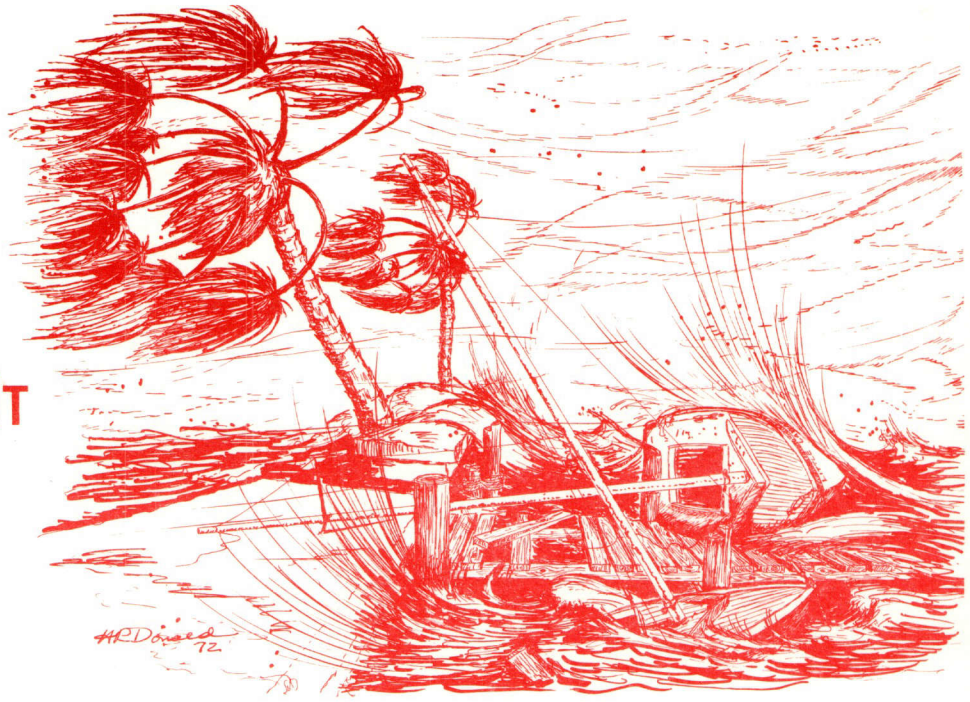
June 1991

LOWER SOUTHEAST FLORIDA HURRICANE EVACUATION STUDY



TECHNICAL ASSESSMENT

MONROE COUNTY

CORPS OF ENGINEERS
FEDERAL EMERGENCY MANAGEMENT AGENCY
NOAA NATIONAL HURRICANE CENTER
FLORIDA DEPARTMENT OF COMMUNITY AFFAIRS

LOWER SOUTHEAST FLORIDA
HURRICANE EVACUATION STUDY

TECHNICAL ASSESSMENT

A SUMMARY FOR MONROE COUNTY THE FLORIDA KEYS

PREPARED FOR:
MONROE COUNTY
OFFICE OF EMERGENCY MANAGEMENT

PREPARED BY:
CORPS OF ENGINEERS
FEDERAL EMERGENCY MANAGEMENT AGENCY
NOAA NATIONAL HURRICANE CENTER
FLORIDA DEPARTMENT OF COMMUNITY AFFAIRS

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MONROE COUNTY

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CHAPTER ONE
INTRODUCTION

GENERAL

One of the most hurricane vulnerable areas of the United States is the lower southeast coast of Florida. This area is comprised of Monroe County (the Florida Keys) and the mainland counties of Dade, Broward and Palm Beach (the other three counties). Historically there has been a high frequency of hurricanes which have affected the region, either directly or indirectly. The tracks of the primary storms affecting the Keys are shown in Chapter 2, Hazards Analysis. This technical report is for the Florida Keys portion of the study area.

PURPOSE

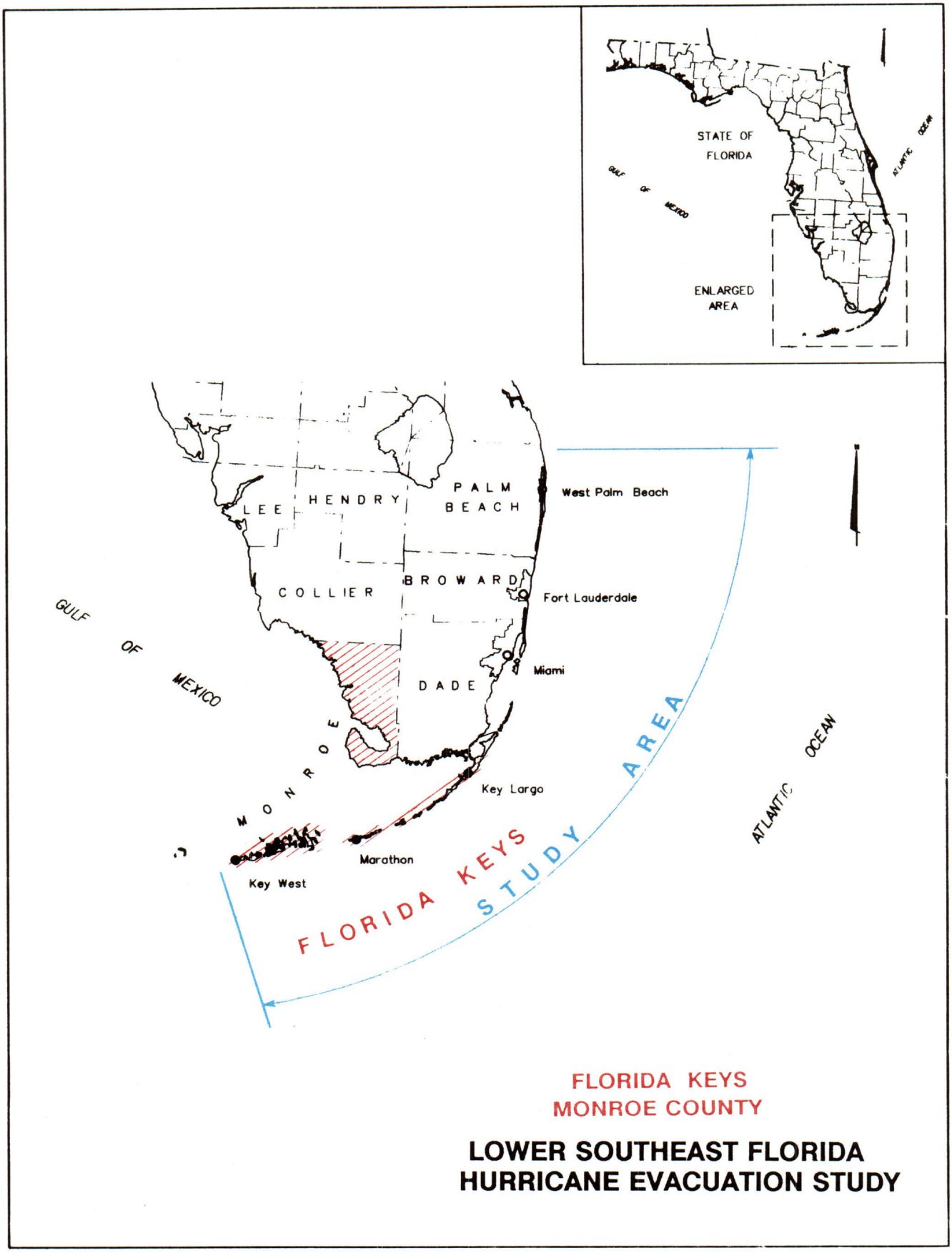
The Lower Southeast Florida Hurricane Evacuation Study is an update of the 1983 regional study for Monroe and the other three counties. See Plate 1 for the map of study area. This update utilized the information from the SLOSH (Sea, Lake, Overland Surges from Hurricanes) models for Biscayne Bay and Florida Bay developed by the National Hurricane Center (NHC), National Oceanic and Atmospheric Administration (NOAA). These models were not available when the original study was done. This fact, coupled with the tremendous development and population growth of the region, necessitated the current work. The primary emphasis of this study was the identification of life-threatening flooding resulting from hurricanes and the safe evacuation of populations from unsafe areas and conditions within the region. Primarily, the Florida Bay model was appropriate to the Florida Keys. The major consideration for the Keys was the clearance times needed to evacuate the residents along the Overseas Highway (U.S. #1) to the mainland.

AUTHORITY

The study authority for the Corps of Engineers is Section 206 of the Flood Control Act of 1960 (Public Law 86-645), and study authority for the Federal Emergency Management Agency is the Disaster Relief Act of 1974 (Public Law 93-288). These laws authorize the allocation of resources for planning activities related to hurricane preparedness. Authority for State of Florida involvement in the study is established by State Emergency Management Act, Chapter 252 (Sections 252.31 through 252.60), Florida Statutes (F.S.).

FUNDING

The Lower Southeast Florida Hurricane Evacuation Study was funded by the Federal Emergency Management Agency, the U. S. Army Corps of Engineers, and the State of Florida Department of Community Affairs. Local officials and agencies provided their input without direct charge to the study funds. This is particularly evident in the Keys where Mr. William A. Wagner, Jr., the Emergency Management Director, spends considerable time and effort working with the National Hurricane Center(NHC) and local entities.



FLORIDA KEYS
MONROE COUNTY

LOWER SOUTHEAST FLORIDA HURRICANE EVACUATION STUDY

FIGURE 1-1

GUIDELINES

This study was conducted in accordance with the Corps of Engineers' publication, Technical Guidelines for Hurricane Evacuation Studies, November 1984, and the Federal Emergency Management Agency's publication, CPG 2-16, A Guide to Hurricane Preparedness Planning for State and Local Officials, December 1984.

STUDY PARTICIPANTS

The Lower Southeast Florida Hurricane Evacuation Study was a joint effort by the Federal Emergency Management Agency (FEMA); the National Oceanic and Atmospheric Administration (NOAA); the U. S. Army Corps of Engineers (Corps); the State of Florida, Department of Community Affairs (DCA) and the Emergency Management directors of Monroe and the other three counties. Development of the technical data for the study was coordinated and documented by the Jacksonville District, Corps of Engineers, in conjunction with the various Federal and State agencies and local officials in the study area.

COORDINATION

In late 1987, in response to local concerns, FEMA and DCA requested the Corps to undertake an update for lower southeast Florida. The original study had been completed by the Corps in 1983, but local interests had expressed concerns about the rate of population growth occurring in the region and the applicability of the original study results. Specifically noted, were the numerous changes in arterials and major highways that would be used as evacuation routes and improvements in the transportation modeling process. Many meetings and review sessions were held on the preparation of this document.

a. Study Management. The Jacksonville District, Corps of Engineers had responsibility for coordinating study efforts. Direction for this study was provided by an executive committee.

DESCRIPTION OF STUDY AREA

a. Geography. The entire study area includes over 300-miles of coastline with numerous islands and barrier islands, many of which are densely populated. The Florida Keys (Monroe County) are essentially low coral islands. Most of Monroe County's population could be impacted by hurricane storm surges. Category 5 worst case storm tides for any given area, would flood all of that area. Only one small area in the city of Key West and several coral ridges on Key Largo would be exempt from total flooding should those specific areas be hit.

The Keys are situated along a string of islands extending some 110 miles from Key Largo to Key West. Thus, evacuating traffic would all move to the northeast, into or towards most approaching storms. This movement involves crossing a large number of bridges and channels. In addition, Key West residents would be moving the 110 miles plus an additional 40 or 50 miles into the Miami area. Geographically, the Keys are in a catastrophic location coupled with a very difficult evacuation process. A map of the total study area and the Florida Keys

is included as Figure 1-1.

b. Population. The projected 1990 permanent population of Monroe County is estimated to be approximately 79,800. Almost all are located in the Florida Keys. In the peak season, the seasonal population in Monroe County is approximately 48,700 additional people.

There continues to be a very large population of senior citizens, many of whom have special needs, which require additional efforts in the event of an evacuation.

STUDY COMPONENTS

The Lower Southeast Florida Hurricane Evacuation Study consists of several inter-related analyses that develop technical data concerning hurricane hazards, vulnerability of the population, public response to evacuation advisories, time needed to complete evacuation, shelter needs, transportation routes, evacuation zones and decision strategies. The six major analyses comprising this evacuation study and a brief description of each are as follows:

a. Hazards Analysis. SLOSH model results showing the maximum of maximum envelopes of water (MOMs) are used as input data to determine land areas expected to be inundated under the different category hurricanes. The storm surge MOMs produced for each category of hurricane are displayed as water elevations above mean sea level. The delineation of land areas, including potential evacuation routes, affected by each category of hurricane is a major part of the hazard analysis. The Florida Keys is one of several areas in the United States that has a major two-sided surge problem (flooding from the Atlantic Ocean and from Florida Bay).

The second part of the hazard analysis consists of estimating the time of arrival of tropical force winds and storm surge at pre-selected time/history points.

b. Vulnerability Analysis. The vulnerability analysis provides a detailed identification of the areas and population vulnerable to specific hurricane threats. This analysis identified the areas in Monroe County affected by particular hurricane intensities, the population at-risk, potential exposure of medical facilities and other institutions to storm surge, and the time period before hurricane eye landfall when high winds or rising waters would make evacuations dangerous or impossible. Evacuation zones were developed for use in creating evacuation scenarios. A scenario is a group of adjacent evacuation zones that will be threatened by the storm surge from a specific hurricane intensity category. The vulnerability analysis began with a review of established evacuation zones in the county as compared with inundation areas identified in the hazards analysis. Working in conjunction with the local emergency management director and other concerned local government representatives, the existing data were revised and modified to reflect the newly developed data. The planning needs of local officials were considered critical, and all revisions were approved by those officials before being included in the study effort.

c. Behavioral Analysis. The behavioral analysis provided quantitative information on how the public can be expected to respond to a hurricane event affecting the Keys. The analysis developed locally usable information on the following: (1) the number of people who will evacuate; (2) the number of evacuating people who will require transportation assistance; (3) the number of private vehicles that will be used during an evacuation; (4) the number of people who leave or attempt to leave the local area; (5) the number of people who will seek refuge in public shelters; and (6) when people in threatened areas would leave in response to forecast storm conditions, evacuation information or order, or local residential conditions (mobile home, structurally questionable home, seasonal or temporary residence, etc.). Several scenarios incorporating the above parameters were developed to reflect early (quick), average (median), and late (slow) responses to an evacuation order.

