, capacities, and surge analyses for those facilities are presented in tables 3-2 through 3-9. Capacities that are unavailable are so noted.

TABLE 3-1

EVACUATING PEOPLE STATISTICS

Area	Estimated Current Population	Storm Scenario	Maximum People Evacuating Dwelling Units
Suffolk	1,322,000	Category 1-2	175,280
		Category 3	270,750
		Category 4	310,060
Nassau	1,287,000	Category 1-2	221,610
		Category 3	293,495
		Category 4	309,210
Brooklyn	2,300,000	Category 1	95,110
		Category 2	171,290
		Category 3	331,910
		Category 4	385,635
Queens	1,951,000	Category 1	67,515
		Category 2	92,210
		Category 3-4	176,420
Manhattan	1,487,000	Category 1-2	56,050
		Category 3-4	178,390
Staten Island	379,000	Category 1-2	39,290
		Category 3-4	47,145
Bronx	1,204,000	Category 1-2	15,085
		Category 3-4	48,285
Westchester	875,000	Category 1-4	29,905

Please note that behavioral assumptions related to participation rates, percent to public shelter, and vehicle ownership/usage were varied by evacuation zone for each jurisdiction depending upon a zone's income level, the distance from the coastline, and the predominance of high-rise buildings.

TABLE 3-2
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Suffolk County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
AMITYVILLE							
Broadlawn Manor Nursing Home	399 County Line Rd.	320	30.8	2.3	12.3	21.0	28.6
Brunswick Nursing Home	366 Broadway	94	31.2	2.3	12.3	21.0	28.6
Brunswick Hospital Center	366 Broadway	94	30.7	2.3	12.3	21.0	28.6
Brunswick Hosp Ctr, Rehabilitation	366 Broadway	94	31.6	2.3	12.3	21.0	28.6
LINDENHURST							
Holiday Manor Adult Home	630 W. Montauk Hwy	20	13.9	2.7	8.3	17.7	25.3
Inver Adult Home	620 W. Montauk Hwy	38	13.3	2.7	8.3	17.7	25.3
Montauk Manor Adult Home	594 W. Montauk Hwy	29	14.2	2.7	8.3	17.7	25.3
WEST BABYLON							
East Neck Nursing Home	134 Great East Neck Rd.	300	23.7	2.7	8.3	17.7	25.3
Babylon Manor Rest Home	170 Little East Neck Rd.	21	21.2	2.7	8.3	17.7	25.3
BABYLON							
Berkshire Nursing Home	10 Berkshire Rd.	175	29.1	2.7	8.3	17.7	25.3
Babylon Beach House for Adults	23 Yacht Club Rd.	58	6.0	3.1	8.0	17.1	24.5
Bayview Home for Adults	143 E. Main St.	58	13.7	3.1	8.0	17.1	24.5
Laurel Haven Rest Home	238 Fire Island Avenue	36	13.7	3.1	8.0	17.1	24.5
Little Flower Residence	163 N. Carll Ave.	69	16.8	3.1	8.0	17.1	24.5
WEST ISLIP							
Consolation Nursing Home	111 Beach Drive	250	7.9	3.1	8.0	17.1	24.5
Good Samaritan Hospital (Rear)	1000 Montauk Hwy	425	8.8	3.1	8.0	17.1	24.5
(Side Dock)			10.1	3.1	8.0	17.1	24.5
(Main Ent.)			12.6	3.1	8.0	17.1	24.5
BAY SHORE							
Open Gate Assoc. Home for the Aged	36 S. Clinton Ave.	33	16.7	3.2	8.4	15.9	22.6
Southshore Villa Home for Adults	19 N. Clinton Ave.	57	23.1	3.2	8.4	15.9	22.6
Bayshore Adult Home	53 Brentwood Rd.	42	19.4	3.1	8.4	15.9	22.6
Southside Hospital	Montauk Highway	489	9.1	3.1	8.4	15.9	22.6

TABLE 3-2 (CONT.)
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Suffolk County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
ISLIP							
Holly Loch Rest Home	36 Locust Ave.	21	16.1	3.1	7.3	14.3	20.9
WEST SAYVILLE							
Maple Rest Home	61 Rollstone Ave.	27	22.5	2.4	5.9	10.9	17.9
Carroll's Home for Adults	191 Main St.	UNK	15.1	2.4	5.9	10.9	17.9
SAYVILLE							
Good Samaritan Nursing Home	101 Elm Street	100	10.9	2.4	5.9	10.9	17.9
BAYPORT							
Pleasant Gardens Adult Home	396 Middle Road	27	15.5	2.4	5.9	10.9	17.9
PATCHOGUE							
Gables Home for Adults	127 Rider Ave.	24	16.4	2.2	5.0	9.7	18.6
Paradise Rest Home	500 W. Main St.	UNK	30.9	2.2	5.0	9.7	18.6
CENTER MORICHES							
South Bay Adult Home	P.O. Box 601	39	16.2	5.5	9.7	13.2	19.7
EAST HAMPTON							
Huntting Lane Rest Home	29 Huntting Lane	33	32.7	5.5	9.4	13.4	17.3
FLANDERS							
Aid to Develop Disabled	1306 Flanders Rd.	10	17.0	3.8	6.8	10.2	13.8
RIVERHEAD							
Henry Perkins Home for Adults	260 W. Main St.	120	18.0	3.8	6.8	10.2	13.8
Suffolk County Jail	County Center		17.0	3.8	6.8	10.2	13.8
AQUEBOGUE							
Aid to Develop Disabled	Route 25	UNK	14.6	3.8	6.8	10.2	13.8
GREENPORT							
Eastern Long Island Hosp. (Basement)	Manor Place	80	2.6	5.1	8.6	12.1	15.6
San Simeon Nursing Home	North Road	150	37.7	4.4	7.5	10.8	14.3

TABLE 3-2 (CONT.)
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Suffolk County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
CUTCHOGUE							
Blaschacks Rest Home	555 New Suffolk Rd.	8	31.6	3.7	6.5	9.6	12.7
CENTERPORT							
Mill Pond Manor	29 Little Neck Rd.	21	29.5	5.4	9.8	13.7	18.1
NORTHPORT							
Hillcrest Home	230 Woodbine Ave.	18	89.9	5.4	9.8	13.7	18.1

TABLE 3-3
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Nassau County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
LONG BEACH							
Long Island Tides Nursing Home	640 W. Broadway	182	12.8	8.8	15.6	20.3	25.0
Ambassador Manor Home for Adults	351 W. Broadway	131	10.6	8.8	15.6	20.3	25.0
King David Manor Home for Adults	80 W. Broadway	272	8.4	8.8	15.6	20.3	25.0
Long Beach Atlantic Home for Adults	125 E. Broadway	200	16.0	8.8	15.6	20.3	25.0
Long Beach Brighton Manor	403 E. Boardwalk	130	18.3	8.8	15.6	20.3	25.0
Palace Home for Adults	275 E. Broadway	138	14.9	8.8	15.6	20.3	25.0
Hoffman Manor Home for Adults	274 W. Broadway	194	10.0	8.8	15.6	20.3	25.0
Morton Cohen Apartments	35 E. Broadway	UNK	8.4	8.8	15.6	20.3	25.0
Sonny Duckman Apartments	175 W. Broadway	UNK	8.3	8.8	15.6	20.3	25.0
Michael J. Valenti Apartments	415 National Blvd.	UNK	5.3	8.8	15.6	20.3	25.0
Sol Scher Apartments	225 W. Park Ave.	UNK	10.3	8.8	15.6	20.3	25.0
Long Beach Grandell Co.	645 W. Broadway	278	8.0	8.8	15.6	20.3	25.0
Long Beach Memorial Hospital	455 E. Bay Dr.	203	12.6	5.2	16.7	22.1	26.7
Long Beach Memorial Nursing Home	375 E. Bay Dr.	200	8.8	5.2	16.7	22.1	26.7
ISLAND PARK							
Bayview Nursing Home	1 Long Beach Rd.	185	8.4	5.2	16.7	22.1	26.7
Abbey Island Park Manor	40-29 Long Beach Rd.	99	8.5	5.2	16.7	22.1	26.7
INWOOD							
Bayview Gardens	339 Bayview Ave.	UNK	11.9	6.7	14.7	23.5	29.3
Inwood Gardens	255 Lawrence Ave.	UNK	10.4	6.7	14.7	23.5	29.3
St. Mary's Manor (Building #41-45)	60 Doughty Blvd.	UNK	14.0	6.7	14.7	23.5	29.3
(Building #57-79)		UNK	15.7	6.7	14.7	23.5	29.3
(Building #84-106)		UNK	16.4	6.7	14.7	23.5	29.3
(Building #60)		UNK	16.2	6.7	14.7	23.5	29.3
WOODMERE							
Woodmere Nursing Home	130 Irving Place	186	31.6	7.2	15.1	24.1	32.0
Woodmere Health Facility (basement)	121 Franklin Place	150	23.8	7.2	15.1	24.1	32.0
HEWLETT							
Nassau County Police, 4th Precinct	Broadway & Sheridan		21.0	6.1	17.3	23.7	28.3
VALLEY STREAM							
Charles Monica Senior Village	Hicks St. & Payan Ave.	UNK	15.5	7.2	15.1	24.1	32.0
Green Acres	400 Flower Rd.	UNK	10.2	7.2	15.1	24.1	32.0

TABLE 3-3 (CONT.)
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Nassau County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
LYNBROOK							
East Rockaway Nursing Home	243 Atlantic Ave.	100	19.0	6.1	17.3	23.7	28.3
Nathan Hale Senior Housing	30 Doxsey Place	UNK	21.4	6.1	17.3	23.7	28.3
ROCKVILLE CENTRE							
Rockville Nursing Center	41 Maine Ave.	158	22.5	6.1	17.3	23.7	28.3
Mill River House	40 Main Ave.	UNK	18.5	6.1	17.3	23.7	28.3
Rockville Residence Manor	50 Maine Ave.	66	23.7	6.1	17.3	23.7	28.3
Halandia Court	266 & 275 N. Centre Ave.	UNK	25.0	6.1	17.3	23.7	28.3
Village of Rockville Centre Housing	579 Merrick Rd.	UNK	25.8	6.1	17.3	23.7	28.3
OCEANSIDE							
Nassau Nursing Home	2914 Lincoln Ave.	100	16.6	6.1	17.3	23.7	28.3
Bishop Kellenburg Gardens	2477 Long Beach Rd.	UNK	17.1	6.1	17.3	23.7	28.3
Mill River Gardens (Building 6-7)	2900 Rockaway Ave.	UNK	9.6	6.1	17.3	23.7	28.3
South Nassau Community Hospital	2445 Oceanside Rd.	UNK	21.4	6.1	17.3	23.7	28.3
BALDWIN							
Halandia Shores (Building B)	2878 Grand Ave.	UNK	9.8	6.4	15.9	22.8	28.4
(Building A)		UNK	12.1	6.4	15.9	22.8	28.4
Brookside Gardens	1810 N. Grand Ave.	UNK	22.2	6.4	15.9	22.8	28.4
BALDWIN							
Nassau County Police, 1st Precinct	Merrick & Harrison	UNK	24.0	6.4	15.9	22.8	28.4
FREEPORT							
South Shore Nursing Home	275 W. Merrick Rd.	100	25.8	4.7	15.4	23.8	28.0
Rev. John Madden Apts (Bldg 250-1)	240, 250, 260 S. Main St.	UNK	12.2	4.7	15.4	23.8	28.0
(Building 260-17)		UNK	13.0	4.7	15.4	23.8	28.0
(Building 240-2)		UNK	14.6	4.7	15.4	23.8	28.0
(Building 250-4)		UNK	12.9	4.7	15.4	23.8	28.0
Dr. E. Mitchell Molette	100 N. Main St.	UNK	17.9	4.7	15.4	23.8	28.0
Rev. Timothy Peternana	45 Wallace St.	UNK	26.1	4.7	15.4	23.8	28.0
BELLMORE							
Bellmore Gardens	2000 Bellmore Ave.	UNK	27.5	4.4	14.0	22.3	29.2

TABLE 3-3 (CONT.)
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Nassau County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
SEAFORD							
Nassau County Police, 7th Precinct	Merrick & Neptune	UNK	15.5	2.2	12.9	21.3	29.0
MASSAPEQUA							
Parkview Nursing Home	5353 Merrick Rd.	169	19.4	2.3	12.3	21.0	28.6
Town of Oyster Bay Housing Authority	20 Lake Street	UNK	11.6	2.3	12.3	21.0	28.6
Town of Oyster Bay Housing Authority	201 Oakley Ave.	UNK	20.6	2.3	12.3	21.0	28.6
PORT WASHINGTON							
Hadley House	464 Main St.	UNK	32.2	6.5	11.8	18.0	23.2
Cow Bay Green Housing	Bay Green Lane	UNK	37.1	6.5	11.8	18.0	23.2
BAYVILLE							
Jones Manor	59 Bayville Ave.	46	47.1	5.7	10.3	15.2	19.8
OYSTER BAY							
Town of Oyster Bay Housing Authority	125 W. Main St.	UNK	23.1	5.7	10.3	15.2	19.8

TABLE 3-4
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Manhattan

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
Bayview Correctional Facility	550 W. 20th St.	339	6.8	10.9	17.7	23.3	28.2
Village Nursing Home (Main Floor)	607 Hudson St.	200	14.8	10.9	17.7	23.3	28.2
(Floor at Basement Stairwell)			9.5	10.9	17.7	23.3	28.2
St. Vincents Hospital	153 W. 11th St.	788	23.1	10.9	17.7	23.3	28.2
Immigration & Naturalization Det.	201 Varick St.	250	13.8	10.9	17.7	23.3	28.2
St. Margaret's House	49 Fulton St.	250	13.1	10.2	16.0	25.1	31.3
N.Y. Infirmary Beekman Dwntwn Hosp.	170 William St.	300	18.3	10.2	16.0	25.1	31.3
Metropolitan Correctional Center	150 Park Row	511	19.1	10.2	16.0	25.1	31.3
Manhattan House of Detention	125 Worth St.	850	15.0	10.2	16.0	25.1	31.3
(Floor at garage entrance)			12.3	10.2	16.0	25.1	31.3
Gouveneur Hospital	227 Madison St.	210	20.6	10.2	16.0	25.1	31.3
St. Rose's Home (Main Floor)	71 Jackson St.	60	15.6	10.2	16.0	25.1	31.3
(Low Point Entry)			10.4	10.2	16.0	25.1	31.3
Home of Sages of Israel (Main Floor)	15-17 Bialystoker Place	58	22.8	10.2	16.0	25.1	31.3
(Low Point Entry)			19.1	10.2	16.0	25.1	31.3
American Nursing Home (Main Floor)	62 Ave. B	240	17.4	10.2	16.0	25.1	31.3
(Window Sill, Low Point Entry)			15.8	10.2	16.0	25.1	31.3
Beth Israel Medical Ctr (So of 17th)	307 Second Ave		21.0	9.2	14.1	17.4	22.3
Hosp for Joint Disease (No of 17th)	301 E. 17th St.	220	19.7	9.2	14.1	17.4	22.3
Cabrini Medical Center (19th St Ent)	227 E. 19th St.	478	22.2	9.2	14.1	17.4	22.3
Veterans Admin Hospital (1st Avenue)	408 First Ave.	540	5.1	9.2	14.1	17.4	22.3
Bellevue Hospital Ctr (Main Floor)	462 First Ave.	1,232	11.7	9.2	14.1	17.4	22.3
(Top of Wall at Window Well)			11.5	9.2	14.1	17.4	22.3
New York University Hospital	550 First Ave.	879	7.8	9.2	14.1	17.4	22.3
Rockefeller University Hospital	York Ave., 66th St.	40	47.0	9.2	14.1	17.4	22.3
New York Hosp Cornell Medical Center	525 E. 68th St.	1,048	30.8	9.2	14.1	17.4	22.3
Hospital for Special Surgery	535 E. 70th St.	192	7.6	9.2	14.1	17.4	22.3
Metropolitan Hospital Ctr (East Ent)	1901 1st Ave.	574	14.8	8.4	12.7	16.4	20.4
(Top of Wall at Window Well)			11.8	8.4	12.7	16.4	20.4
Harlem Hospital	506 Lenox Ave.	678	19.5	8.4	12.7	16.4	20.4
Greater Harlem Nursing Home	30 W. 138th St.	200	11.6	8.4	12.7	16.4	20.4

TABLE 3-5

INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Bronx

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.)			
				Cat 1	Cat 2	Cat 3	Cat 4
Lincoln Hospital (Basement)	234 E. 149th St.	597	8.6	8.4	12.7	16.4	20.4
Bronx House of Detent. (Main Floor)	653 River Ave.	450	31.8	8.4	12.7	16.4	20.4
(Top of Wall at Window Well)			27.9	8.4	12.7	16.4	20.4
Grand Manor Nursing Home	700 White Plains Road	240	22.5	6.5	11.4	16.2	22.7
Calvary Hospital	1740 Eastchester Road	200	12.4	6.5	11.4	16.2	22.7
Bronx State Hospital	1500 Waters Place	UNK	17.8	6.5	11.4	16.2	22.7
Astor Gardens Nursing Home	2316 Bruner Ave.	175	16.0	6.5	12.0	17.8	22.4
Kings Harbor Nursing Home	2000 E. Gun Hill Road	720	16.3	6.5	12.0	17.8	22.4
Hebrew Hospital for Chronic Sick	2200 Givan Ave.	480	17.6	6.5	12.0	17.8	22.4
Providence Rest Nursing Home	3304 Waterbury Ave.	200	10.7	6.5	12.0	17.8	22.4

TABLE 3-6
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Brooklyn

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
Aishel Avraham Nursing Home	40 Heyward St.	200	17.2	10.2	16.0	25.1	31.3
Brooklyn Correctional Facility	136 Flushing Ave.	1,200	14.4	10.2	16.0	25.1	31.3
Veterans Hospital (Poly Place)(Rear)	700 Poly Place	700	16.5	9.3	15.2	20.9	27.0
(First Floor @ Front Entrance)			23.7	9.3	15.2	20.9	27.0
Lemberg Home for the Aged	8629 Bay Parkway	45	16.8	9.2	15.2	20.8	27.2
Bay View Manor Adult Home	2255 Cropsey Ave.	229	18.7	9.2	15.2	20.8	27.2
Sephardic Home for the Aged	2266 Cropsey Ave.	271	14.3	9.2	15.2	20.8	27.2
Haym Salmon Home for the Aged	2300 Cropsey Ave.	220	21.5	9.2	15.2	20.8	27.2
Metropolitan Jewish Geriatric Ctr	29th and Boardwalk	359	5.4	9.1	15.0	20.5	26.4
Sea Crest Health Care Center	3035 W. 24th St.	320	5.5	9.1	15.0	20.5	26.4
Shore View Nursing Home	2865 Brighton 3rd St.	320	11.8	7.8	14.9	21.1	27.5
Coney Island Hospital	2601 Ocean Parkway	445	9.7	7.8	14.9	21.1	27.5
Menorah Nursing Home	1516 Oriental Blvd.	253	8.4	7.8	14.9	21.1	27.5
Palm Beach Home for Adults	2900 Bragg St.	192	12.3	7.8	14.9	21.1	27.5
Sheepshead Nursing Home	2840 Knapp St.	200	16.2	7.8	14.9	21.1	27.5
Harbor View Nursing Home	3900 Shore Parkway	162	18.6	7.8	14.9	21.1	27.5
Crown Nursing Home	3457 Nostrand Ave.	189	17.6	7.8	14.9	21.1	27.5
(Basement Floor)			6.8	7.8	14.9	21.1	27.5
Community Hospital of Brooklyn	2525 Kings Highway	134					
(Top of Wall at Window Well)			22.5	7.8	14.9	21.1	27.5
Kings Highway Hospital	3201 Kings Highway	212	23.9	7.8	14.9	21.1	27.5
South Shore Manor Home for Adults	1041 E. 83rd St.	80	13.8	7.4	15.8	25.3	31.8
Home for the Blind and Disabled	555 E. 86th St.	UNK	24.1	7.4	15.8	25.3	31.8
(Basement Window Sill)			21.2	7.4	15.8	25.3	31.8
Parkshore Manor Nursing Home	1555 Rockaway Parkway	270	21.6	7.4	15.8	25.3	31.8
Adult Retardates' Home	1121 E. 96th St.	UNK	22.0	7.4	15.8	25.3	31.8
Thomas Jefferson Home for Adults (Basement)	650 E. 104th St.	200	8.0	7.4	16.3	26.6	32.6
River Manor Nursing Home (Basement)	630 E. 104th St.	380	7.8	7.4	16.3	26.6	32.6
Seaport Manor Home for Adults (Main Floor)	615 E. 104th St.	346	16.5	7.4	16.3	26.6	32.6
(Basement)			6.2	7.4	16.3	26.6	32.6
Brookdale Hospital Medical Center	Linden Blvd. & Brookdale Plaza	796	31.1	7.4	16.3	26.6	32.6

TABLE 3-6 (CONT.)
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Brooklyn

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.)			
				Cat 1	Cat 2	Cat 3	Cat 4
Brookdale Hospital Center Nrs Home	555 Rockaway Pkwy	220	30.5	7.4	16.3	26.6	32.6
Samuel Shulman Institute	555 Rockaway Pkwy	220	30.9	7.4	16.3	26.6	32.6
Brooklyn Manor Home for Adults	2830 Pitkin Ave.	216	23.4	6.1	16.4	21.2	32.7
Brooklyn United Methodist Home	1485 Dumont Ave.	120	16.6	6.1	16.4	21.2	32.7
Linden Bay Care Center	2749 Linden Blvd.	140	6.4	6.1	16.4	21.2	32.7

TABLE 3-7
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Queens

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
Bird S. Coler Hospital	900 Main St., Roosevelt Island	250	14.5	9.2	14.1	17.4	22.3
Goldwater Hospital	100 Main St., Roosevelt Island	564	10.2	9.2	14.1	17.4	22.3
Scharaf Manor	112-14 Corona Ave.	226	19.8	6.6	11.6	16.2	20.9
St. Mary's Childrens Hospital	29-01 216th St.	95	44.7	6.3	11.5	18.5	25.0
Bernard Fineson Developmental Ctr	155-55 Crossbay Blvd.	UNK	15.5	6.1	16.4	21.2	32.7
Neponsit Home for the Aged	149-25 Rockaway Beach Blvd.	284	12.7	9.1	14.3	20.0	25.9
Seville Home for Adults (Main Floor)	128-03 Rockaway Beach Blvd.	55	11.8	9.1	14.3	20.0	25.9
(Basement)			2.9	9.1	14.3	20.0	25.9
Belle Harbor Manor	209 Beach 125th St.	162	4.6	9.1	14.3	20.0	25.9
Queen Esther Adult Home	124-05 Rockaway Beach Blvd.	47	11.4	9.1	14.3	20.0	25.9
Chai Home for Adults	125-02 Ocean Promenade	71	15.3	9.1	14.3	20.0	25.9
Gloria's Manor Senior Adult Home	140 Beach 119th St.	172	6.3	9.1	14.3	20.0	25.9
Park Inn Nursing Home	115-02 Ocean Promenade	181	13.8	9.1	14.3	20.0	25.9
Park Nursing Home	128 Beach 115th St.	196	9.4	9.1	14.3	20.0	25.9
Promenade Nursing Home	140 Beach 114th St.	240	8.7	9.1	14.3	20.0	25.9
Ocean Promenade Health Facility	140 Beach 113th St.	120	11.3	9.1	14.3	20.0	25.9
Surfside Manor	95-02 Rockaway Beach Blvd.	200	5.5	6.3	13.7	21.4	27.5
Shalom Home for Adults	318 Beach 85th St.	125	8.1	6.3	13.7	21.4	27.5
Resort Nursing Home	430 Beach 68th St.	280	7.2	6.3	13.7	21.4	27.5
Resort Health Related Facility	64-11 Beach Channel Drive	280	9.1	6.3	13.7	21.4	27.5
Lawrence Nursing Home	350 Beach 54th St.	200	8.1	6.3	13.7	21.4	27.5
Peninsula General Hospital	51-15 Beach Channel Drive	272	10.2	6.3	13.7	21.4	27.5
Peninsula Hospital Center Nrs Home	51-15 Beach Channel Drive	200	9.9	6.3	13.7	21.4	27.5

TABLE 3-7 (CONT.)
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Queens

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.)			
				Cat 1	Cat 2	Cat 3	Cat 4
Rockaway Care Center	353 Beach 48th St.	215	8.4	6.3	13.7	21.4	27.5
Brookhaven Beach Health Related Fac.	250 Beach 17th St.	298	10.3	8.1	15.4	20.5	26.2
St. John's Episcopal Nursing Home	327 Beach 19th St.	314	17.3	8.1	15.4	20.5	26.2
St. John's Episcopal Hospital	327 Beach 19th St.	314	34.8	8.1	15.4	20.5	26.2
Queens-Nassau Nursing Home	520 Beach 19th St.	200	27.9	8.1	15.4	20.5	26.2
Surfside Nursing Home	2241 New Haven Ave.	175	30.9	8.1	15.4	20.5	26.2
Far Rockaway Nursing Home	13-11 Virginia Ave.	100	24.1	8.1	15.4	20.5	26.2
Oceanview Nursing Home	315 Beach 9th St.	102	12.7	8.1	15.4	20.5	26.2

TABLE 3-8
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

New York City-Staten Island

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
South Beach Psychiatric Hospital	777 Seaview Ave.	UNK	15.4	9.3	15.3	20.5	26.5
Staten Island Hospital	475 Seaview Ave. & Mason Ave.	437	16.1	9.3	15.3	20.5	26.5
Hylan Manor Home for Adults	3565 Hylan Blvd.	62	23.3	10.1	15.9	21.2	27.1

TABLE 3-9
INSTITUTIONS/MEDICAL FACILITIES SURGE ANALYSIS

Westchester County

Facility	Address	Capacity	1st Floor Elevation (m.s.l.)	Potential Surge Heights (ft. m.s.l.) Cat 1	Cat 2	Cat 3	Cat 4
NEW ROCHELLE							
Woodland Nursing Home	490 Pelham Road	UNK	15.7	6.2	11.3	16.7	21.8
Bayberry Nursing Home	40 Keogh Lane	UNK	13.6	6.2	11.3	16.7	21.8
Dumont Masonic Home	676 Pelham Road	UNK	11.3	6.2	11.3	16.7	21.8

Administrative officials should be aware of the potential for wind damage to multi-story buildings. Post-hurricane surveys in other areas show that extreme winds can inflict major damage to substantial structures, exposing occupants to life-threatening danger. Hurricane preparedness plans based on moving people from potential surge levels vertically to upper floors must take into account the location and size of windows and doors, as well as the structural integrity of the building itself.

Agencies responsible for hurricane preparedness of special needs facilities (hospitals, nursing homes, adult homes, and correctional facilities should ensure that proper attention is given to the complex task of planning and coordinating emergency response. The following information on hurricane preparedness planning for special facilities was furnished by the New York State Emergency Management Office. "Section 405.24 (g) of the New York State Hospital Code requires all hospitals to have written emergency preparedness plans, rehearsed and updated at least twice a year, with procedures for the proper care of patients and personnel, including but not limited to the reception and treatment of mass casualty victims. Personnel responsible for the hospital's accommodation to extraordinary events shall be trained in all aspects of preparedness for any interruption of services and for any disaster. Title 10 of the New York State Codes, Rules, and Regulations; Chapter 5, Medical Facilities Code, requires that nursing homes have written emergency plans, reviewed and rehearsed twice a year. Where no health care is provided (adult homes), the New York State Department of Social Services is the regulating authority. The New York State Corrections Law, Article 3, authorizes the State Commission of Correction to...appraise the management of correctional facilities with specific attention to matters such as safety, security, health of inmates.... Some, but certainly not all facilities have disaster procedures in place. Finally, Section 23 of the Executive Law, Article 2B, authorizes each county, except those in New York City, and each city to prepare disaster preparedness plans. These plans at the local level should take into account all of those special facilities within the given jurisdiction."

Evacuation Route Flooding

Evacuation route flooding can be caused by two sources: rainfall runoff and storm tide. Hurricane evacuations are normally timed so that evacuees can reach safe shelter prior to the arrival of sustained tropical storm winds. Because of the wide variation in amounts and times of occurrence from one storm to another, rainfall can only be addressed in general terms. For most hurricanes, the heaviest rainfall begins near the time of arrival of sustained tropical storm winds. In some cases, however, over 20 inches of rain has preceded an approaching hurricane by as much as 24 hours.

The greatest potential for roadway flooding from rainfall is along the southern east-west arterials of Long Island, including the New York City boroughs of Brooklyn and Queens. Considering the fact that evacuation of the shoreline in those areas will primarily be a south-to-north traffic movement, and that the evacuation should be nearly completed before heavy rains begin, roadway inundation due to rainfall should not result in major disruptions.

Theoretical maximum storm surge levels at the time of arrival of sustained tropical storm winds have been computed by the SLOSH model for 100 critical grid points and are presented in table 3-10. This table shows that the surge height at nearly all listed locations will be 3.5 feet or less at the time the evacuation should be completed. The values given in table 2-5 indicate the possible additional height of the water surface if astronomical high tide occurs coincidentally with the arrival of sustained tropical storm winds. For example, in the case of a category 3 hurricane, Long Beach could experience a surge height at the onset of tropical storm winds of 2.8 feet. If astronomical high tide occurs coincidentally with that surge height, the total still-water elevation could be 4.8 feet m.s.l. The best available topographic information indicates that nearly all causeways in the study area lie above 5 feet m.s.l. In a high-tide situation, an evacuation protracted beyond the arrival of sustained tropical storm winds may be additionally hampered by surge roadway flooding in some low-lying areas.

