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Hurricane Emergency Planning: Estimating Evacuation Times For Non-Metropolitan Coastal Communities

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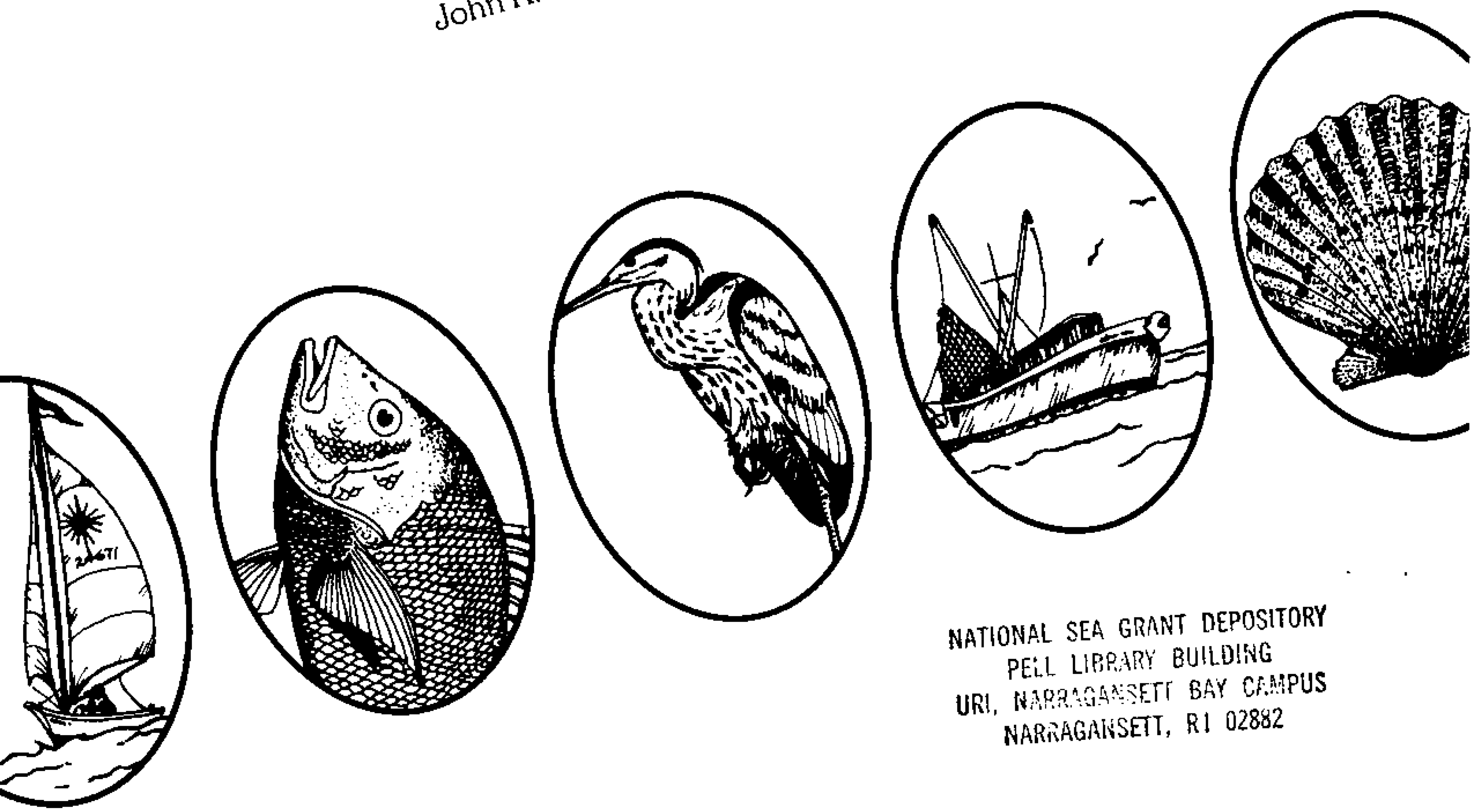

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HURRICANE EMERGENCY PLANNING:

ESTIMATING EVACUATION TIMES FOR NON-METROPOLITAN COASTAL COMMUNITIES

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ABSTRACT

Deciding when to evacuate coastal communities is a critical issue in hurricane emergency planning. Extensive data on the transportation system and the community are normally required, and it is usually processed by computer methods to estimate evacuation time. While computer methods are appropriate for large metropolitan areas which have the necessary technical expertise and resources, computer methods are not practical for small and many medium-size communities. This report addresses this problem and presents simplified methods which will allow the estimation of evacuation time for coastal communities which have relatively few evacuation zones and an uncomplicated network of evacuation routes. The simplified methods are demonstrated for two case study communities.

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I. INTRODUCTION

A. Project Description

Deciding when to evacuate coastal communities is a critical issue in hurricane emergency planning. Sufficient time must be allowed to clear populations from threatened areas, but determining the required amount of time can be a difficult, expensive task unless simplified methods can be used.

Evacuation time depends on the characteristics of the community, the attitudes of its residents, the transportation system, the coastal topography and the storm itself. Extensive data bases and computer analyses, which are usually required to describe and process these characteristics, have been successfully used by consultants and government agencies to develop evacuation plans for large metropolitan areas. However, data-intensive, computer-based methods are not appropriate for small, perhaps rural, coastal communities which wish to conduct their own emergency planning and response. In these areas, extensive data, technical expertise and computers are not usually available, and less sophisticated methods are desirable. Furthermore, traditional computer-based methods that require detailed transportation network coding and programming are not cost-effective methods for even the professional analyst to use for small communities.

For these reasons this project will examine the feasibility of using simplified methods to determine evacuation time.

B. Goals and Objectives

The goal of this study is to demonstrate the use of simplified techniques to estimate evacuation times for several small coastal communities. The several specific steps toward reaching this goal are as follows:

- To define the evacuation problem facing coastal communities
- To review methods for determining evacuation time
- To demonstrate a simplified method for determining evacuation time
- To suggest future directions for developing simplified evacuation planning methods

Each of these objectives is addressed by this project report which is briefly summarized below.

C. Overview

Besides this first introductory chapter, the report contains five other chapters. Chapter II describes the threat of hurricanes and places the problem of estimating evacuation time in perspective with the other aspects of emergency planning. Chapter III defines the components which make up evacuation time, discusses computerized and non-computerized methods for determining the evacuation time components and gives typical values for the components. Chapters IV and V demonstrate the use of simplified methods to estimate evacuation times for two coastal communities in North Carolina. The first community is typical of barrier island vacation communities which have large summertime populations served by limited transportation links to the mainland. The second community is typical of low-lying, mainland communities which are susceptible to flooding by wind tide or set-up in the sounds and major rivers of eastern North Carolina. Chapter VI summarizes the results of the project and makes recommendations for future work.

II. HURRICANE EMERGENCY PLANNING

A. The Hurricane Threat

Hurricanes are born at sea and nurtured by powerful atmospheric dynamics. They are among the most destructive of natural events and have been known to cause billions of dollars in damage and kill thousands of people. As they move toward coastlines, waves and tidal surges as high as 20 feet can crash over beaches and inundate entire communities. Depending on the strength of the storm, beach-front homes, hotels and businesses can be washed away.

While storm tides are the hurricane's worst killer, gale-force winds reinforced by tornadoes wreck their share of damage also. In addition, the torrential rains which accompany hurricanes can flood inland areas, cut off escape routes and leave further death and destruction.

When the hurricane season begins in June, weather officials warn millions of residents along the Atlantic and Gulf coasts that they should not treat lightly the threat of hurricanes. According to James P. Walsh of the National Oceanic and Atmospheric Administration, U.S. coastal areas are more vulnerable to a major hurricane now than ever before (1). More than 60 million persons live on the Atlantic and Gulf coasts and millions more vacation in these areas. If escape is necessary, evacuation routes will be severely congested. In many cases according to Dr. Neil Frank, Director of the National Hurricane Center, evacuation routes have remained virtually unchanged in 25 years while coastal development has boomed. The fact is that in some populous communities or vacation areas with limited access like the Outer Banks of North Carolina, <u>the evacuation time exceeds the reliable warning time</u> that is issued by the National Hurricane Center (2). While state-of-the-art forecasting techniques strive for reliable 12-hour predictions of the landfall of the hurricane eye, evacuation times for some communities and vacation areas approach or exceed 20 hours. Hence, life-threatening situations face many coastal residents unless they receive adequate warnings and know when to evacuate.

The situation is particularly dangerous in North Carolina which has not experienced a major hurricane in more than two decades. The absence of an intense hurricane has bred a false sense of security among coastal residents. People tend to forget Hurricane Hazel which hit North Carolina in 1954 and killed 19 people while destroying $100 million in property (1). Near Wilmington, Hazel destroyed all but 5 of 357 homes on barrier islands. As that memory faded about 2000 new homes were built in the same general area (4). Since there is much more coastal development now than in 1954, the potential for lost lives and property along our coastlines has ominously multiplied.

B. Vulnerable Areas

Any Atlantic or Gulf coast state is vulnerable to hurricanes. In order to alert people to the most hazardous areas so that proper emergency planning can take place, the Federal Emergency Management Administration (FEMA) identified the critically vulnerable areas as shown in Table II-1. FEMA selected these cities on the basis of expert consultation and on data such as population, hurricane history and elevation above sea level (6).