The methodology employed to develop this data consisted of telephone sample surveys and personal interviews within the study area; and data from other hurricane evacuation studies and from post-hurricane studies.

d. Shelter Analysis. The Shelter Analysis provided an inventory of existing public shelter facilities, capacities of the shelters, vulnerability of shelters to both storm surge flooding and high winds, and identified the range of the potential shelter demand for Monroe County. Inventories of existing shelters were provided by the emergency management director of Monroe County in conjunction with the American Red Cross. Potential shelter demands for ranges of hurricane threats were developed using data from the behavioral analysis.

e. Transportation Analysis. The transportation analysis utilized all of the analyses mentioned above to complete a reevaluation of the clearance time requirements. The clearance time is the time required to move evacuees along the roadways from their residences, to places of safety. This was developed for a number of situations or scenarios. Because this report is an update, the transportation analysis required a depiction of necessary changes to evacuation route networks used in Monroe County. New bridges, roads, and the current state of projected roadway improvements (which are massive and on-going in the study area) were included in this analysis.

f. Decision Information. Decision arcs were constructed with centers at Key West, Marathon and Key Largo. Tables were constructed to relate clearance times to distances from those centers. Utilizing the appropriate storm speed each decision arc then defined the needed clearance time. These arcs are then used with real time data from the NOAA marine advisories defining the extent of tropical force winds in miles from the storm center. A computer model called HURREVAC was developed for the Keys to enable the emergency management director to automatically determine the decision thresholds utilizing the study generated data and the NOAA marine advisories.

STORM SURGE ATLAS

A Storm Surge Atlas for Monroe County and each of the other three counties was financed by the State of Florida Department of Community Affairs. This

effort was undertaken by contract and completed in January 1991.

The Atlas is separate from the other study components and the Technical Assessment but delineates pictorially the storm surge inundation associated with the various categories of hurricanes. Additionally, it identifies the related elevations for each of those categories at selected locations.

CHAPTER TWO
HAZARD ANALYSIS

GENERAL

Hazard analyses for the Florida Keys were developed by the National Hurricane Center at Coral Gables, utilizing the SLOSH Model. Florida Bay SLOSH Model data and historical information combined are very accurate in identifying the risks. However, the ultimate direction of approach of the storm, its impact area, and its intensity when it strikes are much more elusive in definition. The major storm threats generally stay in warm waters, have characteristic abrupt changes of direction and maintain inconsistent probabilities of landfall even within 12 hours of landfall. With such uncertainties, the Florida Keys may be the most dangerous hurricane risk area in the nation.

The summary tables and grid results depict the worst case situation for each category storm utilizing the maximum of maximums (MOMs) for any heading or track. Figures 2-1 and 2-2 depict the grid and selected headings and tracks for the SLOSH analysis. The headings shown are the two most likely ones for the county. The remaining headings and tracks are included in the Hazard Appendix. A Storm Surge Atlas utilizing the SLOSH results was prepared for Monroe County and completed in January 1990. Since that effort was done separately from this data assembly, there may be some minor variations in the data presented here and that displayed on the atlas maps. Any differences would be inconsequential to the basic objective of the hazard application. When much of the community is either severely threatened or significantly flooded by most category storms, it is not important to distinguish areas that may have small differences in predicted flood levels. This is particularly true since there are limitations in accuracy for the SLOSH Model results.

From an operational standpoint, the greatest difficulties for Monroe County will be presented by storms whose tropical force wind fields affect the Upper Keys first. This type of storm follows a tract through the Bahamas, generally between the headings of 270 and 292.5 degrees, as shown on Figure 2-3. The figure shows the tracks of three of the most devastating storms to ever hit the Florida Keys. They are the 1919 storm, the 1935 (Labor day) storm, and the 1960 (Donna) storm. Hurricane Betsy in 1965, first went north of the Bahamas then returned in a southerly direction, essentially forming an east to west heading through the Keys. Large, devastating storms also have approached the Keys from the south. Hurricane Gilbert (1988) is included because it depicts a major storm that could curl north and approach the Keys directly from the south. Of particular concern to Key West are the storms which generate in the northwest Caribbean (usually, early or late season storms) and approach from the "back side".

Storm tide heights (elevations) consistent with the Atlas are presented on Figure 2-4 at numerous locations for Categories 2, 3 and 5. Generally there is a two foot increase in elevations from a category 2 storm to a category 3 storm, particularly on the Florida Bay side of the Keys. Storm tide elevations on the Florida Bay side are generally higher than the Ocean side. In some cases, the difference is as much as 4 to 5 feet for any category storm. Reference is made

to the SLOSH Atlas for inundation levels. The elevations on Figure 2-4 agree closely with known elevations for Hurricane Donna (1960 - Category 4) and the Labor Day Storm (1935 - Category 5). The exceptions are the very high 1935 storm elevations recorded at Upper Matecumbe (18 feet), Lower Matecumbe (18 feet), and Long Key (16 feet). It is believed that those values resulted from run-up or water build-up against the railroad embankment which existed at that time.

Sustained winds for Category 3-5 could be expected to be in the 110-150 mile per hour range with gusts in the 140-200 mile per hour range. Evidence exists that a tremendous increase in damage and forces occur when winds move from the 90-100 mile per hour level to the 140-150 mile per hour level. One thing that must be kept in mind is that the hazard data are for worst case situations. The flooded areas shown in the Atlas represent the maximum surge expected to occur at any given location, regardless of the direction of the hurricane. The only variable is the intensity of the hurricane, represented by category strength.

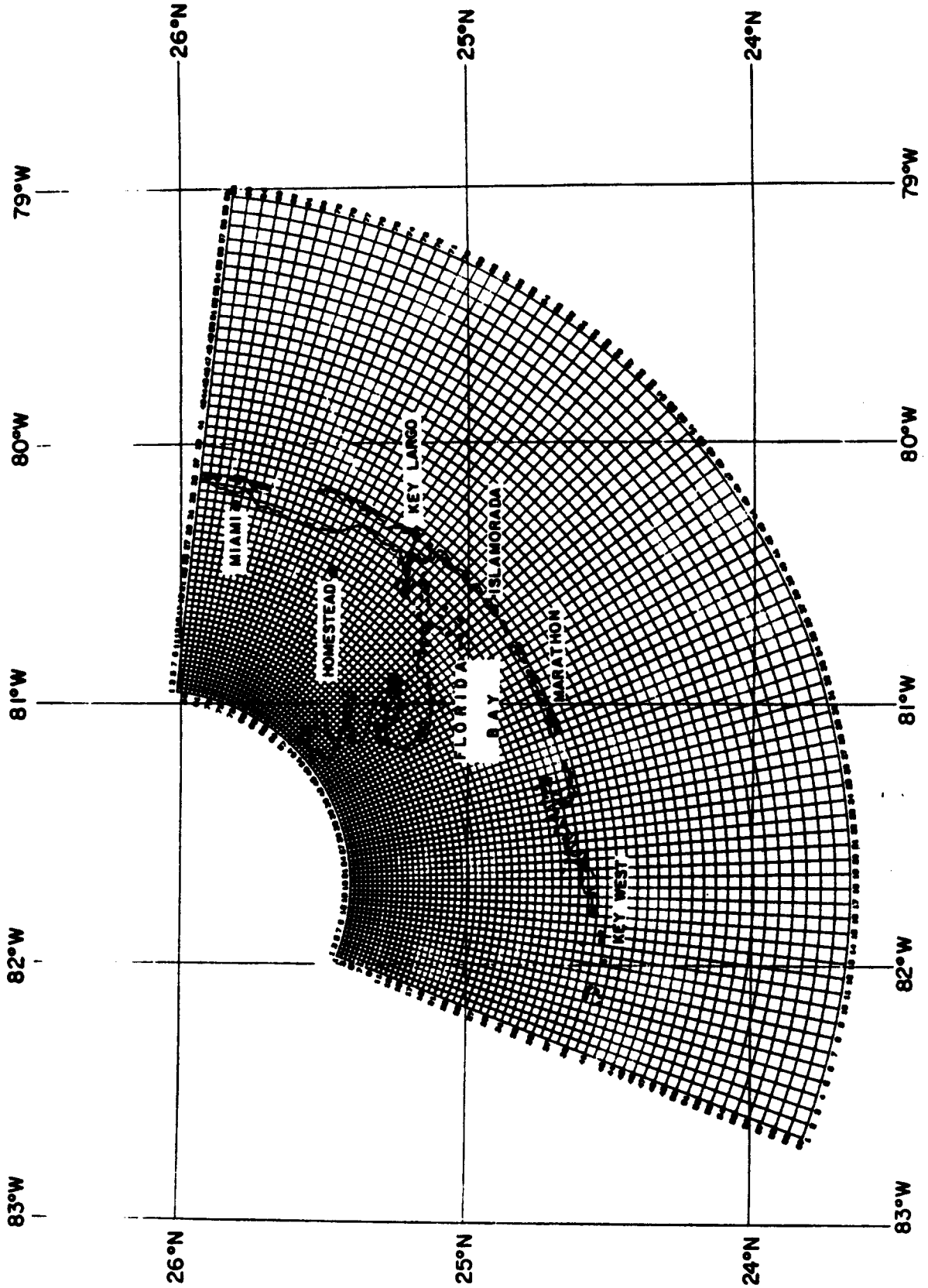
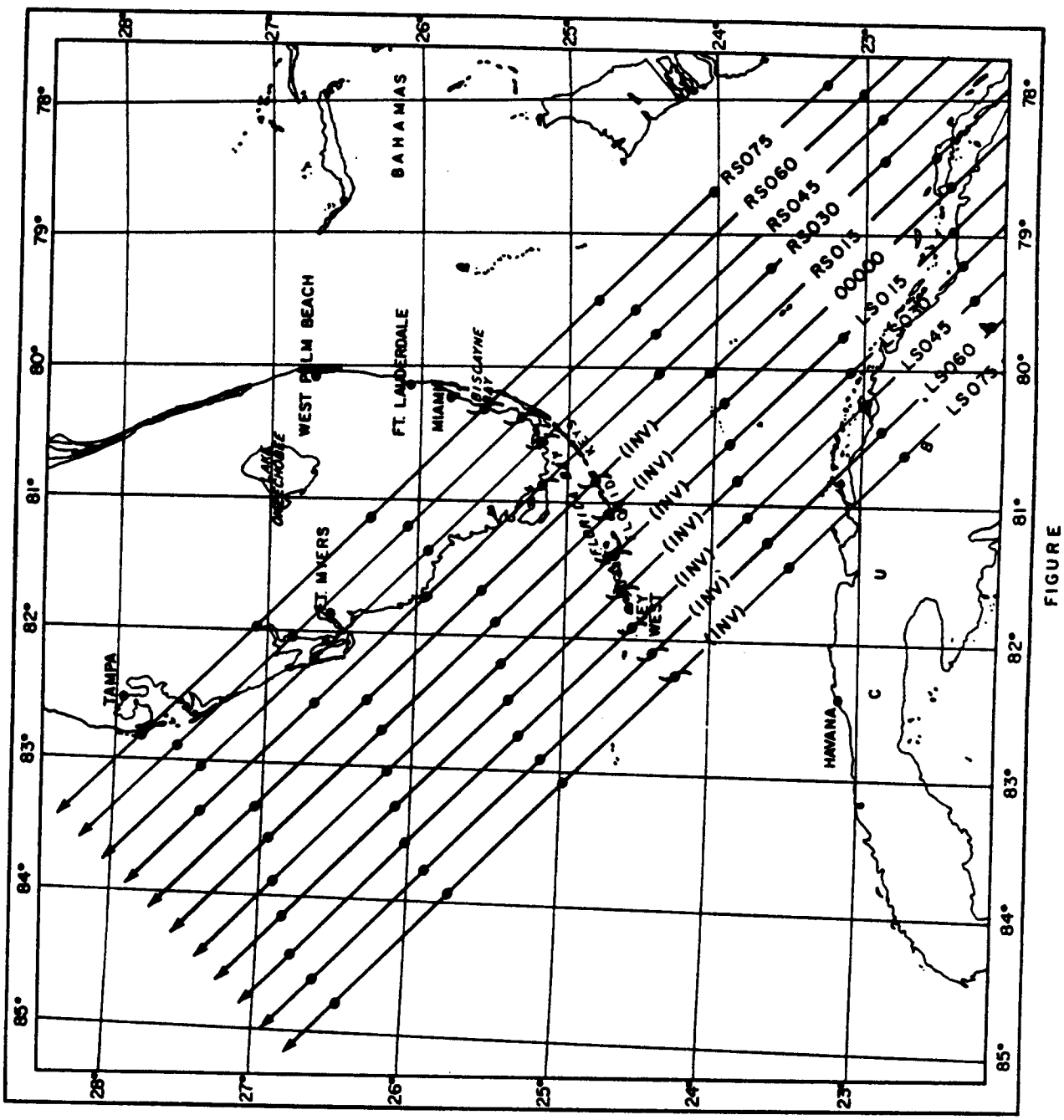


FIGURE 1.