Emergency Transportation Needs

Evacuation preparedness plans should accommodate all persons who do not have access to a private vehicle and therefore would have to rely on public transportation for evacuation. Local government should arrange for adequate resources to meet the demand for public transportation.

Provision of adequate special needs emergency transportation for the infirm residing in private homes is usually the responsibility of local emergency management officials, while transportation for those in health-related facilities should be the responsibility of the individual facilities. Although detailed information concerning residents of private homes may be difficult to obtain, each local government should develop procedures for maintaining an up-to-date roster of persons likely to need special assistance. Emergency management officials should match types of transportation to special needs. Non-ambulatory patients will require transportation that can easily accommodate wheelchairs, stretchers, and, possibly, life-sustaining equipment. Lack of planning for these needs could result in critical evacuation delays and increased hazards for the evacuees.

Whether planning simply for people who lack private transportation or for those requiring special assistance, the resources employed should ensure successful completion of that facet of the evacuation within the calculated clearance times.

TABLE 3-10
SLOSH SURGE ELEVATIONS
(Onset gale-force winds)

	LOCATION	SURGE HEIGHT AT ONSET GALE-FORCE WINDS (msl)*			
		Cat 1	Cat 2	Cat 3	Cat 4
1.	MONMOUTH BEACH	2.7	3.1	3.1	2.8
2.	SANDY HOOK	2.7	3.0	3.1	2.8
3.	KEANSBURG	2.6	3.2	3.5	3.6
4.	KEYPORT HARBOR	2.7	3.2	3.5	3.5
5.	SAYREVILLE	2.7	3.2	3.5	3.4
6.	AMBOY	2.7	3.3	3.8	3.6
7.	VICTORY BRIDGE	2.8	3.3	3.7	3.5
8.	TOTTENVILLE	2.6	3.2	3.7	3.5
9.	WOODBRIDGE	2.4	3.0	3.3	3.1
10.	FRESH KILLS LANDFILL	2.2	2.7	2.8	2.7
11.	TRAVIS	2.4	2.9	3.1	3.0
12.	LINDEN	2.3	2.8	3.0	3.0
13.	GOETHALS BRIDGE	2.2	2.7	2.9	3.0
14.	ELIZABETH	2.2	2.7	2.9	2.9
15.	NEWARK BAY BRIDGE	1.8	2.2	2.4	2.4
16.	US 1 @ PASSAIC RIVER	1.7	2.0	2.2	2.2
17.	PASSAIC RIVER	1.8	2.1	2.3	2.3
18.	PULASKI SKYWAY	1.6	2.0	2.1	2.1
19.	N.J. TURNPIKE	1.6	1.9	2.0	2.1
20.	ROUTE 3	1.5	1.7	1.9	2.0
21.	RIDGEFIELD PARK	Dry	Dry	Dry	Dry
22.	PALISADES PARK	Dry	Dry	Dry	Dry
23.	STAPLETON	2.4	2.8	3.2	3.1
24.	ST. GEORGE	2.3	2.8	3.1	3.0
25.	BAYONNE	2.2	2.7	2.9	2.9
26.	BUSH TERMINAL	2.3	2.7	3.1	2.9
27.	LIBERTY ISLAND	2.3	2.7	3.0	2.9
28.	BATTERY	2.1	2.8	3.1	2.9
29.	LINCOLN TUNNEL	2.3	2.6	2.9	2.9
30.	W 96TH STREET	2.1	2.5	2.7	2.8
31.	GEORGE WASHINGTON BRIDGE	2.1	2.4	2.5	2.6
32.	SPUYTEN DUYVIL	1.9	2.2	2.4	2.4
33.	CITY LINE	1.7	2.1	2.2	2.3
34.	TAPPAN	1.6	1.8	2.0	2.1
35.	OSSINING	1.5	1.7	1.8	1.9
36.	PEEKSKILL/INDIAN POINT	1.7	1.5	1.9	2.0
37.	MANHATTAN BRIDGE	2.1	2.8	3.1	2.9
38.	NEWTOWN CREEK	2.2	2.9	3.1	2.9
39.	HELLGATE	2.8	2.9	3.1	2.9
40.	LA GUARDIA	2.9	3.0	3.1	3.0
41.	FLUSHING BAY	3.0	3.1	3.0	3.1
42.	WHITESTONE (BRONX)	2.9	3.0	3.1	3.0
43.	PELHAM BAY	3.1	3.1	3.2	3.1
44.	WILLETS POINT	3.1	3.2	3.0	3.1
45.	CITY ISLAND	3.2	3.2	3.2	3.2
46.	MANORHAVEN	3.1	3.2	2.9	3.1
47.	SANDS POINT	3.1	3.2	3.0	3.1
48.	ROSLYN	2.9	3.0	3.0	3.0
49.	GLEN COVE	3.1	2.9	2.9	3.0
50.	MILL NECK	2.9	2.9	2.9	2.9

TABLE 3-10 (Cont.)
SLOSH SURGE ELEVATIONS
(Onset gale-force winds)

LOCATION	SURGE HEIGHT AT ONSET GALE-FORCE WINDS (msl)*			
	Cat 1	Cat 2	Cat 3	Cat 4
51. CENTRE ISLAND	2.9	2.9	2.9	2.9
52. COLD SPRING HARBOR	2.9	2.9	2.9	2.9
53. NORTHPORT BAY	2.6	2.7	2.8	2.8
54. ASHAROKEN	2.6	2.7	2.7	2.8
55. PORT JEFFERSON	2.6	2.5	2.6	2.6
56. SHOREHAM	2.2	2.3	2.4	2.5
57. MATTITUCK	2.1	2.1	2.2	2.3
58. ORIENT	2.2	2.3	2.2	2.4
59. SHELTER ISLAND	2.3	2.4	2.4	2.5
60. JAMESPORT	1.8	2.0	2.1	2.1
61. WARD POINT	2.7	3.3	3.7	3.6
62. HUGUENOT	2.6	3.1	3.6	3.5
63. GREAT KILL	2.5	3.0	3.5	3.4
64. OAKWOOD BEACH	2.5	3.0	3.3	3.5
65. MIDLAND BEACH	2.5	2.9	3.3	3.4
66. SOUTH BEACH	2.6	2.8	3.2	3.3
67. FORT HAMILTON	2.6	2.8	3.2	3.3
68. GRAVESEND BAY	2.2	2.8	3.2	3.0
69. SEAGATE	2.4	2.9	3.3	3.1
70. SHEEPSHEAD BAY	2.1	2.8	3.1	2.9
71. FLOYD BENNETT	2.0	2.5	2.6	2.5
72. PENNSYLVANIA AVE.	1.8	2.3	2.3	2.2
73. KENNEDY	1.9	2.1	2.1	2.1
74. BREEZY POINT	2.6	2.9	3.0	2.7
75. ROCKAWAY BEACH	2.6	2.8	2.9	2.6
76. EAST ROCKAWAY INLET	2.5	2.8	2.7	2.6
77. LAWRENCE	2.1	2.6	2.7	2.7
78. LONG BEACH	2.3	2.7	2.8	2.6
79. ISLAND PARK	1.8	2.1	2.2	2.2
80. EAST ROCKAWAY	1.8	2.1	2.2	2.2
81. OCEANSIDE	1.8	2.1	2.2	2.2
82. FREEPORT	1.9	2.6	2.8	2.7
83. LOOP PARKWAY	1.9	2.6	2.8	2.7
84. JONES BEACH	2.3	2.7	2.6	2.5
85. WANTAGH PARKWAY	1.4	1.5	1.5	1.6
86. GILGO BEACH	2.2	2.6	2.6	2.4
87. AMITYVILLE	1.4	1.5	1.5	1.6
88. WEST ISLIP	1.4	1.6	1.6	1.7
89. ATLANTIQUE	2.3	2.6	2.5	2.4
90. DAVIS PARK	2.2	2.5	2.5	2.4
91. PATCHOGUE	1.3	1.3	1.1	1.1
92. SMITH PT./MORICHES	2.5	2.5	2.3	2.2
93. CENTER MORICHES	1.9	2.1	2.2	2.2
94. WEST HAMPTON	2.2	2.5	2.3	2.3
95. MECOX	2.2	2.3	2.3	2.2
96. NAPEAGUE	2.2	2.2	2.2	2.2
97. MONTAUK POINT	2.5	2.5	2.7	2.5
98. NEW ROCHELLE	3.1	3.1	3.1	3.1
99. MAMARONECK HARBOR	3.0	3.1	3.0	3.0
100. PORT CHESTER	3.0	3.1	3.0	3.0

*** For high tide see table 2-5**

CHAPTER FOUR

BEHAVIORAL ANALYSIS

Purpose

The behavioral analysis is conducted to provide reliable estimates of public response to a variety of hurricane threats. These estimates are used in the shelter analysis and transportation analysis, and as guidance in emergency decision-making and public awareness efforts. The study included the permanent population and tourists that would be visiting the area.

Objectives

The specific objectives of the behavioral analysis are to determine the following:

a. The percentages of the population that will evacuate under a range of hurricane threat situations or in response to evacuation advisories.

b. When the evacuating population will leave in relation to an evacuation advisory given by local officials or other persons of authority.

c. The number of vehicles that the evacuating population will use during a hurricane evacuation.

d. The percentage of the total number of evacuating vehicles which may be towing boats, camper trailers, or other vehicular equipment.

e. The probable destinations of the evacuating households. These data consist of percentages of the total number of evacuees going to local public shelters, staying locally with friends or relatives, staying locally in a hotel/motel, or leaving the county/borough for out-of-region destinations.

f. How the threatened population will respond based upon forecasts of hurricane intensity, probability, or other information provided during a hurricane emergency.

g. The evacuation responses of tourists.

Data Sources

The primary data sources for the New York behavioral analysis were <u>Hurricane Evacuation Behavior in the Middle Atlantic and Northeast States</u> and <u>Hurricane Evacuation Behavioral Assumptions for New York</u>, which are included in this report as Appendix F, Parts I and II, respectively. Part I is a comprehensive analysis of hurricane evacuation behavior in eight coastal states from Virginia northward, including New York. It is based to a large extent on a survey of the response of threatened populations to Hurricane Gloria in 1985. Part II is an application of the general analysis focusing specifically on the study area.

Methodology

a. General. Past studies have shown that accurate conclusions regarding behavioral assumptions for evacuation planning cannot be drawn by relying exclusively upon residents' responses to hypothetical questions about their likely behavior in a hurricane threat. The approach used in the New York study, and most other hurricane evacuation studies, was to collect survey data from the population that would be at risk in an actual threat, compare those responses to survey results from other locations, and then interpret the predictive validity of the responses in light of what is known to have occurred in actual threats over several decades (general response model). This method makes it possible to detect patterns which might make the surveyed population genuinely different behaviorally from other populations but still rely on actual past response data for predicting what the population would do in a variety of real threats. As mentioned above, in New York many survey questions involved actual response, or lack of response, to Hurricane Gloria. The analysis consisted of the following steps.

(1) Conduct a sample survey of residents of the eight states, and in particular New York, to document actual response to Gloria and to assess intended responses to hypothetical evacuations.

(2) Compare data on intended response to results of surveys addressing hypothetical hurricane evacuation in other areas.

(3) Compare response in Gloria to the general response model.

(4) Formulate behavioral assumptions by comparing New York survey data to surveys in other areas and adjusting the general response model accordingly.

b. Sample Surveys. Telephone surveys with area residents and personal interviews with public officials were conducted to investigate likely evacuation responses under a variety of hurricane threat situations. In the eight states surveyed, "beach" and "mainland" areas were studied using a questionnaire that included both actual and hypothetical responses. Selection criteria varied from state to state, but in most cases, the locations were considered to be important because of evacuation concerns at those sites or because they were representative of other areas to which generalizations could be extended.

The purpose of the sample surveys was to provide a basis for comparing responses obtained in New York with those obtained elsewhere and to establish a baseline for adjusting the general response model. The questions began by establishing whether the interviewee had evacuated for Hurricane Gloria in 1985. Many respondents did not evacuate in response to the Gloria threat. That information is useful in assessing evacuation rates but provides no information on other behaviors such as shelter use. Therefore, those respondents who evacuated for Gloria were questioned on their actions during that event, while those who did not evacuate were asked hypothetical questions about what they believe they would do in future hurricane threats or what they would have done if they had evacuated.

Over 2,000 samples were taken in the eight state region. In New York, approximately 200 interviews were completed with households in the Far Rockaway, Belle Harbor, and Edgemere areas of Queens and another 200 interviews were conducted in Suffolk County at Quogue and Westhampton Beach. The estimates made from each of the samples of 200 are statistically 90 percent confident and accurate within 3 to 6 percentage points of the actual values of the larger population from which the samples were taken.

c. Hypothetical Responses from Other Areas. Although hypothetical response data usually cannot be used directly for quantitative forecasts, there are certain consistent biases that can be adjusted. Hypothetical response data in one location can be compared to that collected elsewhere to give an indication of relative variation between the samples. For example, if more people in one location say that they would refuse to evacuate than in another location, they probably really are more likely to refuse. At least, more effort will be required to have them move. So, although the magnitude of people saying that they would not evacuate may not be quantitatively valid, the survey gives a relative indication. Several thousand interviews comparable to those conducted as part of this study have been conducted during hurricane evacuation studies in other areas. Responses to hypothetical situations were compared to similar data collected elsewhere and to actual responses by others for Gloria.

d. Single Event Actual Response Data. Caution must be taken not to overgeneralize about behavioral patterns from a single evacuation in a particular location because people will respond differently under various circumstances. Accordingly, response to future hurricane threats could vary substantially from the Gloria findings. However, if data is used properly, single events can provide opportunities to validate and adjust the general response model for forecasting in a specific location. Actual behavior in a single event can be documented and compared to that which would have been predicted. Its "fit" gives a clue as to how the model should be adjusted to work for the location and hazard. Single event data was collected in this study documenting how residents responded during Hurricane Gloria in 1985. This was the first time actual response data had been collected systematically in the study area.

e. General Response Model. Actual hurricane response data is considered to be more reliable than hypothetical surveys as an indication of what people are likely to do in future hurricane threats. A general (generic) response model has been developed for permanent residents from post-hurricane studies of actual response during many hurricane evacuations over about three decades. These evacuations span a wide geographical area and include a variety of hurricane threat circumstances. The general response model was used in the New York analysis to estimate quantitative values for specific responses, given a particular set of circumstances.

A common concern expressed about the model is that it is based on responses of people in "other areas," bringing into question its validity for the area under study. Actually, the strength of the general model is that it accounts for differences in responses as they vary according to the demographic characteristics of the population, actions by emergency management officials, the degree of physical hazard inherent to the area, etc.

The number of post-hurricane studies used to develop the model is large enough that several conclusions about behavioral tendencies can be clearly drawn. Although the studies show social variations from place to place, there are greater variations in public response between differing hurricane threats in the same location than there are between similar events in different locations. With these findings in mind, conclusions drawn about one location can be applied with considerable confidence to similar situations in other areas. Sample surveys can be used to adjust for local conditions, if warranted.

Analysis Results

In order to develop realistic estimates of response, behavioral assumptions should not be overgeneralized. The sample surveys showed that, typically, response can vary within relatively small geographic areas as well as with the circumstances of the storm. The general response model accounts for these variations and evacuation patterns for Hurricane Gloria conformed to those predicted by the model.

The following paragraphs address each of the specific objectives established for the behavioral analysis and present important study results. More detailed information on the behavioral analysis methodology, sampling error, sample questionnaire, and analysis results is given in Appendix F to this Technical Data Report. Participation rates, destination percentages, and socioeconomic data used in developing the total number of evacuees and public shelter demand are shown in tables 6-3 through 6-10.

a. **Evacuation Participation Rates.** Evacuation participation rates refer to the percentages of residents in high-, moderate-, and low-risk areas* who can be expected to evacuate under various hurricane threats. Post-hurricane response studies indicate that a great amount of variation has occurred in evacuation participation from place to place in the same event, as well as from storm to storm in the same location. There are two principal factors that influence whether residents will evacuate: actions by public officials and perception of safety.

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* The term "high-risk areas" refers to barrier islands and other land areas exposed to the open ocean or large bodies of water where, in addition to flooding, wave battering and scour are major hazards. People residing in mobile homes are considered to be at risk from hurricane-force winds and are included with those in high-risk areas. "Moderate-risk areas" are located inland from the coastline but are vulnerable to storm surge inundation without significant battering and scour. Residents in high- and moderate-risk categories comprise the vulnerable population. "Low-risk areas" are adjacent to those of moderate risk but are not threatened by flooding and have substantial housing that affords protection against hurricane winds. Surveys show that a number of these individuals will evacuate along with the vulnerable population, contributing to the evacuating traffic and shelter demand during a hurricane threat.

The Hurricane Gloria survey attests to the greater likelihood of people evacuating if they believe officials have told them to do so. If fact, respondents who believed that they were ordered to evacuate were much more likely to leave than those who believed the notice was advisory. If officials want residents to evacuate, they must clearly tell them, and the only way to ensure that everyone will hear the advisory is to disseminate it door-to-door. In high-rise buildings, volunteers should be recruited beforehand to carry out that task. If door-to-door notification is not possible, vehicles with loudspeakers are the second best method. However, the effectiveness of this method is severely limited in the case of high-rise buildings. The least effective approach is issuing a bulletin through the media. If door-to-door, loudspeaker, or some other onsite means of notification is not used, evacuation participation rates could be 25 percent lower in high-risk areas and 50 percent lower in moderate- and low-risk areas, leaving a sizeable portion of the population vulnerable to hurricane surge and dangerous winds.

The public's perception of safety depends on the security of their dwelling and the forecast track and intensity of the approaching storm. In general, people who live close to the water are more likely to evacuate than those who live farther away. However, proximity to water is not a perfect indicator of the hazard to a dwelling because flooding may extend miles inland or ground elevations may rise quickly to above expected flood levels. Officials are more likely to tell people living near the water to evacuate, and residents of those areas also have a better understanding of the risk involved with staying. The severity and track of the storm not only affects the evacuation rate from the high-risk and moderate-risk areas but will also have a significant impact on residents of low-risk areas. Participation can vary by 3 to 4 times, depending on the storm forecast and the risk area. This pattern is common in hurricane evacuations and is predicted by the general response model.

People living in high-rise structures well above ground level often assume their situation to be safer than may be the actual case. The Hurricane Gloria survey showed that 40 percent of the Rockaway, Queens, sample who lived in single family homes evacuated compared to only 8 percent of residents of high-rise structures. Since wind hazards increase with elevation, high-rise dwellers who do not evacuate could face life-threatening danger. Public officials should target that segment of the population with an education program emphasizing the hazards of hurricane surge, wave action, and extreme winds (see chapter 3, Institutions/Medical Facilities).

Assumptions can be made using the general response model adjusted appropriately to the sample surveys conducted for the study. **The behavioral analysis shows that if public officials take aggressive action urging or ordering evacuation and are successful in communicating the urgency of that message, 85 to 90 percent of the residents of single family homes in high-risk areas will evacuate.** The participation rates of residents of moderate-risk areas are usually somewhat lower than those of high-risk areas and exhibit greater variation. It is expected that about 80 percent of the moderate-risk area residents will evacuate under the threat of major hurricanes, category 3 or higher, if local officials make serious efforts to evacuate those areas. A participation rate of about 40 percent can generally be expected in minor hurricanes. Twenty to thirty per cent of those in low-risk areas will leave, depending on the intensity of the storm. For residents of high-rise buildings, participation in high-risk areas will be about 25 percent for a weak storm to 80 percent for a severe storm. Percentages will range from 15 to 40 percent in moderate-risk areas, and 5 to 20 percent in low-risk areas, according to storm severity. **As previously discussed, all participation rates will be considerably lower lacking an evacuation advisory by public officials that is disseminated onsite.**

The participation rates described above were used as a guide for New York City, Nassau and Westchester Counties. However, after considering the uncertainty of the participation rates and the possible consequences of underestimating the number of evacuees, Suffolk County officials elected to take a more conservative approach. At their request, the shelter analysis and transportation analysis were based on 100-percent participation of the vulnerable population.

The vast majority of vacationers at the New York shore are "day-trippers" that come from New York City and Long Island. There are also a number of vacationers who spend one or more nights in tourist facilities, especially on Fire Island. If local emergency management officials take appropriate action, "day-trippers" should cause relatively few evacuation problems. **Beaches should be closed to the public the day before severe weather is anticipated to virtually reduce the number of these vacationers to zero.** This action was taken for Hurricane Gloria in 1985.

Vacationers who stay in bungalows for one or more nights and who might have begun their vacations prior to the development of the hurricane threat are not usually reluctant to evacuate, particularly when they are a relatively short trip from their homes. Many times, vacationers depend very heavily on the accommodation management or local officials for guidance. Prepaid lodging has not been a significant deterrent to vacationer evacuation in the past. On Fire Island, special attention must be paid to the warning systems that will be used to alert vacationers. It is very unlikely that relying exclusively on the broadcast media to disseminate the evacuation advisories will be adequate to warn all vacationers (see chapter 7, Fire Island).

b. Evacuation Participation Based On Hurricane Strike Probability.
A study addressing residents' use of probability information provided by the National Hurricane Center was conducted in fall 1984 at Wrightsville Beach, North Carolina. During that study, residents were presented with several hypothetical hurricane threat scenarios described in terms of severity, location of the storm, whether a hurricane watch or warning was in effect, and whether officials had advised or ordered evacuation. The respondents were asked to evaluate their probable actions for each of the scenarios.

A second sample of residents was presented the same threats as the first, but with the probability information added. Thus, the responses of the two groups, with and without probabilities, could be compared.

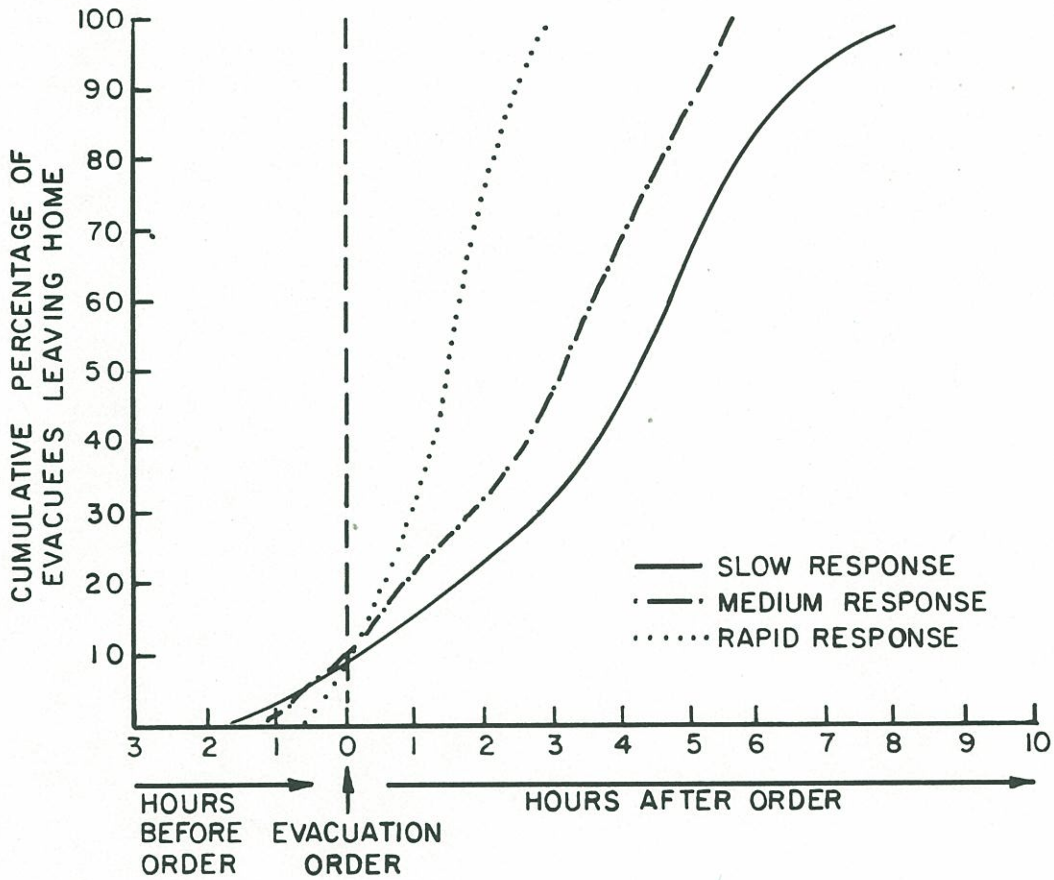
The results of this study indicate that the public understands and will utilize the probability information in their evacuation decision-making; however, the most heavily relied upon source of information is advice from local officials.

c. Evacuee Response Rates. Evacuee response rates refer to the rate of evacuation by the threatened population and when the evacuating residents will leave relative to a given evacuation advisory. These rates are expressed as cumulative percentages of the total number of evacuees departing at time intervals before and after an evacuation advisory. Evacuee response can be shown graphically using response curves by plotting these percentages versus time. Post-hurricane studies show a diversity of slopes and shapes inherent in the response curves. Mobilization and departure of the evacuating population can occur over a period of several hours or several days. This diversity can be primarily attributed to factors such as action by local officials, severity of the threatening hurricane, residents' perception of the probability of the hurricane striking their location, and the evacuation difficulties they expect to encounter. The primary factor consistent with most of the historic response curves is the sharp increase in evacuation response following the advice of local officials to evacuate. Generally, fewer than 20 percent of evacuees will leave before hearing an advisory to evacuate. However, after being told, people will leave as promptly as they believe they must. These increases in evacuation response following local advisements or orders show consistency regardless of location, relative magnitude of the threat, or information previously furnished to the threatened population in the form of hurricane watches, warnings, or other meteorological information.

Since hurricanes often move rapidly in northern latitudes, it is doubtful that New York State evacuees will have the luxury of making a leisurely evacuation decision. For this study, clearance time sensitivity was tested using mobilization rates represented by three different behavioral response curves. These curves define the rate at which evacuating vehicles load onto the roadway network relative to an evacuation order or strong advisory. The response curves shown in figure 4-1 range from rapid to slow response and are intended to include the most probable range of mobilization times that will be experienced in future hurricane evacuations.

For further information on evacuee response rates, see chapter 6, Transportation Analysis Input Assumptions.

d. Vehicle Use. The vehicle usage rate refers to the percentage of all vehicles available to evacuees that will be utilized in a hurricane evacuation. The New York survey shows that the usage rate will be approximately 70 percent. The need for public transportation could be a concern in future evacuations. U.S. Census data shows that 60 percent of the vulnerable households in Queens and 95 percent of those in Brooklyn do not own automobiles. Of the Gloria survey respondents reporting that they did not evacuate, 24 percent of those in Rockaway and 6 percent of those in Suffolk County said that they did not have a vehicle available for evacuation.



CUMULATIVE EVACUATION CURVES

FIGURE 4-1

Residents of high-rise buildings were more likely to rely on public transportation than people in other housing, so the need becomes much greater if evacuation of high-rise buildings is stressed. This reliance on public transportation would apply to Coney Island, Long Beach, and other areas, as well as Rockaway, with concentrations of high-rise structures.

e. Destinations of Evacuating Households. The destinations or types of refuge most commonly utilized by the evacuating population are local friends or relatives, hotels/motels, public shelter facilities, or out of county/borough locations. Significant variation in the percentages of persons utilizing various types of refuge can occur. Historically, this has occurred from storm to storm, as well as from location to location. For example, in Hurricane Diana (1984), it was found that 25 percent of the mainland North Carolina/South Carolina evacuees utilized public shelter facilities compared to 9 percent of the beach evacuees. In Hurricane Frederic (1979), the highest public shelter use rate occurred in Pass Christian, Mississippi, with 13 percent. Grand Isle, Louisiana, and Pensacola, Florida, both experienced only about a 2-percent public shelter use rate in Hurricane Frederic. In Hurricane Camille (1969), 31 percent of the Mississippi evacuees stayed in public shelters. This probably has much to do with the severity of the storm and the fact that many evacuees made a late decision to leave and had insufficient time to reach out-of-county destinations.

The actions of local officials can greatly influence the destinations of evacuees. Because of limited shelter space, in some locations agencies have policies to discourage evacuees from staying in the local area. Where a large percentage of the population relies on public transportation, or officials aggressively provide and publicize local public shelters, fewer evacuees will leave the area. If, for example, public shelters are opened early and advertised, the public shelter use rates will most likely be significantly higher than for areas where the public is strongly advised to leave the county or where shelter locations and availability are not widely advertised.

More affluent evacuees tend to utilize public shelter at much lower rates than the remainder of the population because they can easily afford hotel or even out-of-county accommodations. Also, people living in the more vulnerable locations usually evacuate earlier than those in less vulnerable areas and have sufficient time to seek out-of-county refuge. Conversely, persons with low incomes will utilize public shelter in significantly higher numbers than other residents because of problems with transportation and the affordability of hotels/motels.

CHAPTER FIVE

SHELTER ANALYSIS

Purpose

The shelter analysis serves two primary purposes. The most apparent use of the shelter analysis data is to develop the number of evacuees who will seek public shelter (shelter demand) within each county and to determine the number of shelter spaces available for those evacuees. This is the public shelter demand/capacity analysis. Total shelter capacity for each county is constantly subject to change with the availability of suitable facilities.

The second, and less apparent, purpose of the shelter analysis is to provide information for use in determining evacuation clearance times in the transportation analysis. A thorough discussion of the methodology involved in those determinations is found in chapter 6.

The following paragraphs discuss potential flood vulnerability and present inventories, capacities, and shelter demand for predesignated shelters within the study area. Data developed in the hazards, vulnerability, and behavioral analyses were used in this shelter analysis.