Table II-1

Hurricane Areas

Primary Areas	Secondary Areas
Corpus Christi	Matagorda (Tx)*
Galveston - Houston	Sabine Lake (Tx-La)*
New Orleans	Mobile
Tampa Bay	The Florida Keys*
Miami - Miami Beach	Lake Okeechobee*
Savannah	Pamlico Sound*
Charleston (SC)	Delaware Bay*
Chesapeake Bay*	Providence
Long Island	Buzzards Bay - Cape Cod*
	Boston

*Non-metropolitan areas

(Source: Reference 6)

To date, FEMA and other agencies in the federal government, notably the Army Corps of Engineers, have focused their financial support of evacuation planning on the most populous areas. Miami, Tampa Bay, Galveston, and Houston have recently completed extensive evacuation plans with federal assistance (7, 8). Only recently have non-metropolitan areas received attention. Consultants are preparing evacuation plans for the Florida Keys (9) and initial efforts in storm surge modeling and flood zone mapping are under way for Pamlico Sound (10). Non-metropolitan areas such as these and others listed in Table II-1 are potential candidates for the evacuation time estimating methods discussed later in this report.

C. Hurricane Evacuation Planning

As more attention is focused on evacuation planning for non-metropolitan areas, the plans for larger cities will serve as models. In this regard, the following evacuation planning tasks from the Tampa Bay plan are summarized below to place in perspective the task of estimating evacuation time for a non-metropolitan community (11).

Hazard Analysis - A comprehensive analysis of the potential hurricane hazards to the community.

Vulnerability Analysis - A detailed indentification of the areas and population of the community vulnerable to specific hurricane hazards.

Population Data - A systematic enumeration of the dwelling units and population within the identified vulnerable areas.

Behavioral Data - A statistically significant investigation of the probable tendencies of potential future evacuees - whether they will evacuate, when they will leave and where they will go.

Shelter Data - A regionwide inventory of existing public shelter characteristics and shelter capacity analysis.

Shelter/Medical Facility Surge Analysis - A quantitative analysis of the geographic storm surge vulnerability of existing public shelter structures and hospital/nursing home structures.

Shelter Structural Analysis - An engineering analysis of the estimated structural integrity of existing public shelters in relation to hurricane velocity winds.

Surge Roadway Inundation Analysis - A time history analysis of the expected time of inundation of critical evacuation route points relative to hurricane landfall.

Gale-Force Winds - A time history analysis of the expected time of the arrival of gale-force winds relative to hurricane landfall.

Shelter Duration - A time history analysis of the expected shelter stay duration throughout the life of the storm.

Freshwater Roadway Inundation Analysis - A regionwide identification of historically inundated roadways from rainfall flooding.

Evacuation Zones - A regionwide delineation of the vulnerable areas into evacuation zones with common hazard vulnerability and common evacuation routes.

Evacuation Routes - The assignment of evacuation vehicle volumes from specific zones to specific routes to develop optimum intra- and inter-county routing strategies.

Shelter Assignment - The assignment of specific evacuation zones to specific shelters based on evacuation routing strategies and shelter capacities.

Clearance Time - The calculation of vehicle travel times associated with the movement of the enumerated vulnerable population from specific vulnerable evacuation zones to specific evacuation destinations.

Evacuation Time - The formulation of recommendations for the timing of evacuation orders based on all components of evacuation time.

Preliminary Inventory of Emergency Transportation Needs - A regionwide survey and identification of the geographic location and specific transportation needs of elderly or disabled potential hurricane evacuees.

Coordination - The continuous participation and involvement in accomplishing the tasks by all concerned preparedness and response agencies.

Post Hurricane Recovery - The formulation of procedures to facilitate expedient and effective disaster recovery.

Determining evacuation time is one of the major objectives of any evacuation planning effort. In order to develop reasonable estimates of the evacuation time, however, only several of the tasks in the above list must be considered: vulnerability analysis, population data, surge roadway inundation analysis, gale-force winds, evacuation zones, shelter assignment and clearance time analysis. Information derived from these planning tasks is necessary for the analysis which yields the required evacuation time. This analysis is discussed in the following chapter.

III. A METHODOLOGY FOR ESTIMATING EVACUATION TIME

A. Components of Evacuation Time

A good estimate of total evacuation time is one of the most important keys to hurricane preparedness. Too long an estimate may lower public credibility in the plan;too short an estimate could mean disaster. Only with good estimates of evacuation time can local officials know when to issue the order for residents to abandon their homes and businesses in order to save their lives.

By definition, evacuation time represents the minimum amount of time before projected hurricane eye landfall that local decision-makers must allow for safely completing the evacuation under the particular conditions of the approaching hurricane. Different hurricane situations require different evacuation times.

For example, if the National Hurricane Center forecasts that the eye of a low intensity Category I hurricane (Appendix A) will reach a community's shores by 6 p.m., and the local evacuation time for that type of hurricane is eight hours, then it means that local authorities must officially order the evacuation to begin no later than 10 a.m. (Realistically the evacuation should begin even earlier than 10 a.m. Even a Category 1 hurricane could create inundation problems prior to this deadline and prior to gale force minimum (32 mph winds).)

Several measurable components make up evacuation time as shown by Figure III-1. The transportation-related component, clearance time, is dependent on the attitudes of the evacuating population and on the carrying capacity of the community's transportation network. It is defined as the amount of time necessary for the relocation of all vulnerable evacuees to their respective shelter destinations once the official evacuation order is issued. The clearance time consists of three main subcomponents: mobilization time, travel time and queuing delay time.

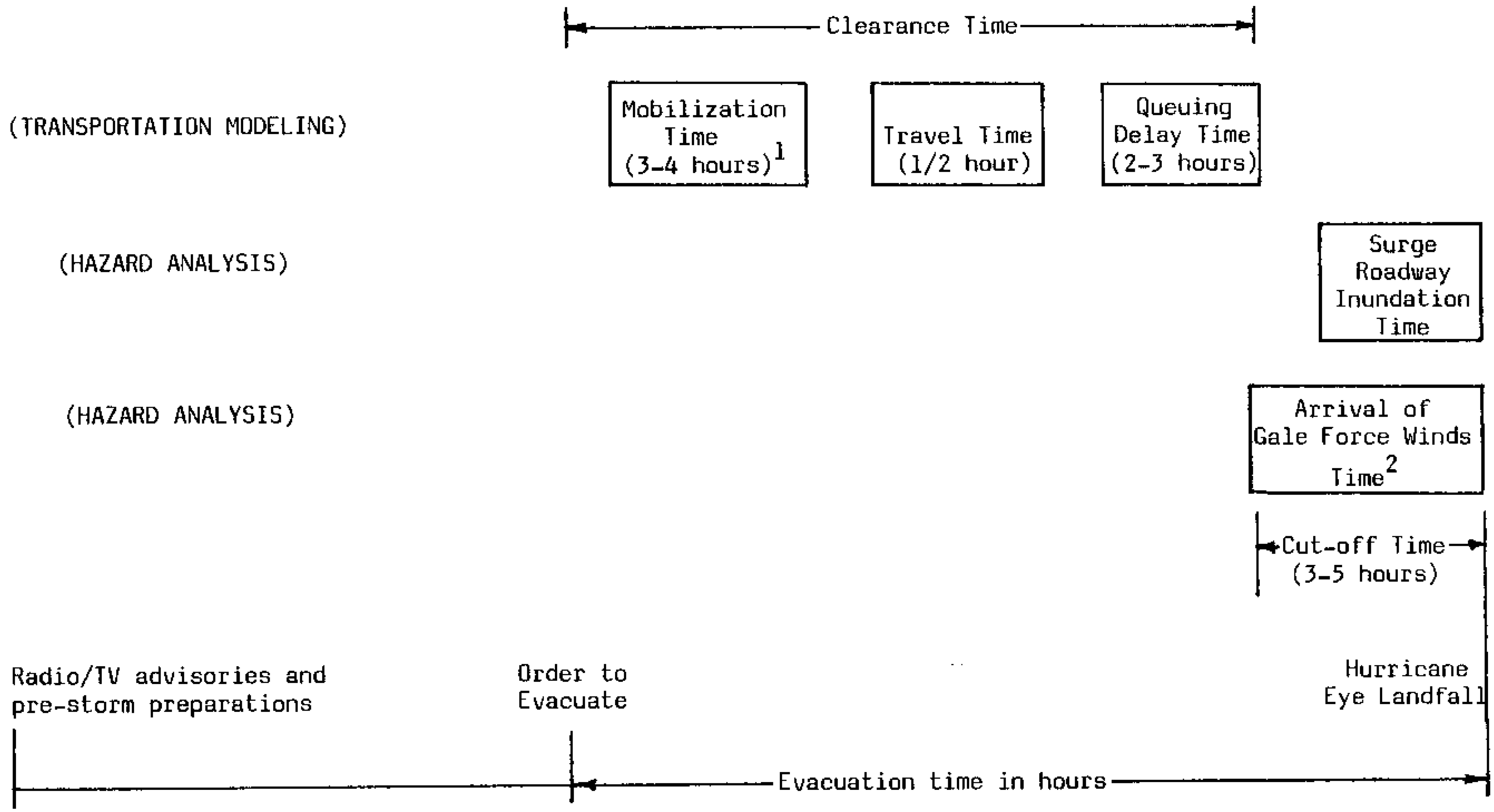
Mobilization time is that period between the issuance of the evacuation order and the departure time of the last vehicle from the vulnerable area. It depends to a large extent on the attitudes and response time of residents. Travel time is the period necessary for the vehicles to travel the length of the evacuation route at an anticipated operating speed assuming no traffic delays (queuing). Queuing delay time is defined as the time spent by vehicles in traffic jams resulting when the capacities of the evacuation routes are exceeded by the number of vehicles entering those routes.