Florida Bay SLOSH Grid

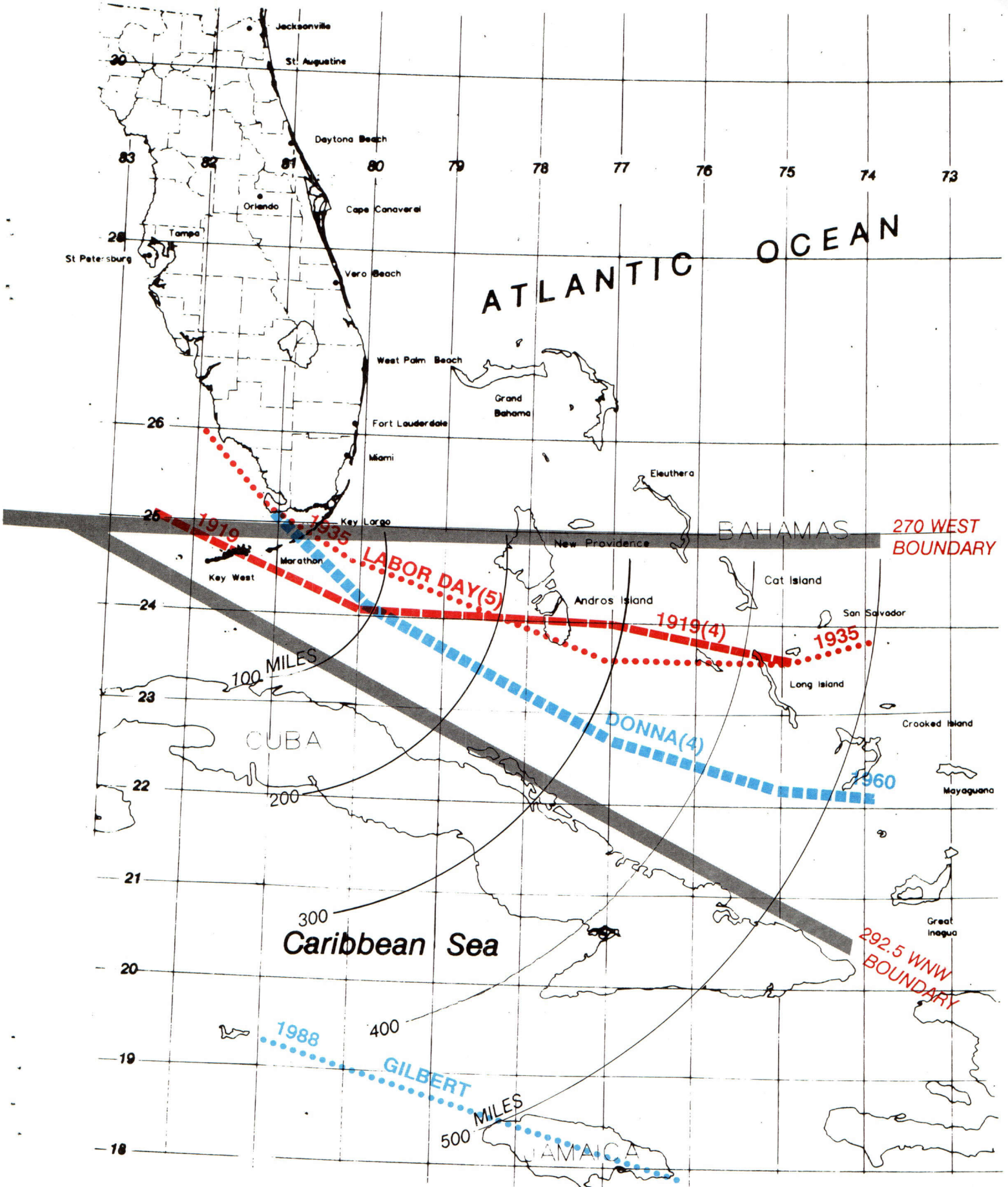
FIGURE 2-1



FIGURE

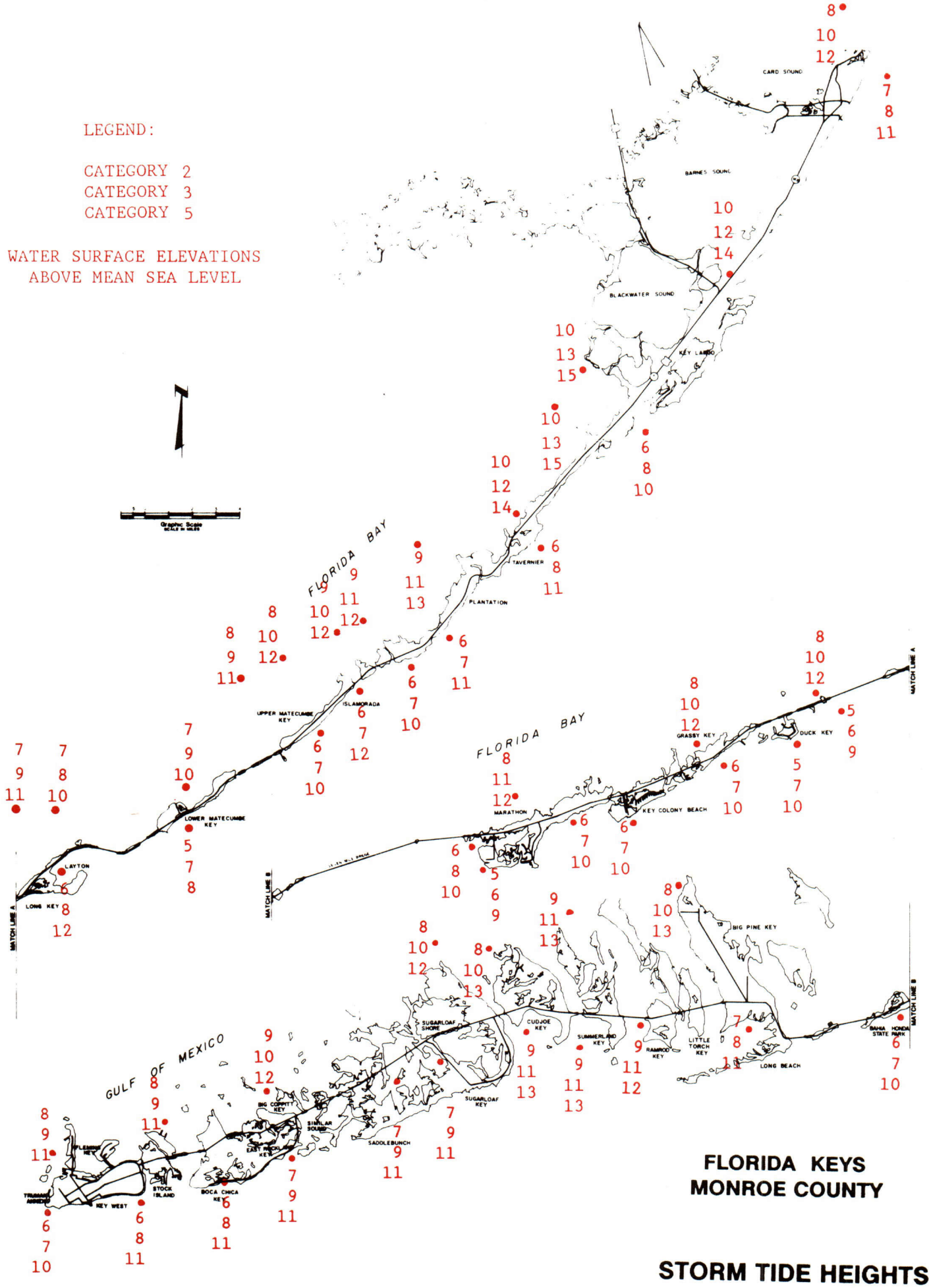
Selected Headings and Tracks
from SLOSH Analysis

FIGURE 2-2



(4) = HURRICANE CATEGORY

CATASTROPHIC STORMS AFFECTING THE FLORIDA KEYS



FLORIDA KEYS
MONROE COUNTY

STORM TIDE HEIGHTS

FIGURE 2-4

CHAPTER THREE
VULNERABILITY ANALYSIS

GENERAL

The purpose of the Vulnerability Analysis is to identify the areas, populations, and facilities which are vulnerable to flooding associated with hurricanes. The storm surge data from the Hazards Analysis were used to develop inundation maps (see Hurricane Storm Tide Atlas for Monroe County), evacuation zones, and evacuation scenarios; to quantify the population at risk under a range of hurricane intensities; and to identify major medical/institutional and other facilities(especially shelters) that are potentially vulnerable to storm surge.

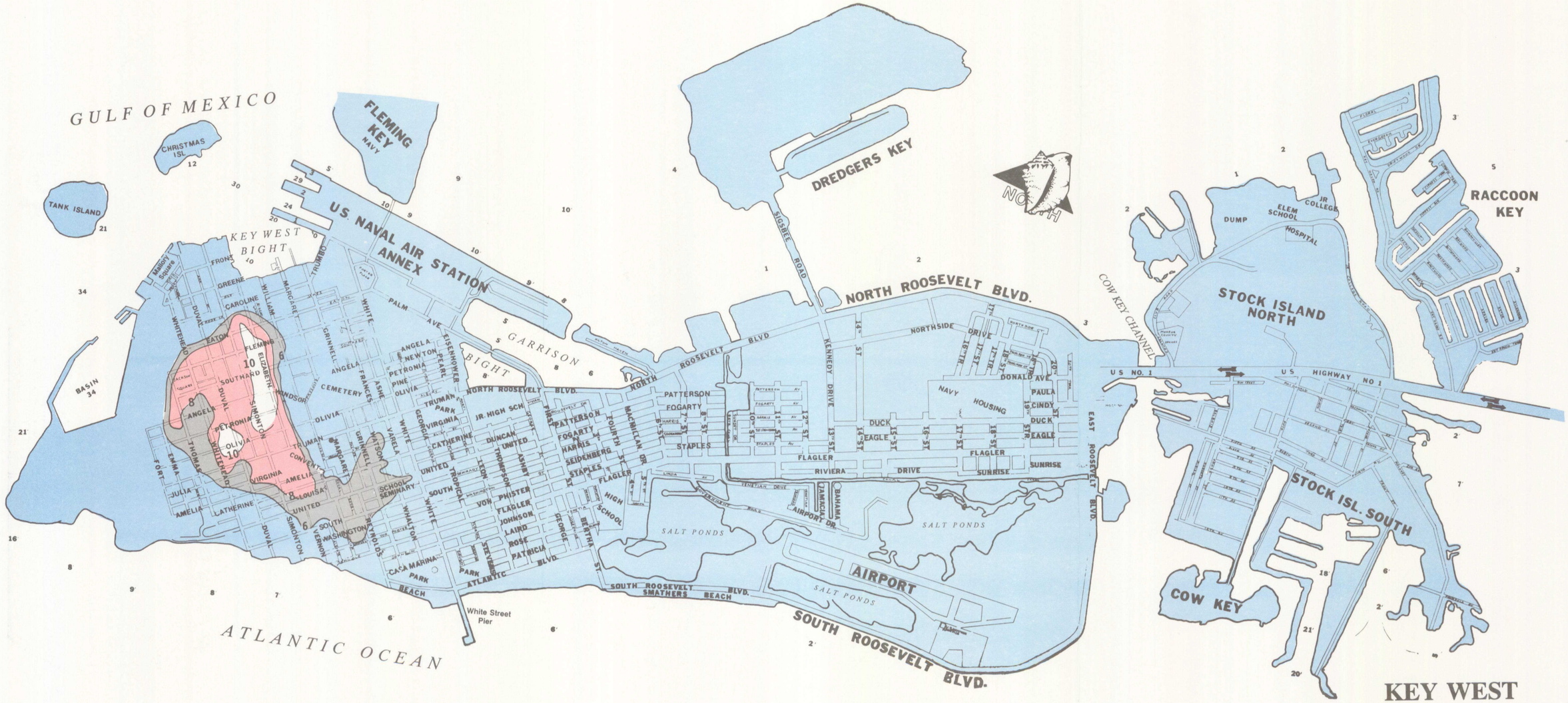
Significant levels of flooding begin to occur at the Category 3 level. That would make use of many shelters questionable, at best. Additionally, wind threats will become so great that many unsubstantial structures will be at extreme risk. Because of the uncertainties of the stability of many buildings, and particularly that of the shelters, the Category 3 level appears to be the major evacuation threshold. The shelter vulnerabilities are presented in the shelter section.

It will be noted in the listing that the large shelters in the Plantation /Key Largo area (Upper Keys) are less vulnerable from a flooding stand point. Therefore, they are logical choices for emergency refuge for the trailing evacuees from the Lower Keys. Shelters 9-12 are all above 12 feet (at least, the sheltering portions) and the hazard potential was identified as minimal for all four in the 1984 report discussed in the Shelter Section.

Figure 2-4 and the Atlas define the general vulnerability for the Keys. In addition, Figure 3-1 is a topographic/inundation map for the Key West area showing the extent of expected storm tide threats from various category storms. The map is a combination of threats from the Florida Bay and Atlantic Ocean sides. Of particular concern are the flooding depths that can be expected. For example, all but a very small portion of Key West would be flooded by a Category 5 storm and flooding could be expected up to 5-6 feet deep in central Key West and up to 7-8 feet deep in areas east from the main part of town.

The foregoing discussion is relevant because of the knowledge of Hurricane Hugo's impacts and the subsequent comparison of those impacts with SLOSH modeling results that preceded the storm. Comparisons were made not only at Charleston, South Carolina but also at Puerto Rico's north and east coast. The certainty of the predicted surges is rather scary. It is noted that the predicted surges in the Keys are "worst case" and do not reflect what would happen as a result of any one storm. Nevertheless, the threats are real and worthy of serious concern.

It should be emphasized that complete inundation by any one storm of the Florida Keys is not what is portrayed on Figure 2-4 or in the Atlas. The large storm tide effects will be within shorter distances on each side of the storm landfall and generally mostly on the right (or strong) side of the storm. Historically, devastating hurricanes have affected all parts of the Keys, 1919 Key West, 1960 Donna- Middle Keys, and 1935, Upper Keys. Therefore, all areas of the Keys are extremely vulnerable to the effects of hurricanes.



CATEGORY 2
CATEGORY 3
CATEGORY 5

KEY WEST STORM TIDE FLOODING

FIGURE 3-1

CHAPTER FOUR
SHELTERS

GENERAL

A list of shelters for the Florida Keys is included as Table 4-1. A more detailed list showing the vulnerability of these shelters is on Table 4-2. Shelter location is an important consideration. All the designated Red Cross shelters are considered to be structurally adequate, at least for the intended use (Category 1 and 2 storms). It is not proposed to use the shelters during larger, more intense storms (Category 3-5).

An evaluation of existing and potential hurricane shelters and buildings for emergency use was made in 1984 by Christopher Jones and Byron Spangler of the University of Florida. That report is available for review in the Monroe County Emergency Management Office, the Monroe County Library in Marathon, and at the Corps of Engineers office in Jacksonville. Major conclusions from that study were:

a. That all the buildings (including those in Table 4-1 and 4-2) should be shuttered.

b. Generally, that all the listed structures are adequate for Category 1 and 2 storms and that some would be very adequate in terms of the anticipated flood levels for higher category storms (see Table 4-2).

c. Generally, that wind threats would preclude safe use of many of the shelters for hurricanes of greater intensity than Category 2.