Shelter Vulnerability

Criteria contained in ARC publication 4496, Guidelines for Hurricane Evacuation Shelter Selection, dated July 1992, were used to predesignate shelters within the study area. The ARC, county, and New York City offices of emergency management have reviewed the areas of potential flooding shown on the inundation maps (Appendixes A through D) and will only open shelters located outside of any potential hurricane surge flood area. In New York State, however, public shelters may be predesignated and operated by the ARC or opened and operated by local governments and private organizations. **It is vitally important that any government or private entity intending to operate a public hurricane shelter carefully adhere to the ARC guidelines and ensure that the shelter is above any expected storm surge elevations.**

There have been no attempts to make comprehensive assessments of the vulnerability of public shelters to damage by hurricane winds.

Shelter Inventories and Capacities

Tables 5-1 through 5-8 list an inventory of predesignated public shelters and capacities furnished to the U.S. Army Corps of Engineers by the ARC, county, and New York City offices of emergency management. As discussed above, this list may not include all public shelter facilities that will be made available in an emergency situation.

At present, agreements needed to predesignate specific public schools as hurricane shelters have not been completed with some Nassau and Suffolk County school districts. Section 155.13 of the regulations of the Commissioner of Education requires that each Board of Education and Boards of Cooperative Educational Services cooperate with appropriate state, county, and city agencies in developing agreements for the use of school-owned facilities and vehicles during a disaster. School districts and Boards of Cooperative Educational Services are required to relinquish to the appropriate state or county agencies the control and use of school vehicles and facilities in accordance with county emergency preparedness plans or directives. Accordingly, agreements should be finalized forthwith, so that adequate shelter space and provisions for the evacuating public can be ensured.

Due to manpower limitations, Nassau and Suffolk Counties could not timely complete the field work necessary to accurately determine public shelter capacities. This information was needed to proceed with the transportation analysis. In order to calculate clearance times, these counties estimated public shelter capacities based on the number of pupils enrolled in each school. Both counties elected to use 90 percent of current enrollment. However, following suggestions contained in the ARC guidelines, Nassau County took a more conservative approach by eliminating the top floor of multi-story school buildings from consideration. Although neither method is as precise as conducting onsite evaluations, clearance times based on this information are of acceptable accuracy. As in the case of shelter agreements, reliable shelter data are essential to thorough hurricane preparedness planning. Emergency management and ARC officials should complete the onsite evaluations to accurately determine shelter capacities.

Public Shelter Demand

The results of the behavioral analysis conducted for the New York State Hurricane Evacuation Study and U.S. Census data were used in determining the shelter demand for a variety of hurricane scenarios. Table 5-9 shows the public shelter demand (number of evacuees seeking public shelter) resulting from each evacuation scenario. Evacuation scenarios are defined for each county in chapter 6, table 6-2. The analysis assumes an adequate warning period for an approaching hurricane and sufficient public knowledge concerning the locations and availability of public shelter facilities. Participation rates, destination percentages, and socioeconomic data used in developing the total number of evacuees and public shelter demand are shown in tables 6-3 through 6-10.

Public Shelter Demand/Capacity Analysis. The results of the public shelter demand/capacity analysis are shown in table 5-9. The table contains the total predesignated public shelter capacity within each county/borough.

TABLE 5-1

MANHATTAN, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
Norman Thomas HS	111 E. 33rd Street	2,030
*Washington Irving HS	40 Irving Place	2,300
PS 63	121 E. Third Street	1,127
PS 20	166 Essex Street	985
*PS 42	71 Hester Street	944
*PS 17	328 W. 48th Street	948
*PS 59	228 E. 57th Street	390
PS 111	440 W. 53rd Street	1,028
Julia Richmond HS	317 E. 67th Street	2,430
JHS 25	145 Stanton Street	1,428
PS 191	210 W 61st Street	808
PS 198	1700 Third Avenue	820
*PS 180	370 W. 120th Street	770
PS 144	134 W. 122nd Street	1,011
PS 149/207	34 W. 118th Street	811
PS 154	250 W. 127th Street	938
PS 123	301 W. 140th Street	1,022
PS 6	45 E. 81st Street	765
PS 7	160 E. 120th Street	905
PS 9	100 W. 84th Street	1,011
JHS 13	1573 Madison Avenue	1,500
JHS 17	328 W. 48th Street	989
PS 92	222 W. 134th Street	1,099
*PS 108	1615 Madison Avenue	915
PS 138	560 W. 169th Street	843
PS 132	185 Wadsworth Avenue	886
PS 133	2121 Fifth Avenue	700
PS 136	6 Edgecombe Avenue	1,204
PS 143	511 W. 182nd Street	1,467
PS 144	134 W. 122nd Street	1,011
PS 145	150 W. 105th Street	847
*PS 151	1763 First Avenue	1,081
PS 152	93 Nagel Avenue	765
PS 153	1750 Amsterdam Avenue	946
PS 161	499 W. 133rd Street	1,080
PS 163	163 W. 97th Street	908
PS 164	401 W. 164th Street	1,152
PS 165	234 W. 109th Street	1,140
*PS 166	132 W. 89th Street	1,095
JHS 167	220 E. 76th Street	1,321
PS 169	110 E. 88th Street	716

* primary evacuation center

TABLE 5-1 (CONT.)

MANHATTAN, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
*PS 173	306 Fort Washington Avenue	716
PS 175	175 W. 134th Street	1,287
*PS 189	2580 Amsterdam Avenue	1,019
PS 194	244 W. 144th Street	1,048
*PS 199	270 W. 70th Street	936
PS 223	131st St & Convent Avenue	292
Arthur Schomburg HS	2005 Madison Avenue	1,400
Mabel Dean Bacon HS	127 E. 22nd Street	2,609
TOTAL		53,443
TOTAL PRIMARY		11,114

* primary evacuation center

TABLE 5-2

BROOKLYN, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
IS 258	141 Macon Street	1,376
PS 305	344 Monroe Street	861
PS 51	350 Fifth Avenue	904
PS 169	18-25 212 Street	1,075
John Jay	237 Seventh Avenue	2,266
JHS 210	188 Rochester Avenue	1,073
Clara Barton	901 Classon Avenue	1,315
JHS 61	400 Empire Boulevard	1,227
*PS 108	200 Linwood Street	656
IS 227	6500 16th Avenue	1,214
Fort Hamilton HS	8301 Shore Road	3,201
PS 259	7305 Fort Hamilton Parkway	1,171
PS 104	9115 Fifth Avenue	1,212
PS 127	7805 Seventh Avenue	299
IS 201	8010 12th Avenue	1,274
PS 247	7000 21st Avenue	490
PS 185	8601 Ridge Boulevard	750
FDR HS	5800 20th Avenue	2,127
PS 176	1225 69th Avenue	1,096
PS 112	7115 15th Avenue	350
PS 199	1100 Elm Avenue	880
PS 177	Avenue P & West First Street	1,112
PS 99	1120 E. 10th Street	1,503
PS 226	6006 23rd Avenue	1,010
PS 193	2515 Avenue L	1,006
IS 55	2021 Bergen Street	1,411
PS 178	2163 Dean Street	650
JHS 111	35 Starr Street	1,526
*JHS 296	125 Covert Street	1,030
*JHS 162	1390 Willoughby Avenue	798
*IS 33	70 Tompkins Avenue	1,270
PS 59	211 Throop Avenue	1,050
PS 23	545 Willoughby Street	540
PS 298	85 Watkins Street	926
PS 289	900 St. Marks Avenue	989
*PS 91	532 Albany Avenue	953
PS 221	791 Empire Boulevard	882
PS 289	900 St. Marks Avenue	988
PS 249	18 Marlborough Road	759
PS 246	72 Veronica Place	1,015
PS 241	976 President Street	1,000

* primary evacuation center

TABLE 5-2 (CONT.)

BROOKLYN, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
*PS 181	1023 New York Avenue	924
PS 138	801 Park Place	1,363
PS 191	1600 Park Place	1,013
PS 161	330 Crown Street	881
PS 167	1025 Eastern Parkway	501
PS 205	6701 20th Avenue	1,324
*PS 204	8101 15th Avenue	963
PS 105	1031 59th Street	1,219
PS 170	7109 Sixth Avenue	1,002
IS 259	7305 Fort Hamilton Parkway	1,171
PS 104	9115 Fifth Avenue	1,212
PS 127	7805 Seventh Avenue	299
IS 201	8010 12th Avenue	1,274
PS 185	8601 Ridge Boulevard	750
PS 186	7601 19th Avenue	1,086
PS 176	1225 69th Street	1,096
PS 102	211 72nd Street	1,056
PS 112	7115 15th Avenue	350
Tele. Comm. Arts & Tech	350 67th Street	1,577
PS 192	4715 18th Avenue	1,025
IS 62	700 Cortelyou Road	1,148
PS 179	202 Avenue C	812
PS 229	1400 Benson Avenue	459
PS 160	5105 Fort Hamilton Parkway	936
IS 223	4200 16th Avenue	1,524
PS 180	16th Avenue & 57th Street	1,198
PS 48	6015 18th Avenue	1,036
PS 164	14th Avenue & 42nd Street	928
PS 121	20th Avenue & 53rd Street	603
IS 226	6006 23rd Avenue	999
PS 217	Newkirk & Coney Island Avenue	1,078
PS 269	1957 Nostrand Avenue	823
PS 198	4105 Farragut Road	741
*PS 152	2310 Glenwood Road	944
PS 139	330 Rugby Road	712
PS 156	104 Sutter Avenue	1,450
PS 243	1580 Dean Street	1,141
PS 271	1137 Herkimer Street	1,547
PS 309	794 Monroe Street	946
PS 262	500 Macon Street	890
PS 45	84 Schaffer Street	943

* primary evacuation center

TABLE 5-2 (CONT.)

BROOKLYN, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
PS 40	265 Ralph Avenue	924
PS 28	1001 Herkimer Street	850
PS 21	180 Chauncey Street	707
*PS 230	1 Albemarle Road	970
PS 169	4305 Seventh Avenue	1,075
PS 131	4305 Fort Hamilton Parkway	866
PS 130	70 Ocean Parkway	672
*PS 94	5010 Sixth Avenue	998
*PS 39	417 Sixth Avenue	90
PS 44	432 Monroe Street	834
*PS 93	31 New York Avenue	930
IS 113	300 Adelphi Street	1,435
TOTAL		95,880
TOTAL PRIMARY		10,526

* primary evacuation center

TABLE 5-3

QUEENS, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
Cleveland HS	2127 Himrod Street	2,255
PS 14	107-01 Otis Avenue	1,081
*Newtown HS	48-01 90th Street	1,861
PS 16	41-15 104th Street	846
PS 13	55-01 94th Street	453
PS 19	171-11 35th Avenue	1,485
PS 120	58th Avenue & 136th Street	849
PS 154	75-02 162nd Street	751
PS 163	159-01 59th Avenue	916
*PS 164	138-01 77th Avenue	756
JHS 168	158-40 76th Road	966
PS 200	70-10 164th Street	864
PS 201	65-11 155th Street	694
PS 219	144-39 Gravett Road	1,018
*John Brown HS	63-25 Main Street	2,304
PS 46	218th Street & 67th Avenue	705
IS 74	61-15 Oceania Street	1,031
PS 115	80-51 261st Street	714
PS 177	56-37 108th Street	668
PS 205	61-21 97th Place	618
JHS 216	64-20 175th Street	1,165
PS 97	85-52 85th Street	955
PS 56	86th Avenue & 114th Street	538
PS 155	130-02 115th Avenue	869
PS 63	90-15 Sutter Avenue	1,019
*PS 96	130-01 Rockaway Boulevard	575
PS 90	86-50 109th Street	684
PS 40	109-20 Union Hill Street	755
PS 55	131-10 97th Avenue	300
*PS 101	2 Russel Place	852
PS 121	126-10 109th Avenue	885
PS 139	93-06 63rd Drive	732
PS 144	93-02 69th Avenue	1,138
JHS 157	64th Avenue & 102nd Street	1,268
PS 175	64-35 102nd Street	889
JHS 190	68-17 Austin Street	1,242
PS 206	61-21 97th Place	691
Forest Hills HS	67-01 110th Street	2,775
*Francis Lewis HS	58-20 Utopia Parkway	1,495
PS 118	190-20 169th Road	923
*PS 35	101-02 90th Avenue	421
PS 131	172nd Street & 84th Avenue	450

* primary evacuation center

TABLE 5-3 (CONT.)

QUEENS, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
*PS 15	121-15 Lucas Street	320
PS 176	120-45 235th Street	665
PS 36	187-01 Foch Boulevard	527
PS 02	75-10 21st Avenue	492
*PS 17	28-37 29th Street	758
*PS 84	22-45 41st Street	724
PS 112	25-05 37th Avenue	801
*PS 122	21-21 Ditmars Boulevard	1,350
JHS 141	37-11 21st Avenue	1,392
*Adams HS	101-01 Rockaway Boulevard	2,559
PS 108	108-10 109th Avenue	1,183
TOTAL		52,227
TOTAL PRIMARY		13,975

* primary evacuation center

TABLE 5-4

BRONX, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
IS 61	1550 Crotona Park East	1,104
PS 83	950 Rhinelander Avenue	1,087
*PS 89	980 Mace Avenue	1,298
JHS 98	1619 Boston Road	1,442
PS 105	725 Brady Avenue	1,178
PS 119	1075 Pugsley Avenue	535
*PS 125	1111 Pugsley Avenue	1,358
PS 134	1330 Bristow Street	1,028
PS 135	2441 Wallace Avenue	1,298
*PS 136	750 Jennings Street	1,360
Columbus HS	925 Astor Avenue	2,020
JHS 127	1560 Purdy Street	994
James Monroe HS	1300 Boynton Avenue	2,455
PS 77	1250 Ward Avenue	1,315
Dewitt Clinton HS	Moshulu Parkway & Paul Avenue	3,211
Bronx Science HS	75 W. 205th Street	2,550
*PS 95	3961 Hillman Avenue	928
TOTAL		25,161
TOTAL PRIMARY		4,944

* primary evacuation center

TABLE 5-5

STATEN ISLAND, NEW YORK CITY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
*Tottenville HS	100 Luten Avenue	3,735
*IS 7	1270 Huguenot Avenue	1,509
PS 45	58 Lawrence Avenue	1,028
PS 22	1860 Forest Avenue	1,065
*PS 39	MacFarland Avenue	690
PS 48	1055 Targee Street	428
PS 8	Park Terrace/Lindenwood Road	720
PS 5	Kingdom Avenue/Deisius Street	371
*IS 27	11 Clove Lake Place	1,377
*Port Richmond HS	Innis Street/St. Joseph Ave.	1,550
TOTAL		12,473
TOTAL PRIMARY		8,861

* primary evacuation center

TABLE 5-6

SUFFOLK COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Amagansett SD	
Amagansett PS	Main Street	113
	Amityville SD	
Amityville JHS	Route 110 & North Drive	550
	Bayport-Blue Point SD	
*Bayport-Blue Point HS	200 Snedecor Avenue	567
James Wilson Young JHS	602 Sylvan Avenue	446
Sylvan Avenue Ele	600 Sylvan Avenue	330
	Bay Shore SD	
*Bay Shore HS	155 Third Avenue	1,055
Bay Shore MS	393 Brook Avenue	934
	Brentwood SD	
*Brentwood Senior HS	5th Avenue & First Street	2,295
10th Grade Northwest	Leahy Avenue	805
East JHS	Claywood Drive	635
North JHS	Wicks Road	554
South JHS	Candlewood Road	577
West JHS	Udall Road	562
East Kindergarten Ctr	Timberline Drive	309
Hemlock Park Ele	Hemlock Drive	408
North Ele	White Street	528
Laurel Park Ele	Swan Place	362
Loretta Park Ele	Stahley Street	393
Oak Park Ele	Wisconsin Avenue	443
Pine Park Ele	Vorrhis Drive	403
Twin Pines Ele	Vorrhis Drive	464
	Center Moriches SD	
*Center Moriches HS	311 Frowein Road	524
	Central Islip SD	
*Central Islip HS	Wheeler Road	1,204
Andrew T. Morrow Ele	Sycamore Avenue	500
Francis J. O'Neill Ele	Clayton Street	555

* primary evacuation center

TABLE 5-6 (CONT.)

SUFFOLK COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Cold Spring Harbor SD	
*Cold Spring Harbor HS	Turkey Lane	577
	Commack SD	
*Commack HS	Scholar Lane	1,591
Commack MS	Vanderbilt Parkway	1,094
Burr IS	Burr Road	581
Mandracchia/Sawmill	New Highway	560
	Comsewogue SD	
*Comsewogue HS	565 Bicycle Path	940
J.F. Kennedy MS	200 Jayne Boulevard	629
	Connetquot SD	
*Connetquot HS	Seventh Street	1,533
Ronkonkoma JHS	Peconic Street	760
John Pearl Ele	Smithtown Avenue	338
Sycamore Avenue Ele	Sycamore Avenue	396
	Copiague SD	
*Copiague HS	1100 Dixon Avenue	1,013
Copiague JHS	Great Neck Road	778
	Deer Park SD	
*Deer Park HS	30 Rockaway Avenue	922
Robert Frost JHS	450 Half Hollow Road	468
John F. Kennedy IS	101 Lake Avenue	670
	Eastport SD	
*Eastport Ele./HS	390 Montauk Highway	524
	East Islip SD	
*East Islip HS	Redman Street	1,139
Islip Terrace JHS	Redman Street	585

* primary evacuation center

TABLE 5-6 (CONT.)

SUFFOLK COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	East Quogue SD	
East Quogue Ele	6 Central Avenue	263
	Elwood SD	
*John H. Glenn HS	478 Elwood Road	562
Elwood MS	478 Elwood Road	428
	Half Hollow Hills SD	
*Half Hollow Hills HS E.	50 Vanderbilt Parkway	1,051
*Half Hollow Hills HS W.	375 Wolf Hills Road	769
Candlewood JHS	1200 Carll's Straight Path	577
West Hollow JHS	250 Old East Neck Road	777
	Hampton Bays SD	
*Hampton Bays J/S HS	Argonne Road	495
	Harborfields SD	
*Harborfields HS	Taylor Avenue	747
Oldfield School	2 Oldfield Road	720
	Hauppauge SD	
*Hauppauge HS	Lincoln Boulevard	1,020
Hauppauge MS	600 Townline Road	737
	Huntington SD	
*Huntington HS	Oakwood & MacKay Roads	1,026
J. Taylor Finley JHS	Greenlawn Road	598
	Kings Park SD	
*Kings Park HS	200 Route 25A	947
William T. Rogers MS	97 Old Dock Road	837
	Longwood SD	
*Longwood Senior HS	Longwood Road	1,762
Longwood JHS	Middle Is-Yaphank Road	1,152
Longwood MS	Middle Is-Yaphank Road	1,222

* primary evacuation center

TABLE 5-6 (CONT.)

SUFFOLK COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
Mattituck-Cutchogue SD		
*Mattituck Ele/HS	Main Road	834
Middle Country SD		
*Centereach HS	43rd Street	1,528
*Newfield HS	Marshall Drive	1,086
Dawnwood MS	43rd Street	903
Selden MS	22 Jefferson Avenue	1,087
Miller Place SD		
Miller Place JHS	15 Memorial Drive	753
Andrew Muller Pri	65 Lower Rocky Pt Rd	728
Mount Sinai SD		
*Mount Sinai HS	North Country Road	495
Mount Sinai JHS	North Country Road	603
North Babylon SD		
*North Babylon HS	Phelps Lane	1,223
Robert Moses MS	Phelps Lane	847
Parliament Place Ele	Parliament Place	432
Northport-East Northport SD		
*Northport HS	Laurel Hill & Elwood Roads	1,800
Northport MS	Laurel Avenue	540
East Northport MS	Fifth Avenue	540
Patchogue-Medford SD		
*Patchogue-Medford HS	Buffalo Avenue	1,883
Oregon MS	Oregon Avenue	703
Saxton MS	Saxton Street	1,001
Port Jefferson SD		
*Earl L. Vandermeulen HS	Old Post Road	492
Port Jefferson JHS	Spring Street	254

* primary evacuation center

TABLE 5-6 (CONT.)

SUFFOLK COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Rocky Point SD	
*Rocky Point J/S HS	Rocky Point-Yaphank Road	1,007
	Sachem SD	
*Sachem HS North Campus	212 Smith Road	2,340
Sachem HS South Campus	51 School Street	2,200
Sagamore JHS	57 Division Street	1,049
Seneca JHS	850 Main Street	1,017
	Sag Harbor SD	
*Pierson HS	Jermain Avenue	231
	Sayville SD	
Sayville JHS	Johnson Avenue	667
	Shelter Island SD	
*Shelter Island Ele./HS	Shelter Island	217
	Shoreham-Wading River SD	
*High School	Route 25A	634
Middle School	Randall Road	397
	Smithtown SD	
*Smithtown HS East	Northern Boulevard	1,410
*Smithtown HS West	Central Road	867
Accompsett IS	Meadow Road	598
Nesaquake IS	Edgewood Avenue	479
Great Hollow IS	Southern Boulevard	436
	Southold SD	
*Southold Senior HS	420 Oaklawn Avenue	214
Oaklawn Avenue MS	Oaklawn Avenue	255
	South Country SD	
*Bellport HS	Beaver Dam Road	1,270
Bellport MS	Kreamer Street	1,059
Hampton Avenue IS	Brookhaven Avenue	678

* primary evacuation center

TABLE 5-6 (CONT.)

SUFFOLK COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	South Huntington SD	
*Walt Whitman HS	West Hills Road	1,445
Henry L. Stimson JHS	Oakwood Road	716
	Three Village SD	
*Ward Melville HS	Old Town Road	1,606
Paul J. Gelinas JHS	Mud Road	778
Robert C. Murphy JHS	Oxhead Road	743
	Westhampton Beach SD	
*Westhampton Beach HS	Lilac Road	707
Westhampton Beach JHS	Mill Road	187
	West Babylon SD	
West Babylon JHS	200 Old Farmingdale Road	808
	West Islip SD	
W. Islip Udall Rd. JHS	Udall Road	442
	William Floyd SD	
*William Floyd HS	240 Mastic Beach Road	1,772
	Wyandanch SD	
*Wyandanch Memorial HS	32nd Street & Brooklyn Ave.	450
Milton L. Olive MS	Garden City Avenue & 36th St.	540
TOTAL		91,255
TOTAL PRIMARY		45,774

* primary evacuation center

TABLE 5-7

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Bethpage SD	
*Bethpage Senior HS	Cherry Avenue	346
John F. Kennedy MS	Broadway	242
Central Boulevard Ele	Central Boulevard	201
C. Champagne Ele	Plainview Road	172
Kramer Lane Ele	Kramer Lane	UNK
	Carle Place SD	
*Carle Place HS	Cherry Lane	290
Rushmore Ele	Rushmore Avenue	194
Cherry Lane Ele	Cherry Lane & Roslyn Ave	310
	Catholic	
Long Island Lutheran HS	Brookville Road	202
	East Meadow SD	
*East Meadow HS	Carmen Avenue	633
*W. T. Clarke J/S HS	Edgewood Drive	612
Woodland JHS	Wenwood Drive	484
Bowling Green Ele 1&2	Stewart Avenue	756
Barnum Woods Ele	Rose & Kalda Lanes	431
Meadowbrook Ele	Old Westbury & N. Newbridge	211
George H. McVey Ele	Franklin & Devon Streets	658
Parkway Ele	Bellmore Road	237
	East Williston SD	
*The Wheatley J/S HS	Bacon Road	449
Willets Road IS	I. U. Willets Road	142
North Side Ele	E. Williston Avenue	221
	Elmont SD	
Elmont Road Pre-K	Elmont Road	48
Alden Terrace Ele	Central Avenue	161
Covert Avenue Ele	Covert Avenue	366
Dutch Broadway Ele	Dutch Broadway	358
Gotham Avenue Ele	Gotham Avenue	256
Clara H. Carlson Ele	Belmont Boulevard	365

* Primary evacuation center

TABLE 5-7 (CONT.)

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Farmingdale SD	
*Farmingdale Senior HS	Lincoln St & Intervale Ave	720
Howitt School E&W MS	Van Cott Avenue	356
Albany Avenue Ele	Albany Avenue	349
East Memorial	Mill Lane	297
Northside Ele	Powell Place	236
Woodward Parkway	Woodward Parkway	452
	Floral Park SD	
John Lewis Childs Ele	Elizabeth Street	UNK
Floral Park-Bellerose	Larch Avenue	UNK
	Franklin Square SD	
John Street Ele	Nassau Boulevard	203
Polk Street Ele	Polk Street	180
Washington Street Ele	Washington Street	270
	Garden City SD	
*Garden City Senior HS	Merillon/Rockaway Avenues	435
Garden City MS	Cherry Valley Avenue	409
Stewart Ele	Clinton @ Stewart Avenue	214
Stratford Ele	Stratford Avenue	210
Homestead Ele	Homestead Avenue	181
Locust Ele	Boylston/Poplar Streets	128
	Glen Cove City SD	
*Glen Cove HS	Dosoris Lane	415
Robert M. Finley MS	Forest Avenue	381
Deasy Ele	Dorosris Lane	95
Landing Ele	McLoughlin Street	110
Gribbin Ele	Seaman Road	164
Connelly Ele	Ridge Drive	205

* primary evacuation center

TABLE 5-7 (CONT.)

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Great Neck SD	
*Great Neck North HS	Polo Road	397
*Great Neck South HS	Lakeville Road	393
Great Neck North MS	Polo Road	263
Great Neck South MS	Lakeville Road	289
Elizabeth Baker Ele	Baker Hill Road	278
John F. Kennedy Ele	Grassfield Road	239
Lakeville Ele	Jayson Avenue	330
Saddle Rock Ele	Hawthorne Lane	220
	Hempstead SD	
*Hempstead HS	Peninsula Boulevard	858
A.B.G. Schultz MS	Greenwich Street	319
Franklin School	S. Franklin Street	585
Marshall School	Marshall Street	171
Fulton School	Fulton Avenue	402
Jackson School	Jackson Street	299
Ludlum School	Williams Street	422
Prospect School	Peninsula Boulevard	131
Marguerite Rhodes Sch	Washington Street	187
Jackson School Annex	Jackson Street	398
	Herricks SD	
*Herricks HS	Shelter Rock Road	507
Herricks MS	Hilldale Road	372
Center Street Ele	Center Street	365
Denton Avenue Ele	Denton Avenue	514
Searington Ele	Beverly Drive	421
	Hicksville SD	
*Hicksville Senior HS	Division Avenue	428
Hicksville MS	Jerusalem Avenue	425
Burns Avenue Ele	Burns Avenue	292
Dutch Lane Ele	Stewart Avenue	280
East Street Ele	East Street	167
Fork Lane Ele	Fork Lane	249
Lee Avenue Ele	Lee Avenue	201
Old Country Road Ele	Old Country Road	297
Woodland Avenue Ele	Ketcham Road	171

* primary evacuation center

TABLE 5-7 (CONT.)

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Island Trees SD	
*Island Trees HS	Straight Lane	293
Island Trees Mem. JHS	Wantagh Avenue South	225
Michael F. Stokes Ele	Owl Place/Condor Road	225
J. Fred Sparke Ele	Robin Place/Condor Road	225
Geneva N. Gallow Ele	Farmedge Rd/Carpender La	225
	Jericho SD	
*Jericho MS/HS	Cedar Swamp Road	512
Cantiague Ele	Cantiague Rock Road	222
George Jackson Ele	Maytime Drive	322
	Levittown SD	
*Division Avenue HS	Division Avenue	438
*Gen. MacArthur HS	Wantagh Avenue	631
Jonas E. Salk JHS	Old Jerusalem Road	340
Wisdom MS	Center Lane	604
Abbey Lane Ele	Gardiners Avenue	590
Gardiners Avenue Ele	Gardiners Avenue	563
Lee Road Ele	Lee Road	122
Northside Ele	Pelican Road	467
Summit Lane Ele	Summit Lane	373
	Locust Valley SD	
*Locust Valley J/S HS	Horse Hollow Road	377
Locust Valley Ele	Ryefield Road	462
Bayville Ele	School Street	482
	Manhasset SD	
*Manhasset J/S HS	Memorial Place	629
Shelter Rock Ele	Shelter Rock Road	324
Munsey Park Ele	Northern Boulevard	194
	Merrick/Bellmore SD	
Saw Mill Road Ele	UNK	UNK
Newbridge Road Ele	UNK	UNK
Park Avenue Ele	UNK	UNK
Camp Avenue Ele	UNK	UNK
Old Mill School	UNK	UNK

* primary evacuation center

TABLE 5-7 (CONT.)

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Mineola SD	
*Mineola HS	Armstrong Road	474
Mineola MS	Emory Road	357
Hampton Street Ele	Hampton Street	122
Jackson Avenue Ele	Jackson Avenue	226
Meadow Drive Ele	Meadow Drive	389
	New Hyde Park-Garden City Park SD	
Garden City Park Ele	Central Avenue & Third St	UNK
Hillside Grade School	W. Maple Drive	UNK
Manor Oaks-Wlm Bowie	Hillside Avenue	UNK
New Hyde Park Road Ele	New Hyde Park Road	UNK
	North Bellmore SD	
Jacob Gunther Ele	Regent Place	130
	North Shore SD	
*North Shore HS	Glen Cove Avenue	465
North Shore JHS	Glen Cove Avenue	197
Glen Head Ele	School Street	174
Glenwood Landing Ele	Cody Avenue	192
Sea Cliff Ele	Carpenter Avenue	310
	Oyster Bay-East Norwich SD	
*Oyster Bay HS	E. Main Street	265
James Vernon MS	Route 106	329
	Plainedge SD	
*Plainedge HS	Wyngate Drive	381
Sylvia Packard JHS	Idaho Avenue	349
John H. West Ele	Stewart & Boundary Aves	191
Eastplain Ele	Michigan Avenue	303

* primary evacuation center

TABLE 5-7 (CONT.)