These three components of clearance time result from analyzing the transportation characteristics of the evacuation route and the behavior of the evacuees. If a vulnerable area is relatively isolated and evacuation behavior (mobilization time) can be assumed to be relatively constant, clearance time will tend to remain the same regardless of hurricane intensity. However, the clearance time may vary with hurricane intensity if several vulnerable areas share the same evacuation route. As the storm intensity increases, storm surge builds, more areas become vulnerable and more people must evacuate. As more vehicles crowd the evacuation routes, clearance time will increase.

Figure III-1

Components of Evacuation Time

(Source: Reference 7)



[1] Typical values

[2] Also includes rainfall roadway inundation time.

Besides clearance time and its three subcomponents, total evacuation time depends on the pre-landfall hazards time. It represents the period of time before the eye of the hurricane reaches the coast that either (a) evacuation routes become inundated and impassable by storm surge, and wind tide, or (b) sustained gale-force winds arrive from the approaching hurricane. The larger of (a) or (b) represents the pre-landfall hazards time or "cut-off" time. The hazards time component is not available for vehicle movements from the vulnerable areas. All vehicles must have left the evacuation zones by the end of the clearance time or they will be cut off from safety. Generally, the cut-off time occurs earlier as hurricane intensity increases, and evacuees must leave earlier in order to reach shelter.

In summary, total evacuation time depends on the category and other parameters of hurricanes being considered; the hazards from storm surge, winds, and flooding; and characteristics of the evacuation population and transportation network. Figure III-2 illustrates the major steps in a methodology to determine evacuation time. The details of each step are discussed in the following sections of this chapter.

B. Scenario Development

To formulate distinct evacuation times and plans for all possible hurricane conditions would be impossible for a community. A plan must be based on probable conditions and be geared to cope with "worst-case" hurricane hazards. The use of a worst-case scenario provides a margin of safety in planning and response activities.

Usually evacuation planners consider five scenarios for vulnerable areas. The primary hurricane parameter which distinguishes different scenarios is intensity as defined by the Saffir/Simpson Scale (Appendix A). Relating the scenarios to this scale is necessary because it is used by the National Hurricane Center when reporting the expected time and location of hurricane eye landfall. Local planners also include in the scenarios probable storm size, direction of approach and landfall location as suggested by historical storm data.

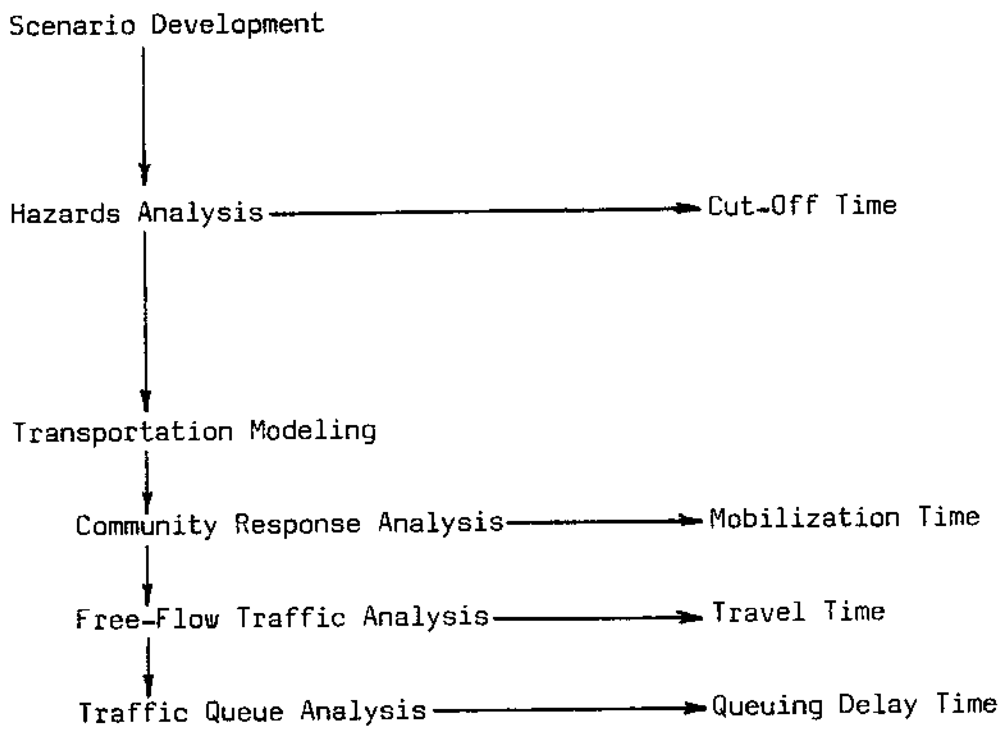
The various combinations of hurricane parameters define worsening evacuation scenarios which in turn identify (as a result of the hazards analysis) successively more vulnerable areas which must be evacuated. As a result of choosing specific evacuation scenarios for planning purposes, analysts can calculate cut-off times and traffic clearance times for the vulnerable areas. For each evacuation scenario a different evacuation time may be subsequently estimated for each evacuation zone.

C. Hazards Analysis

As discussed earlier the pre-landfall hazards time depends on when storm surge, high winds or flooding from rainfall cut off evacuation routes. Storm surge is particularly dangerous, for as records indicate, most of the damage results from the surge and 90 percent of the deaths are by drowning.

Figure III-2

A Methodology for Estimating Evacuation Time



Evacuation Time = Cut-Off Time + Mobilization Time + Travel Time + Queuing Delay Time

The height of water that an evacuation area experiences during a hurricane does not necessarily correspond to the Saffir/Simpson Scale height. If there is a high shoaling factor (shallow water and gradual slope of the bottom off the immediate location of hurricane landfall) then surge heights can be higher than those indicated on the Saffir/Simpson Scale for a hurricane of a certain intensity. The surge height can also be higher than expected if the surge travels into a bay or river. These enclosed bodies of water entrap the surge and amplify its height through a funneling effect.

Estimating the surge height requires the analysis of numerous factors which describe the storm itself and the local physical characteristics of the shoreline. The most practical way of accomplishing this analysis is through computer simulation (12, 13). The results of the computer analysis are in the form of "space-time" plots of predicted storm surges. The plots present information on how high the water level will be at a particular point along the coast for times relative to the time of actual storm landfall or closest approach. Knowing the time history of surge heights and the elevations of low points along the evacuation routes allows calculation of roadway inundation cut-off times.

The computer simulations for surge height also predict space-time information for gale-force winds. This information will indicate when and where it would be hazardous, if not impossible, to operate a vehicle on an evacuation route because of buffeting winds which could overturn the vehicle.

Cut-off times depend on hurricane conditions and local characteristics as discussed above. However, typical hazard analyses suggest that gale-force winds may arrive up to six hours before arrival of the hurricane eye, and low roadways may be inundated five hours before eye landfall (7, 14).

D. Community Response Analysis

A significant fraction of the total evacuation time is represented by the time required for mobilization. Residents and tourists must be warned, they must prepare to evacuate and a traffic control system must be established to ensure optimum utilization of the evacuation routes. For typical communities, it has been estimated that it will take about one hour for all evacuees to learn of the evacuation order, another hour to establish traffic control procedures and at least one hour for residents to make their preparations to depart. Consequently, a total mobilization time of three hours may result before significant numbers of evacuees are moving away from the vulnerable areas (8). The three-hour figure may vary somewhat from community to community depending on its size, preparedness, the behavior of the evacuees and the number of tourists.

To obtain more precise evacuation behavior data, planners often use telephone and mail-back questionnaires to ask residents what actions they will take, when they will begin evacuating and where they will go. Questionnaire results not only help to determine mobilization time, but also how to model the traffic flow on the evacuation routes. Typical hurricane questionnaire responses have suggested the following types of community response (11):

- Up to 80 percent of the vehicles in an area may be used in an evacuation.
- As many as 20 percent to 30 percent of the residents will leave before the evacuation order is given, while up to 20 percent of the residents will delay four or more hours after the order (Figure III-3).
- Public shelters will be used by at least 35 percent of the evacuees, and the remainder will go to friends, relatives, motels, etc.

Such community response data is very important in the evacuation planning process. Unfortunately, the questionnaires are answered by a very small percentage of the total number of potential evacuees and may not be a true reflection of the overall community response.

E. Free-Flow Traffic Analysis

Travel time is calculated assuming "free-flow," uninterrupted traffic movements. Congestion effects which cause delay from traffic jams at intersections and other bottlenecks like narrow bridges are accounted for in the traffic queue analysis.