In view of the results of the 1984 evaluation, the decision not to utilize any of the shelters for storms of greater intensity than Categories 1 and 2, is probably a good one. Nevertheless, it is recognized that in an extreme emergency, the shelters may have to be used. An asterisk beside the name of the most acceptable shelters is provided on Tables 4-1 and 4-2.

It must be recognized that a mass evacuation of the Florida Keys could result in many eventualities. Thus, use of all the most acceptable shelters may be necessary. It is not a black and white, clear cut, process when an extreme emergency arises and lives are at stake. For this reason, it is important that a good description of the potential shelters be maintained and that they be closely monitored. In addition, the determination of additional stable public buildings is extremely important to this cause.

A capacity of 5,000 people was used for the shelter at Florida International University in Dade County to be used by evacuees from the Keys.

TABLE 4-1

RED CROSS SHELTER LOCATIONS

	FACILITY	ADDRESS	MILE
1.	GLYNN ARCHER SCHOOL	1302 WHITE STREET, KEY WEST	
**2.	FEDERAL BUILDING	SIMONTON & CAROLINE, KEY WEST	
**3.	FIRST BAPTIST CHURCH(2nd Flr)	524 EATON STREET, KEY WEST	
4.	SCOTTISH RITE TEMPLE(2nd Flr)	533 EATON STREET, KEY WEST	
5.	SUGARLOAF ELEM. SCHOOL	CRANE BLVD, 1 BL N OF US HWY 1	19.0
6.	PINE BIG CHRISTIAN CENTER	COUNTY ROAD, 1 BL N OF US HWY 1	30.9
7.	SWITLIK SCHOOL(2nd Flr)	GULFSIDE US HWY 1, MARATHON	48.5
8.	DAV BUILDING	GULFSIDE US HWY 1, MARATHON	51.0
*9.	ISLAND CHRISTIAN SCHOOL(2nd Flr)	GULFSIDE US HWY 1, MARATHON	83.5
*10.	CORAL SHORES HIGH SCHOOL	OCEANSIDE US HWY 1, PLANTATION	90.0
*11.	PLANTATION KEY ELEM SCHOOL	GULFSIDE US HWY 1, PLANTATION	90.0
*12.	KEY LARGO ELEM. SCHOOL	OCEANSIDE US HWY 1, KEY LARGO	105.0
13.	ST. JUSTINE CHURCH	GULFSIDE US HWY 1, KEY LARGO	105.5

* LESS VULNERABLE
** SHELTERS 2 AND 3 SUBSEQUENTLY ELIMINATED BY RED CROSS

TABLE 4-2

RED CROSS SHELTER
VULNERABILITIES

	FACILITY	GRD ELEV	FLR ELEV	CAT 2 ELEV	CAT 3 ELEV	CAT 5 ELEV
1.	GLYNN ARCHER SCHOOL	6.5	9.5	6.0	8.0	(11.0)
**2.	FEDERAL BUILDING	8.0	9.5	6.0	8.0	(11.0)
**3.	FIRST BAPTIST CHURCH(2nd Flr)	8.5	N/A	6.0	8.0	(11.0)
4.	SCOTTISH RITE TEMPLE(2nd Flr)	8.5	N/A	6.0	8.0	(11.0)
5.	SUGARLOAF ELEM. SCHOOL	6.0	8.5	8.0	(10.0)	12.0
6.	PINE BIG CHRISTIAN CENTER	5.0	10.0	7.0	8.0	(11.0)
7.	SWITLIK SCHOOL(2nd Flr)	6.0	6.6/20.6	6.0	(7.0)	10.0
8.	DAV BUILDING	7.0	11.0	6.0	7.0	10.0
*9.	ISLAND CHRISTIAN SCHOOL(2nd Flr)	7.0	7.8/15.0	8.0	(10.0)	12.0
*10.	CORAL SHORES HIGH SCHOOL	12.7	14.4	6.0	8.0	11.0
*11.	PLANTATION KEY ELEM SCHOOL	11.5	12.1	6.0	8.0	11.0
*12.	KEY LARGO ELEM. SCHOOL	11.0	12.4	6.0	8.0	11.0
13.	ST. JUSTINE CHURCH	11.8	12.4	10.0	(12.0)	14.0

* LESS VULNERABLE ( ) CATEGORY STORM WHEN SHELTER FIRST BECOMES VULNERABLE

** SHELTERS 2 AND 3 SUBSEQUENTLY ELIMINATED BY RED CROSS

CHAPTER FIVE
BEHAVIORAL STUDY

GENERAL

The current behavioral analysis was developed exclusively for Monroe County by Carnot Nelson, PhD, updating the results of the 1983 analysis. Behavioral information was obtained concerning both a hypothetical Category II and Category III hurricane situation. This information is essential for Monroe County because public shelters and motels/hotels are not open during a Category III or more severe hurricane. Data were collected on evacuation rates, timing, destination, type of refuge and vehicle usage.

Each respondent to the behavioral interview was presented with two situations; one involving a Category II hurricane and the other involving a Category III hurricane. Half of the respondents received the Category II situation first and half of the respondents received the Category III situation first to counterbalance for order effects. A copy of the survey is included in the Behavioral Appendix. The survey required for this study was the Behavioral Analysis Survey in Support of Hurricane Evacuation Studies as approved by the Office of Management and Budget (OMB). Only minor modifications to this model survey were permitted.

Overall, 54.5 percent of those surveyed reside in single-family homes, and 18.8 percent live in mobile homes. Since mobile homes are particularly vulnerable to hurricanes; it is important to note that only 10.8 percent of the Lower Keys residents live in mobile homes. In the Middle and Upper Keys, this percentage increases to 21 percent and 24.5 percent, respectively.

In both a Category II and a Category III hurricane threat, there was a general trend for the respondents in the Lower Keys to be less likely to evacuate than those in the Middle and Upper Keys. The evacuation percentages follow:

Keys	Category II	Category III
Upper Keys	69.8%	78.3%
Middle Keys	65.0%	76.0%
Lower Keys	43.1%	55.9%

A discussion of when these evacuees would leave (i.e. 36hrs, 24hrs, 12hrs, etc.) is contained in the Behavioral Appendix. The survey, also determined how quickly the residents anticipated that they would respond, e.g., "immediately", "between 1 and 3 hours", etc. The results are contained in the appendix.

SPECIFIC

Except for the Lower Keys, the percentage of people who indicate they will shelter in Monroe County is very low (Category 1 through 2). On the other hand, the percentage of people who say they will evacuate out of the county is very high for the Lower Keys and even for a lower category storm.

TABLE 5-1

STORM SCENARIO - EVAC. AREA	TOTAL PEOPLE EVACUATING	TOTAL TO LOCAL SHELTER	TOTAL HOTEL/MOTEL FRIENDS	OUT OF COUNTY
CATEGORY 1-2 -Lower & Middle Keys				
"No" Seasonal Occupancy	28,880	4,945	6,790	17,145
Low Seasonal Occupancy	43,105	6,115	8,710	28,280
High Seasonal Occupancy	52,590	6,895	9,990	35,705
CATEGORY 1-2 -Middle & Upper Keys				
"No" Seasonal Occupancy	22,805	1,605	3,875	17,330
Low Seasonal Occupancy	33,745	1,895	5,020	26,830
High Seasonal Occupancy	41,040	2,090	5,785	33,165
CATEGORY 1-2 -Lower, Middle & Upper Keys				
"No" Seasonal Occupancy	42,940	5,630	8,905	28,410
Low Seasonal Occupancy	62,665	6,800	11,370	44,495
High Seasonal Occupancy	75,815	7,580	13,015	55,220
CATEGORY 3-5 -Lower & Middle Keys				
"No" Seasonal Occupancy	39,580	1,815(R)	1,810	35,955
Low Seasonal Occupancy	59,035	1,815(R)	1,810	55,410
High Seasonal Occupancy	72,005	1,815(R)	1,810	68,380
CATEGORY 3-5 - Middle & Upper Keys				
"No" Seasonal Occupancy	30,875	735(R)	735	29,405
Low Seasonal Occupancy	49,505	735(R)	735	48,035
High Seasonal Occupancy	61,925	735(R)	735	60,455
CATEGORY 3-5 -Lower, Middle & Upper Keys				
"No" Seasonal Occupancy	52,465	1,815(R)	1,815	48,835
Low Seasonal Occupancy	73,290	1,815(R)	1,815	69,660
High Seasonal Occupancy	87,175	1,815(R)	1,815	83,545

(R) = Refugees

Although the percentage of people who say they will go to shelter is low, this information is important because of shelter availability and location. Table 5-1 separates those people who say that they are going to shelter in the Lower, Middle, and Upper Keys. The other extremely important component of Table 5-1 is that the majority of the evacuees will be coming from the Lower and Middle Keys thereby lending more credence to the strategy of moving the minority of the Upper Keys evacuees as early as possible. The 13,000 to 15,000 people evacuating from the Upper Keys ranges from 17 to 25 percent of the total evacuating population for the Florida Keys for the "high seasonal" to "no seasonal" occupancy ranges. Based on numbers of persons and their location, the Upper Keys could be expeditiously evacuated. This would open up the roadway for the greater need of Lower and Middle Keys.

Another important behavioral aspect is participation rates. Several elements were employed in the transportation analysis regarding participation in the evacuation. Based on Carnot Nelson's behavioral analysis of evacuation rates by household, participation rates were varied by storm category and evacuation area. The specific figures were as follows:

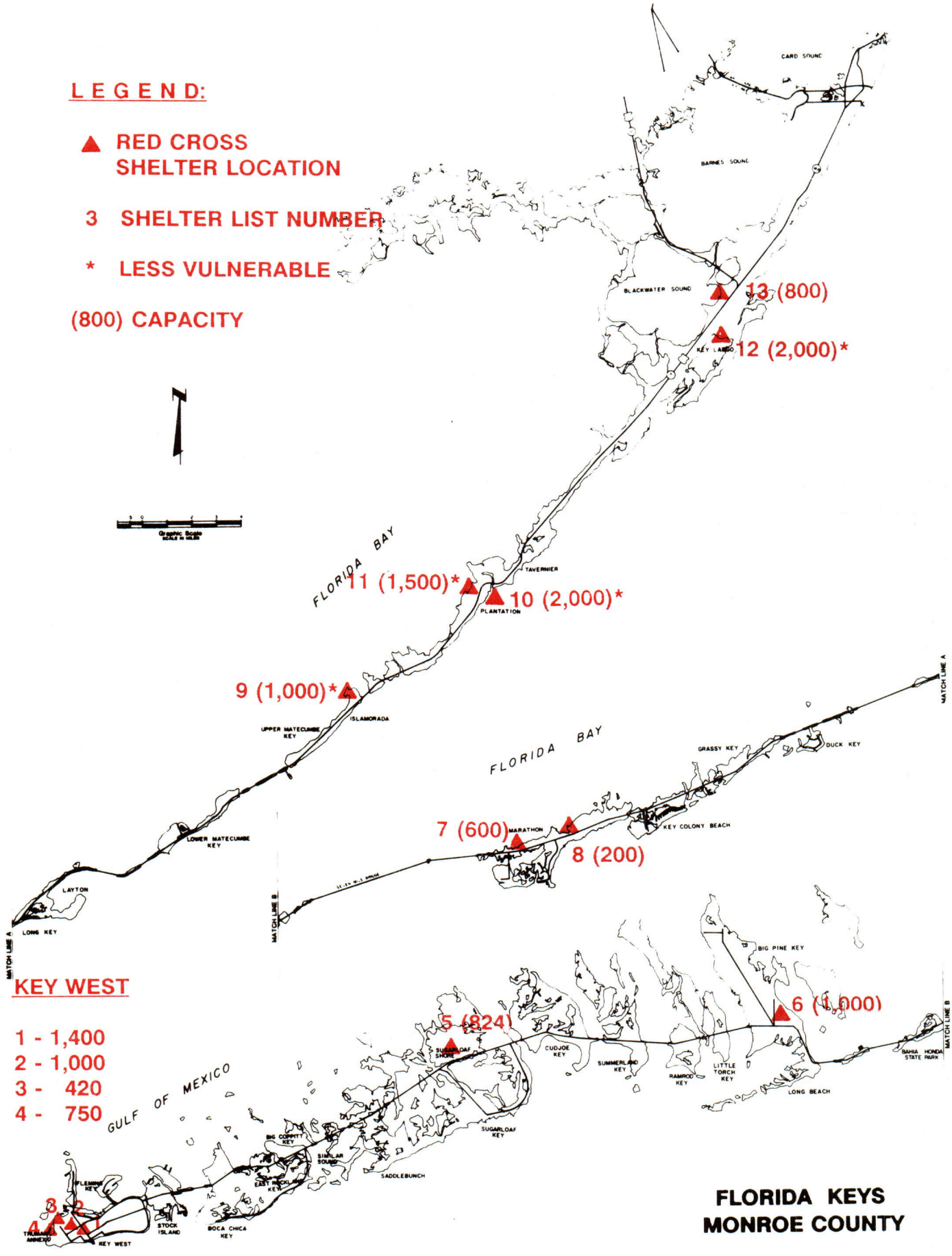
Category 1-2	Lower Keys	90% of mobile homes and 45% of other units
	Middle Keys	90% of mobile homes and 68% of other units
	Upper Keys	90% of mobile homes and 75% of other units
Category 3-5	Lower Keys	95% of mobile homes and 60% of other units
	Middle Keys	95% of mobile homes and 80% of other units
	Upper Keys	95% of mobile homes and 85% of other units

Participation rates by seasonal population were assumed to be near 100% similar to the mobile home participation rates. For those storm scenarios involving partial evacuation of the Keys, a very small percentage of the non-evacuated area was assumed to participate.

The following general destination percentages were used for the transportation analysis:

	Evacuees Monroe Public Shelter	Evacuees Monroe Motel/ Friends Home	Evacuees Out of County
Category 1-2			
Lower Keys	20%	25%	55%
Middle Keys	10%	20%	70%
Upper Keys	5%	15%	80%
Ocean Reef	0%	15%	85%
Category 3-5			
Lower Keys	5%	5%	90%
Middle Keys	5%	5%	90%
Upper Keys	0%	0%	100%
Ocean Reef	0%	0%	100%

It should be noted that the percentage of evacuees going out of county includes those evacuees going to public shelter in Dade County. Florida International University has a capacity of 5,000 persons for evacuees from Monroe County.