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
Plainview-Old Bethpage SD		
*Plainview/JFK HS	Washington Avenue	608
Plainview-Bethpage MS	Stratford/Bedford Roads	267
H.B. Mattlin MS	Washington Avenue	673
Old Bethpage Ele	Round Swamp Road	400
Jamaica Avenue Ele	Jamaica Avenue	268
Parkway Ele	Manetto Hill Road	440
Port Washington SD		
*Paul D. Schreiber HS	Campus Drive	740
Carrie Palmer Weber JHS	Port Washington Boulevard	248
John J. Daly Ele	Rockwood Avenue	171
Guggenheim Ele	Poplar Place	468
Rockville Center SD		
South Side HS	Shepherd Street	428
Covert Ele	Willow Street	234
Roslyn SD		
*Roslyn HS	Round Hill Road	289
Roslyn MS	Locust Lane	208
East Hills Ele	Round Hill Road	178
Harbor Hill Ele	Glen Cove Road	180
Heights Primary Sch	Willow Street	77
Sewanhaka SD		
*Elmont Memorial HS	Ridge Road	839
*Floral Park Mem. HS	Locust Street	518
*H. Frank Carey HS	Poppy Avenue	780
*New Hyde Park Mem. HS	Leonard Boulevard	527
*Sewanhaka HS	Tulip Avenue	737
Roosevelt SD		
*Roosevelt J/S HS	Wagner Avenue	522

* primary evacuation center

TABLE 5-7 (CONT.)

NASSAU COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
	Syosset SD	
*Syosset HS	South Woods Road	1,551
Harry B. Thompson MS	Ann Drive	598
South Woods MS	Pell Lane	510
Baylis Ele	Woodbury Road	332
Berry Hill Ele	Cold Spring Road	288
Robbins Lane Ele	Robbins Lane	363
South Grove Ele	Colony Lane	266
Village Ele	Convent Road	240
Walt Whitman Ele	Woodbury Road	284
Willits Ele	Nana Place	193
	Uniondale SD	
*Uniondale HS	Goodrich Street	565
Lawrence Road JHS	Lawrence Road	255
Turtle Hook JHS	Jerusalem Avenue	250
California Avenue Ele	California Avenue	238
Cornelius Court Ele	Cornelius Court	145
Northern Parkway Ele	Northern Parkway	268
Smith Street Ele	Smith Street	147
Walnut Street Ele	Walnut Street	218
Grand Avenue Ele	School Drive	252
	Wantagh SD	
Wantagh HS	Beltagh Avenue	350
	Westbury SD	
*Westbury Senior HS	Post Road	431
Westbury JHS	School & Rockland Streets	287
Drexel Ele	Drexel	330
Powell's Lane Ele	Powell's Lane	260
Park Sch Childhood Ctr	Park Avenue	444
Dryden Street Ele	UNK	374
	West Hempstead SD	
*West Hempstead M/S HS	Nassau Boulevard	603
George Washington	William Street	212
Cornwell Avenue Sch	Cornwell Avenue	176
TOTAL		
TOTAL PRIMARY		

TABLE 5-8

WESTCHESTER COUNTY
HURRICANE EVACUATION CENTERS

Facility	Location	Capacity
City of New Rochelle		
*New Rochelle HS	Clove Road	2,605
*Albert Leonard JHS	Gerada Lane	1,229
*Isaac Young JHS	Centre Avenue	976
Mount Vernon HS (backup)	California Road	3,015
Village of Larchmont		
*Chattsworth Ave Sch	Chattsworth Ave	641
Village of Mamaroneck		
*Mamaroneck HS	Palmer Ave & W Boston Post	1,894
*Bellows Ele	Carroll Avenue	800
Harrison HS (backup)	Union Avenue	1,217
City of Rye		
*Osborn Sch	Osborn Road	2,300
Port Chester HS (backup)		998
Harrison HS (backup)	Harrison Avenue	1,217
Village of Port Chester		
*Port Chester MS		775
Port Chester HS		998
TOTAL		16,450
TOTAL PRIMARY		11,220

* primary evacuation center

TABLE 5-9

Public Shelter Demand/Capacity Statistics

County/Borough	Storm Scenario	Maximum Demand	Capacity Primary-Total
Suffolk	Category 1-2	10,870	45,774-91,255
	Category 3	25,185	
	Category 4	33,040	
Nassau	Category 1-2	49,315	19,836-58,000
	Category 3	**(73,200)**	
	Category 4	**(78,735)**	
Westchester	Category 1-4	3,795	11,220-13,435
Manhattan	Category 1-2	14,320*	11,114-53,443
	Category 3-4	49,770*	
Brooklyn	Category 1	22,175	10,526-95,880
	Category 2	39,460	
	Category 3	76,890	
	Category 4	93,985	
Queens	Category 1	11,725	13,975-52,227
	Category 2	18,090	
	Category 3-4	39,855	
Bronx	Category 1-2	2,610	4,944-25,161
	Category 3-4	8,485	
Staten Island	Category 1-2	9,700	8,861-12,473
	Category 3-4	11,630	

* Does not include homeless people or commuters seeking public shelter
(XX) Indicates potential shelter demand greater than available capacity

CHAPTER SIX

TRANSPORTATION ANALYSIS

Purpose

The overall goals of the transportation analysis performed for the New York State Hurricane Evacuation Study were to define the evacuation road network, estimate clearance times (the time it takes to clear roadways of all evacuating vehicles) for a variety of hurricane evacuation situations, and investigate traffic control measures for improved vehicular flow through critical segments of the network. To determine the timing of a strong advisory or an order to evacuate, the results of this analysis, along with prelandfall hazards data, must be taken into account. Clearance time must be sufficient for all evacuees to reach safe shelter prior to the arrival of sustained tropical storm winds. Factors that influence clearance time were studied intensively to determine those having the greatest influence. A sensitivity analysis was performed by varying key input parameters and calculating approximately 12 to 24 clearance times for each county and borough.

Transportation Analysis Process

Initially, the transportation analysis identified the kinds of traffic movements associated with a hurricane evacuation that must be considered in the development of clearance times. Then assumptions related to storm scenarios, vulnerable population, behavioral and socioeconomic characteristics, and the roadway system and traffic control were formulated. A transportation modeling methodology and roadway system representation were devised for each county and borough in the study area to facilitate model application and development of clearance times. General information and data related to the transportation analysis are presented in summary form in this chapter. A Transportation Model Support Document, available through the Wilmington District, U.S. Army Corps of Engineers, includes a detailed account of all transportation modeling activities and zone-by-zone data listings for each county and borough.

Traffic Movements

During a hurricane evacuation, an extraordinary volume of vehicles must move from trip origin to destination in a relatively short period of time. This volume becomes particularly significant for an area such as Long Island and some boroughs of New York City where heavily populated urban areas and vulnerable barrier islands lie in close proximity or, in some cases, are conterminous. The number of evacuating vehicles depends on the intensity of the approaching storm, the tourist population, automobile ownership, and behavioral response characteristics of the vulnerable population (discussed in chapter 4).

Vehicles enter the road network at different times depending on the rapidity of the evacuee response and leave the network according to the urgency of the situation and availability of planned destinations. These destinations are principally public shelters, hotels/motels, and friend's or relative's homes in non-vulnerable areas. The speed at which vehicles move across the road network is limited by the relationship of traffic loading on the various roadway segments to their respective capacities.

Evacuation Travel Patterns

Figure 6-1 graphically depicts the five general traffic movement patterns associated with hurricane evacuation situations in New York. It is important to recognize that three of the five defined patterns involve travel generated outside of the boundaries of one county or borough. It is evident that, depending on the assumed storm track, these inter-jurisdictional movements result in a number of different impacts on regional traffic flow. During the transportation analysis, these movements were quantified in order to estimate roadway congestion and resulting clearance times.

The five travel patterns associated with hurricane evacuation are described below:

a. **In-County Origins to In-County Destinations.** Trips made from areas vulnerable to storm surge and/or rainfall flooding and from mobile homes within an individual county or borough to destinations within those same boundaries (see figure 6-1, Pattern A).

b. **In-County Origins to Out-of-County Destinations.** Trips that originate in one county or borough and have destinations outside of those boundaries, possibly outside of the study area (see Pattern B).

c. **Out-of-County Origins to In-County Destinations.** Trips that enter a county or borough and have destinations within its boundaries (see Pattern C).

d. **Out-of-County Origins to Out-of-County Destinations.** Trips that pass through a county or borough with both origin and destination outside of its boundaries (see Pattern D).

e. **Background Traffic.** Trips made by people preparing for the arrival of hurricane conditions or engaged in normal activities. These trips may be shopping trips to purchase supplies and/or trips from work to home to assist with emergency actions. This traffic also includes public transit used to evacuate people who lack access to personal vehicles, a very significant element in New York City and sections of Nassau County.

Transportation Analysis Input Assumptions

Since all hurricanes differ in some respect, it is necessary to set forth clear assumptions about storm characteristics and expected evacuee response before transportation modeling can begin. Not only do storms vary in track, intensity and size, but also in the way they are perceived by residents in potentially vulnerable areas. Even the time of day at which a storm makes landfall influences evacuation response. These factors cause a wide variance in the behavior of the vulnerable population.

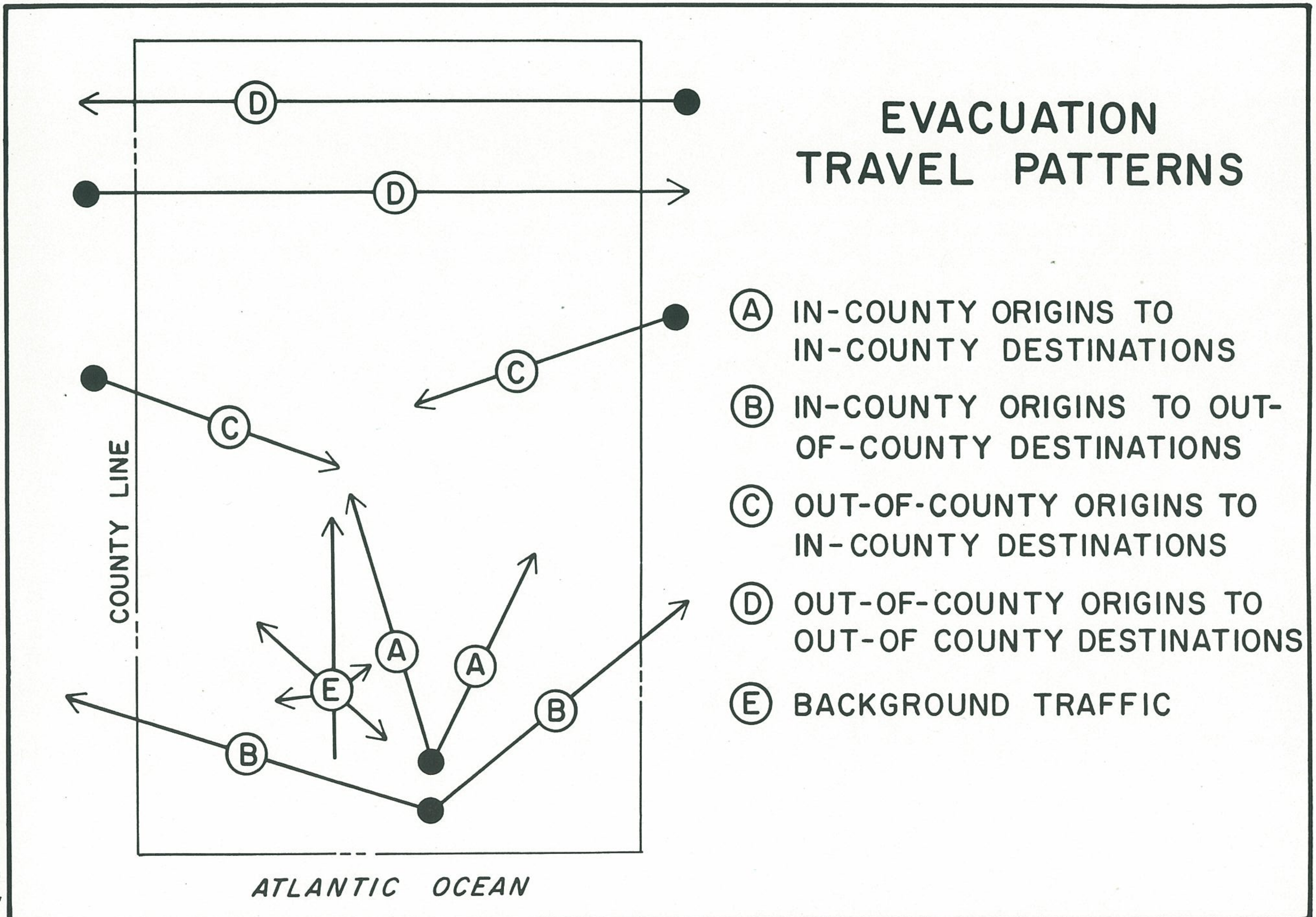

EVACUATION
TRAVEL PATTERNS
A IN-COUNTY ORIGINS TO IN-COUNTY DESTINATIONS
B IN-COUNTY ORIGINS TO OUT-OF-COUNTY DESTINATIONS
C OUT-OF-COUNTY ORIGINS TO IN-COUNTY DESTINATIONS
D OUT-OF-COUNTY ORIGINS TO OUT-OF COUNTY DESTINATIONS
E BACKGROUND TRAFFIC
COUNTY LINE
ATLANTIC OCEAN
A
B
C
D
E

FIGURE 6-1

Since the transportation analysis produces clearance times based on assumed storm parameters and evacuee response, actual conditions could differ considerably from those used for the calculations. Therefore, a sensitivity analysis was performed using logical ranges of the variables that have the greatest influence. Key assumptions guiding the transportation analysis are grouped into the following five areas and are described in the paragraphs below.

Permanent and Seasonal Population Data
Storm Scenarios
Evacuation Zones
Behavioral Characteristics
Roadway Network and Traffic Control

a. Permanent and Seasonal Population Data. The data base for each county and borough was developed using 1980 U.S. Census data and 1992 projections. This information provided a base for permanent population parameters on a sub-jurisdictional basis. Preliminary 1990 census figures were compared to the 1992 projections and no adjustments were deemed necessary. Since data for census units are revised regularly, their use provides a means to facilitate updating the evacuation study. Any future update of the transportation analysis should include careful research for sources of additional seasonal dwelling unit data. The following resources provided seasonal and permanent dwelling unit data for this analysis.

(1) New York State Data Center - 1980 U.S. Census of Population

(2) Local Planning Departments - permanent and seasonal estimates

(3) Fire Island Ferry Operators - seasonal estimates for Fire Island

Current permanent population estimates in the counties and boroughs range from approximately 379,000 on Staten Island to 2,300,000 in Brooklyn. In Suffolk County, the peak seasonal population dramatically increases the number of people residing in surge vulnerable areas. Table 6-1 lists the current estimated population and total number of permanent, high-rise, and seasonal dwelling units. In addition, information is given for the average number of people and vehicles per dwelling unit. This data was used to translate the number of hurricane-vulnerable housing units to roadway demand.

b. Storm Scenarios. Information produced in the hazards analysis was used in the vulnerability analysis to produce the storm surge inundation maps (see Appendixes A-D). These maps show the areas that could be inundated by the maximum potential storm surge related to four hurricane intensity categories (corresponding to the Saffir-Simpson Scale). This information is one of the key inputs to the transportation analysis. For this analysis, it was assumed that persons living in areas of potential surge flooding and all residents of mobile homes are not only in danger of drowning but are also extremely vulnerable to wind hazards; consequently, all should evacuate. Using the inundation maps, those residents who should evacuate, as well as those who should not, were defined. The evacuee group included all residents of mobile homes, permanent residents living in single-family and high-rise multi-family dwellings, as well as vacationers staying in seasonal units.

TABLE 6-1

Key Socioeconomic Data

Borough County	Estimated Current Population	People Per Dwelling Unit	Vehicles Per Dwelling Unit	Surge Area Dwelling Units		
				Permanent	High-Rise	Seasonal
Suffolk	1,322,000	2.97	1.67	90,415		34,065
Nassau	1,287,000	3.04	1.68	143,641	8,094	2,833
Queens	1,951,000	2.56	0.84	117,887	41,494	12,839
Brooklyn	2,300,000	2.53	0.53	331,089	140,803	10,299
Staten Island	379,000	2.96	1.27	20,846	1,533	1,545
Manhattan	1,487,000	1.89	0.89	191,657	178,890	16,568
Bronx	1,204,000	2.59	0.95	54,785	37,252	1,981
Westchester	875,000	2.74	1.40	12,418	3,183	634

When the four levels of evacuation defined by the inundation maps are factored by several varying behavioral parameters, the number of hypothetical hurricane situations can become quite large. Providing a clearance time for each of these situations would be cumbersome for local emergency management officials and inappropriate considering the level of accuracy of hurricane forecasting.

The hurricane evacuation scenarios for each jurisdiction represent combinations of hurricane intensities that affect essentially the same areas and number of people. To develop the scenarios, maps of enumeration districts and census tracts were overlaid with storm surge inundation areas corresponding to the four hurricane categories. This procedure identified where major differences in storm surge limits and number of vulnerable population exist relative to each progressive step in hurricane intensity. Table 6-2 provides the storm scenarios developed in the transportation analysis for each county and borough.

c. **Evacuation Zones.** After defining the vulnerable areas with hurricane evacuation scenarios, a series of zones was established to graphically locate and quantify the vulnerable population and to provide a base for modeling traffic movements from one geographic area to another. Evacuation zones for each county and borough were based on the following factors.

(1) Zones should relate well to maximum potential surge inundation limits for each storm scenario.

(2) Zones should relate well to census, traffic analysis zone, or other data base unit.

(3) Zones should be defined, where possible, to facilitate issuing an evacuation order or advisory.

(4) Zonal boundaries should be delineated along identifiable natural features, roadways, railroads, landmarks, etc.

(5) Small "pocket" zones that would be isolated by surrounding surge should be avoided.

(6) Zones should be served by major evacuation routes.

(7) Zones must allow for appropriate transportation modeling.

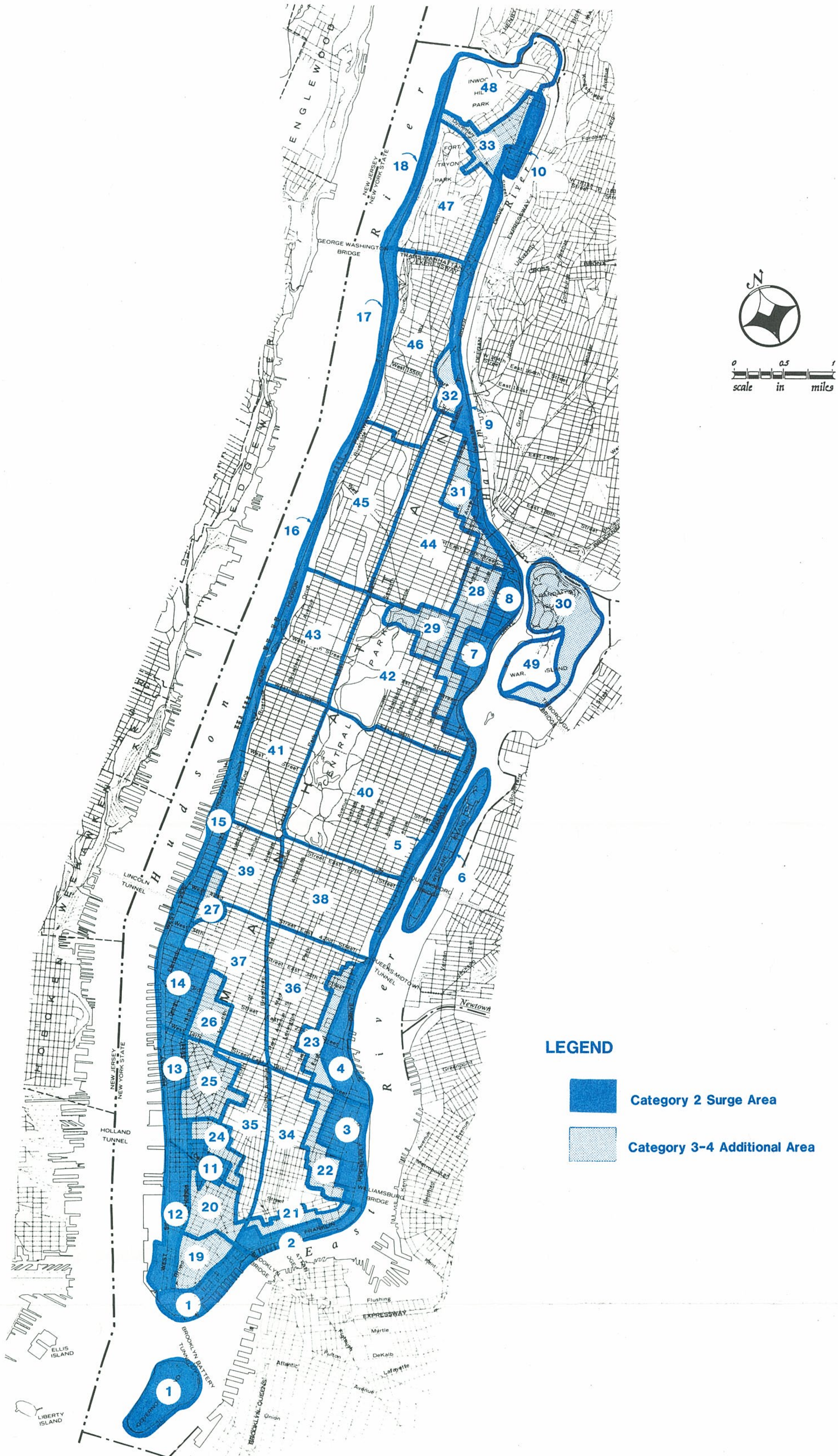
Table 6-2 provides the number of evacuation zones for the transportation analysis and vulnerability of each zone for storm scenarios. The number of zones range from 15 in Westchester County to 55 in Suffolk County. Figures 6-2 through 6-9 illustrate the evacuation zones established in each county and borough.

TABLE 6-2

Transportation Analysis Evacuation Zones
Assumed Vulnerability by Storm Scenario and Jurisdiction

County	Number of Zones	Storm Scenarios	Saffir Simpson Category	All Residents in Zones
Suffolk	55	A	1-2	1-23
		B	3	1-37
		C	4	1-39
Nassau	43	A	1-2	1-2
		B	3	1-19
		C	4	1-25
Brooklyn	50	A	1	1-2
		B	2	1-16
		C	3	1-22
		D	4	1-36
Queens	43	A	1	1-7
		B	2	1-19
		C	3-4	1-34
Manhattan	48	A	2*	1-18
		B	3-4	1-33
Staten Island	30	A	1-2	1-10
		B	3-4	19
Bronx	24	A	1-2	1
		B	3-4	1-16
Westchester	15	A	1-4	1-15

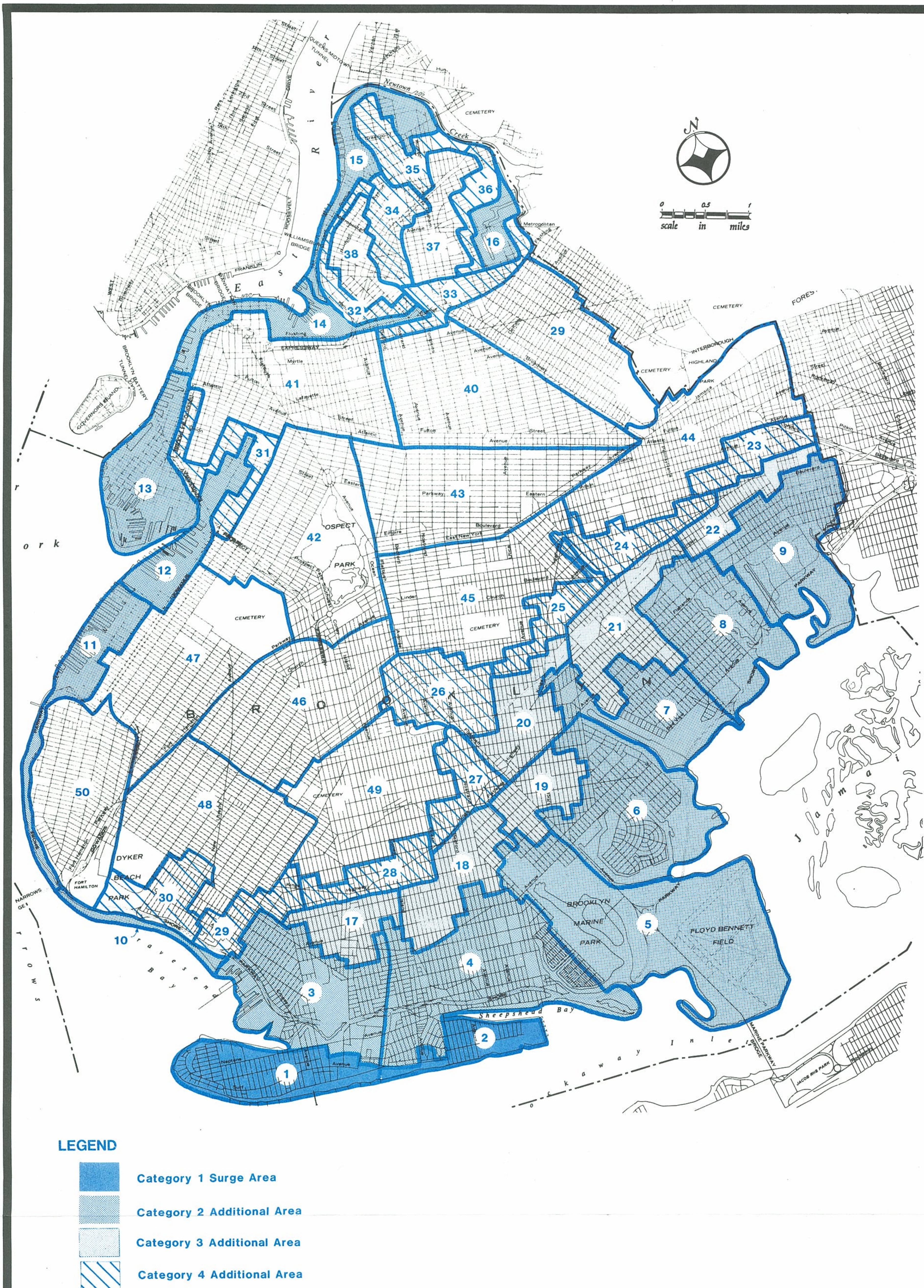
*For transporation analysis considerations, category 1 inundation is negligible