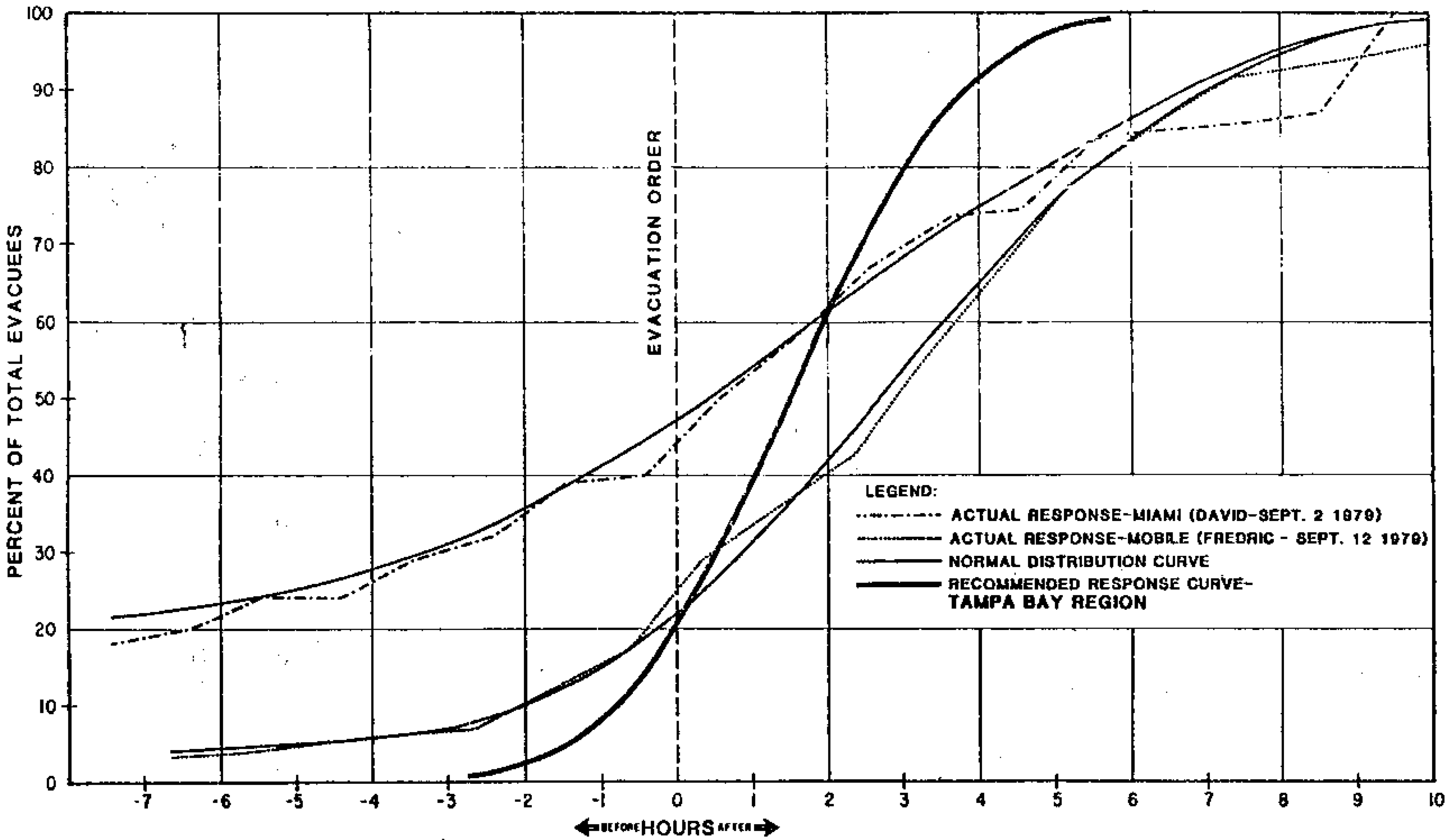
Assuming that a known evacuation route is made up of several roadway sections and that the anticipated free-flow operating speeds on the sections during the evacuation can be estimated, then the free-flow travel time is given by the following formula:

$$\text{Travel Time} = \sum_{i} (\text{Length of section } i \,/\, \text{Operating speed on section } i)$$

The sections' lengths can be estimated from maps and the anticipated operating speeds can be estimated from experience. Usually such speeds will vary between 25 miles per hour (mph) and 45 mph with 35 mph being the average. This range of speeds reflects capacity operating conditions that evacuation routes are likely to experience.

For simple evacuation networks which have few evacuation zones and only one or several independent evacuation routes, the above formula provides a quick and easy method for calculating travel time. However, as evacuation networks become more complex, providing alternative routes to safety and allowing many evacuation zones to share sections of the same evacuation route, more sophisticated methods are required.

The problem of calculating travel time for complex evacuation networks is basically one of bookkeeping if the evacuation routes and the shelter assignments for specific evacuation zones are known. If the community is small or medium size, the non-computerized traffic assignment procedures discussed in Chapter 7 of Reference 15 may be used to accumulate the travel times and traffic volumes on the various sections or "links" of the evacuation network. If the shelter assignments of the evacuation zones are not known, the trip distribution procedures in Chapter 3 of Reference 15 may be used to supply this information.



SOURCE: DRAFT NOTES: COMMUNITY RESPONSE TO NATURAL HAZARD WARNINGS
T.M. CARTER, J.P. CLARK, R.K. LEIK, UNIV. OF MINN. AUGUST 1980

Public Response to
Hurricane Evacuation Orders

Figure III-3

For large metropolitan areas with many evacuation zones and routes, computerized traffic assignment and trip distribution algorithms are used to determine the optimum, i.e., shortest or quickest, routes to safety. The algorithms require extensive coded descriptions of the evacuation network including the distances, assumed operating speeds and capacity characteristics of each roadway section. The traffic demands from each evacuation zone are then "loaded" onto the coded network and the algorithms determine the optimum routes and resulting travel times. The analytical details of computer methods are often the proprietary information of consulting firms (Appendix G in Reference 7); however, general information and algorithms may be obtained from References 16 and 17.

F. Traffic Queue Analysis

Estimating the queuing delay time is the final step in estimating the components of total evacuation time. This is the delay that occurs when evacuating vehicles encounter queues or lines of stopped or slow-moving vehicles.

For unrestrained traffic flow where the total volume assigned to a link is less than its capacity, traffic experiences only the normal travel time, as discussed above, and link travel time is its distance divided by the estimated operating speed. In the traffic assignment "bookkeeping" procedure, however, when the traffic demand assigned to a link during a given time period exceeds the capacity of that link, a queue will form and the evacuating traffic will experience additional delay.

For simple evacuation networks, traffic demand comparisons can be easily made to link capacities, and where demand exceeds capacity, queuing delay time can be estimated by the following formula:

$$\text{Queuing Delay Time} = \text{Queue Length} \,/\, \text{Queue Dissipation Rate}$$

The queue dissipation rate is approximately equal to the capacity of the bottleneck, i.e., the maximum flow of vehicles per hour through the bottleneck. The queue length during a particular time period is estimated as follows:

$$\text{Queue Length} = \text{Rate of Queue Growth} \times \text{Length of Time Period}$$

where the rate of queue growth is proportional to the difference in capacities of the approach link and the bottleneck (19).

For complex networks in which many evacuation zones may share evacuation links, the same formulas as above are used. However, the bookkeeping procedures for the links become more complicated especially as the traffic from different evacuation zones will tend to reach or "load" the links at different times. For small and medium size cities, the manual traffic assignment procedures in Reference 15 may be applied for successive time periods in the evacuation, and for large metropolitan areas, computerized techniques are the most practical (7).

IV. HOLDEN BEACH

A. The Evacuation Area

Holden Beach is a barrier beach located in Brunswick County in the southeastern coastal plain of North Carolina (Figure IV-1). The study area which includes Holden Beach, Sivey Town and Shallotte is a 45-square-mile area bounded by U.S. 17 on the north, Lockwood Folly River on the east, Atlantic Ocean on the South and the Shallotte River on the west. Elevations range from 0 to over 25 feet; the community lies entirely within the hurricane flood zone.