FLORIDA KEYS
MONROE COUNTY

RED CROSS SHELTER LOCATIONS

FIGURE 4-1

CHAPTER SIX
TRANSPORTATION ANALYSIS

GENERAL

During a hurricane evacuation effort, it is generally recognized that a large number of vehicles have to be moved across a road network in a relatively short period of time. The number of vehicles and evacuees becomes particularly significant for an area such as Monroe County, Florida where the 110 mile "Overseas Highway" (U.S. 1) connects both urban areas and seasonal communities. The magnitude of evacuating vehicles varies depending upon the intensity of the hurricane, presence of tourists, and certain behavioral response and participation characteristics of the vulnerable population.

Vehicles enter the road network at different times depending on the evacuee's response relative to an evacuation order or advisory. Conversely, vehicles leave the road network depending on both the planned destinations of evacuees and the availability of acceptable destinations such as public shelters, hotel/motel units and friends' or relatives' homes in non-flooded areas. Vehicles move across the road network from trip origin to destination at a speed dependent on the traffic loadings on various roadway segments and the ability of the segments to handle a certain volume of vehicles each hour.

The overall goals of the transportation analysis performed for the Monroe County portion of the Lower Southeast Florida Hurricane Evacuation Study were to estimate clearance times (the time it takes to clear the county's roadways of all evacuating vehicles), to define the evacuation road network, and to look at general traffic control measures that could improve traffic flow along critical roadway segments. Clearance time is a value resulting from transportation engineering analysis performed under a specific set of assumptions. It must be coupled with pre-landfall hazards data to determine when a strong evacuation advisory must be issued to allow all evacuees time to reach safe shelter before the arrival of sustained tropical storm winds. Factors that influence clearance time must be studied intensively to determine which factors have the strongest influence. Therefore, a sensitivity analysis was performed and approximately 100 clearance times calculated by varying key input parameters.

The transportation analysis task initially identified the kinds of traffic movements associated with a hurricane evacuation which must be considered in the development of clearance times. Basic assumptions for the transportation analysis were developed related to storm scenarios, population-at-risk, behavioral and socioeconomic characteristics, the roadway system and traffic control. A transportation modeling methodology and a roadway system representation were developed for the study area to facilitate model application and development of clearance times. General information and data related to the transportation analysis are presented in the Transportation Appendix. A Transportation Model Support Document is available in the offices of the Jacksonville District Corps of Engineers and includes a detailed account of all transportation modeling activities and zone by zone data listings for Monroe County.

TRANSPORTATION MODELING
CLEARANCE TIMES

The transportation modeling for the Florida Keys addressed different levels of evacuation for all storm intensities. Shelters will only be purposefully utilized for Category 1-2 storms. For the much larger storms, certain shelters will be identified as refuges and reserved for emergency (last ditch) refuge only. This may be necessary just to "save lives".

Results of the transportation modeling are shown on Tables 6-1 and 6-2. These are the times that the decision arcs and the HURREVAC computer model are based on for evacuation timing decisions.

Table 6-2 is most critical because it involves the most people and presents the storm scenario that we all fear(Category 3-5). The manager must ascertain those concepts which will dramatically affect or reduce the clearance time. Then the response strategies must be determined that will give the best results in an almost impossible situation. Suggestions for those strategies and stages of evacuation are outlined in the next section, "Response and Strategies".

From Table 6-2, the following are critical determinations:

a. Requiring tourists to leave the Florida Keys as early as possible is an absolute necessity!

b. Having a four lane highway north towards Homestead from Key Largo, giving an additional evacuation lane, could reduce clearance times by 6 to 7 hours.

It is noted that traffic on I-95 and the Florida Turnpike in the Palm Beach area could impede additional use of those roadways for residents of Monroe County, as well as Broward and Dade Counties.

According to current evacuation plans, the Key West Port and Transit Authority can move people in Zone 1 (Key West, Stock Island, Big Coppitt, and Geiger Key) who require public transportation and can move about 7,000 people to Zone 1 shelters in 7 hours or about 1,000 per hour. Three additional hours would be needed to secure personnel and equipment.

Two permanent DOT traffic counters are used to monitor traffic flow. They are located at Mile Marker (MM) 5 on Stock Island; just north of the Cow Key Channel Bridge and at MM 106 in Key Largo.

Those roadway segments with the highest volume to capacity ratios were identified as the critical links. Critical segments in order of severity are listed on page 26. Volume to capacity ratios calculated for each link are provided in the Transportation Appendix. Clearance time must be weighted with respect to the arrival of tropical storm winds and local surge flooding to make a prudent evacuation decision. These two timing issues and their relationship are depicted on page 26.

TABLE 6-1

CLEARANCE TIMES
(in hours)
CATEGORIES 1-2

EVACUATION AREA	NO* SEASONAL OCCUPANCY		LOW SEASONAL OCCUPANCY		HIGH SEASONAL OCCUPANCY	
Lower and Middle Keys						
Response Rate:						
Immediate	10.5	(7.5)**	12.5	(8.75)**	13.75	(10)**
Rapid	11	(7.75)	13	(9.25)	14.5	(10.75)
Medium	12.25	(8.75)	14.25	(10.75)	16	(12.75)
Slow	13.5	(11)	15.5	(11.5)	17	(14)
Middle and Upper Keys						
Response Rate:						
Immediate	11		12.75		14	
Rapid	11.25		13		14.5	
Medium	12		14		15.75	
Slow	13.5		15		16.5	
Lower, Middle and Upper Keys						
Response Rate:						
Immediate	17.25 [10.5 13.5]		20.0[12.0 16.0]		22.0 [13.5 17.75]	
Rapid	17.5 [10.75 14.0]		20.5[12.5 16.5]		22.75[14.0 18.5]	
Medium	18.25 [12.0 15.0]		21.5[13.5 18.0]		23.75[15.5 20.75]	
Slow	19.5 [13.0 16.0]		22.5[15.0 18.75]		24.75[16.5 22.0]	

* Clearance times were computed on basis that all hotel/guest houses/tourist accommodations will strictly adhere to the policy of issuing evacuation orders upon official posting of a hurricane watch

** Traffic movements staying in Lower and Middle Keys area.

[ ] Reflects having two lanes northbound for evacuation on U.S. 1 from Milemarker 106/C.R.905 to Dade County line. First number is clearance time for Upper Keys residents as critical link shifts to U.S. 1 through Key Largo. Second number is clearance time for Lower and Middle Keys residents as critical link shifts to U.S. 1 between Key Colony Beach and Tavernier.

TABLE 6-2

CLEARANCE TIMES
(in hours)
CATEGORIES 3-5

EVACUATION AREA	NO* SEASONAL OCCUPANCY	LOW SEASONAL OCCUPANCY	HIGH SEASONAL OCCUPANCY
Lower and Middle Keys			
Response Rate:			
Immediate	20.5	24.25	26.75
Rapid	21	24.75	27.5
Medium	22.25	26	28.75
Slow	23.25	27	29.75
Middle and Upper Keys			
Response Rate:			
Immediate	18.5	21.5	23.75
Rapid	18.75	22	24.5
Medium	19.25	22.75	25.5
Slow	20.5	23.25	26.5
Lower, Middle and Upper Keys			
Response Rate:			
Immediate	28.75 [17.0 22.0]	32.75 [19.25 25.5]	35.25 [21.0 27.75]
Rapid	29 [17.25 22.5]	33.25 [19.75 26.0]	36 [21.5 28.75]
Medium	29.75 [18.25 23.5]	34 [20.25 27.5]	37 [23.0 31.0]
Slow	31 [19.5 24.5]	35 [22 28.25]	38 [24.0 32.25]

* Clearance times were computed on basis that all hotel/guest houses/tourist accommodations will strictly adhere to the policy of issuing evacuation orders upon official posting of a hurricane watch.

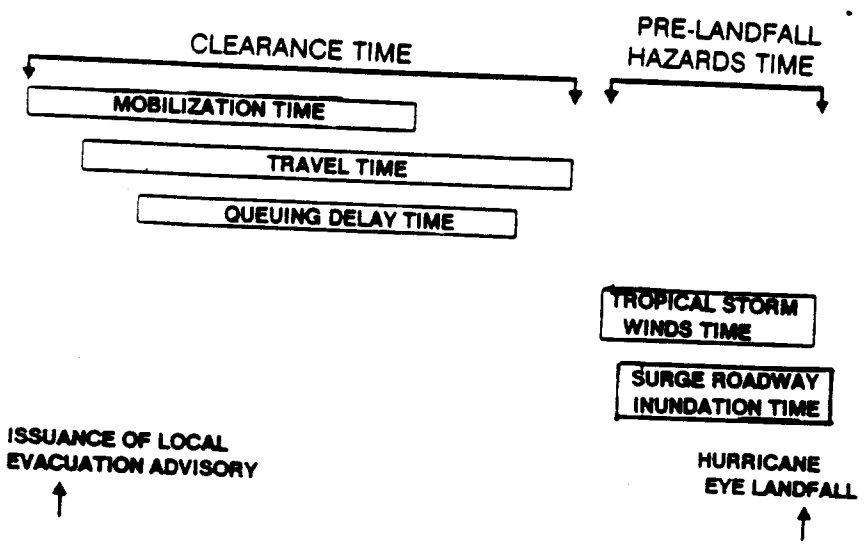
[ ] Reflects having two lanes northbound for evacuation on U.S. 1 from Milemarker 106/C.R.905 to Dade County line. First number is clearance time for Upper Keys residents as critical link shifts to U.S. 1 through Key Largo. Second number is clearance time for Lower and Middle Keys residents as critical link shifts to U.S. 1 between Key Colony Beach and Tavernier.

Critical roadway segments in Monroe County and the components of evacuation time follow:

CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS
MONROE COUNTY

U.S. 1 from County Road 905 intersection to Dade County line
U.S. 1 at Florida Turnpike (in Dade County)
U.S. 1 from Marathon to Tavernier - 2 lane section
Signalized intersection at Florida City on U.S. 1
Seven-Mile Bridge
U.S. 1 through Key Largo (at signalized intersection)
Cow Key Bridge
Jewfish Creek drawbridge
U.S. 1 through Marathon(at signalized intersections)
Flagler Street/Truman Avenue in Key West
Snakefish Creek drawbridge
(All Sheriff's Department control points)

COMPONENTS OF EVACUATION TIME



CHAPTER SEVEN
DECISION ASSISTANCE TOOLS

GENERAL

Decision information for the Florida Keys was developed using the study results, in consultation with Mr. William A. Wagner, Jr. the Emergency Management Director for Monroe County and in consideration of historical information relating to the most damaging modern day storms to hit the Florida Keys. Without question, the greatest risks for the Florida Keys are from intense storms coming from the east (generally, called "Cape Verde" storms) through the Bahamas that have not been impeded by significant land masses such as Cuba and the Dominican Republic. These storms have the following common characteristics (especially, the 1919, 1935 and 1960 storms):

a. They occurred in very early September.
b. They stayed north of Cuba and the Dominican Republic. Two of three passed north of Puerto Rico.
c. All came through the mid or lower Bahamas.
d. All were on west or west-northwest headings
e. None passed over large bodies of land (or mountains) that may have caused some loss of energy.

The storm paths are included in Figure 2-3. Although not included, Hurricane Betsy in 1965 also came through the Bahamas. The distance arcs shown on Figure 2-3 are centered on Marathon, Florida.

The three most important questions to be answered by local emergency management officials when threatened by an approaching hurricane are: 1) "Do I have to evacuate?", 2) "If so, when must the evacuation begin?" and 3) "Who must evacuate?". The general consensus of most emergency management officials is that an evacuation of the threatened population should be completed before the onset of tropical storm conditions in the community. Once these conditions begin to affect a community, evacuation becomes very difficult and dangerous due to the effect the strong winds, heavy rains and flying debris would have on vehicular traffic. It is appropriate to obtain the tropical force wind information from NOAA marine advisories where it is provided in terms of distances in miles from the center of the storm. Thus, if one knows the precise location of the storm, arcs defining the extent of the tropical force winds can be developed using the location of the storm as the center. The point where the tropical force wind arc intersects an arc defining a specific evacuation (or clearance) time converted to distance, would determine when, or at what storm location, the evacuation should begin.

In making a decision to evacuate, a local decision maker must consider a number of different factors. Among these are the strength of the storm, the forward speed of the storm, and the estimated clearance times (the time it takes to clear the county's roadways of all evacuating vehicles). Therefore, a great deal of information concerning each storm situation must be analyzed in order to make a well-informed decision concerning appropriate actions to be taken, and when to take them. To facilitate the foregoing determinations, a set of tables

were developed for a number of storm speeds matching clearance times and distances. These were then converted to a set of lines relating evacuation time and distances. The relationships are included in Figure 7-1. If one knows the approximate time needed for evacuation (from the transportation modeling), the point where the evacuation needs to begin can be determined. This can be called the decision maker's "arc of interest". The storm speeds in Figure 7-1 are shown as values that normally appear in the NOAA advisories. Should one be confronted with a value not appearing on the Figure, the distance can then be calculated or interpolated.

The only thing that the decision maker then needs to determine is where the storm center will be when the tropical force winds arrive at the "arc of interest". He can readily determine the current position and location in miles from his place of interest from the advisories and through plotting on the decision chart. From the advisories he then obtains the extent of the tropical force winds in miles and subtracts that from the center of storm location in miles to see where the tropical force winds are <u>now</u>. He then determines the difference in miles between this point and his "arc of interest" thus determining the distance the hurricane must move. Knowing the storm speed, he then knows how many hours are available before the tropical force winds reach his arc of interest. Examples are provided on Figures 7-2 and 7-3 for determination of the critical values. The example uses statute miles and mph. The information from the advisories is in nautical miles and knots.

Table 7-1 portrays clearance times for four response levels and three tourist occupancy levels. Clearance times were then converted to distances for various storm speeds and matched with a lettered decision arc on Figures 7-4,7-5 or Figure 7-6 (depending on the storm approach). Distances were rounded to match the next highest arc (or the next one away from the center). This decision arc then becomes the "arc of decision" for the emergency manager.