TRAFFIC EVACUATION ZONES
MANHATTAN

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-2

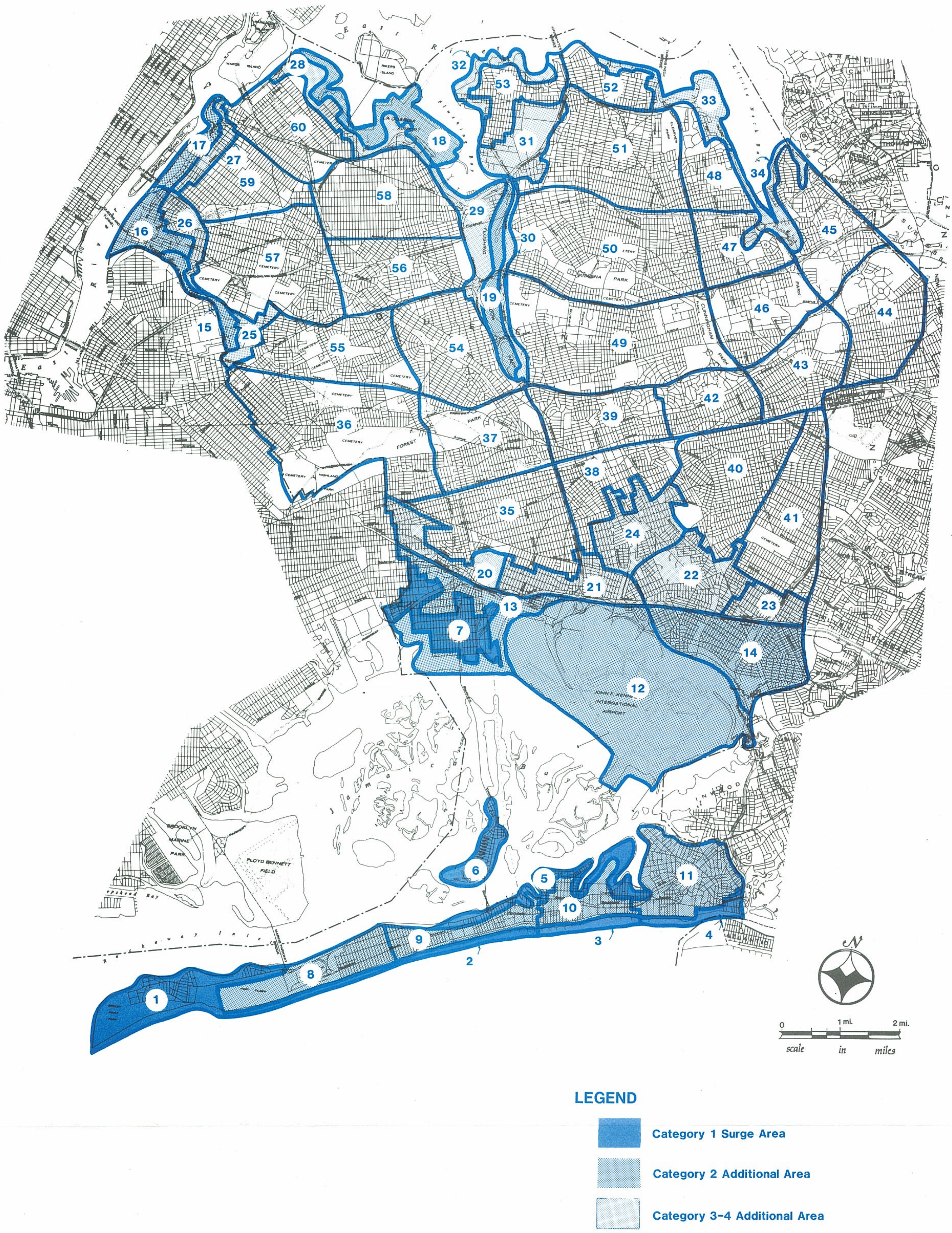


TRAFFIC EVACUATION ZONES

BROOKLYN

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-3

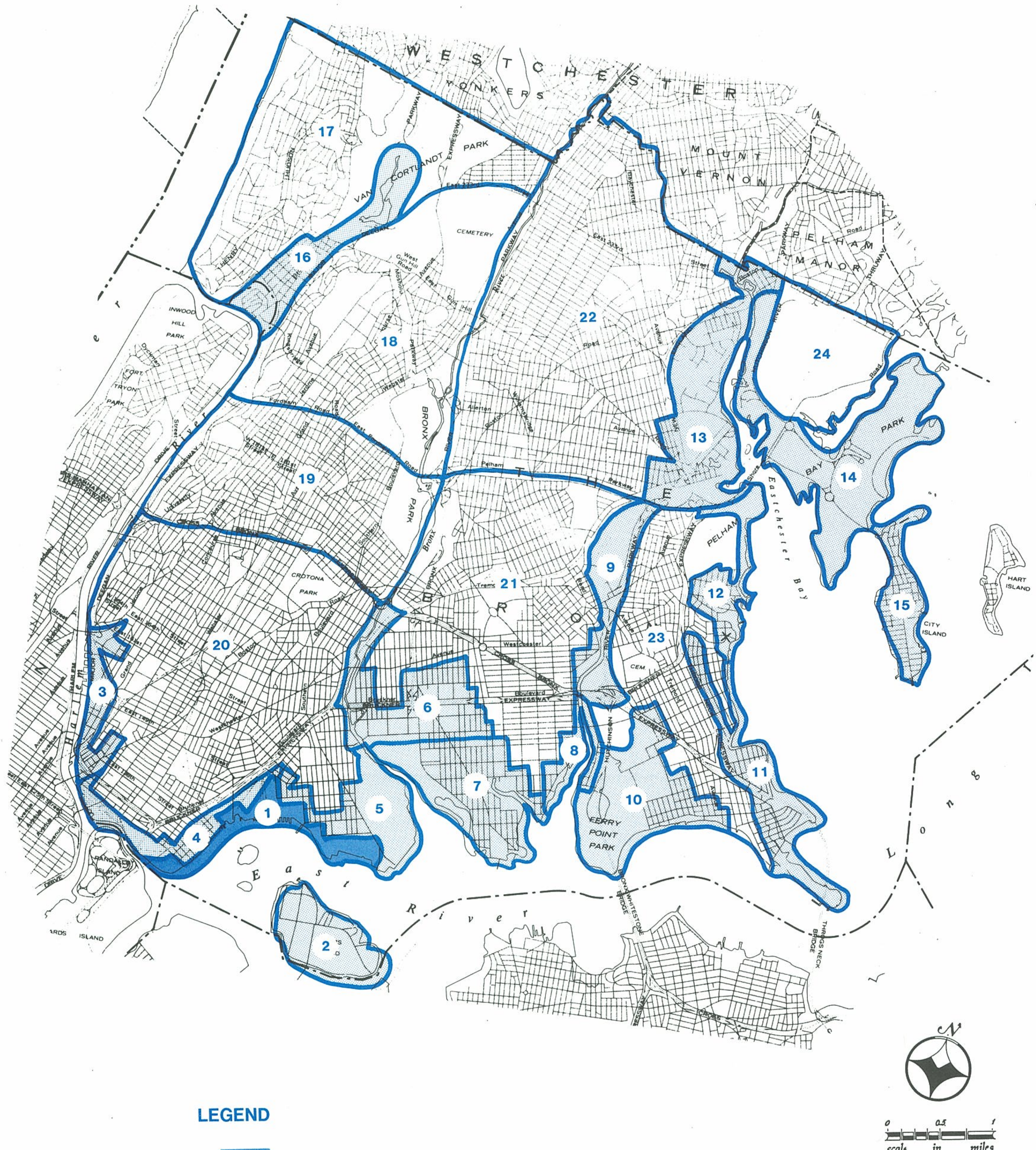


TRAFFIC EVACUATION ZONES

QUEENS

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6–4



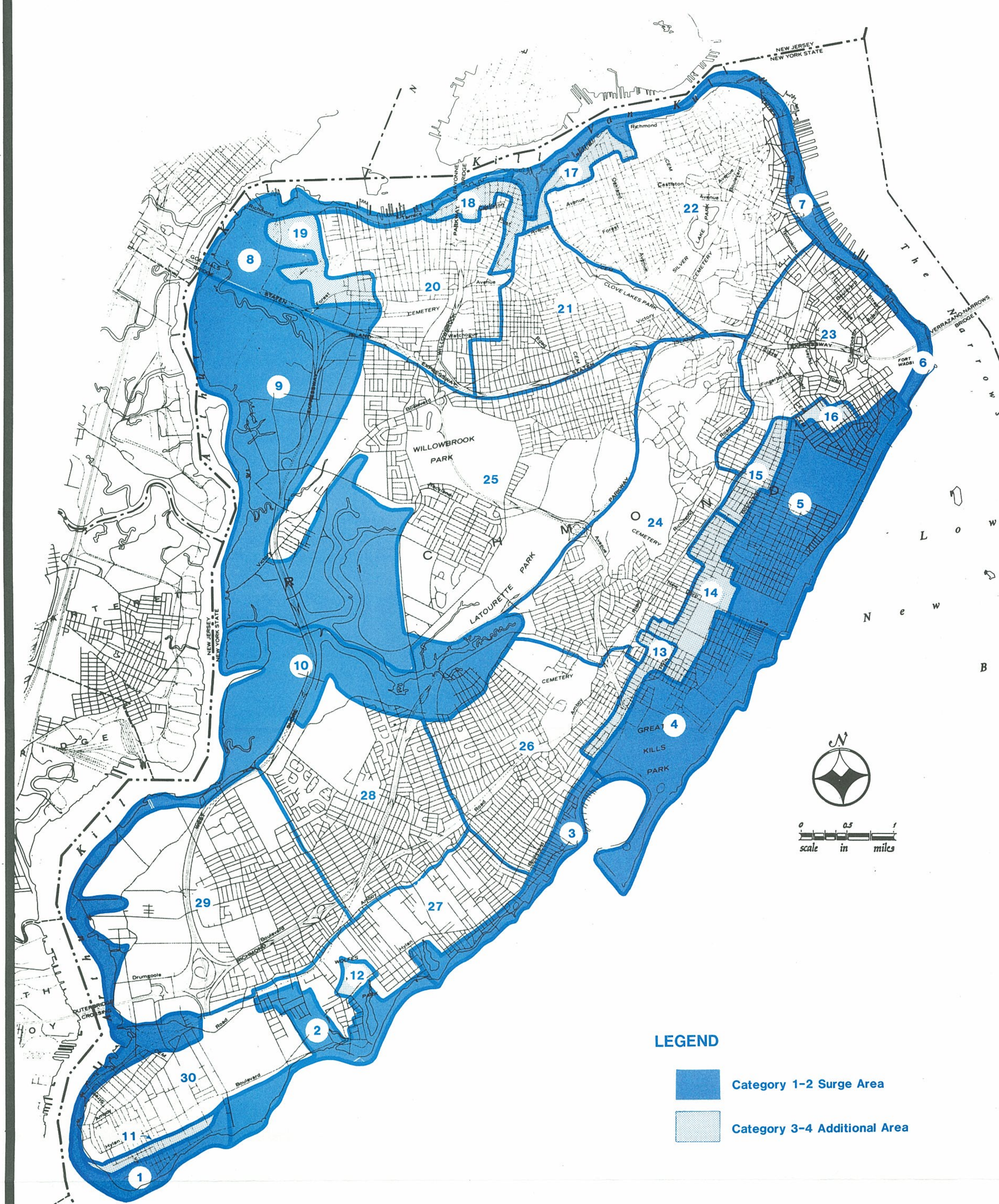
LEGEND

- Category 1-2 Surge Area
- Category 3-4 Additional Area

TRAFFIC EVACUATION ZONES
BRONX

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-5

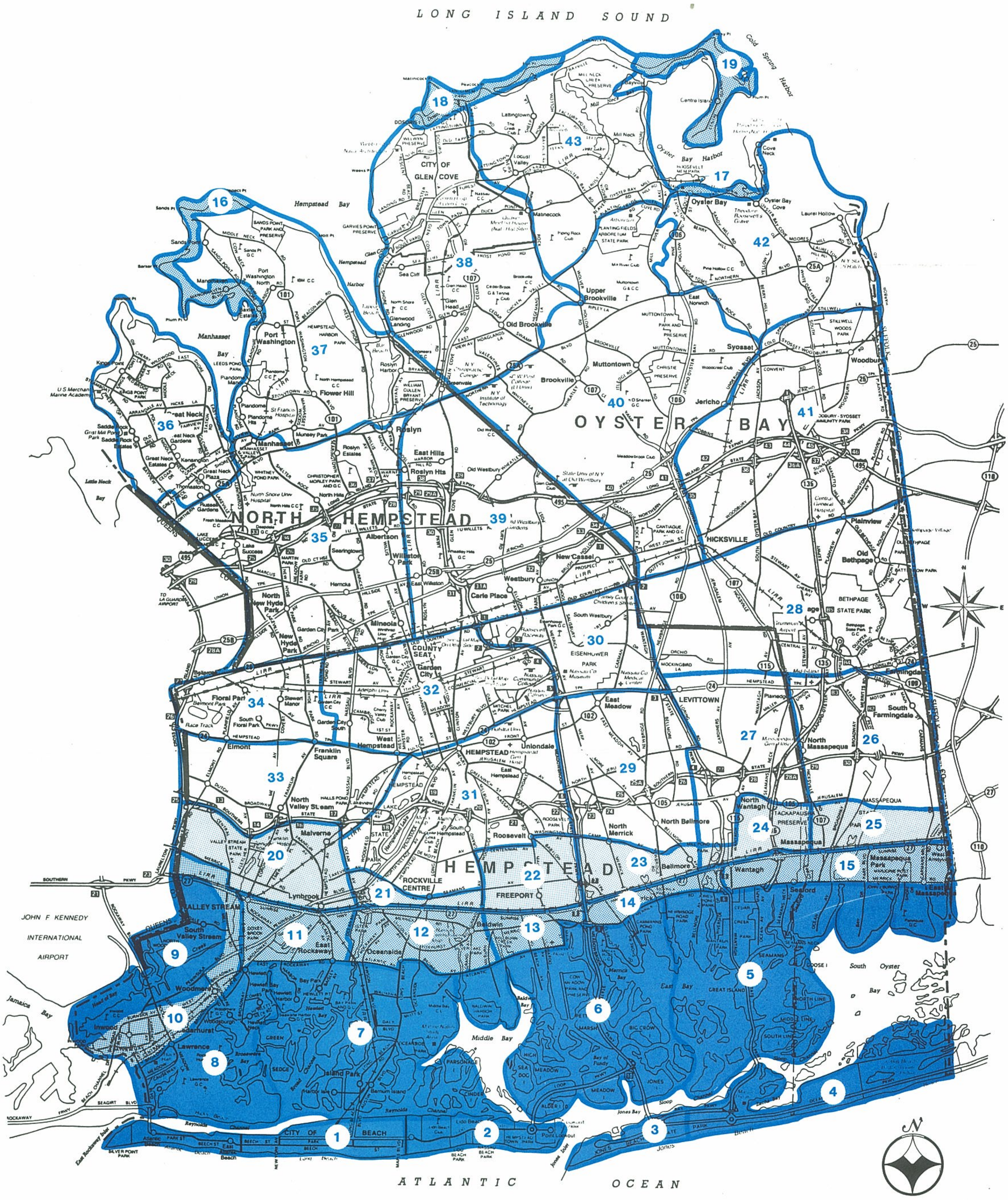


TRAFFIC EVACUATION ZONES

STATEN ISLAND

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-6



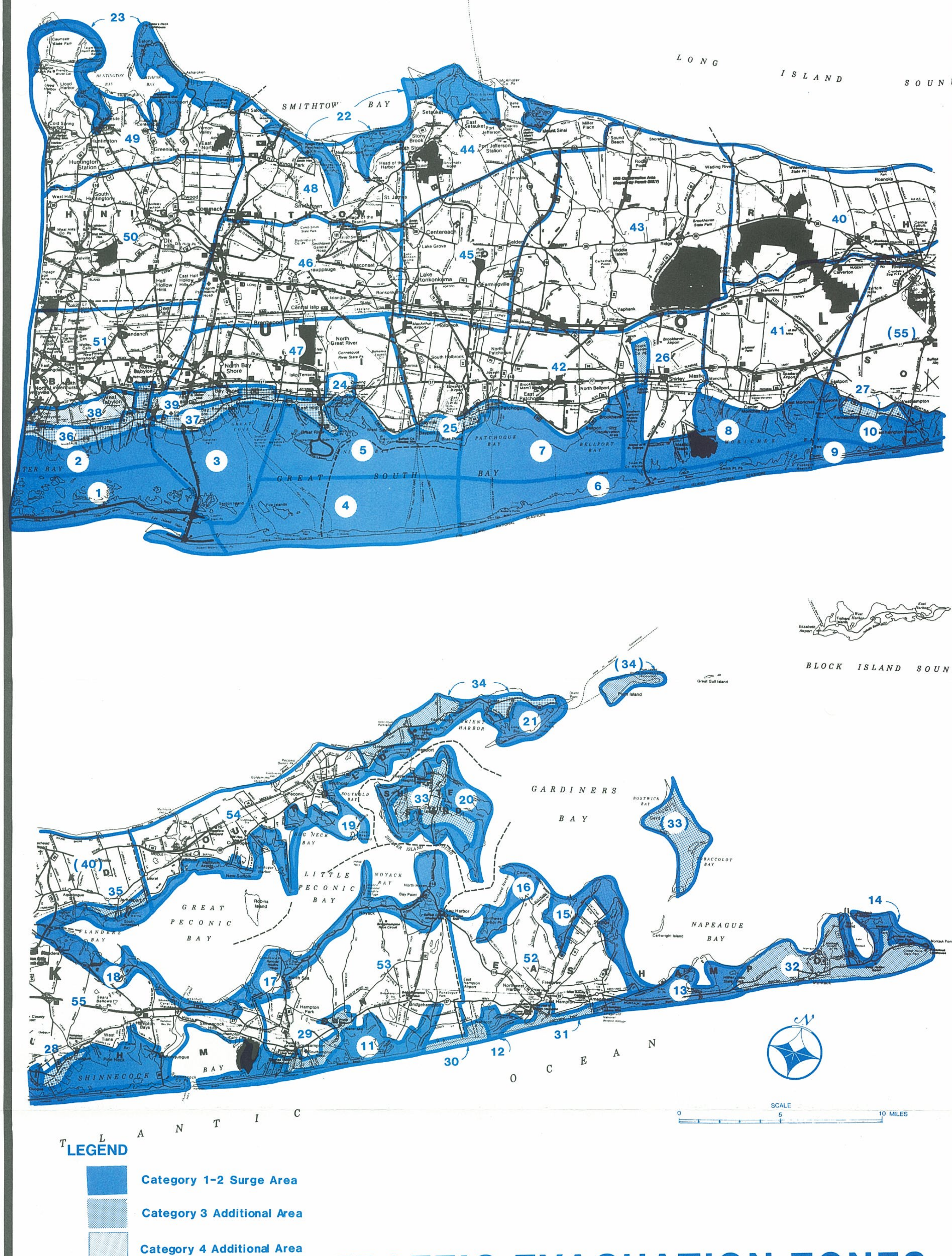
LEGEND

- Category 1-2 Surge Area
- Category 3 Additional Area
- Category 4 Additional Area

TRAFFIC EVACUATION ZONES
NASSAU COUNTY

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-7

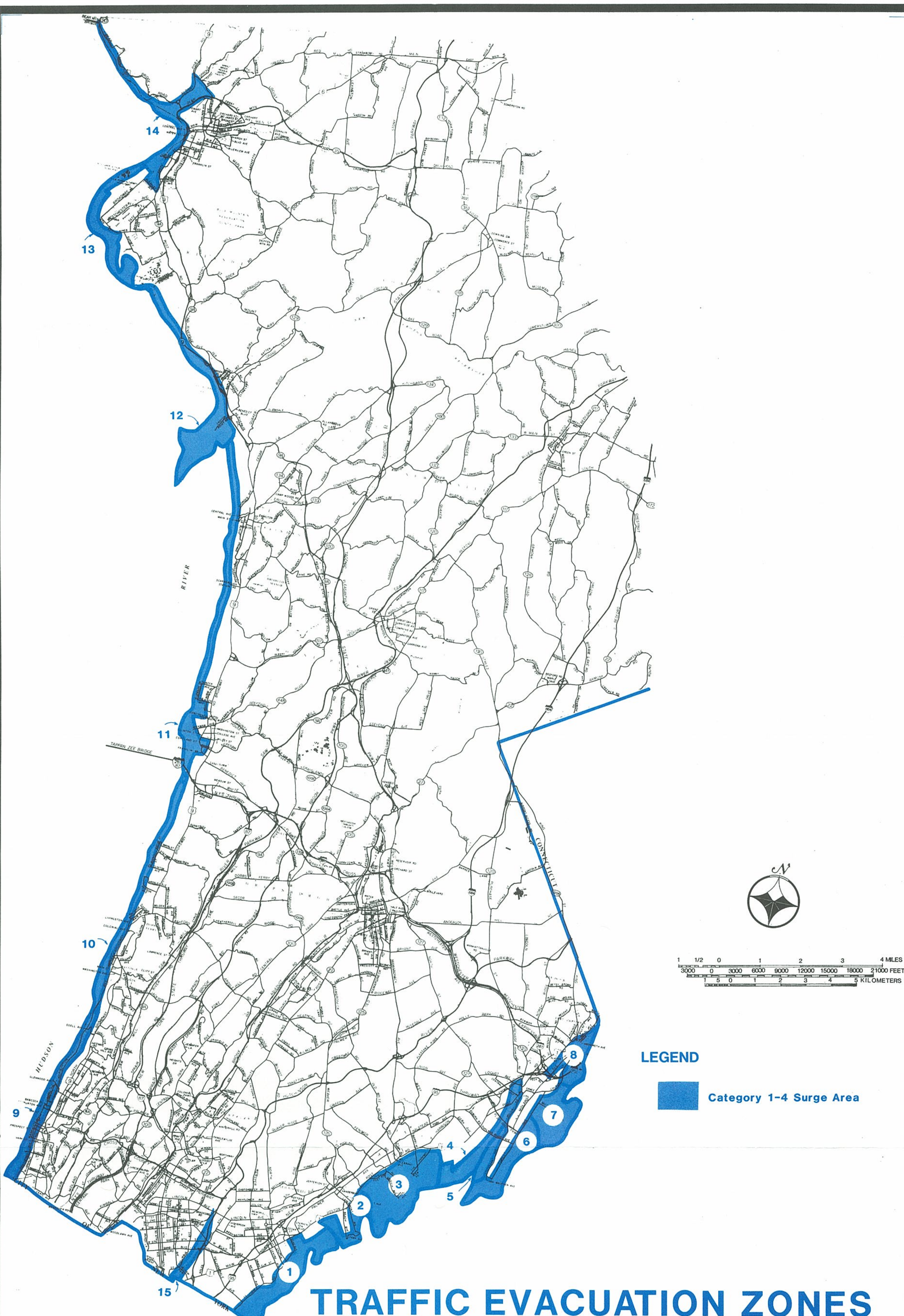


TRAFFIC EVACUATION ZONES

SUFFOLK COUNTY

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-8



TRAFFIC EVACUATION ZONES
WESTCHESTER COUNTY

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-9

d. Behavioral Characteristics. The conclusions drawn in the behavioral analysis (see chapter 4) were used to derive the best assumptions possible for the transportation analysis. The following behavioral aspects were addressed and are discussed below.

(1) Occupancy of seasonal units
(2) Participation rates
(3) Evacuation response rates
(4) Destination desires
(5) Vehicle usage

As a hurricane approaches the study area, the number of seasonal residents who may be required to evacuate along with the permanent residents could be significant. This is especially true in Suffolk County. Discussions with disaster preparedness officials have revealed opposing opinions regarding this issue. Some feel strongly that most vacationers will leave prior to the initiation of an evacuation. Others feel that vacationers might take a "wait and see" attitude, resulting in a significant number present at the start of an evacuation.

The behavioral analysis indicated that most vacationers are day-trippers and would not be involved in an evacuation. However, after Hurricane Bob affected the study area in August 1991, some officials became concerned that seasonal residents on Fire Island will not leave before issuance of an evacuation advisory. Because of these uncertainties, a 50-percent occupancy level was assumed for seasonal units in Suffolk County, a more conservative number than the 20 percent used for other jurisdictions. In those areas, seasonal units are a small fraction of the total number of vulnerable dwellings.

Another important behavioral aspect is participation rates, or the percentage of the vulnerable population within each evacuation zone that can be expected to leave under various hurricane threats. As recommended in the behavioral analysis, participation rates of people residing in surge evacuation zones were generally varied between 15 and 90 percent depending on proximity to the coastline. However, 100-percent participation by the vulnerable population was assumed for Suffolk County. The behavioral analysis specifically recommended reduced participation rates for residents of high-rise (four or more stories) buildings, based on the Hurricane Gloria survey (see chapter 4). Therefore, in the transportation analysis a much lower rate was used for those residents, generally about half that assumed for buildings of less than four stories. This reduced rate is not based on diminished danger to the occupants but rather reflects an effort to keep assumptions realistic. Tables 6-3 through 6-10 provide all participation rates by storm scenario and evacuation zones for each jurisdiction.

TABLE 6-3
NASSAU COUNTY
Trip Generation Assumptions

Storm Scenarios:

Category 1-2
Category 3
Category 4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 1-2	med income	7,9
2	Cat 1-2	low income	1
3	Cat 1-2	high income	2-6,8
4	Cat 3	med income	14-19
5	Cat 3	low income	10-13
6	Cat 4	med income	23-25
7	Cat 4	low income	20-22

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity		
	Cat 1-2	Cat 3	Cat 4
1	85/25	90/50	90/80
2	85/25	90/50	90/80
3	85/25	90/50	90/80
4	40/15	80/40	80/40
5	40/15	80/40	80/40
6	15/5	20/10	30/20
7	15/5	20/10	30/20

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives		Hotel	Out County	
		Cat 1-2	Cat 3-4		Cat 1-2	Cat 3-4
1	15	45	30	10	30	45
2	40	45	35	0	15	25
3	5	40	25	15	40	55
4	20	50	35	10	20	35
5	40	55	45	0	5	15
6	25	50	35	10	15	30
7	40	55	45	0	5	15

Socioeconomic Data

3.04 people per permanent unit
2.50 people per seasonal unit
1.68 vehicles per permanent unit
2.00 vehicles per seasonal unit

Occupancy of Seasonal Units 30%

Vehicle Usage 65%

TABLE 6-4
SUFFOLK COUNTY
(Mainland)
Trip Generation Assumptions

Storm Scenarios:

Category 1-2
Category 3
Category 4

Zone Group	Vulnerability (Category)	Evacuation Zones
1	Cat 1-2	1-23
2	Cat 3	24-37
3	Cat 4	38,39

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity		
	Cat 1-2	Cat 3	Cat 4
1	100/100	100/100	100/100
2	0/0	100/50	100/100
3	0/0	0/0	100/100

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives	Hotel	Out County
1	5	55	10	30
2	15	65	5	15
3	20	65	5	10

Socioeconomic Data

2.97 people per permanent unit
2.50 people per seasonal unit
1.68 vehicles per permanent unit
1.00 vehicles per seasonal unit

Occupancy of Seasonal Units 20%

Vehicle Usage 75%

TABLE 6-5
WESTCHESTER COUNTY
Trip Generation Assumptions

Storm Scenarios:

Category 1-4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 1-4	high income	1-15
2	Cat 1-4	low income	8

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity Category 1-4
1	100/50
2	100/50

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives	Hotel	Out County
1	10	55	15	20
2	35	55	0	10

Socioeconomic Data

2.74 people per permanent unit
1.4/1.0 vehicles per permanent unit

Vehicle Usage 65%

TABLE 6-6
MANHATTAN NEW YORK
Trip Generation Assumptions

Storm Scenarios:

Category 2
Category 3-4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 2	med income	1,11,13,16-18
2	Cat 2	low income	2,3,7-10,14,15
3	Cat 2	high income	4-6,12
4	Cat 3-4	med income	20,23-26,30
5	Cat 3-4	low income	21,22,27-29,31-33
6	Cat 3-4	high income	19

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity	
	Cat 2	Cat 3-4
1	85/25	90/80
2	85/25	90/80
3	85/25	90/80
4	20/5	40/30
5	20/5	40/30
6	20/5	40/30

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives		Hotel	Out County	
		Cat 2	Cat 3-4		Cat 2	Cat 3-4
1	15	45	30	10	30	45
2	40	45	35	0	15	25
3	5	40	25	15	40	55
4	20	50	35	10	20	35
5	40	55	45	0	5	15
6	10	45	30	15	30	45

Socioeconomic Data

1.89 people per permanent unit
1.50 people per seasonal unit
0.89 vehicles per permanent unit
0.60 vehicles per seasonal unit

Occupancy of Seasonal Units 30%

Vehicle Usage 65%

TABLE 6-7
QUEENS NEW YORK
Trip Generation Assumptions

Storm Scenarios:
Category 1
Category 2
Category 3-4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 1	med income	2,6
2	Cat 1	low income	3-5
3	Cat 1	high income	1,7
4	Cat 2	med income	9
5	Cat 2	low income	10,11,15-19
6	Cat 2	high income	8,12-14
7	Cat 3-4	med income	20-24,28-30,32
8	Cat 3-4	low income	25-27
9	Cat 3-4	high income	31,33,34

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity		
	Cat 1	Cat 2	Cat 3-4
1	85/25	85/25	90/80
2	85/25	85/25	90/80
3	85/25	85/25	90/80
4	20/5	40/15	80/40
5	20/5	40/15	80/40
6	20/5	40/15	80/40
7	10/5	15/5	40/30
8	10/5	15/5	40/30
9	10/5	15/5	40/30

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives		Hotel	Out County	
		Cat 1-2	Cat 3-4		Cat 1-2	Cat 3-4
1	15	45	30	10	30	45
2	40	45	35	0	15	25
3	5	40	25	15	40	55
4	20	50	35	10	20	35
5	40	55	45	0	5	15
6	10	45	30	15	30	45
7	25	50	35	10	15	30
8	40	55	45	0	5	15
9	10	50	35	15	25	40

Socioeconomic Data
2.56 people per permanent unit
2.50 people per seasonal unit
0.84 vehicles per permanent unit
1.00 vehicles per seasonal unit
Occupancy of Seasonal Units 30%
Vehicle Usage 65%

TABLE 6-8
BROOKLYN NEW YORK
Trip Generation Assumptions

Storm Scenarios:
Category 1
Category 2
Category 3
Category 4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 1	low income	1
2	Cat 1	high income	2
3	Cat 2	med income	3,4,8,10,12,16
4	Cat 2	low income	9,11,13-15
5	Cat 2	high income	5-7
6	Cat 3	med income	17,18,20,21
7	Cat 3	low income	22
8	Cat 3	high income	19
9	Cat 4	med income	25,27-31
10	Cat 4	low income	23,24,26,32-36

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity			
	Cat 1	Cat 2	Cat 3	Cat 4
1	85/25	85/25	90/50	90/80
2	85/25	85/25	90/50	90/80
3	20/5	40/15	80/40	80/40
4	20/5	40/15	80/40	80/40
5	20/5	40/15	80/40	80/40
6	10/5	20/5	30/20	40/30
7	10/5	20/5	30/20	40/30
8	10/5	20/5	30/20	40/30
9	5/2	10/5	20/10	30/20
10	5/2	10/5	20/10	30/20

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives		Hotel	Out County	
		Cat 1-2	Cat 3-4		Cat 1-2	Cat 3-4
1	40	45	35	0	15	25
2	5	40	25	15	40	55
3	20	50	35	10	20	35
4	40	55	45	0	5	15
5	10	45	30	15	30	45
6	25	50	35	10	15	30
7	40	55	45	0	5	15
8	10	50	35	15	25	40
9	25	50	35	10	15	30
10	40	55	45	0	5	15

Socioeconomic Data
2.53 people per permanent unit
2.50 people per seasonal unit
0.53 vehicles per permanent unit
1.00 vehicles per seasonal unit

Occupancy of Seasonal Units 30%
Vehicle Usage 65%

TABLE 6-9
BRONX NEW YORK
Trip Generation Assumptions

Storm Scenarios:

Category 1-2
Category 3-4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 1-2	med income	1
2	Cat 3-4	med income	2,5-7,10,12,14-16
3	Cat 3-4	low income	3,4,8
4	Cat 3-4	high income	9,11,13

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity	
	Cat 1-2	Cat 3-4
1	85/25	90/80
2	20/5	40/30
3	20/5	40/30
4	20/5	40/30

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives		Hotel	Out County	
		Cat 1-2	Cat 3-4		Cat 1-2	Cat 3-4
1	15	45	30	10	30	45
2	20	50	35	10	20	35
3	40	55	45	0	5	15
4	10	45	30	15	30	45

Socioeconomic Data

2.59 people per permanent unit
2.00 people per seasonal unit
0.95 vehicles per permanent unit
0.75 vehicles per seasonal unit