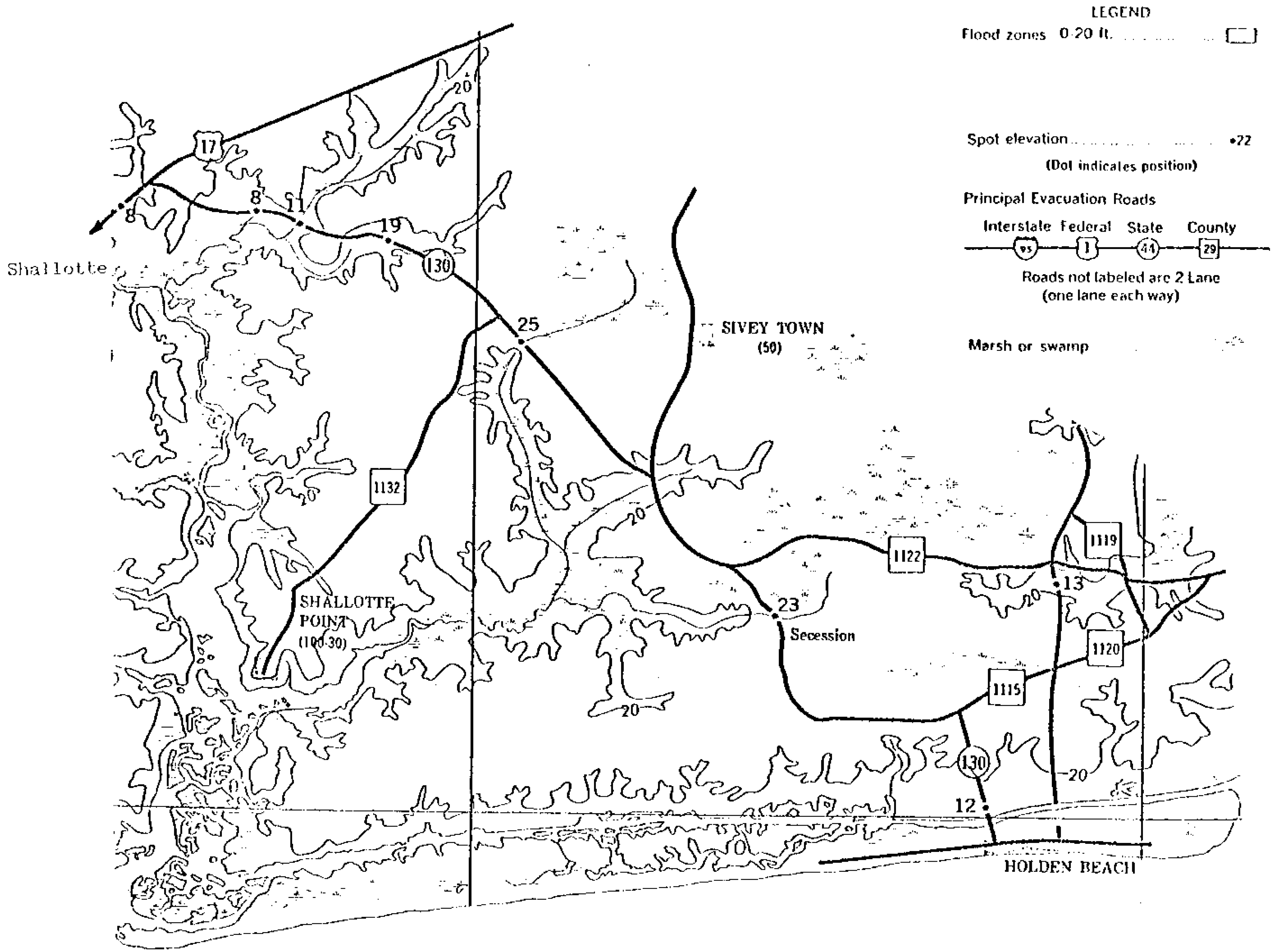
The study area is almost entirely rural. Shallotte with the largest year-round population of 600 is in the northwest corner of the study area and provides shelter for hurricane evacuees from Holden Beach. Holden Beach is the predominant feature in the study area as it is a vacation spot for up to 10,000 people during the summer months. The island on which Holden Beach is located is about eight miles long and ranges from about one-quarter to one-half of a mile in width. It is connected to the mainland by a single-lane, swing-span bridge across the Intracoastal Waterway.

In the event of a hurricane, the only primary highway (U.S. 17) and one secondary road (N.C. 130) will comprise the evacuation route, plus the main street of Holden Beach (S.R. 1116) and several "tributory" streets. N.C. 130 crosses the Intracoastal Waterway at the swing bridge which is 220 feet long, is 14 feet above the mean sea level and has one 17-foot lane. Traffic on the bridge is one-way. The approach roadways to the bridge are 20 feet wide with four-foot shoulders. The elevation of the approach roadway is approximately 10 feet. (Data supplied by the North Carolina Department of Transportation.)

Holden Beach is extremely vulnerable to hurricanes. Its geographic location, low elevation island terrain, high summertime population and limited access to the mainland contribute to its vulnerability. In addition, the swing-span bridge is operated electrically. If power fails or machinery breaks, repair crews must be sent from Wilmington to manually close the bridge, a procedure taking an hour or more, including travel time. If storm conditions are announced while the bridge is stuck in the open position, evacuation of the island could be seriously delayed.

B. Hurricane Scenario

In 1954, when Hurricane Hazel hit North Carolina, a high-water mark from the tidal surge (excluding wave action) of 16 feet above mean sea level was recorded at the Holden Beach Bridge. This is the surge expected from a Category 4 storm. A storm of this magnitude could be expected there roughly once every 100 years. Assuming the hurricane eye from such a storm crossed over Holden Beach, it is likely that nearly 75 percent of the shaded flood zone area in Figure IV-1 would be flooded. Not only would the Holden Beach Bridge have waves washing over it, but also inland points on the evacuation routes as far as Shallotte could be flooded. Hence, to avoid being cut off from safety,



Holden Beach Evacuation Route

Figure IV-1

evacuees may not only have to clear the Bridge but also points on NC 130 and US 17 near Shallotte. The possibility of flooding will be increased by the likelihood of torrential rains.

C. Hazards Time

A complete analysis for the surge and gale-force wind hazards time components of evacuation time would require a computer simulation of the storm. However, the Saffir/Simpson Scale description of a Category 4 storm suggests that low-lying escape routes may be cut by rising water as early as three to five hours before the hurricane eye arrives. This estimate for roadway inundation time is consistent with a storm which moves at a typical 10 mph forward speed and has a surge that extends about 30 miles out from the hurricane eye. The estimate also seems reasonable in that Holden Beach is a barrier beach and the approaches to the bridge are at low elevations.

Gale-force winds and blinding rain can also combine to make it virtually impossible to drive a vehicle on the evacuation route. Wind analysis for barrier islands and coastal areas in Florida suggest that gale-force winds may precede landfall of the eye by six hours.

D. Mobilization Time

As discussed previously, the mobilization time for a community may vary somewhat. However, actual data suggests that it may take over five hours for everyone to begin the evacuation. A value of three to four hours would find 80% to 90% of the evacuees on their way (Figure III-3) and will be used for this study.

E. Travel Time

Evacuation travel is based on the length of the evacuation route and the assumed uninterrupted operating speed of the evacuation vehicles. Assuming an evacuee lives at the western end of SR 1116 on Holden Beach, he or she must travel five miles to reach the bridge. It is another nine miles to Shallotte, giving a total evacuation distance of 14 miles. Assuming storm conditions and evacuation traffic, yet uninterrupted travel, an average operating speed of 35 mph could be maintained on the two-way, two-lane rural roads of the evacuation area. The "free-flow" travel time is, therefore

Travel Time = Distance/Speed
= 14 miles/35mph
= 0.40 hours
= 24 minutes

This estimate does not include queuing delay which is determined below.

F. <u>Queuing Delay Time</u>

Virtually all of the evacuees originate on Holden Beach. Compared to the 7,000 to 10,000 persons that may visit Holden Beach on major summer weekends (Memorial Day, July 4, Labor Day), only several hundred people work or live north of the Intracoastal Waterway. Consequently, the major bottleneck where queues are likely to form is the swing bridge. On normal weekends, congestion also occurs just north of the bridge at the intersection of NC 130 and SR 1120 where a shopping and service area exists. During an evacuation, however, with the majority of the traffic moving one-way under police control, it is expected the flow will be relatively uninterrupted compared to the constrained flow at the bridge.

In order to estimate the queuing delay time during a particular time period of the evacuation, the traffic demand and the bottleneck capacity must be known. For the purposes of this analysis, the following will be assumed:

1. 10,000 persons evacuate.

2. The average automobile occupancy is 2.5 persons per vehicle.

3. 20% of the evacuees leave before the order is given.

4. The remaining 80% of the evacuees leave over a 3.5-hour period.

5. Traffic control officers will be stationed at intersections thereby mitigating the usual intersection capacity constraints.

6. Intersection turning traffic is negligible compared to the evacuation traffic.

7. Traffic moves at "level of service D to E."

The evacuation rate or traffic demand is thus,

Evacuation Traffic Demand = (No. of evacuees/Vehicle occupancy) x (1% remaining after order) x (1/Evacuation period)

or

ETD = (10,000/2.5)(.80)(1/3.5)
= 900 vehicles/hour (3,200 vehicles in 3.5 hours)

These vehicles must be accommodated by the swing bridge which has a capacity which is determined by the methods of Chapter 6 in References 18 and 21. Assuming the bridge is approximated by an intersection, the ideal (perfect day) capacity is given as (Appendix B):

Ideal Capacity = 550 to 825 vehicles per hour

If it is assumed that storm conditions exist, the bridge capacity will be reduced by fluctuations in traffic demand, wind-blown debris and storm conditions (Appendix B). Thus, the capacity calculation for the bridge becomes

Evacuation capacity = Ideal capacity x 0.50
Evacuation capacity = 275 to 400 vehicles per hour (Assume 300).