Three basic decision charts have been developed for Monroe County (Florida Keys). One is centered on Marathon, Florida and another primary one on Key Largo. Using the center at Key Largo would give the decision maker the maximum time available. They are presented as Figures 7-4 and 7-5. In addition a third decision chart is included for Key West on Figure 7-6. An examination of historical storms indicates that some Category 3 storms have approached Key West and the Lower Keys from the South. Thus, it was considered important to also develop arcs with Key West as the center. A storm plot overlay is included as Figure 7-7.

The purpose of this chapter is to describe the decision assistance tools, provided as a product of this study effort, and the proper ways to utilize them. Because of the wealth of technical information which must be reviewed and assimilated in a very short time during periods of threat, it was imperative that tools be developed to assist decision makers with this task. As a result, the Decision Arc system and the HURREVAC computerized decision assistance system were developed for this purpose. The utilization of both are subsequently described.

DECISION ARCS

There are four (4) basic "tools" you will need in your evacuation decision process: (1) county Decision Arc Map; (2) county Decision Arc tables; (3) transparent STORM disk; (4) the NOAA National Weather Service (NWS) marine advisory.

1. From the NWS marine advisory, plot the last reported position of the hurricane eye on the county 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 four forecast positions of the hurricane from the advisory.

2. From the marine advisory, note the largest radius of 34-knot winds, the forecast maximum sustained wind speed at landfall (to determine hurricane category), and the current forward speed.

3. Using the forecast maximum sustained wind speed in knots at landfall and the Saffir/Simpson Hurricane Scale, determine the category of the approaching hurricane. The Saffir/Simpson scale with maximum sustained wind speeds in knots is in a table at the end of this worksheet. Because of potential forecast and SLOSH model inaccuracies, it may be advisable to add one category to the forecast landfall intensity. With the category and the current forward speed, enter the county Decision Arc table and select the appropriate clearance time and corresponding Decision Arc. Mark this arc on the county Decision Arc Map.

4. Plot the largest radius of 34-knot winds onto the transparent STORM.

5. Using the center of the STORM as the hurricane eye, locate the STORM on the Decision Arc Map at the last reported hurricane position. Note if the radius of 34-knot winds falls within the Decision Arc. If so, the hurricane has passed the Decision Point (the point at which the radius of 34-knot winds crosses into the selected Decision Arc). In this case, measures should be taken to ensure a rapid public response in order for the evacuation to be completed prior to the arrival of sustained 34-knot winds (or consider advising no evacuation).

6. Determine the forecast forward speed of the hurricane by measuring the distance between the first and second forecast positions and dividing by 12. A speed faster than the current forward speed will indicate that the hurricane is forecast to accelerate, and, therefore, that less time will be available to the decision-maker. If forecast forward speed is greater than current, reenter the Decision Arc table and select the appropriate Decision Arc.

7. Move the STORM to the first forecast position. Again, note if the radius of 34-knot winds falls within the Decision Arc. If so, the recommendation to evacuate should be given before the hurricane eye reaches the first forecast position.

8. Determine as closely as possible how many hours remain before a decision must be made. Determine if sufficient time remains to evacuate after the next NWS marine advisory will be received. Use the probabilities table in the marine

advisory to determine where an evacuation is likely to take place. Determine how other counties would be affected by an evacuation of your county, and when they should be notified. Check inundation maps to determine where flooding may occur, and evacuation zone maps for zones that should evacuate.

9. At the Decision Point, check the probability table for your location. If probability is greater than 30 percent, strongly consider recommending evacuation. If the probability is less than 30 percent, you are encouraged to contact your Area Coordinator or State emergency operations center for recommendations.

10. Steps 1 through 9 should be repeated after each NWS advisory until a decision is made by the county.

Because information given in the marine advisory is in nautical miles and knots, the Decision Arc Maps and STORM have a nautical miles scale. 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.

SAFFIR/SIMPSON HURRICANE SCALE RANGES

Scale Number 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

HURREVAC

Some of the most important products developed as a part of the FEMA/Corps of Engineers hurricane studies and delivered to local state officials have been evacuation decision making tools. These tools have been decision arc maps and tables such as contained in this report, as well as computer software. Products such as these graphically tie together real-time storm characteristics with clearance time data. Their purpose is to give directors a means of retrieving technical information without having to dig through a report during an emergency. Evacuation decision tools suggest when an evacuation should begin relative to a specific hurricane, its associated wind field, forward speed, probabilities, forecast track, and intensity.

A computerized informational model has been developed which utilizes technical data contained in the study along with information contained in the marine and public advisories from the National Hurricane Center. The model, called HURREVAC, is a tool to assist local officials in making hurricane evacuation decisions. HURREVAC was adapted to Georgia and its data base and delivered to county officials just days before Hugo threatened the area.

After entry of Hurricane Center Marine Advisory data into the HURREVAC program the emergency manager can know within a few seconds, the implications of the latest Advisory for his community..such things as Gale Arrival time, Evacuation Decision time, Eye Arrival time, Evacuation Clearance time, extent of flooding from the Zone Map graphics, etc., all based on official data and Federal studies, and a quick idea of the Evacuation Scenario that could develop, based on historical evacuation patterns.

Using HURREVAC, a new Emergency Management official can quickly get "up to speed" on the complexities of the situation...a process which might have taken many months (or years) of experience to develop. HURREVAC can be used to run hypothetical hurricanes into the area as valuable training.

Following are the main features of the HURREVAC program:

QUICK DATA ENTRY - The Data Entry screen is designed to allow quick and easy entry to data from the NHC Marine Advisory. The program automatically handles non-standard Advisories such as Special and Intermediate Advisories, allowing you to update every 2 or 3 hours when the storm gets close.

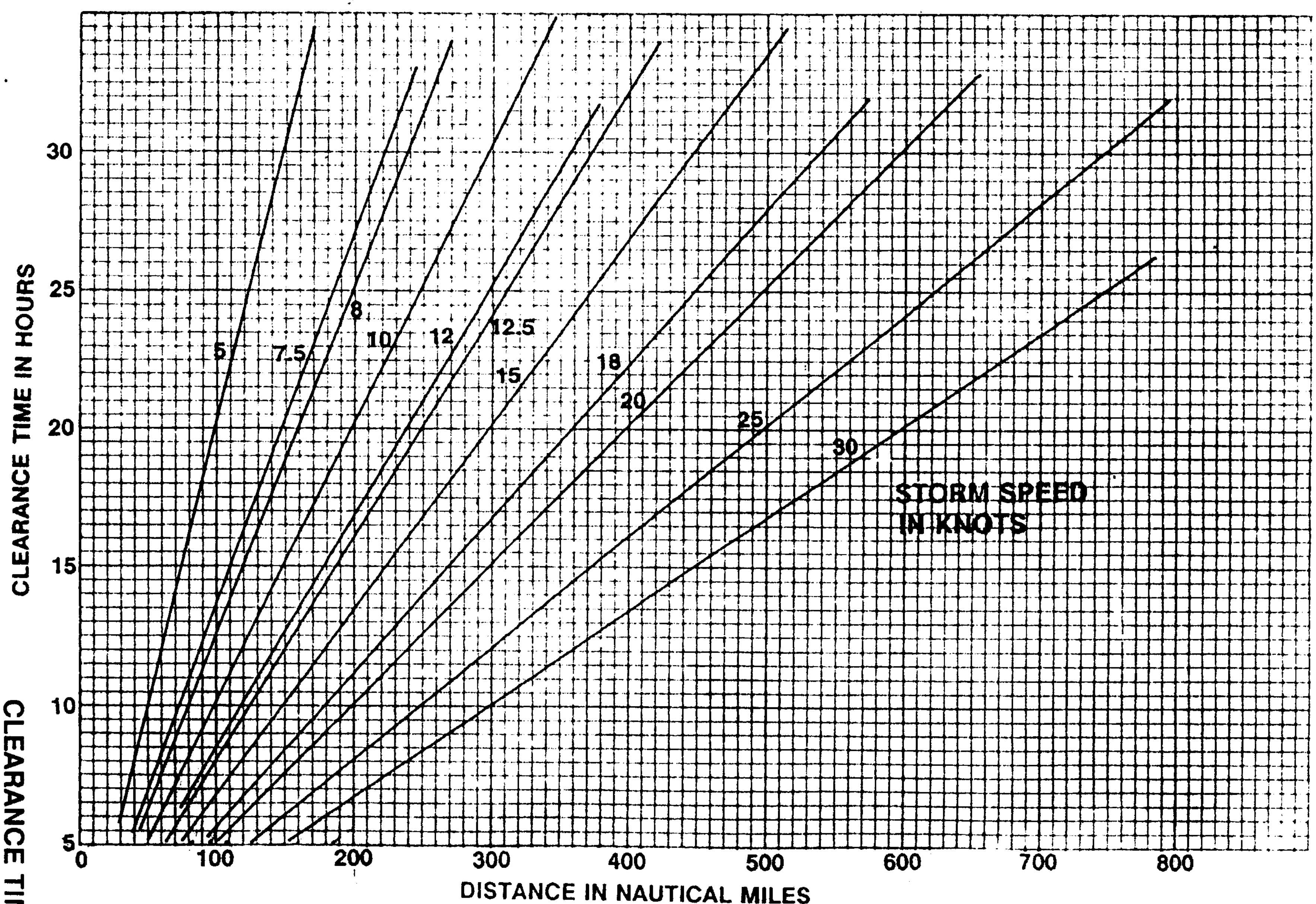
RUN "WHAT IF" SCENARIOS - The program allows you to adjust the Storm intensity and track to quickly see the effect of unanticipated changes in those parameters on your area.

EVACUATION ZONES MAPS - Quickly bring up computer graphics showing the SLOSH generated flooding maps for your area, for this storm or any other Category of storm. Evacuation Zones and Flooding scenarios are highlighted. One can cycle through the maps using just the arrow keys on the keyboard...Up/Down arrows to access the next higher or lower Category map, Right/Left arrows to access maps for an adjacent area or county.

SHELTER DISPLAYS - See which shelters are available, their capacity and their vulnerability to storm surge, for each storm Category.

RESEARCH/TRAINING CAPABILITY - Run old Advisories or make up new storms to test Emergency Management actions and procedures. Computer will set the Date/Time for you and restore your original time upon exit.

The HURREVAC model is being provided all four counties in the Lower Southeast Florida study area.



CLEARANCE TIMES
STORM SPEEDS
AND DISTANCES
FIGURE 7-1

DECISION ARC INFORMATION

EXAMPLE

1. Determine Arc of Interest from lines on Figure 7-1.
   Example: 20 hours clearance time needed.
   Storm moving 15 mph = 300 miles.

2. Determine location of storm center from advisory.
   Example: Longitude 74.7
   Latitude 21.5 @ 500 miles

3. Determine extent of tropical force winds from advisory.
   Example: tropical force winds extend 125 miles
   500 - 125 = 375 miles location

4. Determine how much time is available before tropical force winds reach the "Arc of interest".
   Example: 375 - 300 = 75 miles
   Storm moving 15 mph
   Answer: 5 hours available (before evacuation order must be given)

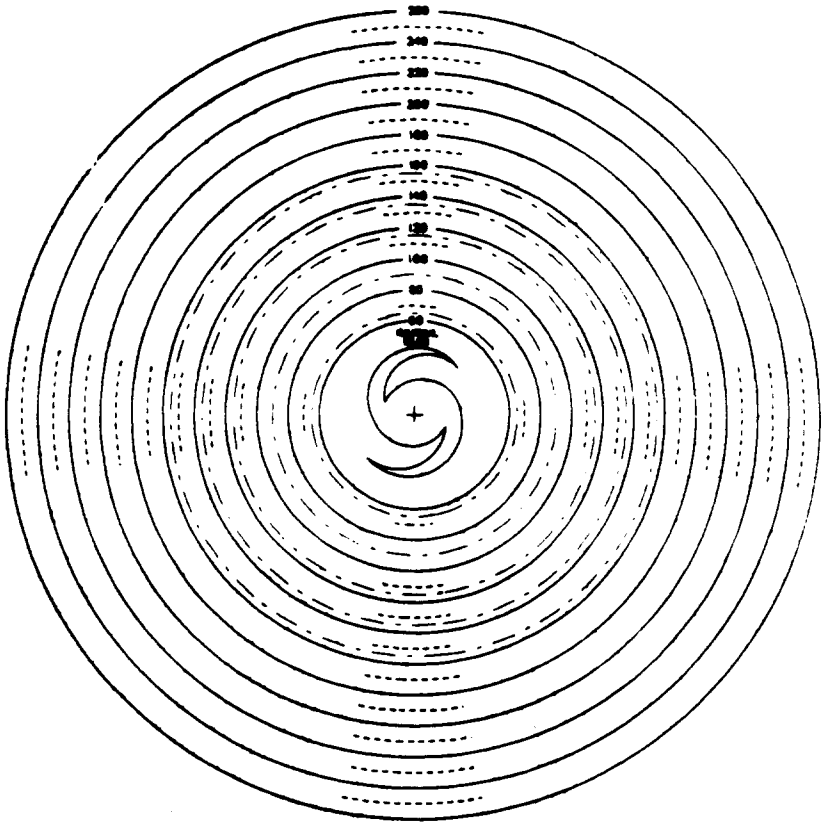
5. From advisory determine 12 hour forecast position of storm. Subtract from current storm center position in miles (in this example 500 miles) to determine how far storm is expected to move in 12 hours. Divide by 12 to determine new forecasted storm speed.

6. Utilizing forecasted storm speed go back and re-determine arc of interest. Continue process, if needed.

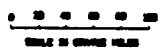
Numbers used in this example are in mph and statute miles.

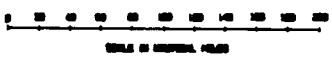
The example is based on arcs centered at Marathon. More than likely, the critical determination may have to be made utilizing arc information at Key Largo(Figure 7-5) because it would give the decision maker the maximum time available.