Occupancy of Seasonal Units 30%

Vehicle Usage 65%

TABLE 6-10
STATEN ISLAND NEW YORK
Trip Generation Assumptions

Storm Scenarios:

Category 1-2
Category 3-4

Zone Group	Vulnerability (Category)	Income	Evacuation Zones
1	Cat 1-2	med income	1,4,7,9,10
2	Cat 1-2	low income	5,8
3	Cat 1-2	high income	2,3
4	Cat 3-4	med income	11-16
5	Cat 3-4	low income	17-19

Participation Rates (%)
other/High-Rise

Zone Group	Storm Intensity	
	Cat 1-2	Cat 3-4
1	85/25	90/80
2	85/25	90/80
3	85/25	90/80
4	30/10	50/30
5	30/10	50/30

Destination Percentages

Zone Group	Public Shelter	Friends/Relatives		Hotel	Out County	
		Cat 1-2	Cat 3-4		Cat 1-2	Cat 3-4
1	15	45	30	10	30	45
2	40	45	35	0	15	25
3	5	40	25	15	40	55
4	20	50	35	10	20	35
5	40	55	45	0	5	15

Socioeconomic Data

2.96 people per permanent unit
2.50 people per seasonal unit
1.27 vehicles per permanent unit
1.00 vehicles per seasonal unit

Occupancy of Seasonal Units 30%

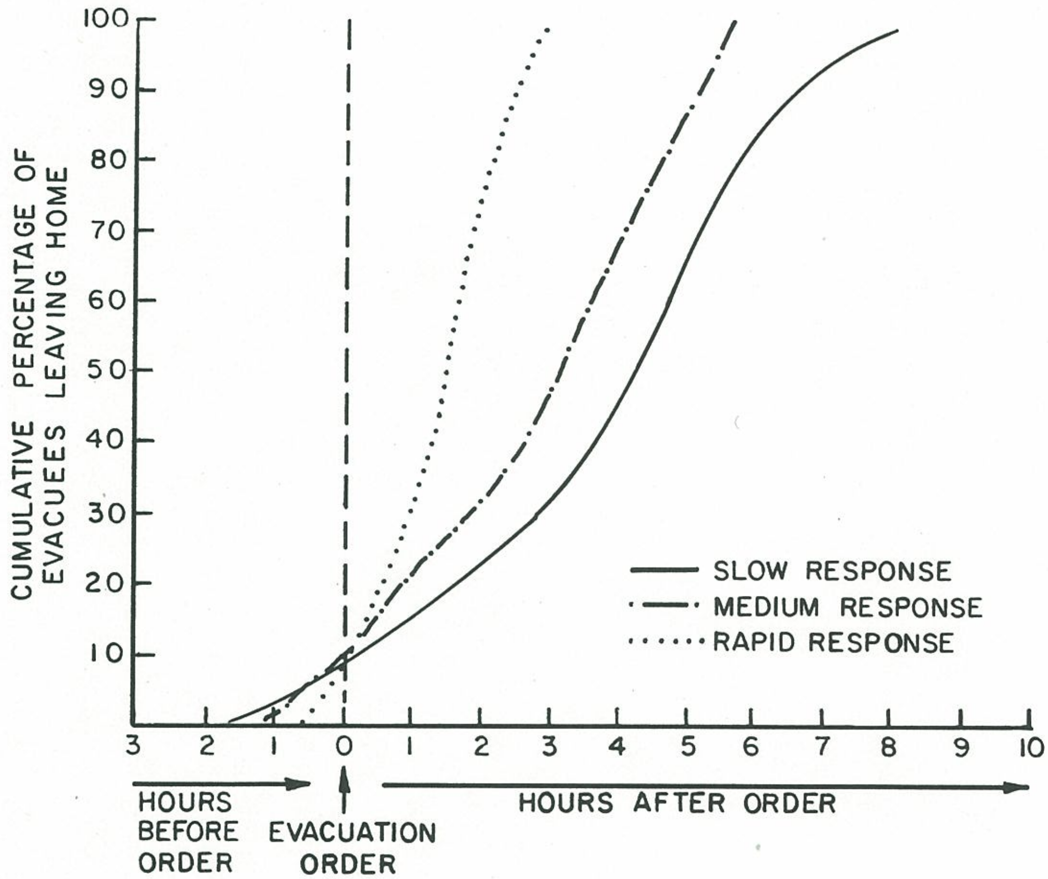
Vehicle Usage 65%

Probably the most critical behavioral consideration for the transportation analysis is the evacuation response rate, or the rate at which evacuees will leave their homes. Behavioral research of past hurricane evacuations shows that mobilization and departures of the evacuating population can occur over a period of many hours and sometimes several days. Since hurricanes generally travel quickly in northern latitudes, it will be especially important for New Yorkers to make a timely evacuation decision. For the sensitivity analysis, clearance times were tested for three evacuation rates represented by different behavioral response curves. These response curves describing mobilization by the vulnerable population define the rate at which evacuating vehicles load onto the roadway system relative to an evacuation order or strong advisory. The percentage of evacuees leaving dwelling units is then available for the calculations related to traffic loadings at critical links along the evacuation network.

The behavioral response curves shown in figure 6-10 range from rapid response to slow response and are intended to include the most probable range of mobilization times that will be experienced in future hurricane evacuation situations. For sensitivity analysis, the mobilization/traffic loading time was varied between 4 hours and 9 hours.

Apportionment of evacuees among four destination types was another important behavioral input. Percentages were applied to the evacuating population based on behavioral research conducted after past hurricane evacuations and interviews with local officials. Destinations are related to evacuees' proximity to the shoreline, as in the case of participation rates, and socio-economic conditions. More affluent evacuees tend to utilize public shelters at much lower rates than the remainder of the population. Conversely, persons with lower incomes will utilize public shelters in significantly higher numbers than other residents because of problems with transportation and the affordability of hotels/motels. Destination percentages were assigned for every evacuation zone in each jurisdiction according to the level of risk (proximity to shoreline) and average family income. The analysis produced an estimate of the number of evacuees going to public shelters, hotels/motels, the home of a friend or relative, or out of the county/borough. Public shelter destination apportionment ranged from 5 to 40 percent with the higher figure related to low-income, highly vulnerable areas. When compared to other coastal areas, a relatively low percentage of evacuees was assumed to leave the local jurisdictions because of normal daily traffic congestion and roadway capacity constraints. Specific assumptions for each storm scenario and evacuation zone are provided in tables 6-3 through 6-10.

Vehicle usage refers to the percentage of available vehicles that are expected to be used in a hurricane evacuation. Usage percentages varied from 65 to 75 percent depending on the availability of public transportation. U.S. Census data indicates that approximately 40 percent of potential Queens evacuees and 60 percent of Brooklyn evacuees do not own automobiles. A large segment of these groups would need public transportation to reach their destinations, primarily public shelters.



CUMULATIVE EVACUATION CURVES

FIGURE 6-10

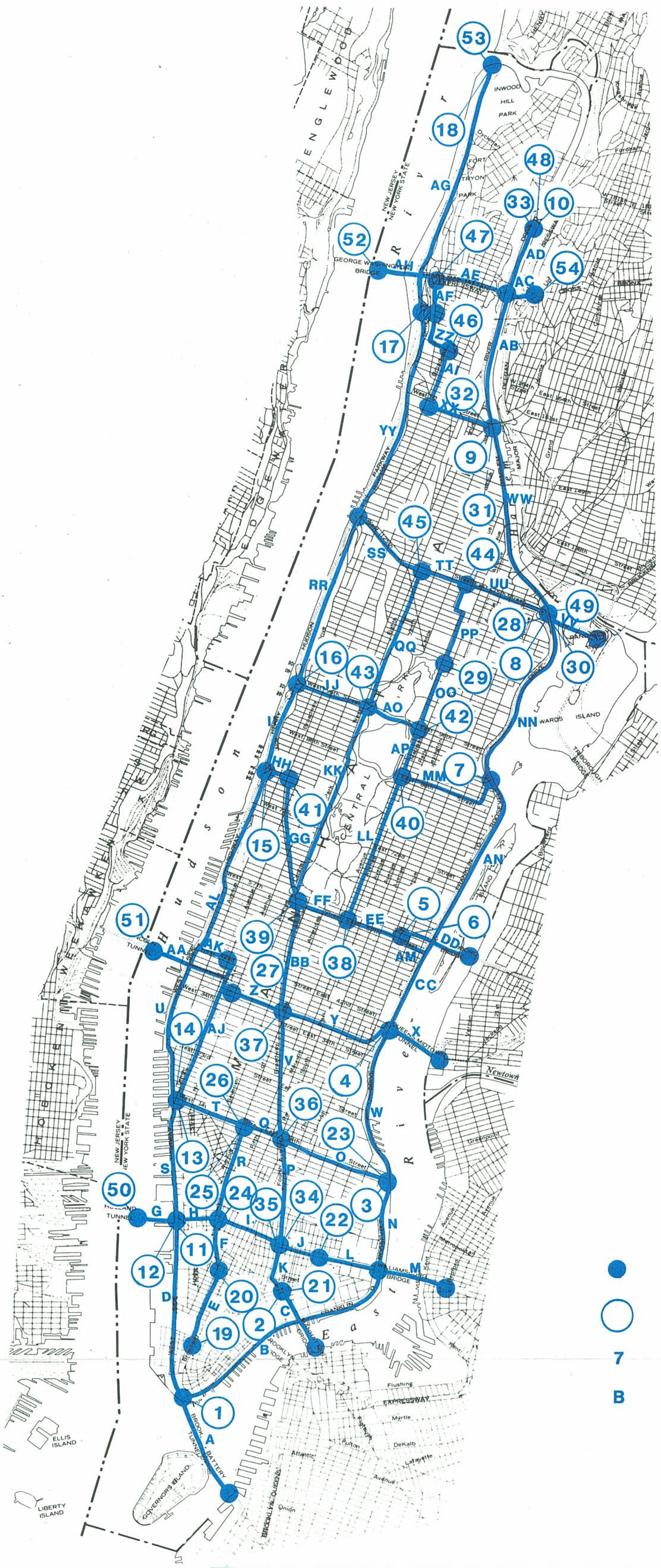
e. Roadway Network and Traffic Control. Certain assumptions regarding the evacuation roadway network and traffic control measures must be made for the transportation analysis. Although these assumptions are general, traffic control and roadway selection at the local level must be quite detailed. Manpower allocations to critical intersections, interchanges, and bridges involve extensive coordination among local and state officials. Reverse laning of roadways can be especially manpower intensive. This study does not presume to replace those efforts but rather seeks to quantify the time elements within which such manpower would be required.

Roadways chosen for the evacuation network were ideally major arterials with sufficient elevation to remain above storm surge levels at least until the arrival of sustained tropical storm winds, little or no adjacent tree coverage, generous shoulder width with substantial surface, and roadways already designated in existing hurricane evacuation plans. In order to determine the routing of evacuation traffic, a schematic representation of the roadway system was constructed. A descriptive "link-node" system was used, where links are portions of the evacuation roadway network and nodes identify the intersection of two roads or the location of significant changes in the roadway. Links specify roadway characteristics, such as the number of traffic lanes and type of facility (urban, rural, limited access, etc.). That information, as well as other important data used in the modeling process, is explained in the Transportation Model Support Document.

Figures 6-11 through 6-18 show the roadway system representations (evacuation networks) for each county and borough in the study area. On the maps, the evacuation zone centers (with identifying circled numbers) are connected by lines to the key intersection locations (nodes) by which they are generally served. As mentioned above, the key intersection symbol is also used at points where roadway characteristics change significantly. Road segments (links) are identified by a letter designation.

For the transportation modeling, an important assumption was made that all moveable bridges would be continuously available for roadway traffic during a hurricane warning period. In some cases, it could be advisable for boat owners to secure their vessels prior to or during the hurricane watch. Since opening bridges considerably reduces the hourly roadway capacity, the lives of evacuees could be jeopardized if bridges do not carry full capacity during a hurricane warning. U.S. Coast Guard Regulation 33-117.1(c) may enable emergency preparedness officials to implement this procedure. At the present time, a request for closure prior to a major disaster (and prior to the warning period) must be directed to the U.S. Coast Guard, and they can act on these requests immediately. It is essential that appropriate authorities review bridge regulations and ensure an immediate response to an evacuation order.

Long Island clearance times include the assumption that law enforcement officers will be assigned to critical intersections to facilitate traffic flowing northward from vulnerable areas along the south shore. In addition, there will be some congested intersections near the north shore that should be controlled by officers. The transportation modeling also assumes that provisions will be made to remove stalled or wrecked vehicles from the roadways and that the evacuation will be completed prior to the arrival of sustained tropical storm winds (39 mph) and storm-surge roadway inundation.



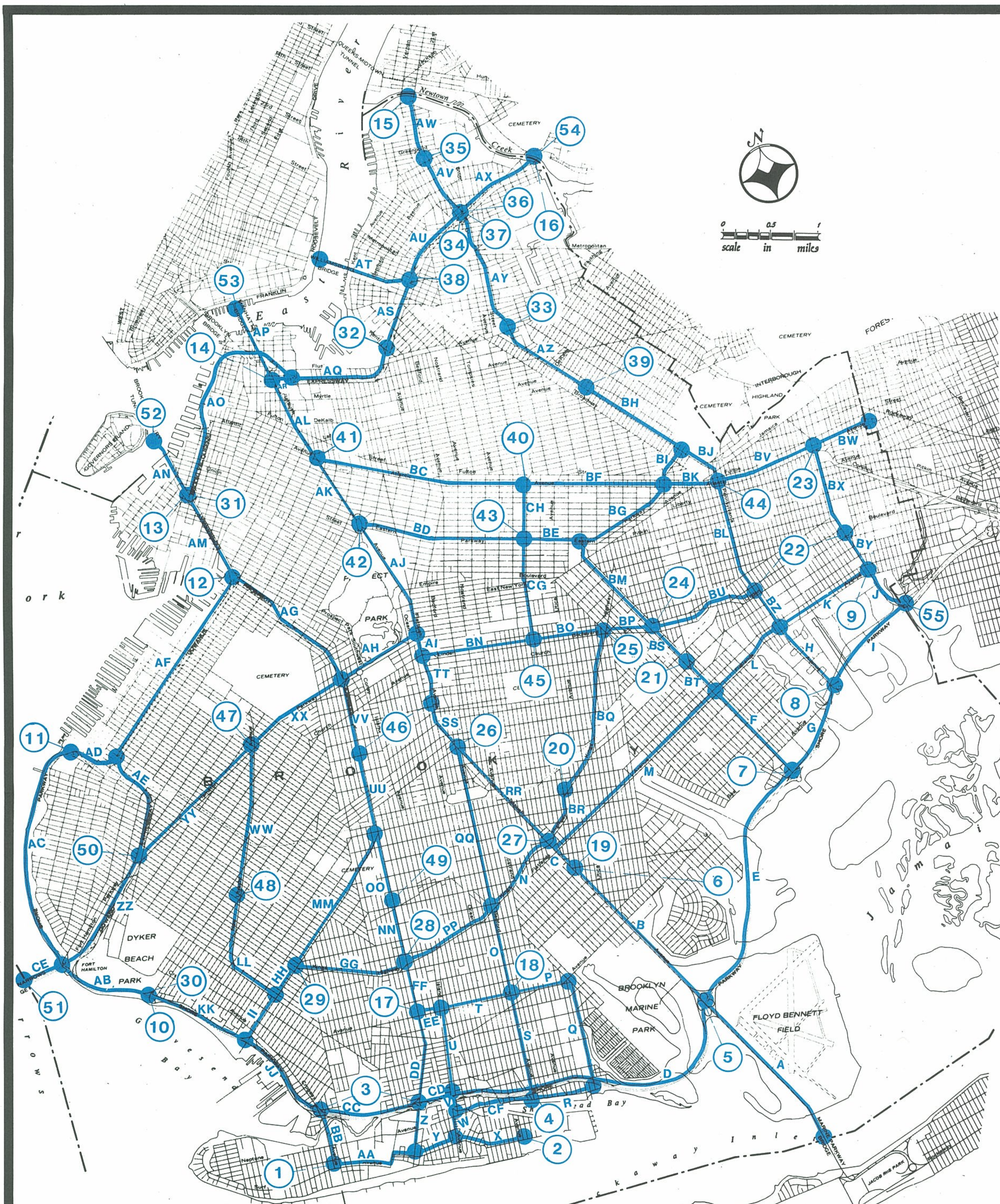
LEGEND

- ● INTERSECTION OR INTERCHANGE LOCATION
- ○ EVACUATION ZONE CENTER
- 7 ZONE NUMBER
- B ROADWAY SEGMENT NAME

EVACUATION ROAD NETWORK
MANHATTAN

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-11



LEGEND

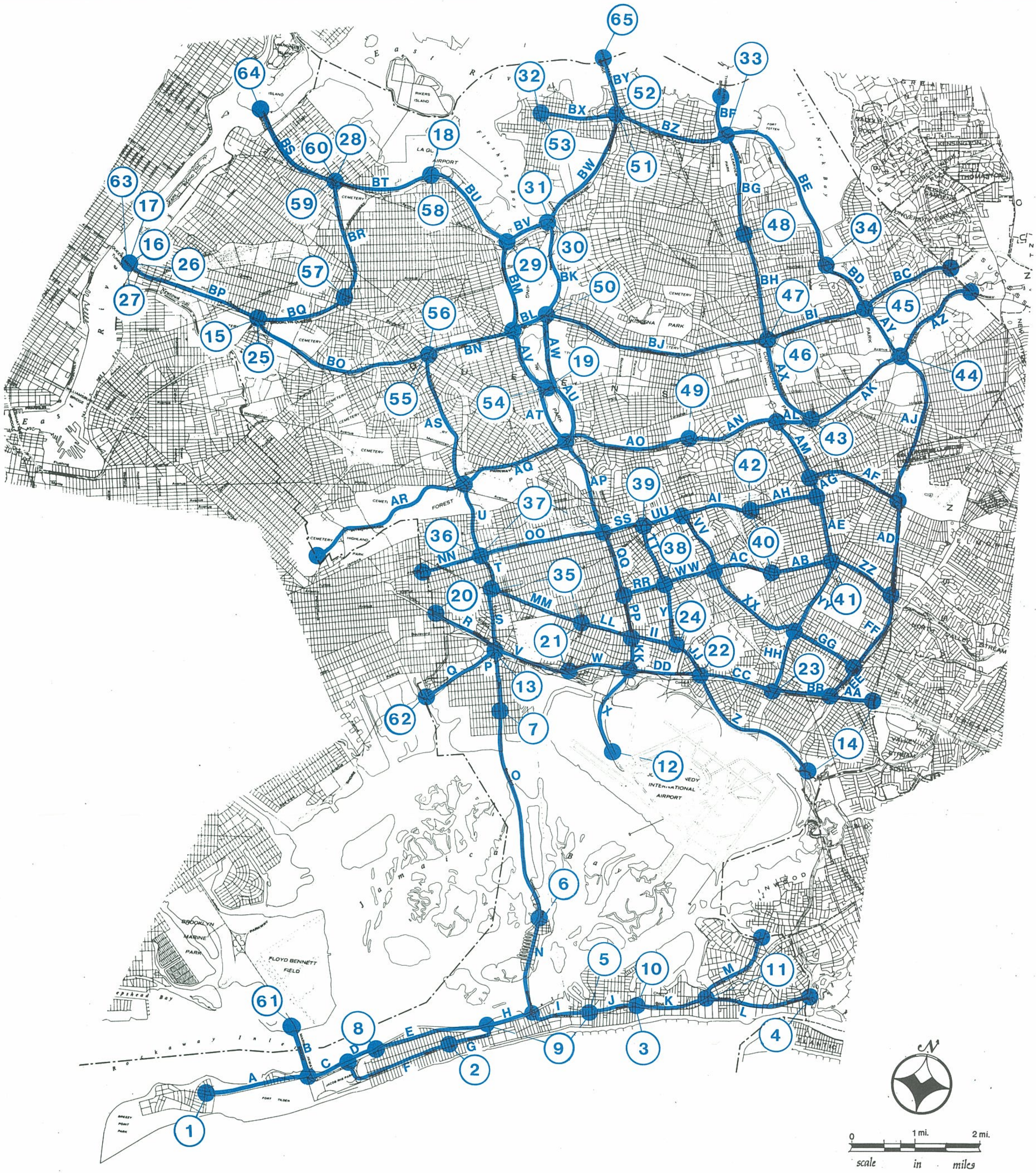
- ● INTERSECTION OR INTERCHANGE LOCATION
- ○ EVACUATION ZONE CENTER
- 7 ZONE NUMBER
- B ROADWAY SEGMENT NAME

EVACUATION ROAD NETWORK

BROOKLYN

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-12



LEGEND

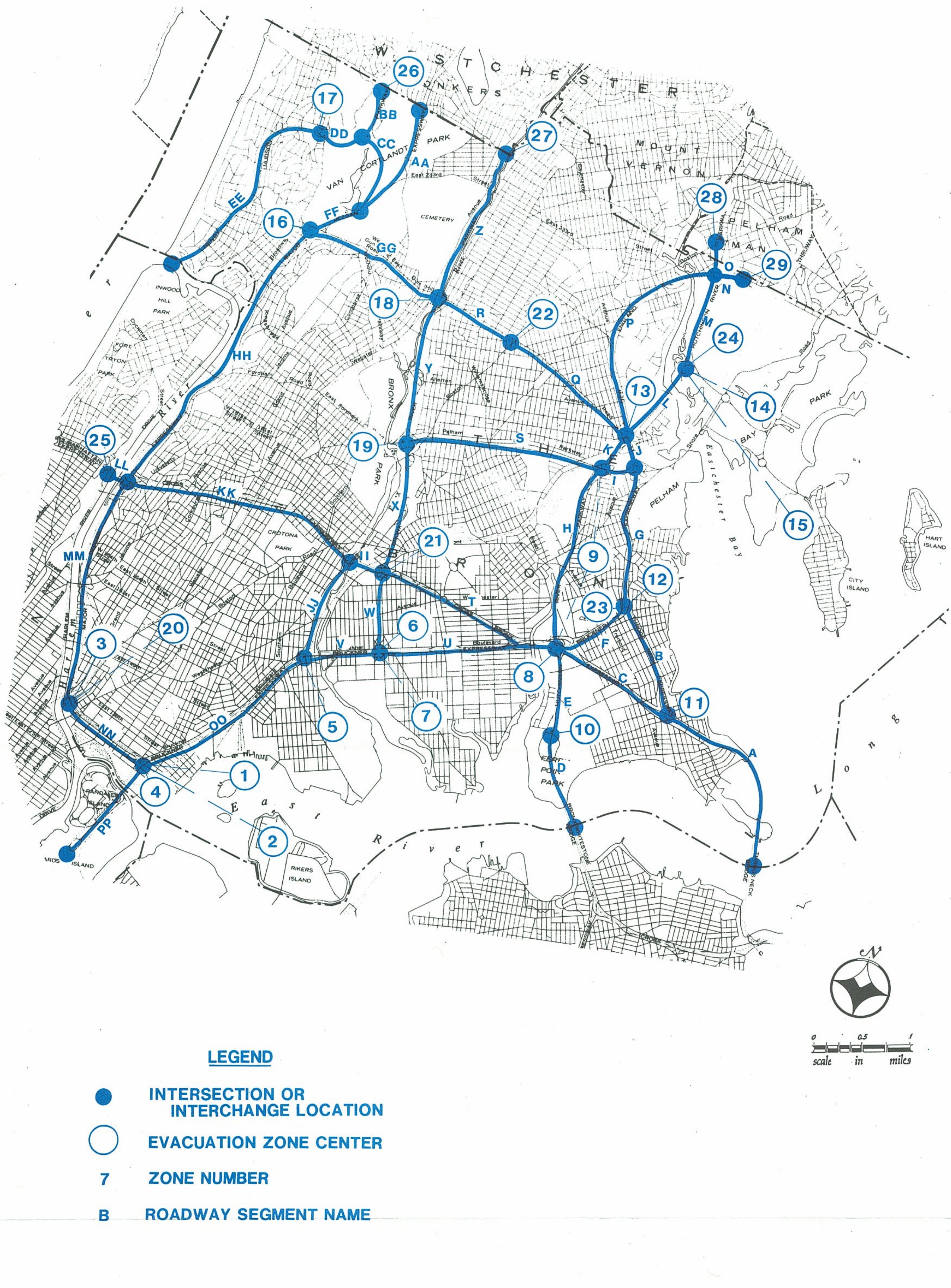
- ● INTERSECTION OR INTERCHANGE LOCATION
- ○ EVACUATION ZONE CENTER
- 7 ZONE NUMBER
- B ROADWAY SEGMENT NAME