According to Chapter 8 in Reference 19, the maximum amount of individual vehicular delay is given by the following formula:

Queuing delay time = (Duration of bottleneck) x (1 - Bottleneck capacity/Average demand)

Hence,

Queuing delay time = (3.5)(1 - 300/900)
= 2 hours

Under the assumed conditions, the traffic demand will also strain the capacity of SR 1116 as it approaches the bridge, as well as the capacity of the bridge. It is likely that evacuees will attempt to form two lanes of evacuation traffic leading to the bridge where the traffic is constrained to one-lane. Consequently, the queue will start at the bridge and grow back along the approach from the beach. Using the Reference 19 formula

Maximum number of vehicles in queue = (Evacuation period) x (Traffic demand - Bottleneck capacity)

it is found that up to 2,100 vehicles of the 3,200 evacuating will be delayed by the bridge.

G. Short-Cut Calculations

For simple evacuation networks like the Holden Beach example, the calculations are relatively simple. There are essentially one evacuation zone, one evacuation route, and one bottleneck. In this case, the evacuation time components may be estimated easily with the exception of queuing delay time. A more approximate approach is given by

Queuing delay time = Traffic demand/Bottleneck capacity

where

Traffic demand = No. of Evacuating vehicles/Mobilization time and bottleneck capacity may be taken from the following list (13, 21):

Bottleneck	Capacity (vehicles/hour)	
Highway detour	300	
Bridge (1-lane)	300	
Bridge (2-lanes)	400-500	(one lane for evacua-
Local streets	500-600	tion: one lane for
State roads	600-800	emergency vehicles)

Of course these values depend on roadway characteristics, traffic operating characteristics and prevailing storm conditions. This approach gives a queuing time delay of three hours for Holden Beach.

H. Total Evacuation Time

The total evacuation time is the summation of the following components:

Cut-off time	3-5 hours
Mobilization time	3-4
Travel time	0.5
Queuing delay time	2-3
Total	8-13 hours

I. Discussion of Results

The evacuation time estimate of 8 to 13 hours was based on one Category 4 hurricane scenario and is dependent on a number of assumptions - number of evacuees, auto occupancy rate, community response, roadway inundation time, to name but a few. Changing the assumptions will change the time estimates. It is interesting to note, however, that certain tradeoffs exist. For example, much importance is placed on community awareness and rapid response to evacuation orders. Unfortunately, a sensitivity analysis would show that an earlier mobilization of the evacuees will lead to higher traffic demands and more queuing delay. What is gained in response time is lost to traffic delay if bottlenecks exist on the evacuation route.

Looking specifically at the Holden Beach estimate of 8 to 13 hours evacuation time, it is seen that the figure is consistent with estimates for roughly similar island situations in Lee County, Florida (7). The estimate is also consistent with the Holden Beach evacuation plan which indicates that evacuation orders will be issued when a hurricane is with 12 hours of landfall. The estimated figures are at variance, however, with those published in the Brunswick County Hurricane Plan (Newspaper Supplement) which suggests that the safe evacuation time for all of Brunswick County is four to six hours. It is, therefore, recommended that the Brunswick County Civil Preparedness Agency reconsider its evacuation time estimates, at least for barrier islands, barrier beaches and other low-lying locations such as those along the Intracoastal Waterway and estuaries.

V. GOOSE CREEK ISLAND

A. The Evacuation Area

Goose Creek Island is located in Pamlico County on the Pamlico Sound. (one of the priority hurricane areas as identified by FEMA, see Table II-1). The island is bounded on the north by the Pamlico River, on the east by the Pamlico Sound, on the south by Jones Bay, and on the west by the Intracoastal Waterway (Figure V-1). A drawbridge connects Goose Creek Island to the mainland. Elevations on the island do not exceed six feet above mean sea level, roadway elevations are approximately four feet and the elevation of the drawbridge is 10 feet.

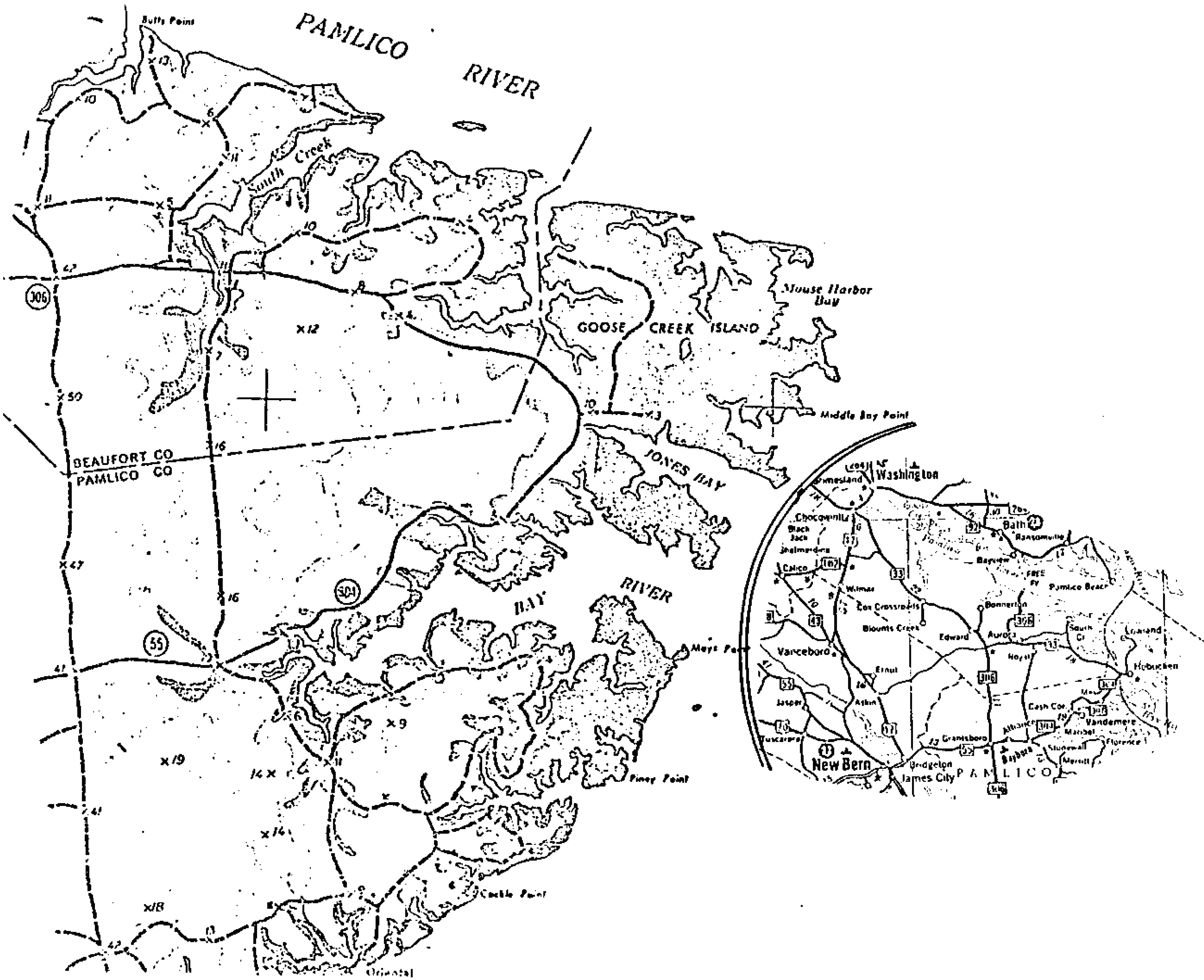
The small communities of Lowland and Hobucken are on Goose Creek Island, and it is their evacuation that is of concern. Combined, the two communities have a population of about 480 people. There is no multifold increase in population during the summer months from vacationers.

If a hurricane is predicted to strike Pamlico County, the residents of Goose Creek Island would be evacuated before anyone else. They are the most vulnerable and they have the longest distance to travel for shelter. The evacuation route (NC 304) crosses the drawbridge and continues on to a shelter located in Bayboro. The evacuation distance is approximately 18 miles from the farthest point of Lowland to Bayboro.

Several potential bottlenecks exist on the evacuation route at bridges and their low-lying approaches. These potential bottlenecks are the drawbridge (elevation 10 feet), the Bear Creek Bridge at Mesic (elevation 5 feet), and the Bay River Bridge (elevation 10 feet) in Bayboro. In addition, virtually all of the evacuation route lies in a flood-prone area where elevations are less than 15 feet. One particularly critical point is just east of Bayboro where the roadway (elevation 5 feet) lies very close to a small "finger" from the Bay River.

Besides the potential roadway bottlenecks which can slow Goose Creek Island evacuation traffic, traffic congestion from other evacuating communities may occur. However, the evacuation of Goose Creek Island will be ordered four hours before the other portions of southern Pamlico County in order to reduce the chances of such congestion. Other communities which evacuate to Bayboro are Mesic (approximate population, 360), Vandemere (380), Hollyville (150) and Maribel (320). Several other communities evacuate to Bayboro but they will use other routes.

According to information from the North Carolina Department of Transportation, all but 2 1/2 miles of the evacuation route is through rural areas where 55 mph speeds can be obtained during normal weather conditions. The road from Hobucken to Hollyville has two ten-foot lanes, and the lateral clearance on both sides is six feet. From Hollyville to Bayboro, there are two eleven-foot lanes with ten feet of lateral clearance on both sides. The drawbridge is 265 feet long with a total horizontal clearance of 18 feet.