FIGURE 7-2



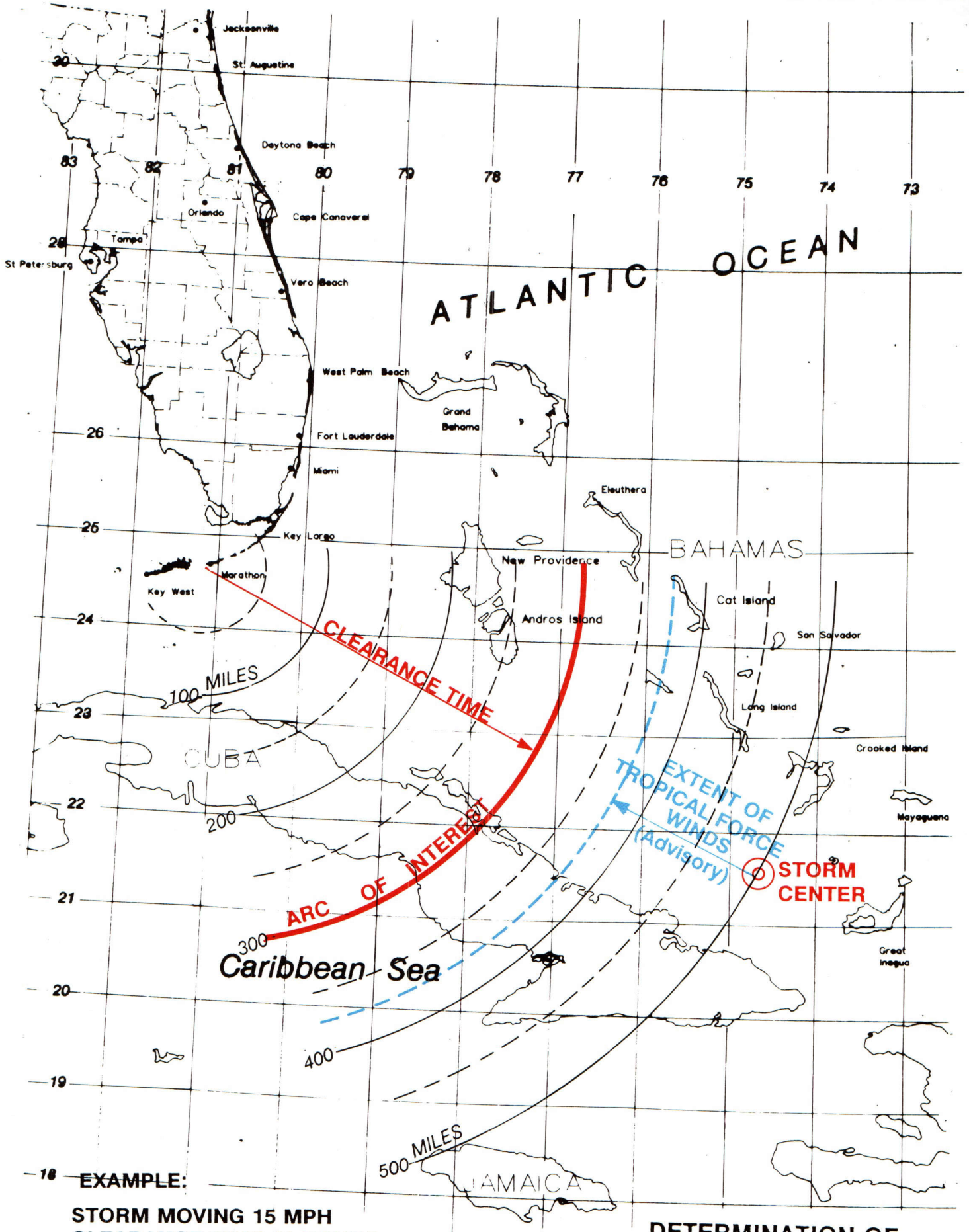
STORM PLOT OVERLAY





MONROE COUNTY

FIGURE 7-7

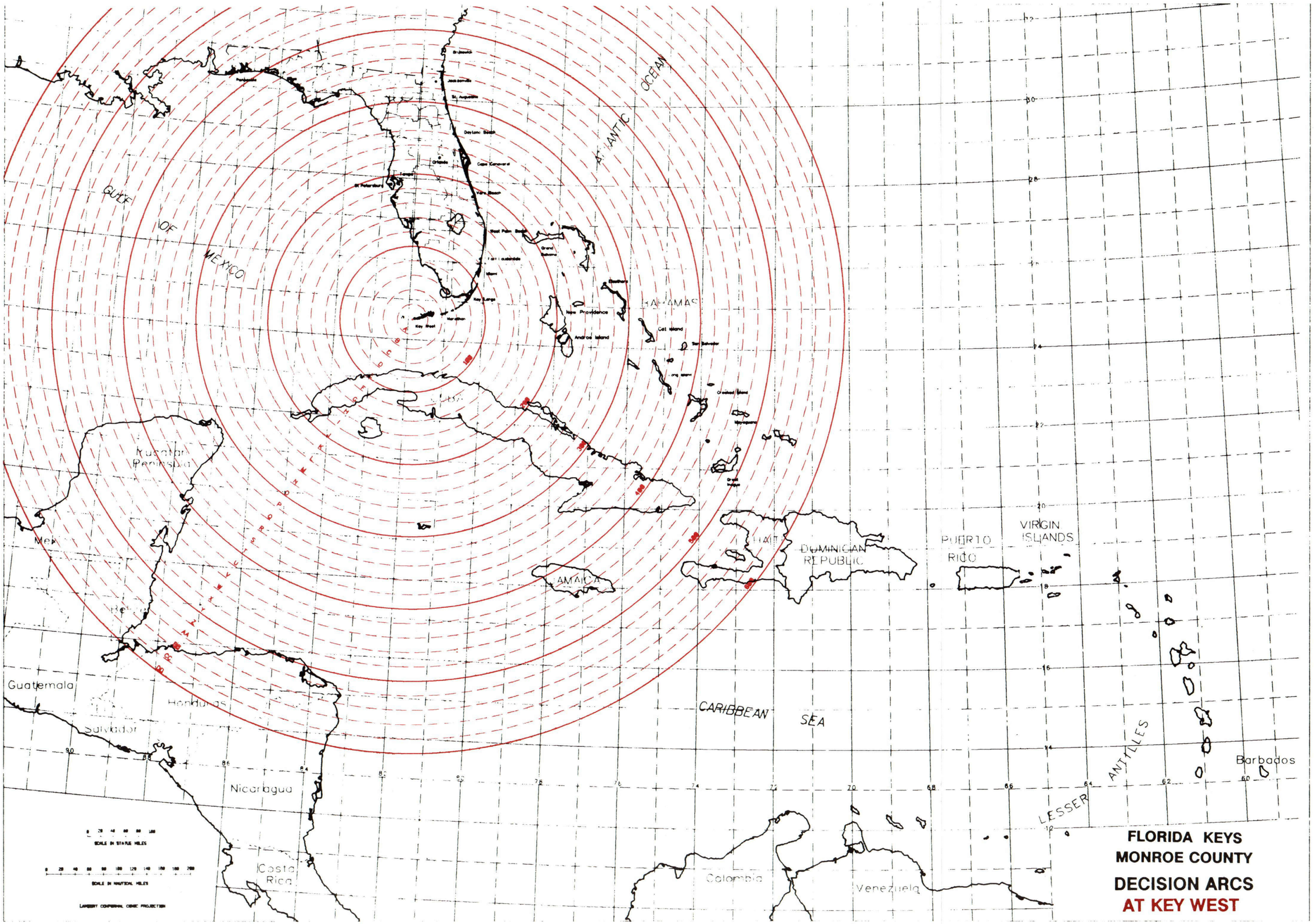


EXAMPLE:

STORM MOVING 15 MPH
CLEARANCE TIME 20 HOURS

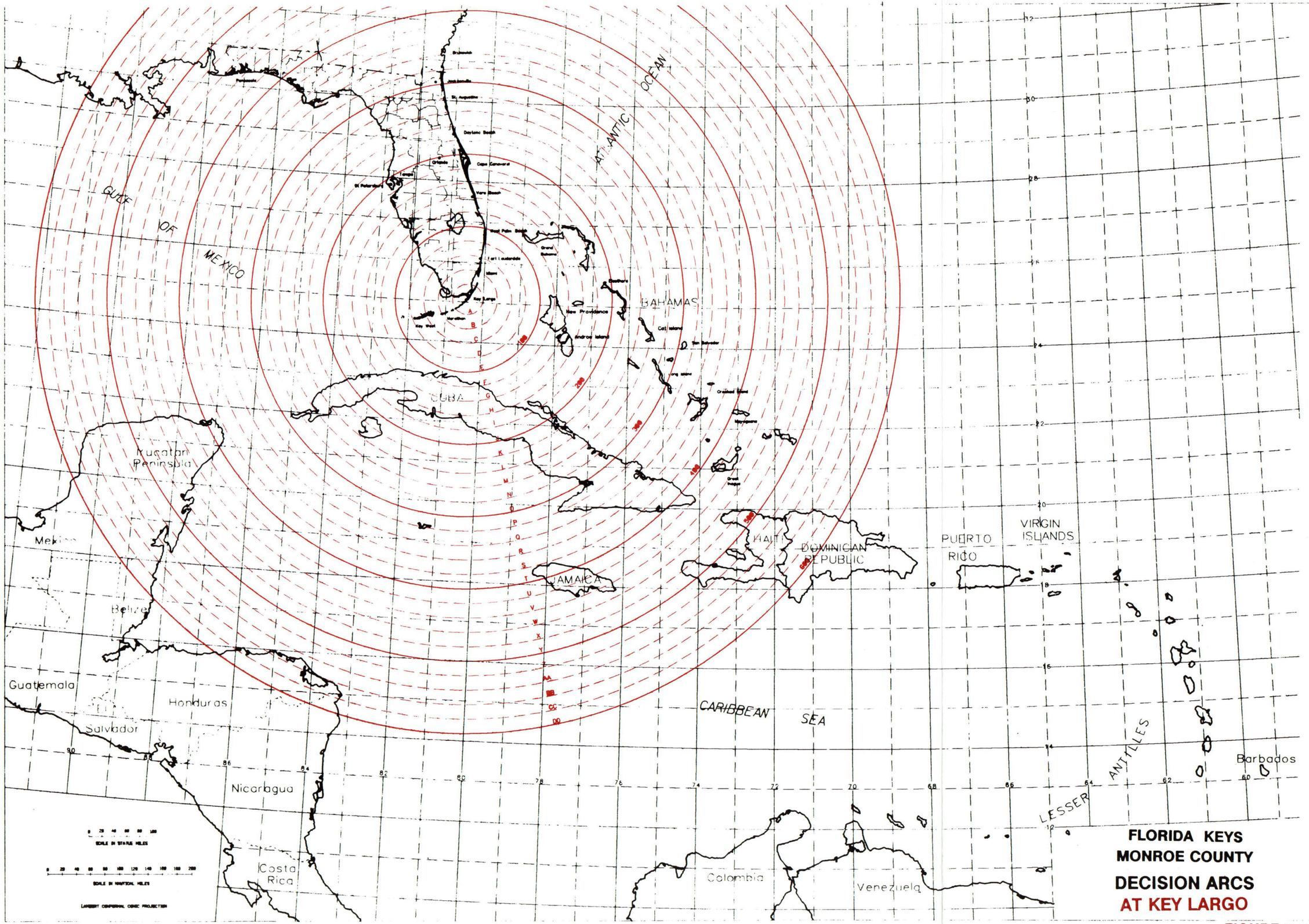
DETERMINATION OF TIME FRAMES AND CRITICAL DISTANCES

FIGURE 7-3



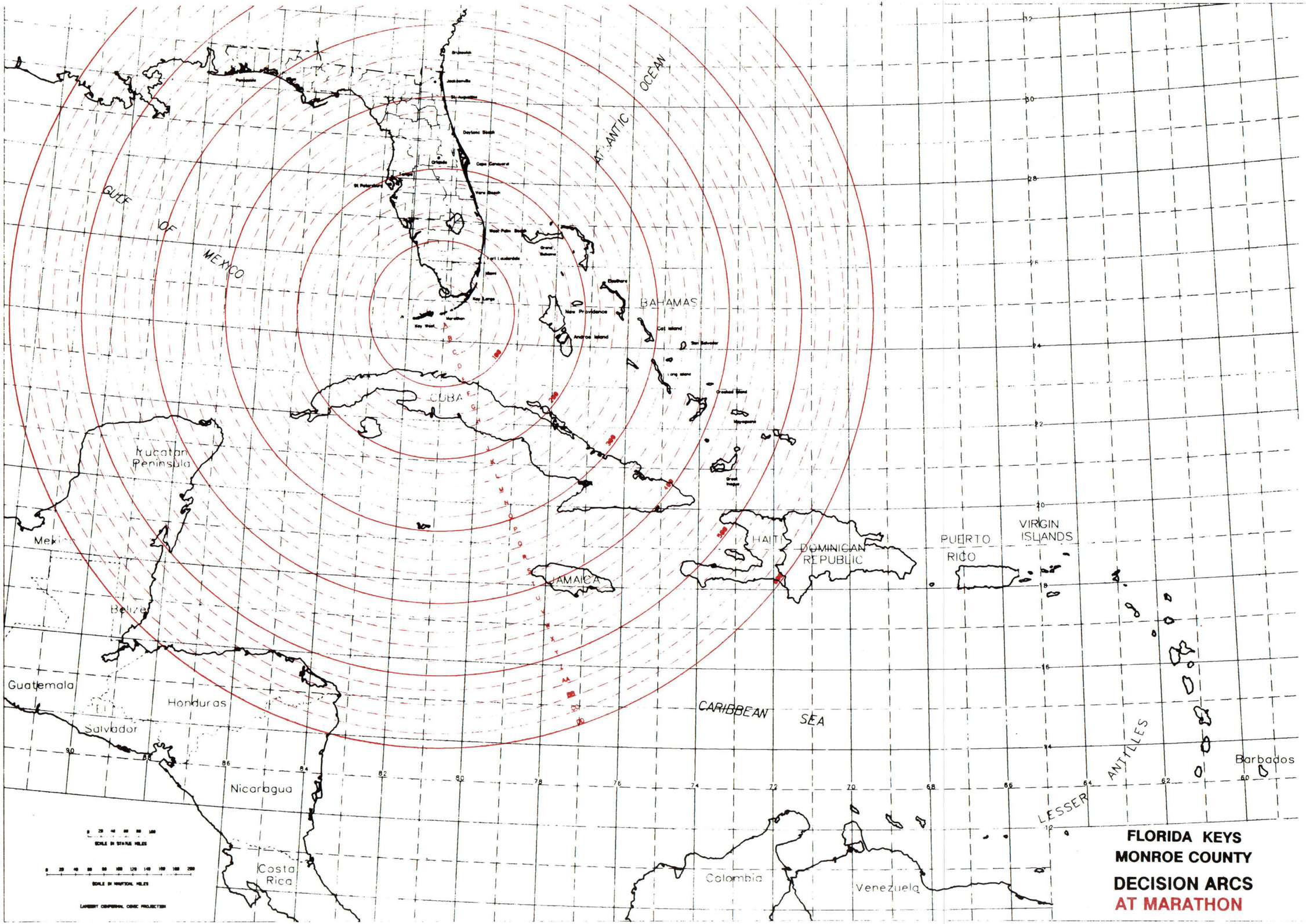
FLORIDA KEYS
MONROE COUNTY
DECISION ARCS
AT KEY WEST

FIGURE 7-4



FLORIDA KEYS
MONROE COUNTY
DECISION ARCS
AT KEY LARGO

FIGURE 7-5



FLORIDA KEYS
MONROE COUNTY
DECISION ARCS
AT MARATHON

FIGURE 7-6

TABLE 7-1

DECISION ARC DATA
LOWER, MIDDLE, AND UPPER KEYS
CATEGORIES 1-2
WITH ONE LANE NORTH OUT OF FLORIDA KEYS

Cat 1-2	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	17 1/4	20	22
R	Rapid	17 1/2	20 1/2	22 3/4
M	Medium	18 1/4	21 1/2	23 3/4
S	Slow	19 1/2	22 1/2	24 3/4