EVACUATION ROAD NETWORK

QUEENS

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-13

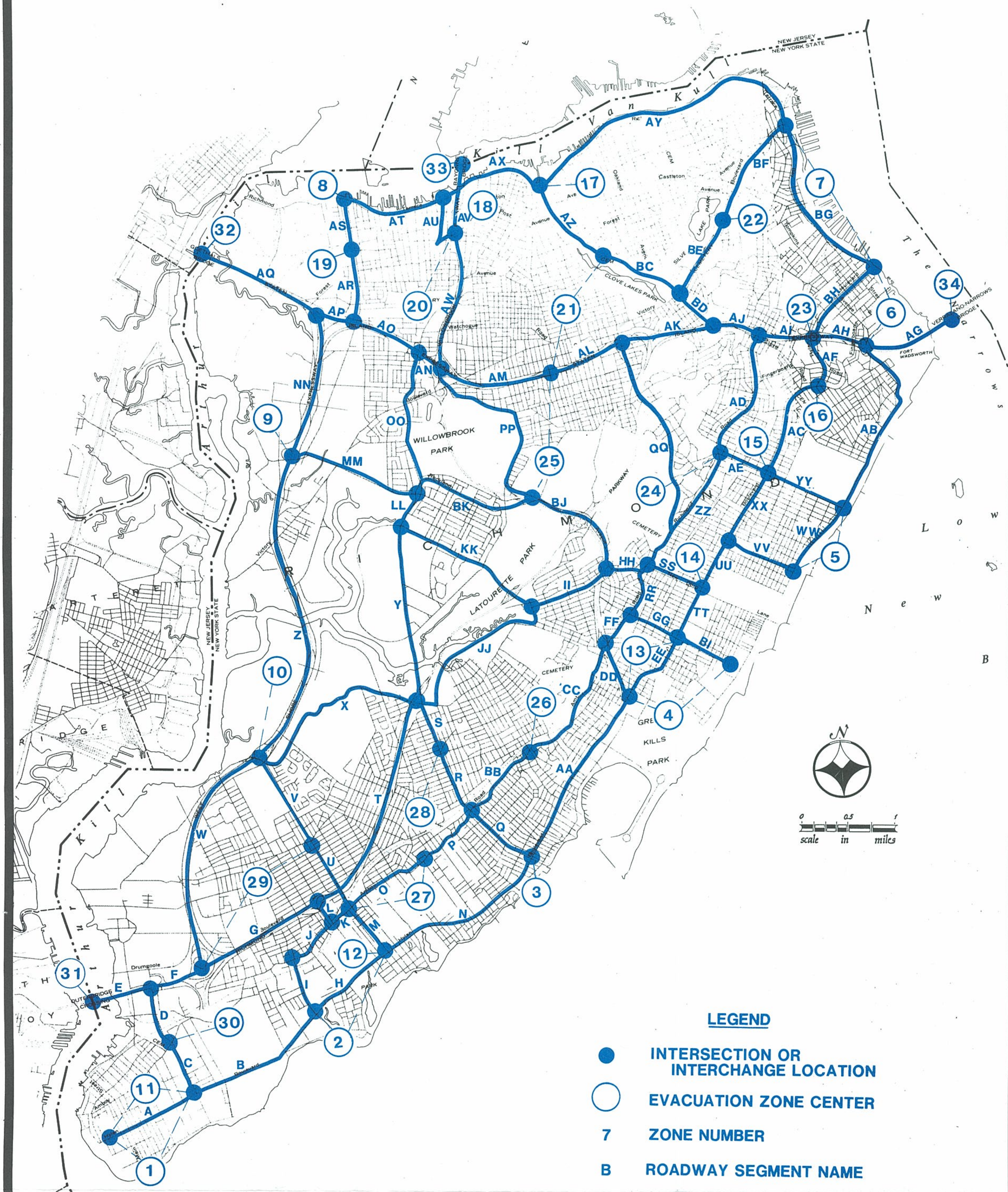


EVACUATION ROAD NETWORK

BRONX

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-14

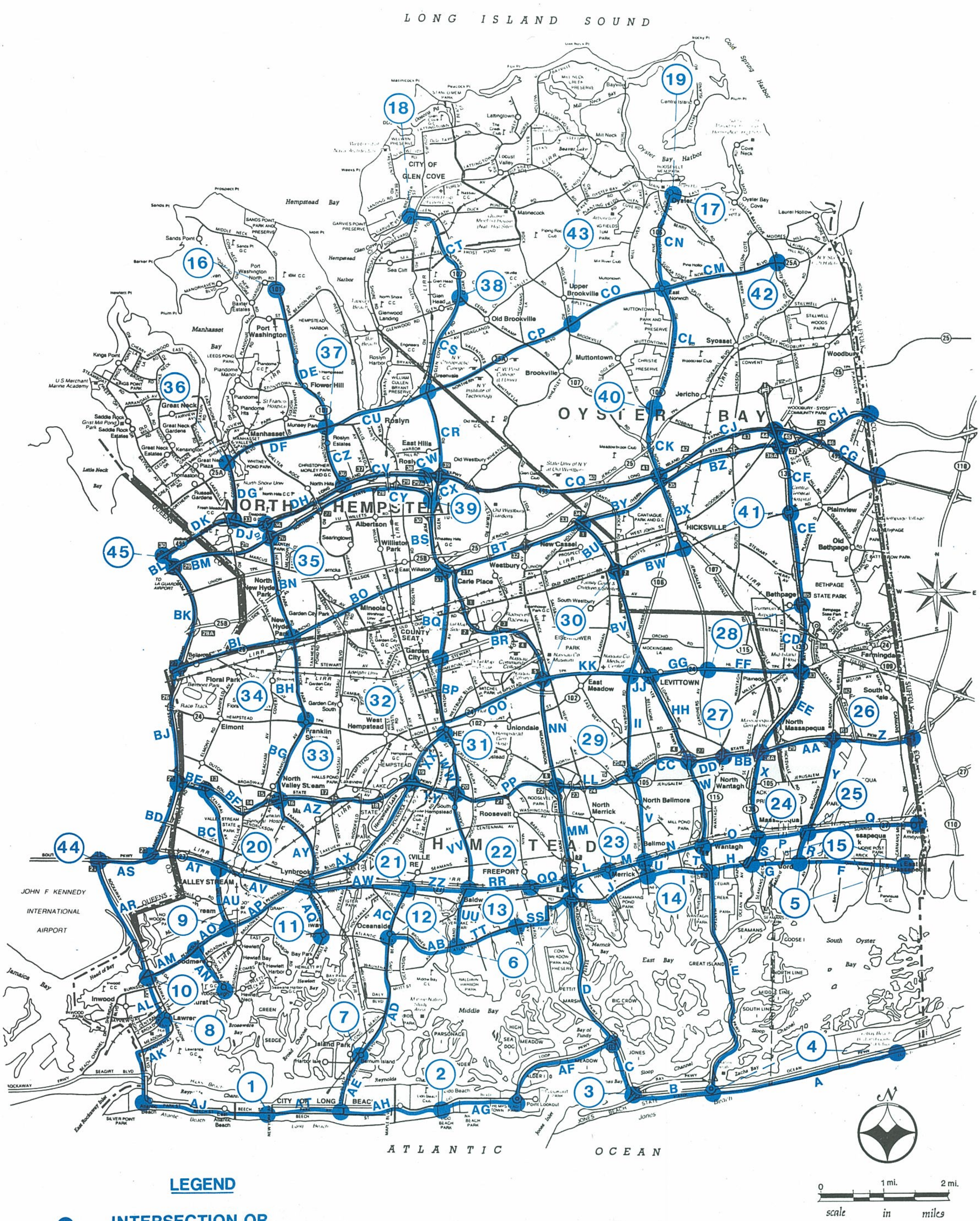


EVACUATION ROAD NETWORK

STATEN ISLAND

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-15



LEGEND

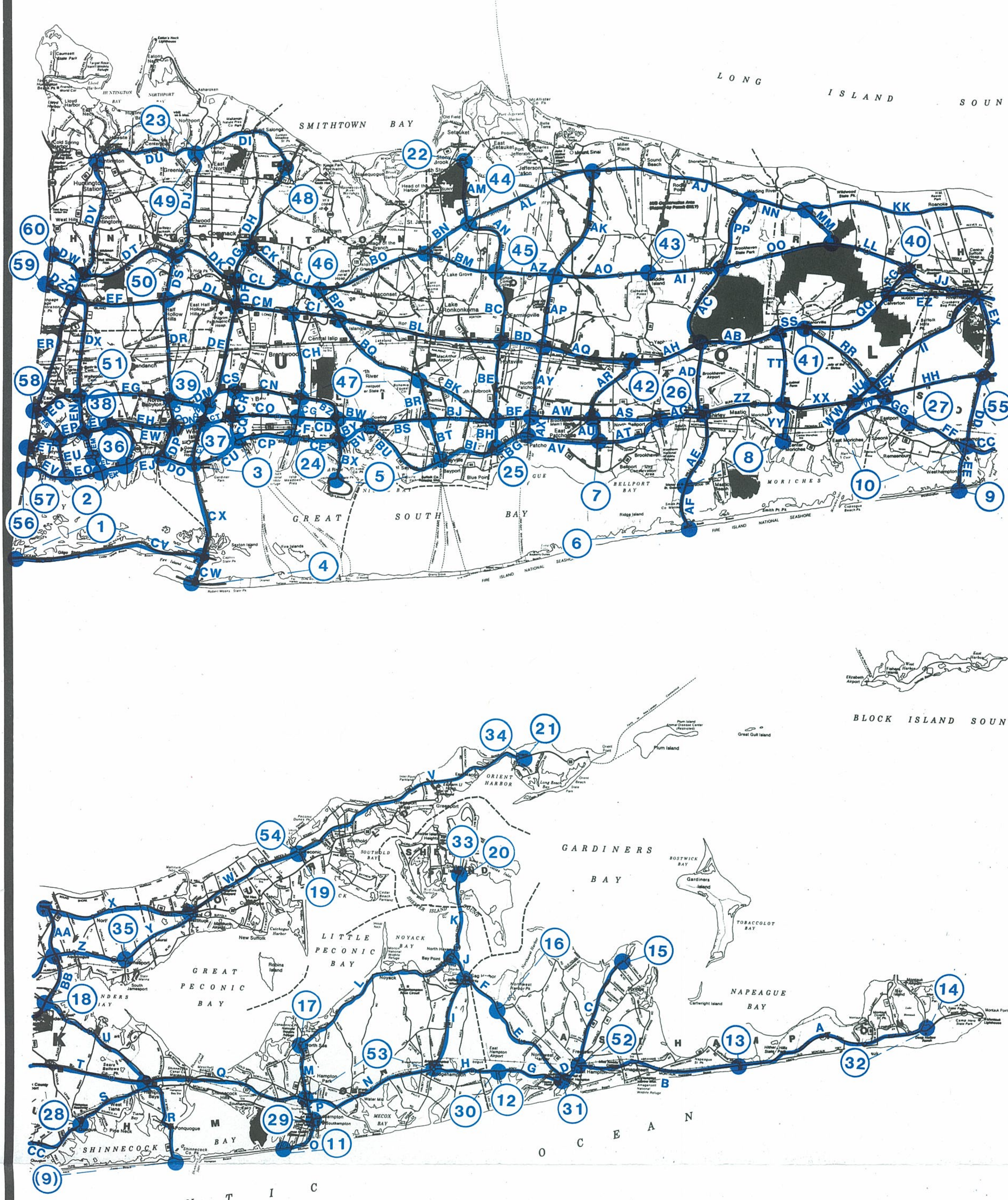
- ● INTERSECTION OR INTERCHANGE LOCATION
- ○ EVACUATION ZONE CENTER
- 7 ZONE NUMBER
- B ROADWAY SEGMENT NAME

EVACUATION ROAD NETWORK

NASSAU COUNTY

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6–16

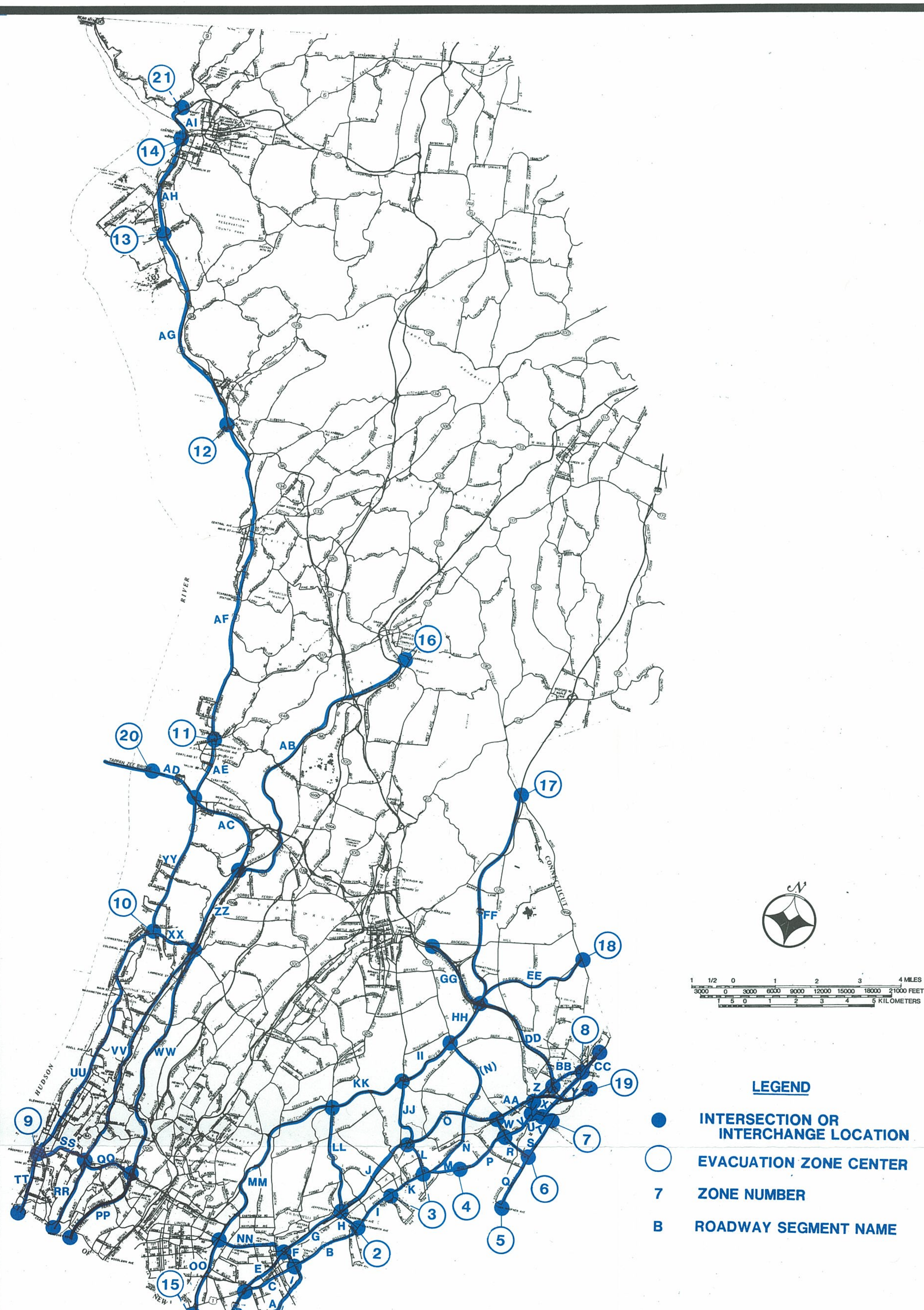


EVACUATION ROAD NETWORK

SUFFOLK COUNTY

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6–17



EVACUATION ROAD NETWORK
WESTCHESTER COUNTY

NEW YORK STATE
HURRICANE EVACUATION STUDY

FIGURE 6-18

Transportation Modeling Methodology

The transportation modeling methodology used for the New York State study area involved a number of manual and computer assisted techniques. The methodology, while very technical, was designed to be consistent with the accuracy of the modeling inputs and assumptions. It is rather unique in that it is sensitive to the key behavioral issues associated with hurricane evacuation.

The Transportation Model Support Document explains in detail the steps used in the transportation modeling. In summary, the modeling methodology involved seven major steps, which are briefly described below.

a. Evacuation Zonal Data Development. Data gathered by enumeration district/census tract were stratified into evacuation zones. Numbers of permanent residential dwelling units, mobile homes, and seasonal units were compiled by zone and formatted for input into trip generation.

b. Evacuation Road Network Preparation. Information was gathered on those roadways that were designated part of the evacuation road network. Information was coded into a "link file" for use by the assignment computer module. The end product was a computerized representation of the evacuation roadway system.

c. Trip Generation. Specific dwelling unit variables were used in the trip generation calculations to produce total evacuating people and vehicles from each evacuation zone. These originating people and vehicles were stratified according to destination type, based on behavioral parameters previously established. Information on available hotel/motel units and public shelter capacity was used to prepare estimates of the number of evacuating vehicles that could find acceptable destinations in each zone. Tables 6-3 through 6-10 present the participation rates and destination percentages that are the basis for the trip generation calculations.

d. Trip Distribution. This step involved only those trips originating in a single county or borough that find acceptable destinations within those same boundaries. Departures from each zone were matched with available destinations in all zones. For each evacuation destination type, a trip table was assembled showing travel from each zone to all other zones. A table was developed for each storm scenario and each tested behavioral assumption.

e. Roadway Capacity Development. To reveal the most critical roadway segments and intersections, information on the number of lanes and facility type for each link in the evacuation network was translated into a general hourly service volume. Specific hourly flow rates were then computed for those areas most likely to cause traffic delays.

f. Trip Assignment. Another computer program was used to assign zone-to-zone trips within the same county/borough through the roadway system. All other categories of evacuation travel (in-county to out-of-county, out-of-county to in-county, out-of-county to out-of-county, and background) were then added to arrive at total vehicles per roadway segment. Volume-to-capacity ratios were then used to determine which roadway segments would be most congested. Those links with highest volume-to-capacity ratios were identified for each jurisdiction.

g. Calculation of Clearance Times. The calculation of clearance times, or travel time/queuing delay analysis, involved a detailed examination of the critical links and intersections identified for each county and borough in the study area. Initially, evacuation zones that use each critical link were identified. Vehicles from each zone were then loaded onto the network in accordance with a behavioral response curve. Based on an assumed hourly flow rate (capacity) for the critical link, the hourly volume desiring to use the link was then translated into a queuing delay time at the link and an evacuation travel time. The end product of the analysis is a set of clearance times for each storm scenario.

Except for Westchester County and the boroughs of Manhattan and the Bronx, all seven of the above steps were used in the transportation modeling. For those areas, modeling was limited to the first three steps (through trip generation). In Manhattan and the Bronx, evacuation is expected to be non-traditional, for the most part non-automotive. Travel distances will be rather short, with most evacuation from surge flooding occurring by public transportation or by walking. In Westchester County, surge inundation will be very localized requiring only short trips to public shelters or other refuge. Public shelter space is plentiful and roadway capacity is sufficient so that further transportation analysis is not required.

Model Application

Application of the transportation model produced the following key data items for hurricane evacuation planning.

Evacuating people and vehicle parameters
Shelter demand/capacity considerations
Traffic volumes and critical roadway segments/intersections
Estimated clearance times

Although a considerable amount of information is produced in the transportation analysis, the above items are the most critical to planning shelter needs, developing traffic control measures, and defining the timing requirements of an evacuation.

a. Evacuating People and Vehicle Parameters. For each storm scenario, total evacuating people and vehicles were apportioned by destination type (public shelter, hotel/motel, friend or relative's home, or out of the region) based on assumed behavioral characteristics of the vulnerable population. The Transportation Model Support Document includes this detailed information for the zones of each county and borough. Table 6-11 provides ranges of this data, which varies according to storm scenario. Thus, the highest number relates to the most severe hurricane category.

TABLE 6-11

Transportation Analysis Evacuating People and Vehicle Statistics by Borough/County

Borough/County	Maximum Number of People Evacuating Dwelling Units	Number of Vehicles Evacuating Dwelling Units
Suffolk	175,280 - 310,060	64,150 - 117,200
Nassau	221,610 - 309,210	79,685 - 110,855
Queens	67,515 - 176,420	14,845 - 38,065
Brooklyn	95,110 - 385,635	13,895 - 53,455
Staten Island	39,290 - 47,145	10,935 - 13,125
Manhattan	56,050 - 178,390	16,810 - 54,255
Bronx	15,085 - 48,285	3,600 - 11,515
Westchester	29,905	9,620

b. Shelter Demand/Capacity Considerations. The data presented above are most useful when matched with available sheltering. It is important to note that evacuating people and vehicle statistics generated for each county/borough, evacuation zone and destination type reflect where evacuees would go if enough safe destinations are available. Table 5-9 provides the calculated public shelter demand and available capacity by storm scenario. For a variety of reasons, shelter locations and capacities are continually subject to change. Based on the best current information, shelter space is generally adequate in the study area, assuming trained management personnel are available for all shelters. One possible exception is Nassau County, where a deficit of space could occur for the southwest portion of the county with hurricane category 3 or 4 evacuations. ARC and emergency preparedness officials should strive to predesignate and provide management for at least the number of spaces indicated by the shelter demand.

c. Traffic Volumes and Critical Roadway Segments/Intersections. The Transportation Model Support Document provides the number of assigned evacuating vehicles for all roadway segments in each county or borough evacuation network. In addition, that document gives the volume-to-capacity ratios calculated for each link. Those roadway segments with the highest ratios were identified as the critical links for each jurisdiction. Table 6-12 lists the critical links and intersections for each county and borough in order of severity. These choking points in the roadway network determine the flow of evacuation traffic and are key areas for special traffic control and monitoring.

d. Estimated Clearance Times. The most important products of the transportation analysis are the clearance times for each county and borough computed for every combination of storm scenario and evacuation response rate. Clearance time is combined with prelandfall hazards time to comprise evacuation time, the factor that relates the timing of an evacuation order or advisory to current hurricane position and movement. The relationship between clearance time, prelandfall hazards time, and evacuation time must be understood for prudent hurricane evacuation decision-making.

Clearance time is the time required to clear all vehicles used in the evacuation from the roadway network. Clearance time begins when the first evacuating vehicle enters the road network prior to an advisory, as defined by an evacuation behavioral response curve, and ends when the last evacuating vehicle reaches an assumed point of safety. Clearance time includes time required by evacuees to secure their homes and prepare to leave (mobilization time), time traveling along the road network (travel time), and waiting due to traffic congestion (queuing delay time). **Clearance times do not relate to the time any one vehicle spends traveling on the road network.** The timing of an evacuation order should ensure that evacuees can reach safety before the arrival of hazardous weather conditions. Thus, clearance times provide the interval from evacuation order or advisory until the arrival of sustained tropical storm winds.

TABLE 6-12

CRITICAL ROADWAY SEGMENTS

Nassau County

Long Beach Road and Sunrise Highway intersection
Franklin Avenue south of Southern St. Parkway
Grand Avenue and Sunrise Highway intersection
Atlantic Avenue and Sunrise Highway intersection
I-495/Long Island Expressway
Peninsula Boulevard and Woodmere Boulevard intersection
Rockaway Boulevard at Southern St. Parkway
Long Beach Boulevard and Park Avenue Intersection at Long Beach

Suffolk County

Route 27 (Sunrise Highway) and North Sea Road intersection at Southampton
Route 25 and Cross River Drive intersection east of Riverhead
Ferry service between Fire Island and mainland
Route 111 (Islip Avenue) and Southern Street Parkway interchange
Nugent Road and West Main Street interchanges with Long Island Expressway west of Riverhead
Montauk Highway east of Southampton
Wellwood Road and Sunrise Highway north of Lindenhurst
I-495 westbound

Staten Island

Goethals Bridge
Seaview Avenue and Hylan Boulevard intersection
Rockland Avenue
New Dorp Lane and Hylan Boulevard intersection
New Dorp Lane and Amboy Road intersection
Richmond Road at Staten Island Expressway
Guyon Avenue
Verrazano - Narrows Bridge

Brooklyn

Flatbush Avenue
Coney Island Avenue and Neptune Avenue intersection
Coney Island Avenue and Shore Parkway
86th Street and Utrecht Avenue
Cropsey Avenue and Shore Parkway
Verrazano - Narrows Bridge
Manhattan Bridge
Brooklyn - Battery Tunnel
Williamsburg Bridge

TABLE 6-12 (CONT.)

CRITICAL ROADWAY SEGMENTS

Queens

Long Island Expressway
Belt Parkway east of Van Wyck Expressway
Cross Bay Boulevard at/south of Belt Parkway
Van Wyck Expressway south of Atlantic Avenue
Queens Midtown Tunnel (toll booths)
Whitestone Bridge (toll booths)
Triborough Bridge (toll booths)
Throgs Neck Bridge (toll booths)
(Lincoln Tunnel and connecting streets through Manhattan)
(Holland Tunnel and connecting streets through Manhattan)
(George Washington Bridge and connecting freeways through the Bronx and Manhattan)

Since evacuation timing is based primarily on the arrival of sustained tropical storm winds, but hurricane tracking monitors the position of the eye of the storm, evacuation orders or advisories must somehow be related to the eye's location and forward speed. Prelandfall hazard time is the period from the arrival of sustained tropical storm winds until the hurricane eye makes landfall or its closest approach to the location of the decision-maker. It can be calculated by simply dividing the radius of tropical storm winds of an approaching hurricane by its forward speed.

Evacuation time is the sum of clearance time and prelandfall hazards time and, thus, sets the timing of the evacuation in relation to hurricane eye location and movement. Obviously, evacuation time for a community can be many hours longer than clearance time and the terms should not be confused. This relationship is shown in figure 6-19. Evacuation decision-making is handled graphically by the Decision Arc Method and is discussed at length in chapter 8.

Table 6-13 presents the clearance times estimated for each jurisdiction in the study area. The times are stratified by intensity of hurricane (storm scenario), rate of response on the part of the evacuating population (evacuation response rate), and level of background traffic (peak or off peak). **It is important to note that clearance times are based on the assumption that local officials will make a determined effort to evacuate all residents from potential flood areas shown on the inundation maps (Appendixes A through D).**

Traffic Control Measures

The movement of evacuating vehicles during a hurricane emergency requires extensive traffic control efforts to make maximum use of roadway capacity and to expedite safe escape from hurricane hazards. The development of traffic control techniques for critical evacuation roadway links and intersections should always involve state and local police, traffic engineers, emergency management officials, and, where appropriate, the U.S. Coast Guard. The following traffic control techniques/strategies are recommended for consideration.

a. As available manpower allows, police officers should be stationed at each critical intersection to direct traffic and assist disabled vehicles.

b. All available tow trucks should be positioned along key travel corridors, especially at critical links. At a minimum, tow trucks should be at major bridge crossings and tunnels to remove disabled vehicles.

c. Where intersections will continue to have signalized control, signal patterns providing the most "green time" for the approach leading away from the coast should be actuated by the State Department of Transportation or local traffic engineer's office, as appropriate.

d. All draw/swing bridges needed for evacuation should be continuously open to roadway traffic during a hurricane warning. Boat owners must be informed of flotilla plans and time requirements for securing vessels. Recreational vessels should be moved to safety before or during a hurricane watch.

e. Law enforcement officers directing traffic should be aided with physical barriers/cones that are adequately weighted and placed so as to channel traffic and prevent unnecessary turning and merging conflicts. This strategy can be used effectively at critical interchanges listed previously.

f. The movement of motor homes and camper trailers along evacuation routes should be minimized after a hurricane warning is issued. Such vehicles are difficult to handle under gusty conditions and a disabled unit could block critical escape routes.

g. Agreements should be reached to suspend tolls when collection becomes a bottleneck to evacuation.

h. Clearance times can be significantly shortened by a reduction in background traffic. The government and the business community should coordinate to curtail commuter traffic when a hurricane warning is imminent.

COMPONENTS OF EVACUATION TIME

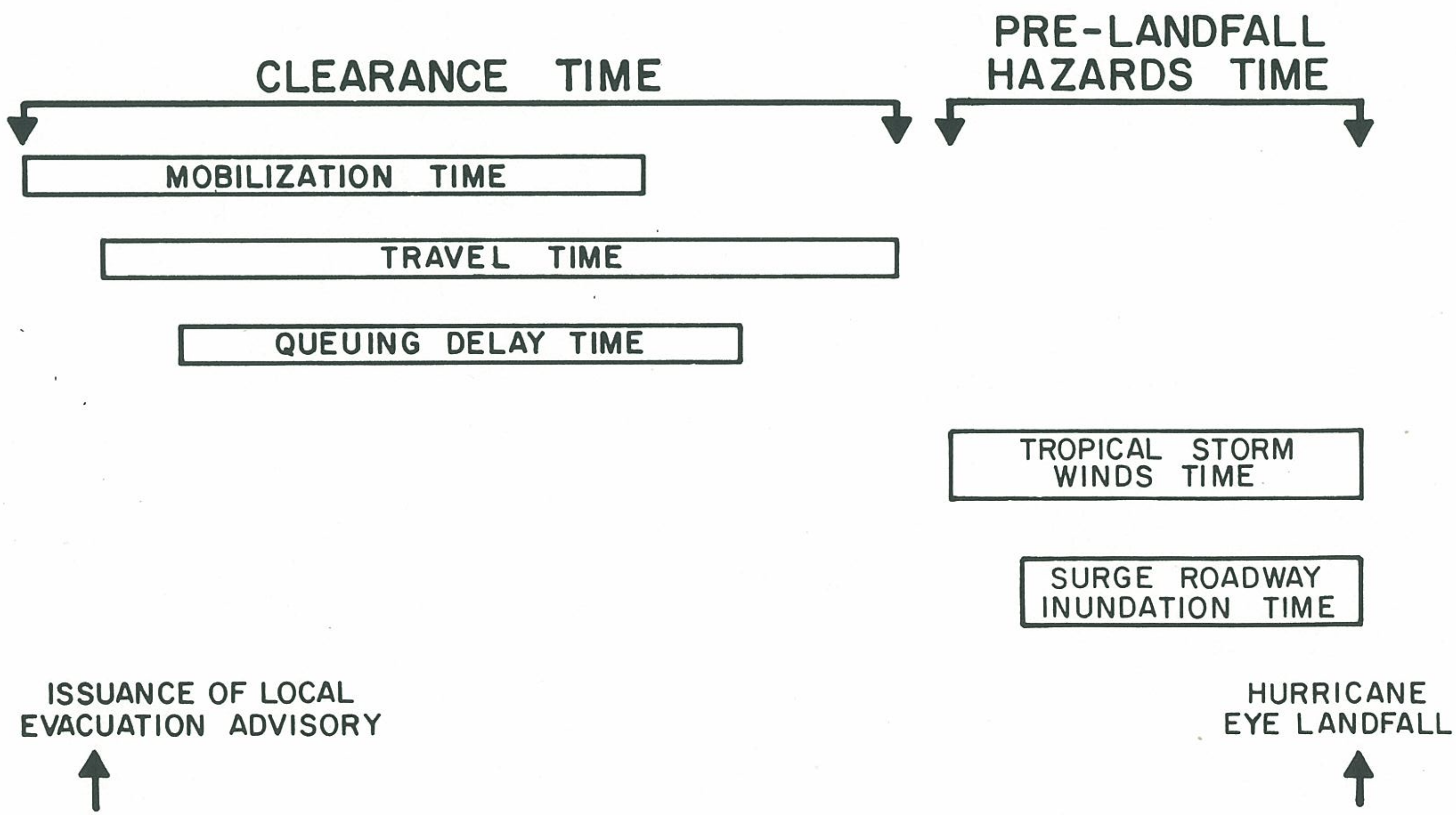


FIGURE 6-19

TABLE 6-13

CLEARANCE TIMES (in hours)

	Nassau County	
	Peak Daily Traffic*	Off-Peak*
Category 1-2 Hurricane		
Rapid Response	15-1/2	10-3/4
Medium Response	16-1/4	11
Slow Response	17-1/2	12
Category 3 Hurricane		
Rapid Response	19-1/4	13-1/2
Medium Response	20	13-3/4
Slow Response	21-1/4	14-1/2
Category 4 Hurricane		
Rapid Response	19-1/4	13-1/2
Medium Response	20	13-3/4
Slow Response	21-1/4	14-1/2

	Suffolk County				
	Auto Evacuation		Fire Island Ferry Service Evacuation		
	Peak Daily Traffic*	Off-Peak*	Sayville	Patchogue	Bayshore
Category 1-2 Hurricane					
Rapid Response	9-1/4	7	8	6	11
Medium Response	11	7-3/4	8	6	11
Slow Response	13-1/2	9-3/4	8	6	11
Category 3 Hurricane					
Rapid Response	14	11-3/4	8	6	11
Medium Response	15-1/2	12	8	6	11
Slow Response	18	13	8	6	11
Category 4 Hurricane					
Rapid Response	14	11-3/4	8	6	11
Medium Response	15-1/2	12	8	6	11
Slow Response	18	13	8	6	11

*Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as nighttime situations. Evacuating vehicles from neighboring counties and boroughs that will use local roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a 4-, 6-, and 9-hour period corresponding to a rapid, medium, and slow behavioral response assumed for the evacuating population.

TABLE 6-13 (CONT.)

CLEARANCE TIMES (in hours)

	Westchester County	
Category 4 Hurricane	Peak Daily Traffic*	Off-Peak*
Rapid Response	4-3/4	4
Medium Response	6	6
Slow Response	9	9

	Manhattan	
Category 4 Hurricane	Peak Daily Traffic*	Off-Peak*
Rapid Response	5	4
Medium Response	6	6
Slow Response	9	9

	Queens	
Category 1 Hurricane	Peak Daily Traffic*	Off-Peak*
Rapid Response	8-1/4	6-1/2
Medium Response	9-1/2	7-1/4
Slow Response	11-1/2	9-1/4
Category 2 Hurricane		
Rapid Response	8-1/2	6-1/2
Medium Response	9-3/4	7-1/4
Slow Response	11-3/4	9-1/4
Category 3-4 Hurricane		
Rapid Response	12-1/2	10-3/4
Medium Response	14	11-1/4
Slow Response	16	12

*Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as nighttime situations. Evacuating vehicles from neighboring counties and boroughs that will use local roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a 4-, 6-, and 9-hour period corresponding to a rapid, medium, and slow behavioral response assumed for the evacuating population.

TABLE 6-13 (CONT.)