Goose Creek Island Evacuation Route

Figure V-1

B. <u>Hurricane Scenario</u>

The analysis will assume that a Category 4 hurricane is approaching Pamlico County from the southeast at a forward speed of approximately 10 mph. The eye of the storm is predicted to cross the Outer Banks at Ocracoke and strike Goose Creek Island "head on." This is a "worst case" scenario for planning purposes: it is estimated that a storm such as this would occur about every 100 years.

C. <u>Hazards Time</u>

Goose Creek Island and its neighboring communities represent a special case for hazards analysis. The island is adjacent to Pamlico Sound which would tend to "bottle up" the effects of wind stress and flux of water through the inlets caused by the open-ocean storm surge. Thus, for the purposes of this study it will be assumed that the water level in the Sound will be at least as high as that predicted by the Saffir/Simpson Scale in spite of the fact that the Outer Banks will absorb much of the force of the open-ocean surge. However, it is likely that whatever force is lost will be recovered in the wide Pamlico Sound and that surge heights as high as those predicted by the Saffir/Simpson Scale should be used for planning purposes. Hence, a surge reaching 13 to 18 feet may occur, completely inundating the island several hours before landfall of the eye. Low-lying sections of the evacuation route will be cut by rising water three to five hours before landfall. Depending on the actual behavior of the surge as affected by the sound and flooding conditions, several points along the route all the way to Bayboro may be cut. Therefore, the hazards time component of evacuation time will be taken as three to five hours. Gale-force winds may add another hour to the hazards time.

D. <u>Mobilization Time</u>

Each community has its own personality and its own potential response to an evacuation order. The residents of Goose Creek Island have been characterized as rather independent, possibly resistant, to an evacuation order issued by county officials. It is anticipated that island residents will require at least the "standard" <u>three to four hours</u> to mobilize.

Since Goose Creek Island residents will share the escape route with evacuees from Mesic, Vandemere, Hollyville and Maribel, their response times must also be considered. While a phased evacuation is planned so that Goose Creek Island residents will receive their order to evacuate four hours before anyone else, it is still likely that there will be some overlap. Goose Creek evacuees may leave later than four hours after the order and experience has shown that up to 20% of an area's residents leave before an order is given. The early departures from Mesic and communities along the route may conflict with late-leaving evacuees. The effects on traffic and evacuation time will be evaluated below.

E. Travel Time

Assuming an uninterrupted 35 mph operating speed, residents of Lowland and Hobucken would require about 30 minutes to reach shelter at Bayboro. This time does not include possible delays from traffic congestion, turning vehicles, and the like.

F. Queuing Delay Time

From the standpoint of roadway capacity, there are four potential bottleneck situations on the Goose Creek evacuation route. They are:

1. The bridge over the Intracoastal Waterway
2. The highway section from the bridge to Hollyville
3. The highway section from Hollyville to Bayboro
4. The intersection just west of the bridge at NC 33 and 304, and intersections in Mesic, Hollyville, Maribel and Bayboro

The capacities of these potential bottlenecks may be calculated using the methods of Reference 18, and depending on the local traffic demand at a specific bottleneck, the minimum value will determine queuing time delay, if any.

The Goose Creek Island Bridge is about one foot wider than the bridge at Holden Beach, and its capacity will essentially be the same, i.e., 300 vehicles per hour. While it is assumed that no passing is allowed on the bridge, it will be assumed for the remainder of the route that passing will be possible 20% of the time. Using the methods in Reference 18, the capacity of the route from the bridge to Hollyville is found to be 550 vehicles per hour, and that from Hollyville to Bayboro is 600 vehicles per hour. Equivalently the shortcut values of Section IV G give 600 to 800 vehicles.

Intersections must accommodate through movements and turning movements. Reference 18 states that the maximum capacity under ideal conditions is 1,500 vehicles per hour for through movements and 1,200 vehicles per hour for turning movements. According to Reference 18 and to Chapter 2 in Reference 20, adjustments must be made for intermittent operation (x 0.80), storm conditions (x 0.65), and wind blown debris (x 0.85). Thus, the anticipated through movement capacity of intersections is about 650 vehicles per hour and for turning movements is about 500 vehicles per hour. These capacities can approach those of the highway sections as a result of control by traffic officers, and they may vary as a result of the assumed parameters used in the analysis.

The capacity analysis suggests that the evacuation of Goose Creek Island residents will be constrained primarily by the bridge over the Intracoastal Waterway. Assuming that the 480 residents will be evacuated in about 200 vehicles (2.5 persons per vehicle), it is seen that all sections of the evacuation route including the drawbridge have adequate capacity even if all 200 vehicles were traveling during the same hour. More than likely, the Goose Creek Island evacuees will be leaving at the rate of about 70 vehicles per hour (200 vehicles/3 hour mobilization time) and any possibility of queuing delay appears to be virtually eliminated. Thus, there is no queuing delay time from any potential bottleneck if the Island evacuates four hours before the rest of Southern Pamlico County.

Since Goose Creek Island residents must share the evacuation route with residents from Mesic, Hollyville and Maribel, it is of interest to consider the potential problem of interjurisdictional traffic conflicts. The worst case situation would occur if all the residents in Southern Pamlico County including Goose Creek Island evacuated during the same hour. The total number of evacuees will be about 1,700 persons traveling in about 650 to 700 vehicles assuming an occupancy rate of 2.5 persons per vehicle. If this unusual situation occurred of everyone leaving at the same time, it is seen that over-capacity conditions will occur on highway sections and intersections in communities. More than likely, however, the evacuees will follow the standard behavior of leaving over a three- to four-hour period. The resulting evacuation rate will then be about 200 to 250 vehicles per hour, which is well below the bottleneck capacities of any section on the evacuation route.

Hence, under the assumed values for the number of evacuating vehicles and the passenger occupancy rate, there will be no queuing delay for Southern Pamlico County residents, even if the four-hour lead time for Goose Creek Island is ignored.

G. Total Evacuation Time

The total evacuation time for Goose Creek Island residents is the summation of the following components:

Cut-off time	3-6
Mobilization time	3-4
Travel time	0.5
Queuing delay time	0
Total	6-11 hours

H. Discussion of Results

It must be realized that the range of evacuation time depends on a number of assumptions regarding the hurricane, the community response and the transportation system. It is interesting to note, however, that the time is more storm-dependent in this case than transportation-system-dependent as was the case for the vacation area of Holden Beach.

The estimate of 6 to 11 hours is consistent with those for other low-lying case study areas. The estimate is also consistent with the official Pamlico County Civil Preparedness Hurricane Evacuation Plan which calls for Southern Pamlico County to be evacuated 10 hours before hurricane eye landfall. The results of this study, however, suggest that the four-hour lead time (14 hours before hurricane eye landfall) that is given to Goose Creek Island residents is unnecessary, that the evacuation route is more than adequate to handle to assumed number of evacuees. (It is interesting to note that neighboring Carteret County calls for an evacuation time of four to six hours as noted in their summary supplement plan. This appears inadequate based on the analysis for Pamlico County.)

VI. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the results of a two-week effort. It has defined the evacuation problems facing two small North Carolina coastal communities. It has reviewed the approaches to hurricane evacuation planning and demonstrated how simple analytical methods can estimate evacuation time.

Beyond this project, however, there is much yet to be done. Similar studies should be conducted for all vulnerable coastal communities in conjunction with comprehensive hurricane planning. Accomplishing such studies will not be easy or inexpensive. But a single devastating hurricane in any future year will leave in its wake the question, "Why wasn't something more done?"

Based on the results of this study, evacuation times for a populous summertime vacation area are likely to exceed the reliable 12-hour warning time issued by the National Hurricane Center. It is vital that the estimated evacuation times for such vulnerable areas as the Outer Banks and communities along bays and estuaries be known. In this regard, it is recommended that a comprehensive evacuation time study be initiated immediately for the Outer Banks, Elizabeth City, New Bern, Beaufort, Morehead City and Wilmington to name but a few of the more populour and potentially vulnerable areas along the North Carolina coast. It might be asked, "Why aren't the present plans adequate?" The answer - as indicated by the published evacuation times of New Hanover and Carteret Counties - there may be major inconsistencies between the time actually required for evacuation and that being given to the public.

In such a comprehensive planning effort, the following issues should be addressed:

1. Application of simplified or computerized methods (as appropriate) to estimate evacuation time.

2. Comprehensive treatment of the full range of hurricane scenarios and strike probabilities.

3. Consideration of future evacuation times assuming full residential and commercial development of an area if it is a barrier island or beach served by limited highway and bridge facilities.

4. Closer examination of traffic congestion and delay caused by evacuating communities which must share evacuation routes.

5. Analysis of expected community evacuation behavior (mobilization time) and how it can be influenced by education on the hurricane threat.

6. Strategies to reduce evacuation time such as phased response, early departure of day visitors and vacationers, traffic control measures, realignment of low approaches to bridges scheduled for replacement, vertical evacuation and the like.

Providing greater safety for all our people will not be easy. A first step, as demonstrated by this study, is the development of reliable planning information and data. For hurricane planning, evacuation time is the key.

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APPENDIX A

THE SAFFIR/SIMPSON HURRICANE SCALE

The Saffir/Simpson Hurricane Scale is used by the National Weather Service to give public safety officials a continuing assessment of the potential for wind and storm-surge damage from a hurricane in progress. Scale numbers are made available to public-safety officials when a hurricane is within 72 hours of landfall.