Note: Minus 3 1/2 hours, on the average, with 2 lanes north out of keys (see corresponding arc data)

Storm* Speed Response	Decision Arc with 1 lane north N	L	H	Storm* Speed Response	Decision Arc with 1 lane north N	L	H
10-I	I	J	K	15-I	M	O	Q
10-R	I	K	L	15-R	N	P	R
10-M	J	K	L	15-M	N	Q	R
10-S	J	L	M	15-S	O	Q	S
	N	L	H		N	L	H
20-I	R	T	V	25-I	V	Y	BB
20-R	R	U	W	25-R	V	Z	CC
20-M	S	V	X	25-M	W	AA	DD
20-S	T	W	Y	25-S	Y	CC	EE

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
LOWER, MIDDLE, AND UPPER KEYS
CATEGORIES 1-2
WITH TWO LANES NORTH OUT OF FLORIDA KEYS

Cat 1-2	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	13 3/4	16 1/2	18 1/2
R	Rapid	14	17	19 1/4
M	Medium	14 3/4	18	20 1/4
S	Slow	16	19	21 1/4

Storm* Speed-Response	Decision Arc with 2 lanes north N	L	H	Storm* Speed-Response	Decision Arc with 2 lanes north N	L	H
10-I	G	I	J	15-I	K	M	N
10-R	G	I	J	15-R	K	M	O
10-M	H	I	K	15-M	L	N	P
10-S	H	J	K	15-S	L	O	P
	N	L	H		N	L	H
20-I	N	Q	S	25-I	R	U	X
20-R	N	Q	T	25-R	R	V	Y
20-M	O	R	U	25-M	S	W	Z
20-S	P	S	V	25-S	V	X	AA

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
LOWER, MIDDLE, AND UPPER KEYS
CATEGORIES 3-5
WITH ONE LANE NORTH OUT OF FLORIDA KEYS

Cat 3-5	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	28 3/4	32 3/4	35 1/4
R	Rapid	29	33 1/4	36
M	Medium	29 3/4	34	37
S	Slow	31	35	38

Note: Minus 6 1/2 hours, on the average, with 2 lanes north out of keys (see corresponding arc data)

Storm* Speed-Response	Decision Arc with 1 lane north N	L	H	Storm* Speed Response	Decision Arc with 1 lane north N	L	H
10-I	O	Q	R	15-I	V	Y	AA
10-R	O	Q	R	15-R	V	Y	AA
10-M	O	Q	S	15-M	W	Z	BB
10-S	P	R	S	15-S	X	AA	CC
	N	L	H		N	L	H
20-I	CC	GG	JJ	25-I	JJ	OO	SS
20-R	CC	HH	JJ	25-R	KK	PP	SS
20-M	DD	HH	KK	25-M	LL	QQ	UU
20-S	EE	II	LL	25-S	MM	RR	VV

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
LOWER, MIDDLE, AND UPPER KEYS
CATEGORIES 3-5
WITH TWO LANES NORTH OUT OF FLORIDA KEYS

Cat 3-5	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	22 1/4	26 1/4	28 3/4
R	Rapid	22 1/2	26 3/4	29 1/2
M	Medium	23 1/4	27 1/2	30 1/2
S	Slow	24 1/2	28 1/2	31 1/2

Storm* Speed-Response	Decision Arc with 2 lanes north N	L	H	Storm* Speed-Response	Decision Arc with 2 lanes north N	L	H
10-I	L	N	O	15-I	Q	T	V
10-R	L	N	O	15-R	Q	U	W
10-M	L	N	P	15-M	R	U	W
10-S	M	O	P	15-S	S	V	X
	N	L	H		N	L	H
20-I	W	AA	CC	25-I	BB	GG	JJ
20-R	W	AA	DD	25-R	CC	HH	KK
20-M	X	BB	EE	25-M	DD	II	MM
20-S	Y	CC	FF	25-S	EE	JJ	QQ

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
UPPER AND MIDDLE KEYS
CATEGORIES 1-2

Cat 1-2	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	11	12 3/4	14
R	Rapid	11 1/4	13	14 1/2
M	Medium	12	14	15 3/4
S	Slow	13 1/2	15	16 1/2

Storm* Speed-Response	Decision Arc N	L	H	Storm* Speed-Response	Decision Arc N	L	H
10-I	F	G	G	15-I	I	J	K
10-R	F	G	H	15-R	I	J	K
10-M	G	G	H	15-M	I	K	L
10-S	G	H	I	15-S	K	L	M
	N	L	H		N	L	H
20-I	K	M	N	25-I	N	P	R
20-R	L	M	O	25-R	O	Q	S
20-M	L	N	P	25-M	O	R	T
20-S	N	O	Q	25-S	Q	S	U

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
UPPER AND MIDDLE KEYS

CATEGORIES 3-5

Cat 3-5	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	18 1/2	21 1/2	23 3/4
R	Rapid	18 3/4	22	24 1/2
M	Medium	19 1/4	22 3/4	25 1/2
S	Slow	20 1/2	23 1/4	26 1/2

Storm* Speed-Response	Decision Arc N	L	H	Storm* Speed-Response	Decision Arc N	L	H
10-I	J	K	L	15-I	N	Q	R
10-R	J	K	M	15-R	O	Q	S
10-M	J	L	M	15-M	O	R	T
10-S	K	L	N	15-S	P	R	T
	N	L	H		N	L	H
20-I	S	V	X	25-I	X	AA	DD
20-R	S	V	Y	25-R	X	BB	EE
20-M	T	W	Z	25-M	Y	CC	FF
20-S	U	X	AA	25-S	Z	DD	HH

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
LOWER AND MIDDLE KEYS

CATEGORIES 1-2

Cat 1-2	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	10 1/2	12 1/2	13 3/4
R	Rapid	11	13	14 1/2
M	Medium	12 1/4	14 1/4	16
S	Slow	13 1/2	15 1/2	17

Storm* Speed-Response	Decision Arc N	L	H	Storm* Speed-Response	Decision Arc N	L	H
10-I	F	G	G	15-I	H	J	K
10-R	F	G	H	15-R	I	J	K
10-M	G	H	H	15-M	J	K	L
10-S	G	H	I	15-S	K	L	M
	N	L	H		N	L	H
20-I	K	M	N	25-I	N	P	R
20-R	K	M	O	25-R	N	Q	S
20-M	M	O	P	25-M	P	R	T
20-S	N	P	Q	25-S	Q	T	V

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
LOWER AND MIDDLE KEYS

CATEGORIES 3-5

Cat 3-5	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	20 1/2	24 1/4	26 3/4
R	Rapid	21	24 3/4	27 1/2
M	Medium	22 1/4	26	28 3/4
S	Slow	23 1/4	27	29 3/4

Storm* Speed-Response	Decision Arc N	L	H	Storm* Speed-Response	Decision Arc N	L	H
10-I	K	M	N	15-I	P	S	U
10-R	K	M	N	15-R	P	S	U
10-M	L	M	O	15-M	Q	T	V
10-S	L	N	O	15-S	R	U	W
	N	L	H		N	L	H
20-I	U	Y	AA	25-I	Z	EE	
20-R	U	Y	BB	25-R	AA	EE	
20-M	W	Z	CC	25-M	BB		
20-S	Y	AA	DD	25-S	DD		

*Storm speed in knots

TABLE 7-1 (con't)

DECISION ARC DATA
TRAFFIC MOVEMENTS WITHIN
LOWER AND MIDDLE KEYS

CATEGORIES 1-2

Cat 1-2	Evacuee Response	Clearance times in hours for 3 tourist occupancy levels N No	L Low	H High
I	Immediate	7 1/2	8 3/4	10
R	Rapid	7 3/4	9 1/4	10 3/4
M	Medium	8 3/4	10 3/4	12 3/4
S	Slow	11	11 1/2	14

Storm* Speed-Response	Decision Arc N	L	H	Storm* Speed-Response	Decision Arc N	L	H
10-I	D	E	E	15-I	F	G	H
10-R	D	E	F	15-R	F	G	I
10-M	E	F	G	15-M	G	I	J
10-S	F	F	G	15-S	I	I	K
	N	L	H		N	L	H
20-I	H	I	J	25-I	J	K	M
20-R	H	J	K	25-R	J	L	N
20-M	I	L	M	25-M	K	N	P
20-S	L	M	N	25-S	N	N	R

Utilizing Key West Decision Arcs

*Storm speed in knots

CHAPTER EIGHT
POSSIBLE ACTIONS
FOR CONSIDERATION

GENERAL

Due to the amount of time required to evacuate based on the evacuation time tables and the need to complete an evacuation operation prior to the arrival of tropical storm conditions, it is likely that a decision would have to be made when the center of the storm is 400 to 600 miles east/southeastward. For most storms, this equates to at least 25 to 30 hours ahead of the arrival of tropical force winds. Obviously, this creates some very real problems because, even for storms within the 270-292.5 "Bahama Boundary", it is still anyone's guess as to where it will actually strike. Thus, there is a great propensity to "buy" as much time as possible to avoid a major (conceivably, unnecessary) evacuation. In this regard, the best available technology, when applied to storm forecasting, can only offer a 15% to 20% probability that the Keys will be affected when the evacuation order must be issued.

All of the above is extremely relevant. However, if it is a large, intense storm, there is no question that evacuation should proceed. At this point strategies must begin in order to minimize the impacts and to maintain the control which must be exercised in the first stages of an evacuation procedure. Obviously, the evacuation should be staged such that,at a minimum, the following might occur:

a. Tourists should leave the Keys as early as possible. All motels, hotels, campsites and RV parks should be closed.

b. Upper Keys residents should leave the Keys as early as possible.

c. An urgent appeal to evacuate must be made by the public officials through the media.

d. Navy and Coast Guard personnel could be utilized to assist in evacuating persons in hospitals, nursing homes and those with special medical needs.

e. Traffic control and vehicle assistance provisions must be available well in advance or when the storm is 500-600 miles out, depending on the forward speed of the storm. Each critical intersection should be manned.

The foregoing basically would result in two evacuations, one as early as possible and another somewhat later. Meanwhile, the storm is being monitored to ensure that selective movements of the remaining people in the Lower and Middle Keys can be made depending on 1) what the storm is doing and 2) on the strike probabilities. All of this assures, of course, that the minimum strategies outlined above are implemented (and agreed upon before hand). If during and near the end of the initial stage, the storm is still a large-intense storm and the probability of landfall in the Florida Keys has not diminished appreciably, full scale mass evacuation of all of the Keys should be ordered. Hurricane Gilbert

was a good example of the foregoing decision making process. Had it turned northerly and the probability been higher, evacuation would have been ordered.

One of the major decisions that has already been made is to evacuate all of the Florida Keys for Category 3-5 storms. The Hurricane Evacuation Study Analysis confirms this decision. It is also possible that all of the Keys will be evacuated for a lesser storm. The shelter analyses confirms that the identified shelters can be purposefully identified for Categories 1 and 2 storms. However, to say they are all safe and acceptable beyond the Category 2 storm may be more of a guess.

In addition to all of the above, to suggest shelter acceptability and use "carte-blanche" may invite a considerable number of "non-evacuees" and this is one thing that needs to be discouraged for a large intense storm.

Additional suggested strategies would be to include having a four lane highway north from Key Largo toward Homestead. This would create an additional evacuation lane. It might also be possible with four lanes, to use three lanes in the evacuation process. One emergency lane must be retained for access to the Keys.

All available tow trucks should be positioned or on call along key travel corridors and critical links. At a minimum, tow trucks should be at all two lane bridge crossings to remove disabled vehicles. Tolls should be suspended on facilities such as the Florida Turnpike, once an evacuation begins. This will facilitate a smoother evacuation throughout southeast Florida. For the traffic coming out of the Florida Keys, it is imperative that traffic be able to flow unimpeded through the Homestead and Tamiami stations.

All draw bridges needed for evacuation should be locked in the "down" position for either a hurricane warning or an ordered evacuation. Boat owners must be made aware of flotilla plans and time requirements for securing vessels. This judgement will need to be made on a case by case basis through discussions with the U. S. Coast Guard, local emergency officials and the State DOT. Past mechanical problems with open bridges in the Keys make this imperative.

All protective actions pertaining to recreational vehicles should be completed prior to or during the hurricane watch period. The movement of mobile homes, campers and boat trailers along evacuation routes should not be permitted after a hurricane warning is issued. A disabled camper/RV could block the only escape route available for evacuation in the Keys. Such vehicles are difficult to handle late in an evacuation due to sporadic wind gusts.

Signal patterns providing the most "green time" for the northbound traffic leading out of the Keys should be actuated by the State DOT field office or local traffic engineer's office, as appropriate. This is especially important for the Palm Avenue intersection in Florida City. Traffic conditions and public information should be conveyed to evacuees through Emergency Broadcast System (EBS) Stations and programmable signs.

The County Emergency Operations Center(EOC) should be built to Category 5 standards.