CLEARANCE TIMES (in hours)

	Brooklyn	
Category 1 Hurricane	Peak Daily Traffic*	Off-Peak*
Rapid Response	6-3/4	5
Medium Response	8	6-1/4
Slow Response	10	9-1/4
Category 2 Hurricane		
Rapid Response	8	6-1/4
Medium Response	9-1/4	7
Slow Response	11-1/4	9-1/4
Category 3 Hurricane		
Rapid Response	12	10-1/4
Medium Response	13-1/4	10-3/4
Slow Response	15-1/4	11-1/2
Category 4 Hurricane		
Rapid Response	13-3/4	12
Medium Response	15-1/4	12-1/2
Slow Response	17-1/4	13-1/4

	Bronx	
Category 1-4 Hurricane	Peak Daily Traffic*	Off-Peak*
Rapid Response	4-3/4	4
Medium Response	6	6
Slow Response	9	9

	Staten Island	
Category 1-2 Hurricane	Peak Daily Traffic*	Off-Peak*
Rapid Response	5-1/4	4
Medium Response	6-3/4	6
Slow Response	9	9
Category 3-4 Hurricane		
Rapid Response	8-1/4	6-1/2
Medium Response	9-3/4	7-1/4
Slow Response	11-1/2	9

*Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as nighttime situations. Evacuating vehicles from neighboring counties and boroughs that will use local roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a 4-, 6-, and 9-hour period corresponding to a rapid, medium, and slow behavioral response assumed for the evacuating population.

CHAPTER 7

FIRE ISLAND

The Situation

Fire Island is a barrier beach that stretches along the south shore of Long Island for over 25 miles and is separated from the "mainland" by the Great South Bay, a distance averaging about 3.5 miles. The width of Fire Island is generally only a few hundred yards and, with the exception of the frontal dune system, elevations are mainly 5 feet or less above sea level. Historically, the island has provided considerable protection from wave action in the Atlantic Ocean to Bay Shore, Islip, Sayville, Patchogue, and other communities on the north shore of Great South Bay. However, in December 1992 a nor'easter devastated the frontal dunes and overwashed the island in several places, leaving scores of vacation homes destroyed or in imminent danger of collapse. This drastic alteration of the topography not only increased the likelihood of future overwash by storm surge but could have a significant effect on storm tides experienced on that portion of Long Island's south shore.

A large percentage of the island is in the Fire Island National Seashore, controlled by the National Park Service, but several incorporated and unincorporated communities, including Saltaire, Ocean Beach, and Davis Park, are comprised of privately owned property. Fire Island is very unusual, if not unique, in that most of the island is closed to privately owned motor vehicles, including electric carts. It is accessible by paved roads and bridges on either end but no roadway connects the length of the island. Visitors to Fire Island travel by bicycle or walk; walkways and the beach serve as emergency vehicle trails.

The vast majority of vacationers arrive on Fire Island by privately owned passenger ferry, load their belongings on a variety of hand-pulled wagons, and stroll to their lodging. The very reason that many people find Fire Island an attractive destination, the "laid-back" atmosphere, contributes to the extraordinary threat to their safety with a hurricane emergency. Many visitors do not care to stay in touch with the latest news and weather forecasts and most of the cottages lack telephones. These factors pose communication problems for law enforcement and emergency management officials that must be overcome with a more personal approach to evacuation notification. Loudspeaker trucks and door-to-door alert will be necessary.

Primary responsibility for hurricane evacuation planning for Fire Island lies with the Suffolk County Townships of Islip and Brookhaven. In addition to coordination with ferry boat operations, preparedness plans should include law enforcement support for traffic control at "mainland" ferry terminals and ground transportation to move passengers to local destinations. Large numbers of vacationers who travel from their homes by bus or the Long Island Rail Road must be accommodated with local transportation to reach their preferred means of departure or a public shelter.

Potential Hurricane Surge Elevations

Since the general elevation of Fire Island is less than 5 feet above sea level, it is wise to place special emphasis on potential storm surge elevations. Hurricanes moving rapidly toward the north-northwest through the north-northeast pose the greatest threat to Fire Island communities. The following maximum potential hurricane surge elevations were calculated by the SLOSH model for the Saffir/Simpson intensity categories indicated.

	Cat 1	Cat 2	Cat 3	Cat 4
Atlantique	6.8	11.4	15.4	19.8
Davis Park	6.5	11.3	15.9	19.6

Ferry Operations

a. **General.** Fire Island ferry operators are well aware of the role they must play in an evacuation of the island. For the hurricane evacuation study, representatives of the three major ferry services were interviewed to obtain information for preparedness planning and calculation of clearance times. Ferry operations were examined in detail to determine hourly capacities and weather conditions that would curtail service. **To be effective, evacuation plans for Fire Island must include detailed coordination with the ferry operators.**

Discussions with ferry company representatives revealed that, for all practical purposes, Fire Island is evacuated every Sunday during peak vacation season with the weekly turnover in rentals and the return of day-trippers to the mainland. Consequently, under good conditions, an orderly evacuation should not be difficult to accomplish. There are several factors that must be considered, however. The evacuation notification must be timely and well coordinated with ferry operations due to the following possible extenuating circumstances that would lengthen clearance times.

(1) Some ferry boats could be out of operation, reducing the hourly capacity for evacuation.

(2) Night or low visibility conditions could slow ferry operations.

(3) Law enforcement officers should be stationed at ferry terminals to prevent day-trippers from going to the island, maintain order, and direct pedestrian and vehicular traffic.

(4) Sufficient local ground transportation must be available.

(5) Public shelters must be opened to accommodate evacuees.

(6) Ferries should be secured in their berths prior to the onset of sustained tropical storm winds (34 knots).

(7) Ferry operations could be curtailed by abnormally high or low tides, conditions that could possibly precede the arrival of sustained tropical storm winds.

b. Major Ferry Operators. Fire Island Ferries, Bay Shore, Long Island, operates 12 ferry boats with a total capacity of 3,246 passengers. An additional boat, the Evening Star, is normally used only for dinner cruises but in an emergency could be pressed into service as a 600-passenger ferry. As with most Fire Island ferries, about 50 percent of the company's total passenger capacity is outside an enclosed cabin and severe weather could significantly reduce the number of evacuees carried per trip. With all boats operating at maximum capacity, Fire Island Ferries can evacuate about 2,860 people per hour. Ferries can operate in nearly zero visibility but wind, rain, fog, and tides can affect loading rates. The company estimates that 50 percent of the evacuees carried on their boats would seek public shelter. Fire Island Ferries serves eight communities on Fire Island with estimated peak summer populations as follows:

Ocean Beach	12,000
Atlantique	300
Dunewood	600
Fair Harbor	2,700
Saltaire	1,500
Kismet	1,000
Ocean Bay Park	5,000
Seaview	2,000
TOTAL	25,100

Sayville Ferry Service, Sayville, Long Island, operates seven ferry boats with a total capacity of 1,122 passengers. With all boats operating at maximum capacity, this company could evacuate 1,400 people per hour in the daytime. As is the case with Fire Island Ferries, Sayville Ferry operators stated that nighttime evacuations would be somewhat slower because terminal operations are not as efficient. Twenty percent or less of these evacuees are expected to seek public shelter. Sayville Ferry Service operates to three communities on Fire Island with estimated peak populations as follows.

Fire Island Pines	5,000
Cherry Grove	3,500
Water Island	500
TOTAL	9,000

Davis Park Ferry Company, Patchogue, Long Island, operates five ferry boats with a total passenger capacity of 1,148. All boats operating at peak capacity can evacuate 1,680 people per hour. Ferries cannot operate with tides lower than 2 feet below normal or higher than 3 feet above normal. Ferry operators estimate that very few passengers (1 to 2 percent) would seek public shelter. Davis Park Ferry Company serves two locations on Fire Island, Davis Park and Watch Hill. The latter has no houses; day-trippers and a few campers would be the only evacuees. Estimated peak populations are:

Davis Park		8,000
Watch Hill		1,500
	TOTAL	9,500

c. Estimated Clearance Times. Estimated clearance times for Fire Island vacationers are based on the time period from the first evacuee leaving their dwelling until the last evacuee reaches safety. Even though it has been pointed out that evacuation notification for vacationers on Fire Island will probably take several hours, it is safe to assume that effort can continue conjunctively with the evacuation itself and have little effect on clearance times. Furthermore, this extended notification period could actually assist with queuing of passengers for evacuation.

Planners must take into account the fact that approximately 3 hours are needed to secure ferry equipment after the last trips to Fire Island. Thus, for operations to be completed prior to the arrival of tropical storm winds, evacuation timing should be determined by adding the ferry operators' requirements to the recommended clearance time. Initiating an evacuation of Fire Island may well act as a catalyst to prompt evacuation of other potential surge inundation areas on the south shore of Long Island.

Clearance times for Fire Island were determined using estimated peak summer populations and ferry boat per hour carrying capacities furnished by the ferry companies. Additional time was allowed for contingencies and local transportation on Long Island. Estimates should be conservative in that **day-trippers should not be allowed to travel to the island after a hurricane watch is posted for the area,** thus reducing the number of evacuees significantly. **Extremely important--timely initiation of the evacuation to avoid the complications of ferry operations in marginal weather.**

Estimated clearance times for the major ferry companies are as follows:

Fire Island Ferries	11 hours
Sayville Ferry Service	8 hours
Davis Park Ferry Company	6 hours

Since it would not be practical to evacuate Fire Island piecemeal, operations of the Fire Island Ferries company determine the clearance time.

Evacuation recovery operations should include plans to deny the public access to Fire Island, both at the ferry terminals and by smaller vessels until it is deemed safe again for occupation. U.S. Coast Guard assistance could be required to limit access and maintain order.

CHAPTER 8

DECISION ARCS

Purpose

This chapter describes the Decision Arc Method, a hurricane evacuation planning and decision-making tool that uses clearance times in conjunction with National Hurricane Center advisories to help determine when and if evacuations should begin.

Background

Along the Atlantic seaboard, hurricanes do not ordinarily approach landfall from a direction perpendicular to the coastline but are often recurving from the tropics and make landfall on a track more nearly parallel to shore. At a typical angle of approach to the shoreline, an error of 10 degrees in predicting the hurricane track can easily mean a 100-mile difference in the point of landfall 24 hours later. Also, as hurricanes move out of the tropics toward the central Atlantic coast, they often lose their steering air currents and begin to behave somewhat erratically. In some cases, hurricanes have become totally unpredictable. Understandably, hurricane forecasting along the Atlantic coast has its uncertainties. The average error of 12-hour forecast landfall positions for Atlantic coast tropical cyclones (including storms of less than hurricane intensity) during 1970-79 was about 59 nautical miles and for 24-hour forecasts, landfall position error was about 125 nautical miles. Thus, if a storm were forecast to make landfall at Coney Island, New York, in 24 hours and if, in fact, it made landfall anywhere along the Atlantic coast between Cape May, New Jersey, and Montauk Point, Long Island, the error in forecast landfall position would be no worse than average.

When a hurricane approaches a coastline at an acute angle, as is the usual case along the Atlantic seaboard, an error in forecast landfall position will increase or decrease the distance to landfall, possibly resulting in a significant error in forecast time of landfall. The forward motion of hurricanes can also accelerate and decelerate, causing the time of landfall to be even more unpredictable. Since hurricane evacuation decision-making and mobilization have typically been dependent upon forecast landfall position and time of landfall, a method was needed that would help compensate for forecast errors by relating evacuation operations to hurricane position.

In addition to maintaining a working knowledge of the Decision Arc Method, hurricane-vulnerable jurisdictions should evaluate the various computer programs available to aid with evacuation decision-making. These programs incorporate Hurricane Evacuation Study data, including some form of the Decision Arc Method presented in this chapter. Computer assistance can be very useful in speeding needed calculations and displaying important information and relationships. Even if a computer program(s) is used, emergency management officials should be familiar with the concepts presented in this chapter. This will promote confidence in the software and ensure that decision-making can proceed despite power outages or computer failure.

Decision Arc Components

a. General. The Decision Arc Method employs two separate but related components which, when used together, present a graphic depiction of the hurricane situation. A specialized hurricane tracking chart, the Decision Arc Map, is teamed with a transparent two-dimensional hurricane graphic, the STORM, to describe the approaching hurricane and its relation to the area considering evacuation.

b. Decision Arc Map. In order to properly evaluate the last reported position and forecast track of an approaching hurricane, a special hurricane tracking chart has been developed for the study area. Superimposed on an ordinary tracking chart is a series of concentric arcs centered on the southernmost boundary of the study area and spaced at 50-nautical-mile intervals. These arcs are labeled both alphabetically and in nautical miles measured from their center. Figure 8-1 is a small-scale example of the Decision Arc Map for the study area.

c. STORM. The Special Tool for Observing Range and Motion (STORM) is used as a two-dimensional depiction of an approaching hurricane. It is a transparent disk with concentric circles spaced at 25-nautical-mile intervals, their center representing the hurricane eye. These circles form a scale used to note the radii of 34-knot (tropical storm) winds reported by the National Hurricane Center in the Marine Advisory. Figure 8-2 is a small-scale example of the STORM.

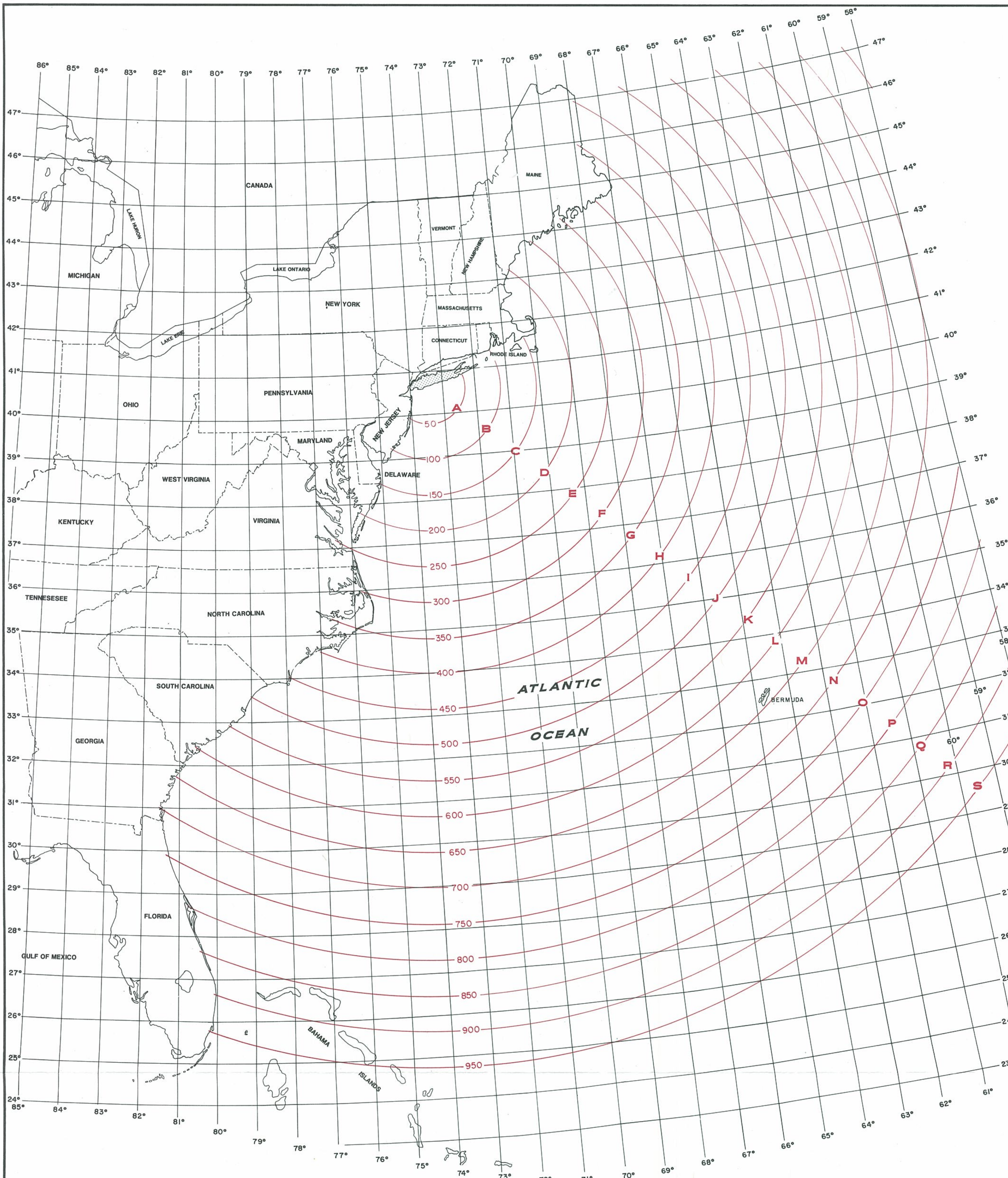
d. National Weather Service Marine Advisory. Marine advisories on tropical storms are normally issued by the National Weather Service every 6 hours: 0000EDT, 0600EDT, 1200EDT, and 1800EDT. At times, supplementary intermediate advisories are also issued. These advisories contain information on present and forecast position, intensity, size, and movement that is used in the Decision Arc Method.

Decision Arc Method

a. General. A hurricane evacuation should be completed prior to the arrival of sustained 34-knot (tropical storm) winds or the onset of storm surge inundation, whichever occurs first. In the New York State Hurricane Evacuation Study area, the limiting factor for hurricane evacuation is the arrival of sustained 34-knot winds (see chapter 2, Time-History Data).

The clearance time is the time required to clear the roadways of all evacuating vehicles. It therefore determines the minimum time period, in hours prior to the arrival of sustained 34-knot winds, necessary for a safe evacuation. Clearance times are based on three variables: (1) the Saffir/Simpson hurricane category, (2) the expected evacuee response rate, and (3) the tourist occupancy situation (where applicable).

Decision Arcs are clearance times converted to distance by accounting for the forward speed of the hurricane. To translate a clearance time into nautical miles (a Decision Arc distance) for use with the Decision Arc Map, a simple calculation of multiplying the clearance time by the forward speed of the hurricane in knots is necessary. This calculation yields the distance in nautical miles that the 34-knot wind field will move while the evacuation is



50 0 100 200 300 400

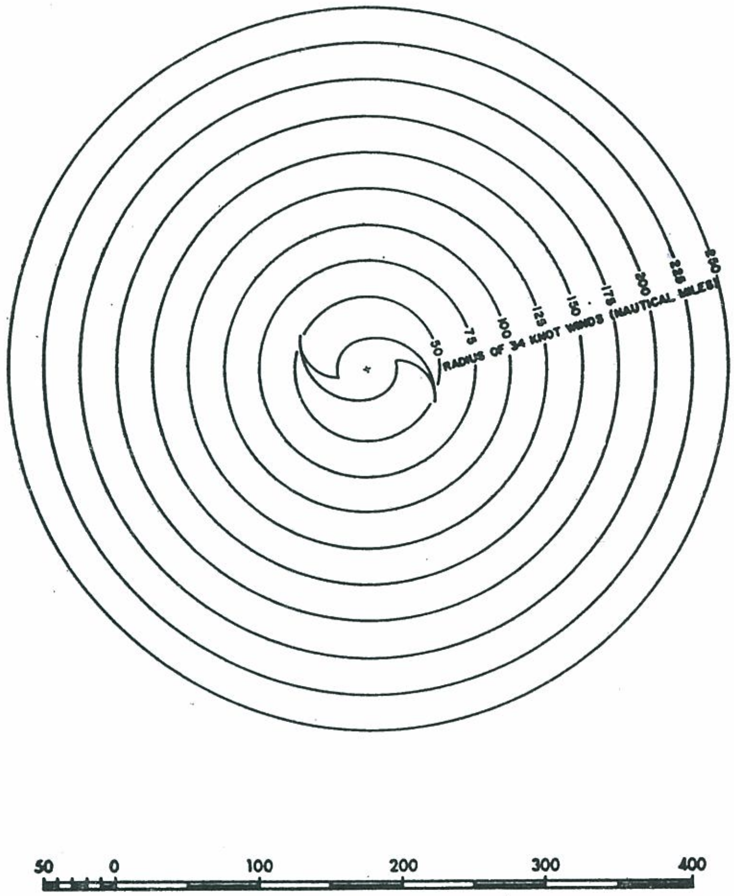
SCALE IN NAUTICAL MILES

Prepared by the U.S. Army Corps of Engineers, Wilmington District, N.C., in cooperation with the Federal Emergency Management Agency, Region II for the New York State Emergency Management Office.

STATE OF NEW YORK HURRICANE EVACUATION STUDY

DECISION ARC MAP

STORM



SCALE IN NAUTICAL MILES

FIGURE 8-2

underway. For convenience, a Decision Arc table has been developed for New York State that converts an array of clearance times and forward speeds to respective Decision Arcs. Table 8-1 presents the Decision Arcs for the study area.

b. Should Evacuation be Recommended. Probability values shown in the National Hurricane Center's Marine Advisory describe in percentages the chance that the center of a storm will pass within 65 miles of the listed locations. To check the relative probability for your location, the Marine Advisory and table 8-2 should be used. The total probability value for your location, shown on the right side of the Marine Advisory probabilities table, should be compared to other locations and to the maximums shown in table 8-2. This will indicate the relative vulnerability of your location as compared with adjacent locations and with the maximum possible probability.

c. When Evacuation Should Begin. As a hurricane approaches, the Decision Arc Method requires officials to make an evacuation decision prior to the time at which the radius of sustained 34-knot winds touches the appropriate Decision Arc (the Decision Point). For example, with a clearance time of 15 hours, and a hurricane forward speed of 30 knots, the evacuation should be initiated before the sustained 34-knot winds approach within 450 nautical miles, the Decision Point (arc "I"). Once the sustained 34-knot winds move across the Decision Arc, there may not be sufficient time to safely evacuate the vulnerable population.

d. Hurricane Evacuation Decision Worksheet. The Hurricane Evacuation Decision Worksheet is designed to guide the decision-maker through the Decision Arc Method. All notes and cautions shown on the worksheet should be heeded as appropriate.

TABLE 8-1
NEW YORK STATE
DECISION ARCS

ESTIMATED CLEARANCE TIME (HRS.)	FORECAST HURRICANE FORWARD SPEED (KNOTS)										
	10	15	20	25	30	35	40	45	50	55	60
4	A	A	B	B	B	C	C	D	D	D	E
5	A	B	B	C	C	D	D	E	E	F	F
6	A	B	B	C	D	D	E	E	F	G	G
7	A	B	C	D	D	E	F	F	G	H	H
8	B	B	C	D	E	F	F	G	H	I	J
9	B	C	D	E	E	F	G	H	I	J	K
10	B	C	D	E	F	G	H	I	J	K	L
11	B	C	D	F	G	H	I	J	K	L	M
12	B	D	E	F	G	H	J	K	L	M	N
13	C	D	E	G	H	I	J	L	M	N	P
14	C	D	F	G	H	J	K	M	N	O	Q
15	C	E	F	H	I	K	L	N	O	Q	R
16	C	E	F	H	J	K	M	N	P	R	S
17	C	E	G	I	J	L	N	O	Q	S	*
18	D	E	G	I	K	M	N	P	R	*	*
19	D	F	H	J	K	M	O	Q	S	*	*
20	D	F	H	J	L	N	P	R	*	*	*
21	D	F	H	K	M	O	Q	S	*	*	*
22	D	G	I	K	M	O	R	*	*	*	*
23	E	G	I	L	N	P	R	*	*	*	*
24	E	G	J	L	N	Q	S	*	*	*	*
25	E	H	J	M	O	R	*	*	*	*	*
26	E	H	J	M	P	R	*	*	*	*	*
27	E	H	K	N	P	*	*	*	*	*	*
28	F	H	K	N	Q	*	*	*	*	*	*
29	F	I	L	O	Q	*	*	*	*	*	*
30	F	I	L	O	R	*	*	*	*	*	*

TABLE 8-2

MAXIMUM PROBABILITY VALUES

FORECAST PERIOD Hours	MAXIMUM PROBABILITY Percent
72	10
60	11
48	13
42	16
36	20
30	27
24	35
18	45
12	60

DECISION ARC METHOD
HURRICANE EVACUATION DECISION WORKSHEET

The following procedure has been developed to assist you in determining, for your jurisdiction, **WHEN** an evacuation decision must be made and **IF** you should initiate an evacuation. The National Weather Service (NWS) hurricane probability table included in the Marine Advisory is used to assist in this decision-making process.

There are four basic "tools" you will need in your evacuation decision procedure: (1) state Decision Arc Map; (2) Decision Arc tables; (3) transparent STORM disk; (4) the NWS Marine Advisory.

PROCEDURE

1. From the NWS Marine Advisory, plot the last reported position of the hurricane eye on the Decision Arc Map. Notate position with date/time. ZULU time (Greenwich mean time) used in the advisory should be converted to eastern daylight time by subtracting four (4) hours. Plot and notate the five forecast positions of the hurricane given in the advisory.

2. From the Marine Advisory, note the maximum radius of 34-knot winds (observed or forecast), the maximum sustained wind speed (observed or forecast), and the current forward speed. Plot the maximum radius of 34-knot winds onto the STORM disk. See note a. for information on nautical miles/knots.

3. Determine the <u>forecast</u> forward speed o the hurricane in knots using the conversion scale provided with this worksheet (figure 8-3). The forecast speed can be read directly from the conversion scale by measuring between the <u>forecast</u> positions (2nd-3rd, 3rd-4th, 4th-5th, 5th-6th plotted points). Compare the forecast forward speeds to the current forward speed noted previously. A forecast speed greater than the current forward speed will indicate that the hurricane is expected to accelerate, reducing the time available to the decision-maker. An alternate method of determining the forecast forward speed in knots is to measure the distance in nautical miles between the <u>forecast</u> positions and divide that distance by 12 (forecast positions are provided for 12-hour intervals).

4. Using the maximum sustained wind speed previously noted, enter the Saffir/Simpson Hurricane Scale (table 8-3) and determine the category of the approaching hurricane. **NOTE:** Because of potential forecast and SLOSH model inaccuracies, the New York State Emergency Management Office recommends that you add one category to the forecast landfall intensity.

5. From table 6-15, select the pertinent clearance time. Using that clearance time and the appropriate forecast forward speed, enter table 8-1 and select the recommended Decision Arc. Mark this arc on the Decision Arc Map.

6. Using the center of the STORM disk as the hurricane eye, locate the STORM on the Decision Arc Map at the last reported hurricane position. Determine if the radius of 34-knot winds falls within the selected Decision Arc; i.e., passed the Decision Point (the point at which the radius of 34-knot winds crosses into the selected Decision Arc). If so, available traffic control measures should be implemented and public advisories issued in order to ensure

a rapid public response and completion of the evacuation prior to the arrival of sustained 34-knot winds (or no evacuation advisory is issued). See note b. for additional evacuation timing information.

7. Move the STORM to the first forecast position. Determine if the radius of 34-knot winds has passed the Decision Point. If so, the Decision Point will be reached prior to the hurricane eye reaching the first forecast position.

8. Estimate the hours remaining before a decision must be made by dividing the number of nautical miles between the current radius of 34-knot winds and the Decision Point by the forward speed used for the Decision Arc table. Determine if the next NWS Marine Advisory will be received prior to the Decision Point.

9. Compare probabilities shown in the Marine Advisory to determine where an evacuation is likely to take place (see note c.). Determine how an evacuation of your jurisdiction would affect the readiness of others and when they should be notified of your evacuation. Check inundation maps to determine where flooding may occur and evacuation zone maps for zones that should prepare to evacuate.

10. At the Decision Point, evacuation decision-makers should compare the latest probabilities for their location with those for surrounding areas and the maximums shown in table 8-2. In addition to that forecast track information, they should also consider the storm's intensity and the potential inundation.

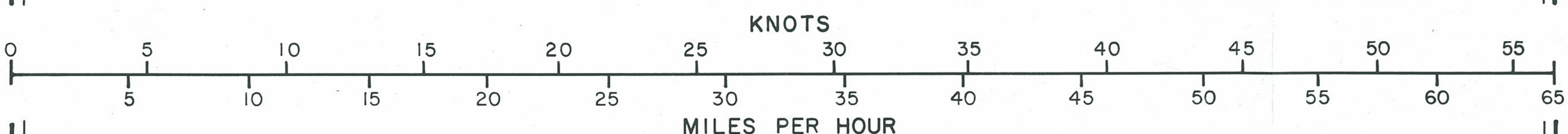
11. Steps 1 through 10 should be repeated after each NWS advisory until an evacuation decision is made or the hurricane threat has passed.

NOTES

a. Because information given in the Marine Advisory is in nautical miles and knots, the scale of the Decision Arc Maps and STORM is nautical miles. When utilizing hurricane information from sources other than the Marine Advisory, care should be taken to ensure that distances are given in or converted to nautical miles and speeds to knots. Statute miles can be converted to nautical miles by dividing the statute miles value by 1.15. Similarly, miles per hour can be converted to knots by dividing the miles per hour value by 1.15.

b. In the Decision Arc Method, there is no time specifically allocated for evacuation decision-making or mobilizing support personnel. Hurricane readiness operations should progress so that, if evacuation becomes necessary, preparations will be complete and the recommendation to evacuate can be given at the Decision Point.

c. Probability values shown in the Marine Advisory describe in percentages the chance that the center of a storm will pass within 65 miles of the listed locations. To check the relative probability for your particular area, the total probability value for the closest location, shown on the right side of the probability table in the advisory, should be compared to other locations. A comparison should also be made with the possible maximums for the applicable forecast period shown in the table of maximum probability values included in these instructions. These comparisons will show the relative vulnerability of your location to adjacent locations and to the maximum possible probability.



1" = 50 NAUTICAL MILES

FORECAST FORWARD SPEED SCALE

FIGURE 8-3

TABLE 8-3

SAFFIR/SIMPSON HURRICANE SCALE RANGES

Scale Number Category	Central Pressure Millibars	Central Pressure Inches	Winds (Mph)	Winds (Kts)	Damage
1	$\geq$ 980	28.94	74 - 95	64 - 83	Minimal
2	965 - 979	28.50 - 28.91	96 - 110	84 - 96	Moderate
3	945 - 964	27.91 - 28.47	111 - 130	97 - 113	Extensive
4	920 - 944	27.17 - 27.88	131 - 155	114 - 135	Extreme
5	< 920	< 27.17	> 155	> 135	Catastrophic