Scale numbers range from 1 to 5. Scale No. 1 begins with hurricanes which have maximum sustained winds of at least 74 miles per hour, or which will produce a storm surge 4 to 5 feet above normal water level, while Scale No. 5 applies to those in which the maximum sustained winds are 155 miles per hour or more, or which has the potential of producing a storm surge more and 18 feet above normal.

The Weather Service emphasizes that the scale numbers are not forecasts but are based on observed conditions at a given time in a hurricane's life-span. They represent an estimate of what the storm would do to a coastal area if it were to strike without change in size or strength. Scale assessments are revised regularly as new observations are made, the public-safety organizations are kept informed of new estimates of the hurricane's disaster potential.

The Saffir/Simpson Hurricane Scale indicates probable property damage and evacuation recommendations as listed below:

Category 1. Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real damage to other structures. Some damage to poorly constructed signs. And/or: storm surge 4 to 5 feet above normal. 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 damage to buildings. And/or: storm surge 6 to 8 feet above normal. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings.

Category 3. Winds of 111 to 130 miles per hour. Foliage torn from 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. And/or: storm surge 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Paralleling hurricanes reveal hazard characteristics that can be correlated to a landfalling hurricane. The passage of a hurricane paralleling from 25 to 100 miles from the coast would require approximately the same response as a Category 3 landfalling hurricane. Evacuation can be upgraded upon short notice.

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 failures of roofs on many small residences. Complete destruction of mobile homes. And/or: storm surge 13 to 18 feet above normal. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches.

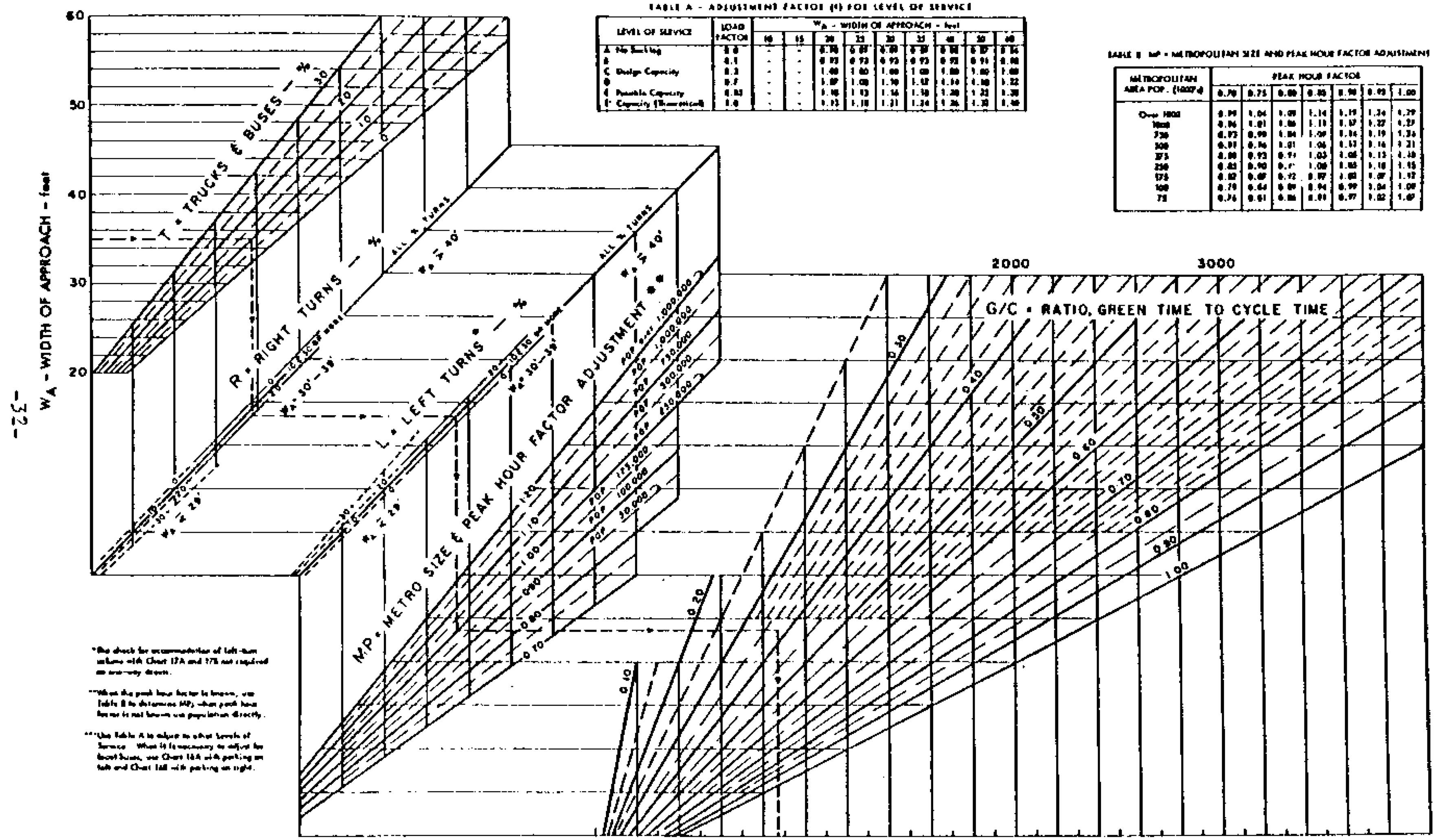
Category 5. Winds greater than 155 miles per hour. Shrubs and trees blown down, considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Some complete building failures. Small buildings over-turned or blown away. Complete destruction of mobile homes. And/or: storm surge greater than 18 feet above normal. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape route inland cut by rising water 3 to 5 hours before hurricane center arrives.

TABLE A - ADJUSTMENT FACTOR (F) FOR LEVEL OF SERVICE

LEVEL OF SERVICE	LOAD FACTOR	W_A - WIDTH OF APPROACH - feet								
		10	15	20	25	30	35	40	50	60
A No Backing	0.0	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	0.1	-	-	0.93	0.93	0.93	0.93	0.93	0.91	[illegible]
C Design Capacity	0.3	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00
D	0.7	-	-	1.07	1.09	1.10	1.12	1.14	[illegible]	1.22
E Possible Capacity	0.85	-	-	[illegible]	1.13	1.14	1.19	1.20	1.22	1.30
E* Capacity (Theoretical)	1.0	-	-	1.13	1.18	1.21	1.24	1.26	1.30	1.40

TABLE B MP = METROPOLITAN SIZE AND PEAK HOUR FACTOR ADJUSTMENT

METROPOLITAN AREA POP. (1000's)	PEAK HOUR FACTOR						
	0.70	0.75	0.80	0.85	0.90	0.95	1.00
Over 1000	0.99	1.04	1.09	1.14	1.19	1.24	1.29
1000	0.96	1.01	1.06	1.10	1.17	1.22	1.27
750	0.93	0.98	1.04	1.09	1.14	1.19	1.24
500	0.91	0.96	1.01	1.06	1.13	1.16	1.21
375	0.88	0.93	[illegible]	1.03	1.08	1.13	1.18
250	0.85	0.90	[illegible]	1.00	1.05	1.10	1.15
175	0.82	0.87	0.92	0.97	1.02	1.07	1.12
100	0.79	0.84	0.89	0.94	0.99	1.04	1.09
75	0.76	0.81	0.86	0.91	0.97	1.02	1.07



SV_C = SERVICE VOLUME OF APPROACH AT LEVEL OF SERVICE C-vph***
(C_D - Design Capacity)

*The check for accommodation of left-turn volume with Chart 17A and 17B not required on one-way streets.

**When the peak hour factor is known, use Table B to determine MP; when peak hour factor is not known use population directly.

***Use Table A to adjust to other Levels of Service. When it is necessary to adjust for local buses, use Chart 16A with parking on left and Chart 16B with parking on right.

ONE-WAY STREET — PARKING ONE SIDE
O.B.D. & RESIDENTIAL AREA
CHART 11

Nomograph and Procedure Developed by Jack E. Leisch

Published by the Traffic Institute Northwestern University

Bridge

W_{bridge} = 17'

W_A = 17' parking one side (allows for left & right lateral clearance that would be especially important if wave action is present, or for a stalled vehicle that may be pushed to one side)

T = 5% (recreational vehicles and cars with trailors)

R = 0

L = 0

MP = 1

G/C = .90 (allows for emergency vehicles to cross 10% of the time in direction opposite to evacuation traffic flow)

Using Chart II (1-way, parking one side. Other charts are used for other bridge and intersection types.)

SV_c = 500-750 (Service volume for Level of Service C)

Ideal Capacity = SV_c (1.1)

550 $\leq$ Capacity $\leq$ 825

Halpren & Associates (21) have estimated that ideal capacity will be reduced by the following factors and amounts:

- 15%, wind-blown debris
- 9%, fluctuations and gaps in traffic demand
- 35%, storm conditions

on

(Ideal Capacity) (.91) (.85) (.65) = Evacuation capacity

(Ideal Capacity) (.50) = Evacuation capacity

275 $\leq$ Evacuation Capacity $\leq$ 400 (Holden Bridge)

For the purposes of this analysis, the Holden Beach Bridge will be assumed to have a capacity of 300 vehs/hour during evacuation and storm conditions.